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BOSCH

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HOW TO TUNE & MODIFY BOSCH FUEL INJECTION

Ben Watson

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This book is dedicated to:
Anne Marie, for her support, her help and 15 fun years of marriage.

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On the front cover: *Bosch fuel injection systems have long been used in Volkswagen vehicles. Shown here is a Volkswagen GTI, which uses a Bosch KE-Jetronic fuel injection system. Vehicle courtesy of Spring Valley Volkswagen, Spring Valley, New York.* Denis Tanney

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Contents

	Introduction	4
Chapter 1	**Electricity and Electronics**	5
Chapter 2	**Emissions**	26
Chapter 3	**Tools**	31
Chapter 4	**Tuning the Bosch-Injected Car**	36
Chapter 5	**The Lambda Sensor**	42
Chapter 6	**D-Jetronic Fuel Injection**	44
Chapter 7	**L-Jetronic System**	64
Chapter 8	**LH-Jetronic System**	87
Chapter 9	**K-Jetronic Fuel Injection**	101
Chapter 10	**K-Jetronic with Lambda**	129
Chapter 11	**KE-Jetronic System**	148
Chapter 12	**Motronic System**	159
Chapter 13	**The Asian Connection**	162
Chapter 14	**Fuel-Injection Performance Modifications**	172
	Index	175

Introduction

When we speak of Bosch fuel-injection systems, we speak of technologies that range from exotic European performance cars through proletariat workhorses such as the Volkswagen Rabbit. When we speak of Bosch electronic fuel-injection systems such as D-Jetronic, we are speaking of the grandfathers of virtually every modern electronic fuel-injection system, domestic and import.

This book defines and describes the major Bosch systems and their variations. Each chapter also addresses the troubleshooting, repair and modification of each system, using the simplest and most direct techniques and tools to do the job.

The author is a veteran of seventeen years working with Bosch fuel-injection systems both in dealerships using specialized tools, and in independent shops where no specialized tools were available.

1

Electricity and Electronics

Electrical systems have been part of the automobile since it was introduced at the end of the last century. Electricity was first used to produce a high-voltage spark to ignite the air-fuel charge in the combustion chamber. As time went on lighting systems, starting systems, radios, windshield wipers and a wide variety of power accessories were added and they, too, were electrically powered. In the late 1960s electronics began to appear on the passenger automobile. Today electronic ignition systems, fuel-injection systems, emission and safety systems are the standard of automotive technology.

As the sophistication of electrical and electronic systems has increased, the sophistication of the power sources for these components has had to keep pace. At the turn of the century when the use of electricity was limited to ignition, the magneto was the only electrical power source. When headlights were added, a source other than the high-voltage magneto was needed to power them, thus the storage battery was added. The addition of the battery gave birth to a whole new automotive service business; the complexities of the lead-acid storage battery and its servicing were beyond the abilities of the typical mechanic. Consequently, battery shops sprang up across the country. Since the storage battery needed frequent recharging to power the headlights and eventually the starter, the generator was created.

Again, the automotive service industry was faced with new technologies. As more power equipment was added during the decades of the thirties, forties, and fifties a more stable and dependable source of power was needed. The generator did an adequate job of keeping the storage battery charged, but could not power the accessories at lower engine speeds. Consequently, in the late fifties and early sixties the alternator replaced the generator. In the more than thirty years since its introduction the alternator has seen many improvements. In fact, on many applications today the alternator is computer controlled.

Yet, with all this increasing sophistication there are still only two primary sources of voltage on today's automobiles: chemical and electromagnetic. We'll discuss their functions in the next several sections.

Chemical Voltage Sources

Battery

The automotive lead-acid storage battery has undergone many changes in the last few decades, but the principle of operation remains the same. Plates of two dissimilar metals, lead and lead peroxide, are submerged in a solution of water and sulfuric acid. This condition sets up an imbalance of electron charges within the battery. The sulfate molecules try to force themselves into the negative lead plate while pulling oxygen atoms from the positive lead peroxide plate. The result is a surplus of electrons on the negative plate and a deficiency of electrons on the positive plate. The end product of this is voltage.

Lambda Sensor

The Lambda sensor was introduced in the late 1970s on some Bosch fuel-injected engines. Much like the lead-acid storage battery, the oxygen sensor has two metallic plates. In this case the plates are the same metal—platinum. Between the two plates there is a layer of zirconium dioxide, a ceramic material. At about 600 deg. Fahrenheit the ceramic becomes conductive for oxygen ions. If there are equal amounts of oxygen exposed to the plates, the zirconium dioxide is faced with equal pressures of oxygen from both sides. The zirconium oxide does not attract the ions, however, so no voltage is created. An imbalance in the amount of oxygen exposed to the two platinum plates will cause the ceramic to attract oxygen ions from the plate exposed to the greater amount. In this case a voltage is created. The oxygen content in the exhaust system drops as a gasoline engine begins to run rich, therefore the Lambda sensor monitors the air-fuel ratio.

Electromagnetic Voltage Sources

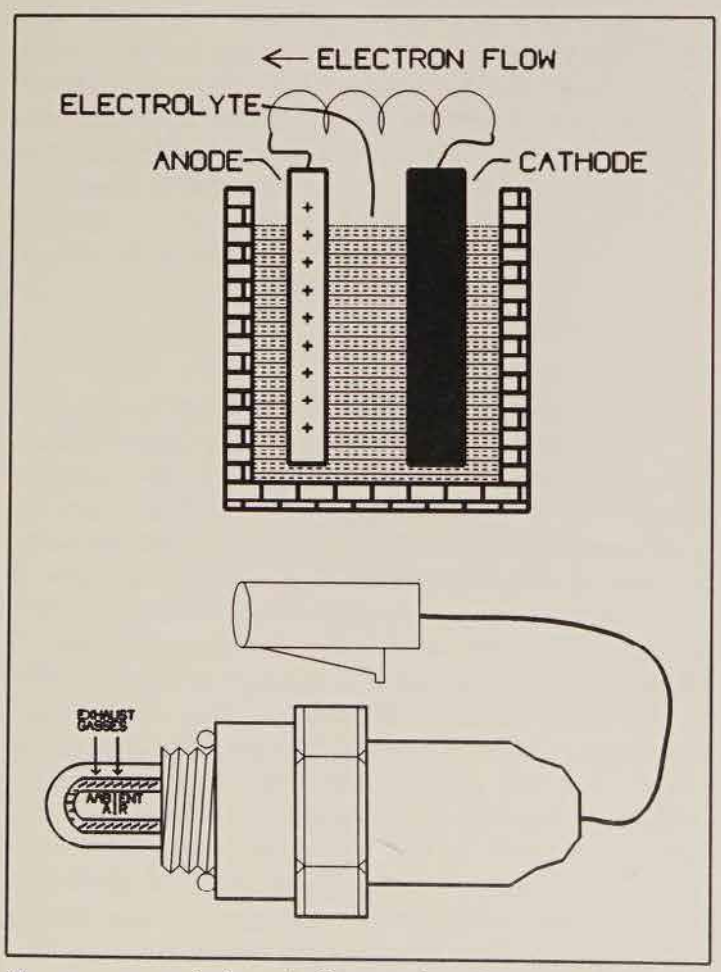
The most common method of creating electrical power or voltage on the automobile is through electromagnetism—that is, magnetism that occurs from electric charge in motion. Electromagnetism is at the heart of the magneto, the generator and the alternator.

Electromagnetism has become very important with the advent of electronic engine control systems and fuel injection. Several of the sensing devices and most actuating devices operate on electromagnetic principles.

The four electromagnetic principles that play an important role in today's fuel-injection systems are induction, the electromagnet, solenoid action and the Hall Effect.

Induction

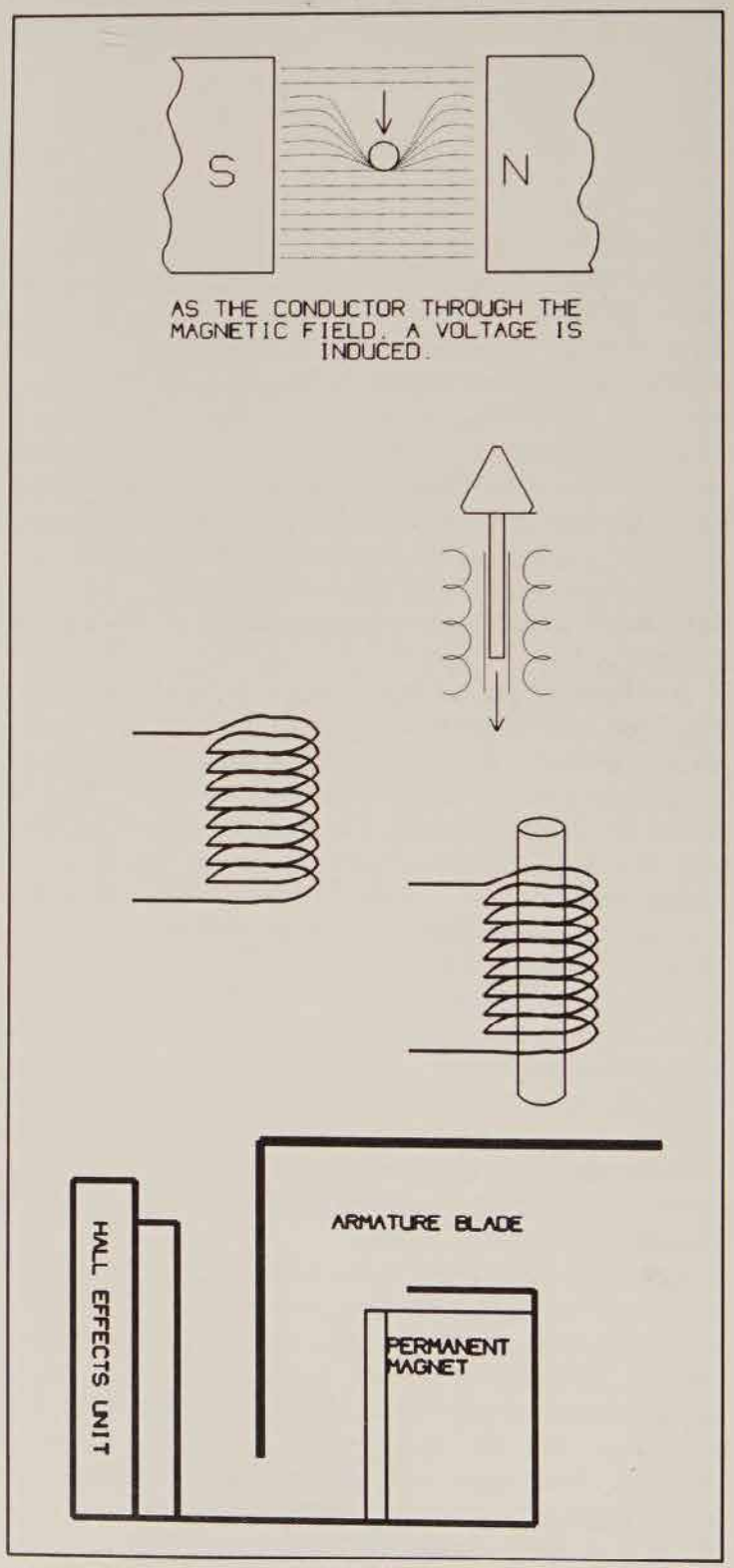
The actual generation of voltage and current with electromagnetism is done through induction. When a conductor is passed through a magnetic field, electrons are pushed into motion. If the conductor is a straight piece of wire, electrons will be pulled from one end and pushed toward the other end. This creates the electron differential that is called voltage. Connect the conductor to an electrical device and a current can flow.



Two sources of chemically produced electricity in the automobile are the battery and, beginning in the late seventies, the Lambda sensor.

The automobile uses induction to produce voltages and currents in generators, alternators and transformers such as the ignition coil. The AC (alternating current) pickup coil used in many electronic ignition systems also uses induction.

The pickup coil, or reluctance pickup, produces an AC voltage as a reluctor wheel rotates through a magnetic field. As the reluctor passes through the



Electromagnetism is essential to the modern automobile. It is used to produce voltage, switch currents on and off, control vacuum and fuel, and monitor the operation of the engine.

magnetic field it distorts across a coil of wire; this induces a voltage. Because the reluctor is rotating, the magnetic field is first distorted in one direction and then the other. This produces an AC signal.

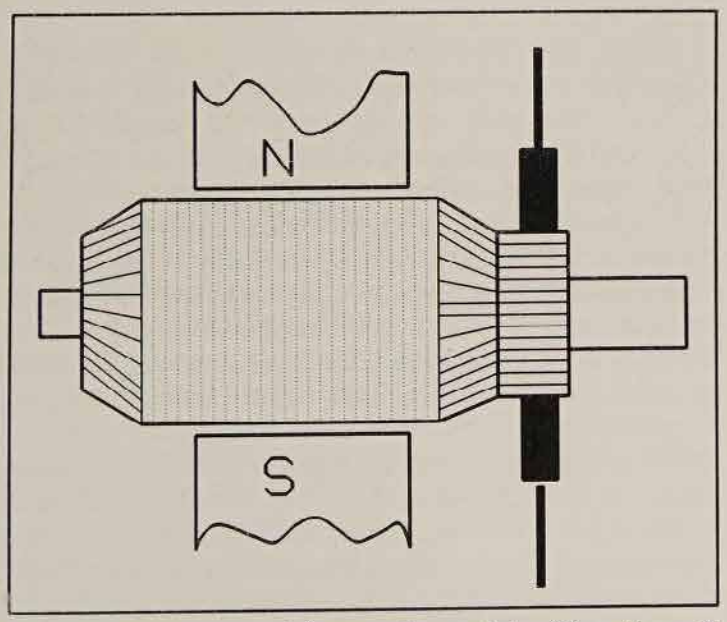
Electromagnet

Uses for the electromagnet do not end with the production of a voltage. When a current passes through a conductor, electrons have been set into motion. When electrons are set into motion a magnetic field is generated around the conduit, or conductor through which they are passing. The strength of this magnetic field is directly proportional to the volume of electrons (size of the current flow) and the force pushing those electrons (voltage).

When the current-carrying conductor is wound into a helix (a spread-out, single-layer coil of wire), the magnetic field generated by the conductor increases dramatically. Forming the helix around a soft iron core concentrates the magnetic lines of force and increases the strength of the field generated. This is the basis for the electromagnetic relay.

A spring-loaded switch is located above an electromagnet. When the electromagnet is energized the movable portion of the spring-loaded switch is attracted to the electromagnet, causing the switch to change position. When the movable contact changes position the switch is either opened or closed. If the switch is open when the electromagnet is de-energized, the relay is normally open. If the switch is closed when this occurs, then the switch is normally closed.

Electromagnets are also fundamental to electric motors. There are two types of electric motors used on today's automobiles—the DC motor and the stepper motor.



The DC motor is used for a wide variety of functions. It starts the engine, operates the wipers and supplies fuel to the injection systems, to name only a few.

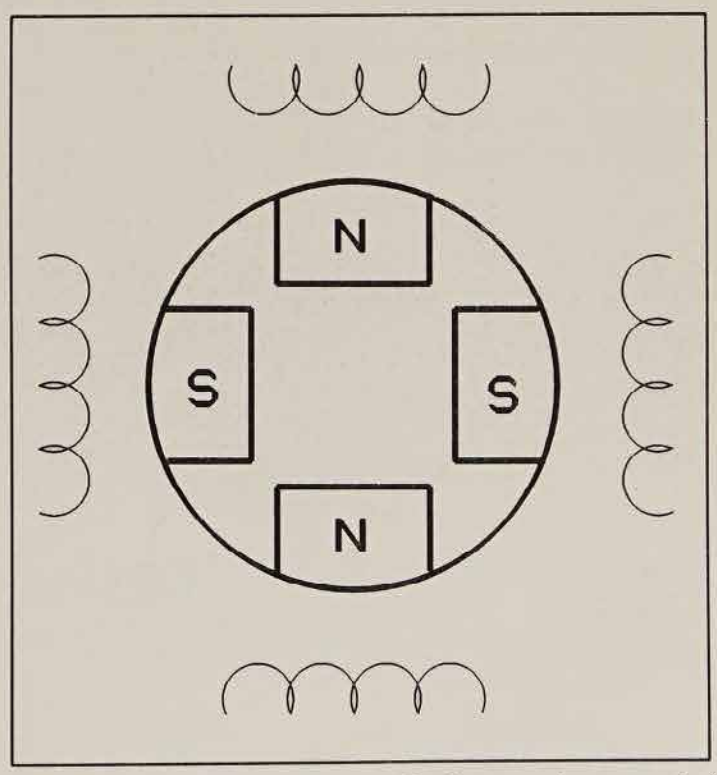
The DC (direct current) motor consists of a rotating armature that holds the conductor. As a current passes through the conductor it generates an electromagnetic field which opposes the field of one or more permanent field magnets, resulting in rotation. The speed of rotation depends on the strength of the magnetic field. The strength of the field in turn relates directly to the voltage and current flow. DC motors are used effectively where needs require either short-term or long-term steady-state rotational speed.

The design of the DC motor holds one inherent flaw, however. The current is carried to the electromagnetic windings through a set of brushes which ride on commutators on the armature. As the armature rotates, the brushes slowly wear down, thereby limiting the motor's service life.

Applications for this type of motor include starter motors, power window motors, windshield wiper motors and some idle speed control motors.

The difference in the construction of the stepper motor and the DC motor is the location of the windings and the permanent magnets. The stepper motor uses a stationary electromagnet while the armature holds the permanent magnets. This eliminates the need for brushes, thereby increasing the component's service life.

The primary disadvantage of this stationary-winding motor is that to maintain a constant rotational speed the current must pass through at least two sets of field windings. Further, these field windings must be switched on and off at an ex-



The brushless DC motor is used when precise control of position is required. As the coil sets are energized, the permanent magnet armature rotates in half-turn steps.

tremely high frequency. Therefore, accurate and consistent motor speed requires electronic or computer control.

Fortunately, this disadvantage can be turned into an advantage. If two opposing sets of stationary field windings are used, then each time a set is powered the armature will rotate one-half revolution. When it reaches a point of magnetic neutrality it will stop. Therefore, precise positioning of controlled devices can be achieved.

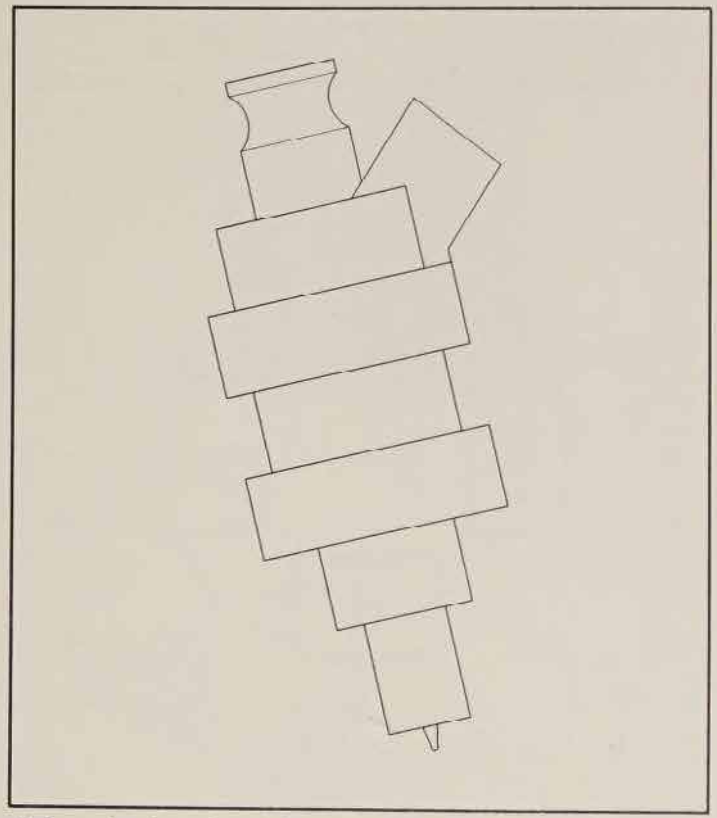
The most common example of the use of a stepper motor is in the idle speed control motors used on late-model fuel-injected cars. Here the stepper motor controls a plunger position with a worm gear. As a current is passed through one set of field windings the armature will rotate one-half turn and stop. As the armature rotates, the plunger is moved in one step. Reversing the current flow through the field causes the armature to rotate in the opposite direction and the plunger moves out one step.

An important advantage of the stepper motor is that it has no brushes to wear, thus increasing the motor's service life.

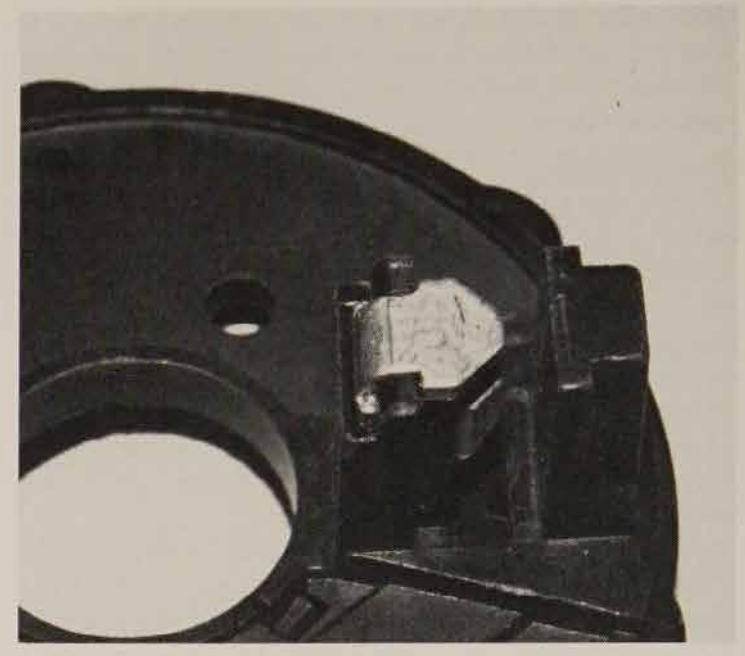
Solenoid Action

Although the solenoid and relay often perform similar tasks, the two are fundamentally different. Like the relay, the solenoid incorporates an electromagnetic coil with an iron core to concentrate the magnetic field. The iron core, however, is spring loaded away from the center of the magnetic field. When energized, the magnetic field of the solenoid windings pull the iron core against spring tension into the center of the magnetic field. To perform a task, one end of the iron core is attached to a switch or a valve. When the solenoid is energized, the valve or switch either opens or closes.

A solenoid can be used for three purposes: as a switch to control high current flow to the starter, as a valve to control vacuum to the EGR (exhaust gas recirculation) valve, or as a valve to flow fuel into the intake manifold (an injector).



Although the solenoid is used in many circuits on the automobile, for our purposes its most important use is in the fuel injector. The injectors used in the D-, L- and LH-systems are solenoid-operated valves.



Although the Hall Effects sensor is not used as part of the fuel-injection system, it is used to provide the sync pulse for the primary ignition system on many Bosch fuel-injected cars. Thus, the sensor is the source of the injector firing pulse on these cars.

Hall Effect

Stated in technical terms, the Hall Effect is defined as follows: When a current passes through a conductor and the conductor is placed in a magnetic field perpendicular to the direction of that current flow, then a voltage is produced which is perpendicular to the direction of that current flow.

Defined in less technical terms, the Hall Effect occurs when a magnetic field is placed perpendicular to a conductor with a current passing through it, and the magnetic field either sucks voltage toward or pushes voltage away from itself.

This characteristic allows the Hall Effect to be an ideal method of detecting rotational speed and position. It has a significant advantage over the reluctance pickup coil since there is no minimum speed of rotation to be measured.

Hall Effects devices are used to measure distributor shaft speed and position as well as that of the crankshaft and camshaft on many applications.

Measuring Voltage

The basic unit of voltage measurement is the volt. Until electronics was introduced to the automobile this single unit of measure, measured to the nearest tenth, was adequate. Many automotive electronic devices produce very small voltages, however. In some devices a change of only 0.1 volt produces dramatic changes in their operating conditions. For this reason, measurement of automotive electronics is done in millivolts (mV), units of 0.001 volt.

Analog Voltmeter

For a long time the analog voltmeter was the standard of not only the automotive industry but also the electronics industry. The meter derives its name from the way in which it displays information to the user. A needle sweeps across the numerical display to indicate voltage readings.

The primary advantage of the analog meter is its ability to show low–frequency fluctuations in voltage by pulsations in the needle. Therefore, the analog voltmeter is an effective tool in tracking down intermittent circuit problems.

The primary disadvantage is that unless a technician uses an analog meter frequently, it can be difficult to read accurately.

Digital Voltmeter

The digital voltmeter displays its reading in a two-and-a-half- to four–digit display. This display is normally either LCD or LED (liquid crystal display or light-emitting diode, respectively).

A major benefit of the digital display meter is that it is easy to obtain accurate readings, even for the infrequent user.

A major drawback, though, is that instead of being a continuous readout, such as that displayed by the analog meter, the digital voltmeter displays only sample readings. How frequently the meter samples the voltage will determine the meter's ability to find intermittent fluctuations in voltage.

High Impedance versus Low Impedance

Impedance relates to the amount of resistance within the meter between the red lead and the black lead. A voltmeter connects in parallel to the circuit being tested. A low-impedance meter has a tendency to pull power away from the circuit being tested. This results in voltage readings lower than fact, particularly in circuits such as the oxygen sensor where the current flow is minimal. A high-impedance meter pulls very little power away from the tested circuit. It is extremely accurate when used on low-current flow circuits.

Voltmeter impedance is measured in volts per ohm. If the voltmeter is a 2k (2,000) volt meter, and the meter is set on the 15 volt scale, the resistance between the red lead and the black lead will be 30,000 ohms. The typical high-impedance meter will have an internal resistance of ten million ohms per volt. If the meter were placed on the 2.0 volt scale to read Lambda sensor output, the resistance between the red lead and the black lead would be twenty million ohms.

The following is an example of the effect of voltmeter impedance on a circuit being measured.

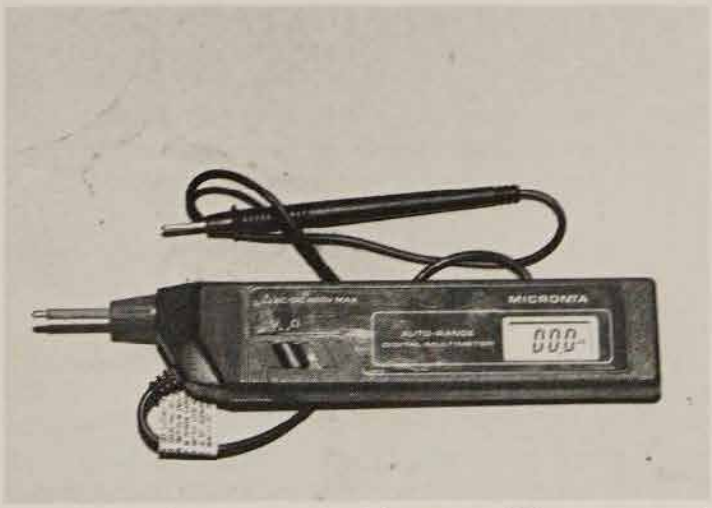
A 5.0 volt power supply is feeding voltage to two devices connected in series. One device has a resistance of 15,000 ohms. The second device has a resistance of 30,000 ohms. The voltmeter is set on the 15.0 volt scale which gives it an impedance of 30,000 ohms (2,000 ohms per volt). Connecting the voltmeter on the input side of the second resistance to ground should yield a reading of about 3.0 volts. However, the voltmeter forms a parallel circuit with the 30k (30,000) resistance. This newly formed parallel circuit lowers the resistance between the point being measured and ground, causing the voltage at the point where the red lead is connected to also drop. The result is 2.5 volts, an error of nearly 25 percent.

To test most automotive electronic circuits the meter should have a minimum of 50,000 ohms per volt. The issue of analog versus digital is purely a matter of choice and the need to see intermittent fluctuations, providing the impedance requirements are met.

AC Voltmeter

The AC voltmeter has limited application to automotive troubleshooting. Its one effective use is to test the reluctance-type pickup. The traditional method of testing these devices is with an ohmmeter. The problem with this method, though, is that it tests the pickup coil for continuity but does not test it for actual operation.

Connecting an AC voltmeter to a pickup coil and cranking the engine should produce an AC voltage of around 0.7 volt.



Voltage can be measured with many different types of voltmeters. Although hundreds of dollars can be spent, one of my favorites cost me less than $30.

Oscilloscope

Long the exclusive domain of the electronics technician, the oscilloscope has begun to make itself at home in the world of auto repair and service. The oscilloscope is a voltmeter that displays changes in voltage over time. The vertical axis of the scope shows voltage, the horizontal axis shows time. There will be a more detailed discussion of scope reading later in this chapter.

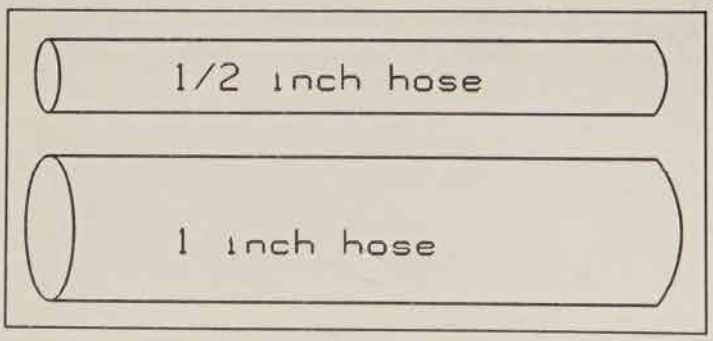
Measuring Amperage

If the pressure pushing electricity through a conductor is known as voltage, then the volume at which the electricity is flowing is amperage. A common analogy used to explain electrical circuits is city water pressure. Volts is like pounds per square inch (psi), and amps is like gallons per minute (gpm).

The measurement and control of amps have always been important in automotive electrical systems. The principle tests of battery performance are the current capacity tests. One of the principle tests of starter performance is the amperage draw test. In both of these cases the volume of current being measured is extremely large. The automotive service industry has traditionally dealt with currents of 1 to 500 amps and even more.

The advent of automotive electronics has brought currents much smaller than the auto technician has ever dealt with before. For example, the oxygen sensor circuit at times carries a current of less than 0.0000000005 (one-half trillionth) amp! Although currents in these ranges behave exactly the same way as larger currents, their perceived behavior can be different.

Normally, when a conductor carrying a current accidentally touches ground prematurely the result is dramatic. Since the power supply for most circuits on the automobile is either the battery or the alternator, a conductor shorting to ground can easily be overloaded. Extreme heat builds up, and the conductor can actually melt. Most of the electronic circuits on the automobile have power supplies with a maximum potential far less than what the conductor can carry, so when a low-current circuit becomes grounded, the conductor is not affected. But the effect on the power supply still can be devastating. The power supply could be overloaded to the point of destruction.



As the diameter on a water hose increases, its resistance to the flow of water decreases. In the same way, as the diameter of a conductor increases, the resistance of the conductor decreases.

The basic unit of measure for current flow is the amp. To the engineer, 1 amp of current flow means 6.28 billion billion electrons per second passing any point in the circuit when pushed by 1 volt. In servicing automotive electronic systems there are very few times when amperage will need to be measured directly.

Units of measurement for current flow are amps and milliamps. The milliamp is 0.001 amp.

Two types of ammeters are used to measure amperage—the inductive type and the shunt type.

Inductive Ammeter

The inductive-type ammeter is usually chosen for large current flow applications. A clamp surrounds the conductor being measured. This clamp measures the strength of the magnetic field being generated by the current passing through the conductor. The strength of the magnetic field is then converted into amps.

The advantage of the inductive ammeter is its ease of use. The conductor in which the current is being measured does not have to be disconnected. Its disadvantage, however, is that the strength of the magnetic field in very low current circuits is too weak to measure accurately. Thus, below 10 amps the inductive ammeter is a poor choice.

Shunt Ammeter

The shunt ammeter is the ideal choice for measuring very small currents like those found in automotive computer circuits. It must be connected in series with the current being measured, which requires that the conductor be disconnected. This makes the shunt ammeter more difficult to use. On the other hand, it is extremely accurate down to milliamps since all the current passing through the circuit being tested passes through the meter.

Resistance

Resistance is anything that impedes or inhibits the flow of electricity through a conductor. All conductors have some natural resistance in them. Resistance can be demonstrated by conducting a simple high-school physics experiment.

Using a number 2 pencil, draw a dark line on a piece of standard notebook paper. Place the black lead of an ohmmeter at one end of the line; place the red lead immediately next to the black but do not allow the leads to touch. Check the ohmmeter reading. Now slowly move the red lead along the pencil line away from the black. Note that the ohmmeter reading increases. This is called resistance.

Several factors determine exactly how much resistance a given conductor will have.

Diameter is a primary factor. The larger the diameter of a conductor, the less resistance there will be. The less resistance there is, the greater current the conductor can carry. It is standard practice to use small wires of low-current circuits such as sensor circuits, and larger wires of higher current flow circuits such as actuator circuits. Compare this to a water hose. A ½ in. hose cannot carry as large a flow, or current, as a 4 in. hose.

The length of the conductor also will affect its resistance. Resistance increases with length in the same way that the ohmmeter reading increases as the red lead is moved along the pencil mark. The basic wire resistor, such as those used for ballast resistors, use this principle.

For most conductors, as their temperature increases so does their resistance. One notable exception is the battery electrolyte.

A peculiar phenomenon occurs as a current passes through a conductor. The current generates heat. As the temperature of the conductor increases, the resistance of that conductor also increases. The increasing resistance tends to impede current flow. If the temperature of the conductor rises beyond the melting point for the material forming the conductor, then the conductor will burn open.

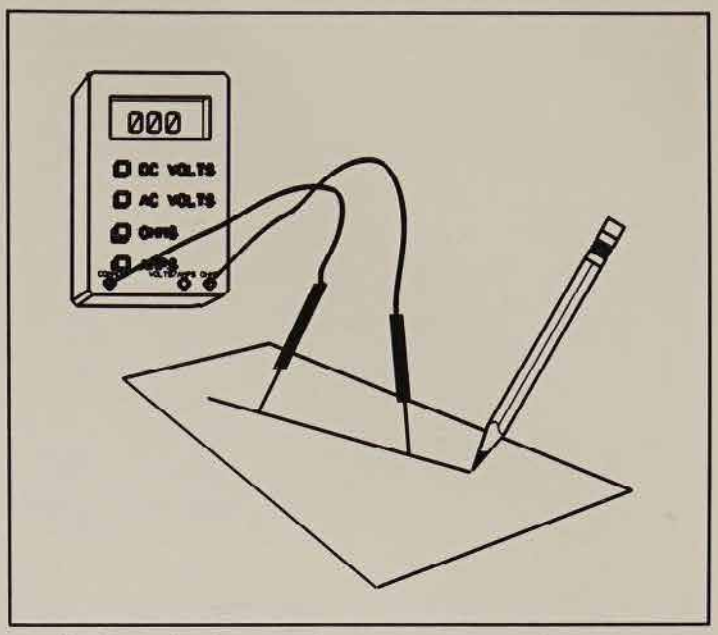
The fourth and possibly the most critical factor in determining the resistance in a conductor is the material that forms the conductor. The best conductor is silver; one of the worst of the more commonly used conductors is aluminum. Gold is used as a conductor on many critical circuits or connections, for although other materials have conductive properties superior to gold, gold does not corrode. Corrosion at connection points increases resistance in a circuit. Because of extremely good conductive properties and a high resistance to corrosion, copper is the most frequently used conductor in automotive circuits.

Resistors

Opening a device with electronic circuitry will reveal the most common electronic component—the resistor. Resistors perform many functions in a circuit. For automotive purposes, we can summarize two ways in which they are used.

First, they are utilized for current limiting. Any resistance in a circuit reduces current flow in that circuit. Resistors are placed in many automotive electronic circuits to limit current flow. When a wire becomes grounded, resistance in the series circuit is reduced. If reduced enough, the increased current flow from the power supply could either damage the power supply or the current-carrying wire. Installing a current-limiting resistor in the series circuit inside the power supply module will prevent this.

Second, resistors are used to create a voltage drop. When a resistance is placed in a circuit carrying a current, voltage will be reduced as the current passes through the resistance. By using resistors that change value as events occur, it becomes possible for a computer to monitor these events through the changes in voltage.



As the length of a conductor increases, the resistance through that conductor increases.

Measuring Resistance

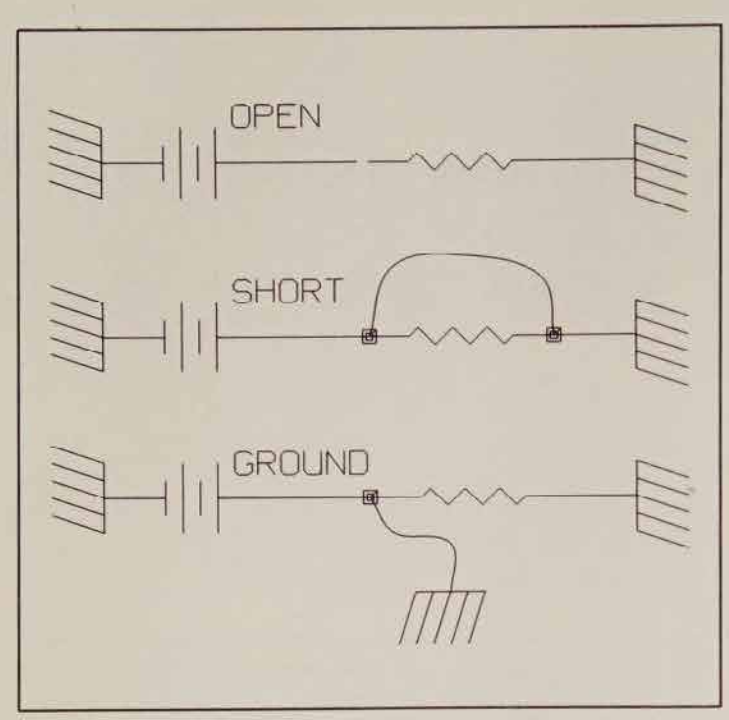
Resistance is measured in ohms. One ohm is the amount of resistance it takes to limit 1 volt applied to a conductor at 1 amp of current flow. An ohmmeter is a device used to measure resistance.

The ohmmeter contains an internal voltage source, such as a 1.5 volt battery, and is connected in series with the component being tested. All power supplies must be removed from the component being tested. The ohmmeter passes a known current through the component, measures the outbound voltage, measures the return voltage and uses the voltage drop to calculate the resistance.

Be careful when testing components that have a polarity, such as diodes. Some ohmmeters apply the positive voltage to the black lead when testing, while others apply it to the red lead. Familiarity with the meter being used will prevent condemning a good component.

Measuring Wattage

Wattage is a measurement of electrical power, expressed in watts. One horsepower is equal to 746 watts. Watt ratings are used for power consumption on many electrical and electronic components. Resistors have watt ratings to indicate the amount of power they will dissipate; motors and lights have watt ratings to indicate how much power they will consume. Beyond this, there are very few times when you'll deal with watts in troubleshooting or diagnostics.



There are three ways that an electrical or electronic circuit can fail. The circuit can go open, short or ground.

Circuit Defects

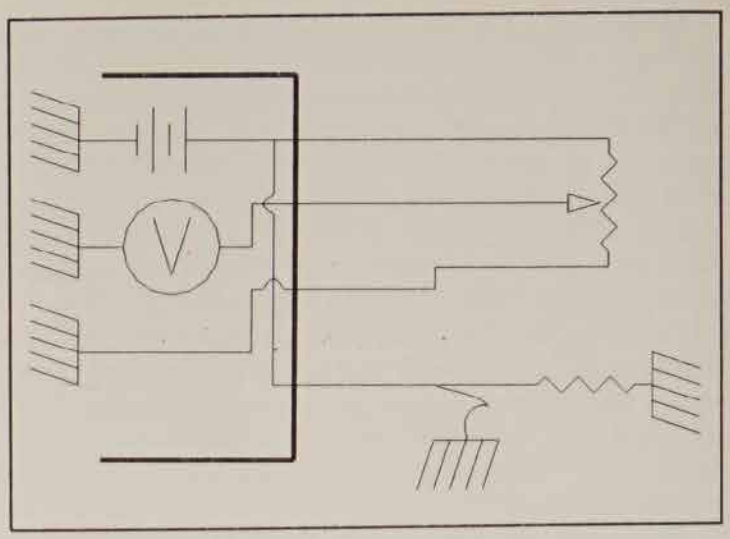
Three types of defects commonly occur in an electrical circuit. These defects include opens, shorts and grounds.

An open circuit is where the path to ground has been broken. When there is an open circuit, there is no current flowing. Because there is no current flowing, there will be no voltage drops through the circuit up to the point of the open. Therefore, if the voltage is measured at the point of the open, source voltage will be indicated.

Short is a term often misused. A short occurs when a conductor or device is by-passed through an alternate current path. This will cause the current flow in the circuit to increase, thus increasing the voltage available to the next device in series. Consequently, the next device in series, the power supply and the current-carrying conductor are all put at risk of being damaged.

The term short is also correctly used when two conductors touch, allowing an improper voltage from one conductor to be transferred into another conductor. Depending on the circumstances, current flow in the circuit may or may not be affected. Excessive voltage applied to a device may put that device at risk.

Ground is the correct name for the condition that is often called a short. A ground occurs when the current path is directed back to the negative terminal of the battery prematurely, before the last powered device. This condition causes the current flow to increase, resulting in possible damage to the conductors and devices in the circuit. Voltage measured on the outbound side of the device in the series before the ground will be zero.



Occasionally, a defect will be more noticeable in a circuit running parallel than it is in the circuit itself.

Parallel Robbery

When troubleshooting automotive electronic systems each circuit being tested is treated as a series circuit. Many of the circuits tested are actually parallel circuits, that is, a circuit shares a common voltage source and a common ground with another circuit. By this definition, technically all circuits on an automobile are parallel circuits. Current will always take the easiest path to ground. If the resistance in one leg of the parallel circuit drops, it will tend to pull power (current) away from the other leg. Thus, problems in one leg of the parallel can affect the operation of all the other legs.

Electrostatic Discharge (ESD)

Since the early 1980s much has been said about the effects of static electricity on electronic components, or electrostatic discharge (ESD). Some components are more sensitive than others. Semiconductor devices with conductivity greater than insulators but less than good conductors, are what all the furor has been about. There are several different types of semiconductors used in automotive electronics, each with a different degree of sensitivity.

Examples of ESD vulnerability in automotive applications are as follows:

MOS (Metal Oxide Semiconductor) circuitry (few automotive applications)	1 to 1,000 volts
CMOS (Complementary Metal Oxide Semiconductor) circuitry (Ford EEC I, II, III)	1,000 to 5,000 volts
TTL (Transistor-Transistor Logic) circuitry (most automotive systems)	5,000 to 15,000 volts

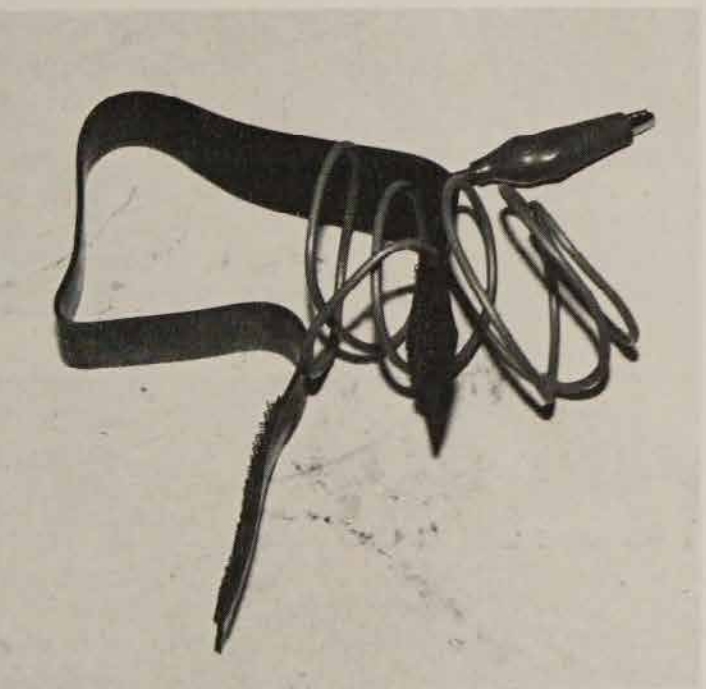
At first, this looks like a very large amount of voltage to be sent into an electronic device acciden-

ally. Here are some examples of static voltages generated by everyday activities. In these examples, temperature was at 75 deg. F. and relative humidity was at 60 percent.

Activity	Voltage Generated (volts)
Stroking a rubber comb through dry hair	−2,500
Rolling a desk chair across a plastic floor mat	−2,000
Crumpling a polyethylene bag	−300
Rubbing a pencil eraser across a circuit board	+100
Rapidly unrolling black electrical tape	+500
Walking across a carpet with rubber-soled shoes	−1,000

Drop the relative humidity to 10 percent and these numbers can increase by up to 50 percent.

There are several ways to protect against electrostatic discharge, however. These include: store components in their original packages; do not touch component leads or pins; before handling the computer, discharge the static from your body by touching a grounded metal surface; do not slide the computer or device across any surface; keep static-generating materials away from the work area—materials such as plastic, cellophane, paper, candy wrappers and cardboard are common static generators; keep clothing away from static-sensitive devices; and never connect static-sensitive devices with power applied.



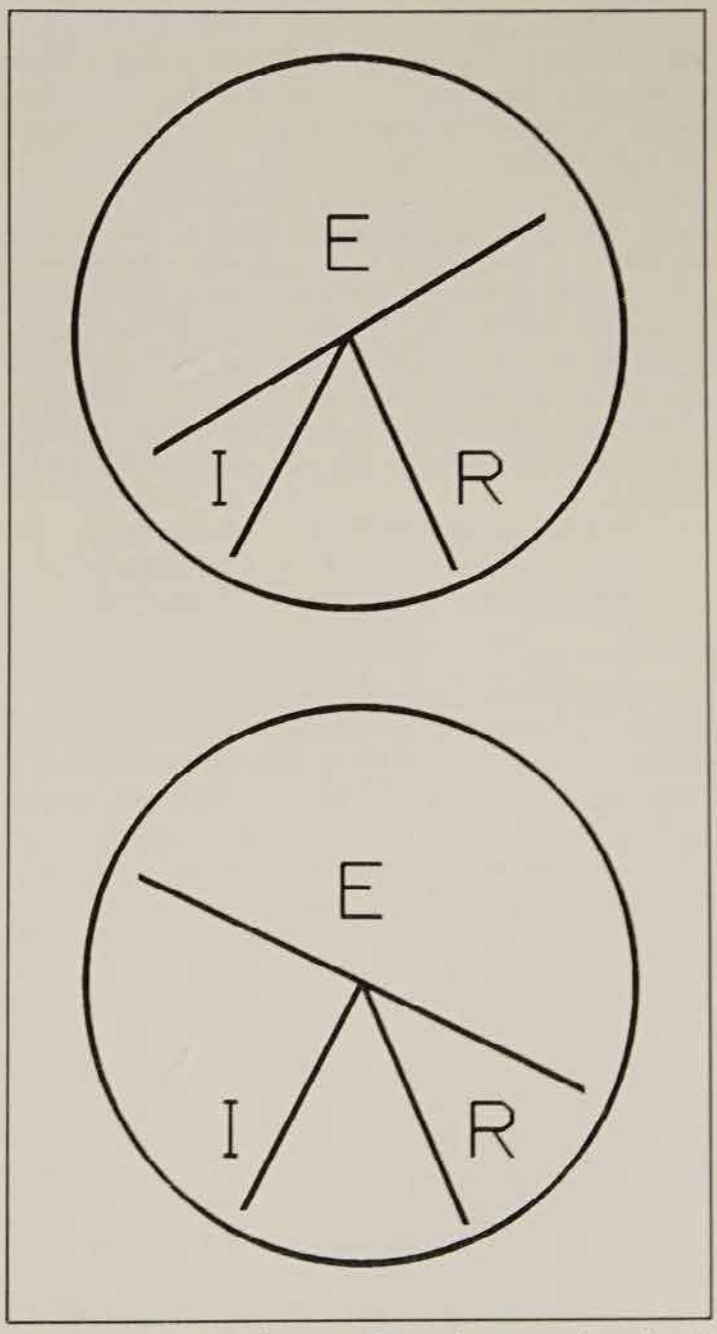
Wrist straps like this are available for only a few dollars and can prevent damage to the computer from electrostatic discharge.

Ohm's Law

When speaking before a group of auto mechanics, one sure way to elicit a group groan is to bring up the subject of Ohm's law. Since it is fundamental to our discussion of electricity and electronics, we will briefly discuss Ohm's law here.

There is a mathematical relationship between volts, amps and ohms. Stated in the simplest terms, it takes 1 volt of electrical pressure to push 1 amp of current through 1 ohm of resistance. For the automotive technician, there are two important facts concerning Ohm's law.

First, assuming we keep the voltage the same, as the resistance in a circuit decreases, the current flow in the circuit increases.



Ohm's law states that as the resistance of a circuit changes, the current that flows through the circuit changes in the opposite direction.

Second, again assuming we keep the voltage the same, as the resistance in a circuit increases, the current flow in the circuit decreases.

The second fact of Ohm's law is what enables the current-limiting resistors used in computer circuits to prevent overload of the power supplies and voltage regulators.

Kirchhoff's Laws

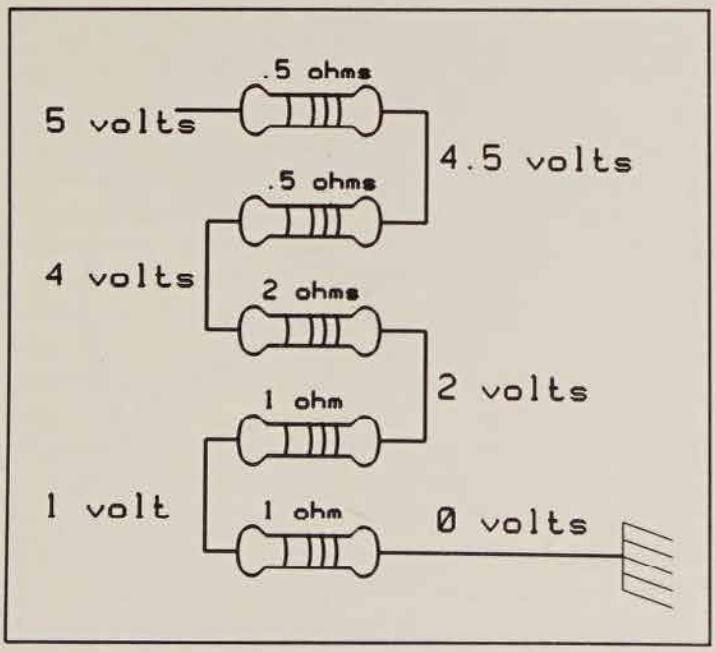
Kirchhoff's first law states that the algebraic sum of the voltage drops in a series circuit equals source voltage. This principle is self-explanatory, thus we will not address it here.

Kirchhoff's second law, also built on the principles of Ohm's law, states that as a current passes through resistances in a series circuit, voltage will be lost.

The amount of voltage lost is directly proportional to the resistance. If a circuit is powered by 5 volts, and if there are five equal resistances in the circuit, there will be 1 volt lost as the current passes through each resistance.

A slightly more scientific explanation involves the notion of voltage drop per ohm. If the source voltage in a circuit is 5 volts, and the total resistance in that circuit is 5,000 ohms, then the drop in voltage as the current passes through each ohm would be 1 mV (millivolt, or 0.001 volt). Therefore, if the 5,000 ohms consist of a 2,000 ohm resistor, a 1,000 ohm resistor and a second 2,000 ohm resistor, then the voltage drop across each resistor will be as follows:

2,000 ohms × 0.001 volt = a 2 volt drop
1,000 ohms × 0.001 volt = a 1 volt drop
2,000 ohms × 0.001 volt = a 2 volt drop



Kirchhoff's law states that as a current passes through resistance in a series circuit, the voltage decreases at a proportional rate.

The sum of the three voltage drops in the example equals 5 volts, or source voltage. Implied here is that if the voltage is measured after the first resistance, the result would be 3 volts. Measuring after the second resistance would yield 2 volts and after the third resistance, zero volts.

This law remains in effect regardless of the number or size of resistances in a series circuit.

Sine Waves

A sine wave is produced when a voltage gradually increases over time, reaches a peak, then gradually decreases. The classic sine wave resembles a series of evenly spaced rolling hills and valleys. However, this classic pattern is seldom seen when looking at waveforms on an oscilloscope. More often the waveform looks like a jagged mountain range.

Two major components produce sine waves in automotive systems. The first and the oldest is the alternator. The stator—the part about which a rotor turns—produces an AC sine wave which is converted into a DC voltage by the rectifier bridge. Although the alternator is a major device, it is not within the scope of this book.

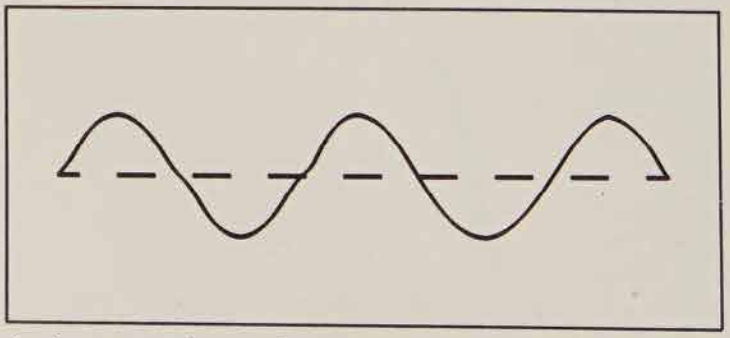
One commonly used sensing device is the variable reluctance transducer or VRT, commonly known as a pickup coil. The sine wave produced by a pickup coil can be viewed on an oscilloscope but is more easily tested with an AC voltmeter.

Other than checking for the presence of the signal, sine waves are not normally tested in automotive electronics.

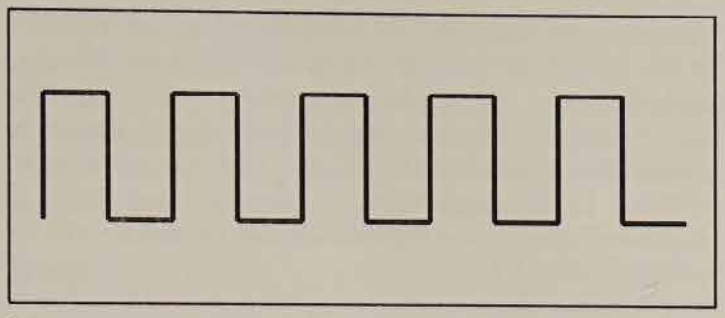
Square Waves

Viewed on an oscilloscope, a square wave appears as a series of right angles. Like the sine wave, the square wave may appear broken or erratic but will follow the basic right-angle pattern.

Electronic devices that produce a square wave include Hall Effects devices, optical position sensors, and pulse generators such as the General Motors MAF (mass airflow) sensor. Unlike the sine wave, however, the square wave is frequently measured when troubleshooting automotive elec-



A sine wave is a voltage that slowly increases, then decreases. Since most sine waves created in the automobile are AC, they can be tested with an AC voltmeter.



Square waves are high-voltage and low-voltage pulses used to monitor engine operating conditions or control output devices. Four elements of a square wave can be changed to monitor or control: amplitude, frequency, duty cycle and pulse width.

tronics. Four characteristics of the square wave are commonly measured: amplitude, frequency, duty cycle and pulse width.

Amplitude

Of the four measurable characteristics of a square wave, amplitude is measured least frequently. Amplitude is the amount of change in voltage from the lowest part of the square wave to the highest part. If the highest part of the square wave were at 5 volts, the amplitude would be 5 volts. This, of course, assumes that the lowest part is at zero volts. If the lowest part of the square wave were at 2 volts, then the amplitude would be 3 volts.

Since there is no way of determining the lowest point of the square wave with a voltmeter, the only accurate way of measuring amplitude is with an oscilloscope. With the waveform displayed on the scope, observe the voltage of the lower horizontal line and subtract from the voltage of the higher horizontal line.

When the amplitude increases, the average voltage will also increase. When a voltmeter is connected to a circuit where the amplitude is changing, the voltmeter will reflect a corresponding change.

Extreme changes in amplitude will also affect the controlled devices. When the amplitude drops below the minimum operating voltage for a given device, that device will cease to function. When the amplitude exceeds the maximum safe working voltage, the device can burn out. Other than these extremes, changes in amplitude will not affect the operation of a controlled device. For example, changing amplitude will not alter the amount of fuel sprayed through an injector.

Frequency

To the automotive technician, a far more important measurement of the square wave is frequency. Frequency is the number of pulses, or waveforms, that occur within a given period. The most common time interval is one second; the most common unit of measurement is hertz (Hz), or cycles per second. Therefore, a square wave occurring ten times per second has a frequency of 10 Hz. A complete square wave includes both a high- and a low-voltage portion of the waveform.

An automotive technician can use three different devices to measure frequency. The first is the frequency counter. Many electronic test equipment manufacturers produce dedicated frequency counters. These meters can be very expensive and are usually capable of reading from fractions of a hertz up to megahertz (millions of pulses per second). This level of flexibility is wasted on the automotive technician, however. Automotive electronics only requires an ability to read frequencies ranging from 1 to 500 Hz.

A second device is the oscilloscope. To measure frequency on an oscilloscope, count the number of milliseconds required for the complete high- and low-voltage portions of the waveform. Then divide the number of milliseconds into 1.

For example, let's say a square wave displayed on the oscilloscope covers 5 milliseconds (ms). The equation would read like this:

$$\frac{1}{0.005 \text{ sec}} = 200 \text{ Hz}$$

The tachometer may be the most accessible method used by the automotive technician to measure frequency. However, there is a conversion formula required: Rpm reading, times the number of cylinders that the meter is set on divided by 2, divided by 60 equals frequency.

$$\frac{\text{Rpm} \times \left(\frac{\text{No. of Cyl.}}{2}\right)}{60}$$

This formula can be abbreviated by always placing the tachometer on the four-cylinder scale. On the four-cylinder scale, simply divide the tach reading by 30.

As an example, a tachometer is set on the four-cylinder scale and connected to a circuit carrying a frequency. The tachometer displays 4300 rpm. Thus the equation would read:

$$\frac{4300}{30} = 143.33 \text{ Hz}$$

When the frequency changes, there is no change in the average voltage of a circuit. The exception is when the frequency drops to a point approaching the sampling frequency of the meter. At this point the meter will begin to vary with the pulsing, and changes in frequency may become apparent.

Changing the frequency of a signal to a controlled device will not alter the operation of that device. An injector will not spray more fuel or less fuel because of a change in frequency. And a vacuum control solenoid will not alter the amount

of vacuum applied to the EGR valve simply because of frequency change.

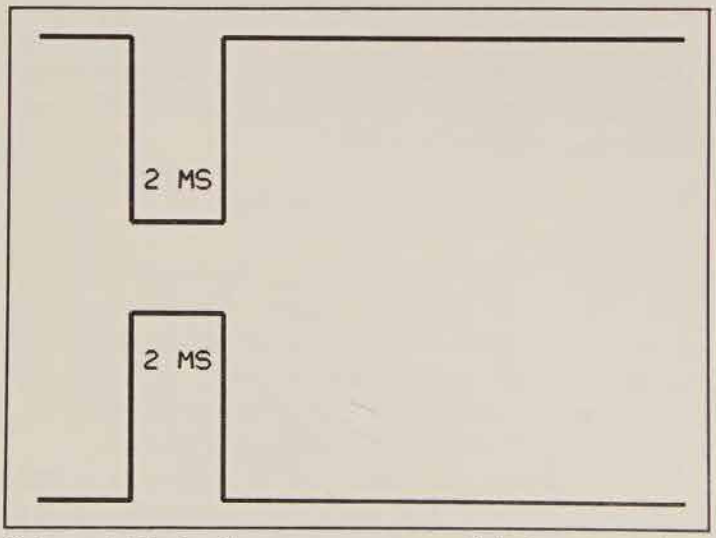
Duty Cycle

A third commonly measured characteristic of the square wave is the duty cycle, or the relationship between the high-voltage and low-voltage portion of a square wave, measured in percentages. If the square wave has a high voltage half of the time and a low voltage the other half, then the duty cycle is 50 percent.

Looking at a 50 percent duty cycle on an oscilloscope would reveal a waveform with equal high- and low-voltage lines. If the waveform displayed on the scope had a high-voltage line that was one time unit long and a low-voltage line that was three time units long, then it would be a little more difficult to check the duty cycle. The duty cycle might be 25 percent or it might be 75 percent. The determining factor would be whether current is flowing through the circuit when the voltage is high or when the voltage is low. Thus, duty cycle can be explained another way. It is the relationship between current flowing through a circuit and current *not* flowing through a circuit, measured in percentage.

Many test equipment manufacturers offer a dedicated duty cycle meter. Others offer a duty cycle function on voltmeters or engine analyzers. These meters provide a direct reading of duty cycle, so the technician does not need to be concerned with when current is flowing through the circuit. The meter analyzes that.

The dwell meter is another device used to measure duty cycle. Since the days of Charles F. Kettering (the man who developed the point-condenser distributor ignition system) we have been measuring the duty cycle of the primary ignition system. The more familiar term for this is dwell. Duty cycle is measured on a scale of 0 to 100.



Pulse width is the measurement of injector on-time. Typical injector on-time at an idle ranges from one to five milliseconds.

The four-cylinder scale of the dwell meter reads 0 to 90. Using the dwell meter on the four-cylinder scale will yield a displayed reading with only a 10 percent error. In most cases where the automotive technician is measuring duty cycle, an error of 10 percent is insignificant. If greater accuracy is required, the four-cylinder scale reading can be multiplied by 1.1.

Example:

36 deg. of dwell $\times$ 1.1 = 39.6%

Measuring duty cycle with a voltmeter can be accurate if the lowest voltage and the highest voltage of the square wave are both known. However, the calculation procedure is complex. In many cases there is no need to determine the duty cycle accurately; the need is to only see that the duty cycle is changing. As the duty cycle changes, the average voltage changes. As with determining duty cycle on an oscilloscope, the voltage may increase or decrease as the duty cycle increases.

One method by which automotive computers control the volume of something is through a variable duty cycle square wave. A variable duty cycle-controlled, solenoid-operated valve is used to control fuel or vacuum. This valve could be either a normally open valve or a normally closed valve. If the valve is normally open, then the flow through the valve decreases as the duty cycle increases. If the valve is normally closed, then the flow through the valve increases as the duty cycle increases.

Pulse Width

The fourth measurable characteristic of a square wave is pulse width. In automotive electronics, measurement is limited to length of time that the injector is open. Similar to duty cycle, pulse width is the length of time that current is flowing through the injector solenoid. The difference is that duty cycle is measured in percentage, while pulse width is measured in fractions of a second, or actual time.

Basically, there are three ways to measure pulse width. The pulse width meter measures the length of time that current is flowing through the injector. These meters tend to be expensive. Since it is rare that injector width measurement is important to troubleshooting, investing in a pulse width meter may not be wise.

Next is the method utilizing an oscilloscope. To measure pulse width on an oscilloscope it is only necessary to align the injector pulse with the time measurement mark on the scope.

Finally, for those not blessed with either an oscilloscope or a pulse width meter, there is an alternative. Using a tachometer or dwell meter, measure the duty cycle and the frequency of the signal. Then use the following formula:

1 divided by frequency, times duty cycle percent, divided by 100

Example: Where the frequency of the pulse is 25 Hz and the duty cycle of the pulse is 3 percent.

1 divided by 25, times 3, divided by 100 = 0.0012 seconds or 1.2 milliseconds

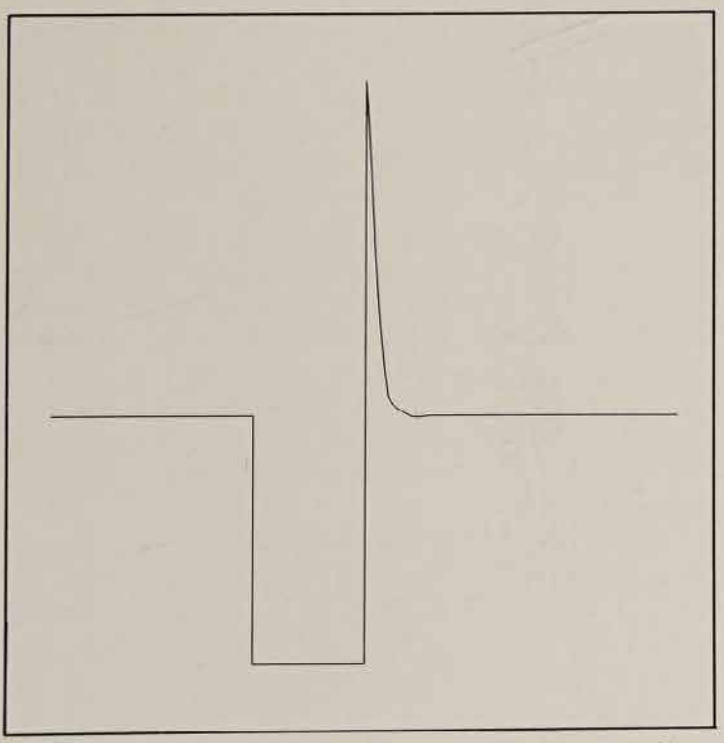
Just as for duty cycle changes, the average voltage changes as the pulse width changes. As the pulse width to the injector increases, the fuel flow through the injector also increases.

Inductive Kick

When the current passing through a solenoid is shut off, the magnetic field created by that current—surrounding the windings of the solenoid—collapses. As the magnetic field collapses it induces more voltage in the circuit. This induced voltage shows up as a spike on the square wave at the point where the current was shut off.

Subunits of Automotive Electronics Measurement

Volts
1 microvolt = 0.000001 volt
1 millivolt = 0.001 volt
1 kilovolt = 1,000 volts
Amps
1 microamp = 0.000001 amp
1 milliamp = 0.001 amp
Ohms
1 kilo-ohm = 1,000 ohms
1 megohm = 1,000,000 ohms
Watts
1 milliwatt = 0.001 watt
1 kilowatt = 1,000 watts



When a square wave is used to control a solenoid, such as an injector, a voltage is induced in the solenoid coil when the control current is shut off. When viewed on an oscilloscope, this kick appears as a transient rise in voltage.

Thermistors

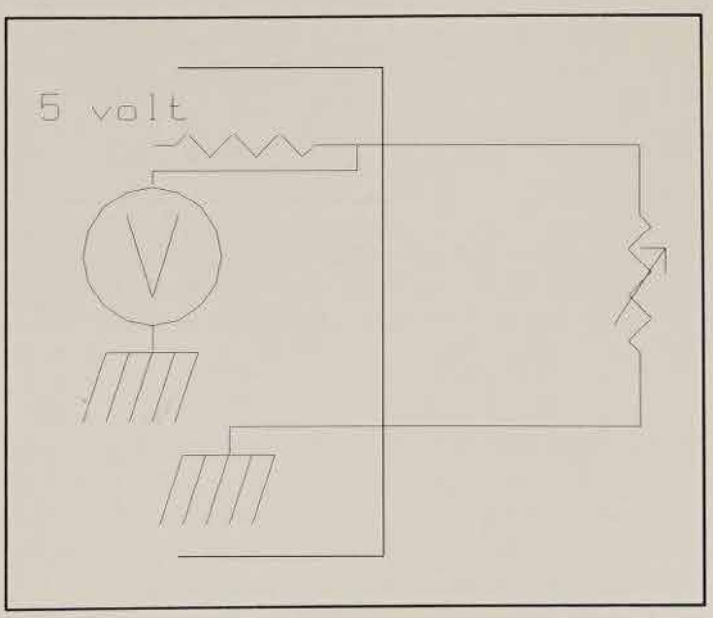
Thermistors are used to measure temperature. There are two basic types of thermistors: the positive temperature coefficient (PTC) thermistor, and the negative temperature coefficient (NTC) thermistor. Both types are resistors that change value when exposed to different temperatures. All conductors change resistance when their temperatures change and thermistors are designed to maximize this change. The positive temperature coefficient thermistor behaves like most conductors: as the temperature increases, its resistance increases. The negative temperature coefficient thermistor decreases resistance as the temperature increases. Most thermistors used in automotive electronics are NTC.

Thermistors are used to measure coolant temperature, air temperature, intake manifold temperature, car interior temperature and sun intensity. With all these different uses, many share the same resistance specifications. Note that the chart indicates temperature and resistance for *most* Bosch thermistors.

Bosch Thermistor Temperature-Resistance Chart

Temperature (deg. F.)	Resistance (ohms)
14	7,000–12,000
68	2,000–3,000
122	700–1,000
176	250–400

These examples would work for most of the applications described, but be sure to check the reference manual for the vehicle being tested.



The thermistor circuit uses a fixed resistor inside the ECU and a variable resistor to measure temperature. As the resistance of the variable resistor drops, the voltage between the resistors also drops. The ECU measures this changing voltage to measure the temperature.

Thermistor Circuit

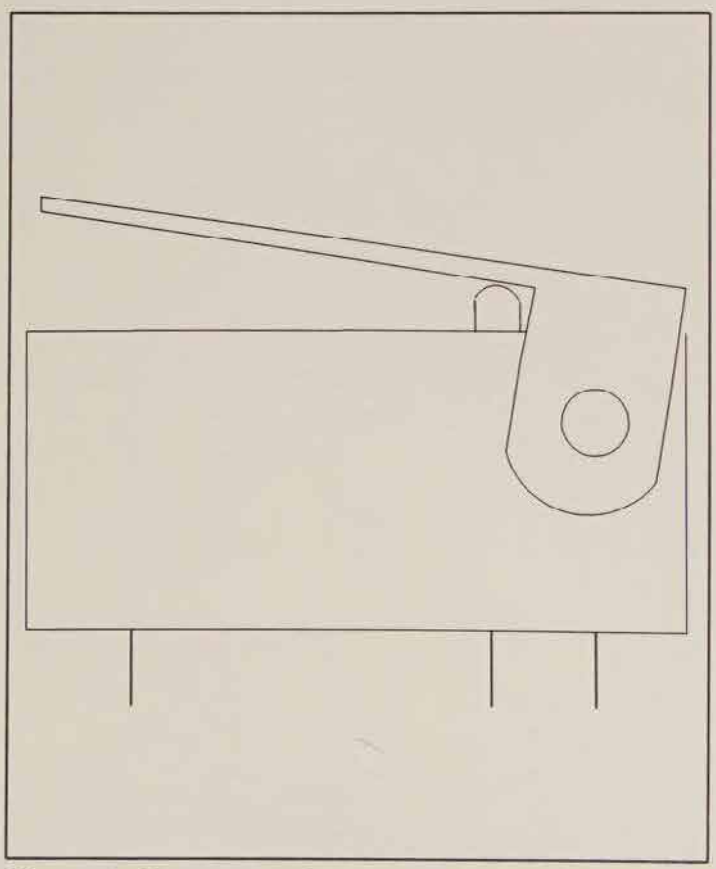
The thermistor circuit behaves a little differently from the electrical circuits with which most automotive technicians are familiar. A power supply (usually 5 volts) carries a reference voltage to the circuit. Before leaving the computer, the 5 volt current passes through a fixed-value resistor, causing a voltage drop. The current then continues through the thermistor and on to ground where the voltage is zero. As the resistance of the thermistor changes, the voltage on the wire between the fixed-value resistor and the thermistor will also vary. The computer measures this voltage on the outbound side of the fixed-value resistor to determine the temperature.

When the computer sees a comparatively high voltage on the wire to the NTC thermistor, it knows that the resistance in the thermistor is high, therefore, the temperature of the thermistor is low. A low voltage on this wire means that the resistance is low and therefore the temperature must be high.

The thermistor circuit is subject to three characteristic faults, however. When an open circuit occurs at any point in a thermistor circuit (other than inside the computer itself) the voltage at all points before the open circuit will rise to reference voltage. The reason is that when a circuit has an open, no current is flowing, and where there is no current flow there is no voltage drop. The voltage after the open will be zero volts. When the NTC thermistor circuit goes open, the computer sees the high voltage and assumes that the temperature is low (in fact, about −40 deg. F.).

When the NTC thermistor circuit is shorted to voltage, the computer will believe that the temperature is low. The voltage on the wire between the computer and the thermistor would be unusually high.

Should the wire between the computer and the thermistor become grounded, the voltage seen by the computer will drop to zero. The computer will believe that the temperature of the thermistor is more than 275 deg. F.



Microswitches are used on many LH and K-Lambda applications to detect either wide-open throttle or closed-throttle conditions.

Testing the Thermistor Circuit

The simplest way to test a thermistor circuit is to connect a voltmeter to the reference voltage wire between the thermistor and the computer. If the voltmeter reads between 0.5 and 4.9 volts (assuming a 5.0 volt reference in the system), then the circuit and the thermistor are good. A voltage approaching 5.0 volts would indicate an open circuit or short to voltage, while zero volts would indicate a ground. Since thermistors seldom develop a problem when their resistance is just a bit off, this test is usually sufficient. If further testing of the sensor is desired, use an ohmmeter.

Throttle Microswitch

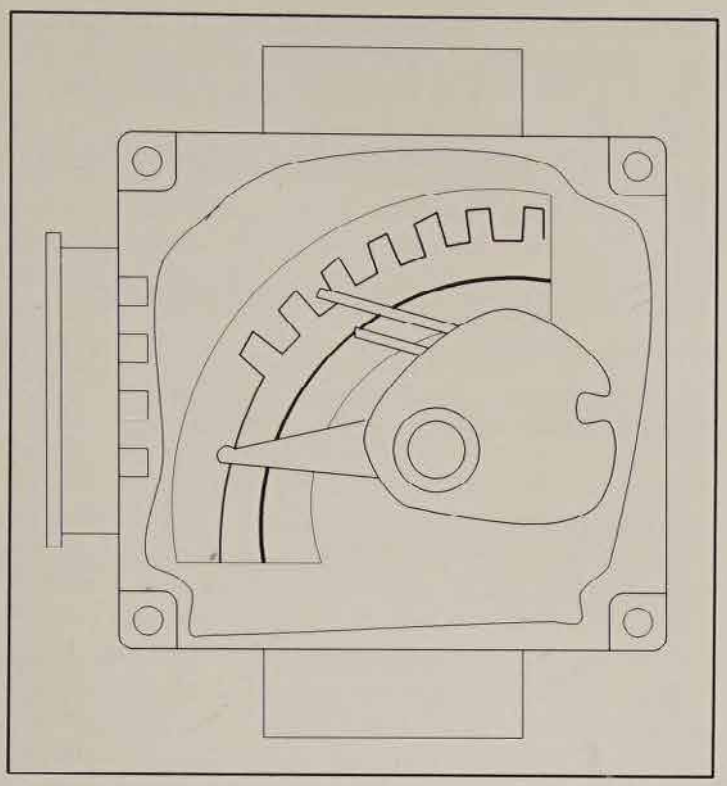
Many Bosch fuel-injection systems incorporate one or two microswitches on the throttle assembly to inform the computer about throttle position. These switches may be normally open, meaning there is no current flow until the switch is depressed; or normally closed, meaning there is no current flow when the switch is depressed. These switches are used to inform the computer that the throttle is either closed or wide open.

Electrically, the most common circuit design uses a resistor on the reference voltage wire within the computer (similar to the thermistor circuit) where its voltage is monitored by the computer. This wire continues out to one terminal on the microswitch; the other terminal is connected to ground. When the switch closes, the voltage drops low and the computer knows that the throttle has changed position.

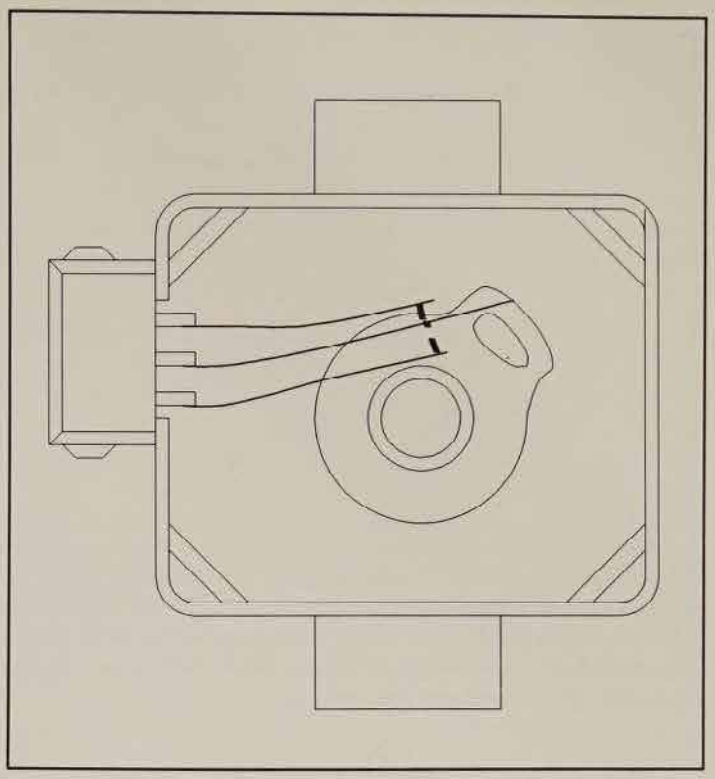
Testing the circuit is a simple matter of connecting a voltmeter to the wire between the computer and the switch. As the switch is manually opened and closed, the voltage on the wire should change dramatically. An alternative method is to use an ohmmeter.

Two-Contact Throttle Switch

Most European and Japanese electronic fuel-injection systems use a throttle switch that incorporates two microswitches in a single unit. As with



The D-Jetronic system uses a twenty-position throttle switch to detect closed throttle, wide-open throttle and movement in between.



The L-Jetronic system uses a two-position switch mounted on the throttle shaft to detect wide-open throttle and closed-throttle conditions.

the Bosch systems, the switch is mounted on the throttle assembly, and it informs the computer about throttle position.

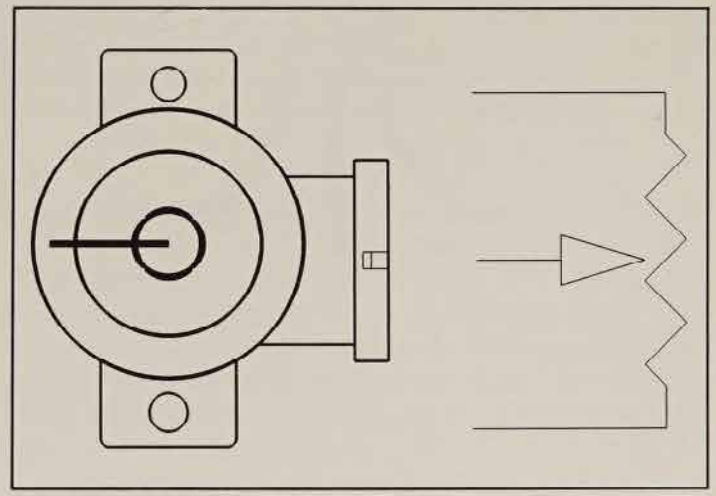
Potentiometer Throttle Position Sensor

The modern throttle position sensor, or TPS, is a potentiometer. There are three wires connected to the TPS: a 5.0 volt reference, a ground (sometimes called signal return) and a signal wire. As the throttle is opened, the signal voltage will proportionately increase from a low of about 0.5 volt to a high of more than 4.0 volts.

To test this sensor, turn the ignition switch to the on position. There should be 5.0 volts on one wire, 0.5 to 1.0 volt on another wire and zero volts on the third wire.

Note: If the voltage on the signal wire is well over 1.0 volt with the throttle closed, inspect the ground wire for an open circuit before attempting to adjust or replace the TPS.

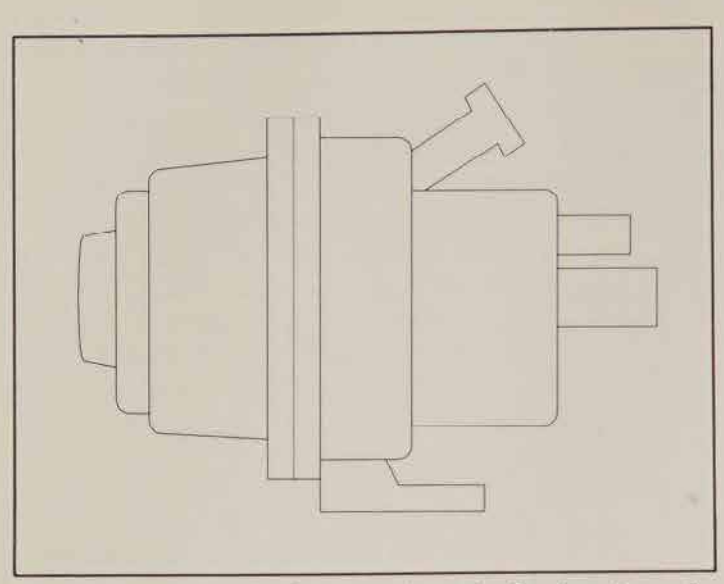
If the signal voltage is between 0.5 and 1.0 volt, gradually open the throttle and monitor the voltage (this is most accurate with an analog voltmeter). The voltage should gradually increase to more than 4.0 volts. If the increasing voltage hesitates or drops as the throttle is opened, replace the TPS.



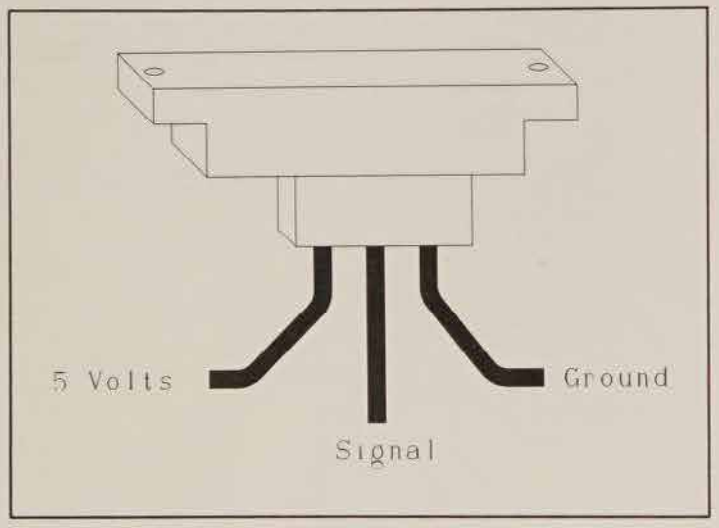
Many late-model fuel-injected cars use a potentiometer to measure throttle position. The advantage is that the ECU is able to know the exact position of the throttle at all times, thereby providing increased accuracy in fuel control.

Variable Voltage Manifold Absolute Pressure Sensor

Today's most commonly used technology for measuring airflow into the intake manifold is called speed-density. Barometric pressure is compared to the pressures in the intake manifold. When these pressures are far apart it is assumed that very little air is entering the intake manifold. When the pressures are close together it is assumed that a large amount of air is entering the engine, causing the intake manifold pressure to rise. As early as 1968 the LVDT of the Bosch D-Jetronic system was using this method of measuring airflow.



The oldest method of measuring air flowing into the engine is speed-density. This involves the measurement of barometric and intake manifold pressures. The D-Jetronic system accomplishes this with the use of the linear variable displacement transducer.



Later model cars that use speed-density, such as Honda, use a variable voltage sensor to measure barometric and manifold pressure.

The modern replacement for the LVDT (linear variable-differential transformer) is the Variable Voltage Manifold Absolute Pressure (MAP) Sensor. This sensor consists of an extremely thin diaphragm strung between four variable resistors that form a Wheatstone Bridge. When the pressure on the diaphragm increases the resistors are stretched, causing their resistance to change. The result is that the output voltage of the sensor varies from reference voltage as the pressure on the diaphragm changes.

For most applications using this type of sensor, full atmospheric pressure causes an output voltage of about 4.5 volts (where reference voltage is 5.0 volts). If the sensor is being used to measure manifold pressure this voltage will drop to about 1.5 volts when the engine is idling. (These voltages are approximate.) This drop in voltage is proportional to the drop in manifold pressure that occurs when the engine is at an idle.

The following mathematical expressions show how this occurs:

Normal
barometric
pressure = 29.92 in.Hg (inches of mercury)
= 15 psi
= 100 kPa (kilopascals)
Variable voltage MAP output = 4.5 volts
Manifold pressure at an idle = 10.0 in.Hg
= 5 psi
= 35 kPa
MAP sensor output voltage = 1.5 volts

Note: These pressures are about one third of atmospheric pressure.

Turbocharged applications that use a variable voltage pressure sensor to measure manifold pressure simply cut these voltage readings in half. This accommodates the accurate measurement of pressures greater than atmospheric when under boost.

Testing the MAP Sensor

The voltmeter is the best instrument for testing the Variable Voltage MAP Sensor. With the harness connected, the ignition on but the engine not running, the three wires should read 5.0 volts VREF (for volt reference), 4.5 volts (pressure signal) and zero volts (ground). If these readings are obtained, apply a vacuum with a hand-held vacuum pump or by starting the engine. Only the signal voltage should drop to 1.5 volts. If these readings are obtained, then the pressure sensor is good.

Open-circuit voltage on the harness can behave in a somewhat unusual manner. The VREF wire should have 5.0 volts in all cases; the ground wire should have zero volts in all cases; and the signal wire will usually have zero volts. This would be expected since the current path is from the computer's 5.0 volt power supply through the sensor, then back to the computer. Some applications, however, have an extremely high-value resistor inside the computer between VREF and the signal wire. When there is an open circuit in either the VREF wire or the signal wire, current travels through this pull-up resistor, simulating a high pressure. This supplies a limp-in signal in the event of an open circuit. Open-circuit voltage for these applications is 5.0 VREF, 4.8 (approximately) signal wire and zero on the ground.

A signal voltage that is in the midrange and changing very little with changes in pressure may indicate an open in the ground wire.

A vacuum hose connects the MAP sensor to the intake manifold. Hydrocarbons and acids can build up in this hose and damage the MAP sensor.

Airflow Meter

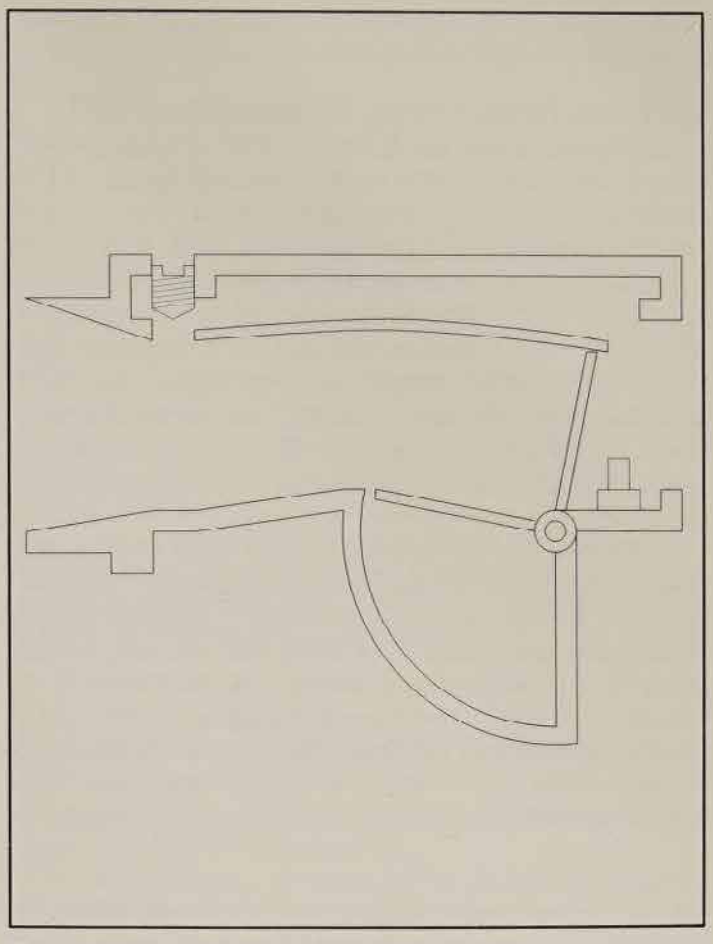
The airflow meter was developed by Bosch for use with the L-Jetronic fuel-injection system introduced in 1974. In 1975 Datsun, the Japanese automobile manufacturer, incorporated the airflow meter in the fuel-injection system on its new 280Z. Since the mid 1970s this sensor has been used extensively by both European and Japanese manufacturers. Its use on North American-built automobiles has been limited to Ford's turbocharged four-cylinder engines.

The airflow meter consists of a spring-loaded flap mounted on a rotating shaft. Mounted between the air cleaner and the throttle assembly, all of the air entering the engine to be used for combustion passes through the meter. As the air flows into the engine it moves the flap which in turn rotates the shaft. The rotating shaft is connected to a variable-resistance device known as a potentiometer. As the shaft is rotated the resistance between the input reference voltage terminal and the output terminal changes; therefore, the output voltage changes as well. A small airflow causes little movement and thus a small output voltage. A larger airflow causes a greater deflection and therefore a greater output voltage.

A damper flap forms an L with the airflow measuring flap. This damper flap reduces the erratic movement of the sensor flap caused by sudden acceleration, deceleration or the normal fluctuation in airflow caused by valve action.

A secondary air channel allows a metered amount of air to by-pass the L-shaped flap. Many applications have a manual mixture adjustment screw to control the amount of air allowed through this by-pass. If the screw is turned in, it reduces the amount of air allowed through the by-pass channel. As a result, more air is forced across the L-shaped flap, causing it to be deflected more. The more the L-shaped flap is diverted, the greater the output signal to the computer and the more fuel the computer allows through the injectors. The result is the engine runs richer when less air goes through the by-pass.

Also included in most airflow meters is a fuel pump switch. When the flap comes to rest indicating that no air is flowing into the engine, the switch opens, shutting off the fuel pump. Most applications also include a thermistor to measure the temperature of incoming air.



The airflow meter was introduced on Bosch fuel-injected cars in 1974. The L-Jetronic system measures the air flowing into the engine by measuring the voltage from the potentiometer that is attached to the moving flap.

Testing the Airflow Meter

Three steps are involved when testing most airflow meters. The wide range of this sensor's applications prevents me from providing a set of rule-of-thumb specifications, however. Consult the manufacturer's service material for terminal identification.

Step one is to test the fuel pump cutoff switch. Connect an ohmmeter to the fuel pump cutoff switch. The meter will show either an open switch (infinite ohms) or a closed switch (zero ohms). When the flap is moved by hand the ohmmeter reading will change.

Step two involves testing the air temperature sensor by connecting an ohmmeter to the air temperature sensor terminals. Consult the manufacturer's specifications for details.

For step three, remember that the airflow measuring portion of the airflow meter is the sensor's most important task. Leaving the vehicle wiring harness attached to the airflow meter, connect a high-impedance voltmeter to the sensor's airflow output terminal. With the flap closed the output voltage should be low. Slowly open the flap by hand; the output voltage should slowly increase until it approaches system reference voltage. More important than the specific voltage, however, is that the change in voltage should occur smoothly and with direct proportion to the amount of opening. Common failures of the airflow meter relate to its electromechanical nature. The potentiometer is subject to wear; the shaft on which the flap rotates can wear, causing sticking and binding. Be sure to test the flap for smooth movement. The airflow meter itself has one inherent problem; the flap that

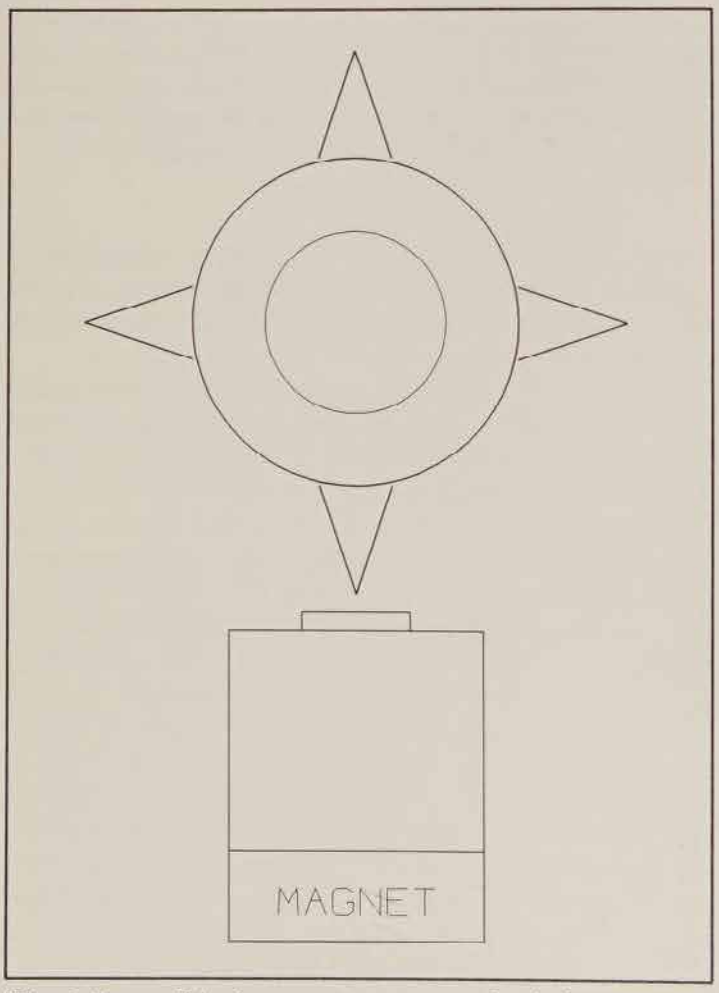
responds to the volume of air entering the engine is a serious restriction to airflow.

Variable Reluctance Transducer (VRT)

A more common term for the VRT is pickup coil. The typical automotive technician will think of the electronic ignition distributor when this component is mentioned. In reality, the VRT has many uses. It is used to measure crankshaft rotational speed on some distributorless ignition systems, wheel speed for four-wheel antilock braking systems, differential speed on rear-wheel antilock braking systems and in some vehicle speed sensors. The VRT produces an AC sine wave with a frequency directly proportional to the speed of the rotation.

The primary advantage of the VRT over other rotational speed sensors is its simplicity. Consisting of a coil of wire, a permanent magnet and a rotating reluctor, there is little that can go wrong with it. Its main disadvantage is its inability to detect accurately low-speed rotation; at low rotational speeds the VRT is unable to produce a signal.

Here is how it works. A coil of wire sits in a magnetic field created by a permanent magnet. A metal wheel with protruding reluctor teeth rotates through the magnetic field. As it rotates and one of the teeth approaches the magnetic field, the field is bent toward the approaching tooth. As it is bent it passes across the coil of wire, inducing a voltage. Continuing to rotate the reluctor tooth drags the magnet field across the coil of wire, eventually bending it in the opposite direction. The result is an AC signal.



The pickup coil is the most common method of measuring crankshaft speed. This sensor produces an AC signal. The ignition and fuel-injection systems are synchronized to the signal from this sensor.

Testing the VRT

For troubleshooting electronic ignition systems, most books will describe using an ohmmeter to test a reluctance pickup. Although this is not a totally invalid test, it tests only the coil of wire; reluctor air gap, conditon of the permanent magnet and adequate rotational speed are not tested.

First, disconnect the pickup from the ignition module or vehicle wiring harness leads. Connect the ohmmeter to the pickup coil leads and measure the resistance. Typical ohmmeter readings for a good reluctance pickup coil would be between 500 and 1,500 ohms.

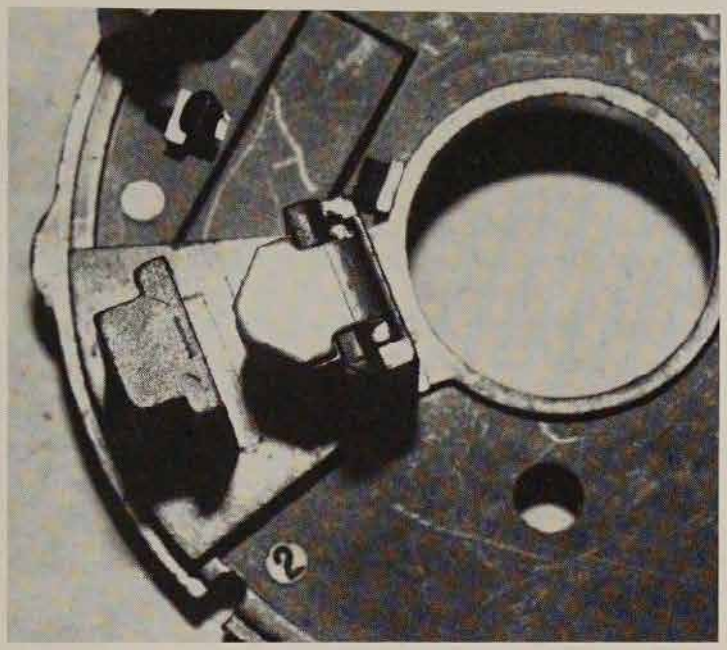
A much better way to test a reluctance pickup is with an oscilloscope. Connect the scope to the pickup coil leads and rotate the reluctor (crank the engine and rotate the wheel). A series of ripples should appear on the scope. If the line remains flat there is an open in the coil of wire, the permanent magnet has been damaged or the air gap between the pickup and the reluctor teeth is too large.

The AC voltmeter is a practical and effective alternative to the oscilloscope for testing the VRT. Connect the AC voltmeter as described for connecting the oscilloscope. Rotating the reluctor at minimum speed (cranking the engine and rotating a wheel at one revolution per second) would yield between 0.5 and 1.5 volts. Again, if the AC voltmeter does not produce a voltage, there is an open in the coil of wire, the permanent magnet has been damaged or the air gap between the pickup and the reluctor teeth is too large.

Note: Since the VRT is primarily a coil of wire and a permanent magnet, it is prone to intermittent failures with changes in temperature and vibration. If the failure being diagnosed is intermittent, the sensor should be heated and tapped while testing.

Hall Effects Sensor

The Hall Effects sensor is often used as an alternative to the VRT. Many ignition systems, both with and without a distributor, use a Hall Effects device. Its primary advantage over the VRT is its ability to detect position and rotational speed from zero rpm to a reading in the tens of thousands. Its primary disadvantage is that it is not as rugged as the VRT and is more sensitive to errant magnetic fields. An intense magnetic field can shut down the proper operation of a Hall Effects sensor.



The Hall Effects sensor is being used more often to provide the synchronizing signal for ignition and fuel injection. This device produces a DC pulse that can be detected with a voltmeter, dwell meter, tachometer or oscilloscope.

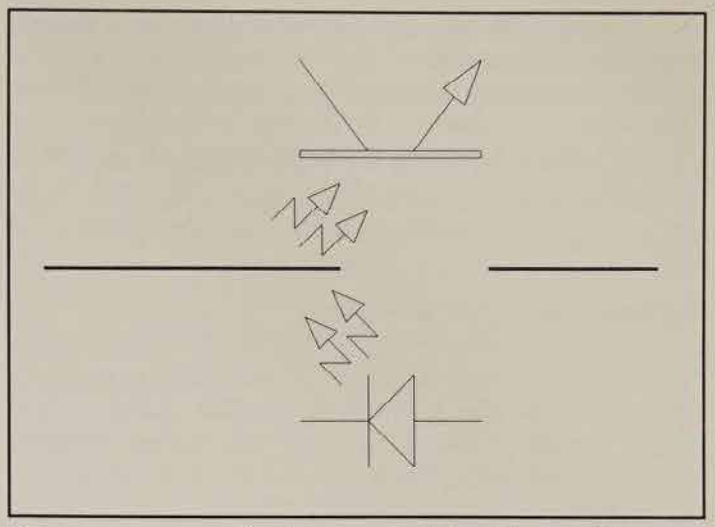
How does it work? A Hall Effects pickup is a semiconductor carrying a current flow. When a magnetic field falls perpendicular to the direction of that current flow, part of that current is redirected perpendicular to the main current path. The semiconductor is placed near a permanent magnet. A set of metal blades, or armature, attached to a rotating shaft or other device passes between the Hall Effects semiconductor and the permanent magnet. As the armature rotates, the magnet field is alternately applied to the Hall Effects and interrupted. The result is a pulsing current perpendicular to the main current path. This frequency is directly proportional to the speed of armature rotation. Since the output is dependent only on the presence of the magnetic field, the Hall Effects unit can detect armature position even when there is no rotational speed.

Testing the Hall Effects Sensor

There is no valid test procedure on the Hall Effects sensor using an ohmmeter.

When testing with an oscilloscope, connect the oscilloscope to the Hall Effects signal lead. Rotate the armature. Depending on the number of blades and the rotational speed of the armature, the scope pattern could appear either as a square wave or a flat line that rises and falls with rotation.

The test procedure for using a voltmeter is to first connect the voltmeter to the Hall Effects output lead. The voltmeter should display either a digital high (4 volts or more) or a digital low (around zero volts). Slowly rotate the armature while observing the voltmeter. If the voltmeter had read low, it should now read high. If the voltmeter had read high, it should now read low. If the voltage changes in this manner as the armature is rotated, then the Hall Effects is good.



Nissan uses an optical sensor to detect the position and speed of the engine. The signal is produced with a light emitting diode and photodiode. The output signal is similar to the Hall Effects sensor.

Since the signal generated by the Hall Effects is a square wave, the dwell meter becomes a natural for testing. Connect the dwell meter between the Hall Effects output and ground. Rotate the armature as fast as possible; for instance, crank the engine. The dwell meter should read something besides zero and full scale. If it does, the Hall Effects is good.

The tachometer is another good tool for detecting square wave. Connect the tachometer between the Hall Effects output and ground. With the armature rotating as described in the dwell meter test procedure, the tachometer should read something other than zero if the Hall Effects is good.

Optical Sensor

The signal produced by the optical sensor is identical to the one produced by the Hall Effects. The signal, however, is produced by an armature interrupting light. A light emitting diode, or LED (usually infrared, invisible light), sits opposite an optical receiving device such as a photodiode or phototransistor. An armature is rotated between the LED and the receiver. Unlike the Hall Effects, the armature in the optical sensor can be metal, plastic or any translucent material. As the armature rotates, light alternately falls on and is kept from falling on the receiver. As this occurs the current flowing through the receiver is turned on and off, creating a square wave with a frequency directly proportional to armature rotation. In some cases, such as many GM vehicle speed sensors, the light is reflected off of rotating blades rather than being interrupted.

The major benefit of the optical rotational sensor over the VRT and the Hall Effects is its ability to produce extremely high frequencies. The 3.0 liter Chrysler distributor produces a frequency of 540,000 Hz (0.54 MHz, or megahertz) at just 3000 rpm. The primary drawback is its sensitivity to dirt, oil and grease, which creates erroneous signals.

Testing the Optical Sensor

Using an oscilloscope, connect the scope to the optical sensor signal lead. Rotate the armature. Depending on the number of blades and the rotational speed of the armature, the scope pattern could appear either as a square wave or a flat line that rises and falls with rotation.

To test with a voltmeter, connect the device to the optical sensor output lead. The voltmeter should display either a digital high (4 volts or more) or a digital low (around zero volts). Slowly rotate the armature while watching the voltmeter. If the voltmeter had read low, it should now read high; if the voltmeter had read high, it should now read low. If the voltage varies in this manner as the armature is rotated, then the optical sensor is good.

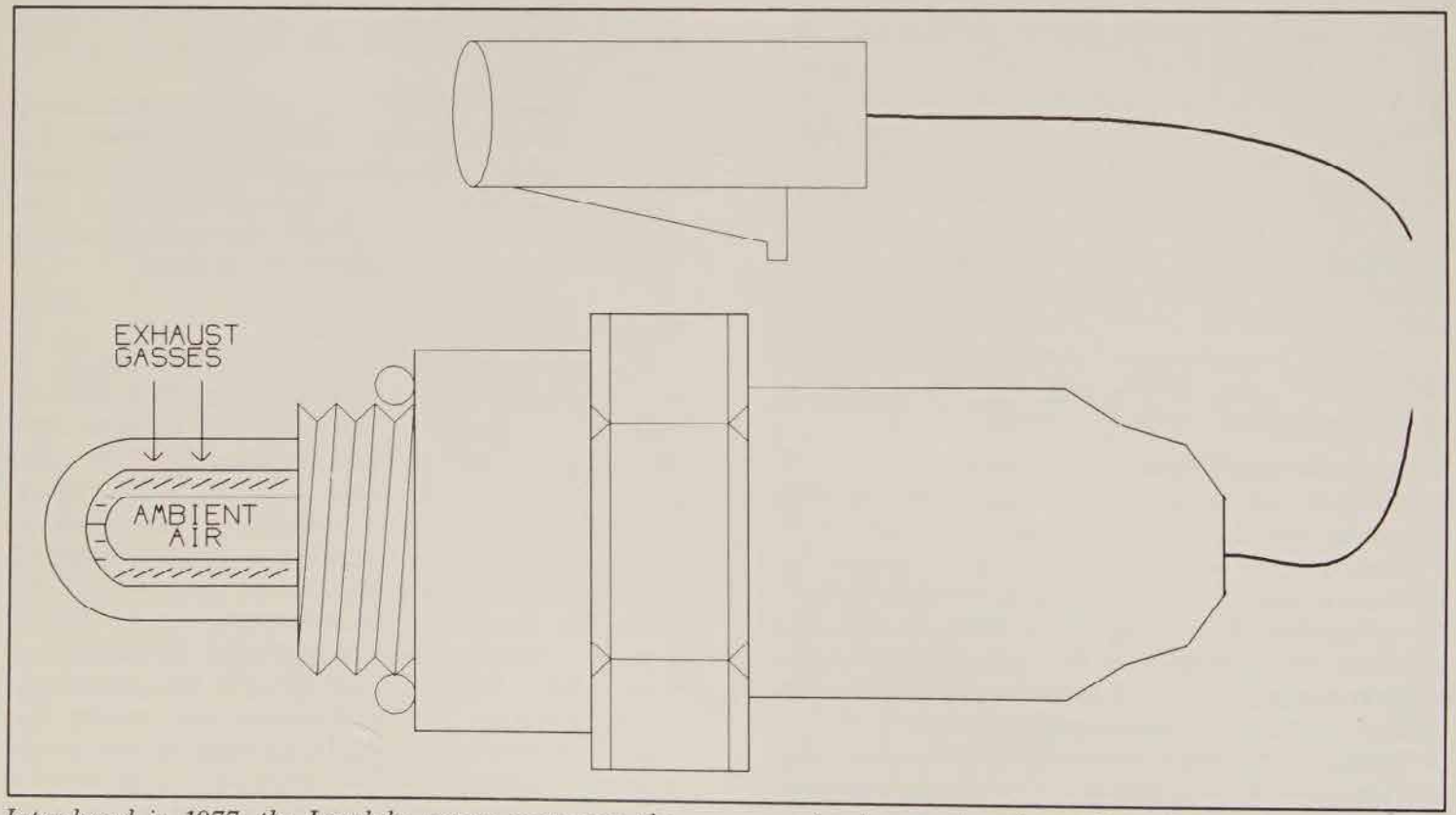
Since the signal generated by the optical sensor is a square wave, once again the dwell meter is naturally suited for testing. Connect the dwell meter between the optical sensor output and ground. Rotate the armature as fast as possible; for instance, crank the engine. The dwell meter should read something besides zero and full scale. If it does, the optical sensor is good.

The tachometer is also a good tool for detecting square wave. Connect the tachometer between the Hall Effects output and ground. With the armature rotating as described for the dwell meter, the tachometer should read something other than zero if the optical sensor is good.

Lambda Sensor

The Lambda sensor consists of a zirconium oxide ceramic which becomes conductive for oxygen ions at 600 deg. F. One part of the ceramic is located in the exhaust stream while the other is exposed to ambient oxygen. The surface of the ceramic is covered with a thin, gas-permeable layer of platinum. When the percentage of oxygen contacting the two ends of the ceramic is equal, there is a balance of oxygen ions and no voltage is generated. When there is an imbalance, oxygen ions are attracted from the surplus side and a voltage is generated. The Lambda sensor output voltage varies from about 100 to 900 mV during normal engine operation.

When the engine is running rich there is a low oxygen content in the exhaust, thus a high voltage



Introduced in 1977, the Lambda sensor measures the amount of oxygen in the exhaust. As the oxygen content increases, the output voltage of the sensor decreases. As the output voltage decreases, the ECU assumes that the engine is running lean, thus the ECU enriches the mixture. As the oxygen content decreases, the output voltage increases and the ECU assumes that the engine is running rich. The ECU then leans out the mixture.

is produced. When the engine is running lean there is a high percentage of oxygen in the exhaust, thus a low voltage is generated. At the point of perfect combustion, known as the stoichiometric point, the Lambda sensor produces 450 mV. This is known as the crossover point. Many applications have a very high impedance circuit that will replace a missing Lambda sensor signal with a default voltage of 450 mV. This voltage can be detected with a high-impedance voltmeter whenever the Lambda sensor is cold or disconnected.

The Lambda sensor will very seldom develop a defect. It is, however, very susceptible to contamination. Common contaminants are tetraethyl lead, RTV silicone and soot.

Testing the Lambda Sensor

A voltmeter is the device of choice for testing the Lambda sensor. Connect the voltmeter to the sensor output lead. Warm the engine to operating temperature, then raise the engine speed to 2000 rpm for two minutes. Allow the engine to return to an idle and watch the voltmeter. If the output voltage is continuously fluctuating between 100 and 900 mV, the Lambda sensor and its computer circuitry are good. If the voltage fluctuations are sluggish, or are stuck high or low, the sensor may be contaminated and further testing may be required.

Further testing may be done by disconnecting the Lambda sensor and connecting a high-impedance voltmeter to it. Connect the lead going to the computer to a good ground. This lies to the computer, telling it that the engine is running lean. The computer should respond by enriching the mixture. The Lambda sensor voltage should increase. If it does not, enrich the mixture with propane. If the sensor voltage increases, then the sensor is good and the computer, actuator circuit or input circuit may be defective.

Now touch the positive battery terminal with one finger, and touch the computer's Lambda sensor input wire with another finger. This delivers a small voltage to the computer, telling it that the engine is running rich. The sensor voltage should drop as a result. If it does not, lean out the mixture by creating a vacuum leak. If the Lambda sensor voltage decreases, then the sensor is good and the computer, actuator circuit or input circuit may be defective.

2

Emissions

Since the 1960s, automobile manufacturers have had several government–mandated issues to deal with. Safety, fuel economy and emission standards have all been stipulated and regulated by federal and state governments. This onslaught of regulation was unprecedented, and contributed to the dissolution or reorganization of many manufacturing companies.

Of these three new areas of government regulation the one that affects the automotive repair technician most directly is emissions. When fuel and air are combined in the combustion chamber of a gasoline engine and heat is added, a complex chemical reaction occurs. Because of the complex make-up of the chemicals involved, the result of combustion is usually a foul, smelly mess.

Combustion Chemicals

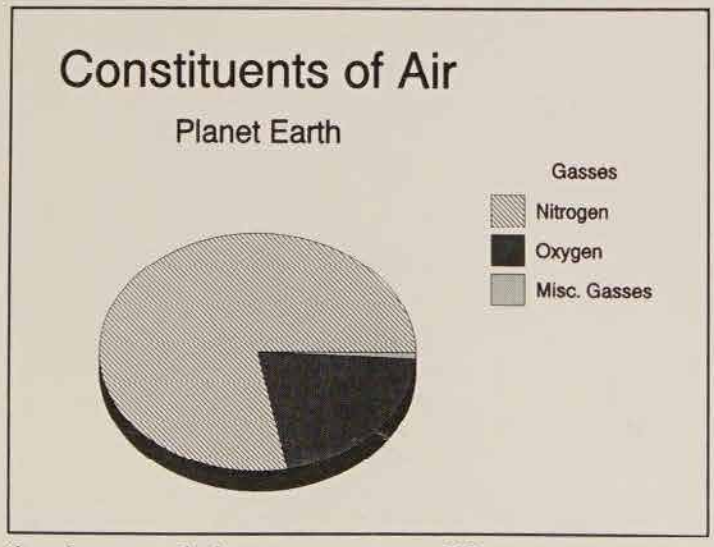
Air

Air is a blend of several gases, including 21 percent oxygen, 78 percent nitrogen and 1 percent miscellaneous gases. During ideal combustion the nitrogen and miscellaneous gases remain in their original form while the oxygen combines with the fuel. When something goes wrong with the combustion process nitrogen begins to combine with oxygen, resulting in a disastrous chemical bonding. The union forms two chemicals usually referred to under the umbrella oxides of nitrogen.

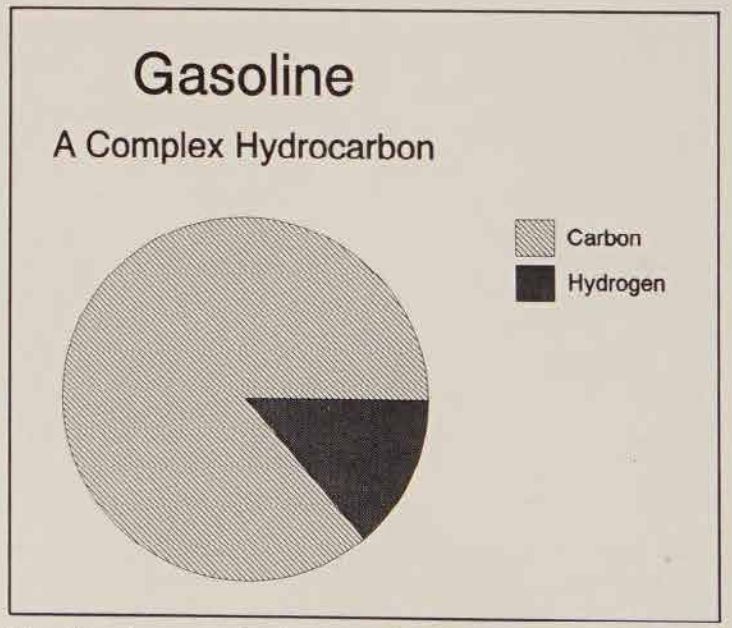
Oxides of nitrogen are responsible for some of the visual elements of photochemical smog. When exposed to sunlight these chemicals form the reddish brown haze familiar to most city dwellers. Elements of this haze burn the eyes and lungs. These gases have also been linked to acid rain and the destruction of tropical rain forests.

Gasoline

Gasoline is a complex hydrocarbon consisting of 86 percent carbon and 14 percent hydrogen by weight. Along with these elements are trace amounts of sulfur. If perfect combustion were possible, the combining of air and gasoline would



On planet earth the oxygen content of the atmosphere is 21 percent, the nitrogen content is 78 percent and the remaining 1 percent consists of miscellaneous inert gases.



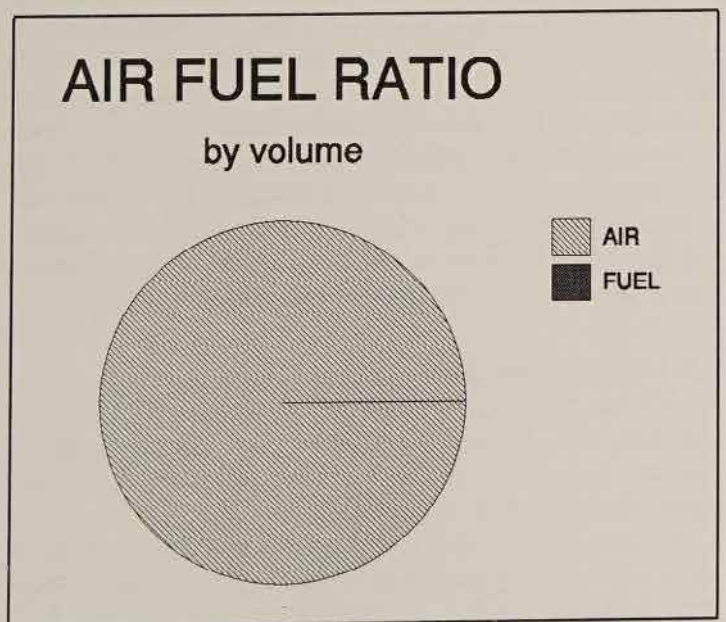
Gasoline is a complex hydrocarbon containing 86 percent carbon and 14 percent hydrogen by weight.

yield only carbon dioxide, water and nitrogen. The presence of sulfur in the gasoline provides an opportunity for the formation of sulfuric acid and sulfur dioxide. Some of the sulfuric acid finds its way past the piston rings and into the crankcase, often damaging bearings and other engine parts. Some goes directly into the atmosphere. Sulfuric acid emissions have been linked to the type of acid rain that damages lakes. Sulfur dioxide emissions are responsible for the rotten-egg smell familiar to commuters.

Other by-products of the combustion process include formaldehyde, paraffin, olefins, aromatic hydrocarbons, keytones, carboxylic acids, acetylene, ozone, soot, peroxyacetyl nitrates and polycyclic acids. This amounts to a soup of toxins and irritants. Many of these chemicals are present in fairly large quantities even after near-perfect combustion. As the quality of combustion deteriorates, the levels will often increase dramatically. This government-mandated list of automotive exhaust by-products is mainly for those who pay little attention to the environmental laws and regulations after the refining process.

Chemical emissions that the auto manufacturers must directly deal with during combustion are carbon monoxide, raw hydrocarbons and oxides of nitrogen. Possible additions to the list include carbon dioxide and ozone. Of these two, carbon dioxide could be the most difficult emission to deal with. Up to this point, the majority of emission control technologies used by the automotive industry have dramatically *increased* the production of carbon dioxide.

The allowable levels of each of these emissions differ from one jurisdiction to another. Surprising to many is that although California has a reputation for tight standards, its standards are among the loosest for carbon monoxide.

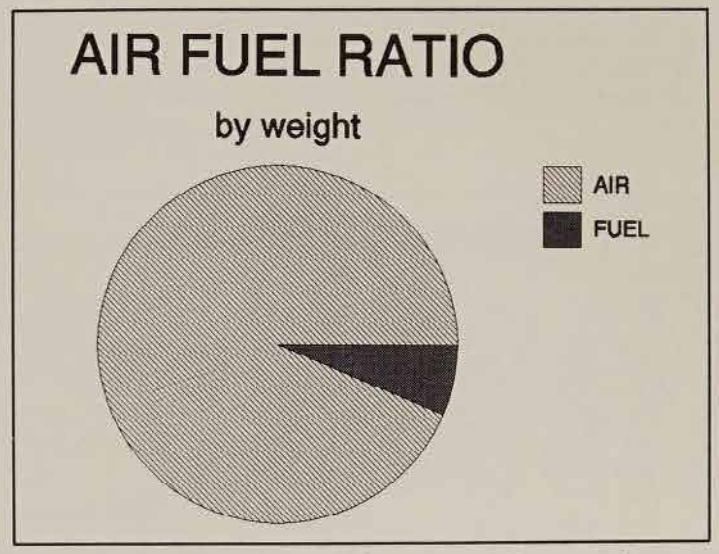


By volume, the correct air-fuel ratio is over 10,000 parts air to one part fuel.

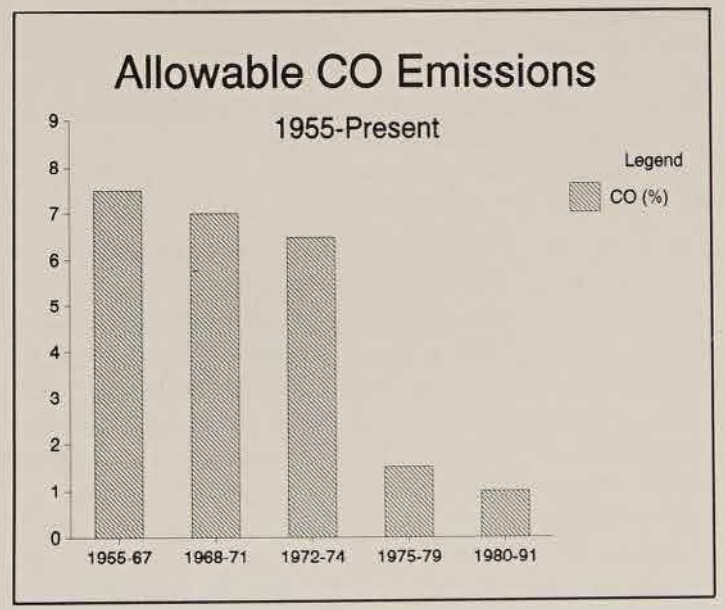
Harmful Exhaust Emissions

Carbon Monoxide

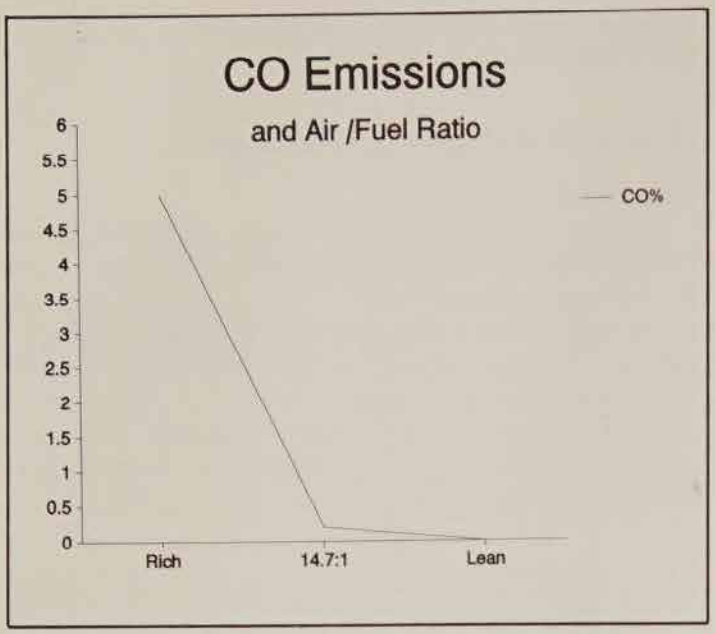
During perfect combustion the gasoline hydrocarbons combine with atmospheric oxygen to produce carbon dioxide (CO_2). This requires that two molecules of oxygen combine with one molecule of carbon. If there is not enough oxygen to provide two molecules per carbon molecule, then some carbon molecules will only combine with one oxygen molecule. Carbon monoxide (CO) results, therefore, from a partial burning of the fuel.



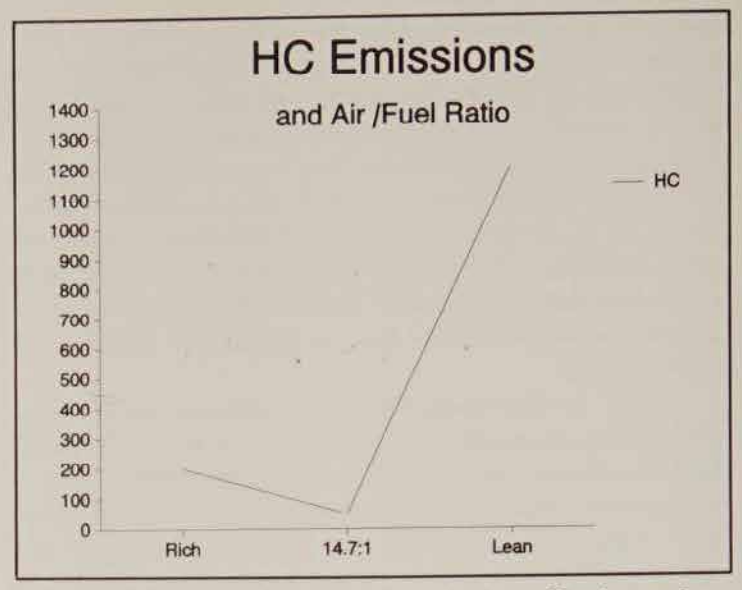
By weight, the correct air-fuel ratio is 14.7 parts air to one part fuel.



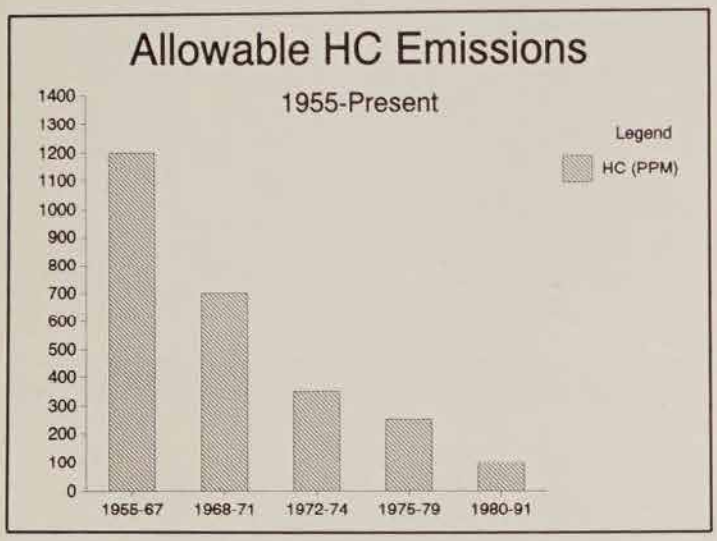
Since the 1960s, the CO emissions allowed by the federal government have steadily decreased. Today they are about one seventh, by percentage of exhaust content, of what was allowable in the early 1960s.



As the engine runs leaner, the production of carbon monoxide (CO) decreases.



As the engine runs leaner, the emission of hydrocarbons decreases. At slightly leaner than 14.7:1, however, the HC content of the exhaust begins to increase dramatically once again.



Since the 1960s, the HC emissions allowed by the federal government have also steadily decreased. Today they are about one twelfth, by part per million of exhaust content, of what was allowable in the early 1960s.

Two related factors are mainly responsible for high levels of CO emissions: either there is not enough air being provided for the amount of fuel delivered, or there is too much fuel being delivered for the amount of air. High CO content can result from a dirty air filter, high fuel pressure, a defective Lambda circuit or anything that affects air or fuel delivery to the combustion chamber.

Carbon monoxide is an odorless, tasteless, colorless gas. When entering the bloodstream through the lungs, the blood's red corpuscles have a many times greater affinity for the CO than they do for oxygen. This results in the CO being carried throughout the bloodstream. Short-term exposure to even low levels of CO can be fatal. Long-term exposure to even lower levels has been linked to brain damage. Levels as low as ten parts per million (0.0001 percent) can dull reflexes and thinking processes severely during the course of an eight-hour day. These levels can be attained very quickly in a closed shop. Even a car running at a very low level of 0.2 percent CO can cause a two-car garage to reach this level in less than ten seconds. So treat this gas with the respect its toxicity demands.

Hydrocarbons

Hydrocarbon (HC) emissions result when part of the gasoline does not become heated enough to combine with oxygen. As a result, the fuel enters and leaves the combustion chamber unchanged.

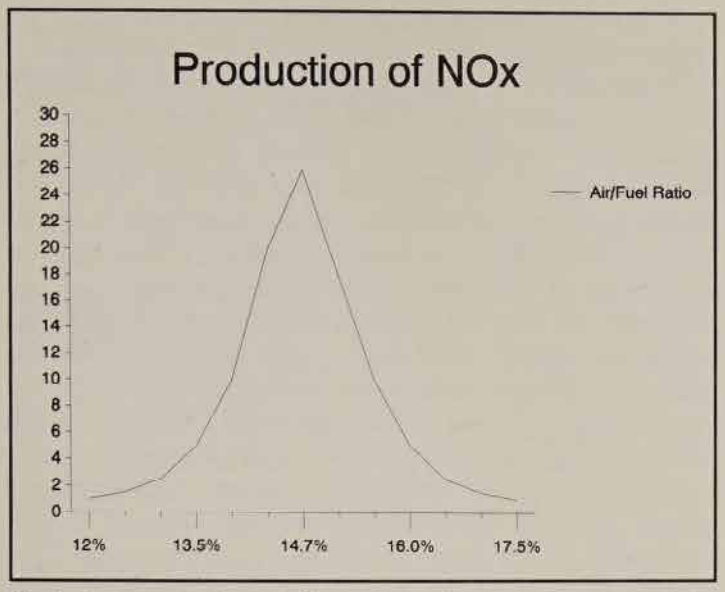
High hydrocarbons can be detected by smell. Exhaust containing high levels of HC has a distinctive, biting odor. Relatively low levels, such as 300 parts per million (0.03 percent) will cause a burning sensation of the eyes and nose.

Poor ignition quality, low compression or an incorrect air-fuel ratio can severely increase HC emissions. Although the air-fuel ratio does affect HC levels, its effect is not nearly as profound as on the emissions of carbon monoxide.

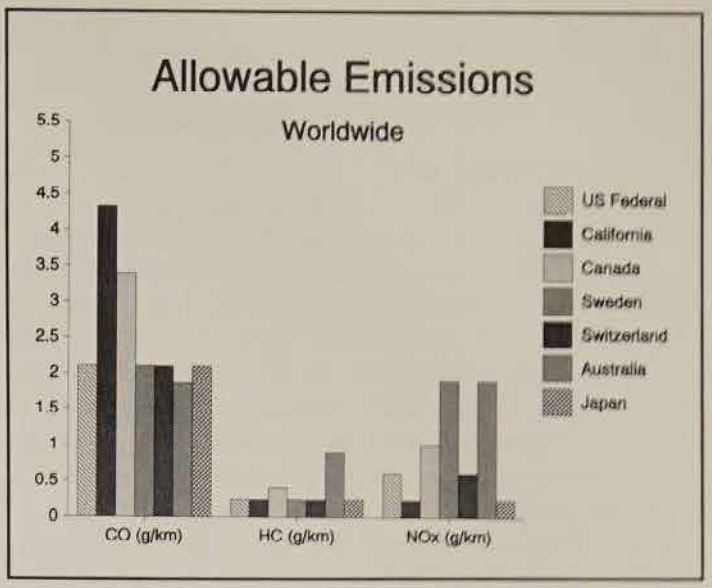
Oxides of Nitrogen

As mentioned, oxides of nitrogen (NO_x) are among the primary elements of photochemical smog. One of the gases, nitrogen dioxide, is highly toxic and can destroy lung tissue.

Atmospheric nitrogen begins to combine with atmospheric oxygen when their temperature reaches 2,500 deg. F. Therefore, unlike CO and HC, NO_x increases as the quality of combustion increases. Consequently, automotive emission sys-



Emission control would be relatively easy if it were not for oxides of nitrogen. When CO and IIC are at their lowest levels—14.7:1 air-fuel ratio—NO_x is approaching its highest level.



In spite of its reputation, California does not have the world's toughest emission standards. Although different jurisdictions place emphasis on different gases, Japan has the toughest overall standards.

tem design engineers were faced with the problem of cleaning up emission that fueled the production of yet another emission.

Overview of Emission Control Devices

Automotive engineers have designed a number of emission control devices and modifications to meet government standards. They include the following:

Engine Modifications

By dropping the compression ratios in the mid 1970s, manufacturers were able to lower combustion temperatures and thereby lower the production of NO_x. This caused fuel economy to plummet, however, and destroyed the potential for performance.

Increased valve overlap allows for some of the exhaust gases to be drawn back in during the beginning of the intake stroke. These exhaust gases are inert—the fuel and the oxygen were burned out of them during the previous combustion cycle. As the next combustion cycle begins, these inert gases act as a heat sink to lower the combustion temperature and decrease the production of NO_x.

Exhaust Gas Recirculation (EGR) Valve

The EGR valve is used to reduce the production of oxides of nitrogen. As the engine rpm rises above idle, vacuum applied to either a diaphragm or solenoid lifts the pintle of the EGR valve, allowing exhaust gases into the combustion chamber. Approximately 7 percent of the combustion chamber volume will lower the burn temperature by about 500 deg. F. This lower temperature reduces the production of NO_x.

Positive Crankcase Ventilation (PCV)

The PCV system draws crankcase vapors through a metered check valve known as the PCV valve into the intake manifold. These gases, the result of combustion chamber blow-by, are given a second chance to be burned. The PCV system is designed to reduce the amount of hydrocarbons allowed to escape to the atmosphere from the crankcase.

Fuel Evaporation

Since the 1970s, cars have been equipped with an evaporative control system. This system consists of a canister filled with activated charcoal. The canister is then connected to the fuel tank (and in carbureted cars, to the carb fuel bowl) by hoses. As gasoline (hydrocarbons) evaporates from the fuel tank, the fumes are stored in the activated charcoal. The canister purge valve opens when the engine can accept the extra fuel, and the manifold vacuum sucks the fuel into the engine to be burned.

Air Pump

The air pump has two purposes. Air is pumped into the exhaust manifold while the engine is cold. Since a rich mixture is present in the combustion chamber at this time, the resulting exhaust gases will be laden with CO and HC. As the air pump injects air into the exhaust manifold, the oxygen in the air meets with the CO and HC, their temperature increases dramatically and afterburning takes place. Afterburning consumes much of the residual CO and HC.

A side benefit of afterburning is that a great deal of heat is generated. The heat is used to assist in bringing the catalytic converter and the oxygen sensor up to their proper operating temperature.

Before the electronic control unit, or ECU, goes into its Closed Loop mode, the air being pumped by the air pump must be diverted either to the atmosphere or downstream of the oxygen sensor.

Catalytic Converter

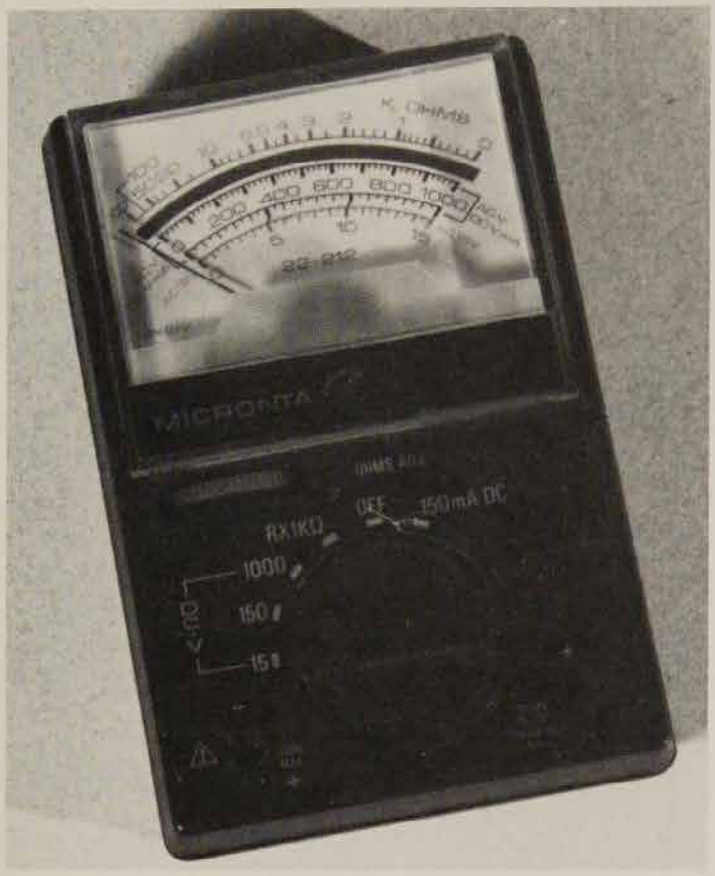
When the catalytic converter was introduced in 1975, it spelled the beginning of the end for leaded gasoline. This oxidizing catalytic converter consisted of a platinum/paladium coating over an aluminum oxide substrate. Over the years, the substrate has been seen in the form of pellets, beads and a honeycomb monolith. The platinum was not compatible with tetraethyl lead, however, requiring its absence in the fuel used in catalyst-equipped vehicles.

The job of the catalyst is to provide an environment where enough heat can be generated to allow further combustion of the HC and CO to occur. The converter is heated by a chemical reaction between the platinum and the exhaust gases. The minimum operating, or light-off, temperature of the converter is 600 deg. F., with an optimum operating temperature of about 1,200 to 1,400 deg. At a temperature of approximately 1,800 deg. F. the substrate will begin to melt. These excessive temperatures can be reached when the engine runs too rich or is misfiring. This type of catalytic converter requires plenty of oxygen to do its job, which means that the exhaust gases passing through it must be the result of an air-fuel ratio of 14.7:1 or leaner.

Between 1978 and 1982 the dual-bed converter was gradually introduced. This converter adds a second rhodium catalyst known as the reducing section, ahead of the oxidizing section. The rhodium coats an aluminum oxide substrate and reacts with the NO_x passing through it. When heated in excess of 600 deg. F., the nitrogen and oxygen element of the NO_x passing through it will be stripped apart. Although only about 70 to 80 percent efficient when coupled with the EGR, it does a dramatic job of reducing NO_x. Since the job of the reducing catalyst is to strip oxygen away from nitrogen, it works best when the exhaust gases passing through it are the result of an oxygen-poor air-fuel ratio of 14.7:1 or richer.

The only air-fuel ratio that will permit both sections of the converter to operate efficiently is a ratio of 14.7:1. The job of the oxygen feedback fuel-injection systems being used today is to control the air-fuel ratio at 14.7:1 as often as possible.

Note: On many applications the air from the air pump, after completing its role of preheating the catalytic converter, will be directed between the front reducing section and the rear oxidizing section of the converter. This will supply extra oxygen to improve the efficiency of the oxidizer.



Analog voltmeters can be purchased for as little as $10. Unfortunately, these inexpensive meters are hard to read and rob power from the circuit being tested.

Unlike inexpensive analog meters, high-impedance meters do not rob power from the circuits they are testing. The advantage they have over a digital voltmeter is their ability to closely track and display changes in voltage.

A good rule of thumb is: use the analog meter when you are looking for fluctuations in voltage, and the digital when you are looking for precise readings.

Note: Because of the extremely low current output of the oxygen (Lambda) sensor, most analog voltmeters will ground out the Lambda reading and the meter will display zero volts continuously. Always use a digital voltmeter or a 10 megohm input impedance analog when taking Lambda readings.

Test Light

It may seem odd to include such a low-tech testing device in a book about sophisticated fuel-injection systems, but the test light still has a place in diagnosing wiring harness grounds.

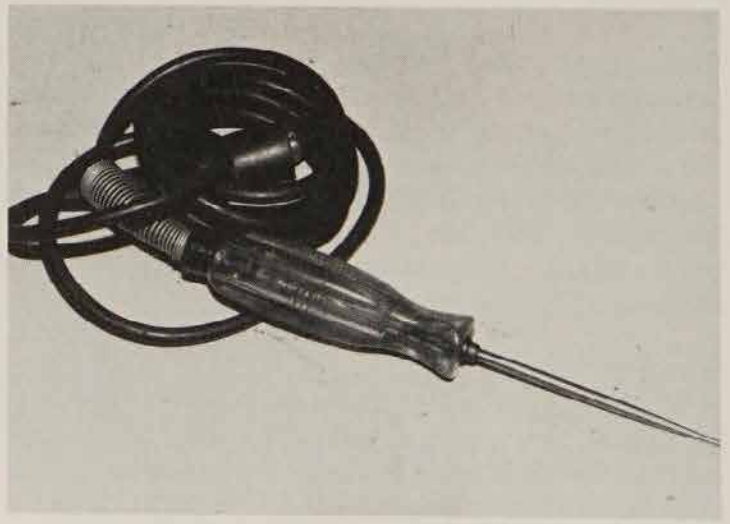
Ohmmeter

Ohmmeters are used to measure the resistance in electrical and electronic devices. I am often asked if it is acceptable to use a low-impedance ohmmeter on a given circuit. Actually, the concept of high impedance and low impedance does not apply to ohmmeters at all. An ohmmeter should be connected to a component of a given circuit with the power removed from that component. Connecting an ohmmeter to a powered circuit can damage both the tester and the circuit.

Special warning: The ohmmeter has its own power source that it uses as a reference to determine the resistance of what is being measured. Since the Lambda sensor is a voltage generator, connecting an ohmmeter to a Lambda sensor will destroy the sensor.

Tachometer

Still handy for checking engine speeds, a digital tachometer also has other uses. One of the new



The test light is basically a low-impedance voltmeter. Although low-tech, the test light is still the easiest way to test power supplies and grounds.

3

Tools

Digital Voltmeter

It's ironic that the most important tool in working with and troubleshooting modern Bosch fuel-injection systems is one of the cheapest and easiest to acquire. Digital voltmeters that are adequate to do the job range in price from as low as $25 to as high as $500 or more. The more expensive meters hold one advantage, however; they combine many of the functions into one package.

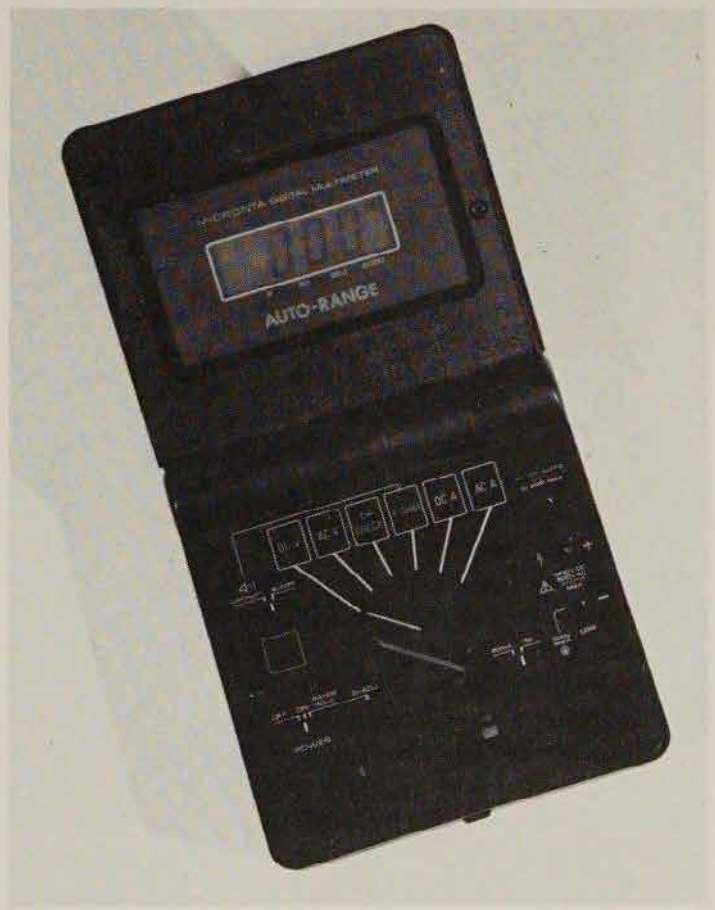
The digital voltmeter boasts a high-impedance input (ten million ohms or more), which allows the voltmeter to be connected to very small current flow circuits without affecting the voltage reading. Voltmeters with a low-input impedance rob power from the circuit being tested. This causes the voltage readings to be lower than they really are. For this reason, the digital meter should be used anytime precise voltage readings are required.

But there is one drawback to using a digital voltmeter: since it is digital, it merely samples the voltage and displays it. However, there are major gaps between these samples; transient fluctuations are completely missed. There may be a device, such as the airflow meter potentiometer, that could create a steadily increasing voltage as the throttle is opened. As the airflow meter wears, there may be places where the wiper does not contact the carbon film strip, resulting in a sudden drop in voltage. If the digital voltmeter's sampling did not happen to coordinate with the drop in voltage, the fluctuation could be the cause of a major driveability problem. For this reason there is a better tool for measuring variations in voltage—the analog voltmeter.

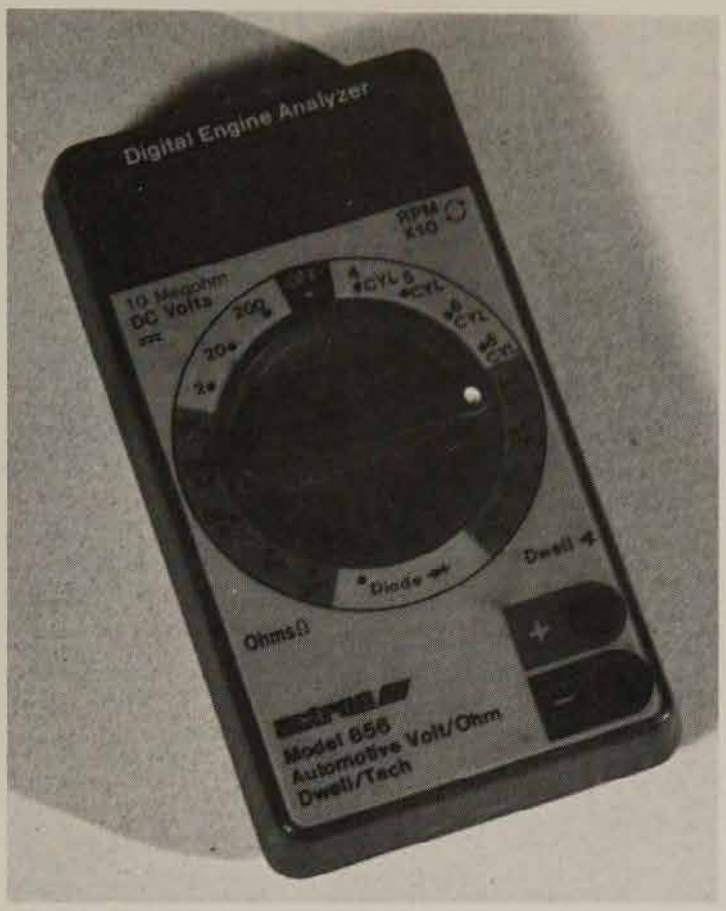
Analog Voltmeter

Where the digital voltmeter displays its reading as digits, the analog voltmeter uses a needle moving across a scale to display its readings. The benefits of the analog voltmeter have suffered much abuse since the introduction of the electronic engine control systems at the end of the 1970s. This is because most of the inexpensive analog meters have a low-input impedance. As mentioned previously, a low-impedance meter can distort readings. Rumors about technicians ruining computers and other components by using analog meters to take measurements are exaggerated.

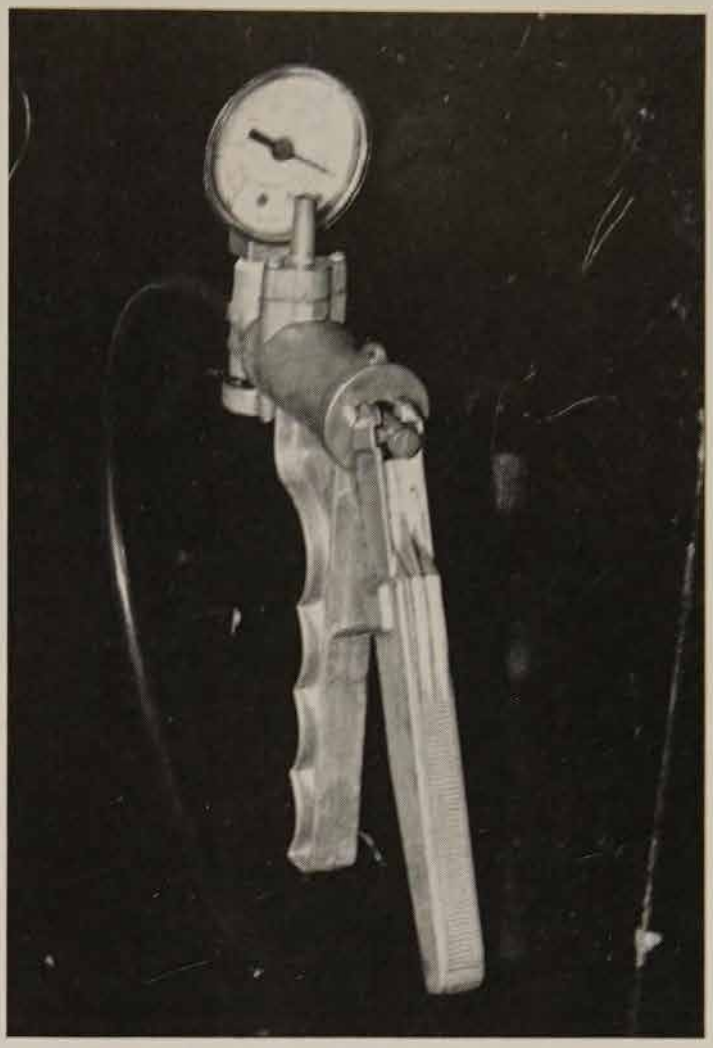
The analog meter will detect fluctuations in voltage much better than the digital voltmeter. When a transient voltage change occurs, it will show up in the analog meter as a fluctuation in the needle.



Digital voltmeters are easy to read and extremely accurate for the less-experienced user. Although priced from under $40 to well over $500, the cheaper ones are as good as the expensive ones for automotive use.



Several test equipment companies make multipurpose meters. This one combines ohm, volt, tach and dwell functions.



The hand-held vacuum pump is essential for testing the many vacuum-controlled devices and sensors.

diagnostic instruments needed on fuel-injected cars is a frequency counter. Since even most professional fuel-injection technicians do not own a frequency counter, use a digital tachometer.

The tachometer measures the number of primary ignition pulses per minute. It then mathematically converts the number of pulses into crankshaft revolutions per minute (rpm). With some very simple math we can reverse this to get a frequency reading in cycles per second, or hertz.

First, switch the tachometer to the four-cylinder scale. It does not matter whether the engine you are working on is a four-cylinder, six-cylinder or eight-cylinder (remember, we are counting pulses per second, not crankshaft rpm), always use the four-cylinder scale. This technique will work equally well on the six- or eight-cylinder scale, but the math is more complex. Next, connect your tachometer to the wire (usually ground side of an actuator circuit or the output of an appropriate sensor) you want to test and a good ground. Observe the reading on the tachometer and divide by 30. That will be the reading in hertz.

Example:

$$\frac{4800 \text{ rpm}}{30} = 160 \text{ Hz}$$

An analog tachometer is not recommended for this purpose since this requires a precision that is not found in most analog units.

Dwell Meter

Since the advent of electronic ignition, the dwell meter has been gathering dust. No longer do we adjust the points during a tune-up. However, as the tachometer was actually measuring the frequency of the primary ignition system, the dwell meter was measuring its duty cycle. Therefore, when duty cycle needs to be measured, the dwell meter again becomes a handy tool.

The duty cycle is a measurement of the relationship of the on-time and the off-time. Place the dwell meter on the four-cylinder scale. Again, do not be concerned with the number of cylinders the engine has. Connect your dwell meter to the wire you want to read the duty cycle on and observe the reading. Then multiply the reading by 1.1.

(In reality, there will rarely be a time in automotive troubleshooting where that degree of precision is required. Simply using the observed reading will suffice.)

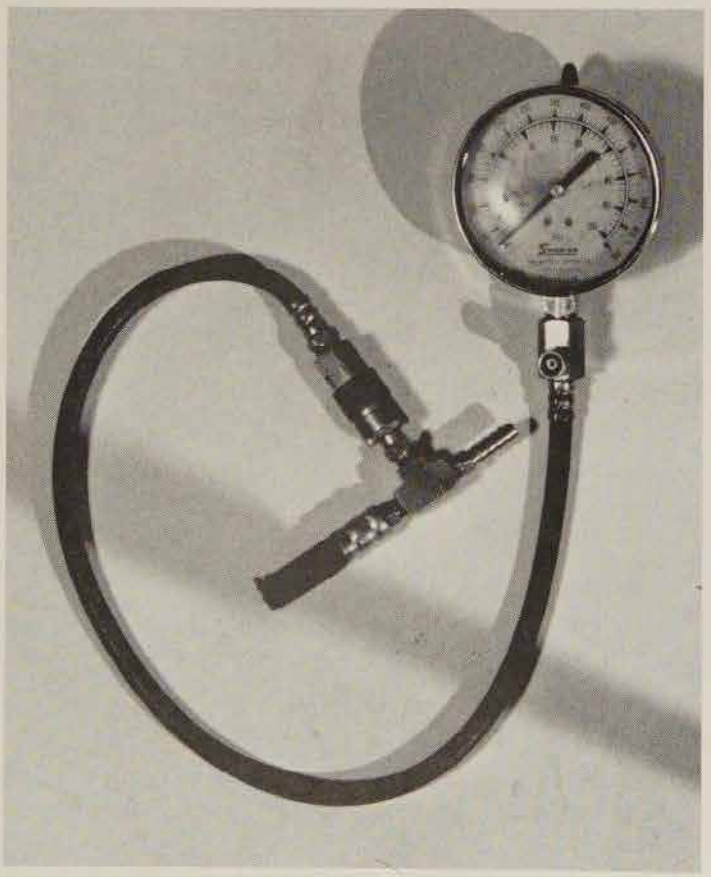
Hand-Held Vacuum Pump

The hand-held vacuum pump can be an invaluable addition to your toolbox. Not only will it come in handy for testing manifold pressure sensors, EGR valves and vacuum-controlled actuators, but it is also handy for testing such low-tech items as vacuum advance units.

Fuel Pressure Gauge

If you do not own a fuel pressure gauge you might as well forget about troubleshooting fuel-injection systems. All good troubleshooting begins with a fuel pressure test. The fuel pressure gauge that is combined with your vacuum gauge will no longer fit the bill, however. You will need a gauge capable of accurate readings up to 100 psi. A variety of fittings and adapters will also be necessary. Shop around a little. The prices on these gauges with fittings can run anywhere from $100 to $1,000. A little ingenuity and a trip to a local hydraulics or air conditioning supply store could probably yield a more than adequate gauge and a substantial savings.

For working on the K-Jetronic system a T-hose is required, with a valve in one branch of the T so fuel flow to the control pressure regulator can be controlled during testing.



Next to the voltmeter, the most important tool for testing fuel-injection systems is the fuel pressure gauge. The one shown is part of a kit costing well over $500. A little cleverness and a trip to the hardware store can save the occasional fuel-injection technician several hundred dollars, however.

Vacuum Gauge

Although an ancient workhorse, the vacuum gauge is still valuable for detecting mechanical problems with the engine and troubleshooting misrouted or damaged vacuum circuits.

Low-Voltage Oscilloscope

The low-voltage oscilloscope is new to the arsenal of automotive diagnostic weaponry. The engine analyzer scope has been used for decades to troubleshoot primary and secondary ignition systems. Early in the 1980s, analyzer manufacturers saw the need to test patterns and waveforms at much lower voltages than what you would experience in the ignition system. As a result, they began to incorporate low-voltage functions in their professional-quality engine analyzer scopes.

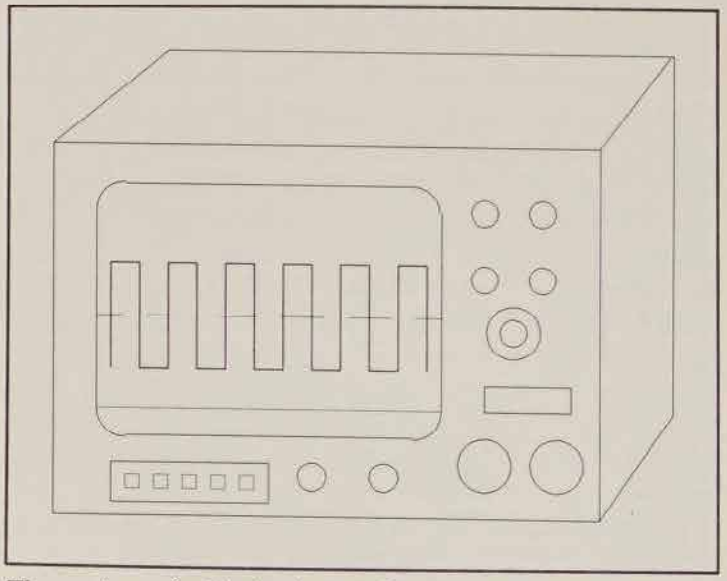
Unlike the professionals, though, you don't need to invest thousands of dollars in one of these testers. A low-voltage oscilloscope can be found for as little as $100. Or, you can purchase one from an electronics hobby store for around $500.

Keep in mind, though, that this type of scope cannot be used to analyze either primary or secondary ignition.

Injector Pulser

Owatonna Tool Company in Owatonna, Minnesota, and other tool companies sell a tester for fuel injectors to determine if they are restricted. This tool pulses the injector for a total of 1 to 100 times.

To use this tool, connect a fuel pressure gauge to the fuel rail. Attach the tester to the number one



The serious fuel-injection technician will need a low-voltage oscilloscope. These are priced from a few hundred dollars and up. Sensor output and injector pulse width can be measured. For the average technician, voltmeters and ohmmeters work just as well.

injector, then pressurize the fuel system. Push the button on the tester and watch the amount that the fuel pressure drops. Repeat the procedure on each of the remaining injectors. There should be no more than 1.5 psi difference between injectors. If there is, clean or replace the injectors.

The injector tester can be used to find restricted injectors. The battery clips connect to the car battery; the remaining lead connects to an injector. To pressurize the fuel system turn off the engine, press the button labeled "activate injector" and the injector is pulsed. Then record the pressure loss for each injector. The pressure losses should be within 1.5 psi of each other.

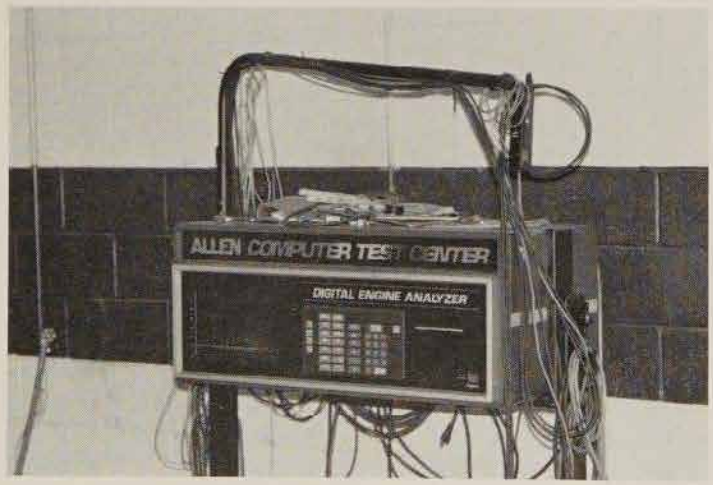
4

Tuning the Bosch-Injected Car

Fuel injection, tough emission standards and extended service intervals have not eliminated the need for regular maintenance and routine tune-ups. Many cars from the late 1980s and into the 1990s boast of spark plug replacement at intervals of 50,000 miles or more. And there are air filters and fuel filters with similar service intervals. These service intervals may be fine for the typical consumer who uses his or her car to go to and from work, with an annual trip to Yellowstone or Disneyland. But the owner who expects a little more out of his car—more performance, more economy or more reliability—should consider the following tune-up maintenance schedule:

Every 12,000 miles:
- Replace spark plugs
- Replace fuel filter
- Replace air filter
- Check vacuum hoses and intake air tubes

Every 24,000 miles:
- Replace spark plugs
- Replace fuel filter
- Replace distributor cap
- Replace rotor
- Replace plug wires
- Check vacuum hoses and intake air tubes



Although expensive engine analyzers can completely test the ignition system in a matter of minutes, there is little that can be detected with one that cannot be detected another way, with less-expensive analyzers that individually cannot completely test the entire system.

The Story on Spark Plugs

Replacing spark plugs is one of those tasks that gives every Saturday afternoon mechanic a feeling of pride. Yet there are many subtle details about spark plug replacement and about what the old spark plugs can tell you. Let us begin with some of the basics of what the spark plug does.

To begin with, the spark plug ignites the air-fuel charge in the combustion chamber via a high-voltage spark across its electrodes. The source of the spark is the ignition coil. The spark is conducted to the spark plugs by way of the secondary ignition cables. It lasts for about 1.5 to 2.0 milliseconds at around 1,000 volts. However, for the first 30 microseconds the voltage of the spark is much higher, somewhere between 5,000 and 30,000 volts. This higher voltage is necessary to initiate the spark across the gap of the plug.

The ignition coil is basically a transformer. The amount of energy available to the plugs is limited to the number of watts passing through the primary ignition coil. If too much of the available energy is used to initiate the spark, then the amount of energy left to maintain the spark will be reduced. Today's leaner running engines will extinguish the fire in the cylinder when the spark goes out. Therefore, anything that affects the duration of the spark affects power and driveability a lot more than it did in the 1960s. Similarly, anything that affects the voltage required to initiate the spark will affect the duration of the spark.

The following factors will affect the spark initiation voltage: spark plug heat range, compression (and compression ratio), air-fuel ratio, spark plug wear and condition of distributor cap, rotor, coil and secondary ignition wires.

Spark Plug Heat Range

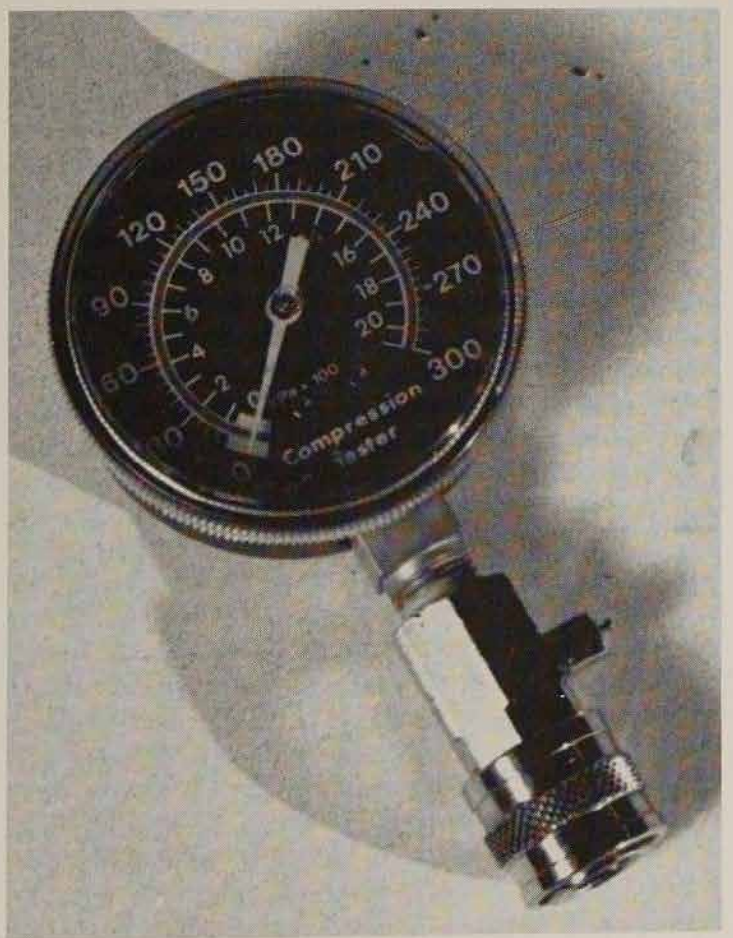
Unless you have a highly modified engine you should stick with the heat range recommended by the car spark plug manufacturer. If the incorrect heat range selected is too cold, it can increase the spark initiation voltage, thus robbing power from the engine. Another difficulty with a cold plug is that it can result in misfiring and fouling. Using spark plugs with too hot of a heat range can result in pre-ignition or pinging.

Compression

The effect of compression on the power from an engine is like a two-edged sword. On one hand, increased compression increases the power potential of the engine; yet increased compression also increases spark initiation voltage. The increase in spark initiation voltage means that high-performance, high-compression engines may require an ignition coil with greater potential energy. As compression in each cylinder drops, the voltage required to initiate the spark across decreases—but so does engine power.

Air-Fuel Ratio

Air-fuel ratio is one of the most critical variables when it comes to driveability. If the ratio is too rich, spark initiation voltage will be quite low and the burn in the combustion chamber will be slow and incomplete. A lean air-fuel ratio makes it difficult for the spark to start jumping the spark plug gap. A great deal of energy will be used during the first 30 microseconds, leaving very little energy to maintain a burn in the combustion chamber. The result is reduced power, stumbling, hesitation and misfire.



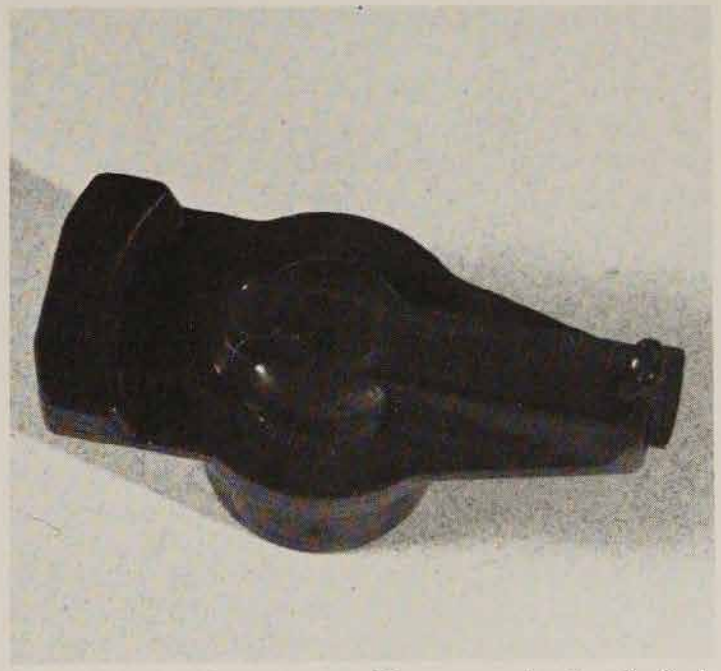
Because sensor accuracy assumes that the engine is in good condition, the compression must be good. Testing the compression should be one of the first things you do when troubleshooting a driveability problem.

Spark Plug Wear

If you have ever removed an old spark plug, you may have noticed that the gap is much wider than when it was installed. This is because like many other components in the engine, spark plugs wear as they are used. The wider the gap, the higher the voltage required to begin the spark jumping the gap, and the less energy there is to accomplish the burn in the combustion chamber. This has a direct effect on combustion, thereby decreasing power, increasing toxic emissions and causing poor driveability.

Condition of Distributor Cap, Rotor, Coil and Secondary Ignition Wires

Within the high-voltage side of the ignition system there are several other items that wear as they work. On cars equipped with a distributor, the distributor cap is used along with the rotor to transfer the high-voltage spark from the ignition coil to the spark plug wires. High voltage arrives at



Many times, fuel-ignition problems are mistaken for fuel-injection problems. This rotor sat in the distributor of a K-Jetronic V-6 Volvo while several fuel-injection components were replaced in vain. Although it looked good, the resistance between the center and end electrodes was much too high. Replace any ignition components that are suspect before tampering with the fuel-injection system.

the center of the distributor cap either through the coil wire or directly from the ignition coil; this voltage is conducted to the rotor by a carbon nib.

The current then travels through either a solid metal conductor or a resistive element in the rotor. As the rotor swings past each of the plug wire electrodes, a spark jumps from the rotor. Wear on the carbon nib or an excessive gap between the rotor and the distributor cap electrodes will increase the amount of energy consumed on the way to the spark plugs. This decreases the amount of available energy to fire the cylinder. Distributorless ignition systems are one of the methods used to reduce the vulnerable areas where wear can affect secondary ignition energy, thereby increasing tune-up service intervals.

As plus wires age their resistance increases, and as their resistance increases a greater portion of the potential spark energy heading toward the spark plugs is consumed.

Replacing Spark Plugs

Removal

With the engine cold, unscrew the spark plugs two or three turns. Using compressed air or a solvent-soaked brush, clean the area around each plug to remove any dirt or foreign objects that might fall into the cylinder when the plug is removed. Should you find it difficult to unscrew, there may be accumulations of dirt or grit on the threads. If this occurs, put a couple of drops of oil on the exposed threads and allow it to soak in for a few minutes. Screw the plug back in, then out several times, a little more each time until the spark plug is removed.

Inspection of the removed spark plugs can tell you a lot about the running condition of the engine. Carbon deposits, ash formations, oil fouling, soot and other conditions can indicate engine or injection system problems.

Installation

Before installing the new spark plugs, be sure to check the gap. Although some spark plug manufacturers make an effort to pre-gap their plugs, they can be unintentionally regapped in shipping. Inspect the threads in the cylinder head to ensure that they are clean and undamaged. Also check the mating surface where the plug contacts the head—it should be clean and free of burrs.

Start the new spark plug and screw it in a few turns by hand. Continue to screw in the plug either by hand or with a socket and ratchet until it contacts the mating surface firmly. To avoid overtightening, use a torque wrench and tighten a tapered seat plug to 26 lb-ft in a cast-iron head, or 21 lb-ft in an aluminum head. A torque wrench is seldom used when installing spark plugs, so use this rule of thumb: firm contact plus 15 deg. of rotation.

Replacing Secondary Ignition Cables, Cap and Rotor

Testing and Replacing Spark Plug Wires

There are two ways of testing spark plug wires. The first is to use an engine analyzer oscilloscope. The second method involves using an ohmmeter. For the second method, remove each plug wire and with your ohmmeter on the "X1000" ohm scale measure their resistance end to end. A good plug wire will have less than 10,000 ohms but greater than 1,000 ohms per foot.

You need to remember a couple of important things when replacing secondary ignition wires. First, if the plug wires are installed in the incorrect order a backfire may occur, resulting in damage to the airflow meter or air mass meter or the rubber tube that connects it to the throttle assembly. The original equipment plug wires have numbers on them indicating to which cylinder they should be connected. Aftermarket or replacement plug wires may not have these numbers, however. 3M and other companies make adhesive numbers that can be attached to ensure proper reinstallation.

Replacing the Distributor Cap

Replacement consists of simply releasing the attachment screws or clips and making sure that the plug wires are installed in the correct order.

Whichever type of distributor you have on your car, it would be a good idea to replace the distributor cap and rotor at the same time and use the same brand. Pairing caps and rotors of two different manufacturers can result in the incorrect rotor air gap. Excessive rotor air gap in turn can cause excessively high spark initiation voltage, which can result in incomplete combustion.

Replacing the Air and Fuel Filters

The real value of the air filter is significantly underestimated. It is the engine's only defense against sand, grit and other hard particle contamination. When these substances enter the combustion chamber they can act like grinding compound on the cylinder walls, piston rings and valves. Therefore, replace the air filter at least once a year or every 24,000 miles. In areas where sand blows around a lot, like West Texas or Arizona, the air filter should be replaced much more often.

On most carbureted cars a restricted air filter will cause the engine to run rich. This is because the restriction causes a reduction of pressure in the venturi of the carburetor while the pressure in the fuel bowl remains constant at atmospheric pressure. The increased pressure differential increases the flow of fuel into the venturi and the mixture enriches.

On a fuel-injected engine, the electronic control unit (ECU) measures the exact volume of air entering the engine with the airflow meter and delivers the correct amount of fuel for the mea-

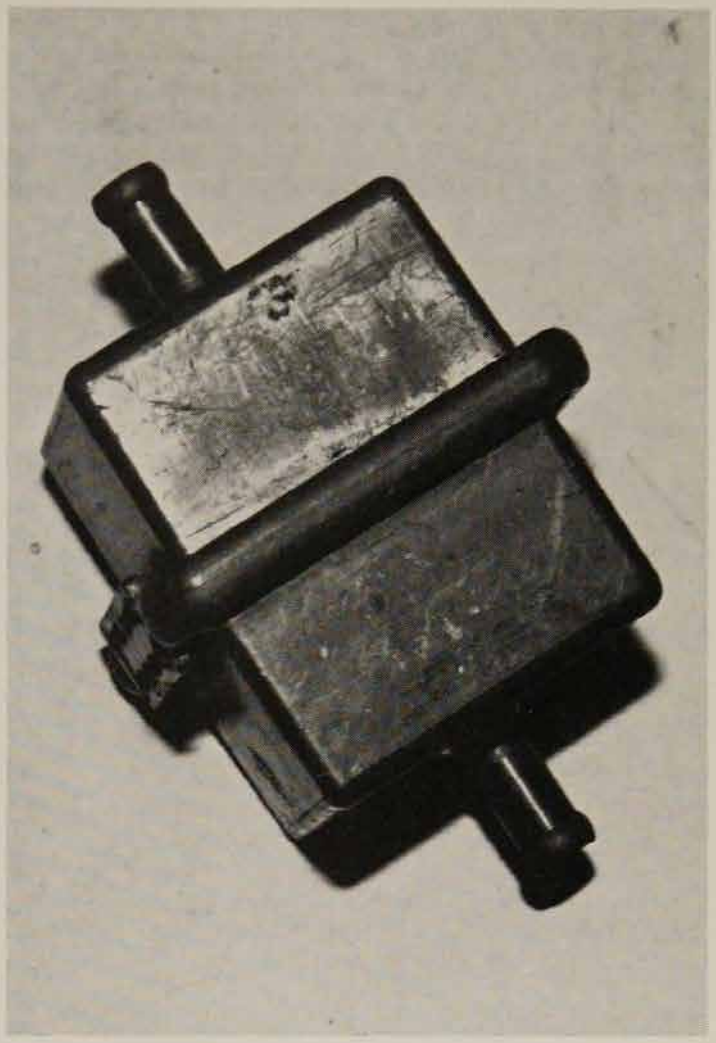
sured amount of air. If you restrict the flow of incoming air, less air will be measured, and less fuel will be metered into the engine. D-Jetronic air measurement is not very precise and therefore may run a little rich as a result of a restricted air filter.

The fuel filter is the most important service item among the fuel components of the fuel-injection system. In my seventeen years of experience with fuel-injected cars, I have replaced many original fuel filters on cars that were over ten years old. This lack of routine maintenance is just begging for trouble.

After removing the fuel filter, find a white ceramic container, such as an old coffee cup, and drain the contents of the filter through the inlet fitting. Inspect the gasoline in the cup for evidence of sand, rust or other hard particle contamination. Now pour the gas into a clear container such as an old glass and allow it to sit for about thirty minutes. If there is a high water content in the fuel, it will separate while sitting; the fuel will float on top of the water. If there is excessive wear or hard particle contamination in the tank it may have to be removed and professionally cleaned. For minor water contamination problems, additives can be purchased at your local auto parts store.

Should the fuel filter become excessively clogged, the following symptom might develop. You start the car in the morning and it runs fine. As you drive several miles down the road the car may begin to buck a little or lose a little power, then suddenly the engine quits almost as though someone had shut off the key. After sitting on the side of the road for several minutes, the car can be restarted and driven for a couple of miles before the symptom recurs.

This could be caused by a severely restricted fuel filter. The car runs well initially because the bulk of what is causing the restriction has fallen to the bottom of the fuel filter as sediment. When the engine is started and the fuel begins to flow through the injection system, this sediment gets stirred up and pressed against the paper elements of the fuel filter. As it does, fuel volume to the injectors is decreased and the engine begins to run lean. Sooner or later the engine leans out so much that it dies. The really bad news is when the fuel filter becomes that restricted, some of the contaminants have forced their way through the filter and may contaminate the rest of the fuel system.



Fuel filters are often so well hidden that they are not replaced during routine service. The fuel filter should be replaced whenever the spark plugs are changed. If it is not replaced regularly, you may end up replacing expensive injectors, regulators and pumps.

Alcohol Contamination

Alcohol contamination can damage many of the fuel-injection components. Use of gasohol can be one source of alcohol. If you suspect that excessive alcohol content has caused the failure of system components, then you might want to test a fuel sample for alcohol content. Pour 200 milliliters (ml) of the sample fuel into a glass or clear plastic container along with 100 ml of water. Immediately after putting the two liquids in the container the dividing line will be at the 100 ml mark. Wait about thirty minutes. If the dividing line rises by more than 10 percent of the volume of the container's contents, then there is excessive alcohol in the fuel. Drain the fuel from the tank and replace it with good fuel.

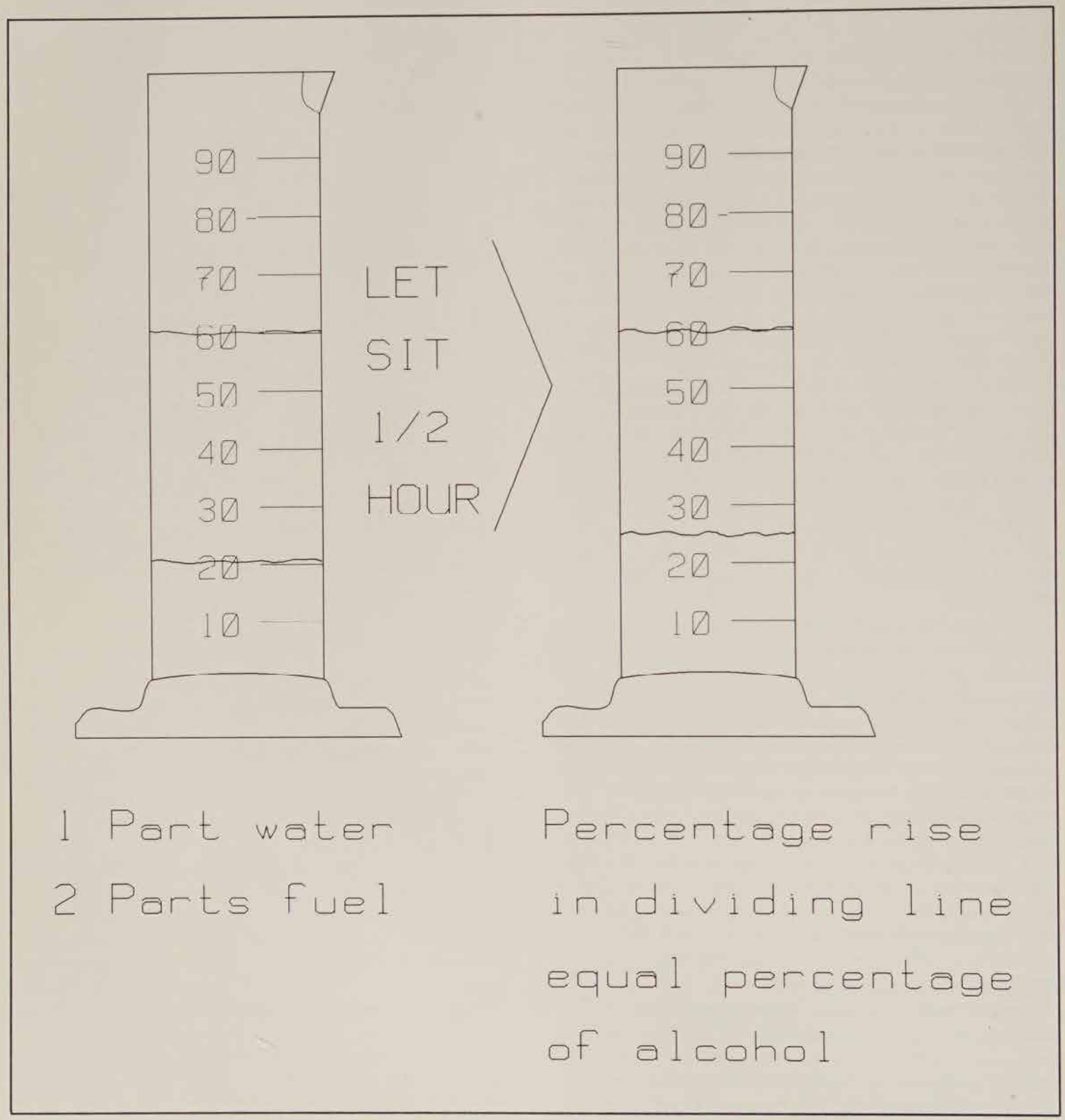
There are many fuel additives on the market that contain alcohol. The alcohol content of these additives is so small compared to the size of the typical fuel tank, however, that they pose no threat to the fuel system. Nevertheless, use caution, ask around a bit and be selective when purchasing these products. Some are much better than others.

A rich running condition can be caused by a tricked Lambda sensor. You will find the Lambda sensor may be tricked by any of the following: an exhaust leak; low compression; a secondary ignition problem; incorrect ignition timing; a defective air pump system; or a defective Lambda sensor.

Testing for the Dead Hole

When a late-model fuel-injected engine has a cylinder with a misfire, the effects can go far beyond a rough idle or loss of power. A cylinder that is still pulling in air but not burning that air will be pumping unburned oxygen past the Lambda sensor. This confuses the electronic control unit, making it believe that the engine is running lean. The ECU responds by enriching the mixture, and the gas mileage deteriorates dramatically.

There are several effective methods that can be used to isolate a dead hole, or cylinder. All of these methods measure the power produced in each cylinder by killing them one at a time with the engine running a little above curb idle.



A simple test with a fuel sample, water and a graduated cylinder can reveal alcohol contamination in the fuel.

Many alcohols are highly corrosive and can damage fuel-injection components.

Back in the good old days, we used to take a test light, ground the alligator clip and pierce through the insulation boot at the distributor cap end of the plug wire. This would ground out the spark for one cylinder and an rpm drop would be noted. The greater the rpm drop, the more power that cylinder was contributing to the operation of the engine. Actually, this is a valid test procedure; however, piercing the insulation boot is just asking for more problems than you started with.

Another former method of performing a cylinder balance was to isolate the dead hole by pulling off one plug wire at a time and noting the rpm drops. The problem with this method is that you run the risk of damaging either yourself or the ignition module with a high-voltage spark.

So, let's explore some current, effective alternatives.

Several tool companies produce a cylinder-shorting tachometer or dwell meter. These devices electronically disable one cylinder at a time while displaying rpm, thus engine speed drops can be noted. Unfortunately, these testers can cost $500 or more.

Another method does the old test light technique one better. Cut a piece of 1/8 in. vacuum hose into four, six or eight sections each about 1 in. long. With the engine shut off and one at a time so as not to confuse the firing order, remove a plug wire from the distributor cap, insert a segment into the plug wire tower of the cap and set the plug wire back on top of the hose. When you have installed all the segments, start the engine. Touching the vacuum hose conductors with a grounded test light will kill the cylinder so that you can check rpm drop. Again, the cylinder with the smallest drop in rpm is the weakest.

Whichever methods you use, follow this procedure for the best results:

Step 1. Adjust the engine speed to 1200-1400 rpm by blocking the throttle open. Do not hold the throttle by hand; you will not be steady enough.

Step 2. Electrically disconnect the idle stabilizer motor to prevent its affecting the idle speed.

Step 3. Disconnect the Lambda sensor to prevent it from altering the air-fuel ratio to compensate for the dead cylinder.

Step 4. Perform the cylinder kill test. Rpm drop should be fairly equal between cylinders. Any cylinder that has a considerably lower rpm drop than the rest is weak. Proceed to step 5.

Step 5. Introduce a little propane into the intake—just enough to provide the highest rpm. Repeat the cylinder kill test. If the rpm drop from the weak cylinder tends to equalize with the rest, then you have a vacuum leak to track down. If the car has an idle stabilizer, be sure to disable it so that it will not attempt to compensate for the lack of power input from the dead cylinder.

5

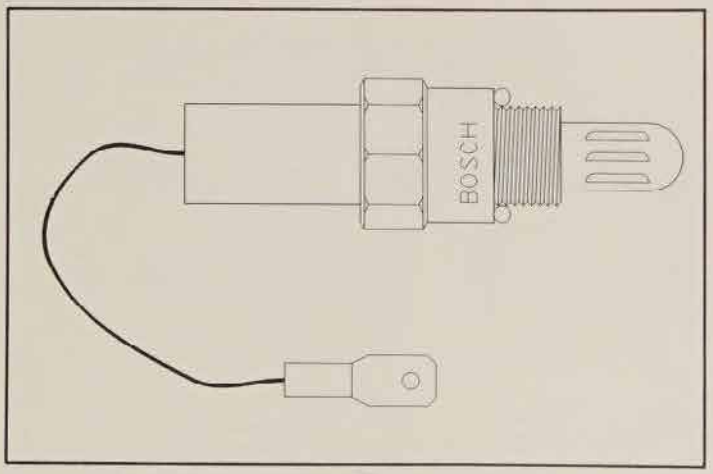
The Lambda Sensor

The Lambda sensor was introduced in 1977 in answer to ever-tightening automotive emission regulations. The sensor sits in the exhaust system and monitors the amount of oxygen present in the exhaust gases.

There are three major components of combustion: fuel, heat and air. The combustible portion of atmospheric air is oxygen—28 percent of air is oxygen. If the correct ratio of fuel and air have been combined in the combustion chamber, then all of the oxygen will be consumed during combustion. If the engine is running rich, either too much fuel or not enough air has been fed into the combustion chamber. Consequently, when the engine runs rich there is almost no oxygen left over. When the engine runs lean, either too much air or not enough fuel has been delivered to the combustion chamber. The result is a high-oxygen constant in the exhaust system.

The Lambda sensor consists of two gas-permeable layers of platinum separated by a layer of zirconium oxide ceramic. When the temperature of the Lambda sensor reaches 600 deg. F., the ceramic becomes conductive for oxygen ions. The outer layer of platinum is exposed to exhaust gases. The inner layer of platinum is exposed to ambient air. When the percentage of oxygen is balanced between the inner and outer layers, the ceramic will not attract oxygen ions from either side. When the percentage of oxygen in the exhaust decreases, the Lambda sensor begins to attract oxygen ions from the ambient air side, and a voltage is produced.

The output voltage of the Lambda sensor usually ranges from 100 to 900 mV. A voltage greater than 450 mV is considered rich; a voltage less than 450 mV is considered lean.



The Lambda sensor reports the oxygen content of the exhaust gases to the ECU. The ECU uses this information to control air-fuel ratio. Since its introduction in late 1977, the Lambda's use has expanded from only a few European cars to virtually every fuel-injected and carbureted car in the industrialized world.

Lambda Sensor Contamination

The Lambda sensor can be contaminated or damaged in several ways.

Leaded fuel is one example. The lead additive in regular gasoline forms a coating over the platinum, keeping the oxygen from passing through to the ceramic layer.

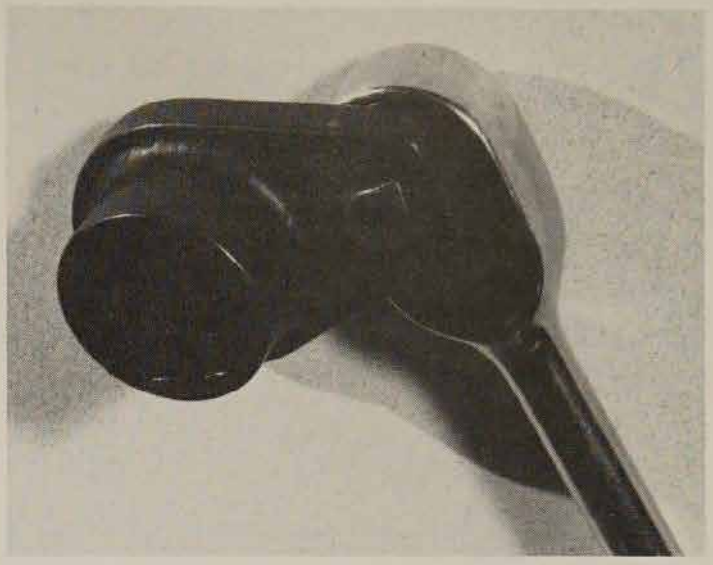
A second possibility for contamination is some RTV silicone sealants. Use caution when purchasing engine repair sealants to ensure that they are Lambda sensor safe. Many silicone sealants also form a coating over the platinum, keeping the oxygen from passing through.

A third potential source of problems for the Lambda sensor is soot. Soot results from an engine running extremely rich or from the engine burning oil. Soot coats the Lambda sensor, preventing the oxygen from penetrating the platinum layer and reaching the zirconium oxide.

When working around the Lambda sensor, be aware that even small amounts of voltage can damage the sensor. Do not allow voltage to go down the wire to the sensor. Even small voltages, such as those from an ohmmeter, can damage it.

Vibration can cause damage to the internal connections of the Lambda sensor or even destruction of the sensor. Sources of vibration would include hammering on the exhaust system, driving

In the past it has been common practice to use sealers such as RTV silicone when replacing engine gaskets. If this practice is continued, the technician must be certain that a low-volatile or oxygen-sensor-safe silicone is used.



When replacing the Lambda sensor, torquing it to the proper spec is essential. Several tool companies market special sockets to ensure proper installation.

over rough roads and driving at excessively high speeds.

Finally, heat can damage the Lambda sensor. Although the sensor requires high temperatures to operate, excessively high temperatures can melt it. These temperatures can occur in the exhaust system when there is a crack in the manifold.

Testing the Lambda Sensor

A simple test of the Lambda sensor involves two steps.

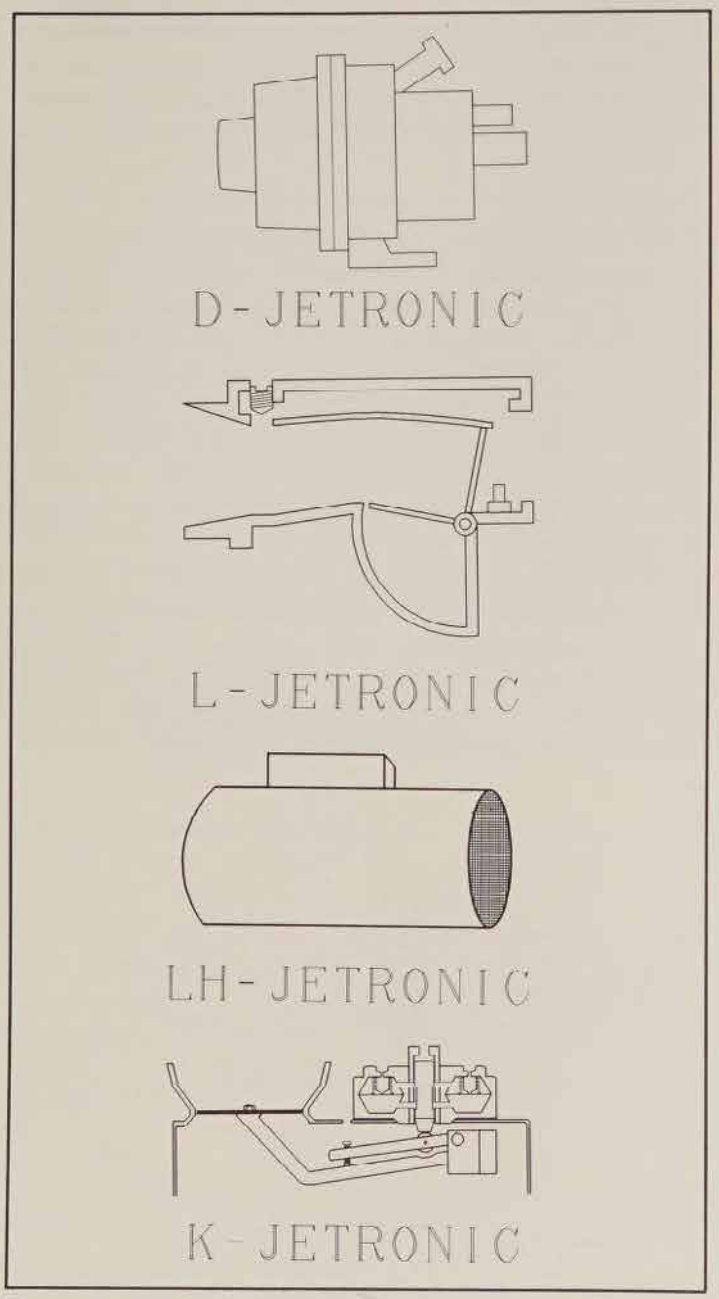
First, disconnect the connector between the Lambda sensor and the computer. Connect a high-impedance voltmeter between the sensor and ground. Then start the engine and allow it to run until the upper radiator hose is hot and pressurized. Next, hold the Lambda lead to the computer with one hand and touch the positive battery terminal with the other hand. This delivers a small voltage to the computer, causing the computer to believe that the engine is running rich. The engine rpm and the Lambda sensor voltage should drop.

If there is no response, connect the Lambda wire that goes to the computer to ground. This makes the computer believe that the engine is running lean. The rpm and the Lambda sensor voltage should both rise.

If the system passes either test, then the system is working properly. If the rpm changes but the Lambda voltage does not, replace the Lambda sensor. If neither change, check for continuity on the wire to the computer. If the wire is good and the connection is good, replace the computer.

6

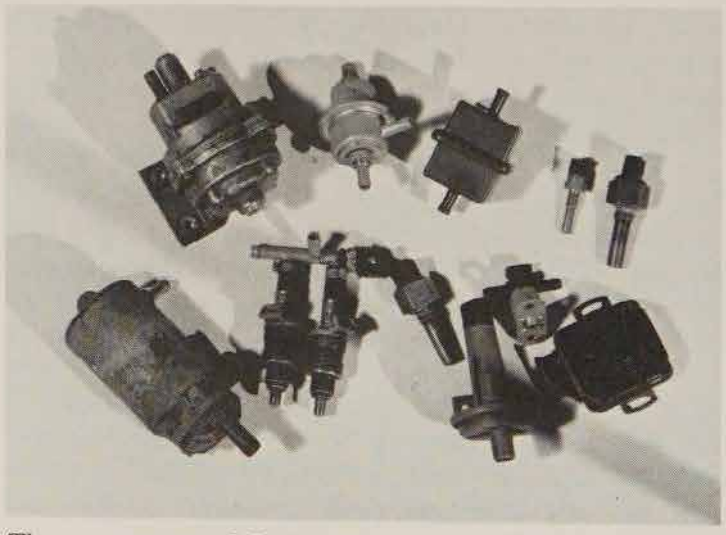
D-Jetronic Fuel Injection



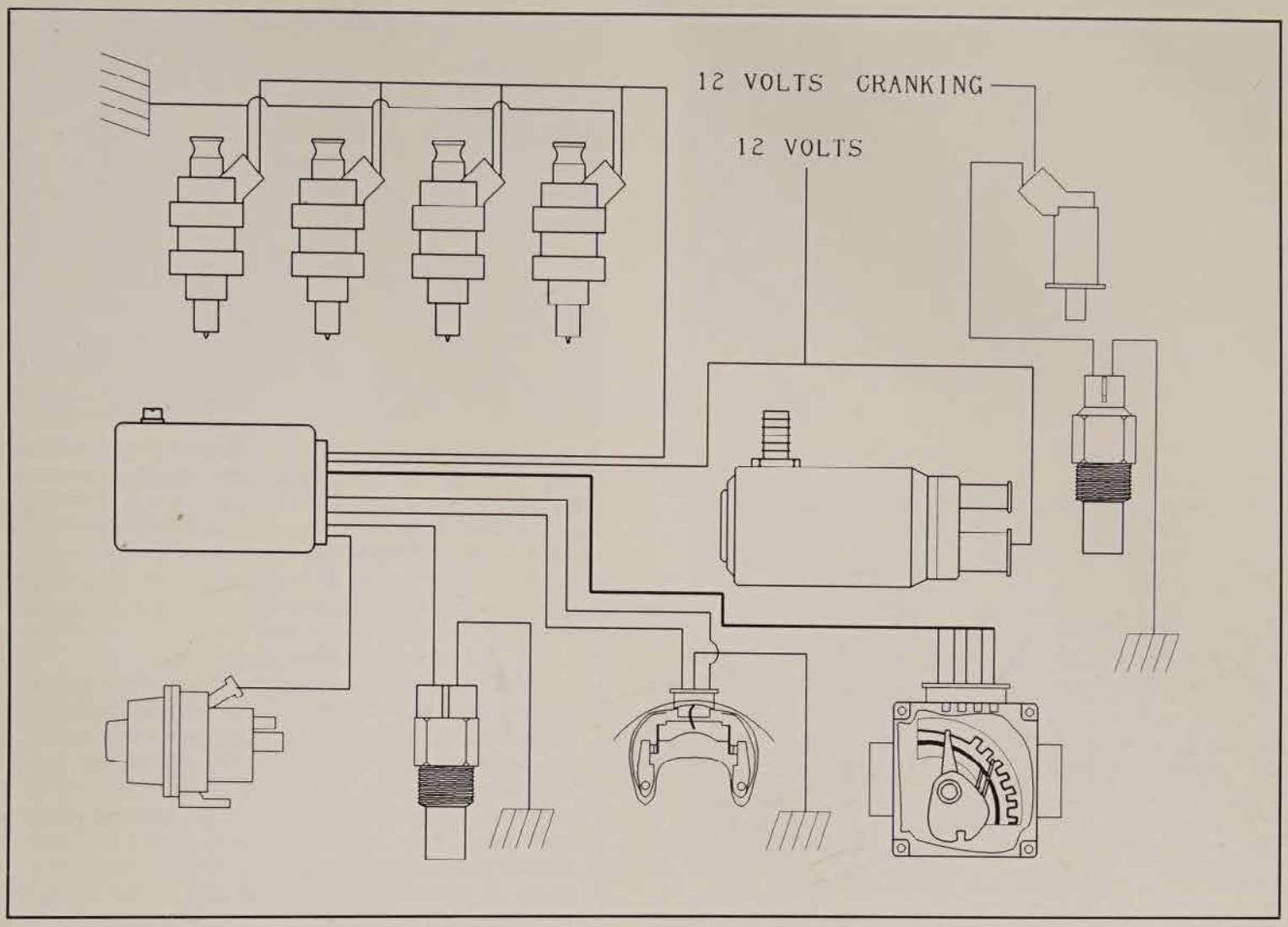
Recognizing the fuel system you are working with is a matter of recognizing the type of air measuring system being used. D-Jetronic uses a pressure sensor. L-Jetronic uses an airflow meter. LH-Jetronic uses an air mass meter. Both the K- and the KE-Jetronic systems use an airflow sensor.

The D-Jetronic fuel-injection system was the first electronic fuel injection to reach true mass production. At the time, the industry saw it as a one-of-a-kind system—more of a marketing strategy of the automotive repair industry than a realistic alternative to the carburetor. Also known as the manifold pressure control (MPC) system, the main sensor for the control of fuel volume is the manifold pressure sensor. It is interesting that the domestic manufacturers (Ford, GM and Chrysler) use the same principle on the bulk of their fuel-injected cars. Of course, more than twenty years of advancements in technology have seen the manifold pressure sensor evolve from the hard-wire transducer used by Bosch, to the solid-state devices used on modern systems. Although the last D-Jetronic-equipped car rolled off the assembly line in 1976, many of them are still being used today.

Troubleshooting and repair of the D-Jetronic system is as much an art as it is a science. The operating principles of the system will be ex-



The components of the D-Jetronic system. Starting clockwise at the upper left: the pressure sensor, fuel pressure regulator, fuel filter, Temperature Sensor I, Temperature Sensor II, throttle switch, cold-start valve, auxiliary air valve-thermo-time switch, injectors and the fuel pump.



Block schematic of the D-Jetronic fuel-injection system.

plained component by component, along with their potential effects on driveability. The bulk of the poor running problems on D-Jetronic-equipped cars are actually related to engine and ignition. Therefore, any real troubleshooting must begin with a thorough analysis of these systems.

Applications for D-Jetronic fuel injection include the following:

Mercedes-Benz
- 250
- 280
- 300
- 350
- 450

Porsche 914

Renault
- R17
- R17G

Saab 99E

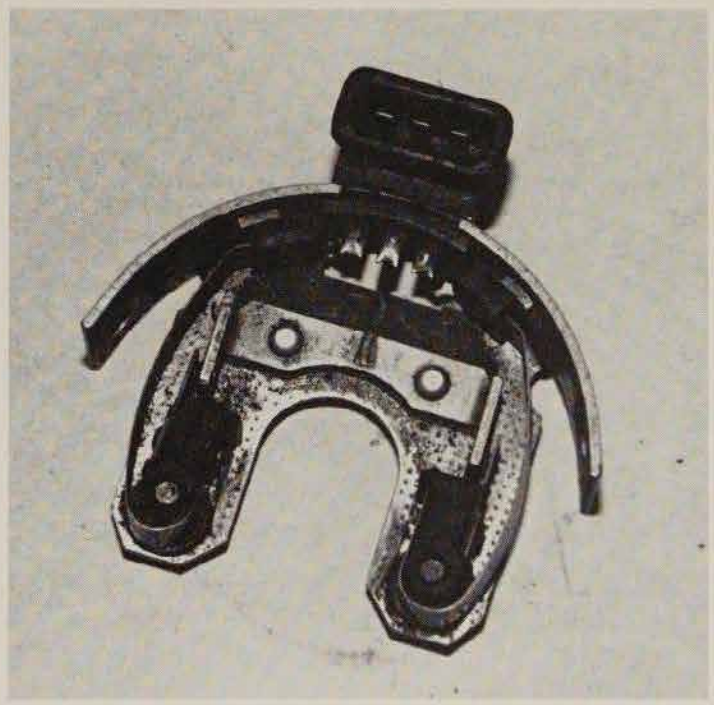
Volkswagen
- Type 3
- Type 4

Volvo
- 1800E
- 1800ES
- 140
- 160
- 164

Sensors

Trigger Points

The trigger points are located in the base of the distributor below the ignition point breaker plate.



The trigger points resemble a set of dual-ignition points. The points are opened and closed by a cam in the bottom of the distributor. They provide the synchronizing signal for opening the injectors in the D-Jetronic system.

Located in the bottom of the distributor on D-Jetronic-injected engines, the trigger points carry very small currents and have been known to last more than twenty years. A defective set of points will prevent the opening of either group of injectors, or all the injectors if both points are defective.

Temperature Sensor I is located either in the air cleaner or the radiator bulkhead. This thermistor-based sensor decreases its resistance as the temperature it is measuring increases. A defective Temp Sensor I often will not cause a perceptible driveability problem.

These points are used to produce the signal that synchronizes the injector to the crankshaft. They consist of two low-voltage, low-current contact points which are driven by a cam located on the distributor shaft. Each set of points initiates the opening of one of two groups of injectors. On a four-cylinder engine, two injectors are opened by each set of contacts; on a six-cylinder engine, each set of contacts controls three injectors and so on.

Unlike ignition points, the trigger points can last 100,000 miles or more. As the distributor rotates, a pulse is created by the opening and closing of the trigger points. This pulse is sent to the electronic control unit, or ECU. The ECU uses this signal to open the injectors and will use the inputs from the other sensors to determine when to close them.

Temperature Sensor I

Temperature Sensor I is an ambient air temperature sensor. As the ambient air temperature decreases, the density of the air increases. As a result, the ECU must inject more fuel on a cold day than on a warm day.

Temp Sensor I is a temperature-sensitive resistor known as a negative temperature coefficient (NTC) thermistor, as mentioned earlier. This sensor has a resistance of between 400 and 500 ohms at 50 deg. F. At 100 deg. F. the resistance is between 150 and 200 ohms.

Temp Sensor I actually has little effect on the operation of most D-Jetronic-equipped cars. This is because most of these cars have tens of thousands of miles on the engine and are running very rich due to this wear. The troubleshooting consequence of this is that disconnecting the air temperature sensor during the diagnostic procedure may have little effect on the way the engine runs, and in some cases it may actually *improve* the way it runs.

An 'Unauthorized Trick'

Among the old Bosch guys there is a popular trick to improve driveability as an engine begins to deteriorate. Disconnect Temp Sensor I; this tricks the ECU into enriching the mixture throughout the operating range of the engine. This richer mixture has only a marginal impact on fuel economy and power, but often load and rpm changes are accomplished with improved smoothness. The result is often what is perceived to be better performance.

The other side of this is that a conscientious technician noticing a disconnected wire and reconnecting it can cause a noticeable change in the performance of the engine.

Temperature Sensor II

Temperature Sensor II is the coolant temperature sensor on water-cooled engines, and the cylinder head temperature sensor on air-cooled engines. Like Temp Sensor I it is an NTC thermistor. The temperature of the engine is important because the intake manifold design of a fuel-injected engine does not permit the use of an air-restrictive choke. Additionally, restricting the air to enrich the engine during warm-up would cause inaccurate readings from the manifold pressure sensor. The warm-up choke function is therefore performed by Temp Sensor II.

When the coolant or cylinder head temperature is about 50 deg. F., the resistance of Temp Sensor II is between 3,000 and 4,500 ohms. As the temperature increases to more than 120 deg. the resistance drops to less than 1,000 ohms. Thus, the sensor's work is done once the engine is warmed up. Also, it must continuously remind the ECU that the engine has warmed up. If damaged, Temperature Sensor II

will not continue to partially function (such as the resistance values shifting). It will fail completely, creating an open short or ground.

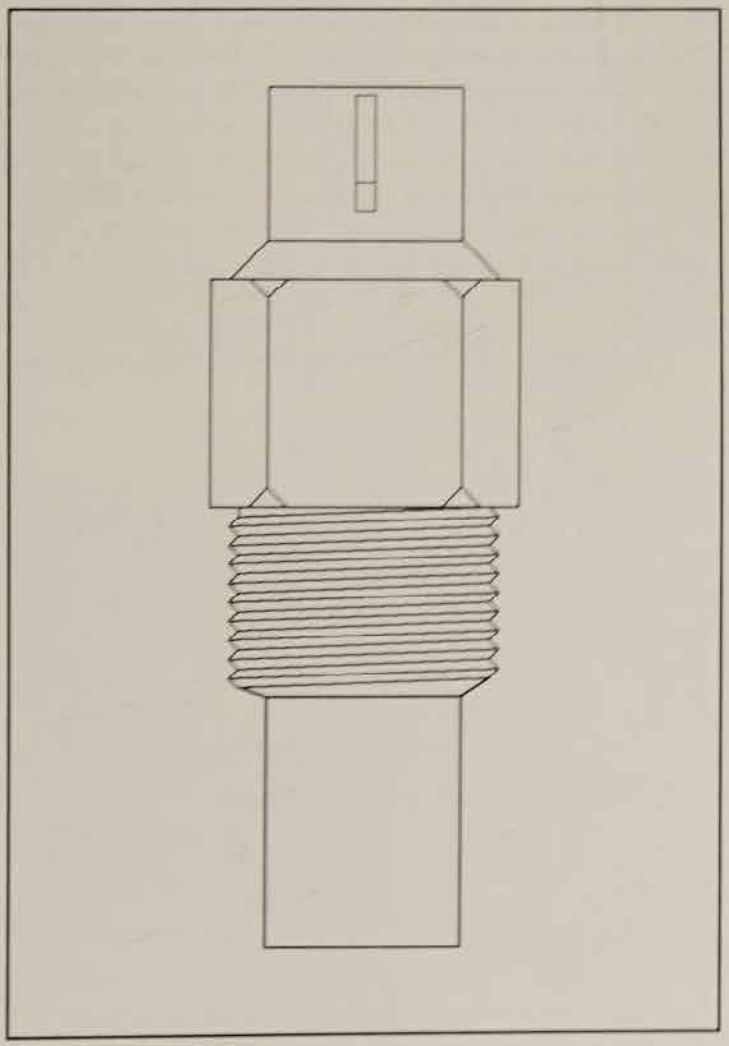
An open circuit in Temp Sensor II or the wiring leading to it will cause the engine to run extremely rich once warmed up. Symptoms would be dark smoke from the tailpipe (most noticeable at an idle), rough idle and poor power. Keep in mind that these same symptoms could also be caused by engine compression problems and ignition.

Should the sensor become shorted or the wiring harness grounded, the effects may not be noticeable at all when the engine is warmed up. The symptoms would be more like a carburetor with the choke stuck open—rough or erratic idle, stalling or hesitation when the engine is cold and progressively running better as the engine warms up.

Throttle Switch

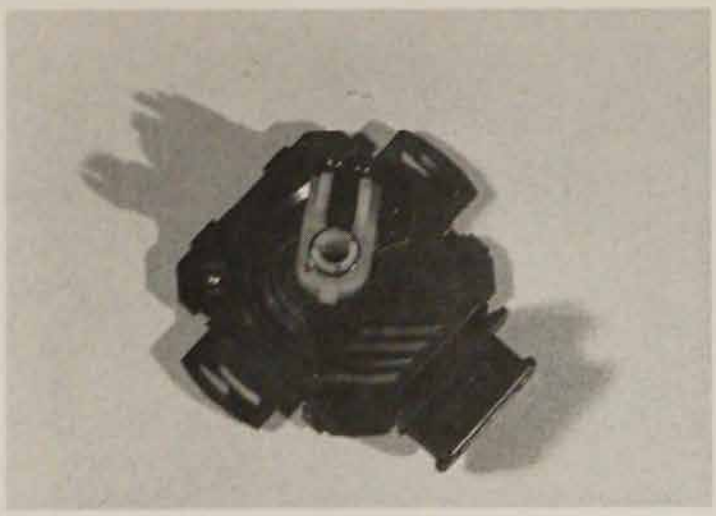
The throttle switch tells the ECU when the throttle is closed, when the throttle is wide open and when the throttle is moving toward the open position. The switch consists of twenty-two contacts, with a set of wiping contacts that move across them as the throttle progresses from the closed position to the wide-open position.

One wiping contact is used to inform the ECU that the throttle is closed. Another makes contact only when the throttle is wide open and a third makes and breaks contact twenty times as the throttle opens. The electrical pulses created by the making and breaking of the contacts signal the ECU to open the injectors more frequently, thereby enriching the mixture for acceleration. This fea-

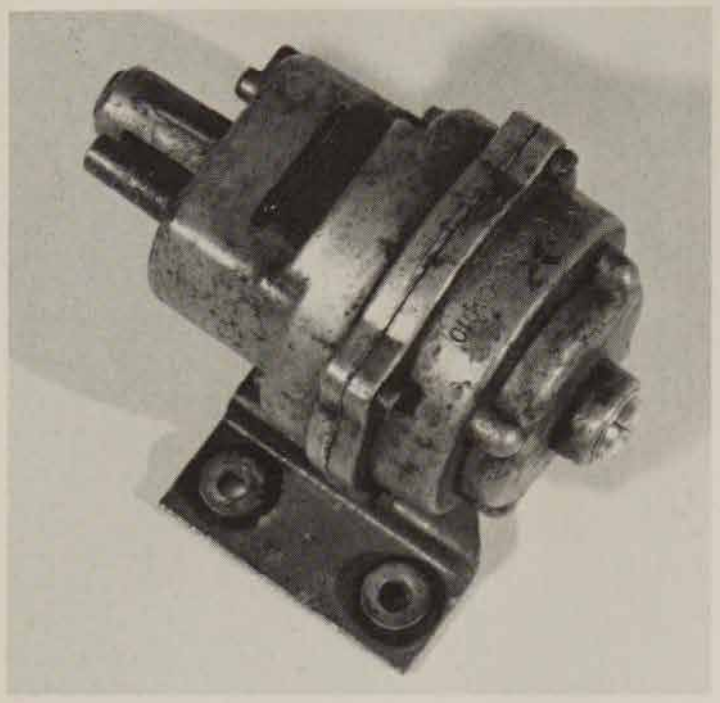


Temperature Sensor II is found in the water jacket on water-cooled engines, and in the cylinder head of air-cooled engines. In contrast to Temp Sensor I, when defective this sensor can produce very serious driveability problems. In many cases a defective Temp Sensor II can result in a no-start.

The throttle switch used on the D-Jetronic system is a twenty-contact switch mounted on the throttle shaft. Most applications have five wires going into the switch. When installing or adjusting the throttle switch, proper adjustment is essential. Note the adjustment slots for the mounting screws top and bottom.



One of the most common failures of the throttle switch involves an intermittent miss at cruise. The sawtooth contacts seen to the left in this picture begin to arc as the throttle is held at a steady position. To test for this condition, turn the ignition switch to the on position, and with the engine off, slowly open the throttle. There should be twenty evenly spaced clicks from the injectors. If there are not, adjust the throttle switch. If adjusting causes no improvement, replace the throttle switch.



The pressure sensor is normally mounted on the inner fenderwell. A vacuum hose connects the sensor to the intake manifold. Although these all look the same from one car to another, on the rare occasions where one needs to be replaced be certain that the correct one is being installed.

ture behaves much like an accelerator pump on a carburetor.

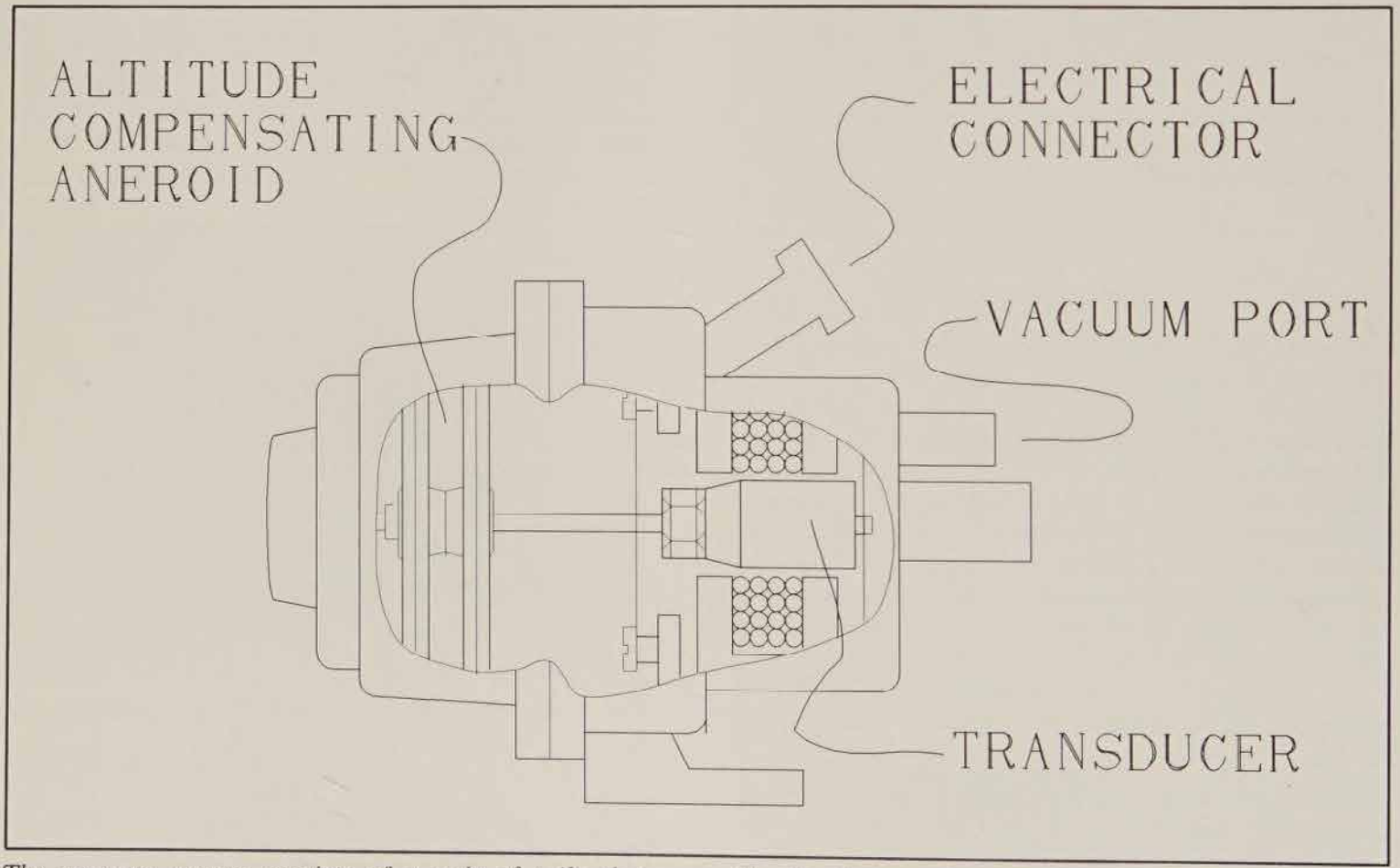
Symptoms associated with a defective throttle switch include a rich (smoky) idle and hesitation. An intermittent condition at cruise—which feels like you shut off the engine and immediately turned the key back on—can also be caused by the throttle switch.

To test the throttle switch, open the throttle with the key on but the engine not running. The injectors should open exactly twenty times, evidenced by twenty evenly spaced clicks.

Pressure Sensor

To an engineer, the D-Jetronic pressure sensor is known as a linear variable displacement transducer (LVDT). It consists of a pair of coils, one with about 150 ohms of resistance and the other with about 85. An iron core attached to a diaphragm runs through the center of these coils. As changes in manifold pressure move the diaphragm, the iron core moves inside the coils, causing ripples in the current flowing through these coils. This signal is used by the ECU to monitor the relationship between barometric pressure and manifold pressure.

The most common symptom from a defective pressure sensor is a rich running condition. Of



The pressure sensor consists of a pair of coils that measure the movement of a soft iron core. The iron core is connected to a thin metal diaphragm. As vacuum acts on the diaphragm, the iron core is moved. An altitude-compensating aneroid adjusts the sensor automatically for changes in altitude.

course, rich running can be caused by several other defects as well.

Of all the sensors used in the D-system, this one is both the easiest and the most difficult to test. Usually, a simple resistance test of the coils is enough to determine if the unit is good or bad. On the other hand, at times, the only way to be sure is to replace it with a known good unit.

Electronic Control Unit (ECU)

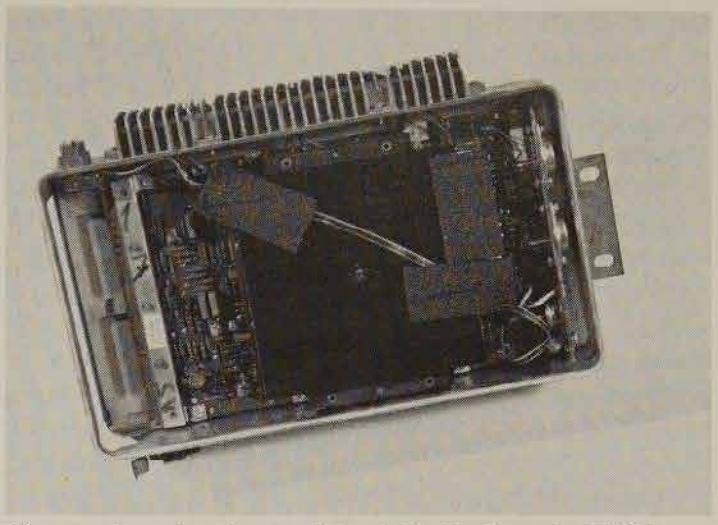
The ECU receives input signals from the pressure sensor, Temp Sensor I, Temp Sensor II and the throttle switch to determine how long to leave the injectors open. By 1990s standards, this control unit is a primitive device. It is only able to respond to air-fuel ratio requests from one sensor at a time. As a result, whenever a sensor fails the tendency will be for the ECU to send the injectors a full rich supply of fuel.

The electronic unit has no serviceable components. In the event of a failure, the ECU is replaced as a unit. Failures are extremely rare, however, and usually cause a no-start.

D-Jetronic applications that have an adjustable air-fuel ratio have a detent potentiometer on the side of the ECU. This potentiometer can be used to fine-tune the air-fuel ratio during a tune-up.

Pin numbers 19 and 25 of the ECU are connected to the fuel pump relay. When the ignition switch is turned to the on position, the ECU energizes the fuel pump to ensure that the fuel system is filled for ease in starting. If the engine is not cranked, the ECU will shut off the fuel pump after one or two seconds. If the engine is started, the fuel pump runs continuously until the engine is shut off.

The ECU used by the D-Jetronic fuel-injection system is, by 1990s standards, stone knives and bearskins. Its simplicity, however, works to its advanatage when it comes to durability. In nearly twenty years of working with this system I can think of only three or four that needed to be replaced to solve a driveability problem. On one of those, the car owner had drilled a hole in it.

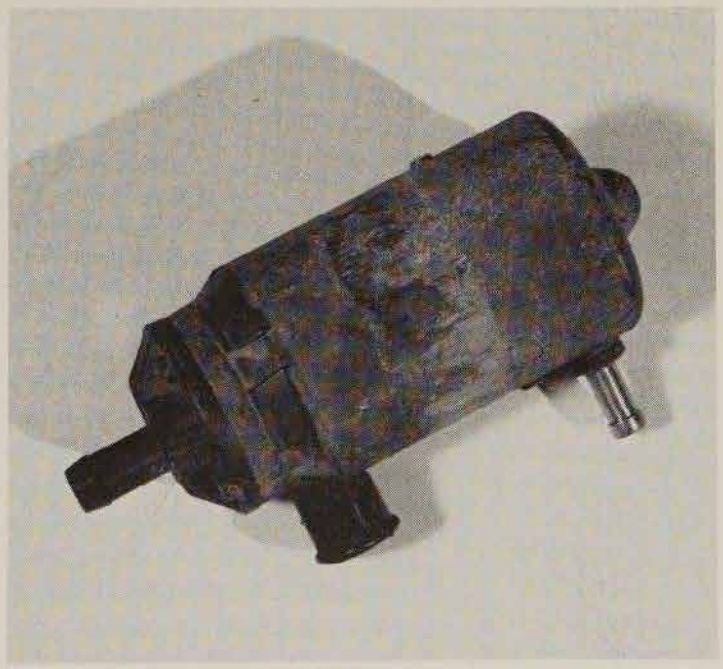


Comparing the electronics of the D-Jetronic ECU to a modern Motronic computer is like comparing a World War II P-51 to a modern-day F-18 fighter jet. Both are sophisticated, but the F-18 does so much more than the P-51. Note the gray thumbscrew at the upper left; this is used to adjust the CO.

Fuel Components

In-Tank Filter

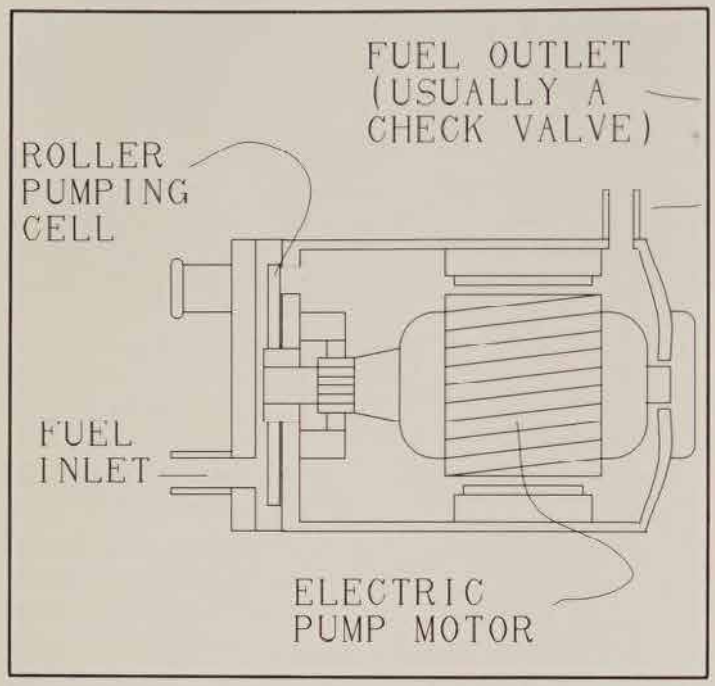
Located inside the fuel tank is a screen or filter designed to protect the fuel pump from rust, dirt and debris. Although seldom the cause of a driveability problem, the in-tank filter should be high on the list of items to check. In many cases these filters have been ignored, even on well-maintained cars. I have seen hours and even days wasted hunting for a problem as basic as a restricted in-tank filter.



The fuel pump is a high-pressure roller vane pump. In the photograph the gray, plastic fitting to the right is the inlet. The metal fitting on the top to the left is the outlet. The pump is usually mounted near or in the fuel tank.

Fuel Pump

The fuel pump is a high-speed roller vane pump. It is capable of pumping fuel at pressures and volumes much higher than the engine or injection system would ever require. This type of pump is very efficient at pushing fuel, but does not do a good job of pulling fuel. As a result these pumps are located very close to the fuel tank, or even inside the fuel tank, to reduce the chance to vapor lock.



In the D-Jetronic fuel pump, fuel enters through the inlet, passes through the roller cell, passes through the electric motor section of the pump, then out the outlet. The fuel passing through the electric motor acts as a coolant and a lubricant. If the pump is allowed to cavitate, it takes only a few minutes for it to be destroyed.

On many applications the fuel pump is extremely loud. But this in itself should not be viewed as a problem. If, however, the pump on a familiar car suddenly sounds much louder, this could be a sign of impending failure.

The fuel pump can react adversely and even fail as a result of using some fuel additives. Exercise extreme caution when selecting them to ensure that they do not contain methanol or other corrosive substances.

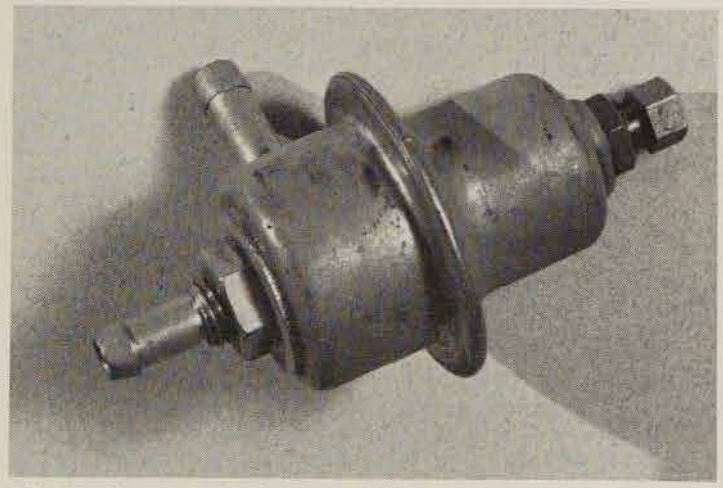
A defective fuel pump can cause low fuel pressure which would result in symptoms such as hesitation, stalling and poor power. Often a defective fuel pump by-passes the poor-running stage and simply stops operating. This causes the engine to die or keeps the engine from starting.

Fuel Filter

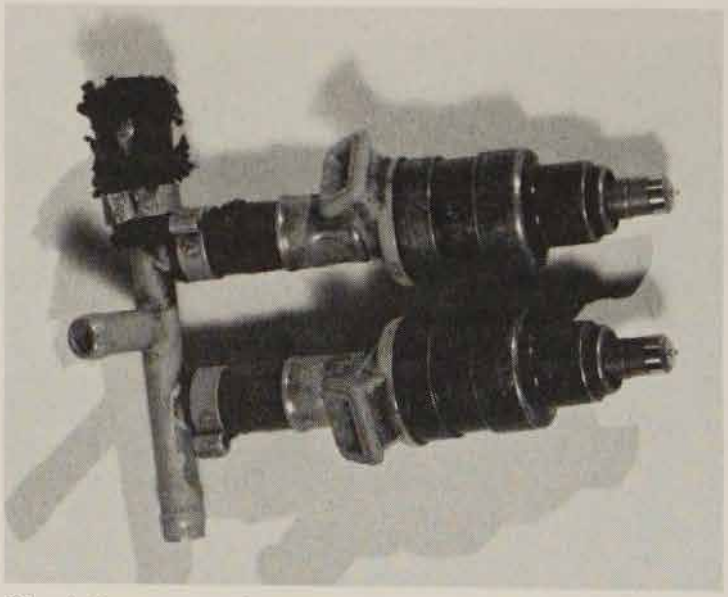
The fuel filter on the D-Jetronic is usually very well hidden and may not have been changed since the car left the factory. The fuel filter is the only real protection the injection system has from internal contamination from dirty fuel. Therefore, the filter should be replaced whenever the spark plugs are replaced.

Fuel Pressure Regulator

The fuel pressure regulator used on the Bosch D-Jetronic system consists of a valve connected to a spring-loaded diaphragm. The regulator controls the fuel pressure at 28-32 psi and is adjustable so the technician can ensure the proper fuel pressure throughout the life of the vehicle. Incorrect fuel pressure can cause a lean-running engine if the



The D-Jetronic fuel pressure regulator is adjustable. Loosen the lock nut shown at upper right. Adjust the 10 mm bolt to alter the fuel pressure. The correct pressure for the D-Jetronic system is 30 psi. This pressure regulator is from a 1969 air-cooled Volkswagen. Other applications are similar, but may have three fuel-line connections.



The injectors are located in the intake system immediately above the intake valves. Not counting contamination, injectors have an incredibly low failure rate. These were removed from a 1969 VW that was being parted out. The injectors were possibly the only original components that still worked properly.

fuel pressure is too low, and a rich-running engine if the fuel pressure is too high.

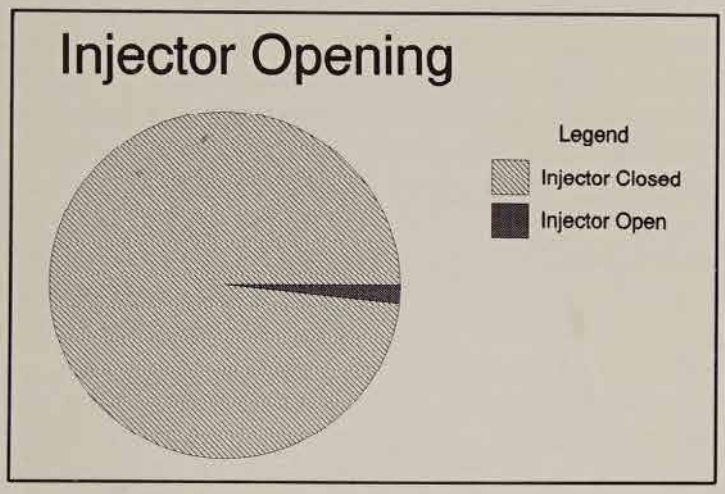
A defective fuel pressure regulator can result in high fuel consumption, rough or erratic idle and poor power.

Injectors

The injectors are solenoid-operated, normally closed valves controlled by the ECU. Grounded to the engine block or chassis, each injector is opened by a 3 volt pulse from the ECU. The length of the pulse is only a few milliseconds (two to five), and it takes time for the injector to close from the spring tension. Thus the injector is open for a total of about three to six milliseconds.

Very little goes wrong with the D-Jetronic injectors themselves. An occasional burned-out solenoid winding or restriction from contamination is the most common problem. Another chronic problem is leaking from the hoses that attach the injector to the fuel rail. After twenty-plus years of dramatic temperature changes within the engine compartment, even the best rubber can break down and begin to leak. Replacement kits are available for these hoses without having to replace the entire injector.

Typical symptoms of injector problems include rough idle and poor power.



The fuel injectors open for very short times. This pie chart shows what the relationship is between injector open and injector closed at an idle. As the rpm increases, the time that the injector is open increases slightly, but the time that the injector is closed decreases dramatically.

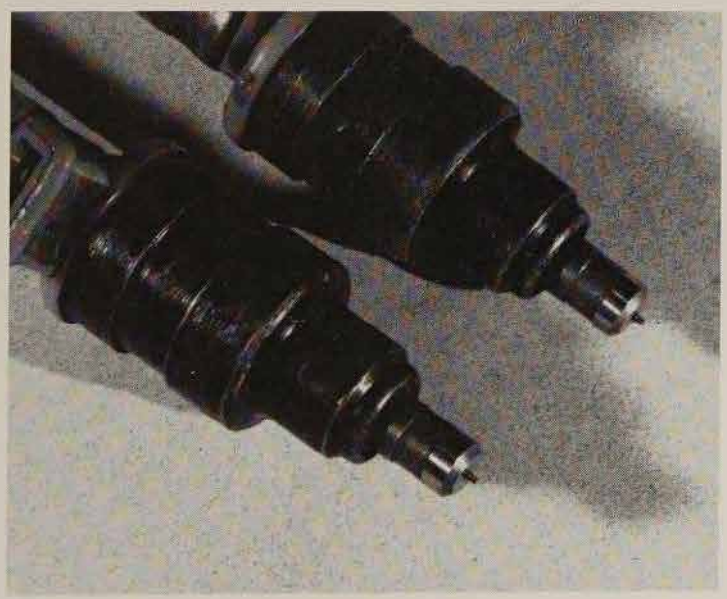
Fuel Rail

The injectors and the fuel pressure regulator are attached to steel tubing known as the fuel rail. The inbound fuel lines from the fuel pump and filter feeds fuel to the injectors and the fuel pressure regulator through the fuel rail.

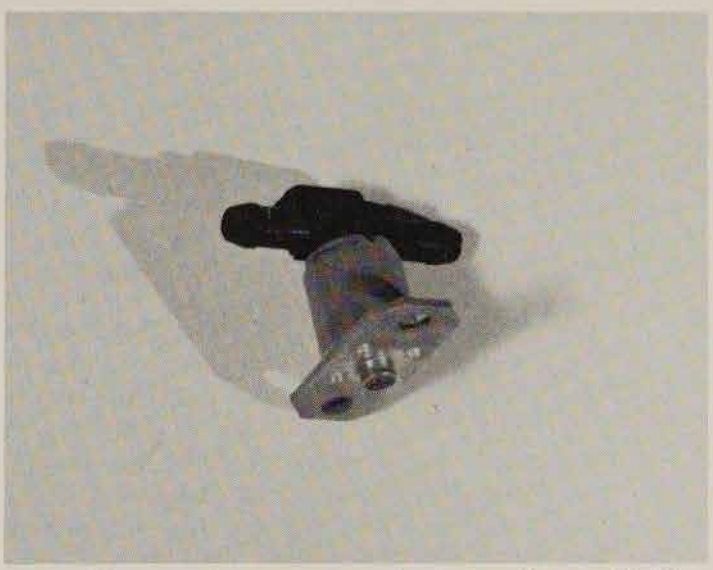
As a passive component of the system, very little can go wrong with it except for leaks and restrictions.

Cold-Start Injector

Also attached to the fuel rail is a solenoid-operated valve known as the cold-start injector. Since the earliest applications of the D-system were four-cylinder, the cold-start valve picked up the moniker "fifth injector." It stuck in some circles, even for six- and eight-cylinder applications.



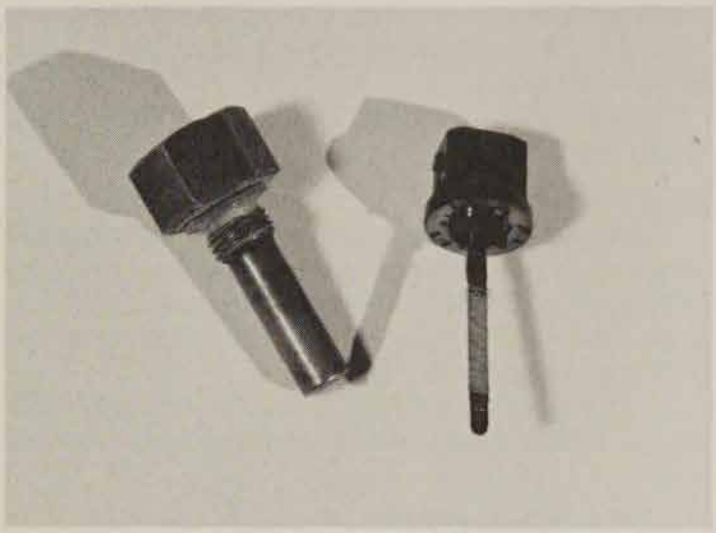
The most common problem with injectors is restriction. Although rust, sand and dirt in the fuel tank can cause internal contamination, the most common restrictions are external. Carbon deposits build up on the tip of the injectors where they protrude through the end of the injector into the intake. These restrictions can be removed by using one of the many injector cleaners on the market.



The cold-start injector mounts in the intake manifold so the fuel sprayed through it is distributed fairly evenly to all cylinders. This injector is from an air-cooled VW. Notice that there are two fuel fittings; most applications have only one. Power to the cold-start injector is from the crank position of the ignition switch or starter solenoid.

The cold-start injector receives battery voltage whenever the starter is engaged and is grounded through a device known as a thermo-time switch. The thermo-time switch is a temperature-sensitive bimetal switch designed to provide a ground for the cold-start injector when the temperature of the engine is less than 95 deg. F. A second circuit in the switch is an electric heating element intended to heat the bimetal as the engine is being cranked. Consequently, the cold-start injector should operate only when the engine is being cranked, the temperature of the engine is less than 95 deg., and for a maximum of five to twelve seconds.

Two of the most common symptoms of a cold-start injector problem are hard starting when cold because the cold-start valve is not operating, and a leaking cold-start injector, which can cause an extremely rich running condition.



The ground for the cold-start injector is through the thermo-time switch. This switch consists of a set of contacts on a bimetal strip. When the temperature of the engine is less than 95 deg. F., the cold-start injector is grounded and will spray while the engine is being cranked. Wrapped around the bimetal strip is an electric heater. As the engine is cranked, the heater heats the bimetal. After five to twelve seconds the switch will open, turning off the cold-start injector.

Air Components

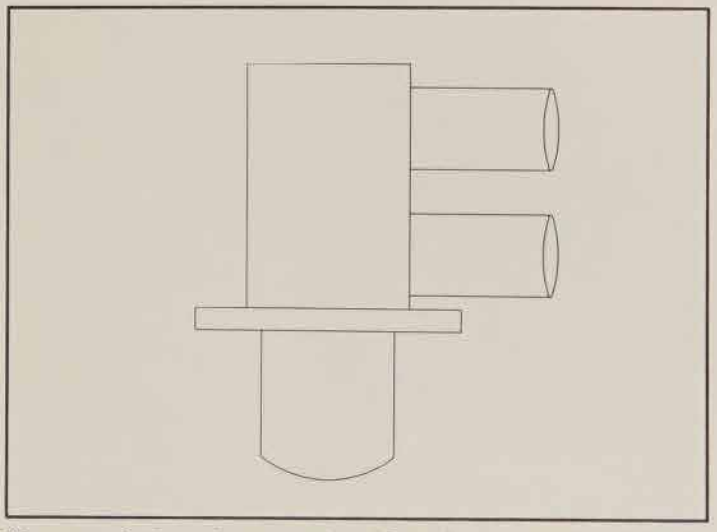
Pressure Sensor Vacuum Hose

It may seem odd at first to identify a vacuum hose as a fuel-injection component; however, when troubleshooting a driveability problem, this simple vacuum hose can have just as much of an effect on the operation of the pressure sensor as a defect in the pressure sensor itself.

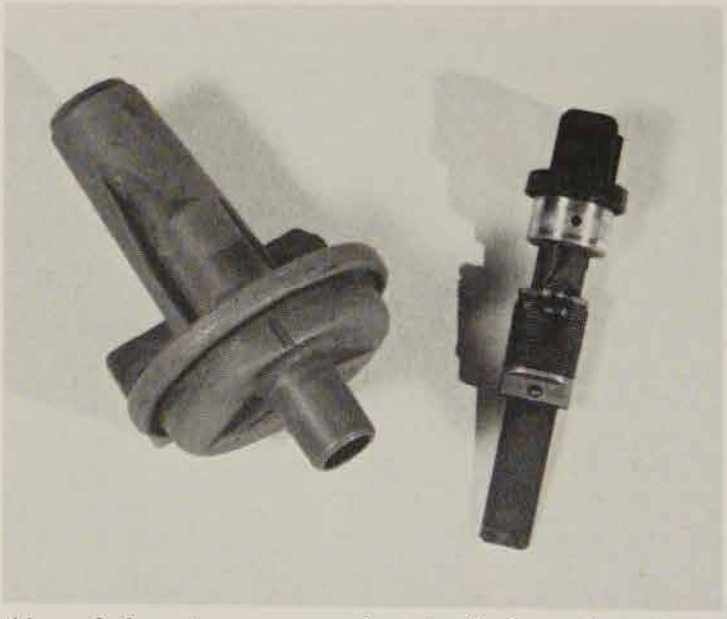
Auxiliary Air Valve

The auxiliary air valve is used to allow air to by-pass the throttle plates while the engine is warming up to permit a fast idle. The valve comes in two forms, depending on whether the engine is air cooled or water cooled.

In water-cooled applications, the auxiliary air valve consists of a thermal expansion bulb mounted in the cylinder head water jacket. This controls a slide valve to control air volume through a by-pass around the throttle plates. When the engine is cold the thermal bulb is fully retracted, allowing the slide to be fully open. This permits



Water-cooled engines equipped with the D-Jetronic system use an auxiliary air slide. A thermal bulb sitting in the water jacket expands and closes a slide which allows air to go from in front of the throttle plates to behind when the engine is cold. This provides a fast idle function that automatically drops to curb idle as the engine warms up.



Air-cooled engines use an electrically heated auxiliary air valve. A bimetal strip opens and closes a valve that allows air around the throttle plates when the engine is cold. As the engine runs, the electric heater wrapped around the bimetal heats the strip and the valve closes. This provides a fast idle function that automatically drops to curb idle as the engine runs.

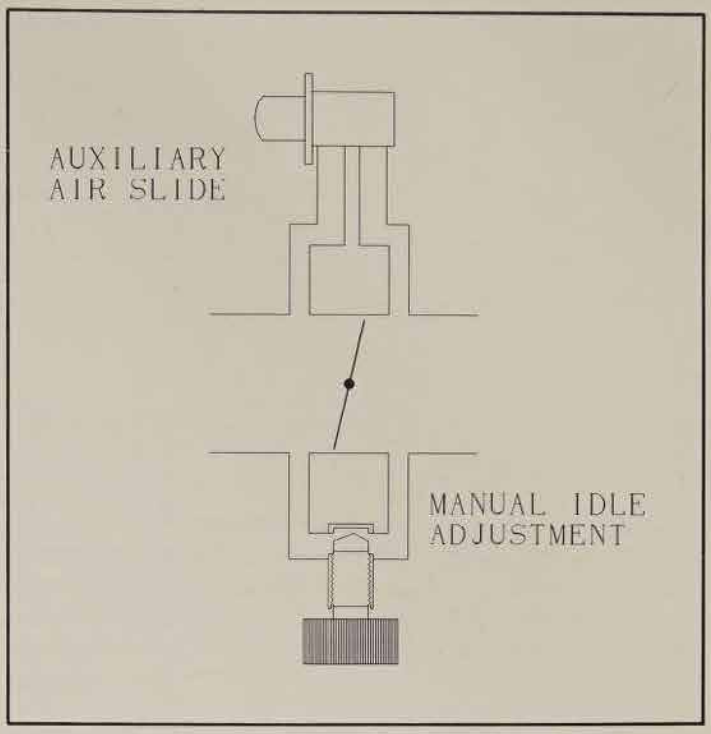
maximum airflow through the auxiliary air by-pass. As the engine coolant temperature increases the thermal bulb expands, closing the slide and reducing the amount of air allowed through the by-pass.

The air-cooled applications use an electrically heated bimetallic valve. When the engine is first started, the valve will be open. As the engine runs, the bimetallic valve is heated by the electric element, slowly closing off the auxiliary air by-pass and reducing the engine idle speed.

A defective auxiliary air valve will result in either a low idle speed when the engine is cold, or a high idle speed when the engine is warm.

Idle Air By-pass

Unlike a carbureted engine, the D-Jetronic system does not use the throttle stop screw to adjust the idle speed. Instead, it uses a by-pass channel similar to the auxiliary air by-pass. Unlike the auxiliary air by-pass, though, the idle air by-pass is adjusted by the technician. Curb idle speed should be changed only by adjusting the idle air by-pass and *never* by using the throttle stop screw.



The idle air by-pass, not *the throttle stop screw, is used to adjust the curb idle speed. Be sure that the auxiliary air valve or slide has completely closed before adjusting curb idle. Incorrect adjustment of the throttle stop can result in rough idle and surging.*

D-Jetronic Tune-Up Adjustments

All the standard tune-up adjustments such as ignition point dwell, timing, air-fuel ratio and idle speed can be made to the D-Jetronic fuel-injection system. Three additional adjustments can be made as well: fuel pressure, throttle stop and the throttle switch are all adjustable. In this section, however, we will cover only those adjustments that apply directly to the fuel-injection system.

It is important to note that the sequence in which these adjustments are made is crucial. Failure to follow this sequence can affect the accuracy of the adjustments.

Fuel Pressure Adjustment

The fuel pressure regulator is found in the fuel rail on most applications. On top of the pressure regulator is a 10 mm hex-bolt adjustment, secured in place by a lock nut.

Disconnect the fuel hose from the cold-start injector and attach a fuel pressure gauge. Start the engine and allow it to idle. If the fuel pressure is other than 28 psi, loosen the lock nut and adjust the fuel pressure with the 10 mm hex-bolt. After adjusting the pressure, ensure that the lock nut is tight to prevent engine vibration from changing the fuel pressure.

Throttle Stop Adjustment (Minimum Idle Speed)

Although the actual curb idle speed should never be adjusted with the throttle stop screw, proper and smooth operation of the fuel-injection system can be affected by this adjustment.

Begin by ensuring that the auxiliary air valve is closed off completely. To do this, allow the engine to warm up and check the engine idle speed. Now shut off the engine and remove the hose from the auxiliary air valve to the intake manifold downstream of the throttle plates. Plug this hose and restart the engine. The speed should be almost exactly the same now as it was with the hose connected in the normal manner. If the speed is now significantly lower (50 to 100 rpm or more), replace the auxiliary air valve.

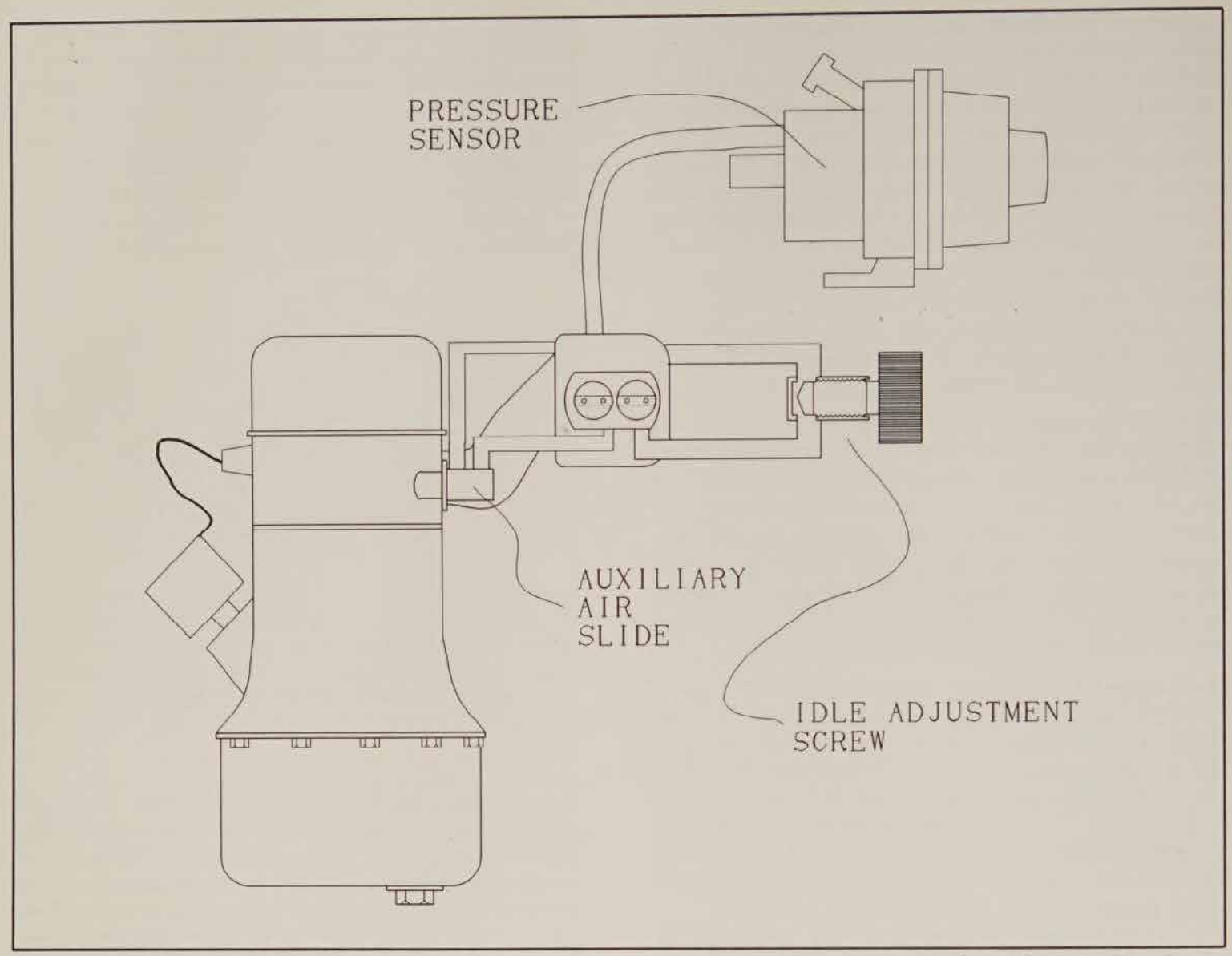
Locate the idle air by-pass adjustment. This is normally located on or near the intake manifold. With the engine idling, close off the idle air by-pass completely. Loosen the lock nut on the throttle stop screw and adjust for the lowest possible speed without the engine dying. Then shut off the engine and check the throttle carefully for binding in the closed position.

Idle Speed Adjustment

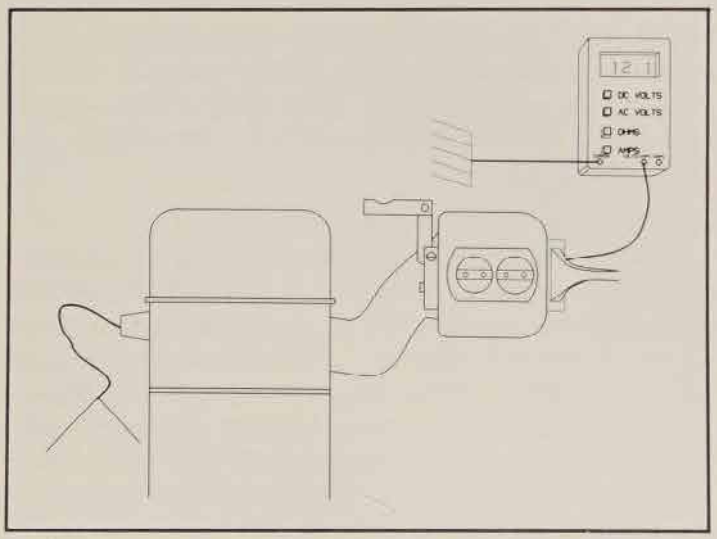
To adjust the idle speed, first connect a tachometer to the negative terminal of the coil. Start the engine and allow the idle to stabilize. Ensure that the auxiliary air valve is closed off completely and that the engine is thoroughly warmed up. Then, using the idle air by-pass, adjust the curb idle speed to the specification listed on the underhood sticker. If the sticker is missing or illegible, use the chart included in this section.

Throttle Switch Adjustment

Locate the throttle switch mounted on the throttle shaft. Place a 0.016 in. (0.4 mm) feeler gauge



To adjust the idle speed make sure that the auxiliary air slide or valve is closed. Close the idle adjustment screw. The engine should barely idle (500 to 650 rpm). If the engine speed is too fast or too slow, adjust the throttle stop screw. Adjust the idle thumbscrew for the proper curb idle speed.



With a feeler gauge inserted between the throttle linkage and the throttle stop screw, there should be voltage at terminal 17. When the feeler gauge is removed, the voltage should drop to zero.

between the throttle stop and the throttle stop screw. Connect a voltmeter to terminal number 17 of the throttle switch. The voltmeter should read a voltage with the key on. If you remove the feeler gauge, the voltage should drop to zero volts.

If these conditions are not met, loosen the throttle switch mounting screws, and rotate the switch either clockwise or counterclockwise until they are met.

Note: If pin number 17 reads voltage all the time, even after an adjustment attempt is made, replace the throttle switch. If the voltmeter reads nothing, even during the adjustment, confirm that there is voltage being supplied to the switch. If there is, replace the switch.

Air-Fuel Ratio Adjustment

Again, as in the idle speed adjustment, the engine must be thoroughly warmed up for the air-fuel ratio adjustment to be made.

Insert a CO (carbon monoxide) probe up the tailpipe. Using the detent potentiometer located on the side of the ECU, adjust the CO percentage reading to the specification stated on the underhood decal. If the decal is unreadable or missing, use the nearby chart.

Fuel-Injection Tune-Up Specifications

Application	Idle Rpm	CO%
Mercedes-Benz		
1968-69	750-800	1.5-3.0
1970-71	750-800	1.0-2.0
1972-75	700-800	0.5-2.0
Porsche 914		
1970-71	850-950	0.7
1972	850-900	0.7
1973 1.7 liter	850-900	0.7
1973 2.0 liter	850-950	1.5
1974 1.8 liter	800-900	2.0-3.0
1974-76 2.0 liter	850-950	1.0-3.0
Renault		
1972-74	950-1050	2.0-3.0
Saab		
1969-74	800-900	2.5-3.5
Volkswagen Type 3		
1968	850-900	Not adjustable
1969-70	850-900	2.8-3.1
1971	850-900	Not adjustable
1972	800-900	0.7
1973	800-900	Not adjustable
Volkswagen Type 4		
1971	800-900	Not adjustable
1972	850-900	0.7
1973	850-900	Not adjustable
1974	800-900	Not adjustable
Volvo		
1970-75	800-900	0.5-1.5

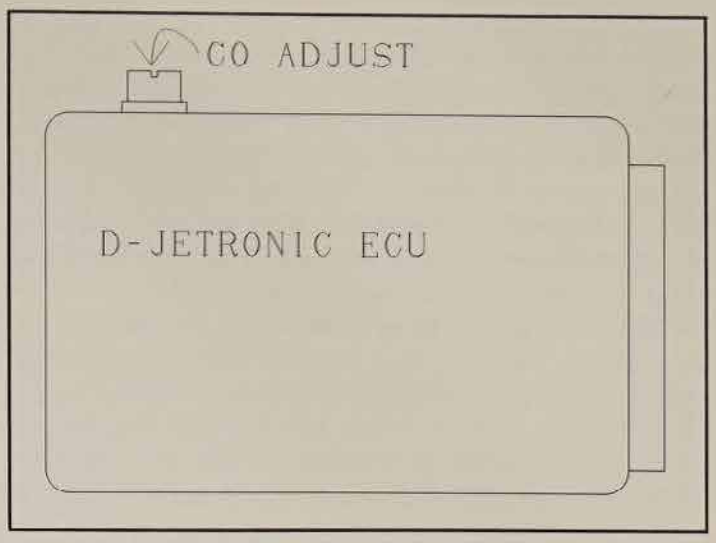
If the car is equipped with an automatic transmission, adjust the idle to 1000 rpm in neutral. When the transmission is placed in drive, the idle speed should not drop below the specification for the application.

Troubleshooting the D-Jetronic System

When troubleshooting a driveability problem on a D-Jetronic fuel-injected car there is a tendency to forget the basics of engine condition and the ignition system. What follows is a logical diagnostic progression, applicable regardless of the symptom.

Compression Test

Unless the engine is in good shape the D-Jetronic system cannot accurately control the delivery of fuel into the engine. The ECU is designed to assume that the changes in manifold pressure reported by the manifold pressure sensor are changes from a programmed base idle vacuum. Since engine wear can affect this vacuum, any troubleshooting must begin with knowing that the engine is in good shape.



Insert a CO gas analyzer probe in the tailpipe. With the engine idling, adjust the ECU thumbscrew for the proper air-fuel ratio. Some Volkswagens do not have a thumbscrew on the side of the ECU. Thus, CO is not adjustable on these cars.

When running the compression test, ensure that the compression gauge is snugly installed and that the throttle is held wide open to guarantee the most accurate reading.

Valve Adjustment

Since most applications that use the D-system have mechanical lifters, take time at this point to see that the valves are properly adjusted. While the compression test would point out severely maladjusted valves, do not rely on it to confirm that the valves are properly adjusted. Remove the valve cover and follow the valve adjustment procedure outlined in the factory service manual for the application that you are working on.

Vacuum Leaks

Since the principal source of information for determining the amount of fuel the engine requires is manifold pressure, the chance of a vacuum leak causing a driveability problem is even higher than on a carbureted car.

One of the best ways of hunting for a vacuum leak is with standard hardware store propane. With the engine warmed up and at an idle, run an unlit propane torch along both the top and bottom sides of the intake manifold. Pay particular attention to the gasket between the throttle assembly and the intake manifold, the seals where the injectors mount in the intake manifold, and the throttle shafts.

Any vacuum leaks found must be repaired before valid testing can continue.

Ignition System

After confirming that the basic engine is in good shape, inspect the condition of the ignition components. Inspect the points for evidence of burning,

pitting and metal transfer. Check for the proper dwell. Inspect the distributor cap and rotor for cracks and burning. Whenever you replace the cap and rotor it is advisable that they be the same brand. The spark plugs cannot always be checked satisfactorily without an engine analyzer, therefore, if there is any doubt at all about the condition of the spark plugs, just replace them. It's cheaper than wondering about their condition.

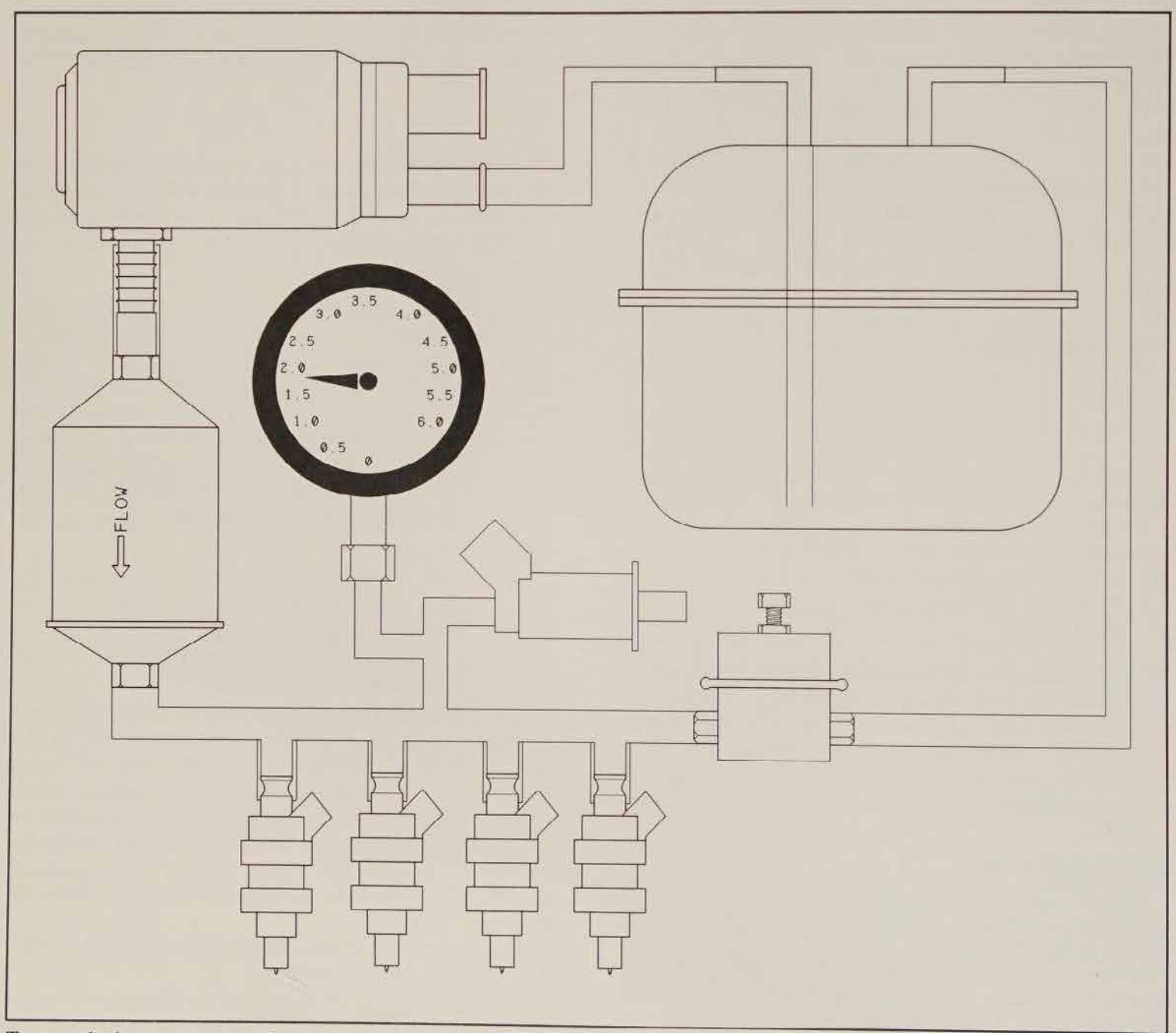
Check the spark plug wires' resistance with an ohmmeter. The original factory wires were solid metal with resistors that screwed onto the ends. These wires should have almost no resistance, while the resistor on the end of the wire should have 5,000 to 10,000 ohms of resistance. Many of the replacement secondary ignition cables are resistor wires. Resistor wires should have between 2,000 and 10,000 ohms per foot. Also inspect the wires for cracks or breaks in the insulation which may allow the ignition spark to arc to ground.

Testing the Fuel-Injection System

Once the engine and ignition condition have been confirmed, testing of the fuel-injection system begins.

Fuel Pressure

Testing must begin with checking fuel pressure. Connect the fuel pressure gauge to the hose going to the cold-start injector. Start the engine and



To test fuel pressure on the D-Jetronic fuel-injection system, connect the fuel pressure gauge to the line going to the cold-start injector. Adjust the pressure (if necessary) to 30 psi. A range of 28 to 32 psi is acceptable. The gauge illustrated above reads in bar. One bar equals approximately 15 psi.

allow it to idle. The fuel pressure should be 30 psi. Minor discrepancies in pressure can be corrected by adjusting the fuel pressure regulator.

If the symptom occurs only on acceleration or when the engine is under load, then fuel pressure must be tested under the same conditions that the symptom occurs. Position the fuel pressure gauge where it can safely be seen while driving the car. Then watch for a drop in fuel pressure that coincides with the symptom. This is the most effective method for testing fuel volume.

If the pressure is extremely high, there are two possible causes: (1) the fuel pressure regulator is defective, and (2) the fuel return line from the regulator back to the tank is restricted. To determine which is at fault, shut off the engine, remove the return line from the fuel pressure regulator and install a test hose which will allow the return line fuel to be pumped into an approved fuel receptacle. Then restart the engine. If the fuel pressure is now normal, repair the restriction in the return line. If the pressure remains high, then replace the fuel pressure regulator.

If the fuel pressure is low, however, there are ten possible causes. The following list is not in any specific order. Check them in the order of convenience based on your work environment and their accessibility on your car.

1. Inspect the system for external leaks. A fuel leak severe enough to result in a significant loss in fuel pressure would be severe enough to be very noticeable and very dangerous. Use extreme caution.

2. Ensure that there is enough fuel in the tank to pull easily into the system by the fuel pump and fuel pickup.

3. Check the fuel tank vent. If there is a venting problem with the fuel tank, it may not be possible for the fuel pulled out by the fuel pump to be replaced by air. A suction is created in the tank, limiting the pump's ability to pull fuel out of the tank and resulting in low fuel pressure. Remove the gas cap and drive the car. If the sympton is gone, replace the fuel tank vent valves.

4. The in-tank fuel filter may be restricted. Most cars will have a screen in the fuel tank to protect the pump from sand, rust and other hard particle contaminants. If this filter is restricted, the fuel volume will be reduced, causing a loss in pressure. Checking the filter is especially important when the loss of fuel pressure occurs only with the engine under load.

5. Inspect the fuel pickup connector hose. There is often a hose that connects the in-tank filter to the fuel pickup. Occasionally this hose will perforate, causing the fuel pump to suck in air rather than fuel. The likelihood of this causing low fuel pressure increases if the symptom occurs only when the fuel level is below half a tank.

6. The main fuel filter may be clogged. If this filter is restricted the fuel volume will be reduced, causing a loss in pressure. The filter should especially be considered when the loss of fuel pressure occurs only with the engine under load.

7. Check the fuel pressure regulator. If the pressure is low all the time, one of the prime causes could be the pressure regulator. Squeeze off the return line. If the pressure increases, replace the fuel pressure regulator.

8. If the line running from the fuel tank to the fuel rail is restricted there will be a reduction in volume. This could cause a loss of pressure at times of high fuel demand. Check these lines for kinks and clogs.

9. Confirm that there is a 12 volt drop across the pump. Connect the red lead of a voltmeter to the positive terminal of the fuel pump, and connect the black lead to the negative terminal. If the reading is less than 12 volts, attach the black lead of the voltmeter to chassis ground. If the voltage is now 12 volts, repair or clean the fuel pump ground. If the voltmeter still reads less than 12 volts, then repair the high resistance on the positive wire to the fuel pump.

10. The fuel pump may be malfunctioning. Assuming the fuel filters have been replaced, if squeezing off the return line does not increase the fuel pressure and the voltage drop across the pump is 12 volts, then the pump becomes a prime candidate for replacement.

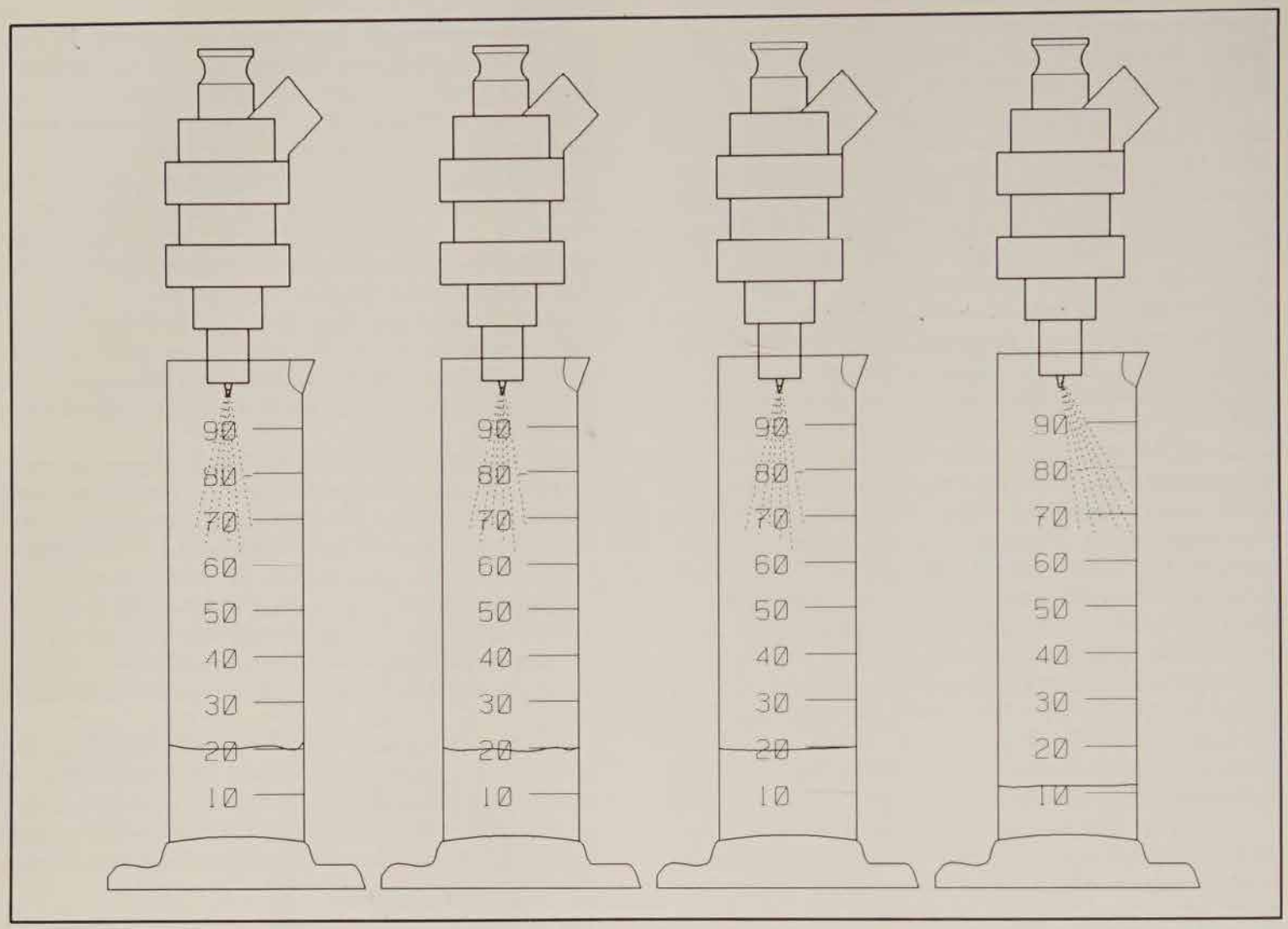
No Fuel Pressure

Lack of any fuel pressure will usually be due to an electrical problem. There are two fuses and a relay that could keep the fuel pump from running. Inspect the fuses not only for being burned open but also for corrosion on the ends. The fuel pump relay should click when the engine is being cranked. If it does not, connect a test light to pin number 28 of the relay. If it lights when the engine is cranked, replace the relay. If it does not, inspect the wiring from the relay back to the ignition switch. If the relay clicks as the engine is being cranked, check for voltage at pin number 37 of the fuel pump relay. If pin number 37 illuminates a test light, repair the open wire between the relay and the fuel pump (or the fuel pump and ground if the positive side of the pump also lights the light). If it does not activate the test light, replace the relay (again, confirm voltage at relay pin number 28).

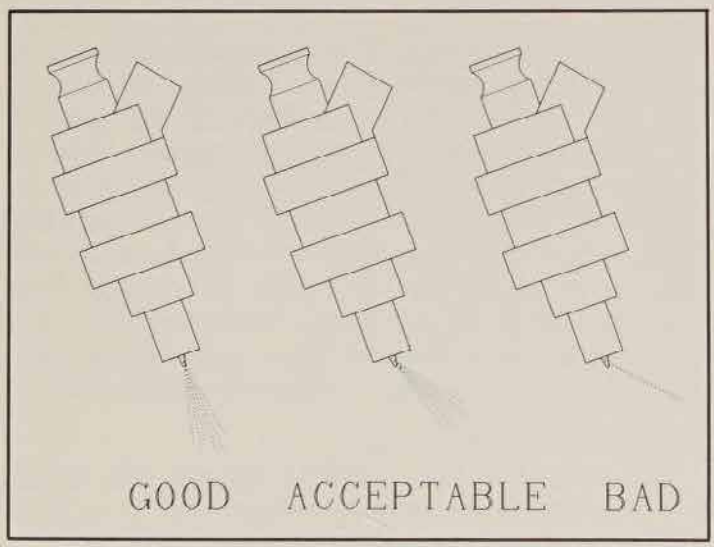
Injector Flow Testing

If your car is experiencing erratic idle, rough running and low power it is important to confirm the proper flow rate through the injectors.

Remove the injectors from the intake system, leaving them attached to the fuel rail. Place each injector in a small, graduated cylinder (these can be purchased from any photographic supply store).



To flow test the D-Jetronic injectors, remove the injectors from the intake and remove the spark plugs. Place each injector in a graduated cylinder, leaving them attached to the fuel rail. Crank the engine for thirty seconds. The amount of fuel sprayed through each injector should be approximately equal. If the volume through each injector is not consistent, clean the injectors. Injector cleaners are available at most auto parts stores. After cleaning the injectors, repeat the test. If the quantity is still not equal, replace the injectors.



While flow testing the injectors, watch the spray flow through the injectors. The spray pattern should be cone shaped and straight down from the center of the injector. If the spray is cone shaped but off center, it should not noticeably affect a car's driveability.

Remove the spark plugs, disconnect the battery lead to the coil, and crank the engine for sixty seconds. Observe the amount of fuel flowed by each of the injectors. If the quantity varies by more than 10 percent, either clean or replace the injectors.

Testing Electrical and Electronic Components

Once engine and ignition quality as well as proper fuel pressure and volume have been confirmed, it is time to begin testing the electrical and electronic components of the system. For the sake of both convenience and accuracy, I advise accessing the ECU and performing all of the following resistance checks at the ECU harness. This allows a single operation to test both the component and its wiring harness. If a resistance is incorrect, a quick test will determine if the problem is the wiring harness or the component itself.

Main Relay: The main relay supplies power to the ECU which in turn supplies power to the various

sensors and components of the fuel-injection system. With the engine cranking or running, there should be 12 volts at pin number 24 of the ECU. If there is not, check for 12 volts at pin number 24 of the relay. If 12 volts are not present at the relay, yet the relay clicks, replace the main relay. If there are 12 volts at pin number 24 of the relay, repair the number 24 wire between the relay and the ECU.

If the relay fails to click, inspect the wire from main relay pin number 45 to ground. If there is a good ground and 12 volts at relay pin number 38 when the engine is being cranked, replace the main relay.

Trigger Points: With the engine shut off and the ECU harness disconnected from the ECU, check the resistance between ECU harness terminal numbers 12 and 21, then from numbers 12 to 22. One measurement should show very low resistance while the other should show an open circuit. Now rotate the crankshaft 360 deg. The pair of terminals that showed continuity should now show an open, and the pair that showed the open should now show continuity. If these conditions are not met, repeat the test at the trigger points to determine if the problem is in the component or the wiring harness.

Temperature Sensor I: With the engine shut off and the ECU harness disconnected from the ECU, connect an ohmmeter between ECU harness pin numbers 1 and 13. This sensor measures the temperature of the ambient air. With an ambient air temperature of 85 deg. F., the resistance should be around 200 ohms. If the ambient temperature is higher, the resistance will be a little lower. If the temperature is a little lower, the resistance will be a little higher.

Should the resistance be a great deal higher or lower than described, check the resistance at the sensor itself to determine if the problem is the sensor or the wiring harness. Normally, the problem is found either in the air cleaner or in the radiator bulkhead.

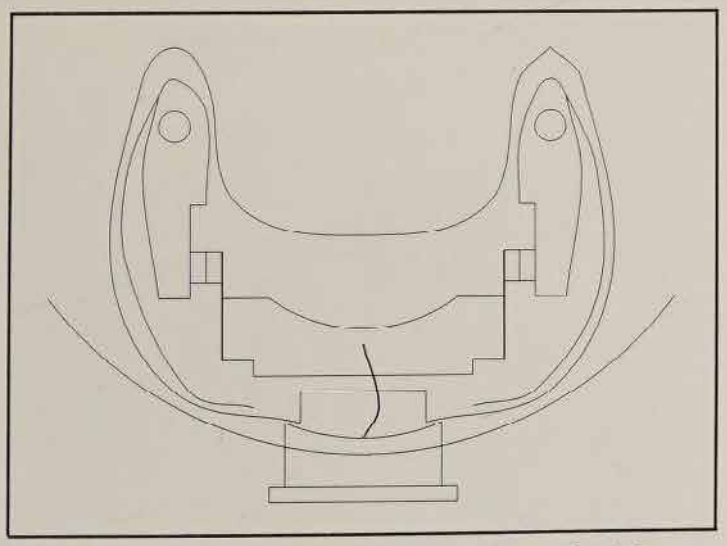
Also check resistance of all terminals to chassis ground. This should always be an open circuit.

Temperature Sensor II: Temperature Sensor II is the coolant or cylinder head temperature sensor. With the engine shut off and the ECU harness disconnected from the ECU, check the resistance between harness terminal number 23 and ground. With the engine at ambient temperature (65-85 deg. F.), the resistance should be about 2,000 ohms. When the engine is at operating temperature, the resistance should be well below 1,000 ohms. If the resistance does not meet these specs, test at the sensor itself. On an air-cooled engine the sensor is located on the left cylinder head; on a water-cooled engine it is normally near the thermostat housing.

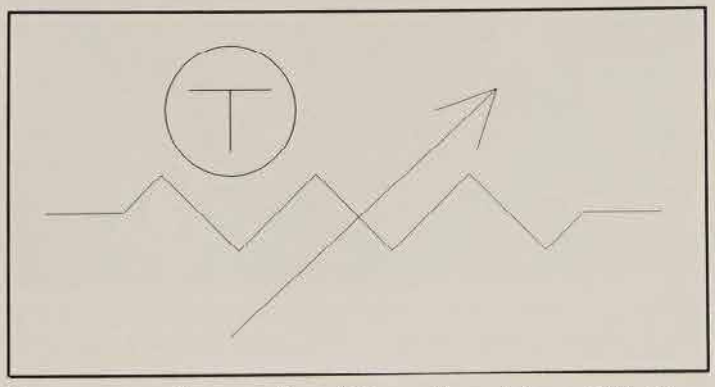
Throttle Switch: Test the throttle switch by reconnecting the harness at the ECU, and slowly opening the throttle—key on, engine off. As the throttle is opened the back of each injector should alternately click. You should hear twenty evenly spaced clicks. If there are not twenty clicks, check the throttle switch adjustment as outlined in the adjustments section of this chapter. If you still don't hear twenty clicks after the adjustment is made or if the clicks are not evenly spaced, replace the throttle switch.

If no clicks are heard, check wire numbers 20, 17, 14 and 9 for continuity end-for-end from the ECU to the throttle switch.

Pressure Sensor: With the engine shut off and the ECU harness disconnected from the ECU, test the resistance from ECU harness terminal numbers 7 to 15. The reading should be 90 ohms. Now check



The trigger points provide the pulse to open the injectors. Connect an ohmmeter to the center terminal and one of the outer terminals. As the engine is cranked, the ohmmeter should indicate the making and breaking of continuity. Repeat the procedure at the second outer terminal. If continuity does not make and break on both terminals, replace the trigger points. A simpler way to test the points is to crank the engine. If all the injectors open, the points are good.



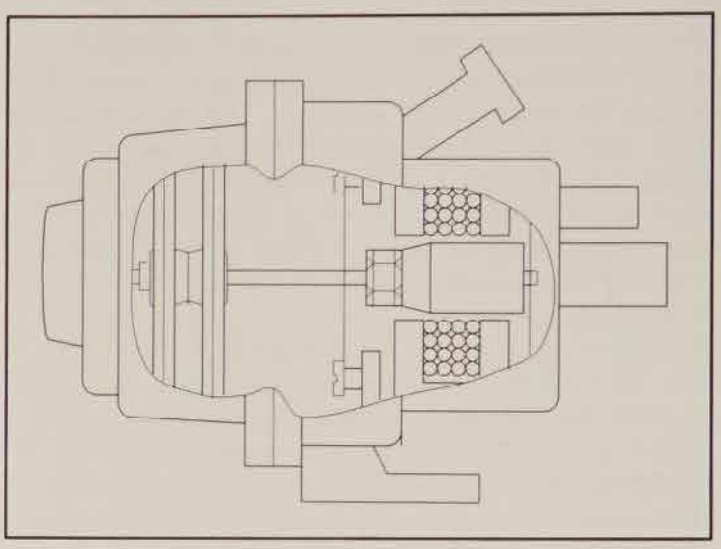
Temperature Sensors I and II are thermistors. With these sensors, as the temperature increases, the resistance decreases. This is the symbol used to represent such a sensor in schematic diagrams.

the resistance between numbers 8 and 10; it should be 350 ohms. If the readings do not come close to these figures, then repeat the test at the sensor itself. If the sensor is functioning correctly, repair the wiring harness. If it is not, replace the sensor.

In some instances, the pressure sensor resistances will be OK and the unit still will not hold vacuum. Test for this with a hand-held vacuum pump. Even with the proper resistances and the ability to hold vacuum, other conditions could be present in the sensor that require replacing it with a known good unit.

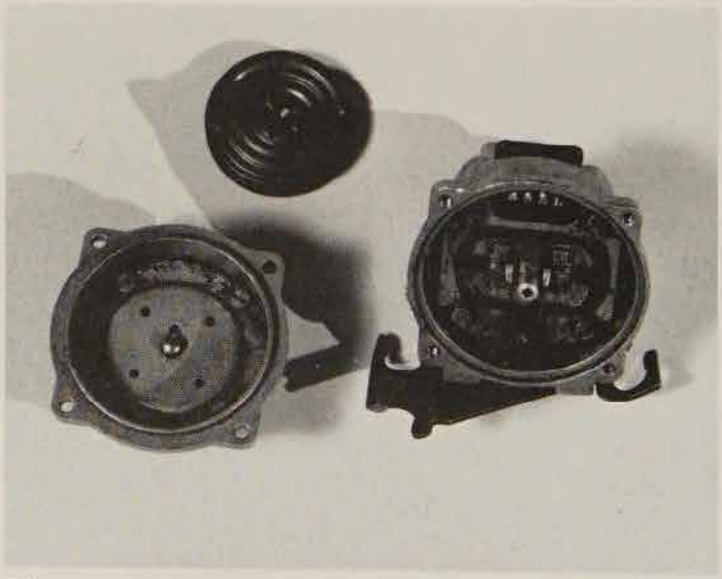
Injector Circuit: If the symptom being diagnosed could be attributed to one or more of the injectors not opening, such as poor power, a miss or a rough idle, then continuity of the injector circuits should be checked. With the engine shut off and the ECU harness disconnected from the ECU, check for resistance of ECU harness pin numbers 3, 4, 5 and 6 to ground. In each case there should be some resistance, but less than 25 ohms. If the resistance read is excessively higher or lower, test the resist-

When the throttle is opened during acceleration, the throttle switch wiper moves across the sawtooth contacts. These contacts send pulses to the injectors which open more frequently to enrich the mixture.



The resistance through one coil of the pressure sensor, terminals 7 to 15, should be 90 ohms. The resistance between the other terminals (8 and 10) should be 350 ohms.

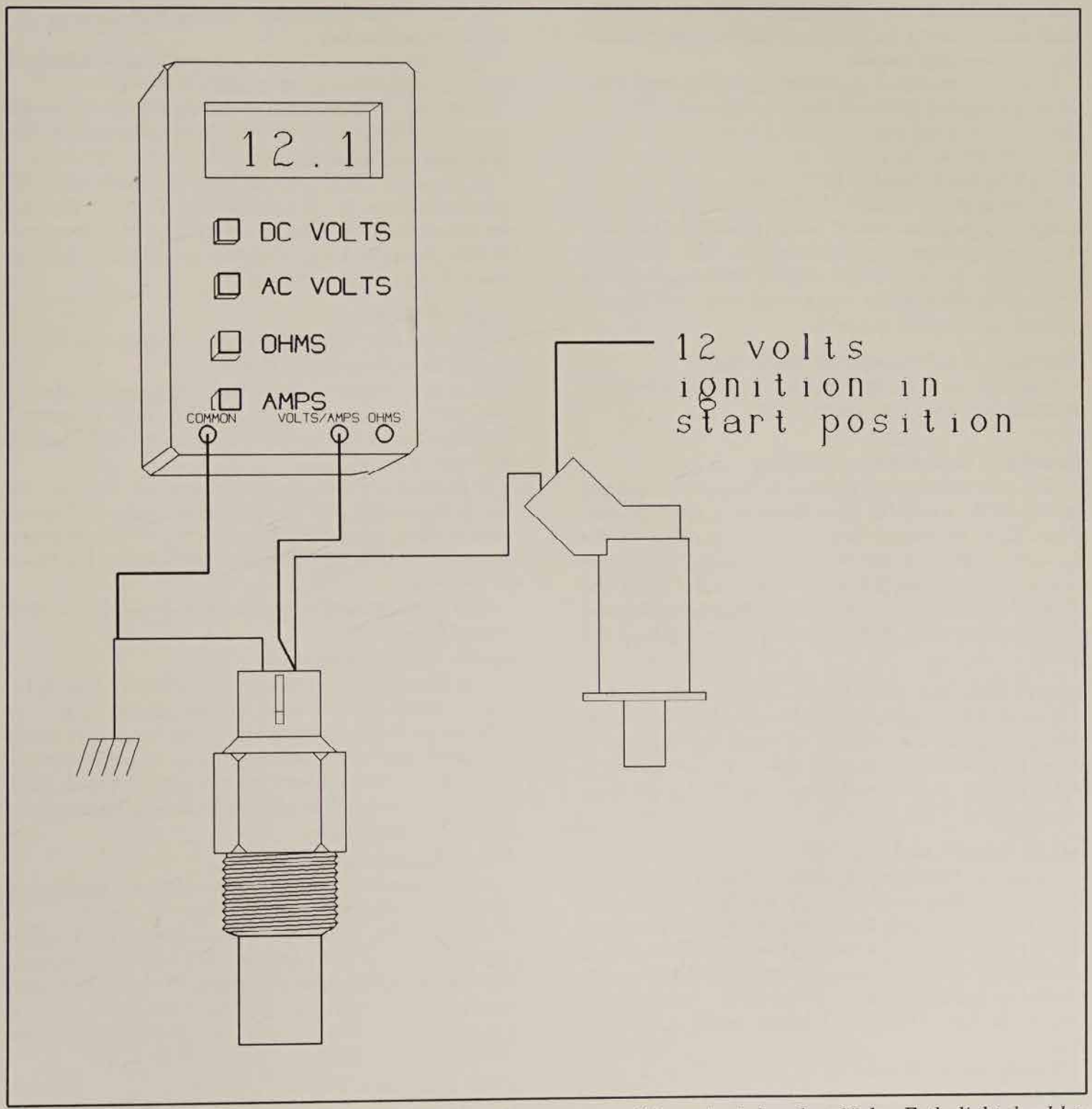
Behind the plug of the pressure sensor is an adjustment screw. Experienced Bosch technicians use this screw to adjust air-fuel ratio on problem cars. Accessing the screw requires drilling or removing the plug. Although this adjustment will lean out an engine running rich at an idle, it will also lean out the engine at higher speeds. This could severely decrease the life expectancy of the engine.



The output signal depends on the sensor diaphragm, located in the section shown on the right. The rod in the center is moved by the diaphragm. Test the diaphragm with a hand-held vacuum pump.

ance in the injector itself. If the injector resistance is adequate, then repair the wiring harness.

Cold-Start System: The cold-start injector is not controlled by the ECU. Rather, it is an electrical device controlled by the ignition switch as a source of power, and the thermo-time switch as the ground. The cold-start injector is designed to operate only when the engine is being cranked and only when the temperature of the engine is less than 95 deg. F. As a result, in hot climates the cold-start valve may not operate at all. But beyond the problem of getting the engine started when cold or leaking, it will never cause major driveability problems. Even seasoned fuel-injection technicians will make the mistake of looking for a cold-running problem with the cold-start injector.



When the engine is cranked there should be 12 volts at one terminal of the thermo-time switch. With a test light connected to the positive terminal of the battery, probe the other terminal of the thermo-time switch. If the temperature of the engine is less than 95 deg. F., the light should go on. If all this occurs but the cold-start injector does not spray, replace the injector.

To begin with, remove the cold-start injector from the intake manifold, then place the nozzle in a safe container and crank the engine. If the temperature of the engine is below 95 deg., the cold-start injector should spray. If it does not, connect a test light to each of the two terminals of the injector and crank the engine.

If one terminal activates the light but the other does not, then replace the cold-start injector.

If both terminals activate the light, inspect the wiring between the cold-start injector and the thermo-time switch. If the wiring is OK, replace the thermo-time switch.

If neither terminal activates the light, repair the wiring harness between the starter solenoid and the cold-start injector.

What to Test, and When

As mentioned earlier in this chapter, there are many components other than those of the fuel-injection system that can cause the following symptoms. Always begin troubleshooting by confirming that the basic engine, ignition and intake system are in good shape.

No-Start, Fuel Pump Not Working

Test the fuel pump circuit including the fuse, relay, wiring and fuel pump itself.

No-Start, Fuel Pump Working

Test the main relay system and its power supply to the ECU. Confirm that there is a good ground from ECU terminal number 11 to ground. If the ignition system is delivering a good spark, if there is a good power supply and ground to the ECU and if there is continuity through the trigger points and the injectors still fail to pulse, then replace the ECU.

Starts Cold but Dies When Key Is Released

Inspect the trigger point circuitry for continuity. What may be happening is that the engine is starting off of the cold-start injector, then dying as soon as the key is released and the cold-start injector shuts off.

Stalls When Cold

Begin troubleshooting this problem by inspecting the auxiliary air valve. Start the engine cold and remove the hose on the intake manifold side of the auxiliary air valve and allow it to draw air. If the engine speed increases significantly, then replace the auxiliary air valve. (*Note:* A minor increase in rpm is normal when performing this test.)

Temperature Sensor II is also critical to cold engine operation.

Misfire or Erratic Idle

Confirm that the basic engine, intake and ignition system are in good shape as these are far more likely to cause this symptom than the fuel-injection system. This is a fundamental starting point.

Inspect the circuits and sensors for Temp Sensors I and II, and for continuity through both sides of the trigger points. Also inspect the vacuum hose that runs from the intake manifold to the pressure sensor. Ensure there are no leaks or kinks, and that it is not collapsing under vacuum.

If all of these functions test satisfactorily, perform the injector flow test. If the flow test checks out, then something basic was missed.

Misfire at Cruise

Confirm that the basic engine, intake and ignition system are in good shape.

Perform a fuel pressure-volume test. Notice especially if there is a drop in fuel pressure that coincides with the misfire.

If the fuel pressure remains constant, test the pressure sensor, Temp Sensor II and throttle switch circuits. If these tests do not yield the source of the problem, begin the test procedure again as something has been missed.

Lack of Power

Confirm that the basic engine, intake and ignition system are in good shape.

The most likely cause of this symptom related to the fuel-injection system is low fuel pressure. Perform the fuel pressure-volume test and observe any loss of pressure.

If the fuel pressure tests OK, test the circuits for Temp Sensor II and the pressure sensor. If these circuits and sensors test to specifications, perform the injector flow test. Clean or replace the injectors as necessary.

If all of these test adequately, then begin the test procedure again.

Stalls on Deceleration

Confirm that the basic engine, intake and ignition system are in good shape. Begin this test procedure by inspecting the hoses and wiring for tightness that may cause an intermittent disconnection as the engine torques and stresses back and forth. Next, check the throttle stop adjustment and curb idle speed.

Runs Rough, Smoking

Again, confirm that the basic engine, intake and ignition system are in good shape.

Perform the fuel pressure-volume test. Inspect the circuits for the pressure sensor, Temp Sensor II, trigger points and injectors. If these test positively, then perform the injector flow test. If everything is functioning, something has been missed.

Poor Mileage

Confirm that the basic engine, intake and ignition system are in good shape.

Perform the fuel pressure-volume test. Inspect the circuits for the pressure sensor, Temp Sensor

II, trigger points and injectors. If these test out OK, then perform the injector flow test. If everything is satisfactory, something has been missed.

Misfire under a Load

Confirm that the basic engine, intake and ignition system are in good shape.

Perform the fuel pressure-volume test. Inspect the circuits for the pressure sensor, Temp Sensor II, trigger points and injectors. If these test well, then perform the injector flow test. If everything is OK, something has been missed.

Trailer Hitching

This symptom gives the driver the feeling that there is a trailer with a tongue designed for a 2 in. ball hooked up to a car with a 1⅞ in. ball.

Confirm that the basic engine, intake and ignition system are in good shape.

Perform the fuel pressure-volume test. Inspect the circuits for the pressure sensor, Temp Sensor II, trigger points and injectors. If these test OK, then perform the injector flow test. Also test the throttle switch. If everything is working properly, something has been missed.

Idle Speed Too High

Confirm that the basic engine, intake and ignition system are in good shape.

Check and adjust as necessary the throttle stop and curb idle speed.

Idle Speed Too Low

Confirm that the basic engine, intake and ignition system are in good shape.

Check and adjust as necessary the throttle stop and curb idle speed.

7

L-Jetronic System

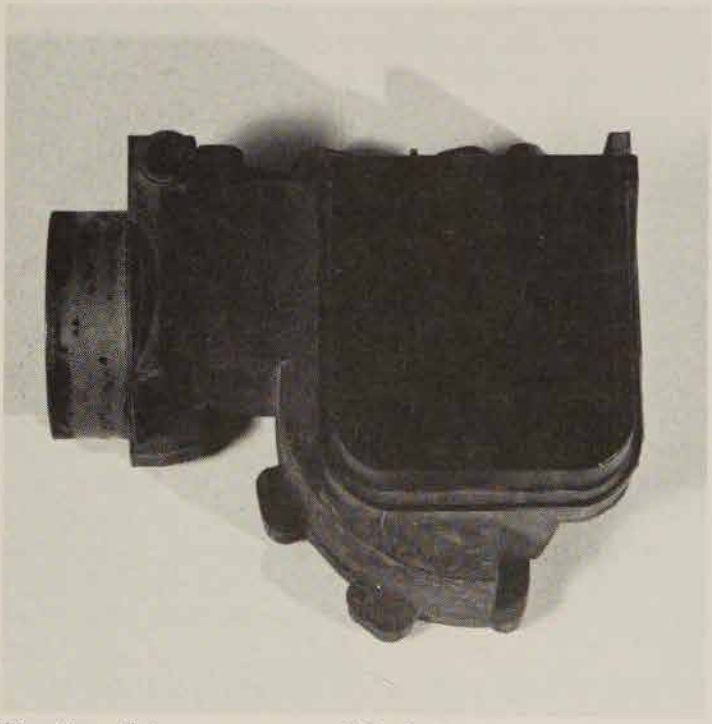
The Bosch L-Jetronic system was introduced in 1974. It featured an air measuring system that was far less sensitive to engine wear than the manifold pressure sensor used by the D-Jetronic system. Other subtle differences, along with ongoing development have made the L-system the basis for most fuel-injection systems manufactured outside of North America. L-Jetronic is easily recognized by the airflow meter or air box. The airflow meter is its primary source of information for the control of fuel through the injectors. As stated, the L-Jetronic system and its offspring have met the needs of a long list of manufacturers. Among them are:

Alfa Romeo
Autobianchi
Bertone
Bitter
Datsun/Nissan
Ford
Honda
Isuzu
Jaguar
Mazda
MG
Mitsubishi
Opel
Peugeot
Porsche
Range Rover
Seat
Subaru
Toyota
Volkswagen

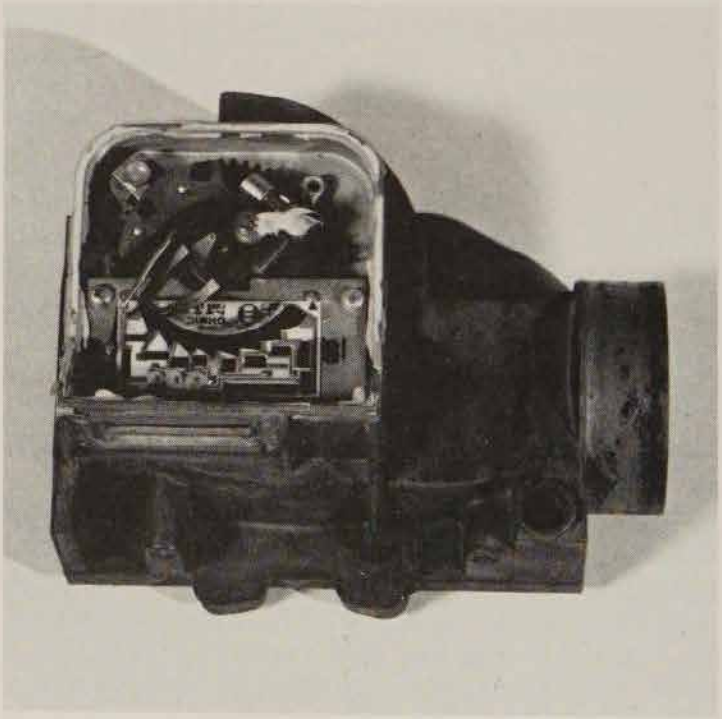
Sensors

Airflow Meter

To start our inspection of the system's components, we look to the heart of the L-Jetronic



The identifying component of the L-Jetronic fuel-injection system is the airflow meter or air box. The airflow meter can be found in the air intake system between the air filter and the throttle assembly.



The airflow meter uses a potentiometer attached to the sensor flap. As air enters the intake system, it passes through the meter and the flap moves. As the flap moves, it moves the potentiometer. One of the more common failures is wear on the potentiometer, resulting in erratic readings from the sensor.

system, the airflow meter. This is an electro-mechanical device that combines a spring-loaded flap which moves with changes in the volume of air entering the engine, and a potentiometer which rotates as the flap changes position. There is also a temperature sensor located in the airflow meter. By measuring changes in air volume and by monitoring the temperature, the computer is able to calculate the mass of air entering the engine. Once the air mass is calculated, the computer is able to meter the proper amount of fuel through the injectors.

A defective airflow meter usually results in hesitation or loss of power when the engine is under load. A binding or mechanically worn airflow meter can also result in sagging power, stalling and severe backfiring through the intake manifold.

Temperature Sensor I

Temperature Sensor I is the ambient air temperature sensor. Generally, it is located in the airflow meter but may be located in the air cleaner or the radiator bulkhead. The sensor is a negative temperature coefficient (NTC) thermistor.

Air temperature is a measurement of air density: as the temperature of the air increases, the density of the air decreases. As a result, the amount of fuel required to maintain the proper air-fuel ratio at higher ambient temperatures is reduced.

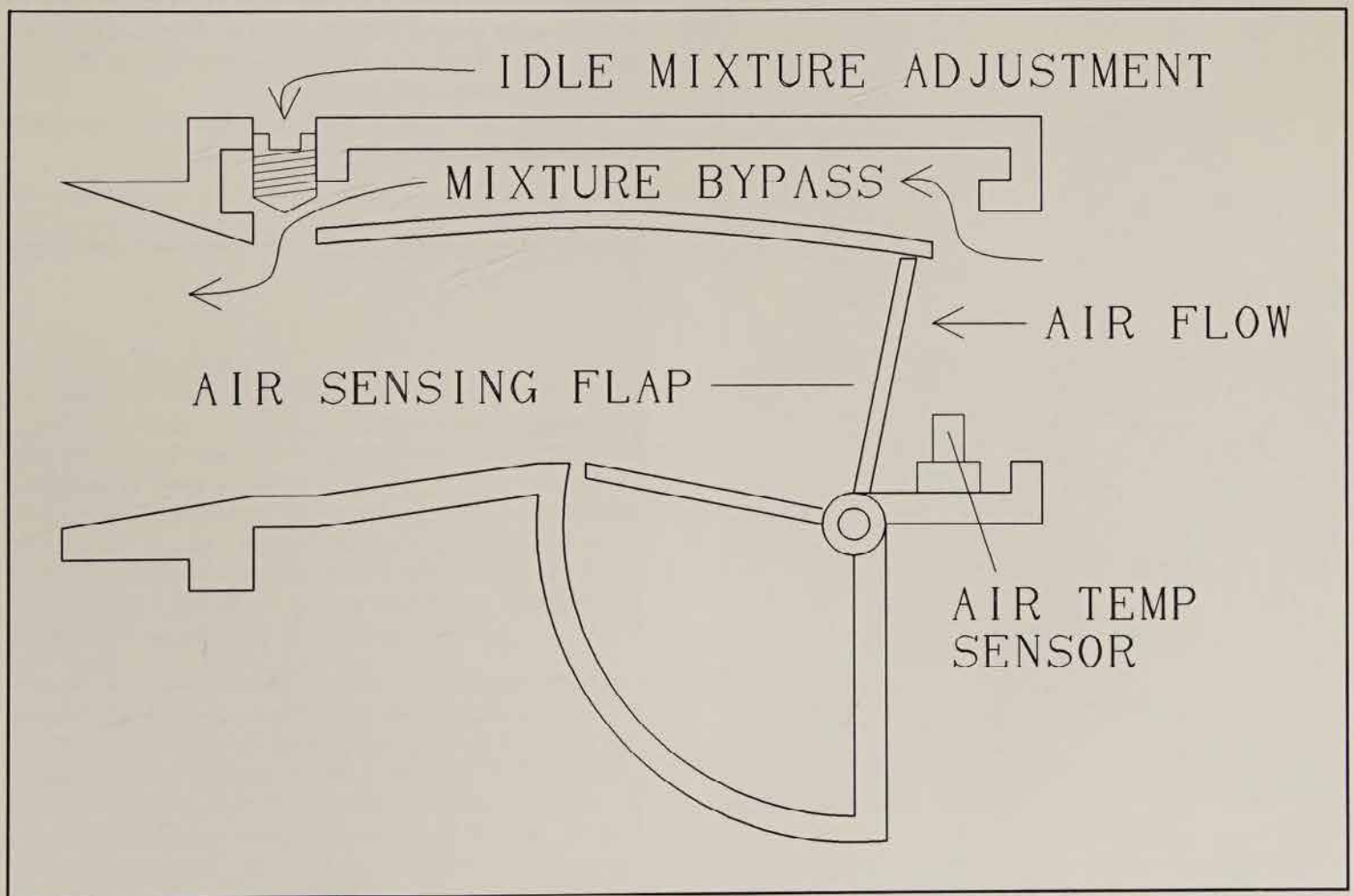
For specifications on this sensor, refer to the airflow sensor resistance chart in the L-Jetronic troubleshooting section.

A defective Temp Sensor I usually results in subtle changes in the air-fuel ratio. Poor mileage is is the most common symptom.

Temperature Sensor II

The coolant, or cylinder head temperature sensor (in the case of an air-cooled engine) is also an NTC thermistor. The primary job of this sensor is to replace the warm-up function of the choke. As the temperature of the engine increases, the resistance of the thermistor decreases. As the computer sees the decrease in resistance, it reduces the length of time the injectors are left open. This leans out the air-fuel ratio.

This NTC thermistor drops in resistance from around 10,000 ohms at 14 deg. F. to less than 300 ohms at normal operating temperature. These resistances differ somewhat from one car to an-

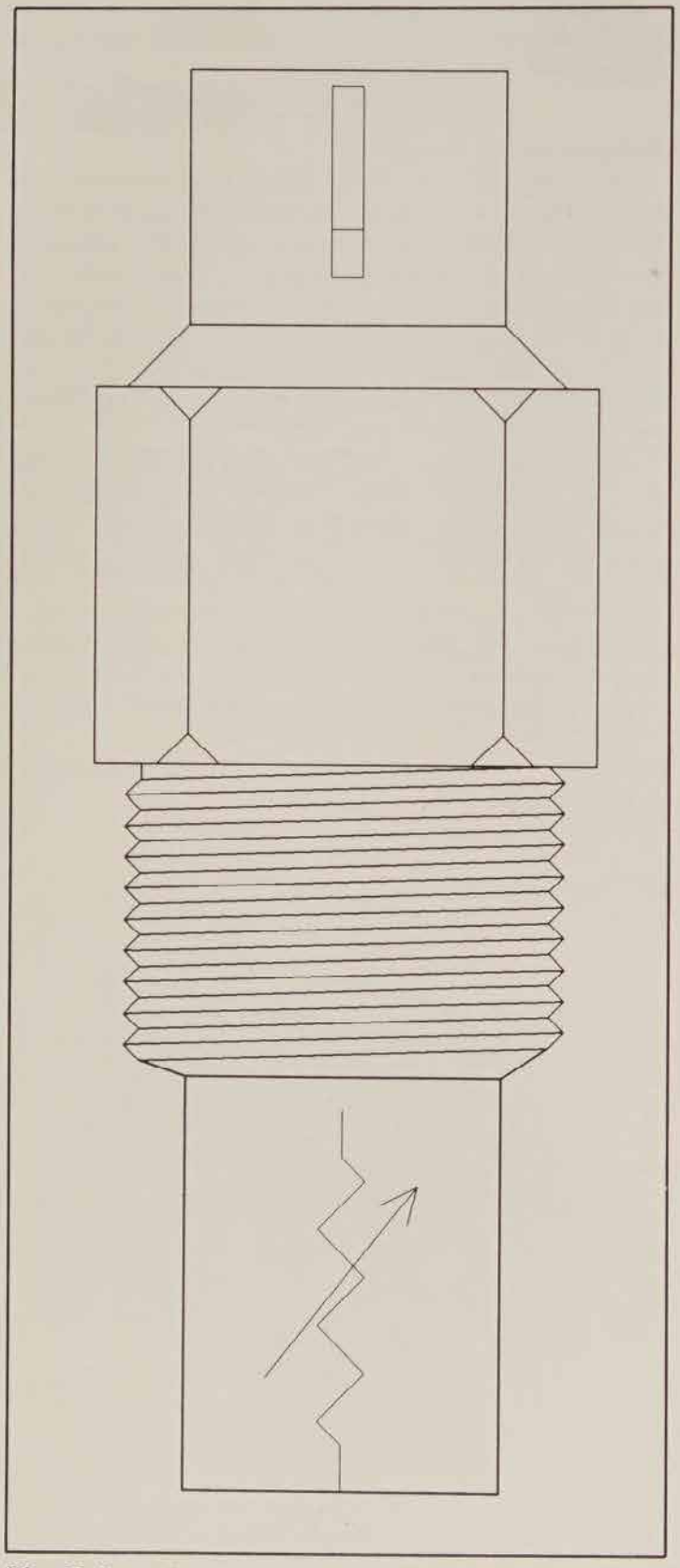


The airflow sensor includes the sensor flap and potentiometer, the idle mixture adjustment screw and the air temperature sensor. On later model applications, the idle mixture adjusting screw may be plugged. This plug can be removed by drilling a ⅛ in. hole halfway through the plug and using a sheet-metal screw to extract the plug.

other. For more details refer to the troubleshooting section.

Many late-model applications also use Temperature Sensor II when cold starting. The computer dramatically increases the injector pulse width when cold cranking the engine. This replaces the cold start-up enrichment function performed by the cold-start injector on D-Jetronic, K-Jetronic and older L-Jetronic applications.

A defective Temp Sensor II can result in poor fuel economy, excessive spark plug fouling, rough engine operation and difficulty starting the engine hot or even cold.



The L-Jetronic system uses a negative temperature coefficient (NTC) thermistor to measure the temperature of the engine. This sensor is normally located near the thermostat housing.

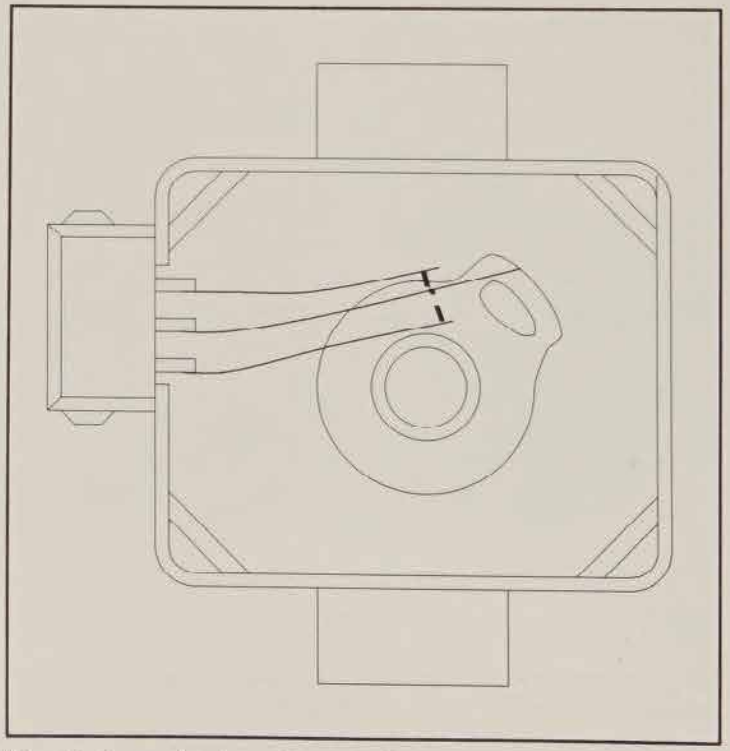
Tach Signal

The D-Jetronic system depended on a pulse from a twin set of points located in the distributor below the ignition breaker points known as the Trigger Points. As technology progressed into the L-Jetronic, this injector synchronizing pulse became the same primary ignition signal used to fire the ignition coil. Although this reduced the number of components directly counted among fuel-injection parts, it ties the injection system to any problems that might occur in the primary and secondary ignition.

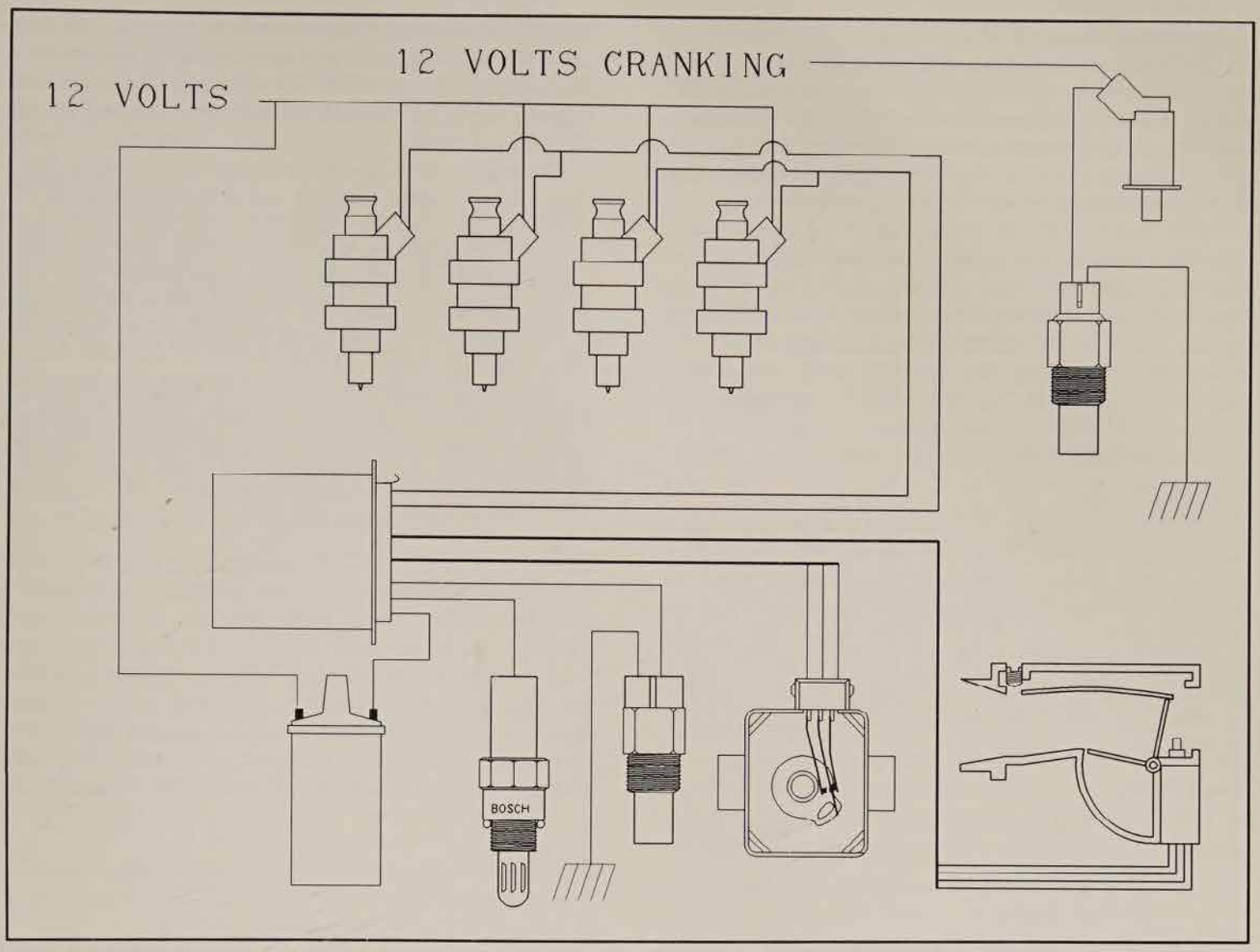
Throttle Switch

Since the airflow meter reports changes in the volume of air entering the engine and since the volume of air is closely related to the throttle position, it is necessary for the throttle switch to report only closed throttle and wide-open throttle to the ECU. Two sets of contacts within the throttle switch perform this function.

A defective throttle switch will cause fuel economy problems or tip-in hesitation.



The L-Jetronic throttle switch is a two-contact sensor. One set of contacts should be closed when the throttle is closed, the other set should close at wide-open throttle.



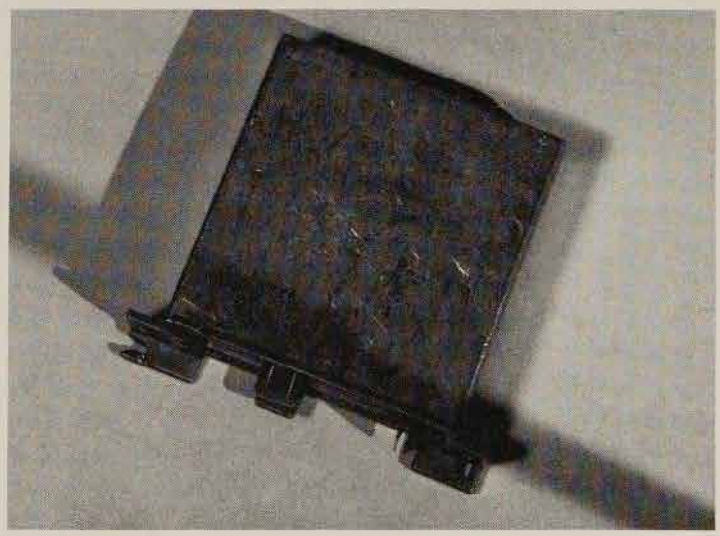
Beginning in the late 1970s L-Jetronic systems began to use a Lambda sensor. This sensor is used to fine-tune the air-fuel ratio decisions made by the other sensors and the ECU.

Lambda Sensor

Lambda sensor is Bosch's name for what is commonly known in the automotive industry as the oxygen sensor. This device began to appear on L-Jetronic applications in 1979. Its purpose is to detect imbalances in the air-fuel ratio so that the ECU can make minor adjustments. The term Lambda comes from the Greek letter that German automotive engineers use to represent the perfect, or stoichiometric, air-fuel ratio.

The device consists of platinum electrodes separated by a layer of zirconium dioxide ceramic. The ceramic begins to conduct oxygen ions when its temperature reaches about 600 deg. F. Behaving like a voltage generator, as the oxygen content of the exhaust decreases, the voltage output of the sensor increases. This output voltage ranges from 100 to 900 mV (0.1 to 0.9 volt).

Chapter 5 covers in-depth the operation and testing of the Lambda sensor.



The ECU gathers information from the sensors. Using a tach signal to initiate injection the ECU uses information from the coolant sensor, air temperature sensor, airflow meter and Lambda sensor to calculate an injector on-time. The on-time for the L-Jetronic system ranges between one and five milliseconds.

Electronic Control Unit (ECU)

The ECU gathers data from the various sensors to decide how long the fuel injectors should be left open. Power to operate the ECU is delivered through a relay controlled by the ignition switch. ECU failures are extremely rare and usually occur in the form of a no-start.

ECU failures have been known to occur as a result of voltage spikes, however—sudden and dramatic increases in voltage which result from the sudden collapsing of magnetic fields. Such a spike could occur when jump-starting a car, or when disconnecting the battery with the headlights or other large current draw turned on.

Fuel Components

In-Tank Filter

Located inside the fuel tank is a screen or filter designed to protect the fuel pump from rust, dirt and debris. Although seldom the cause of a driveability problem, the in-tank filter should be high on the list of items to check. Often these filters are completely ignored when the car is serviced. As I said earlier, I have seen hours and even days wasted looking for a problem as basic as a restricted in-tank filter.

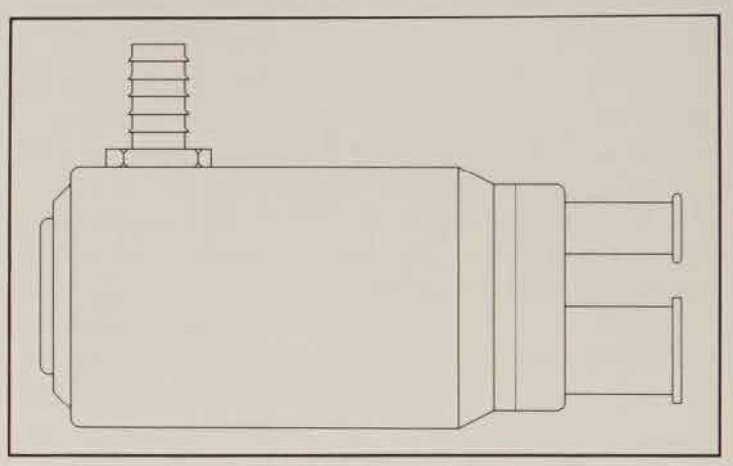
Fuel Pump

The fuel pump is a high-speed roller vane pump capable of pumping fuel at pressures and volumes far higher than any engine or fuel-injection system require. This type of pump is efficient at pushing fuel, but does a poor job of pulling fuel. As a result, these pumps are located very close to or even inside of the fuel tank.

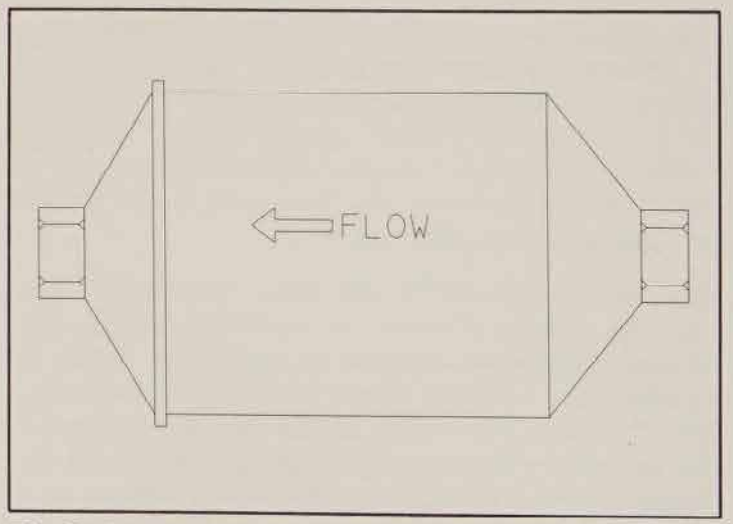
On some cars the fuel pump is normally loud. But this in itself doesn't necessarily indicate impending failure. Familiarity with the individual car or comparison with a similar car can help distinguish between potential problems and just noise. Keep in mind that the fuel pump will make more noise when the tank is nearly empty than it does when the tank is full.

The pump can react adversely and even fail as a result of using some fuel additives. Use extreme caution when selecting these additives to ensure that they do not contain methanol or other corrosive substances.

The ECU contains dozens of resistors, transistors and amplifiers. Inputs from the sensors cause the ECU circuitry to adjust the injector on-time for the proper air-fuel ratio. If the car is equipped with a Lambda sensor, it corrects any errors made by the other sensors and the ECU.



The fuel pump used with the L-Jetronic fuel-injection system is a roller vane pump. The roller cell is driven by an electric motor at over 3500 rpm. This pump is capable of pressures in excess of 100 psi. In most cases, there is a check valve at the output of the pump.



The L-Jetronic fuel filter is usually metal, but can be plastic. Capable of filtering contaminants as fine as ten microns (0.000001 meter), the fuel filter should be replaced every time the spark plugs are replaced.

A defective fuel pump can cause low fuel pressure which results in symptoms such as hesitation, stalling and poor power. Often a defective fuel pump by-passes the poor-running stage and simply stops operating.

Fuel Filter

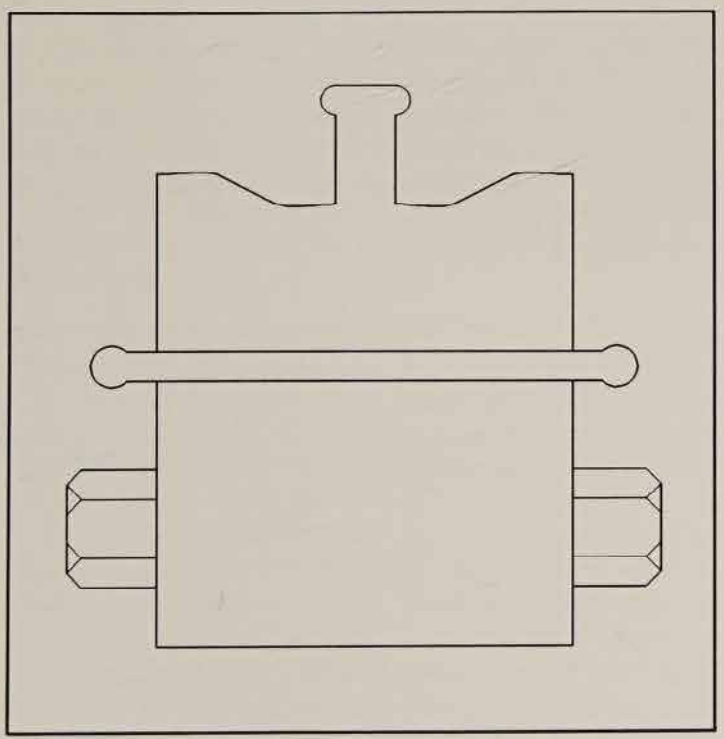
The L-Jetronic fuel filter should be replaced during every tune-up. Factory-recommended service intervals do not always consider the extreme conditions under which most cars driven in North America are operated. This filter is extremely important as it is the fuel-injection system's only real defense against internal contamination.

The fuel filter used with the L-Jetronic system is capable of filtering particles as small as 10 microns (0.000010 meter or 0.000003 in.). This level of filtration is necessary because of the extremely small opening at the tip of the injector.

Fuel Pressure Regulator

The fuel pressure regulator used on the L-Jetronic system consists of a valve connected to a spring-loaded diaphragm. The regulator controls the fuel pressure at between 30 and 40 psi on most applications at an idle. A vacuum line connects the regulator to the intake manifold, allowing manifold pressure to be applied to the backside of the diaphragm. The net effect is that when the throttle is opened and intake manifold pressure increases, the fuel pressure increases between 5 and 10 psi. This accomplishes two things: it allows the proper pressure differential to be maintained across the tip of the injector, and it acts as an accelerator pump.

Incorrect fuel pressure can cause the engine to run lean or rich. If the pressure is too low, the engine will run lean. If the pressure is too high, the engine will run rich. A defective fuel pressure regulator can lead to high fuel consumption, rough or erratic idle and poor power.



The fuel pressure regulator uses a valve attached to a spring-loaded diaphragm to control fuel pressure. A vacuum port connected by a vacuum hose to the intake manifold causes an increase of fuel pressure when manifold pressure increases. Manifold pressure increases when the car accelerates or the engine is put under load. The increase in fuel pressure acts like an accelerator pump in a carburetor.

Injectors

The injectors are solenoid-operated, normally closed valves powered by switched ignition voltage through a fuse. The ECU provides a pulsed ground by which the injectors open. The typical length of time that the injectors are energized is two to five milliseconds.

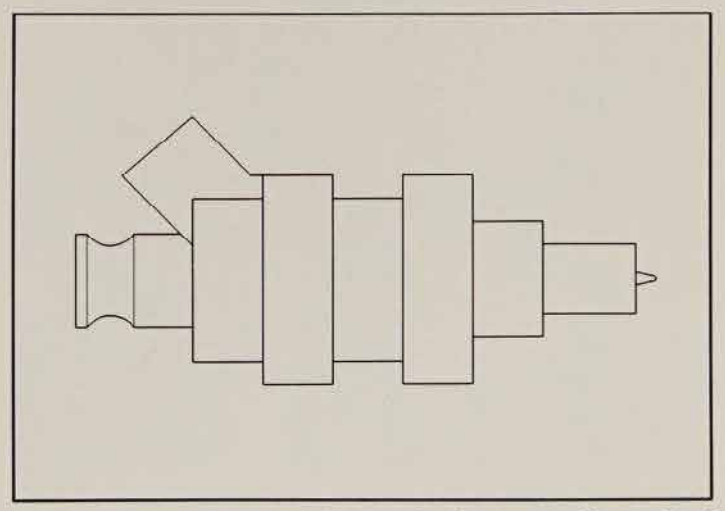
Other than occasional restricting or contamination there is little to go wrong with the injector. The L-Jetronic injector's design is virtually identical to that of the D-Jetronic system. Some of those injectors have been on the road since 1968 and still have plenty of life left in them.

Symptoms associated with injector problems include rough idle and poor power.

Fuel Rail

The injectors and the fuel pressure regulator are attached to steel tubing known as the fuel rail. The inbound fuel line from the pump and filter feeds fuel to the injectors and the pressure regulator through the fuel rail.

As a passive component of the system very little can go wrong with the fuel rail, except for leaks and restrictions.



The injectors used in all Bosch electronically pulsed injection systems are normally closed, solenoid-operated valves. A signal from the ECU energizes the solenoid, opening the valve for one to ten milliseconds (depending on engine load).

Idle Air By-pass

Unlike a carbureted engine, the L-Jetronic system does not use the throttle stop screw to adjust the idle speed. Instead, it uses a by-pass channel similar to the auxiliary air by-pass. Unlike the auxiliary air by-pass, however, the idle air by-pass is adjusted by the technician. Curb idle speed should be changed only by adjusting the idle air by-pass and *never* by using the throttle stop screw.

L-Jetronic Tune-Up Adjustments

All the standard tune-up adjustments—such as ignition point dwell, timing, air-fuel ratio (at least on most applications before 1983) and idle speed—still apply to cars using the L-Jetronic fuel-injection system. Unlike the D-Jetronic system, fuel pressure is no longer adjustable but there are throttle stop and throttle switch adjustments. When performing a tune-up, or attempting to solve a driveability problem it is important to follow the instructions for performing each adjustment precisely and in the correct sequence. Failure to do so could affect the accuracy of each adjustment and result in extremely poor fuel economy or other severe driveability problems.

Fuel Pressure Adjustment

In the world of auto repair and maintenance certain preliminary checks and tests must be done to ensure the accuracy and effectiveness of work that will be performed. Included on this list are many things that should be done but never are, such as testing fuel pressure prior to making any adjustments. If the fuel pressure is incorrect, adjustments for the air-fuel ratio and the throttle switch are inaccurate or meaningless.

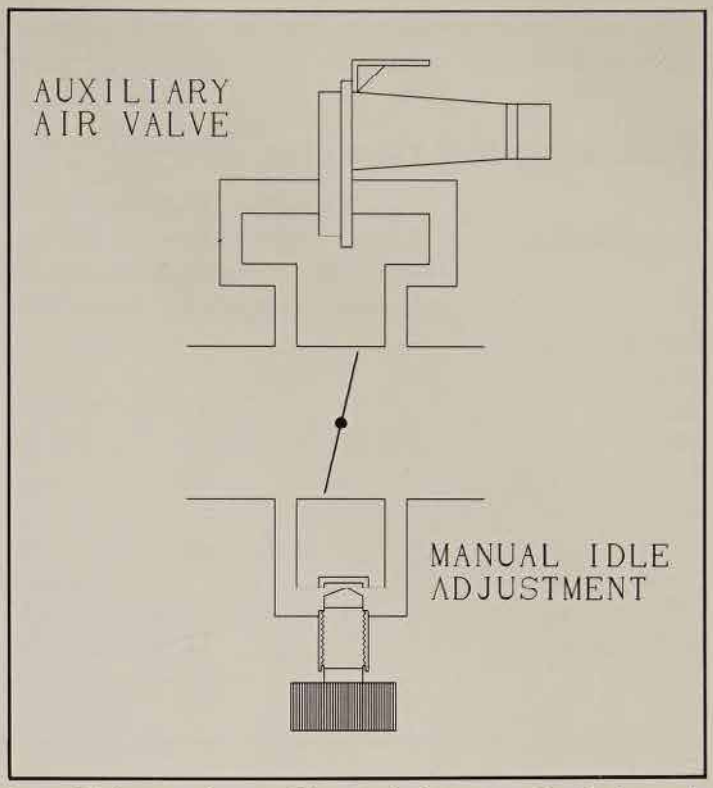
The fuel pressure should always be tested and corrected before any fuel-injection related adjustments are made.

Throttle Stop Adjustment (Minimum Idle Speed)

Although the curb idle speed should never be adjusted with the throttle stop screw, proper and smooth operation of the fuel-injection system can be affected by this adjustment.

Begin by visually checking (this may require the use of a mirror) the auxiliary air valve to ensure that it is completely closed. If the valve is inaccessible, allow the engine to warm up and then measure the idle speed. Shut off the engine and disconnect and plug the hose that runs from the auxiliary air valve to the intake manifold. Then restart the engine and measure the idle speed again. If there is not a significant difference between the speed of the engine with the hose connected and with the hose plugged, the auxiliary air valve is closed.

If the auxiliary air valve does not close, confirm that there are 12 volts and good ground going to the valve, and then replace the valve.



In addition to the auxiliary air by-pass, the L-Jetronic throttle assembly also has a manual idle adjustment. This is where curb idle adjustment is made.

Locate and close the idle air by-pass manual adjustment. The idle air by-pass is generally located on top of the intake manifold, near the throttle assembly. Loosen the lock nut on the throttle stop screw and adjust for the lowest possible speed without the engine dying. This speed should be around 600 rpm for a four-cylinder, 550 rpm for a six-cylinder and about 500 for an eight-cylinder. Shut off the engine and check the throttle carefully for binding in the closed position.

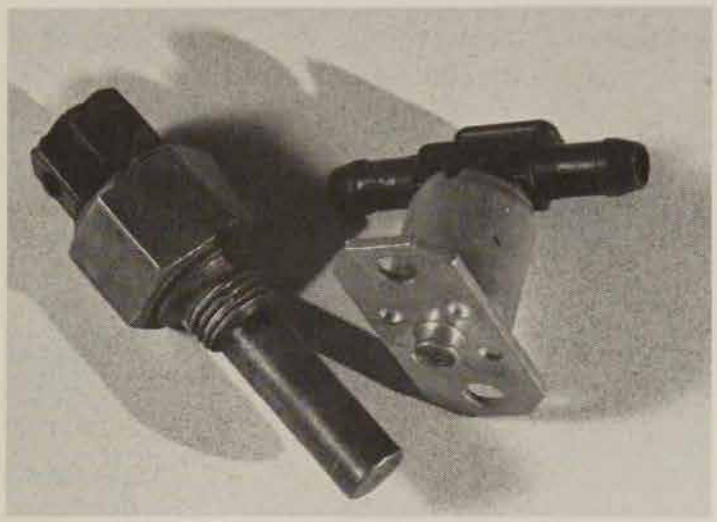
Throttle Switch Adjustment

There are three terminals on the L-Jetronic throttle switch. One terminal is common, one is for closed throttle and the third is for wide-open throttle. Disconnect the throttle switch harness and connect an ohmmeter between the common terminal and the wide-open throttle contact. Slowly open the throttle; just before you reach wide-open throttle the ohmmeter should indicate zero ohms. Now close the throttle slowly; immediately off of wide-open throttle the ohmmeter should indicate infinite ohms. Leave the ohmmeter lead connected to the wide-open throttle terminal and connect the other lead to the closed-throttle terminal. With the throttle closed the resistance should be zero ohms. Crack the throttle open a few degrees and the ohmmeter should read infinity. If these conditions are not met, adjust the throttle switch. If these conditions cannot be met through adjustment, the throttle switch or throttle switch

Cold-Start Injector

Until the latter half of the 1980s, most L-Jetronic applications used a cold-start injector or fifth injector, as it was formerly known. The cold-start injector receives battery voltage when the ignition switch is in the crank position. It finds ground through the thermo-time switch. The thermo-time switch is a temperature-sensitive bimetal switch designed to provide a ground for the cold-start injector when the coolant temperature is below about 95 deg. F. A second circuit in the switch is an electric heating element intended to heat the bimetal as the engine is being cranked. Consequently, the injector should operate only when the engine is being cranked, the temperature of the engine is less than 95 deg., and for a maximum of five to twelve seconds.

Two symptoms are most common with a defective cold-start system: hard starting when cold (if the valve is not working), and rich running (if the valve is leaking).



The cold-start injector and thermo-time switch work as a team to enrich the mixture for cold starting. When the ignition key is in the crank position the cold-start injector (also called a cold-start valve) receives 12 volts. If the temperature of the engine is less than 95 deg. F., the thermo-time switch will ground the injector. Fuel should spray through the cold-start injector when the engine is cranked cold, but not when the engine is running or the temperature is greater than 95 deg.

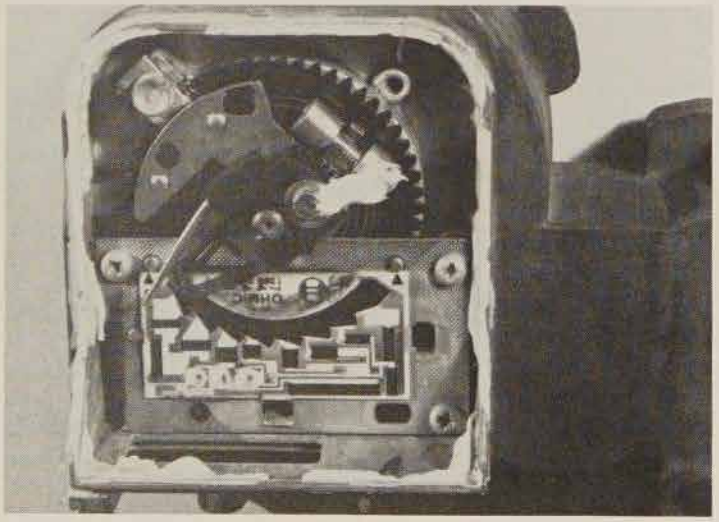
Air Components

Airflow Meter

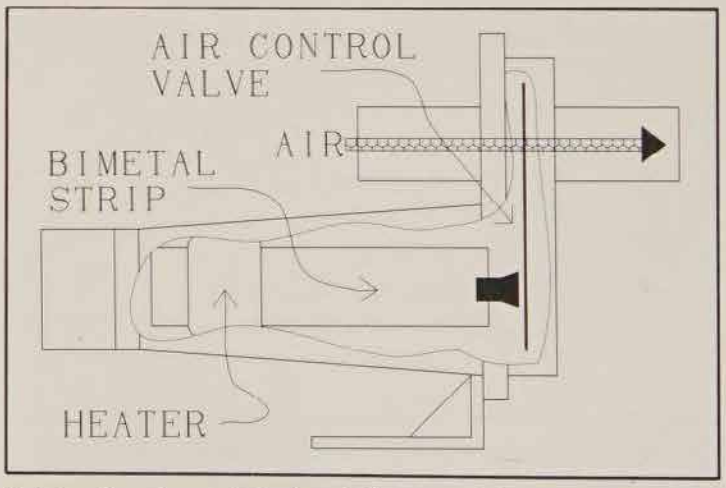
The airflow meter is not only one of the system's sensors, it is also part of the air intake system. All of the air passing into the engine to be used as part of the air-fuel ratio passes through the airflow meter. Thus, it is important that there are no air leaks either in the meter itself or in the rubber tube that connects it to the throttle assembly of the intake manifold. Such a leak is called false air. False air enters the intake manifold and is used as part of the air-fuel charge. Since this air by-passes the meter, it is unmeasured and therefore causes the engine to run lean.

Auxiliary Air Valve

The auxiliary air valve is used to allow air to by-pass the throttle plates while the engine is warming up to permit a higher idle speed. The valve consists of an electrically heated bimetal valve. When the engine is first started, the valve will be open. As the engine runs, the bimetallic valve is heated by the electric element, slowly closing off the auxiliary air by-pass and reducing the volume of air entering the engine. Reducing the air in turn reduces the idle speed.



The airflow meter measures the volume of air entering the engine. Air moving through the intake system moves an L-shaped flap inside the meter. As the flap moves, it rotates a potentiometer. The voltage changes from the airflow meter potentiometer are used by the ECU to monitor changes in airflow.



Taking the place of the fast idle cam of the carburetor, the auxiliary air valve allows air to by-pass the throttle plates following a cold start. This increases the idle speed. The electric heater causes the airflow to decrease as the engine is run. Therefore, the engine speed will automatically decrease as the engine warms up.

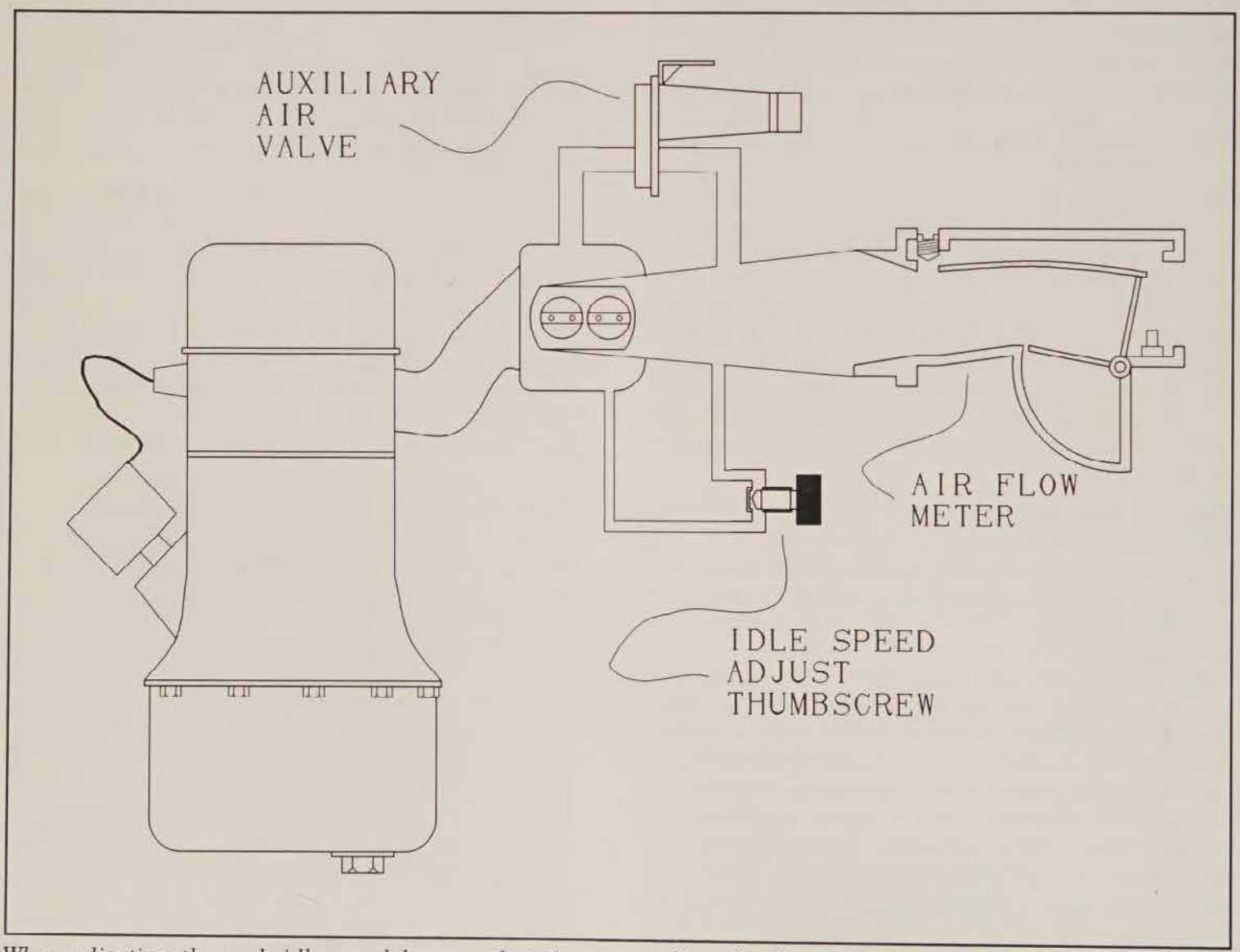
circuit is defective (see L-Jetronic throttle switch troubleshooting).

Throttle Switch Contacts

Application	Throttle Position Idle (terminal number)	Common (terminal number)	Full (terminal number)
Alfa Romeo			
1978-87	2	18	3
AMC			
1983	D2-13	D2-4	D2-6
1984	2	18	3
BMW			
318i	2	9	3
528e, 533i, 633i, 733i	2	5	3
528i, 630i	2	18	3
Datsun/Nissan			
280ZX Turbo	18	25	
All other models	29	30	24
Fiat	2	18	
Porsche	2	18	3
Renault			
1980-82	2	9	3
1983	2	18	3
Subaru	Blue/ White	Green/ Yellow	Green/ Red
Toyota			
Supra	IDL	E1	PSW
All other models	IDL	TL	PSW

Curb Idle Speed Adjustment

After adjusting the minimum idle speed, it is time to adjust the curb idle speed. This is done through the idle air by-pass adjustment. Keep in mind two things: first, the idle speed for most cars with an automatic transmission should be set in



When adjusting the curb idle speed be sure that the auxiliary air valve is closed. The throttle stop adjustment is preset by the factory. If there is evidence of tampering, warm the engine, close the manual idle adjustment and adjust the throttle stop screw for as close to 500 rpm as possible without the engine stalling. Adjust the idle speed thumbscrew to the specified curb idle.

drive. Second, after the air-fuel ratio adjustment it may be necessary to readjust the idle speed.

Adjust the curb idle speed according to the accompanying spec chart.

Curb Idle Speed Specifications

Application	Manual Transmission (Idle rpm)	Automatic Transmission (Idle rpm)
Alfa Romeo		
1982-87 All models	900	
AMC		
1983 Alliance	650	650
1984 Alliance, Encore	700	700
BMW		
1975-78 All EFI	950	950
1979 528i	950	950
1979 633CSi and 733i	950	950
1980-81 All EFI	950	950
1982 All EFI	Electronically controlled 700	700
1983 All models	Electronically controlled 700	700
1984-85 318i	Electronically controlled 750	750
1984-88 All models except 318i	Electronically controlled 700	700
Datsun/Nissan		
1975-76 280Z	800	700
1977-79 280Z and 280ZX	800	700
1977-79 810	700	650
1980 200SX	700	700
1980 280ZX and 810	700	700 (810 is 650)
1981 200SX	750	700
1981 280ZX and 810	700	700 (810 is 650)
1982-83 200SX	750	700
1982-83 Turbo and 280ZX	700	650
1982-83 810	700	650
1984 Maxima	700	700
1984 Stanza	750	700
1984 200SX	700	650
1984 200SX Turbo	750	700
1984 300ZX	700	700
1984 300ZX Turbo	700	650
1985-88 Maxima	700	700
1985-88 Stanza	750	700
1985-88 200SX and Turbo	750	700
1985-88 300ZX and Turbo	700	700
1987-88 Pulsar NX SE	750	750
1987-88 Stanza Wagon	750	700
1987-88 200SX SE	700	700
Fiat		
1980-82 All EFI	850	750
Peugeot		
1985-86 505	900	950
1987-88 505	925	975
Porsche		
1974 914	850	850
1975-76 914	850	850
1976 912E	925	925
1980-83 928	750	750
1982-86 944	900	900
1984-86 911 Carrera	800	800
1984-86 928	750	750
Renault		
1975-77 R-17G	850	850
1981 18i	850	650
1982-83 Fuego Turbo	750	
1982-85 All other models	800	650
Subaru		
1984 All models		800
1985-88 All models	700	800
Toyota		
1979-80 Supra	800	800
1980 Cressida	800	800
1981-82 All EFI	800	800
1983 Four-cylinder	800	800
1983 Six-cylinder	650	650
1984 Four-cylinder	700	750
1984 Six-cylinder	650	600
1985-86 Camry and Van	700	750
1985-88 Corolla and MR2	800	800

Curb Idle Speed Specifications

Application	Manual Transmission (Idle rpm)	Automatic Transmission (Idle rpm)
1985-86 Celica	750	750
1985-88 Cressida	650	650
1985-86 Pickup and 4Runner	750	750
1985-87 Supra	650	650
1987-88 Camry and Celica	700	700
1987-88 Pickup and 4Runner Turbo	800	800
1987-88 Van	700	750
Volkswagen		
1975-77 Type 1 and 2	875	950
1978-79 Type 1 and 2	875	950
1980-83 Vanagon (federal)	875	925
1980-83 Vanagon (Calif.)	900	900
1984-86 Vanagon	900	900

The L-Jetronic carbon monoxide adjustment is located on the side of the airflow meter. Several turns of this screw make only small changes in the air-fuel ratio. Turning the screw clockwise enriches the mixture; counterclockwise turns lean the mixture.

Air-Fuel Ratio Adjustment

Accurate adjustment of the air-fuel ratio, or carbon monoxide, will require the use of a CO meter. Typically, these are found only as part of an engine or emissions analyzer, costing thousands of dollars. For the individual or even a small shop the cost of such a device is prohibitive. As a result, for this adjustment it may be necessary to take the car to a shop that has one of these machines. On some makes, such as Toyota and Renault, the adjustment can be made with a voltmeter.

Perform the CO adjustment by turning a large screw on the airflow meter. This screw alters the amount of air that is allowed to by-pass the airflow meter flap, which in turn changes the air-fuel ratio.

Use caution when making the CO adjustment. Incorrect procedure can severely affect the mixture and the fuel economy. Refer to the spec chart for details on various applications.

Air-Fuel Ratio Specifications

Application	Idle Mixture (volts)	Location	Lambda Sensor Lead
Alfa Romeo			
1982-88 All models	0.5-0.7	Catalytic converter	Disconnected
AMC			
1983 Alliance	6.0 to 7.0 volts with 0.5 volt fluctuation measured with red voltmeter lead on test terminal D2-2 and the black voltmeter lead on test terminal D2-7.		
1984 Alliance and Encore	6.0 to 7.0 volts with 0.5 volt fluctuation measured with red voltmeter lead on test terminal D2-2 and the black voltmeter lead on test terminal D2-7.		
BMW			
1975-78 All EFI	1.5-3.0	Tailpipe	NA
1979 528i	0.2-0.8	Exhaust Manifold	Disconnected
1979 633CSi and 733i	1.5-3.0	Tailpipe	NA
1980-81 All EFI	0.2-0.8	Exhaust Manifold	Disconnected
1982 All EFI	0.2-1.2	Exhaust Manifold	Disconnected
1983 All models	0.2-1.2	Exhaust Manifold	Disconnected
1984-88 All models	0.2-1.2	Exhaust Manifold	Disconnected
Datsun/Nissan			
1975-76 280Z	0.5-1.5	Tailpipe	NA
1977-79 280Z and 280ZX	1.0 (0.5 Calif.)	Tailpipe	NA
1977-79 810	2.0 (0.5 Calif.)	Tailpipe	NA

1980 200SX	0.3-2.3	Tailpipe	NA
1980 280ZX and 810	0.2-1.8	Tailpipe	Connected
1981 200SX	6.0	Tailpipe	Connected
	(*Note*: On this model, disconnect the throttle switch wiring harness and place a jumper wire between connector 24 and 30 of the harness.)		
1981 280ZX and 810	5.0	Tailpipe	Connected
	(*Note*: On this model, disconnect the throttle switch wiring harness and place a jumper wire between connector 24 and 30 of the harness.)		
1982-83 200SX	5.0	Tailpipe	Disconnected
1982-83 Turbo and 280ZX	5.0	Tailpipe	Disconnected
1982-83 810	3.0	Tailpipe	Grounded
1984 Maxima	0.2-4.0	Tailpipe	Disconnected
1984 Stanza	0-8.0	Tailpipe	Disconnected
1984 200SX	0-5.0	Tailpipe	Disconnected
1984 200SX Turbo	0-8.0	Tailpipe	Disconnected
1984 300ZX and Turbo	0.2-4.0	Tailpipe	Disconnected
1985-88 Maxima	0.2-4.0	Tailpipe	Disconnected
1985-88 Stanza	0.2-4.0	Tailpipe	Disconnected
1985-88 200SX and Turbo	0.2-4.0	Tailpipe	Disconnected
1985-88 300ZX and Turbo	0.2-4.0	Tailpipe	Disconnected
1987-88 Pulsar NX SE	0.2-5.0	Tailpipe	Disconnected
1987-88 Stanza Wagon	0.2-5.0	Tailpipe	Disconnected
1987-88 200SX SE	0.2-5.0	Tailpipe	Disconnected
Fiat			
1980-82 All EFI	0.3-0.6	Catalytic converter	Disconnected
Peugeot			
1985-86 505	1.3	Catalytic converter	Disconnected
1987-88 505	0.3-1.3	Catalytic converter	Disconnected
Porsche			
1974 914	2.0-3.0	Tailpipe	NA
1975-76 914	0.2-0.8	Catalytic converter	NA
1976 912E	0.5-1.2	Catalytic converter	NA
1980-83 928	0.4-0.8	Catalytic converter	Disconnected
1982-86 944	0.4-0.8	Catalytic converter	Disconnected
1984-86 911 Carrera	0.6-1.0	Catalytic converter	Disconnected
1984-86 928	0.6-0.8	Catalytic converter	Disconnected
Renault			
1975-77 R-17G	1.0-3.0	Tailpipe	NA
1981 18i	1.0-2.5	Tailpipe	Connected
1982-83 Fuego Turbo	6.5 to 7.5 volts with 0.5 volt fluctuation measured with red voltmeter lead on test terminal 8 and the black voltmeter lead on test terminal 2.		
1981-85 All other models	1.0-2.5	Tailpipe	Connected
Subaru			
1984-88 All models	0.1	Tailpipe	Disconnected
Toyota			
1979-80 Supra	0.5 volt fluctuation measured with red voltmeter lead on test terminal VF and the black voltmeter lead on test terminal B+.		
1980 Cressida	0.5 volt fluctuation measured with red voltmeter lead on test terminal VF and the black voltmeter lead on test terminal B+.		
1981-82 All EFI	3.0-9.0 volts fluctuating eight times in ten seconds measured with the red lead of the voltmeter connected to terminal VF and the black voltmeter lead connected to terminal E1.		
1983 Four-cylinder	5.9-9.0 volts with a 2.0 volt fluctuation measured with red voltmeter lead on test terminal VF and the black voltmeter lead on test terminal E1.		
1983 Six-cylinder	0.1-0.2 volts with a 0.1 volt fluctuation measured with red voltmeter lead on test terminal 10 or 20 and the black voltmeter lead on test terminal B+.		
1984-present	All models computer controlled, no adjustment.		

Air-Fuel Ratio Specifications

Application	Idle Mixture (volts)	Location	Lambda Sensor Lead
Volkswagen			
1975-77 Type 1 and 2	0.2-2.0	Catalytic converter	NA
1978-79 Type 1 and 2	1.0	Catalytic converter	NA
1980-83 Vanagon (federal)	0.5-1.5	Catalytic converter	Connected
1980-83 Vanagon (Calif.)	0.3-1.1	Catalytic converter	Disconnected
1984-88 Vanagon	0.3-1.1	Catalytic converter	Disconnected

A trick that would eliminate the need for a gas analyzer is to connect a high-impedance voltmeter parallel to the Lambda sensor circuit. Warm up the engine thoroughly and watch the voltage being generated by the Lambda sensor. The voltage should be constantly fluctuating. If the voltage is stuck above 0.5 volt, the air-fuel ratio needs to be leaned out. If the voltage is steady below 0.5 volt, the ratio is too lean.

Troubleshooting the L-Jetronic System

Good troubleshooting begins with confirming the condition of the basic engine and ignition system.

Compression Test

Although the L-Jetronic system is less sensitive to engine condition than the older D-Jetronic system, unless the engine is in good shape the L-system cannot accurately control the delivery of fuel into the engine. The L-Jetronic system uses air volume into the intake manifold as one of the primary inputs for the ECU to decide how long to leave the injectors open. Since engine wear can affect the amount of air flowing into the intake manifold, any troubleshooting must begin with knowing that the engine is in good shape.

When running the compression test, make sure that the compression gauge is installed snugly and that the throttle is held wide open to ensure the most accurate reading.

For many models of Toyotas equipped with the L-Jetronic system, CO adjustments are made by measuring voltages at these test terminals. Their usual location is the forward portion of the left shock tower.

Valve Adjustment

Since most applications that use the L-system have mechanical lifters, time should be taken to ensure that the valves are properly adjusted. While the compression test would point out severely maladjusted valves, do not rely on it to confirm that the valves are adjusted properly. Remove the valve cover and follow the valve adjustment procedure outlined in the factory service manual for the car you are working on.

Vacuum Leaks

Since the principal source of information for determining the amount of fuel that the engine requires is the flow of air into the intake manifold, accurate measurement of the volume of air entering the intake is vital. Any air entering the intake system between the airflow meter and the intake valve will be false air. False air can cause the fuel system to run lean. The chance of a vacuum leak or false air causing a driveability problem is even higher than on a carbureted car.

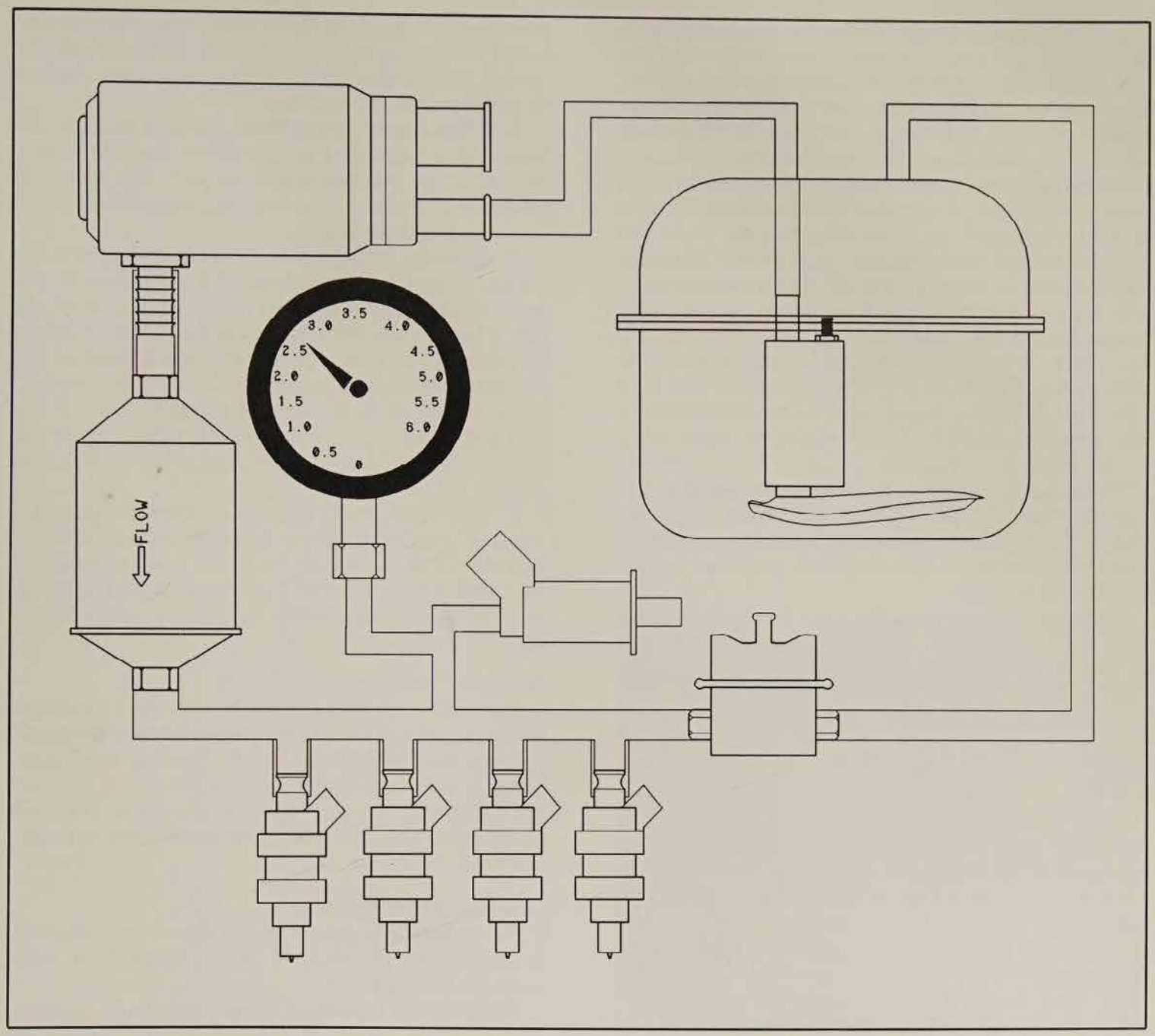
One of the best ways to hunt for a vacuum leak is with a standard hardware store propane torch. First, warm the engine. At an idle, run the unlit propane torch along both the top and bottom sides of the intake manifold. Pay particular attention to the gasket where the throttle assembly bolts onto the intake manifold, the seals where the injectors mount in the intake manifold, and the throttle shafts.

Any vacuum leaks that are found must be repaired before valid testing can continue.

Ignition System

After confirming that the basic engine is in good shape, inspect the condition of the ignition components. Inspect the points for evidence of burning, pitting and metal transfer. Check for the proper dwell. Inspect the distributor cap and rotor for cracks and burning. Whenever you replace the cap and rotor, make sure they are the same brand. The spark plugs cannot always be checked satisfactorily without an engine analyzer. Therefore, if there is any doubt at all about the condition of the plugs, just replace them. It is cheaper than wondering about their condition.

Inspect the spark plug wires' resistance with an ohmmeter. The original factory wires were solid metal with resistors that screw onto the ends.



L-Jetronic fuel pressure is normally around 35 psi at an idle. The pressure gauge in this illustration is calibrated in bar (1 bar = 15 psi). The pressure shown here is 2.6 bar which is about 38 psi. Although slightly high, this pressure would not cause a driveability problem significant enough to warrant troubleshooting.

These wires should have almost no resistance, while the resistor on the end of the wire should have 5,000 to 10,000 ohms of resistance. Many of the replacement secondary ignition cables are resistor wires. Resistor wires should have between 2,000 and 10,000 ohms per foot. Also inspect the wires for cracks or breaks in the insulation which may allow the ignition spark to arc to ground.

Testing the Fuel-Injection System

Once the engine and ignition condition have been confirmed, testing may begin on the fuel-injection system itself.

Fuel Pressure

Testing of the fuel-injection system must begin with testing fuel pressure. Connect the fuel pressure gauge to the hose going to the cold-start injector. Start the engine and allow it to idle. The fuel pressure should be 30-35 psi. The L-Jetronic fuel pressure regulator is *not* adjustable.

A vacuum hose between the fuel pressure regulator and the intake manifold allows the fuel pressure to increase as the throttle is opened, and the manifold pressure increases. The increase in fuel pressure acts like an accelerator pump.

If the symptom occurs only on acceleration or when the engine is under load, then the fuel

pressure must be tested under the conditions that the symptom occurs. Position the fuel pressure gauge where it can safely be seen while driving the car, and watch for a drop in fuel pressure that coincides with the symptom. This is the most effective method for testing fuel volume.

If the pressure is extremely high, there are two possible causes: (1) the fuel pressure regulator is defective, or (2) the fuel return line from the regulator back to the tank is restricted. To determine which is at fault shut off the engine, remove the return line from the fuel pressure regulator and install a test hose that will allow the return line fuel to be pumped into an approved fuel receptacle. Then restart the engine. If the fuel pressure is now normal, repair the restriction in the return line. If the fuel pressure remains high, replace the fuel pressure regulator.

If the fuel pressure is low, there are ten possible causes. The following list is not in any specific order. Check them in the order of convenience based on your work environment and their accessibility on your car.

1. Inspect the system for external leaks. A fuel leak severe enough to result in a significant loss in fuel pressure would be severe enough to be noticeable and very dangerous. Use extreme caution.

2. Ensure that there is enough fuel in the tank to be pulled easily into the system by the fuel pump and fuel pickup.

3. Check the fuel tank vent. If there is a venting problem in the fuel tank, it may not be possible for the fuel being pulled out by the fuel pump to be replaced by air. A suction is created in the tank, limiting the pump's ability to pull fuel out of the tank and resulting in low fuel pressure. Remove the gas cap and drive the car. If the symptom is gone, replace the fuel tank vent valves.

4. The in-tank fuel filter may be restricted. Most applications will have a screen in the fuel tank to protect the pump from sand, rust and other hard particle contaminants. If this filter is restricted the fuel volume will be reduced, causing a loss in pressure. The filter should be especially considered when the loss of fuel pressure occurs only with the engine under load.

5. Inspect the fuel pickup connector hose. There is often a hose that connects the in-tank filter to the fuel pickup. Occasionally this hose will perforate, causing the fuel pump to suck in air rather than fuel. The likelihood of this causing low fuel pressure increases if the symptom occurs only when the fuel level is below half a tank.

6. The main fuel filter may be clogged. If this filter is restricted the fuel volume will be reduced, causing a loss in pressure. The filter should be especially considered when the loss of fuel pressure occurs only with the engine under load.

7. Check the fuel pressure regulator. If the pressure is low all the time, one of the prime causes could be the pressure regulator. Squeeze off the return line. If the fuel pressure increases, replace the fuel pressure regulator.

8. If the line running from the fuel tank to the fuel rail is restricted at any point there will be a reduction in volume which could cause a loss of pressure at times of high fuel demand. Check these lines for kinks and clogs.

9. Confirm that there is a 12 volt drop across the pump. Connect the red lead of a voltmeter to the positive terminal of the fuel pump, and connect the black lead to the negative terminal. If the reading is less than 12 volts, attach the black lead of the voltmeter to chassis ground. If the voltage is now 12 volts, repair or clean the fuel pump ground. If the voltmeter still reads less than 12 volts, repair the high resistance on the positive wire to the fuel pump.

10. The fuel pump may be malfunctioning. Assuming the fuel filters have been replaced, if squeezing off the return line does not increase the fuel pressure and the voltage drop across the pump is 12 volts, then the pump becomes a prime candidate for replacement.

No Fuel Pressure

Generally speaking, lack of any fuel pressure will be electrical in nature. There are two fuses and a relay that could keep the fuel pump from running. Inspect the fuses not only for being burned open, but also for corrosion on the ends. The fuel pump relay should click when the engine is being cranked.

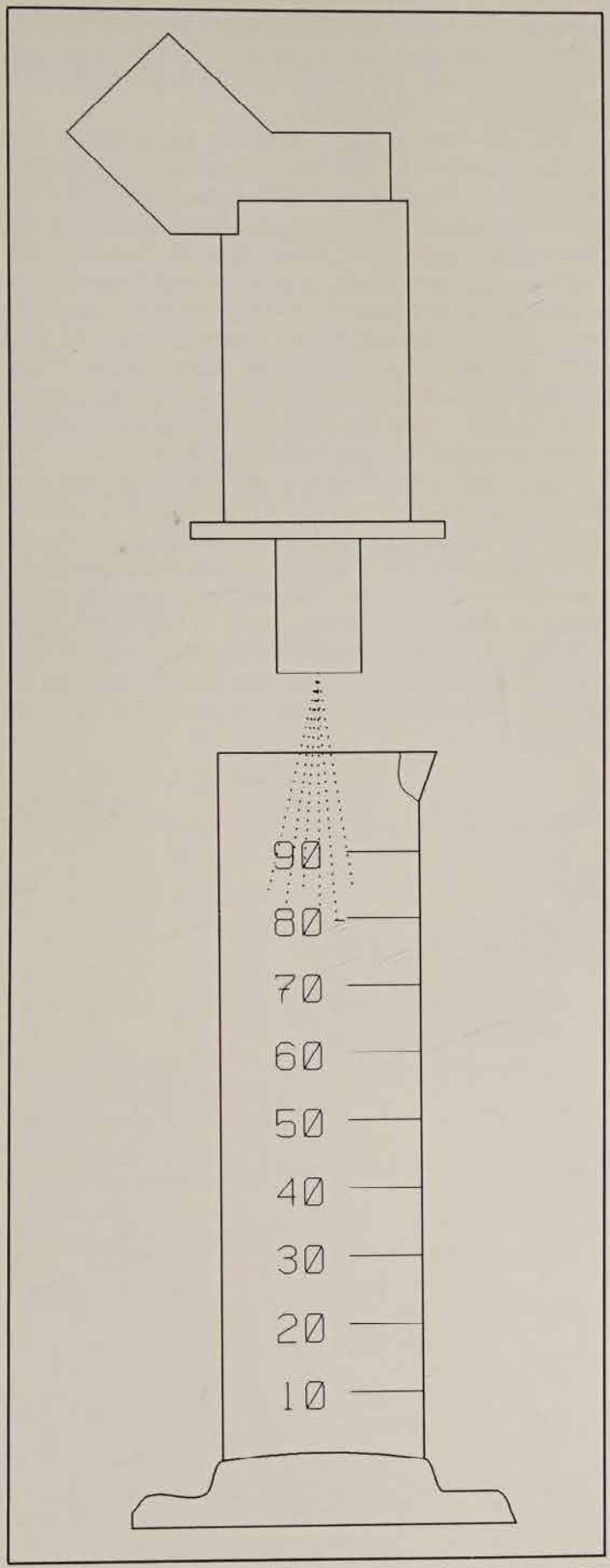
Injector Flow Testing

For erratic idle, rough running and low power it is important to confirm the proper flow rate through the injectors.

Remove the injectors from the intake system, leaving them attached to the fuel rail. Place each injector in a small, graduated cylinder (these can be obtained from any photographic supply store). Remove the spark plugs, disconnect the battery lead to the coil, and crank the engine for sixty seconds. Observe the amount of fuel flowed by each of the injectors. If the difference in quantity is greater than 10 percent, either clean or replace the injectors.

Testing the Cold-Start System

The cold-start injector is not controlled by the ECU. It is an electrical device controlled by the ignition switch as a source of power, and by a device known as a thermo-time switch as the ground. The cold-start injector is designed to operate only when the engine is being cranked and only when the temperature of the engine is less than 95 deg. F. As a result, in hot climates the cold-start valve may not operate at all. Beyond problems getting the



The initial test of the cold-start system is to remove the cold-start injector and hold it over a container. When the engine is cranked, the injector should spray. Of course, if the temperature of the engine is greater than 95 deg. F. it will not spray.

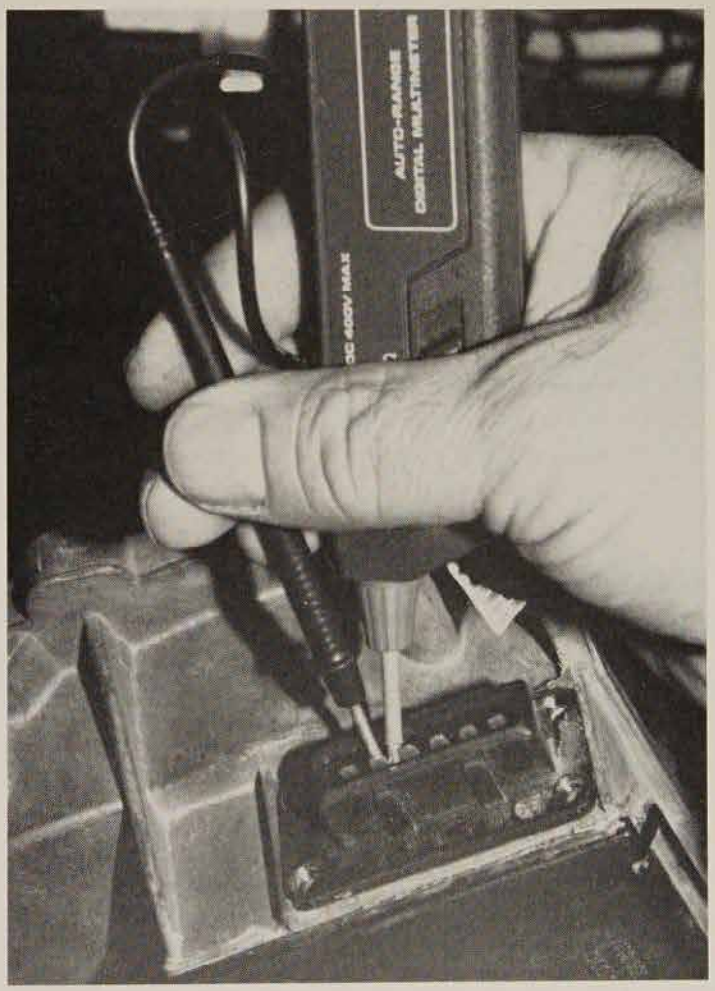
engine started when cold or leaking, it will never lead to a major driveability problem. Even seasoned fuel-injection technicians will make the mistake of looking for a cold-running problem with the cold-start injector.

Remove the cold-start injector from the intake manifold, place the nozzle in a safe container and crank the engine. If the temperature of the engine is below 95 deg., the cold-start injector should spray. If it does not, connect a test light to each of the two terminals of the injector and crank the engine.

If one terminal activates the light but the other does not, replace the cold-start injector.

If both terminals activate the light, inspect the wiring between the cold-start injector and the thermo-time switch. If the wiring is OK, replace the switch.

If neither terminal lights up the light, repair the wiring harness between the starter solenoid and the cold-start injector.



Test the airflow meter with an ohmmeter. Measure the resistance through the potentiometer, the fuel pump cutoff switch and the air temperature sensor. If these readings are drastically different than the specs, replace the airflow meter. Keep in mind, though, that many meters have been replaced unnecessarily because they did not exactly meet specifications.

Testing L-Jetronic Components

The D-Jetronic application boasts very few differences in configuration from one application to another. The L-Jetronic system, on the other hand, has been so widely used and adapted that there are many variations that need to be addressed here. A given application may utilize an altitude sensor or other device to control fuel-injection computer peripheral systems such as timing control or air pump systems. Although these will be covered for some applications, it would be impossible to discuss all the possibilities. Therefore, refer to the factory service manual for the application that you are working on.

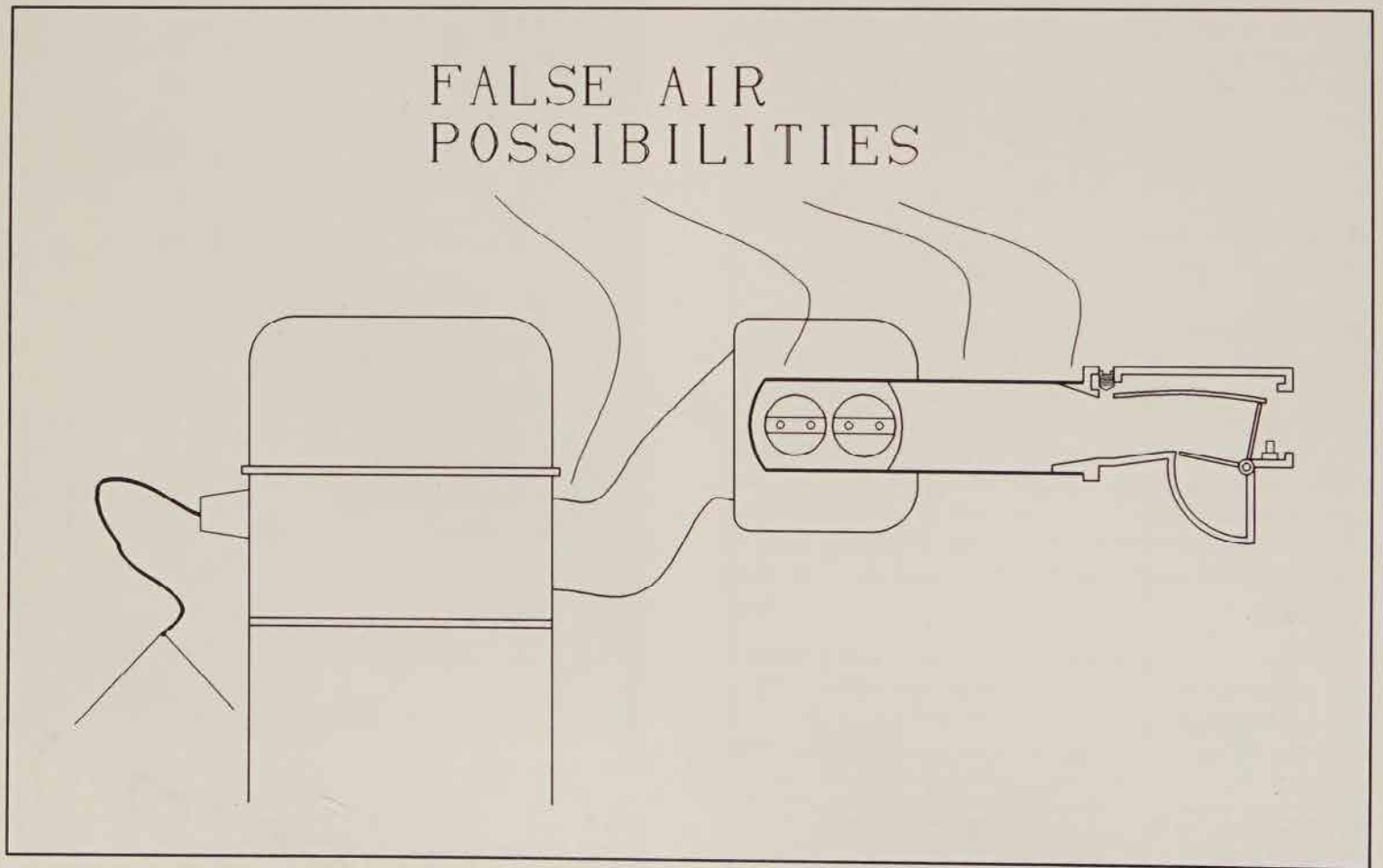
What follows is a look at how to troubleshoot the various L-Jetronic components.

Airflow Meter

The airflow meter has two major components: the air temperature sensor, and the airflow potentiometer. The airflow potentiometer is connected by a shaft to a movable flap inside the meter. As air flows through the meter it moves the flap. As the flap moves, the potentiometer is rotated, causing the voltage being sent back to the computer to change. In addition, remember that the airflow meter circuit also consists of the wires leading to it. Thus, all tests on the meter should be performed at the connector to the ECU.

The air temperature sensing element of the airflow meter is a negative temperature coefficient thermistor. The resistor is designed such that as the temperature of the air around it increases, its resistance decreases. Keep this in mind when performing resistance checks; it could cause the readings to vary slightly as the ambient temperature changes. An additional component in the airflow meter is the fuel pump relay switch. This switch is closed when air is flowing into the engine and opened—switching off the fuel pump relay—when air stops flowing into the engine.

Begin the test procedure by disconnecting the harness connector from the ECU. Using the airflow sensor resistance chart, test the resistances across the terminals of the ECU connector. If the readings are different from those shown, perform the same tests on the airflow meter itself. If the tests show correct readings at the airflow meter but not at the ECU connector, then repair the wiring harness. If neither are accurate, then replace the airflow meter.



Air entering the intake system without having first passed through the airflow meter is called false air. False air causes an engine to run lean. On cars not equipped with a Lambda sensor, the engine may run extremely rough or die at an idle.

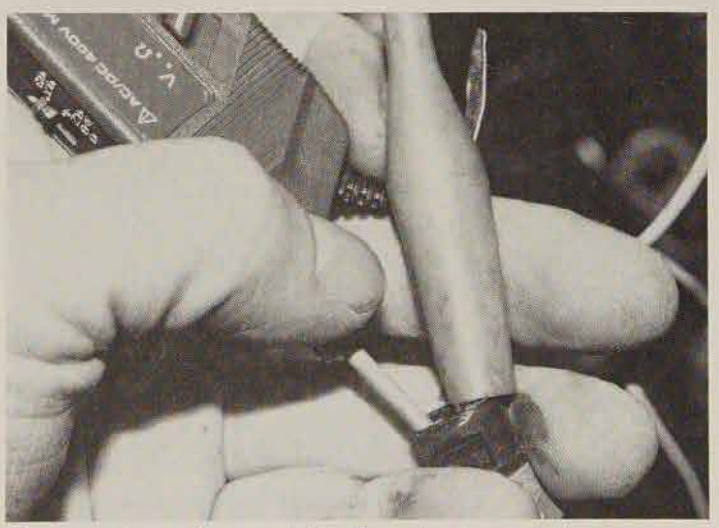
Airflow Sensor Resistance

Application	Test between Terminals	Resistance (ohms)
	Any terminal to ground	0–Infinity
Alfa Romeo		
All makes and models	34 & 48	30-35
BMW		
318i	7 & 8	95-335
	7 & 9	70-180
	8 & 9	90-185
	9 & 11	0-Infinity
528i, 530i	6 & 9	100-600
	7 & 9	70-800
	10 & 20	0.0-2.0
528e, 533i, 633i, 733i	6 & 9	475-840
	7 & 9	475-1,900
	18 and/or 35 & 9	75-105
Datsun/Nissan		
280ZX Turbo	33 & 26	200-500
	31 & 33	0-Infinity (varies with movement of flap)
810, Maxima, 200SX and 280ZX	34 & 35	200-500
	32 & 34	0-Infinity (varies with movement of flap)
	33 & 34	100-400
Porsche		
914 (1974 only)	6 & 9	200-400
	7 & 8	120-200
928 (1983 only, 1980-82 is the same as Volkswagen)	6 & 7	80-600
	6 & 8	260-520
	7 & 8	200-1,000
	8 & 9	140-280
Renault Fuego	6 & 9	50-150
	7 & 8	100-500
Subaru	Green & Yellow/Blue	225-325
	Blue & Yellow/Blue	175-225
	Yellow & Yellow/Blue	50-500
Toyota		
All models	E2 & Vb	200-500
	El & Fc	0-Infinity (varies with movement of flap)
	E2 & Vc	100-400
Camry, Celica, Starlet	E2 & Vs	200-400
Cressida and Supra	E2 & Vs	20-400
Volkswagen	6 & 7	40-300
	6 & 8	130-260
	6 & 9	200-400
	7 & 8	100-500
	8 & 9	70-140
All other makes	6 & 8	130-260
	7 & 8	100-500
	8 & 9	70-140

Notice that on several applications there is a measurement of zero to infinity. Realistically, as the flap is moved the resistance measured at the point will increase. Do not assume that because the low-end spec is zero and the car you are troubleshooting has a low-end resistance of several hundred ohms, you have found the source of your symptom. Additionally, do not assume that because the resistance does not go to infinity the airflow meter is defective. As long as the movement of the flap yields a resistance that begins low and increases evenly and smoothly, peaking at a very high resistance of several thousand ohms, the sensor is good.

Temperature Sensor I

Temperature Sensor I is located in the airflow meter. (For some applications, testing of this sensor was covered in the airflow sensor resistance chart.) At 68 deg. F. the airflow meter should read between 2,100 and 2,900 ohms. As the ambient temperature increases, the resistance of this sensor decreases and may read below 2,100 ohms. At temperatures colder than 68 deg. the resistance may be a little higher than 2,900 ohms. Test this resistance according to the Temp Sensor I test connections chart. If the resistance is incorrect, you'll need to replace the entire airflow meter since



Temperature Sensor I is the air temperature sensor. Although normally located in the airflow meter, some cars use a separate sensor located in the air cleaner. This part is tested with an ohmmeter.

the temperature sensor is not serviceable as a separate unit.

Temperature Sensor I Test Connections

Application	Test between Terminals	Terminal to Ground
Alfa Romeo	13 & 49	13
BMW		
318i, 528e,		
633CSi, 733i	6 & 22	25
528i, 530i, 533i	6 & 27	25
Datsun/Nissan		
Maxima, 200SX, 280ZX	25 & 34	25
280ZX Turbo	30 & 33	30
Toyota	E2 & THA	
All other makes and models	6 & 27	25

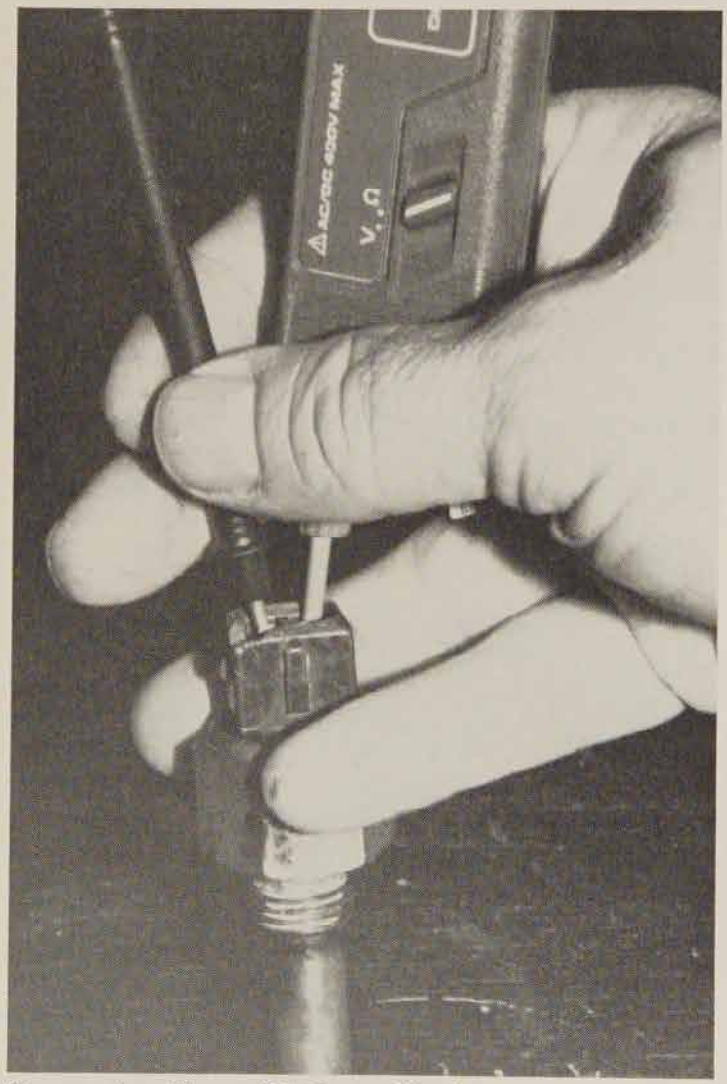
Temperature Sensor II

The coolant temperature sensor is located in the water jacket of the cylinder head, usually close to the thermostat housing. On air-cooled engines it is located in the left cylinder head. On water-cooled applications there are two wires on this sensor; on air-cooled engines there is only one as it grounds through the cylinder head.

For water-cooled engines, take the first resistance measurement at the ECU harness connector. If this proves to be incorrect, take another reading at the sensor itself. If the first reading was bad, but the second good, then the sensor is good and the wiring harness needs to be repaired. If the second reading was also bad, then replace the sensor.

For air-cooled engines, take the first reading from the Temp Sensor II pin at the ECU harness connector to chassis ground. If this reading is bad, take a second reading from the sensor connection to the engine block. If the second reading is good, repair the wire back to the ECU. If the second reading is bad, connect the ohmmeter from the sensor wire to the body of the sensor. If the third reading is good, remove the corrosion between the sensor and the cylinder head. If the reading is not within specification, replace the sensor.

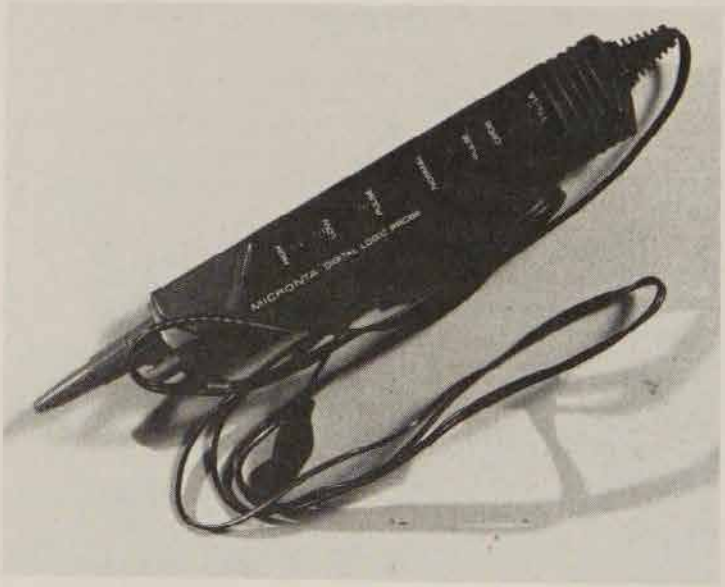
Test the resistance using the Temp Sensor II resistance chart.



Temperature Sensor II is located in the water jacket or the cylinder head of air-cooled engines. The ECU will provide for a richer mixture when the engine is cold. As the engine warms, the mixture will lean out. Test this sensor with an ohmmeter.

Temperature Sensor II Temperature-Resistance Chart

Temperature (deg. F.)	Resistance (ohms)
14	7,000-12,000
68	2,000-3,000
122	700-1,000



The tach signal to the ECU comes from the ignition module. The signal that the ECU receives is a square wave. Several different instruments can be used to verify the presence of this signal, including: a tachometer reading of anything other than zero, a dwell meter reading of anything other than zero (or full scale), or a pulse indication on a logic probe such as this one.

176	200-400
Operating temperature	Less than 200

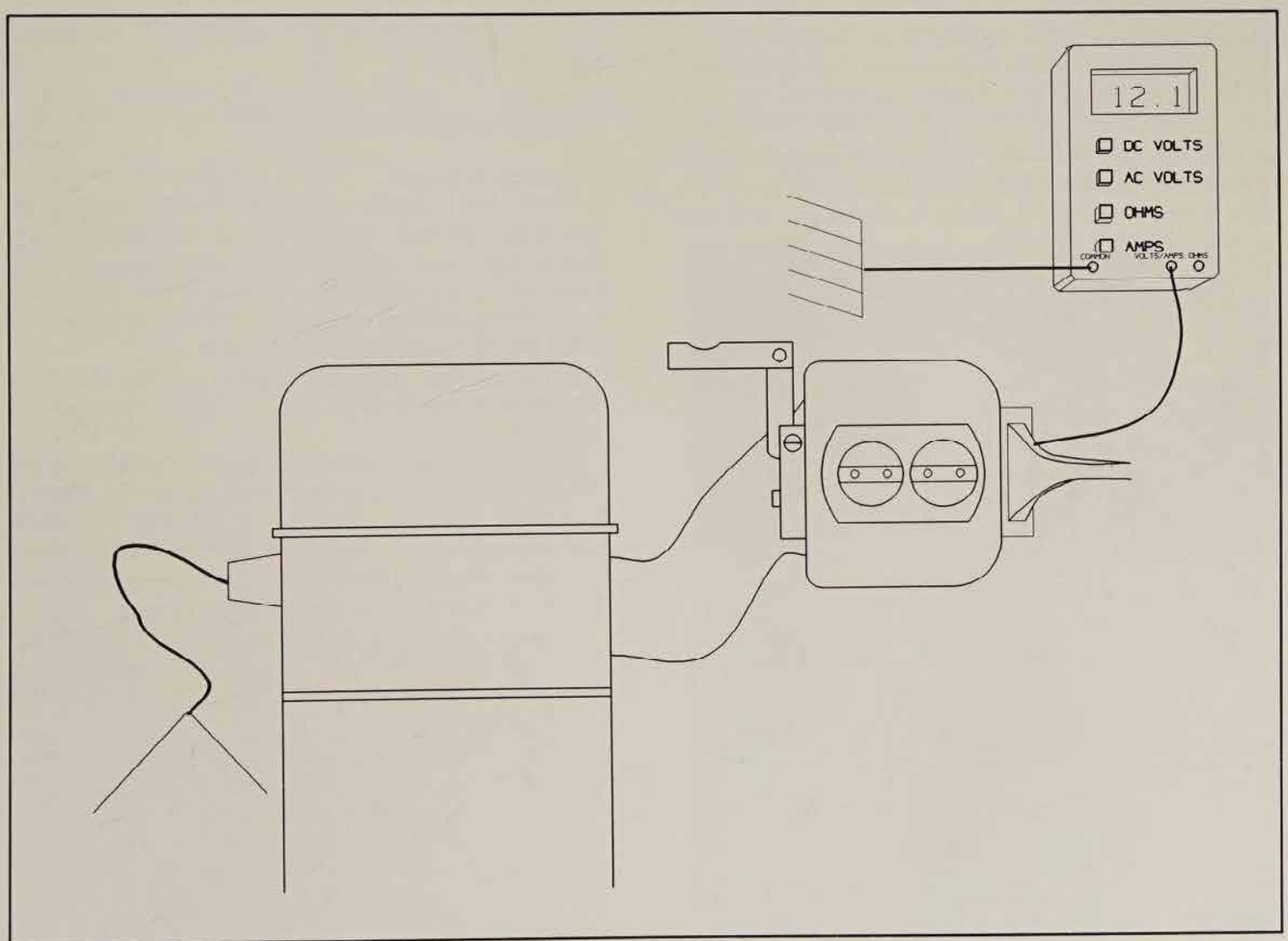
Tach Signal

Without the tach signal to the electronic control unit the engine will not start. This signal is used by the ECU to synchronize the fuel injectors to the rotation of the crankshaft. If the engine runs, the signal is being received by the ECU and there is no need to test the ECU tach input.

If you conduct a test, connect a digital tachometer to the tach lead input of the ECU and crank the engine. If the tachometer reads anything other than zero, the signal is being received by the ECU. If the tachometer reads zero, connect it to the negative terminal of the coil. If the tachometer reads something other than zero, repair the wire from the coil to the ECU. If it reads zero, repair the primary ignition system.

ECU Harness Tach Terminal Specifications

Application	ECU Terminal Number
All makes and models 1974-78	1
Alfa Romeo Spider 1982-83	1
AMC Alliance and Encore 1983-84	1
BMW	
1979-81 528i, 633CSi	1
1979-81 733i	1
1982-83 All models	1
Datsun/Nissan	
1979-81	18
1981-83 Turbo	5
1982-83 non-Turbo	18
Fiat 1980-82	1
Porsche	
1980-82 928	1
1982-83 944	1
Renault 1981-83	1



When a feeler gauge is inserted between the throttle stop screw and the throttle linkage bellcrank, a voltmeter should read voltage at the two outer terminals of the throttle switch. When the feeler gauge is removed, the voltage at one of the two outer terminals should drop. If the voltage does not drop, adjust or replace the throttle switch. An alternative to this test is a continuity test with an ohmmeter.

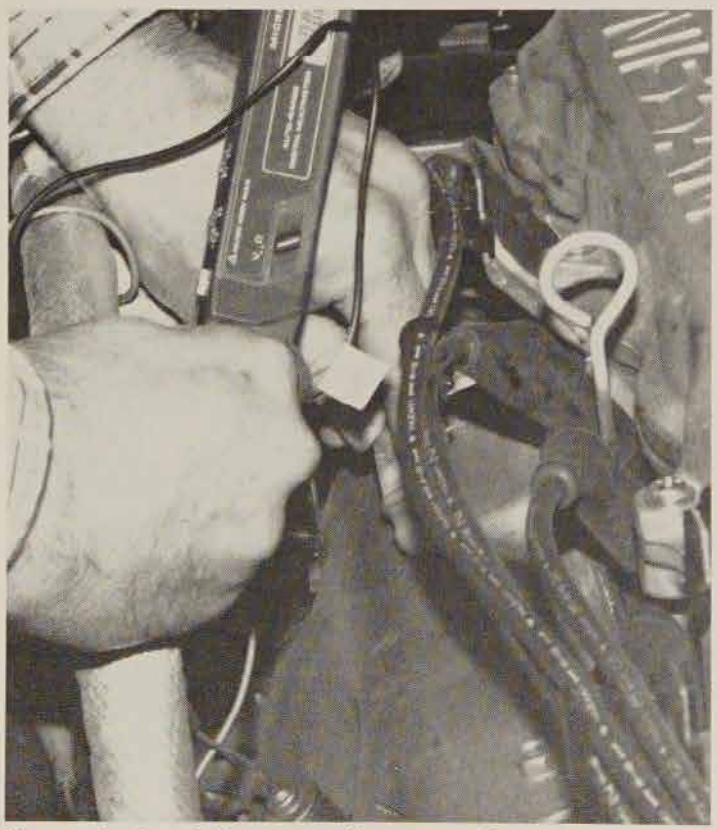
Subaru 1983	20
Toyota 1979-83	Ig
Volkswagen	
1974-78	1
1980-83	1

Throttle Switch

Since the troubleshooting and adjustment procedures are the same, follow this procedure for testing the throttle switch.

There are three terminals on the L-Jetronic throttle switch. One terminal is common, one is for closed throttle and the third is for wide-open throttle. Disconnect the throttle switch harness and connect an ohmmeter between the common terminal and the wide-open throttle contact. Slowly open the throttle; just before you reach wide-open throttle the ohmmeter should indicate zero ohms. Now close the throttle slowly. Immediately off of wide-open throttle the ohmmeter should indicate infinite ohms.

Leave the ohmmeter lead connected to the wide-open throttle terminal and connect the other lead to the closed-throttle terminal. With the throttle closed the resistance should be zero ohms. Crack the throttle open a few degrees and the ohmmeter should read infinity. If these conditions are not met, adjust the throttle switch. If these conditions *cannot* be met through adjustment, the throttle switch or throttle switch circuit is defective.



To test the Lambda sensor, disconnect the sensor from the lead going to the ECU. Then ground the ECU's Lambda lead. If the Lambda sensor is good, its output voltage should increase.

Throttle Switch Contacts

Application	Throttle Position		
	Idle (terminal number)	Common (terminal number)	Full (terminal number)
Alfa Romeo	2	18	3
AMC			
1983	D2-13	D2-4	D2-6
1984	2	18	3
BMW			
318i	2	9	3
528e, 533i, 633i, 733i	2	5	3
528i, 530i	2	18	3
Datsun/Nissan			
280ZX Turbo	18	25	
All other models	29	30	24
Fiat	2	18	
Porsche	2	18	3
Renault			
1980-82	2	9	3
1983	2	18	3
Subaru	Blue/ White	Green/ White	Green/ Red
Toyota			
Supra	IDL	E1	PSW
All other models	IDL	TL	PSW

Lambda Sensor

To test the Lambda sensor, make sure the engine is warmed up and running for two minutes before beginning. Then, connect a high-impedance voltmeter to the Lambda sensor input to the ECU. The voltmeter should be continuously moving back and forth between about zero and 1 volt.

If the voltage is steady (again, ensure that the engine is warmed up) at about 0.5 volt, replace the sensor.

If the Lambda sensor voltage is stuck high, check the fuel pressure, Temp Sensor I, Temp Sensor II, throttle switch, any leaking injectors, leaking cold-start injector and the evaporative canister system. If all of these circuits and systems are good, then replace the Lambda sensor.

If the Lambda sensor voltage is stuck low, check the fuel pressure, and check for vacuum and exhaust leaks. If all check out OK, replace the Lambda sensor.

When replacing the Lambda sensor it is important to know why it went bad. If the sensor is covered with a dark, sooty coating, replace the sensor beause it is carbon contaminated. This is most likely the result of a rich-running engine.

Mount the sensor in a vise; connect a high-impedance voltmeter to the sensor output and ground the voltmeter to the vise. Heat the sensor with a propane torch. The voltmeter should climb to over 0.6 volt in fifteen seconds. If it does not, it is silicone contaminated. Remove the propane flame

from the sensor. The voltage should drop to less than 0.4 volt in six seconds. If it does not, then the sensor is lead contaminated. Whatever the source of the contamination, if it is not eliminated, the new Lambda sensor will develop the same problem.

If soot is the contaminant, check the fuel pressure, Temp Sensor I, Temp Sensor II, the throttle switch, any leaking injectors, a potentially leaking cold-start injector and the evaporative canister system.

If lead is the contaminant, then there has been leaded fuel or a leaded additive used in the engine and the practice must be stopped to prevent future damage.

If silicone is the problem it is likely that an engine repair was done with RTV silicone. Wait until the silicone is fully cured before replacing the sensor.

Lead, silicone and soot contamination cannot be effectively cleaned from a Lambda sensor.

Lambda Sensor ECU Pin Number

Application	Pin Number
Alfa Romeo Spider 1982-83	24
AMC Alliance and Encore 1983-84	20
BMW	
1979-81 528i, 633CSi	24
1982-83 All models	24
Datsun/Nissan	
1979-81	31
1981-83 Turbo	24
1982-83 non-Turbo	31
Fiat 1980-82	24
Porsche	
1980-82 928	24
1982-83 944	24
Renault 1981-83	24
Subaru 1983	4
Toyota 1979-83	Ox
Volkswagen 1980-83	24

Auxiliary Air Valve

Testing the auxiliary air valve can be done in two different ways. The first is a functional test. To begin, start the engine cold. If the engine speed slows over a period of two to three minutes, then the auxiliary air valve is OK. If there is no change in the speed of the engine as it runs, remove the valve and inspect to see if the passage is closed. If the engine has been run for several minutes, the passage should be closed. If the passage is open, ensure that there is power and a good ground on the harness to the auxiliary air valve. If there is, replace the valve. If not, place it in the freezer for fifteen to twenty minutes. Then remove it from the freezer and recheck. If the passage is still closed, replace the valve.

What to Test, and When

As mentioned earlier in this chapter, there are many components other than those of the fuel-injection system that can cause the following troublesome symptoms. Always begin troubleshooting by confirming that the basic engine, ignition and intake system are in good shape.

No-Start, Fuel Pump Not Working

Test the fuel pump circuit including the fuse, relay, wiring and fuel pump itself.

No-Start, Fuel Pump Working

Test the main relay system and its power supply to the ECU. Confirm that there is a good ground for the ECU. If the ignition system is delivering a good spark, if there is a good power supply and ground to the ECU, and if the ECU is receiving tach pulses from the primary ignition system and the injectors still fail to pulse, then replace the ECU.

Starts Cold but Dies When Key Is Released

Be sure that the ECU is receiving pulses from the primary ignition system. What may be happening is that the engine is starting off of the cold-start injector, then dying as soon as the key is released and the cold-start injector shuts off.

Stalls When Cold

Begin troubleshooting this problem by inspecting the auxiliary air valve. Start the engine cold and remove the hose on the intake manifold side of the auxiliary air valve and allow it to draw air. If the engine speed increases significantly, replace the auxiliary air valve. (*Note*: A minor increase in rpm is normal when performing this test.)

Temperature Sensor II is also critical to cold engine operation, so verify its proper operation.

Misfire or Erratic Idle

Confirm that the basic engine, intake and ignition system are in good shape as these are far more likely to cause this symptom than the fuel-injection system.

Inspect the circuits and sensors for Temp Sensors I and II. Also inspect the connector tube that runs from the intake manifold to the airflow meter for evidence of false air.

If all of the above test satisfactorily, perform the injector flow test. If the flow test checks out, then something more basic has been missed.

Misfire at Cruise

Confirm that the basic engine, intake and ignition system are in good shape.

Perform a fuel pressure-volume test. Notice especially if there is a drop in fuel pressure that coincides with the misfire.

If the fuel pressure remains constant, test the pressure sensor, Temp Sensor II and throttle switch circuits.

If these tests do not yield the source of the problem, begin the test procedure again as something has been missed.

Lack of Power

Confirm that the basic engine, intake and ignition system are in good shape.

The most likely cause of this symptom related to the fuel-injection system is low fuel pressure. Perform the fuel pressure-volume test and observe any loss of pressure.

If the fuel pressure tests OK, test the circuits for Temp Sensor II and the airflow meter. If these circuits and sensors test to specifications, then perform the injector flow test. Clean or replace the injectors as necessary.

If all of these test adequately, then begin the test procedure again.

Stalls on Deceleration

Confirm that the basic engine, intake and ignition system are in good shape.

Begin this test procedure by inspecting the hoses and wiring for tightness that may cause an intermittent disconnection as the engine torques and stresses back and forth. Next, check the throttle stop adjustment and curb idle speed. Some cars have a deceleration valve. For these applications, snap the throttle to about 3000 rpm and release immediately. The rpm should drop to around 1500, hold there briefly, then drop to curb idle speed. If this does not occur on applications using a deceleration valve, then adjust or replace the deceleration valve.

Runs Rough, Smoking

Confirm that the basic engine, intake and ignition system are in good shape.

Perform the fuel pressure-volume test. Inspect the circuits for the airflow meter, Temp Sensor II and the injectors. If these test positively, then perform the injector flow test. If everything is functioning, something has been missed.

Poor Mileage

Confirm that the basic engine, intake and ignition system are in good shape.

Perform the fuel pressure-volume test. Inspect the circuits for the airflow meter, Temp Sensor II and the injectors. If all test out OK, then perform the injector flow test. If everything checks out, something has been missed.

Misfire under Load

Again, confirm the performance of the engine, intake and ignition system.

Perform the fuel pressure-volume test. Inspect the circuits for the airflow meter, Temp Sensor II and the injectors. If these test well, then perform the injector flow test. If everything is OK, something has been missed.

Trailer Hitching

This symptom gives the driver the feeling that there is a trailer with a tongue designed for a 2 in. ball hooked up to a car with a 1⅞ in. ball.

Confirm that the basic engine, intake and ignition system are in good shape.

Perform the fuel pressure-volume test. Inspect the circuits for the airflow meter, Temp Sensor II and the injectors. If these test OK, then perform the injector flow test. Also test the throttle switch. If everything is working correctly, something has been missed.

Idle Speed Too High

Confirm that the basic engine, intake and ignition system are in good shape.

Check and adjust as necessary the throttle stop and curb idle speed.

Some applications are equipped with a deceleration valve. For these applications, snap the throttle to about 3000 rpm and release immediately. The rpm should drop to around 1500, hold there briefly, then drop to curb idle speed. If this does not occur on applications using a deceleration valve, then adjust or replace the deceleration valve.

Idle Speed Too Low

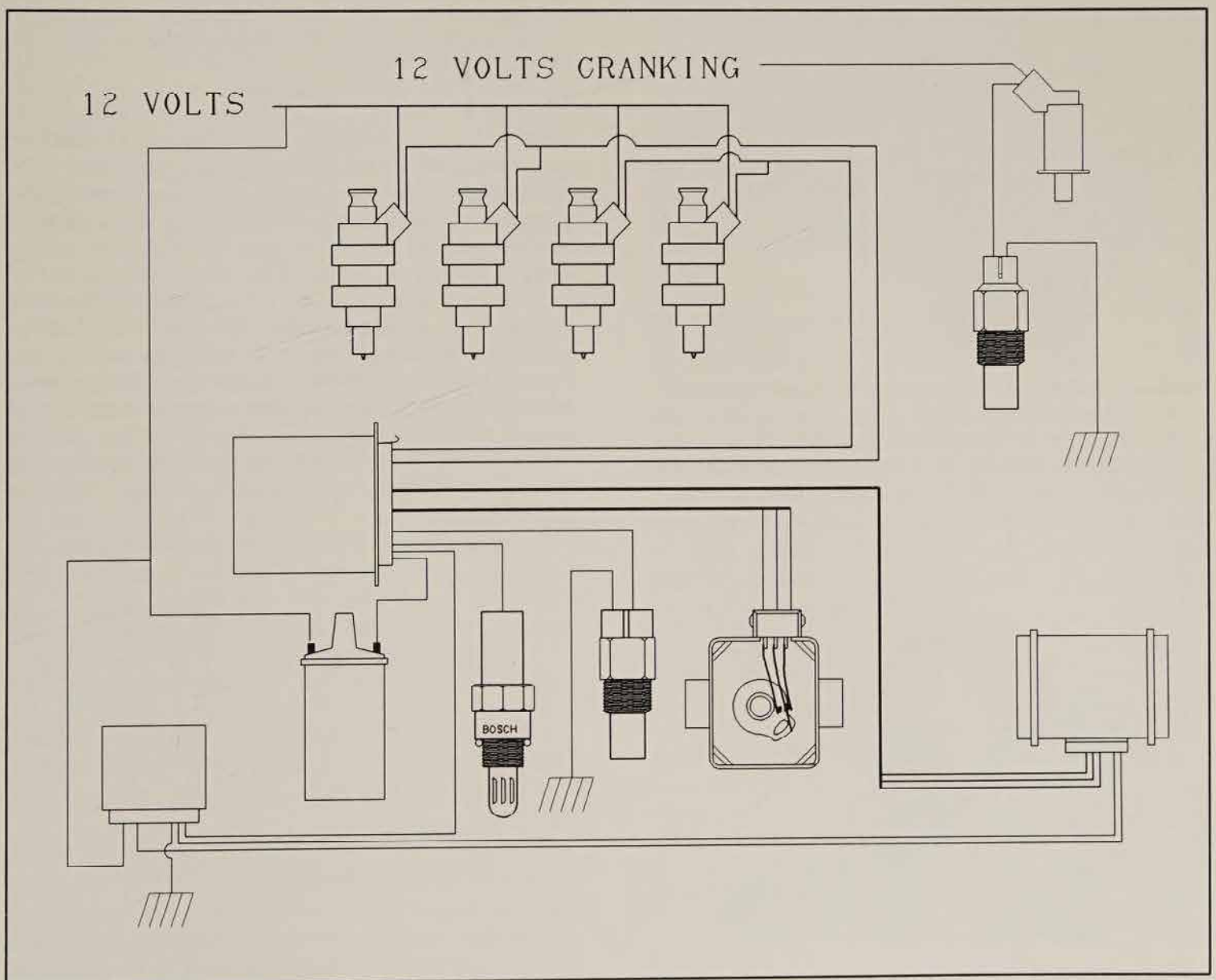
Confirm that the basic engine, intake and ignition system are in good shape.

Check and adjust as necessary the throttle stop and curb idle speed.

8

LH-Jetronic System

There are many similarities between the LH-Jetronic and the L-Jetronic systems. In fact, the only significant difference is the replacement of the L-Jetronic's airflow meter with the LH-Jetronic's air mass meter. The air mass meter's design provides two important advantages over the air-



The LH-Jetronic fuel-injection system is similar to the L-Jetronic system. The only significant difference is that the LH-system uses an air mass meter in place of the airflow meter. Both systems use a Lambda sensor.

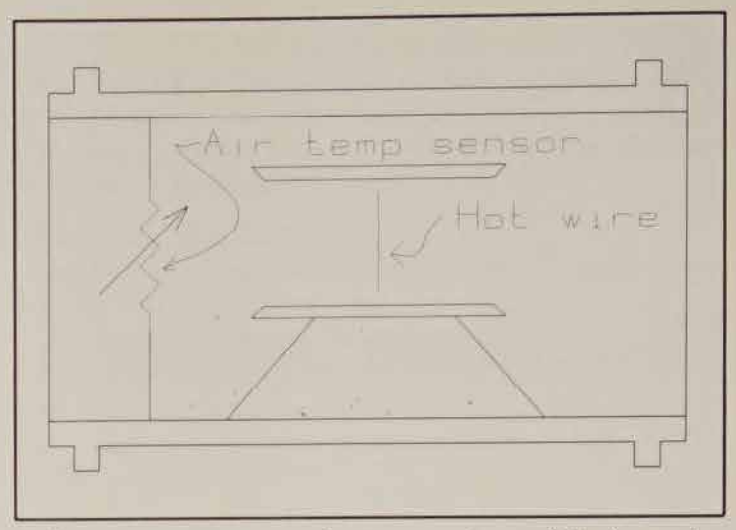
flow meter: there is no moving flap to restrict airflow, and there are no moving parts to wear out or bind.

Applications for the LH-system are limited to Volvo, Saab and Porsche.

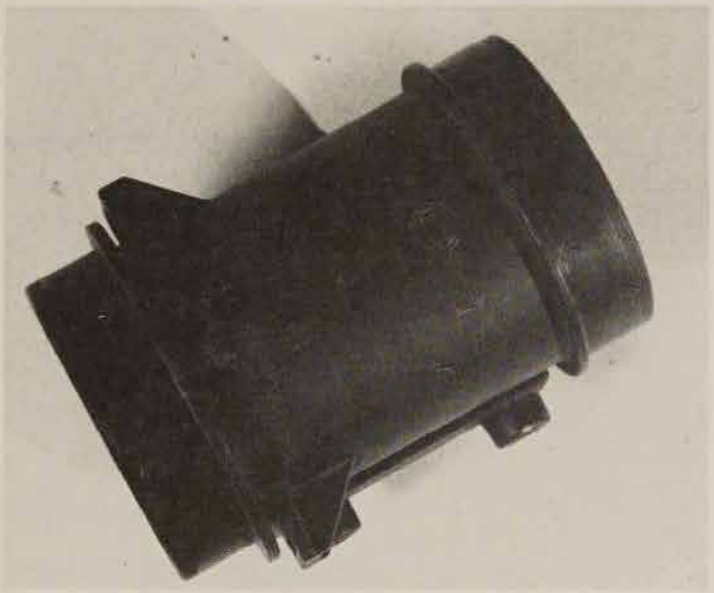
Sensors

Air Mass Meter

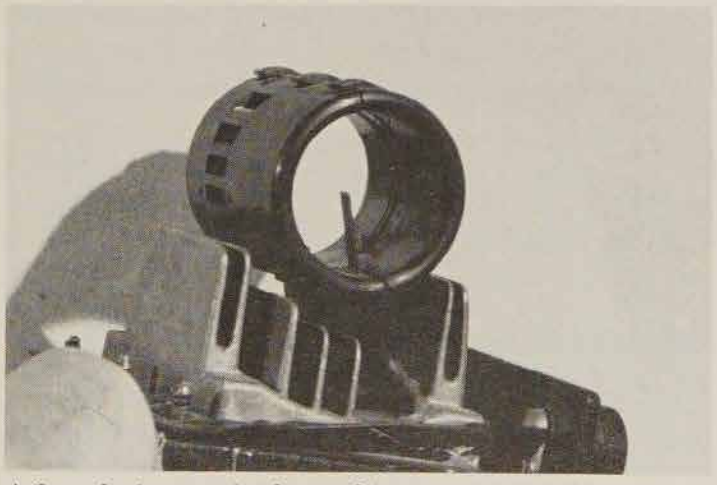
The air mass meter is located between the air filter and the throttle assembly. All of the air entering the intake system to be used as part of the air-fuel mixture passes through it. The sensor consists of a 0.07 mm platinum wire looped across the main channel of airflow. A thermistor in the air mass meter measures the temperature of the incoming air. A computer on the side of the sensor passes enough current through the platinum wire to cause the wire to heat to 180 deg. F. above the temperature of the incoming air. As the engine is started and air begins to pass through the intake system the wire is cooled. The computer notices the drop in resistance that will accompany the cooling of the wire and increases the current flow to maintain the temperature of 180 deg. above incoming air. As the sensor varies the current flow through the heated wire, the output voltage of the sensor will also vary. This output voltage ranges from nearly zero to 5 volts. As the air mass flowing through the sensor increases, the output voltage increases as well.



A thermistor measures the temperature of the incoming air. The platinum wire is heated to approximately 100 deg. F. above that temperature. As air passes through the air mass meter on its way to the engine, the platinum wire is cooled. The meter increases the current flow to maintain the proper temperature differential over incoming air. As the current changes, the air mass meter output also changes. The ECU uses the variable voltage output to calculate the amount of air the engine is taking in.



The heart, and distinguishing characteristic, of the LH-system is the air mass meter. First introduced in the United States on California Volvos in 1982, the air mass meter occupies a position between the air cleaner and the throttle assembly.



A fine platinum wire located in a venturi in the center of the air mass meter measures the volume and density of the air entering the engine.

Because the air mass meter's platinum wire sits across the main channel of airflow it may become coated by road oils and crankcase vapors. To prevent an insulating jacket from being built up over the wire, a burn-off cycle is provided. Approximately four seconds after the engine is shut off the ECU grounds a relay which applies power to the platinum wire, heating it red hot. The burn-off lasts about one second and cleans off anything that may have stuck to the wire while the engine was running.

Symptoms associated with a defective air mass meter include stalling and erratic running.

Tach Signal

The ECU receives a signal from the primary ignition system. This signal is used by the ECU to synchronize the injectors to the speed of the engine. A problem with the tach signal may affect

the injectors or prevent them from working. Typical symptoms include erratic running, stalling and no-start.

Coolant Temperature Sensor

The coolant temperature sensor, located in the cylinder head water jacket, is a negative temperature coefficient thermistor. The sensor's main job is to replace the warm-up function of the choke. As the temperature of the engine increases, the temperature of the thermistor decreases. The ECU responds to this decrease in resistance by shortening the injector's on-time, thereby leaning out the air-fuel ratio.

At 32 deg. F. the resistance of the coolant temperature sensor is between 7,000 and 11,600 ohms. When the engine reaches operating temperature the sensor's resistance will be less than 300 ohms.

The LH-II system places extra emphasis on the coolant temperature sensor when cold starting. The ECU dramatically increases the injector pulse width when cold starting the engine. This replaces the cold-start enrichment function performed by the cold-start injector on D-Jetronic, K-Jetronic and early L-Jetronic systems.

A defective coolant temperature sensor may result in poor fuel economy, spark plug fouling, rough engine operation and difficulty starting the engine either hot or cold.

Vacuum Switch

From 1982 to 1984, Volvo used the LH-1 system on its four-cylinder engines. These applications used a vacuum switch mounted on the firewall. When the engine comes under a heavy load the switch signals the ECU, which responds by increasing the injector pulse width.

If the vacuum sensor fails to function properly the engine will run lean when it is under load. This can result in stumbling, hesitation or intake manifold backfire.

Throttle Switch

The LH-II system, which includes all applications except the 1982-84 Volvo 240 series, uses a throttle switch instead of a vacuum switch. The throttle switch consists of two sets of contacts. One set is closed when the throttle is closed, the other is closed only at wide-open throttle. The switch is located on the intake manifold throttle assembly.

If the closed-throttle points fail to close at an idle, fuel economy can suffer. If the wide-open throttle contacts fail to close at wide-open throttle the engine will run lean under load and result in a stumble, hesitation or intake manifold backfire.

Lambda Sensor

Lambda sensor is Bosch's name for what is commonly known in the automotive industry as the oxygen sensor. Its purpose is to detect imbalances in the air-fuel ratio so the ECU can make minor adjustments. The term Lambda comes from the Greek letter that German automotive engineers use to represent the perfect, or stoichiometric, air-fuel ratio.

The device consists of platinum electrodes separated by a layer of zirconium dioxide ceramic. The ceramic begins to conduct oxygen ions when its temperature reaches about 600 deg. F. Behaving like a voltage generator, as the oxygen content of the exhaust decreases, the voltage output of the sensor increases. This output voltage ranges from 100 to 900 mV (0.1 to 0.9 volt).

Chapter 5 covers in-depth the operation and testing of the Lambda sensor.

Electronic Control Unit (ECU)

The ECU gathers data from the various sensors to decide how long the fuel injectors should be left open. Power to operate the ECU is delivered through a relay controlled by the ignition switch. ECU failures are extremely rare and usually occur in the form of a no-start.

ECU failures have been known to occur as a result of voltage spikes, however—sudden and dramatic increases in voltage which result from the sudden collapsing of magnetic fields. Such a spike could occur when jump-starting a car, or when disconnecting the battery with the headlights or other large current draw turned on.

Fuel Components

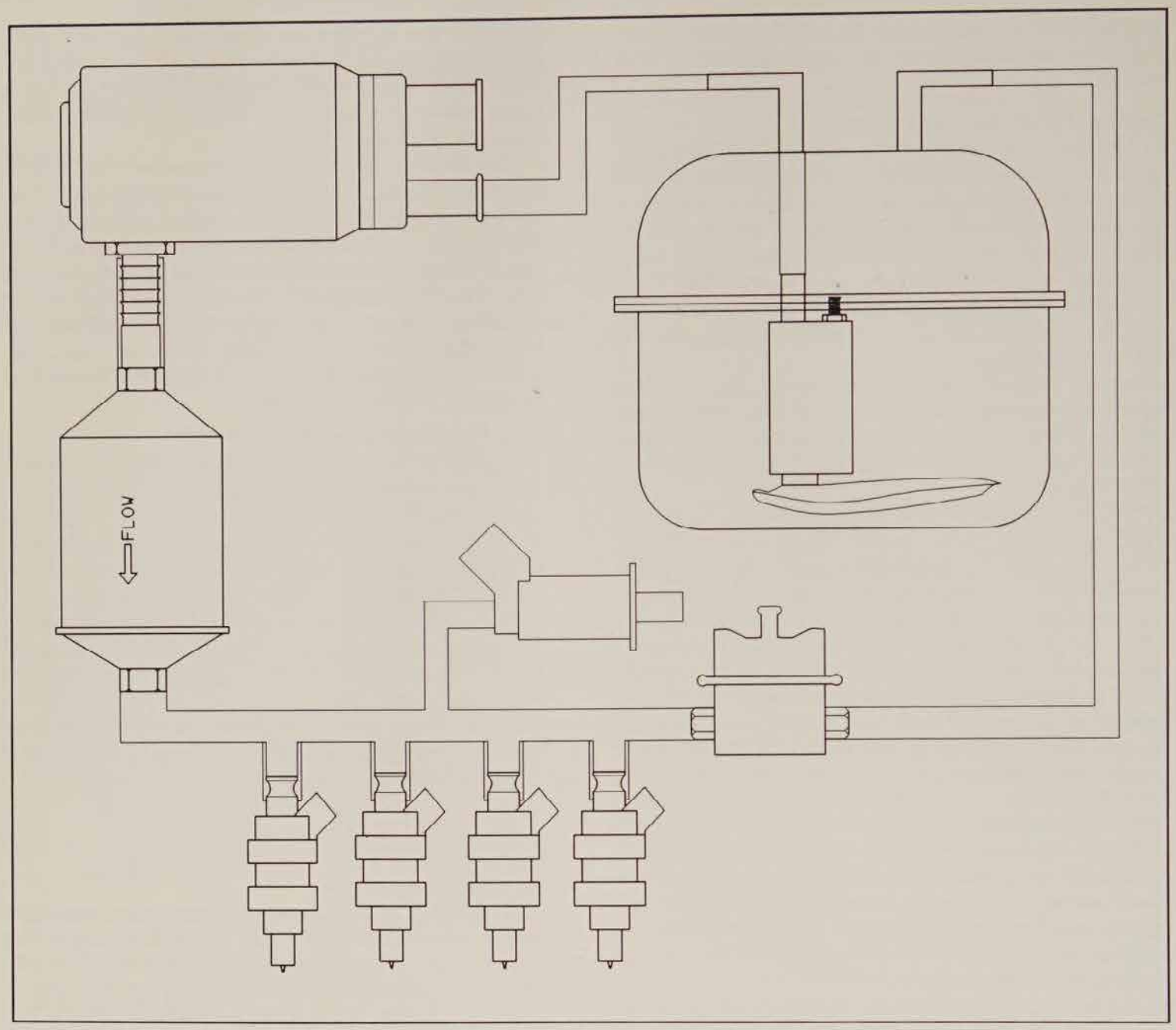
In-Tank Filter

Located inside the fuel tank is a screen or filter designed to protect the fuel pump from rust, dirt and debris. Although seldom the cause of a driveability problem, it should be high on the list of items to check. In many cases these filters are completely ignored when the car is serviced, even on well-maintained cars. I have seen hours and even days wasted looking for a problem as basic as a restricted in-tank filter.

Fuel Pump

The fuel pump is a high-speed roller vane pump capable of pumping fuel at pressures and volumes far higher than any engine or fuel-injection system would require. This type of pump is efficient at pushing fuel, but does a poor job of pulling fuel. As a result, these pumps are located close to or even inside the fuel tank.

On many applications this pump is extremely loud. But this in itself doesn't necessarily indicate impending failure. Familiarity with the individual car or comparison with a similar car can help distinguish between potential problems and just noise. Keep in mind that the fuel pump will make more noise when the tank is nearly empty than it does when the tank is full.



The LH-Jetronic fuel system is typical of EFI fuel systems. There may be a lift pump in the tank that sends fuel to the main pump. The main pump pressurizes the fuel, sending it through a check valve, a fuel filter and on to the fuel rail. The fuel rail feeds the fuel to the injectors and (if there is one) the cold-start valve. The fuel pressure regulator controls the fuel pressure at about 35-40 psi.

The pump can react adversely and even fail as a result of using some fuel additives. Use extreme caution when selecting these additives to ensure that they do not contain methanol or other corrosive substances.

A defective fuel pump can cause low fuel pressure which results in symptoms such as hesitation, stalling and poor power. Often a defective fuel pump by-passes the poor-running stage and simply stops operating.

Fuel Filter

The LH-Jetronic fuel filter should be replaced during every tune-up. Factory-recommended service intervals do not always take into account the extreme conditions under which most cars driven in North America are operated. This filter is extremely important as it is the fuel-injection system's only real defense against internal contamination.

The fuel filter used with the LH-Jetronic system is capable of filtering particles as small as 10 microns (0.000001 meter or 0.00003 in.). This level of filtration is necessary because of the extremely small opening at the tip of the injector.

Fuel Pressure Regulator

The fuel pressure regulator used on the LH-Jetronic system consists of a valve connected to a

spring-loaded diaphragm. The regulator controls the fuel pressure at between 30 and 40 psi on most applications at an idle. A vacuum line connects the regulator to the intake manifold, allowing manifold pressure to be applied to the backside of the diaphragm. The net effect is that when the throttle is opened and intake manifold pressure increases, the fuel pressure increases between 5 and 10 psi. This accomplishes two things: it allows the proper pressure differential to be maintained across the tip of the injector, and it acts as an accelerator pump.

Incorrect fuel pressure can cause the engine to run lean if the pressure is too low, and rich if the pressure is too high. A defective fuel pressure regulator can result in high fuel consumption, rough or erratic idle and poor power.

Injectors

The injectors are solenoid-operated, normally closed valves powered by switched ignition voltage through a fuse. The ECU provides a pulsed ground by which the injectors open. The typical length of time that the injectors are energized is two to five milliseconds.

Other than occasional restricting or contamination there is little to go wrong with the injector. The LH-system's injector design is virtually identical to that of the D-Jetronic system. Some of those injectors have been on the road since 1968 and still have plenty of life left in them.

Symptoms associated with injector problems include rough idle and poor power.

Fuel Rail

The injectors and the fuel pressure regulator are attached to steel tubing known as the fuel rail. The inbound fuel line from the pump and filter feeds fuel to the injectors and the pressure regulator through the fuel rail.

As a passive component of the system very little can go wrong with the fuel rail, except for leaks and restrictions.

Cold-Start Injector

Until the latter half of the 1980s most LH-Jetronic applications used a cold-start injector or fifth injector, as it was formerly known. The cold-start injector receives battery voltage whenever the ignition switch is in the crank position. It finds ground through the thermo-time switch. The thermo-time switch is a temperature-sensitive bi-metal switch designed to provide a ground for the cold-start injector when the coolant temperature is below about 95 deg. F. A second circuit in the switch is an electric heating element intended to heat the bimetal as the engine is being cranked. Thus, the cold-start injector should operate only when the engine is being cranked, the temperature of the engine is less than 95 deg., and for a maximum of five to twelve seconds.

Two symptoms are most common with a defective cold-start system: hard starting when cold (if the valve is not working), and rich running (if the valve is leaking).

Air Components

Air Mass Meter

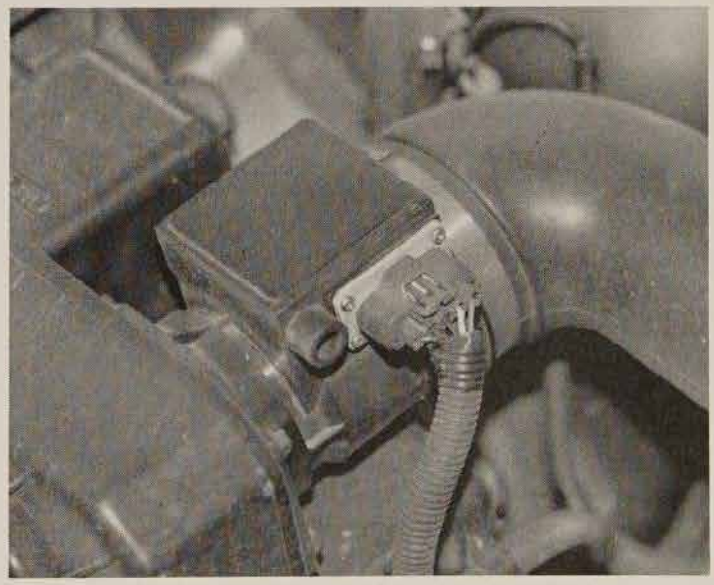
The air mass meter is not only a sensor, it is also part of the air intake system. Since all of the air passing into the engine to be used as part of the air-fuel ratio passes through the air mass meter, it is important that there be no air leaks either in the meter itself or in the rubber tube that connects it to the throttle assembly of the intake manifold. Such a leak is called false air. False air enters the intake manifold and is used as part of the air-fuel charge. Since this air by-passes the meter, it is unmeasured and therefore causes the engine to run lean.

Auxiliary Air Valve

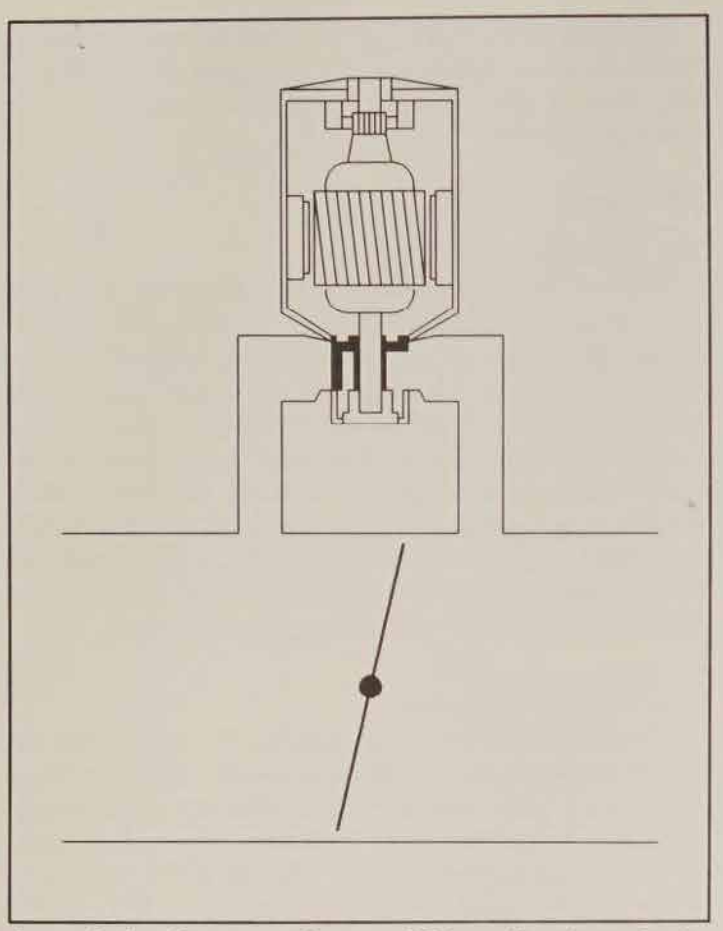
The auxiliary air valve allows air to by-pass the throttle plates while the engine is warming up to permit a higher idle speed. The valve consists of an electrically heated bimetal valve. When the engine is first started, the valve will be open. As the engine runs, the bimetallic valve is heated by the electric element, slowly closing off the auxiliary air by-pass and reducing the volume of air entering the engine. Reducing the air in turn reduces the idle speed.

Idle Stabilizer

Instead of the auxiliary air valve, most LH-Jetronic systems use a computer-controlled idle stabilizer valve. This device allows much better control of the idle speed as air conditioners and



The air mass meter sits in the intake system so that all the air entering the engine to be used for combustion passes through it. An air leak between the meter and the throttle assembly is called false air. False air will make the engine run lean, rough and may cause poor idling and stalling.



One of the features of most LH applications is the automatic idle stabilizer. This replaces the auxiliary air valve of earlier fuel-injection systems, allowing the ECU or an idle stabilizer computer to control the idle speed accurately regardless of temperature or accessory load.

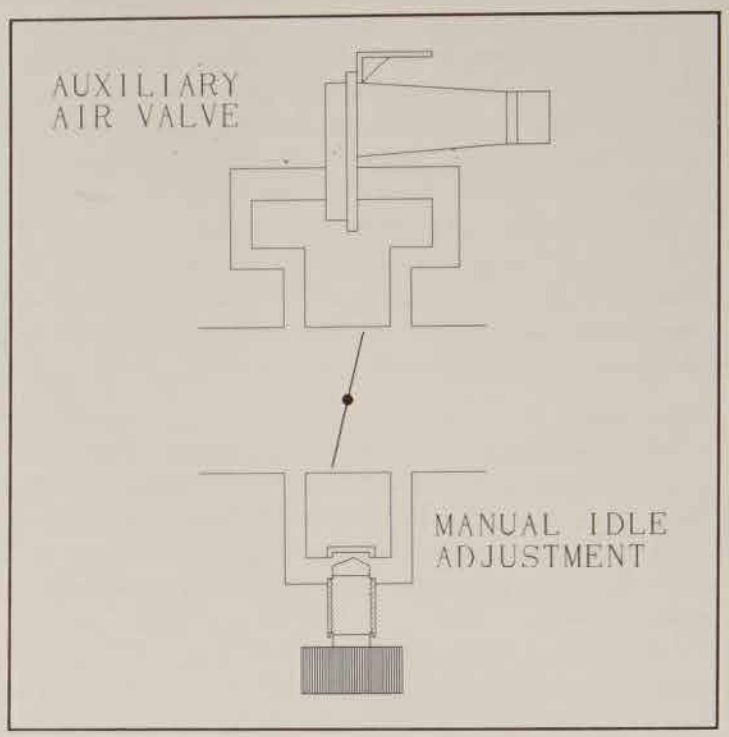
power steering pumps vary their load. The computer sends a variable duty cycle signal to the idle stabilizer. This signal operates a valve that controls air volume into the intake to control the idle speed.

Idle Air By-pass

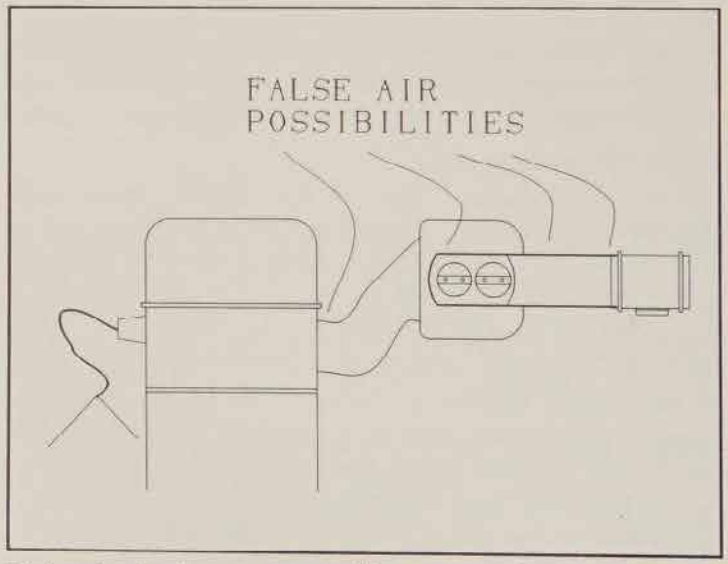
Unlike a carbureted engine, the LH-Jetronic system does not use the throttle stop screw to adjust the idle speed. Instead, it uses a by-pass channel similar to the auxiliary air by-pass. Unlike the auxiliary air by-pass, though, the idle air by-pass is adjusted by the technician. Curb idle speed should be changed only by adjusting the idle air by-pass and *never* by using the throttle adjusting screw.

LH-Jetronic Tune-Up Adjustments

The standard tune-up adjustments such as ignition timing, air-fuel ratio and idle speed still apply to cars using the LH-Jetronic fuel-injection system. LH-Jetronic system fuel pressure is not adjustable, but there are throttle stop and throttle switch adjustments. When performing a tune-up or attempting to solve a driveability problem it is important to follow the instructions for performing each adjustment precisely and in the correct sequence. Failure to do so could affect the accuracy of each adjustment and result in extremely poor fuel economy or other severe driveability problems.



When making the curb idle speed adjustment, be sure that the auxiliary air valve is closed. The throttle stop adjustment is factory preset. If there is evidence of tampering, warm the engine, close the manual idle adjustment and adjust the throttle stop screw for as close to 500 rpm as possible without the engine stalling. Adjust the idle speed thumbscrew to the specified curb idle. If the car is equipped with an idle stabilizer, it will be necessary to force the stabilizer closed.



Before beginning tune-up adjustments, check thoroughly for false air. Likely places for false air leaks to occur are in the tube between the air mass meter and the throttle assembly, the throttle assembly gaskets, the intake manifold and gaskets as well as the injector seals.

Fuel Pressure Adjustment

When repairing or maintaining a car certain preliminary checks and tests must be done to ensure the accuracy and effectiveness of work to be performed. Included on this list are many things that should be done but never are, such as testing fuel pressure before making any adjustments. If the fuel pressure is incorrect, adjustments such as for the air-fuel ratio and the throttle switch are inaccurate or meaningless.

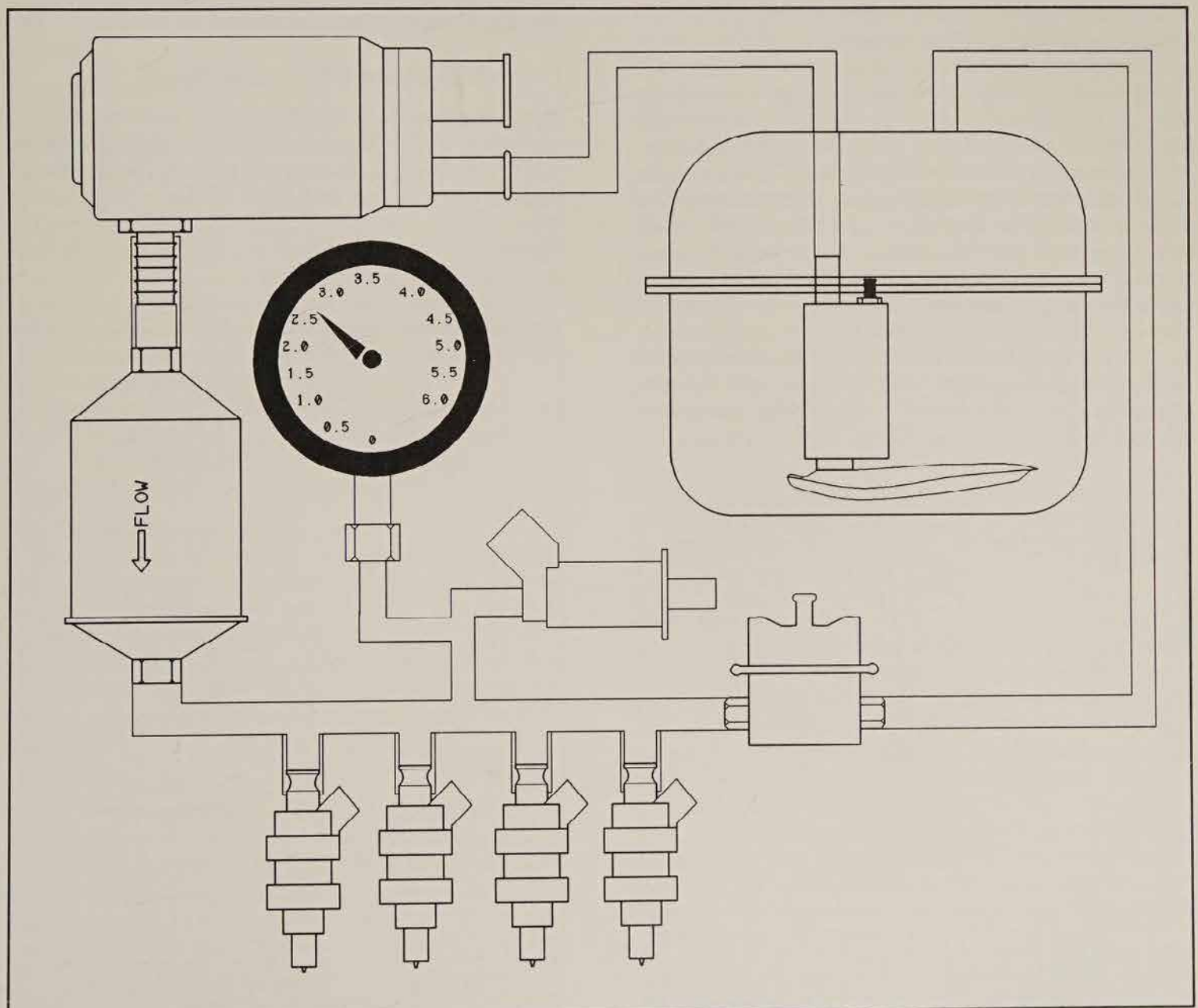
The fuel pressure should always be tested before any fuel-injection related adjustments are made.

Throttle Stop Adjustment (Minimum Idle Speed)

On applications using an auxiliary air valve, although the curb idle speed should never be adjusted with the throttle stop screw, proper and smooth operation of the fuel-injection system can be affected by this adjustment.

Begin by visually checking (this may require the use of a mirror) the auxiliary air valve to ensure that it is completely closed. If the valve is inaccessible, allow the engine to warm up and then measure the idle speed. Shut off the engine, and disconnect and plug the hose that runs from the auxiliary air valve to the intake manifold. Then restart the engine and measure the idle speed again. If there is not a significant difference between the speed of the engine with the hose connected and with the hose plugged, the auxiliary air valve is closed.

If the auxiliary air valve does not close, confirm that there are 12 volts and a good ground going to the valve, and then replace the valve.



Normal fuel pressure for the LH-system is 38 psi (2.6 bar) at idle. This pressure should increase to roughly 45 psi when the throttle is snapped open, or when the fuel pressure is tested with the engine not running.

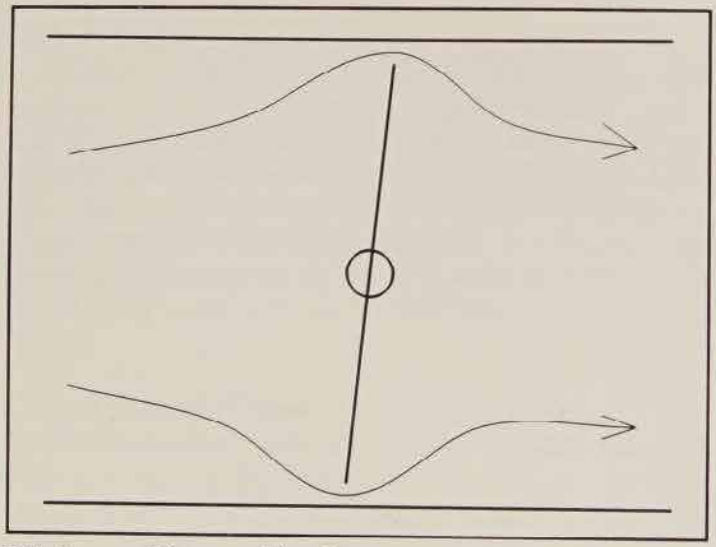
Locate and close the idle air by-pass manual adjustment. The idle air by-pass is generally located on top of the intake manifold near the throttle assembly. Loosen the lock nut on the throttle stop screw and adjust for the lowest possible speed without the engine dying. This speed should be around 600 rpm for a four-cylinder, 550 rpm for a six-cylinder and about 500 rpm for an eight-cylinder. Shut off the engine and check the throttle carefully for binding in the closed position.

Minimum Idle Speed

This applies to applications using an idle stabilizer. If working on a Volvo, locate the blue and white wire in front of the left shock tower. If it is a Saab, the wire is green and red. Ground this wire and close off the idle air by-pass screw. The only air entering the engine at this point would be the air passing across the throttle plates. Adjust the throttle stop screw so the engine just barely idles.

Throttle Switch Adjustment

There are three terminals on the LH-Jetronic throttle switch. One terminal is common, one is for closed throttle and the third is for wide-open throttle. Disconnect the throttle switch harness and connect an ohmmeter between the common terminal and the wide-open throttle contact. Slowly open the throttle; just before you reach wide-open throttle the ohmmeter should indicate zero ohms. Now close the throttle slowly; immediately off of wide-open throttle the ohmmeter should indicate infinite ohms. Leave the ohmmeter lead connected to the wide-open throttle terminal and connect the other lead to the closed-throttle terminal. With the throttle closed the resistance should be zero ohms. Crack the throttle open a few degrees and the ohmmeter should read infinity. If these conditions are not met, adjust the throttle switch. If these conditions cannot be met through adjustment, the throttle switch or throttle switch circuit is defective (see LH-Jetronic throttle switch troubleshooting). For the 1982-84 Volvo applications that use a vacuum switch there is no adjustment for this sensor.



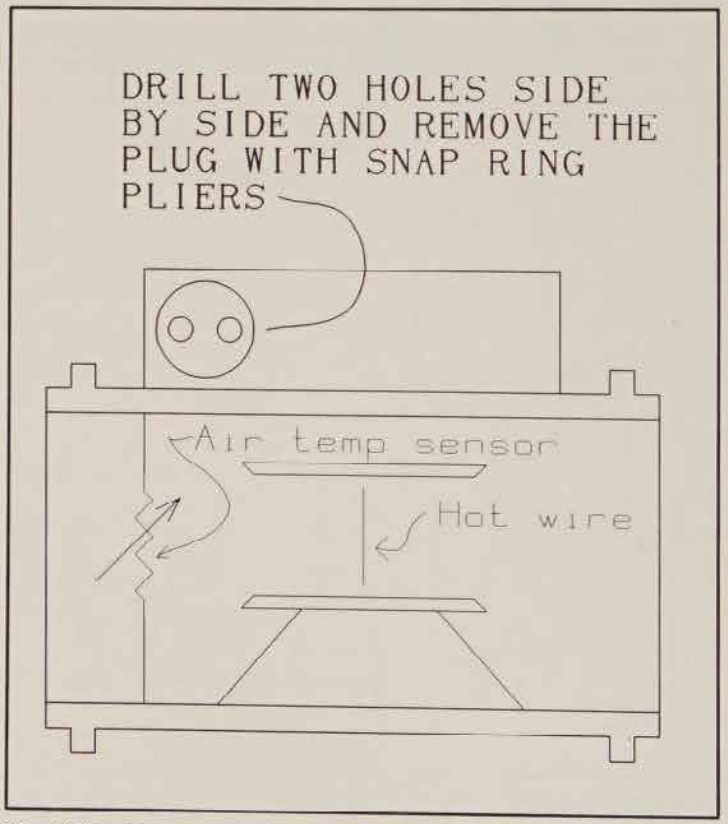
Minimum idle speed is the amount of air entering the engine with the throttle, the auxiliary air by-pass and the manual idle adjustment all closed. This measurement is made in rpm. For most four- and six-cylinder engines the correct setting is 500 to 600 rpm.

Curb Idle Speed Adjustment

After adjusting the minimum idle speed, it is time to adjust the curb idle speed. This is done through idle air by-pass adjustment. Keep in mind two things: First, the idle speed for most cars with an automatic transmission should be set in drive. Second, after the air-fuel ratio adjustment it may be necessary to readjust the idle speed. Leaving the blue and white (or green and red) wire grounded, adjust the curb idle speed according to the following chart. When the adjustment is completed, disconnect the grounded wire.

Curb Idle Speed Specifications

Application	Manual Transmission (Idle rpm)	Automatic Transmisson (Idle rpm)
Porsche	640-720	
Saab	778-925	
Volvo	750	750



The CO adjustment potentiometer is located under a plug located on the computer section of the air mass meter. Drill two holes to create a pig's nose. Then remove the plug with a pair of snap ring pliers.

Air-Fuel Ratio Adjustment

Located on the side of the air mass meter is a metal plug about 7/16 in. in diameter. Drill two small holes about ¼ in. apart in this plug for a "pig's nose." Do not drill all the way through. Using a pair of snap ring pliers, insert them into the hole and remove the plug.

Remove the plug in front of the catalytic converter and install the carbon monoxide probe. (*Note:* For accuracy this must be an air-tight fit.) Disconnect the Lambda sensor and read the CO; if not within specifications, adjust the screw below the pig's nose plug. Reconnect the Lambda sensor and confirm that the readings are still within spec.

For a Volvo, for example, the carbon monoxide reading will range between 0.4 and 0.8 percent.

Troubleshooting the LH-Jetronic System

Good troubleshooting begins with confirming the condition of the basic engine and ignition system.

Compression Test

Although the LH-Jet system is less sensitive to engine condition than the older D-Jetronic system, unless the engine is in good shape the LH-system cannot accurately control the delivery of fuel into the engine. The LH-Jetronic system uses air volume into the intake manifold as one of the primary inputs for the ECU to decide how long to leave the injectors open. Since engine wear can affect the amount of air flowing into the intake manifold, any troubleshooting must begin with knowing that the engine is in good shape.

When running the compression test, make sure that the compression gauge is properly installed and that the throttle is held wide open. This ensures the most accurate reading.

Valve Adjustment

Ensure that the valves are properly adjusted. While the compression test would point out severely maladjusted valves, do not rely on it to confirm that the valves are properly adjusted. Remove the valve cover and follow the valve adjustment procedure that is outlined in the factory service manual for the application you are working on.

Vacuum Leaks

Since the principal source of information for determining the amount of fuel that the engine requires is the flow of air into the intake manifold, accurate measurement of the volume of air entering the intake is vital. Any air entering the intake system between the air mass meter and the intake valve will be false air. Any false air can cause the fuel system to run lean. The possibility of a vacuum leak or false air causing a driveability problem is even higher than it is on a carbureted car.

A good way to find a vacuum leak is with a standard hardware store propane torch. With the engine warmed up and at an idle, run an unlit propane torch along both the top and bottom sides of the intake manifold. Pay particular attention to the gasket where the throttle assembly bolts onto the intake manifold, the seals where the injectors mount in the intake manifold, and the throttle shafts.

Any vacuum leaks that are found must be repaired before valid testing can continue.

Ignition System

After confirming that the basic engine is in good shape, inspect the condition of the ignition components. Inspect the points for evidence of burning, pitting and metal transfer. Check for the proper dwell. Inspect the distributor cap and rotor for cracks and burning. Whenever you replace the cap and rotor it is advisable that they both be the same brand. The spark plugs cannot always be checked satisfactorily without an engine analyzer. Therefore, if there is any doubt at all about the condition of the spark plugs, just replace them. It is cheaper than wondering about their condition.

Inspect the spark plug wires' resistance with an ohmmeter. The original-style factory wires were solid metal wires with resistors that screw onto the ends. These wires should have almost no resistance, while the resistor on the end of the wire should have 5,000 to 10,000 ohms of resistance. Many of the replacement secondary ignition cables are resistor wires. Resistor wires should have between 2,000 and 10,000 ohms per foot. Also inspect the wires for cracks or breaks in the insulation which may allow the ignition spark to arc to ground.

Testing the Fuel-Injection System

Once the engine and ignition condition have been confirmed, the testing of the fuel-injection system itself begins.

Fuel Pressure

Testing of the fuel-injection system must begin with testing fuel pressure. Connect the fuel pressure gauge to the hose going to the cold-start injector, as was previously described. Start the engine and allow it to idle. The fuel pressure should be around 30-35 psi. The LH-Jetronic fuel pressure regulator is *not* adjustable.

A vacuum hose between the fuel pressure regulator and the intake manifold allows the fuel pressure to increase as the throttle is opened, and the manifold pressure increases. The increase in fuel pressure acts like an accelerator pump.

If the symptom occurs only on acceleration or when the engine is under load, then fuel pressure must be tested under the same conditions that the symptom occurs. Position the fuel pressure gauge

where it can safely be seen while driving the car, and watch for a drop in fuel pressure that coincides with the symptom. This is the most effective method for testing fuel volume.

If the pressure is extremely high, there are two possible causes: (1) the fuel pressure regulator is defective, or (2) the fuel return line from the regulator back to the tank is restricted. To determine which is at fault shut off the engine, remove the return line from the fuel pressure regulator and install a test hose that will allow the return line fuel to be pumped into an approved fuel receptacle. Then restart the engine. If the fuel pressure is now normal, repair the restriction in the return line. If the fuel pressure remains high, replace the fuel pressure regulator.

If the fuel pressure is low, however, then there are ten possible causes. The following list is not in any specific order. Check them in the order of convenience based on your work environment and their accessibility on your car.

1. Inspect the system for external leaks. A fuel leak severe enough to result in a significant loss in fuel pressure would be severe enough to be very noticeable and very dangerous. Use extreme caution.
2. Ensure that there is enough fuel in the tank to easily pull into the system by the fuel pump and fuel pickup.
3. Check the fuel tank vent. If there is a venting problem on the fuel tank, it may not be possible for the fuel being pulled out by the fuel pump to be replaced by air. A suction is created in the tank, limiting the pump's ability to pull fuel out of the tank and resulting in low fuel pressure. Remove the gas cap and drive the car. If the symptom is gone, replace the fuel tank vent valves.
4. The in-tank fuel filter may be restricted. Most applications will have a screen in the fuel tank to protect the pump from sand, rust and other hard particle contaminants. If this filter is restricted the fuel volume will be reduced, causing a loss in pressure. The filter should be especially considered when the loss of fuel pressure occurs only with the engine under load.
5. Inspect the fuel pickup connector hose. There is often a hose that connects the in-tank filter to the fuel pickup. Occasionally this hose will perforate, causing the fuel pump to suck in air rather than fuel. The likelihood of this causing low fuel pressure increases if the symptom occurs only when the fuel level is below half a tank.
6. The main fuel filter may be clogged. If this filter is restricted, the fuel volume will be reduced, causing a loss in pressure. The filter should be especially considered when the loss of fuel pressure occurs only with the engine under load.
7. Check the fuel pressure regulator. If the pressure is low all the time, one of the prime causes could be the pressure regulator. Squeeze off the return line. If the fuel pressure increases, replace the fuel pressure regulator.
8. If the line running from the fuel tank to the fuel rail is restricted at any point, there will be a reduction in volume which could cause a loss of pressure at times of high fuel demand. Check these lines for kinks and clogs.
9. Confirm that there is a 12 volt drop across the pump. Connect the red lead of a voltmeter to the positive terminal of the fuel pump, and connect the black lead to the negative terminal. If the reading is less than 12 volts, attach the black lead of the voltmeter to chassis ground. If the voltage is now 12 volts, repair or clean the fuel pump ground. If the voltmeter still reads less than 12 volts, repair the high resistance on the positive wire to the fuel pump.
10. The fuel pump may be malfunctioning. Assuming the fuel filters have been replaced, if squeezing off the return line does not increase the fuel pressure and the voltage drop across the pump is 12 volts, then the pump becomes a prime candidate for replacement.

No Fuel Pressure

Generally speaking, lack of any fuel pressure will be electrical in nature. There are two fuses and a relay that could keep the fuel pump from running. Inspect the fuses not only for being burned open, but also for corrosion on the ends. The fuel pump relay should click when the engine is being cranked.

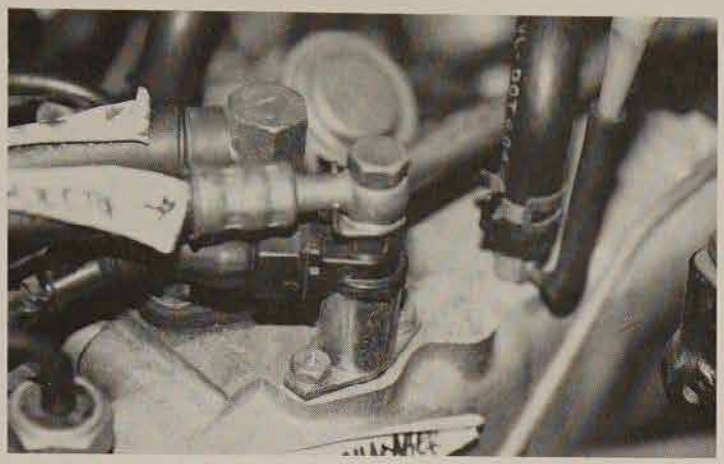
Injector Flow Testing

For erratic idle, rough running and low power it is important to confirm the proper flow rate through the injectors.

Remove the injectors from the intake system, leaving them attached to the fuel rail. Place each injector in a small, graduated cylinder (these can be obtained from any photographic supply store). Remove the spark plugs, disconnect the battery lead to the coil, and crank the engine for sixty seconds. Observe the amount of fuel flowed by each of the injectors. If the difference in quantity is greater than 10 percent, either clean or replace the injectors.

Testing the Cold-Start System

The cold-start injector is not controlled by the ECU. It is an electrical device controlled by the ignition switch as a source of power, and by a device known as a thermo-time switch as the ground. The cold-start injector is designed to operate only when the engine is being cranked and only when the temperature of the engine is less than 95 deg. F. As a result, in hot climates the cold-start valve may not operate at all. Additionally, beyond the problems of getting the engine started when cold or leaking, it will never lead to a major driveability



The initial test of the cold-start system is to remove the cold-start injector and hold it over a container. When the engine is cranked the injector should spray. Of course, if the temperature of the engine is greater than 95 deg. F. it will not spray. If the engine is not equipped with a cold-start injector, the mixture is enriched as a result of an input from the coolant sensor. If cold starting is difficult, test the coolant sensor.

An easy test of the air mass sensor is to position the air mass meter so that the hot wire is visible but the air tube and the electrical connector are still connected. Start the engine and allow it to warm up. Then shut off the engine. After about four seconds the wire should glow for one second. This ensures that the hot wire is good, but does not necessarily confirm that the meter is good.

problem. Even seasoned fuel-injection technicians will make the mistake of looking for a cold-running problem with the cold-start injector.

Remove the cold-start injector from the intake manifold, place the nozzle in a safe container and crank the engine. If the temperature of the engine is below 95 deg., the cold-start injector should spray. If it does not, connect a test light to each of the two terminals of the injector and crank the engine.

If one terminal activates the light but the other does not, then replace the cold-start injector.

If both terminals activate the light, inspect the wiring between the cold-start injector and the thermo-time switch. If the wiring is OK, replace the switch.

If neither terminal lights up the light, repair the wiring harness between the starter solenoid and the cold-start injector.

Testing LH-Jetronic Components

This section will look at how to troubleshoot the various LH-Jetronic components.

Air Mass Meter

The air mass meter has five wires. One wire supplies power to the meter, a second is a ground and a third carries the variable voltage air mass signal to the ECU. The two remaining wires provide power and ground for the burn-off function.

The first test of this sensor is a function test. Start the engine and allow it to idle. Locate the signal wire. This wire will be producing a varying voltage between 0.25 and 4.75 volts. At idle the voltage should be low; as you increase the speed of the engine the voltage should increase. If the voltage on the signal wire does not meet these specifications, then check for 12 volts between the meter and ground. If the power supply and ground to the meter are adequate, perform resistance tests on the meter. Results should be as follows:

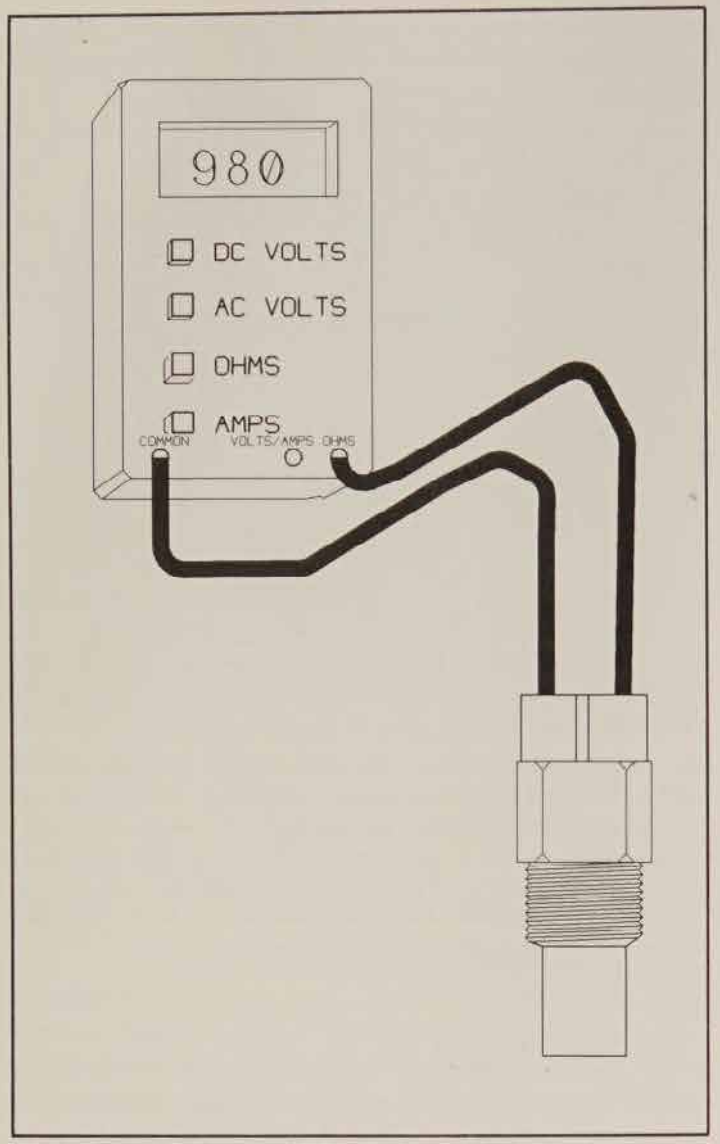
For the LH-Jetronic system, voltage at terminals 6 and 12 should be 0-1,000 ohms; for the LH II-Jetronic, terminals 6 and 7 should produce 3.7 ohms, and voltage at terminals 6 & 14 should read 0-1,000 ohms.

If the resistance between terminals 6 and 12 (6 and 14 on the LH-II system) is greater than 1,000 ohms, turn the mixture adjustment potentiometer. If the resistance does not drop below 1,000 ohms, replace the meter. (*Note*: If the same meter is reinstalled after performing this test the CO must be readjusted.) If the resistance from pin 6 to 7 is greater than or less than 3.3 to 4.2 volts, replace the air mass meter.

Coolant Temperature Sensor

The coolant temperature sensor is located in the water jacket of the cylinder head, usually close to the thermostat housing. On air-cooled engines it is located in the left cylinder head and has only one wire since it grounds through the cylinder head. On water-cooled applications the sensor has two wires.

For water-cooled engines, take the first resistance measurement at the ECU harness connector.



Test the coolant temperature sensor, also called Temperature Sensor II, with an ohmmeter. The resistance of this sensor (980 ohms) indicates the current temperature of the sensor is about 120 deg. F.

If this proves to be incorrect, take another reading at the sensor itself. If the first reading was bad but the second good, then the sensor is good and the wiring harness needs to be repaired. If the second reading was also bad, then replace the sensor.

Temperature Sensor II Temperature-Resistance Chart

Temperature (deg. F.)	Resistance (ohms)
14	7,000-12,000
68	2,000-3,000
122	700-1,000
176	200-400
Operating temperature	Less than 200

Tach Signal

Without the tach signal to the electronic control unit the engine will not start. This signal is used by the ECU to synchronize the fuel injectors to the rotation of the crankshaft. If the engine runs, the signal is being received by the ECU and there is no need to test the ECU tach input.

If a test is required, connect a digital tachometer to the tach lead input of the ECU and crank the engine. If the tachometer reads anything other than zero, then the signal is being received by the ECU. If the tachometer reads zero, connect it to the negative terminal of the coil. If the tachometer still reads something other than zero, repair the wire from the coil to the ECU. If it now reads zero, repair the primary ignition system.

ECU Harness Tach Terminal Specifications

Application	ECU Terminal Number
Volvo	
1982-84	1
1985-90	1

Throttle Switch

Since the troubleshooting and adjustment procedures are the same, follow this procedure for testing the throttle switch.

There are three terminals on the LH II-Jetronic throttle switch. One terminal is common, one is for closed throttle and the third is for wide-open throttle. Disconnect the throttle switch harness and connect an ohmmeter between the common terminal and the wide-open throttle contact. Slowly open the throttle; just before you reach wide-open throttle the ohmmeter should indicate zero ohms. Now close the throttle slowly. Immediately off of wide-open throttle the ohmmeter should indicate infinite ohms.

Leave the ohmmeter lead connected to the wide-open throttle terminal and connect the other lead to the closed-throttle terminal. With the throttle closed the resistance should be zero ohms. Crack the throttle open a few degrees and the ohmmeter should read infinity. If these conditions are not met, adjust the throttle switch. If these conditions *cannot* be met through adjustment, the throttle switch or throttle switch circuit is defective.

Throttle Switch Contacts

Application	Throttle Position	
	Idle (terminal number)	Common (terminal number)
Volvo		
1982-84	NA	
1985-90	12	Orange, number 3

Lambda Sensor

To test the Lambda sensor, make sure the engine is warmed up and running for two minutes prior to

beginning the testing. Then, connect a high-impedance voltmeter to the Lambda sensor input to the ECU. The voltmeter should be continuously moving back and forth between about zero and 1 volt.

If the voltage is steady (again, ensure that the engine is warmed up) at about 0.5 volt, replace the sensor.

If the Lambda sensor voltage is stuck high, check the fuel pressure, coolant temperature sensor, throttle switch, any leaking injectors, leaking cold-start injector and the evaporative canister system. If all of these circuits and systems are good, then replace the Lambda sensor.

If the Lambda sensor voltage is stuck low, check the fuel pressure, and check for vacuum and exhaust leaks. If everything looks good, replace the Lambda sensor.

When replacing the Lambda sensor it is important to know why it went bad. If the sensor is covered with a dark, sooty coating, replace the sensor as it is carbon contaminated. This could be the result of a rich-running engine. Mount the sensor in a vise; connect a high-impedance voltmeter to the sensor output and ground the voltmeter to the vise. Heat the sensor with a propane torch. The voltmeter should climb to over 0.6 volt in fifteen seconds. If it does not, it is silicone contaminated. Remove the propane flame from the sensor. The voltage should drop to less than 0.4 volt in six seconds. If it does not, then the sensor is lead contaminated. Whatever the source of the contamination, if it is not eliminated, the new Lambda sensor will develop the same problem.

If soot is the contaminant, check the fuel pressure, coolant temp sensor, throttle switch, any leaking injectors, leaking cold-start injector and the evaporative canister system.

If lead is the contaminant, then there has been leaded fuel or a leaded additive used in the engine and the practice must stop to prevent future damage.

If silicone is the problem, it is likely that an engine repair was done with RTV silicone. Wait until the silicone is fully cured before replacing the sensor.

Lead, silicone and soot contamination cannot be effectively cleaned from a Lambda sensor.

Lambda Sensor ECU Pin Number

Application	Pin Number
Volvo	
1982-84	24
1985-90	20

Auxiliary Air Valve

Testing the auxiliary air valve can be done in two different ways. The first is a functional test. To begin, start the engine cold. If the engine speed slows over a period of two to three minutes, then the auxiliary air valve is OK. If there is no change in the speed of the engine as it runs, remove the valve and inspect to see if the passage is closed. If the engine has been run for several minutes, the passage should be closed. If the passage is open, ensure that there is power and a good ground on the harness to the auxiliary air valve. If there is, replace the valve. If not, place it in the freezer for fifteen to twenty minutes. Then remove it and recheck. If the passage is still closed, replace the valve.

Idle Stabilizer

With the engine warmed up and idling, disconnect the idle stabilizer. The rpm should drop significantly (if the engine dies, the idle air by-pass and/or the minimum air must be adjusted). Reconnect the idle stabilizer and ground the blue and white (green and red on Saabs) wire at the test terminal. The rpm should increase. If these tests fail, confirm that there is power on the brown wire back to the fuel pump relay. Connect a dwell meter set on the four-cylinder scale to the white wire and confirm that there is a signal going to the solenoid. If a pulse is present, the reading will be something other than zero or 90.

What to Test, and When

As mentioned earlier in this chapter there are many components other than those of the fuel-injection system that can cause the following symptoms. *Always* begin troubleshooting by confirming that the basic engine, ignition and intake system are in good shape.

No-Start, Fuel Pump Not Working

Test the fuel pump circuit including the fuse, relay, wiring and fuel pump itself.

No-Start, Fuel Pump Working

Test the main relay system and its power supply to the ECU. Confirm that there is a good ground for the ECU. If the ignition system is delivering a good spark, if there is a good power supply and ground to the ECU, and if the ECU is receiving tach pulses from the primary ignition system and the injectors still fail to pulse, then replace the ECU.

Starts Cold but Dies When Key Is Released

Verify that the ECU is receiving pulses from the primary ignition system. What may be happening is that the engine is starting off of the cold-start injector, then dying as soon as the key is released and the cold-start injector shuts off.

Stalls When Cold

Begin troubleshooting this problem by inspecting the auxiliary air valve. Start the engine cold and remove the hose on the intake manifold side of the auxiliary air valve and allow it to draw air. If

the engine speed increases significantly, replace the auxiliary air valve. (*Note*: A minor increase in rpm is normal when performing this test.)

Later LH-systems use the idle air stabilizer to provide the fast idle function.

The coolant temperature sensor is also critical to cold engine operation.

Misfire or Erratic Idle

Inspect the circuits and sensors for the coolant temp sensor. Also inspect the connector tube that runs from the intake manifold to the air mass meter for evidence of false air.

If all of the above test OK, perform the injector flow test. If the flow test checks out satisfactorily, then something more basic has been missed.

Misfire at Cruise

Perform a fuel pressure-volume test. Notice especially if there is a drop in fuel pressure that coincides with the misfire.

If the fuel pressure remains constant, test the air mass meter, coolant temp sensor and throttle switch circuits.

If these tests do not yield the source of the problem, begin the test procedure again as something has been missed.

Lack of Power

The most likely cause of this symptom related to the fuel-injection system is low fuel pressure. Perform the fuel pressure-volume test and observe any loss of pressure.

If the fuel pressure tests adequately, test the circuits for the coolant temp sensor and the air mass meter. If these circuits and sensors test to specifications, then perform the injector flow test. Clean or replace the injectors as necessary.

If all of these test positively, then begin the test procedure again.

Stalls on Deceleration

Begin this test procedure by inspecting the hoses and wiring for tightness that may cause an intermittent disconnection as the engine torques and stresses back and forth. Next, check the throttle stop adjustment and curb idle speed.

Runs Rough, Smoking

Perform the fuel pressure-volume test. Inspect the circuits for the air mass meter, coolant temp sensor and the injectors. If these test out, then perform the injector flow test. If everything is working, something has been missed.

Poor Mileage

Perform the fuel pressure-volume test. Inspect the circuits for the air mass meter, coolant temp sensor and the injectors. If these test well, then perform the injector flow test. If everything checks out, something has been missed.

Misfire under Load

Perform the fuel pressure-volume test. Inspect the circuits for the air mass meter, coolant temp sensor and the injectors. If these test OK, then perform the injector flow test. If everything still tests OK, then something has been missed.

Trailer Hitching

This symptom gives the driver the feeling that there is a trailer with a tongue designed for a 2 in. ball hooked up to a car with a 1⅞ in. ball.

Perform the fuel pressure-volume test. Inspect the circuits for the air mass meter, coolant temp sensor and the injectors. If these test OK, then perform the injector flow test. Also test the throttle switch or vacuum switch. If everything is working, something has been missed.

Idle Speed Too High

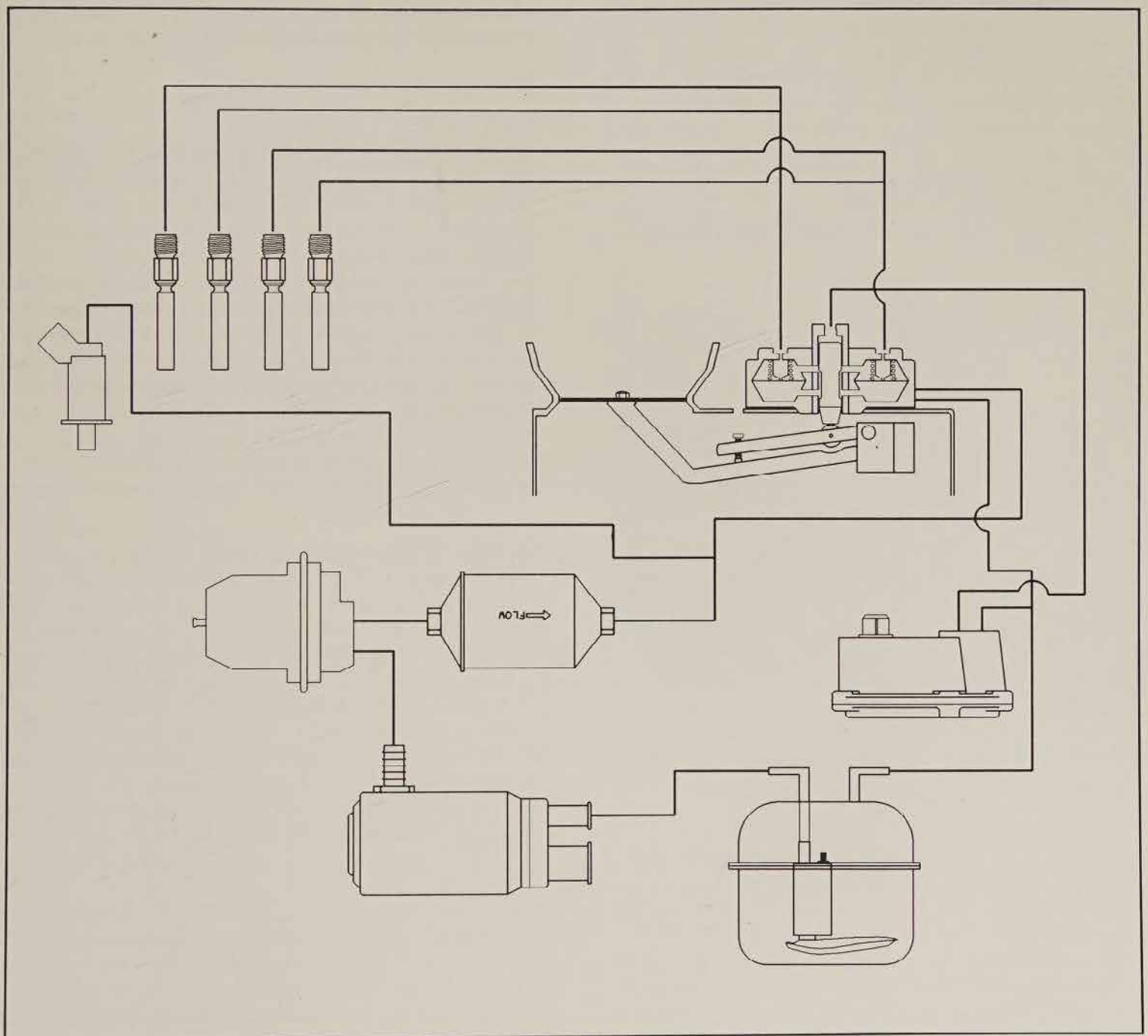
Check and adjust as necessary the throttle stop and curb idle speed.

Idle Speed Too Low

Check and adjust as necessary the throttle stop and curb idle speed.

9

K-Jetronic Fuel Injection



The K-Jetronic system is a mechanical fuel-injection system. Introduced in 1974, the K-system is sometimes called Continuous Fuel Injection because once the engine starts, fuel is sprayed through the injectors continuously until the engine is shut off.

The K-Jetronic system owes its name to the German word *kontinuerlich* which means continuous. Thus, the K-system is often referred to as the Continuous Injection System, or CIS. The CIS is a mechanical system that sprays fuel through the injectors continuously. Although this may seem like a waste of fuel, the fuel is sprayed at a minimal rate to provide only what is needed for each cylinder to have the proper air-fuel ratio. When the intake valve closes, fuel begins to accumulate in the intake runner leading to that cylinder. Opening the intake valve results in a volume of air rushing into the intake runner and pulling the fuel along with it into the combustion chamber.

The K-Jetronic system was introduced in 1974 as a replacement for Bosch's technologically aging mechanical fuel-injection system developed in the 1930s and refined through the early 1970s. Although simple to troubleshoot, the K-system has been viewed as a nemesis by many technicians. A unique feature of this system is that rather than being controlled by electronics, the control of injection is through the hydraulic action of the fuel passing through the system.

K-Jetronic fuel-injection system applications include the following:

Audi
Fox
100
4000
5000
BMW 320i
Mercedes-Benz
6.9 liter
280
450
Porsche
Turbo Carrera
911 series
924
928
Saab
99
900
Volkswagen
Dasher
Jetta
Rabbit
Rabbit pickup
Scirocco
Volvo
140
240
260

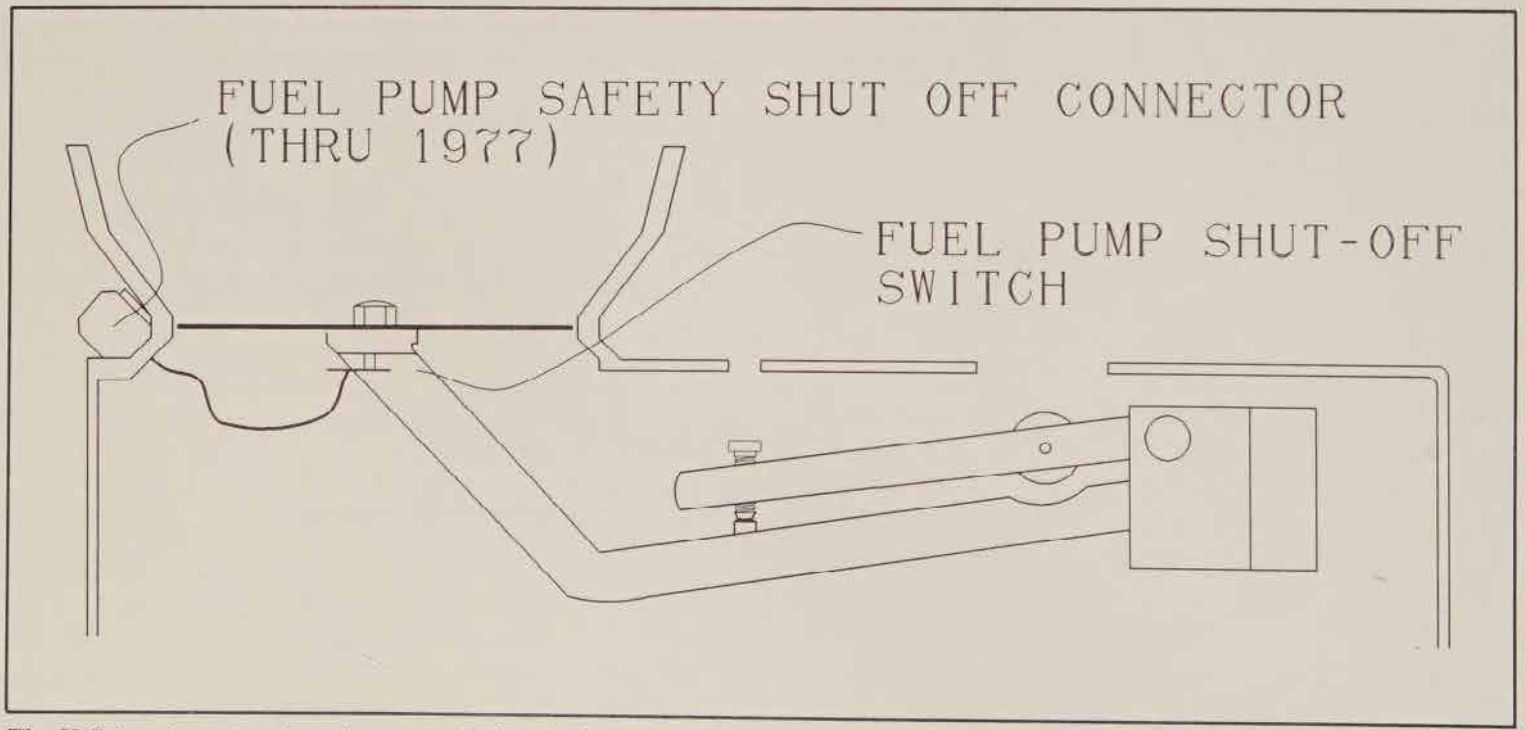
Hydraulic Theory

To easily troubleshoot the K-system one must understand two basic principles of hydraulics: (1) Pumps do not create pressure, they only supply a volume. Both wanted and unwanted restrictions in the system create the pressure. (2) Any restriction holds pressure back upstream of the restriction and causes the pressure to drop downstream.

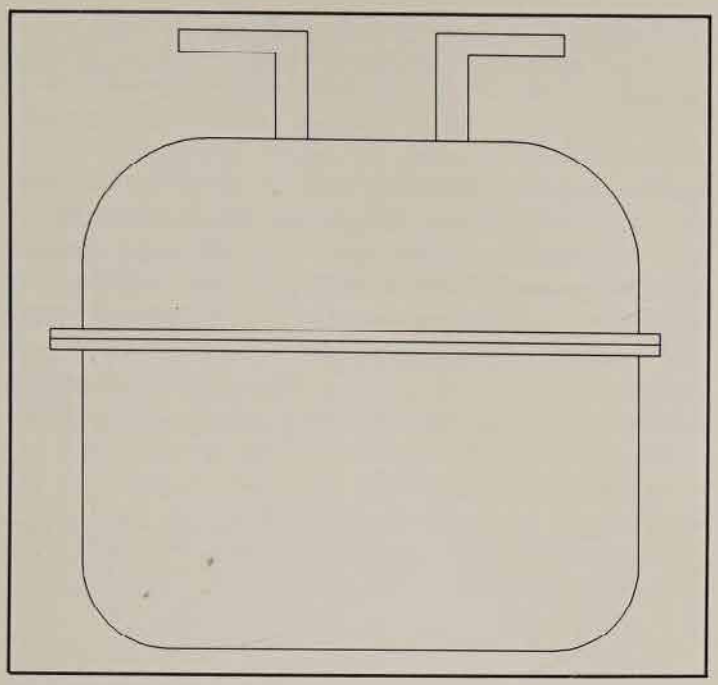
K-Jetronic Components

Fuel Tank

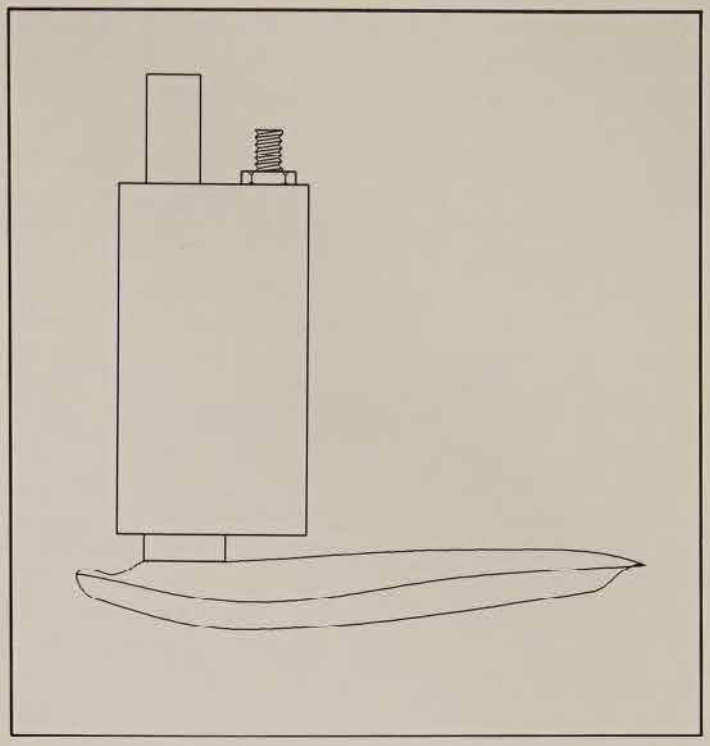
In electronic fuel-injection systems the design of the fuel tank is not critical. However, there are times when as much as 90 percent or more of the fuel pumped by the fuel pump will pass through the engine compartment, be warmed and returned to the tank unused by the engine. This warm fuel needs to combine evenly with the colder fuel sitting in the tank. For that purpose the K-Jetronic fuel tank is designed to be narrow and deep. Baffling around the fuel pickup also reduces the possibility of fuel starvation when the car is low on fuel.



The K-Jetronic system's main sensor is the airflow sensor. This unit consists of a disc, or airflow sensor plate, that lifts as air flows into the engine. Model years 1977 and earlier incorporated a fuel pump switch in the airflow sensor. This switch was supposed to shut off the fuel pump if the engine died as a result of a fuel line being ruptured in an accident.



The fuel tank in the K-system is usually narrow and deep. This design is to improve the even mixing of fuel as warm fuel from the engine compartment returns to the tank.



Most applications since 1977 use a pre-pump in the fuel tank. Its purpose is to push the fuel to the main pump. On the end of the pre-pump is the in-tank filter.

In-Tank Filter

Located on the end of the fuel pickup or in-tank fuel pump is a sock-style filter. This filter is relatively coarse and is designed specifically to prevent damage to the fuel pump from rust, metal, dirt and sand. When the filter becomes plugged it can result in a loss of volume to the extent that system pressure will drop, causing a loss of power, hesitation and stalling.

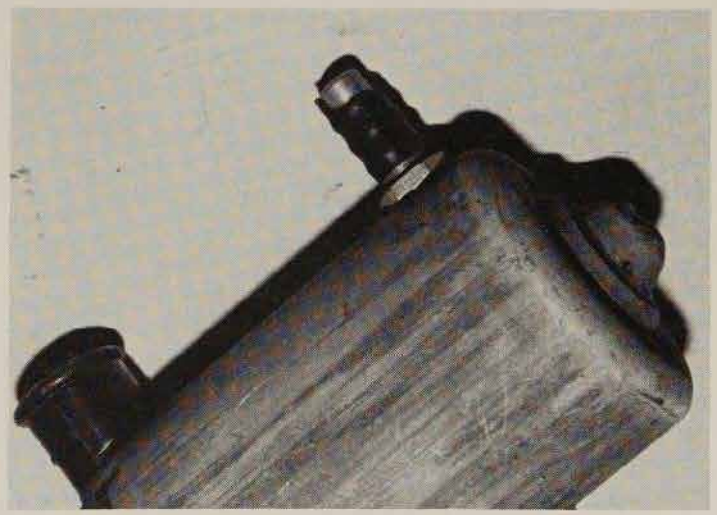
Pre-Pump

The pre-pump is used on most post 1976 applications that do not have the main pump located in the fuel tank. This pump's job is to ensure a steady volume of fuel to the chassis-mounted main pump to prevent vapor locking. The pump is fused separately from the main fuel pump and on applications such as the 1976-80, the fuse is not located in the fuse panel but rather under a plastic cover beneath the carpet in the trunk.

When the pre-pump fails, the most common symptom will be a severe stumble or hesitation off idle when the fuel level is below half a tank, especially on hot days.

Fuel Pump

The fuel pump used by the K-Jetronic system is a high-speed electrically driven roller vane pump. This type of pump delivers a high and relatively even volume to the fuel system, allowing the system to maintain an even and consistent pressure. The pump can be located in the fuel tank or on the chassis. If located in the tank, there will be no pre-pump.

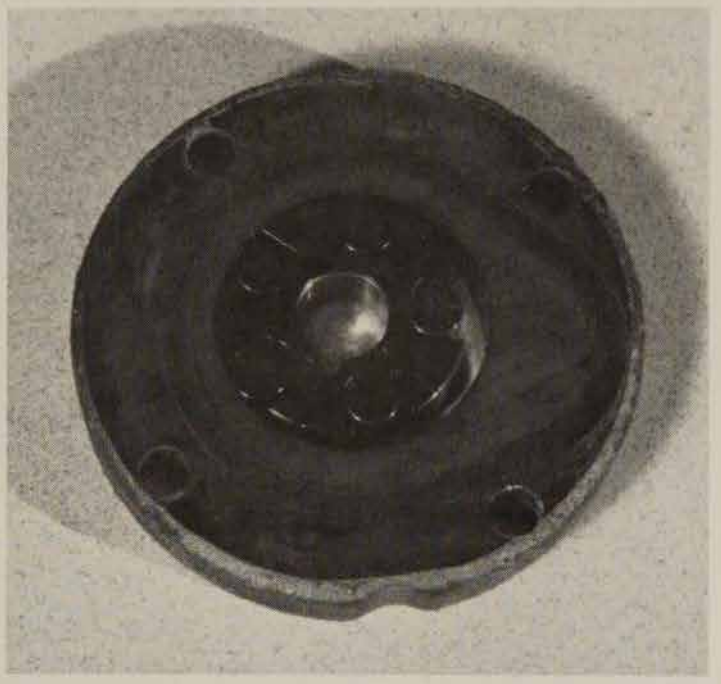


The K-Jetronic fuel pump always has a check valve. Should the check valve fail to hold pressure after the engine is shut off, the engine will be difficult to start when hot.

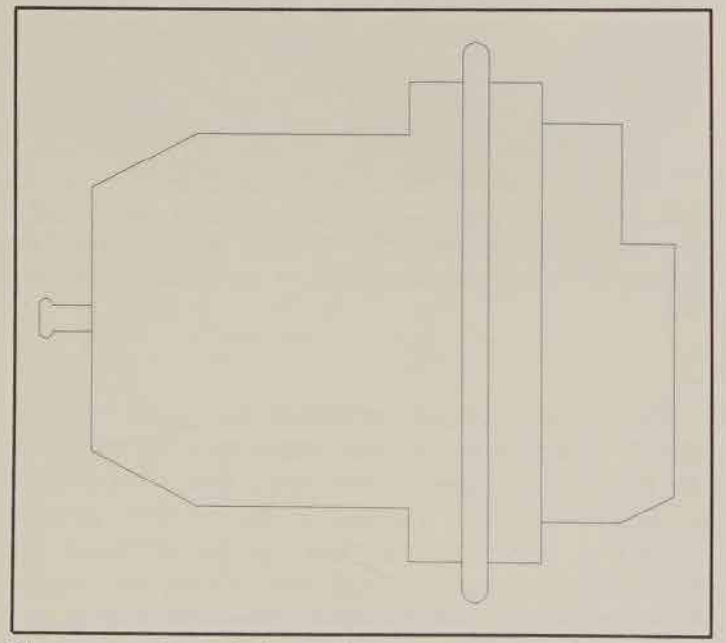
Two different safety systems are used, depending on model year, to shut down the fuel pump in the event of a ruptured fuel line. From 1974 to 1977 a safety switch is located in the airflow sensor. Should a fuel line rupture, in an accident for instance, the engine would die. When the engine dies air stops flowing into the engine and the airflow sensor plate drops, grounding a switch that turns off the fuel pump relay and shutting down the fuel pump. The problem with this method is that should the car come to rest inverted, the

airflow sensor plate will not drop to the rest position and therefore the fuel pump would continue to run even after the engine dies.

Later models utilize a relay that receives a signal from the primary ignition system. When the engine dies, the primary ignition system shuts down; the relay stops sensing the signal and shuts off the fuel pump.



This is a fuel pump roller cell. The center pumping section is about the size of a quarter. The 3500 rpm speed of the pump enables the pump to deliver 0.5 gpm at over 100 psi.



The accumulator is located near the fuel pump. It serves two functions: to reduce the noise created by pulsations of pressure from the fuel pump, and to maintain rest pressure when the pump is shut off.

Typically, a defective fuel pump or fuel pump wiring system manifests itself as a no-start problem.

Accumulator

The accumulator is located close to the fuel pump. It consists of a spring-loaded diaphragm in a can and serves two purposes in the fuel system. First, the accumulator dampens or smooths out pressure pulsations created by volume fluctuations from the fuel pump. Its second job is to help maintain pressure in the system after the engine has been shut off and the fuel pump has shut down.

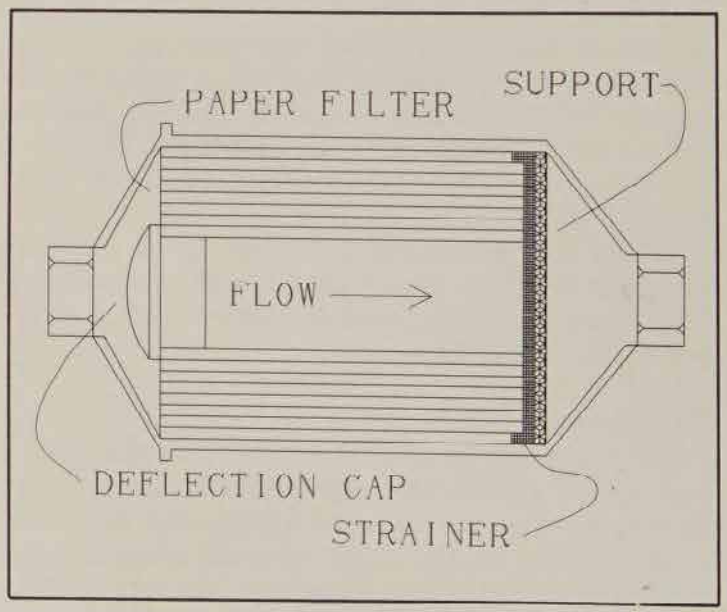
The most common failure of the accumulator is a ruptured diaphragm. On most applications, if the diaphragm ruptures fuel will leak out the back of the accumulator. Some applications have a hose connecting the back or dry side of the accumulator to the fuel tank.

If the accumulator diaphragm ruptures, system pressure will drop to the point where the engine will shut off and not restart.

Fuel Filter

The fuel filter is important to an electronic fuel-injection system, but not nearly as important as it is to the CIS system. The injectors and the fuel distributor have some tiny openings and orifices. Consequently, very small particles can collect, causing severe restrictions in the fuel system.

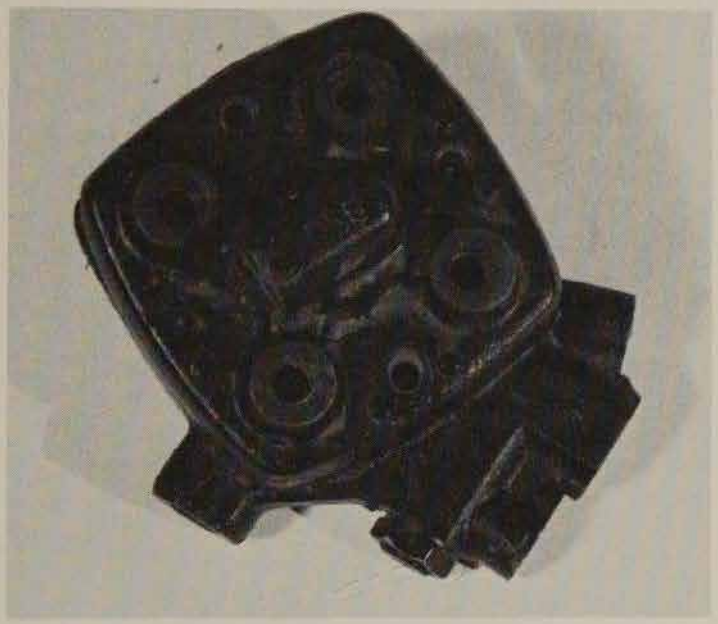
The fuel filter on the K-Jetronic is usually in plain sight in the engine compartment but probably has not been changed since the car has left the factory. The fuel filter is the only real protection that the injection system has against internal contamination from dirty fuel. The filter should be replaced every time the spark plugs are replaced.



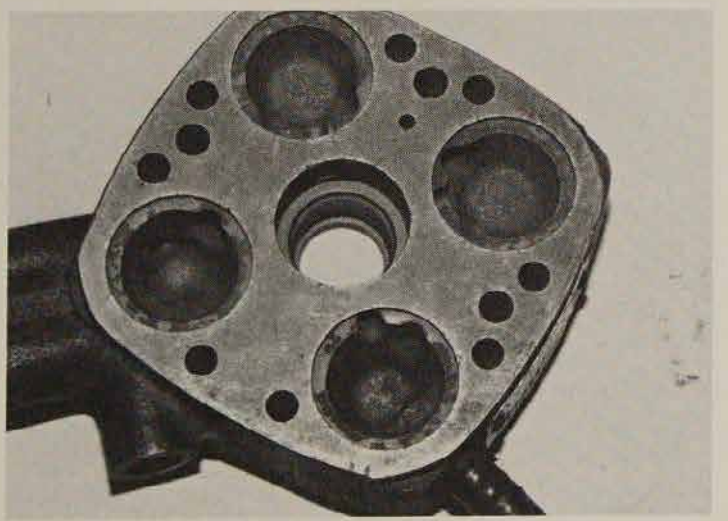
The fuel filter is a paper mesh filter in a metal can. This filter is capable of filtering to 10 microns. A restricted filter can cause poor power and dying.

Fuel Distributor

The fuel distributor is the heart of the K-Jetronic system. It is divided into two sets of chambers, the lower chambers and the upper chambers. These chambers are separated by a thin stainless-steel diaphragm which seals an orifice that protrudes down from the top of the upper chamber. A spring in the upper chamber applies pressure against the diaphragm, forcing it downward and opening the orifice when the pressures in the upper and lower chambers equalize. This pair of chambers is known as a differential pressure regulator. There is a differential pressure regulator for each engine cylinder.

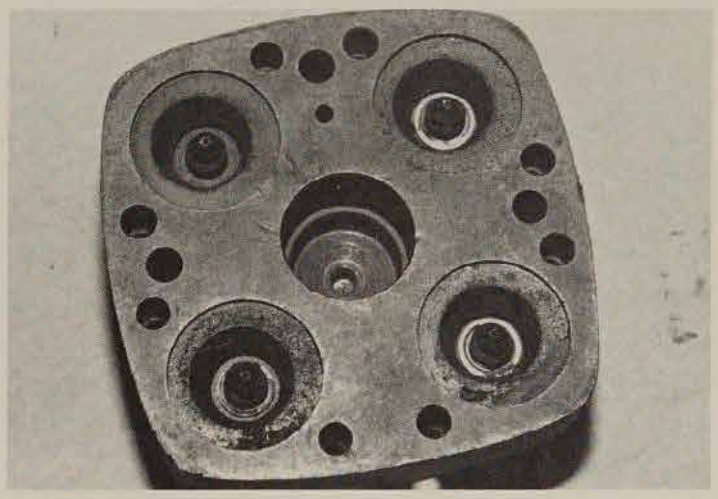


The fuel distributor routes and meters the fuel to the injectors. This high-precision device is located on the airflow sensor assembly.

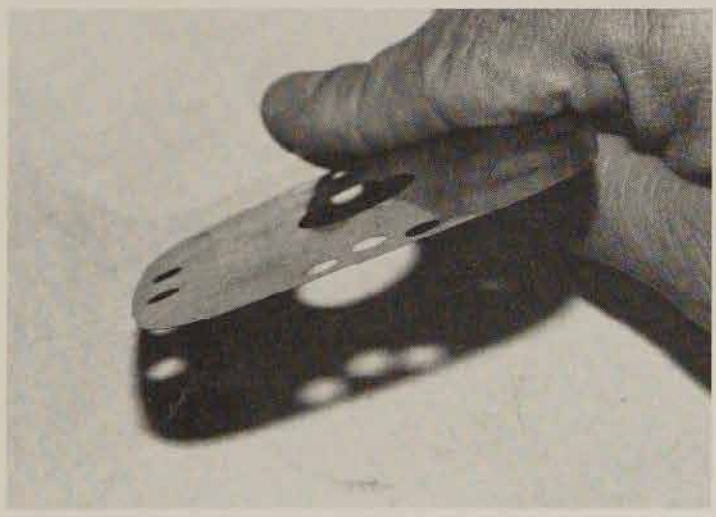


Fuel enters the fuel distributor through the lower chambers. These are the lower chambers of a four-cylinder engine. Notice that there is one lower chamber per cylinder.

With the fuel pump running but no air flowing into the engine, the pressure in the lower chambers is 1.5 psi higher than the pressure in the upper chambers. This pressure differential works against the tension of the spring in the upper chamber. In the center of the fuel distributor is the metering cylinder. In the center of the metering cylinder is the control plunger. A set of holes in the lower portion of the metering cylinder allows fuel to flow along a tapered area in the control plunger toward the upper chambers. If there is no air flowing into the engine the plunger will be in its lowest position, allowing no fuel to flow into the upper chambers. As the airflow sensor plate is lifted by air entering the engine, the control plunger is lifted as well. As the plunger is lifted, metering slots adjacent to the upper portion of the



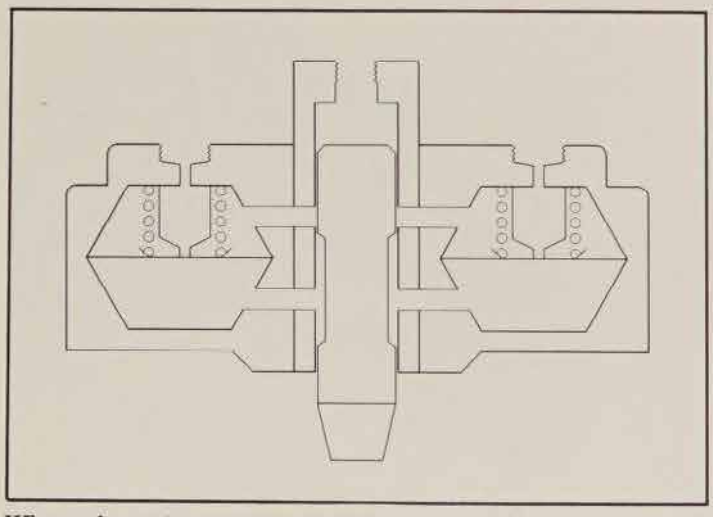
Located in the upper chambers are the injector valve orifices which control the flow of fuel to each injector.



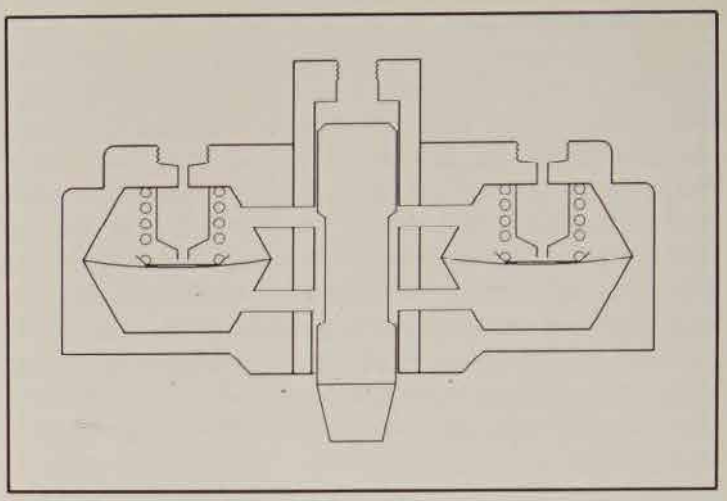
This thin stainless-steel diaphragm separates the lower chambers from the upper, and provides a seal for the injector valve orifices to shut off fuel when fuel should not be flowing to the injectors. Together with the upper and the lower chambers the diaphragm forms the differential pressure regulators.

control plunger are opened, allowing fuel to flow from the lower chambers into the upper chambers. The pressures in the upper and lower chambers equalize, allowing the springs to push the diaphragm downward, in turn allowing fuel to flow to the injectors. The quantity of fuel reaching the injectors is governed by how much the control plunger has been lifted and how much the metering slots have been opened.

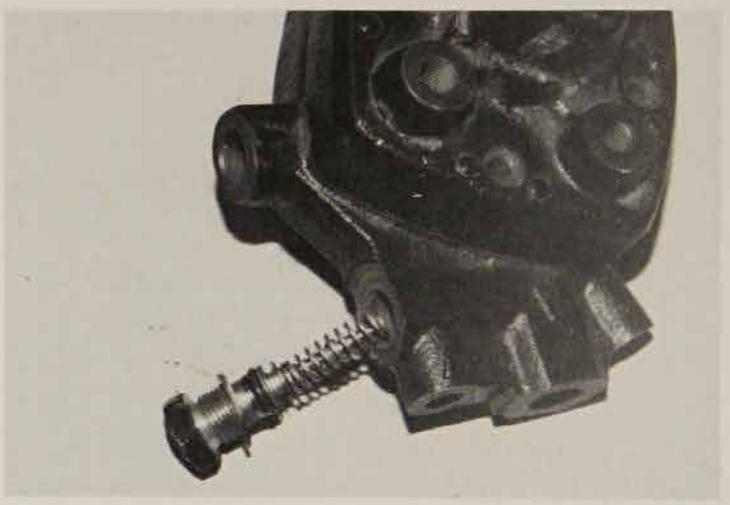
The control cylinder and plunger sit in the large hole in the center of the fuel distributor. These components are machined to a perfect match.



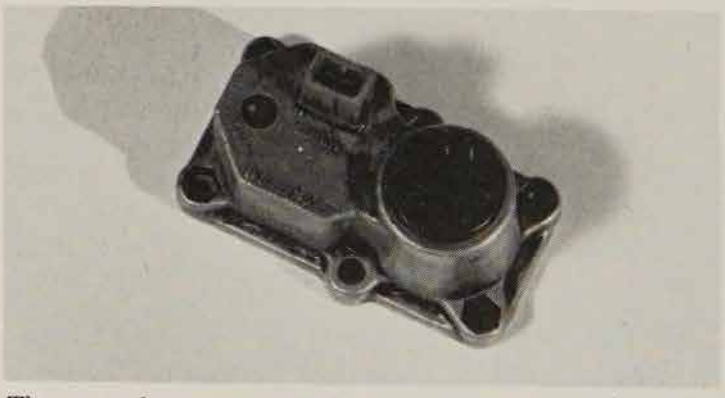
When there is no air entering the engine, the airflow sensor plate is in its rest position. The plunger keeps the fuel in the lower chambers from flowing into the upper chambers. As a result, the pressure in the lower chambers is greater than the pressure in the upper chambers and the diaphragm is forced upward, sealing the injector valve orifices.



When air enters the engine, the airflow sensor plate lifts the control plunger and fuel flows from the lower chambers into the upper chambers. The pressures in the two chambers equalize and the diaphragm deflects downward, opening the injector valve orifice and allowing fuel to flow to the injectors.



The system pressure regulator is located in the lower chamber section of the fuel distributor. System pressure can be adjusted by removing or adding shims.



The control pressure regulator, or warm-up regulator, is located in a warm place on the engine. When the engine is cold the control pressure regulator lowers control pressure to around 20 psi. This lower pressure allows greater movement of the plunger which provides for a richer mixture when the engine is cold.

Rough running and poor power are symptoms associated with a defective fuel distributor.

System Pressure Regulator

The system pressure regulator is located in the side of the fuel distributor. Its primary task is to control system pressure at about 5 bar (1 bar = 15 psi), with some variation from one application to another. The secondary task of the regulator is to close off the return line to the tank when the engine is shut off in order to maintain residual or rest pressure.

The design of the system pressure regulator prior to 1978 did not seal rest pressure adequately. Later systems use a push valve with rubber O-rings to increase the valve's sealing ability.

System pressure can be adjusted to a small degree by adding or removing shims, thus altering the spring tension in the pressure regulator. These shims are not typically a stock item for most dealerships, however.

Failure of the system pressure regulator normally results in a dramatic rise or drop in system pressure. Either condition will cause the engine to run extremely lean. Typical symptoms include backfiring, stalling, rough running and poor power.

Control Pressure Regulator (or Warm-Up Regulator)

There is a tiny hole in the stainless-steel diaphragm that separates the lower from the upper chambers of the fuel distributor. This hole allows fuel to flow from the lower chambers into an area above the control plunger. The control pressure regulator controls the pressure in this area, limiting the degree to which the control plunger can be lifted for a given amount of airflow into the engine. Limiting the movement of the control plunger in turn limits the richness of the air-fuel ratio. When the engine is cold the control pressure will be relatively low (around 1.5 bar), allowing greater movement of the control plunger and therefore a richer mixture. As the engine warms up the control pressure increases (to about 3.5 bar), leaning out the air-fuel ratio.

Defects in the control pressure regulator will typically cause cold-starting problems, hot-starting problems or rough running.

Injectors

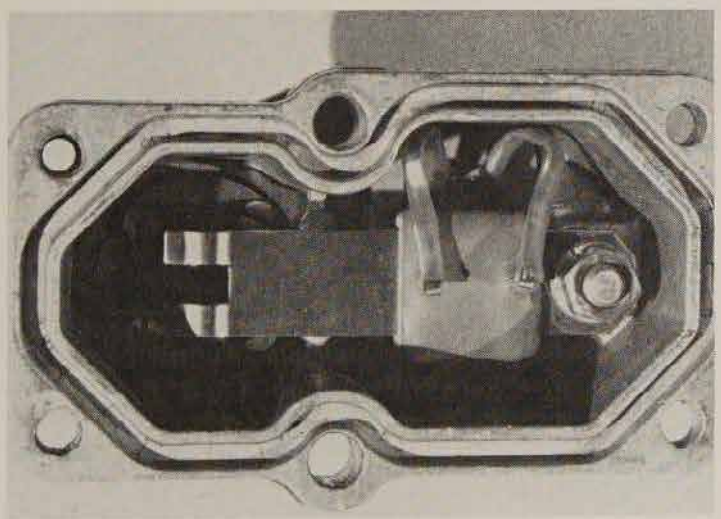
The CIS system uses pressure-opened injectors. When the pressure supplied by the upper chambers of the fuel distributor reaches approximately 3.0 bar (45 psi), the injectors open and spray fuel just above the intake valves continuously. A small disc located just above the valve in the injector vibrates as the fuel passes across it. This helps to atomize the fuel and is responsible for the characteristic hum from the injectors.

These injectors are so simple in design that nothing ever goes wrong with them, except for restrictions and leaking.

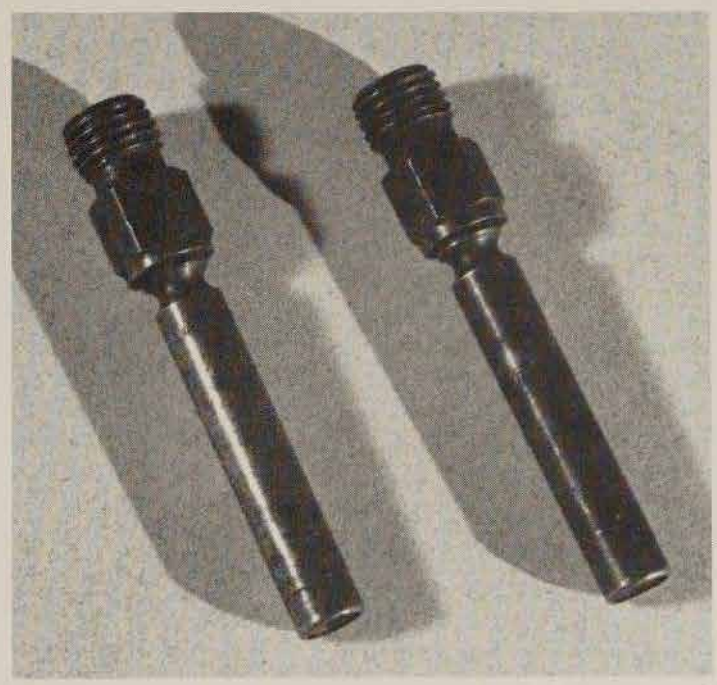
A defective injector will result in erratic engine operation, poor power and increased fuel consumption.

Cold-Start Injector

Also connected to system pressure is a solenoid-operated valve known as the cold-start injector. Since the earliest applications of the K-system were all four-cylinder, the cold-start valve picked up the moniker fifth injector. It stuck in some circles, even for six- and eight-cylinder applications.



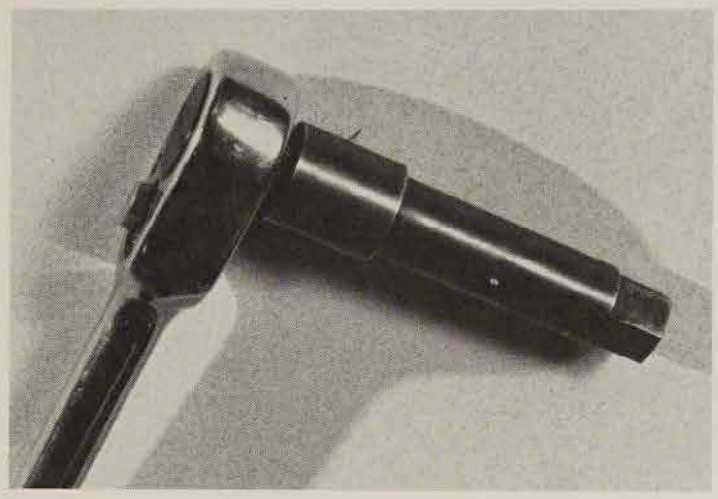
An electric heater in the control pressure regulator slowly heats a bimetal strip. This allows the control pressure to increase to about 50 psi when the engine is warmed up. The higher control pressure limits the travel of the control plunger, leaning out the mixture.



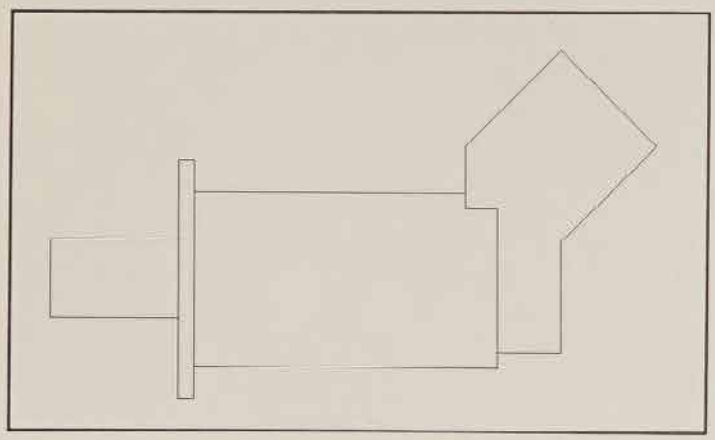
The K-Jetronic injectors are simple, pressure-activated pop-off valve injectors. When pressure behind the injectors reaches around 50 psi the injectors will open and spray continuously until the engine is shut off.

The cold-start injector receives battery voltage whenever the starter is engaged, and is grounded through a device known as a thermo-time switch. The thermo-time switch is a temperature-sensitive bimetal switch designed to provide a ground for the cold-start injector when the temperature of the engine is less than 95 deg. F. A second circuit in the switch is an electric heating element intended to heat the bimetal as the engine is being cranked. The result is that the cold-start injector should operate only when the engine is being cranked, the temperature of the engine is less than 95 deg., and for a maximum of five to twelve seconds.

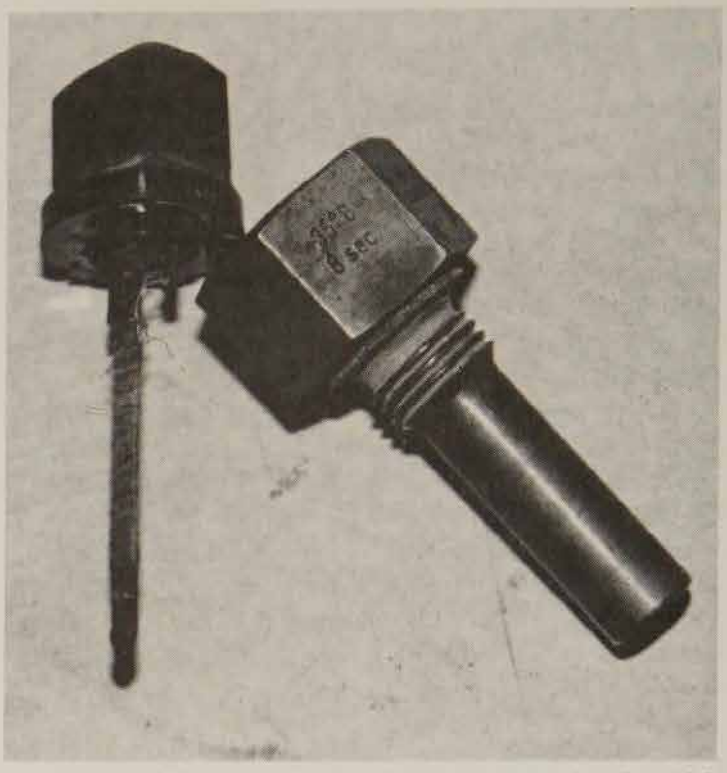
Two of the most common symptoms of a cold-start injector problem are hard starting when cold because it is not operating, and a leaking injector, which can cause an extremely rich running condition.



Audi and Volkswagen use a screw-in mount in the cylinder head for the injectors. This mount is prone to cracking with heat and time, however. The tool shown can be used to remove and replace these mounts. An alternative is a bolt with a 13 mm head.



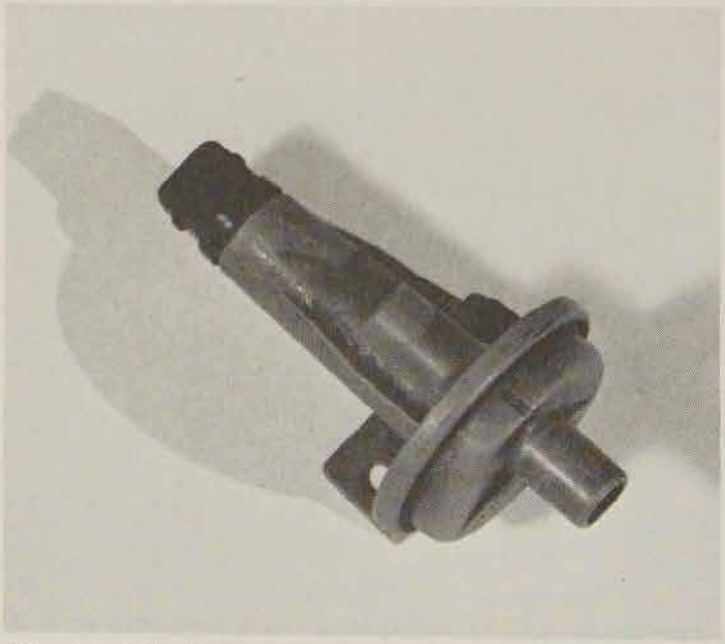
The cold-start injector is a solenoid operated valve located in an area of the intake manifold common to all cylinders. When the key is in the crank position the cold start injector receives 12 volts from the starter solenoid or ignition switch.



The thermo-time switch provides a ground for the cold-start injector. This switch was rated at 35 deg. Celsius (95 deg. F.) for eight seconds. You will find this marked on the switch. Therefore, it would allow the cold-start injector to spray only when the temperature of the engine was below 95 deg. and only for a maximum of eight seconds.

Auxiliary Air Valve

The auxiliary air valve is used to allow air to bypass the throttle plates while the engine is warming up to permit a higher idle speed. The valve consists of an electrically heated bimetal valve.



The fast-idle function is provided by the auxiliary air valve. This valve should be open when the engine is cold to increase the idle speed, and closed when the engine is warm.

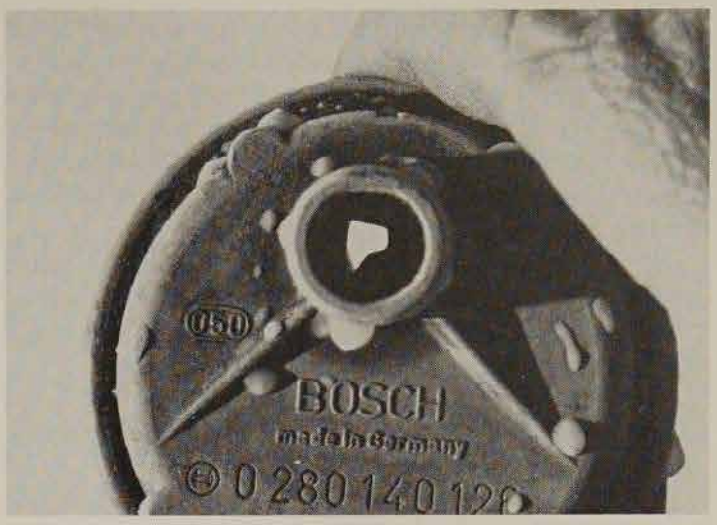
When the engine is first started the valve will be open. As the engine runs, the bimetal valve is heated by the electric element, slowly closing off the auxiliary air by-pass and reducing the volume of air to the engine. Reducing the air entering the engine reduces the idle speed.

Idle Air By-pass

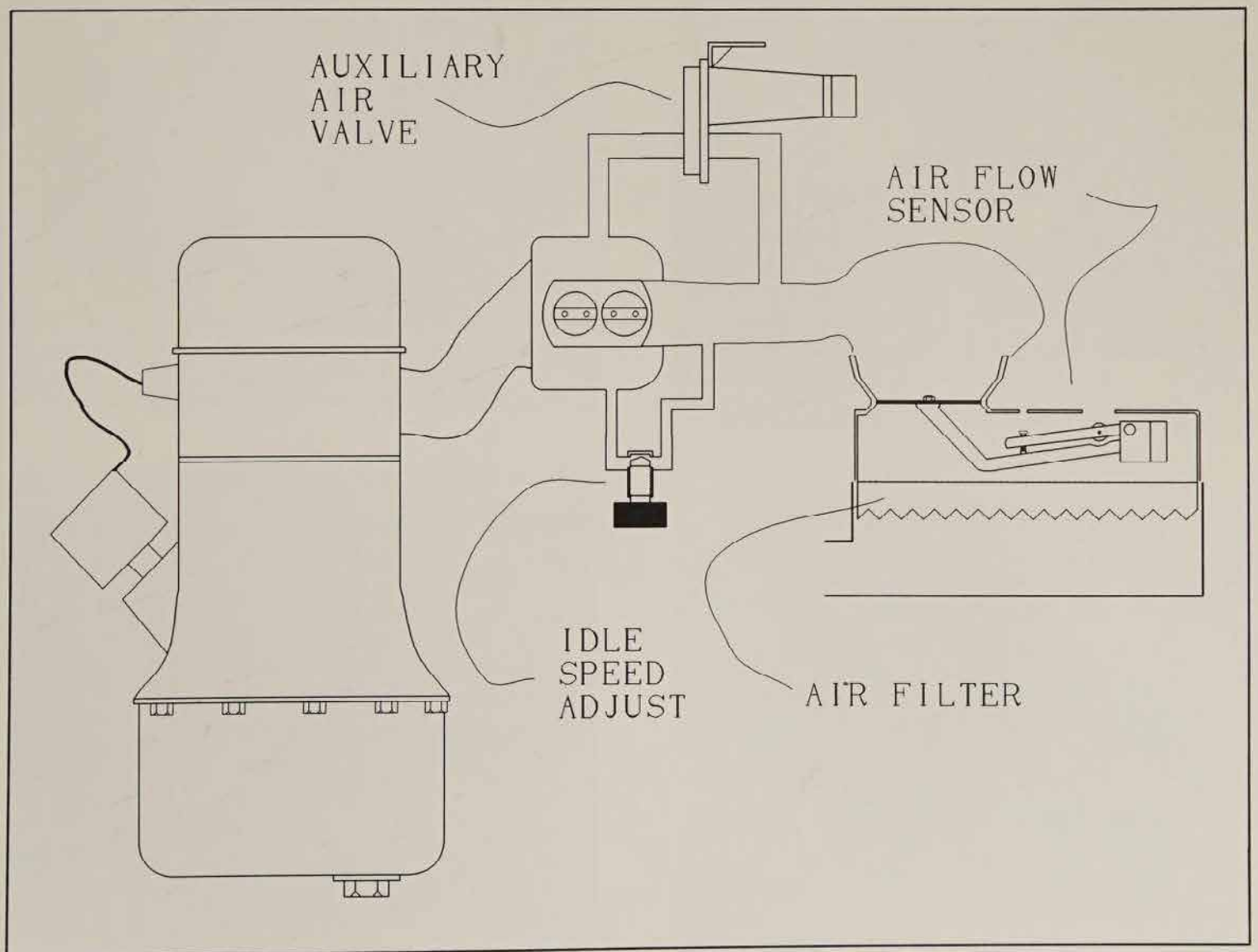
Unlike a carbureted engine, the K-Jetronic system does not use the throttle stop screw to adjust the idle speed. Instead, it uses a by-pass channel similar to the auxiliary air by-pass. Unlike the auxiliary air by-pass, however, the idle air by-pass is adjusted by the technician. Curb idle speed should be changed only by adjusting the idle air by-pass and *never* by using the throttle stop screw.

Airflow Sensor

A reference was made earlier in this chapter to the airflow sensor lifting the plunger. The airflow sensor consists of a disc called an airflow sensor



A simple test of the auxiliary air valve is to remove it from the car and place the valve in the freezer for fifteen minutes. When removed from the freezer the valve should be open like this one. If it is, install it back on the car and run it for five minutes. The valve should now be closed.



The idle air by-pass, not *the throttle stop screw, is used to adjust the curb idle speed. Be sure that the auxiliary air valve or slide has completely closed before adjusting curb idle. Incorrect adjustment of the throttle stop can result in rough idle and surging.*

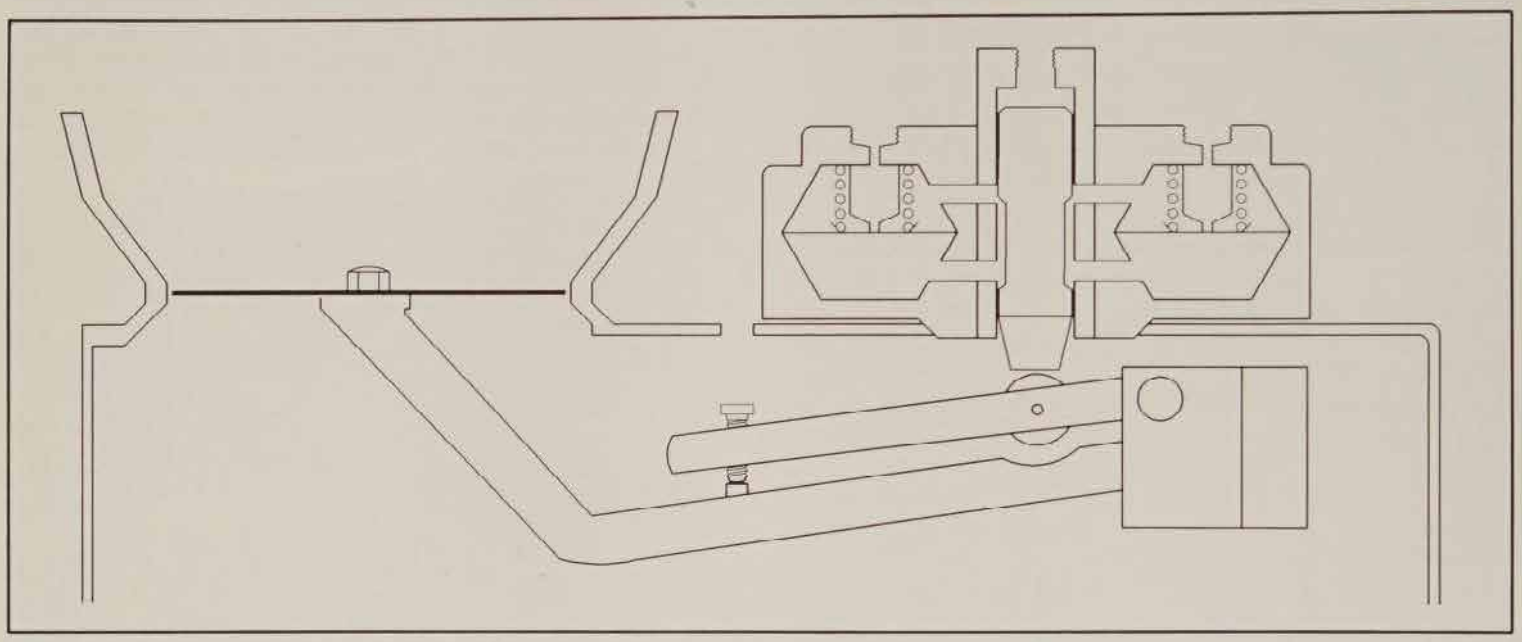
plate that is mounted on a counterweighted lever. The plate sits in a venturi. When the engine is started and air begins to flow into the engine, the airflow sensor plate is lifted. The lever rotates on the fulcrum and a roller lifts the control plunger. The lever is in two pieces, with a screw that allows for the adjustment of air-fuel ratio.

Early models incorporate a safety switch that shuts off the fuel pump when the air stops flowing into the engine and the airflow sensor plate comes to rest.

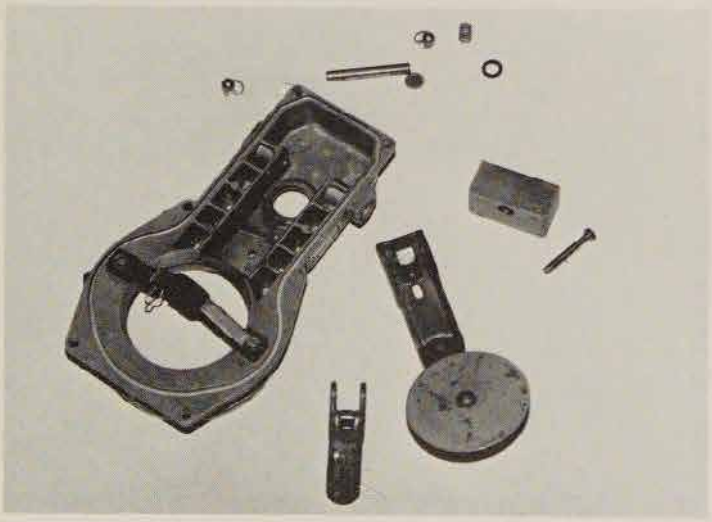
Airflow sensors on V-6s and V-8s are pulled down by air flowing into the engine. The control plunger on these applications is located on the opposite side of the fulcrum from the sensor plate so that as the air flowing into the engine presses down on the plate, the plunger is lifted.

K-Jetronic Tune-Up Adjustments

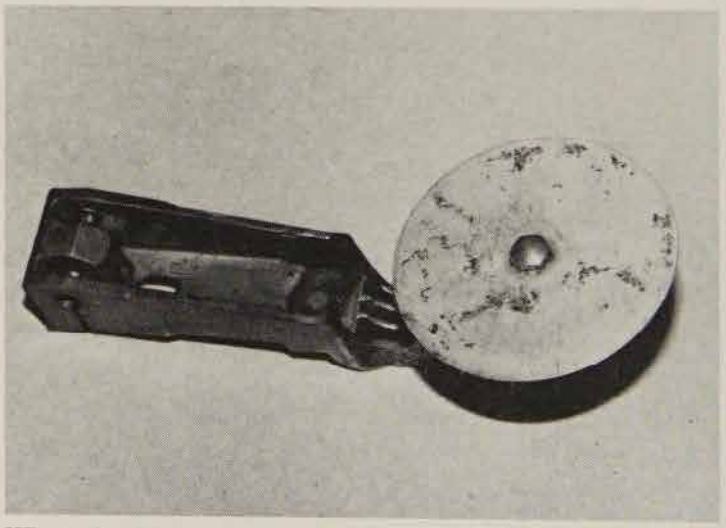
For most engines equipped with the K-Jetronic system, all of the standard ignition adjustments are made in the same way as for a carbureted engine. Spark plug gap has the same relevance, as well as ignition timing, point dwell, curb idle and so on.



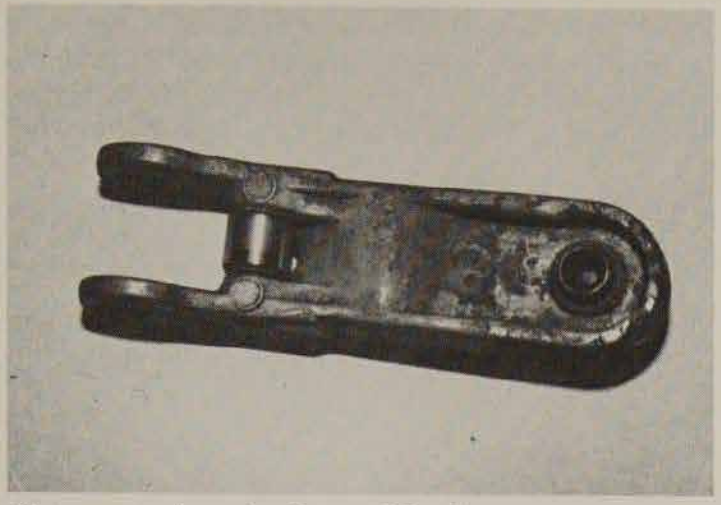
The fuel distributor plunger rides on the airflow sensor plate arm. As air flows into the engine the sensor plate is lifted. As the plate lifts the plunger moves upward, allowing pressure from the lower chambers into the upper chambers. The pressures equalize, the springs in the upper chambers push the diaphragm downward opening the orifice valves, and fuel goes off to the injectors.



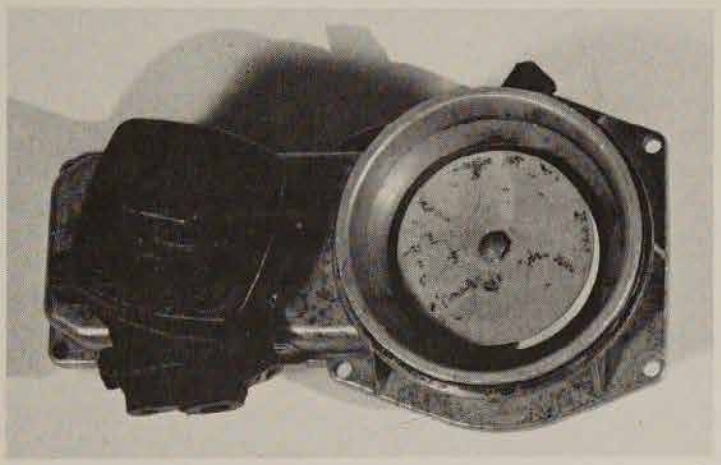
The airflow sensor assembly is the only component of the K-Jetronic system that can be overhauled. Should the plate arm begin to stick or bind, disassemble the sensor, clean and lubricate.



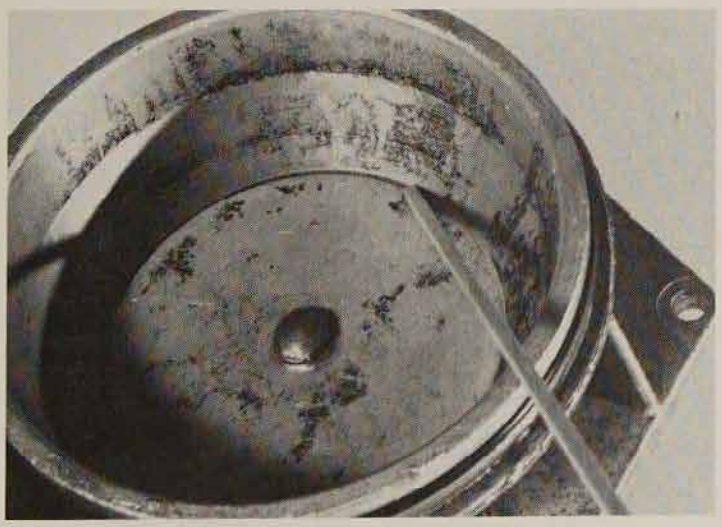
When the airflow sensor is disassembled the sensor arm can be easily cleaned and lubricated.



Dirt can get into the 3 mm CO adjustment screw and cause the screw to strip when adjustment is attempted. Thus while the airflow sensor is disassembled, be sure to clean the adjustment screw.



The bulk of the K-Jetronic tune-up adjustments are made at the airflow sensor assembly.



The airflow sensor plate height is the vertical adjustment of the sensor. Begin the adjustment by cracking loose the centerline on the top of the fuel distributor. This will relieve control pressure from the top of the plunger. The airflow sensor should rest with the top of the plate just below the top of the narrowest part of the venturi.

Airflow Sensor Plate Rest Height

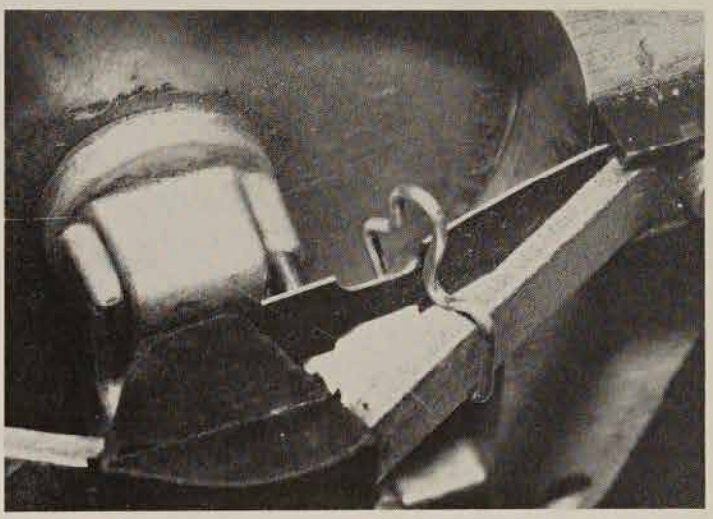
Adjust the rest height of the airflow sensor plate by adjusting the spring clip under the sensor plate. The plate should rest with the top of the plate just below the upper edge of the narrowest part of the airflow sensor venturi.

Airflow Sensor Plate Centering

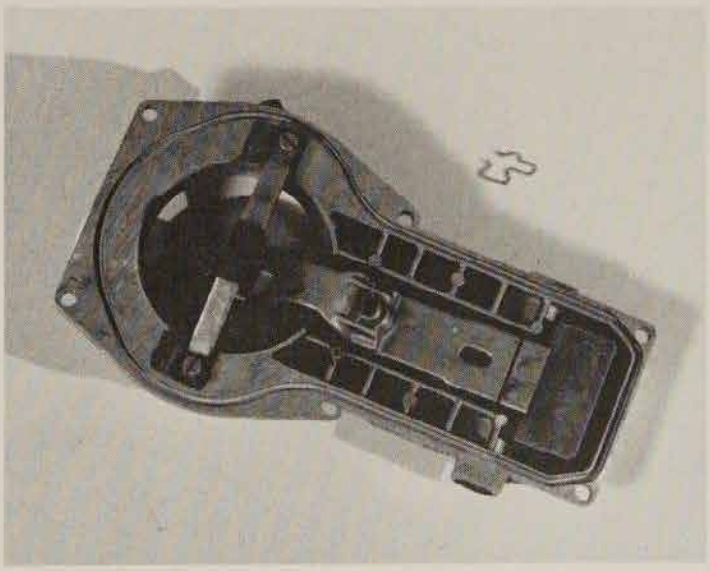
The bolt in the center of the airflow sensor plate goes through a hole that is larger than the bolt. When the bolt is loosened, the plate can be moved to center it. Center the plate visually and ensure that the plate does not stick or bend in the venturi as the plate is lifted.

Adjusting Minimum Air

After completing the standard ignition system adjustments of dwell and timing, begin work on the fuel injection by adjusting the throttle plate for



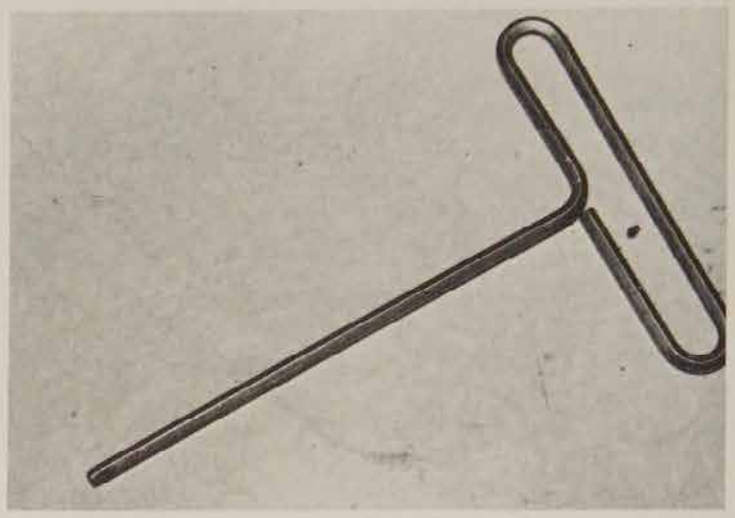
If the airflow sensor plate needs to be adjusted, bend the clip that holds the spring rest for the sensor plate.



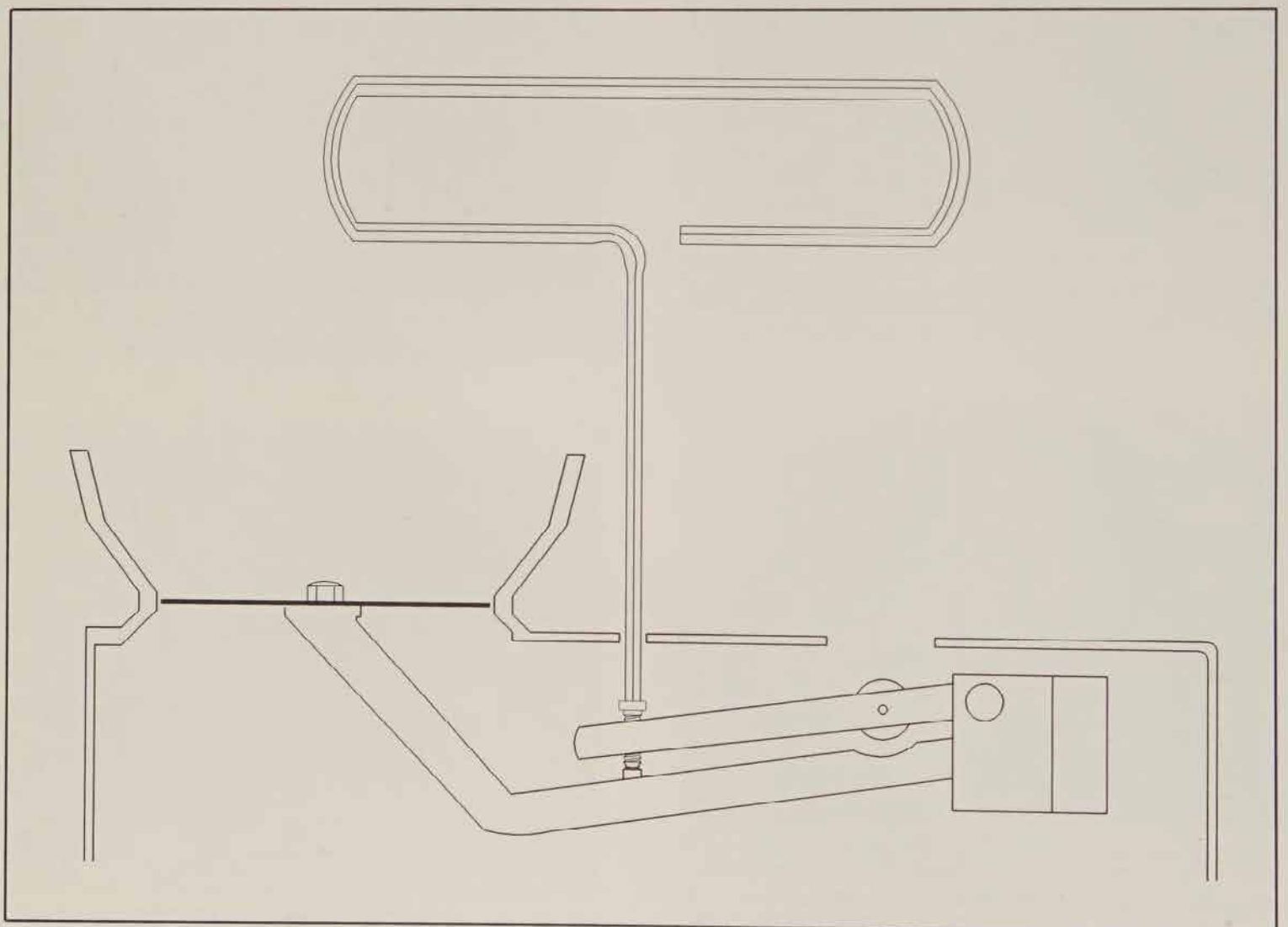
Should the clip come off during adjustment, it will usually be necessary to remove the airflow sensor assembly to reinstall it.

minimum airflow. Start up and warm the engine to operating temperature, then shut it off and visually inspect the auxiliary air valve to ensure that it has closed completely. Next, connect a tachometer and restart the engine. Close the manually adjusted idle air by-pass, and adjust the throttle stop screw so that the engine just barely idles—at

Airflow sensor plate centering can usually be done visually. If that does not work, a feeler gauge can be run around the plate to ensure centering.



A 3 mm Allen wrench is used to adjust CO (air-fuel ratio).



To adjust the air-fuel ratio (CO), insert the 3 mm Allen wrench in the hole between the airflow sensor venturi and the fuel distributor. A gentle hand is required since very slight turns can make drastic differences in CO.

about 450 rpm on an eight-cylinder, 550 rpm on a six-cylinder and 650 rpm on a four-cylinder.

After completing the minimum air adjustment, ensure that the throttle does not bind in the closed position.

Adjusting Curb Idle Speed

After completing the minimum air adjustment, use the manual adjustment on the idle air by-pass to set curb idle speed. Refer to the EPA chart under the hood of the car. If the EPA chart is missing, set the curb idle to 950 rpm.

Adjusting CO

The CO (carbon monoxide) adjustment on the CIS system is located in the airflow sensor near the fuel distributor. A 3 mm long Allen wrench is required for the job. After completing the minimum idle and curb idle adjustments and after ensuring again that the engine is thoroughly warmed up, insert a CO exhaust gas analyzer into either the tailpipe or the sampling port located ahead of the catalytic converter, as indicated in the EPA sticker under the hood. If the sticker is missing, set the CO to 1-1.5 percent at the tailpipe.

Very small movements of the 3 mm Allen wrench make an enormous difference in the CO reading. For this reason, the only practical and accurate way to adjust the CO is by using a gas analyzer.

After the CO is adjusted, recheck the idle speed.

Component Testing and Troubleshooting

Since the K-Jetronic system controls itself through the variation of hydraulic pressures throughout the system, the bulk of serious troubleshooting will be done by testing pressures in the system. There are six pressures that are relevant to the control of the K-Jetronic system: operating pressures, supply pressure, system pressure, cold control pressure, warm control pressure, injector opening pressure and return line pressure.

Understanding the function and purpose of each of these pressures is essential in troubleshooting system faults. However, only four pressures are actually measured directly in the troubleshooting method. These pressures include testing pressures, cold control pressure, system pressure, warm control pressure and rest pressure.

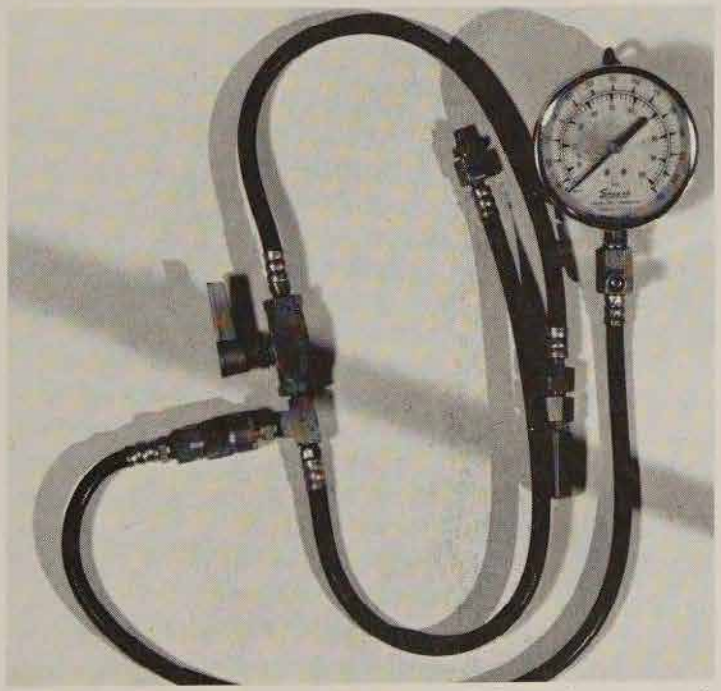
Hooking Up the Gauge

A gauge capable of reading approximately 100 psi is required to troubleshoot the K-Jetronic system. Additionally, the hoses from the gauge must form a T. One leg of the T must be equipped with a shutoff valve.

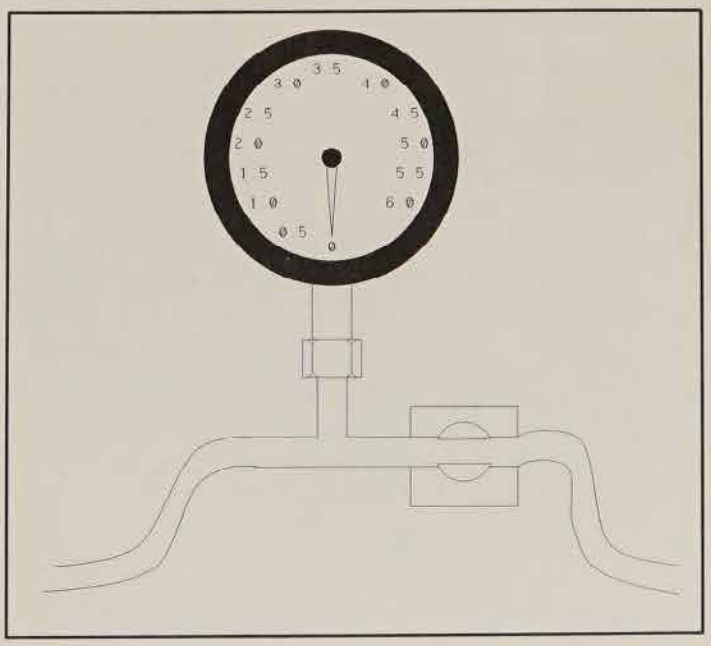
Connect the gauge in the line that runs from the center of the fuel distributor to the control pressure regulator. The hose with the valve should be installed on the control pressure regulator side of the hose going to the gauge.

For an effective and accurate diagnosis, follow the proper operational sequence from beginning to end and diagnose your results only after the entire procedure has been completed.

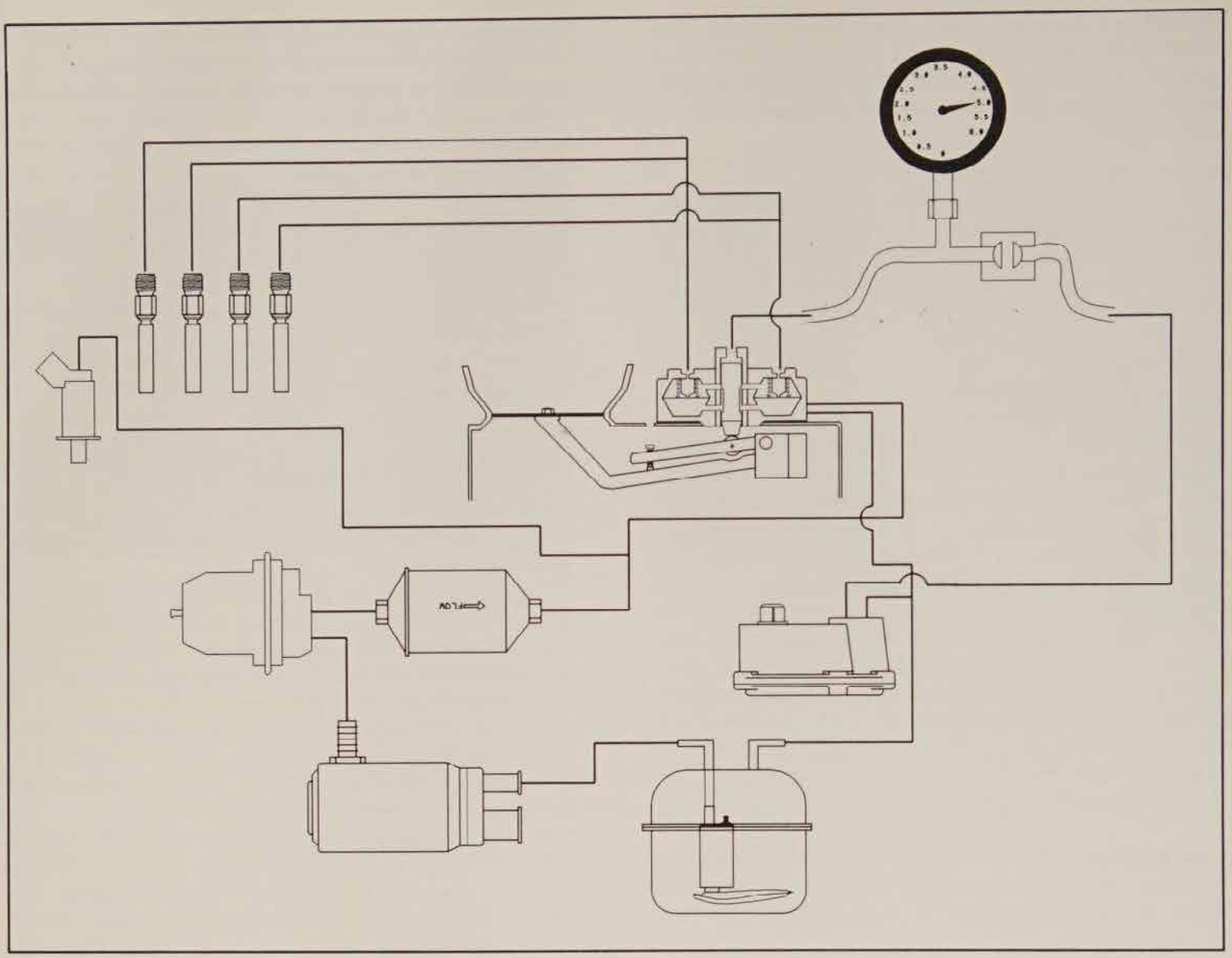
Begin with a cold engine. Disconnect the electrical connectors at the auxiliary air valve and at the control pressure regulator. Then connect the gauge. By-pass the fuel pump relay according to specifications.



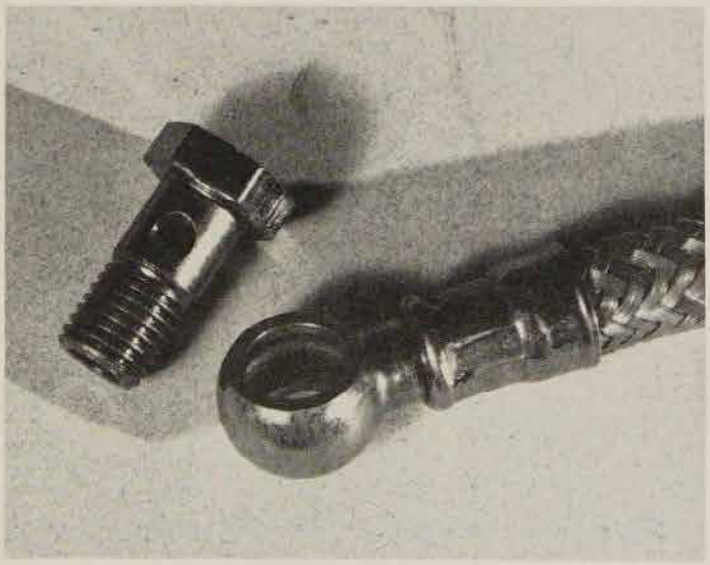
Most troubleshooting done on the K-Jetronic system is done with a pressure gauge. The gauge should be able to read over 100 psi (7 bar). Notice that there is a valve in one branch of the T on the gauge.



Upcoming test procedure pressure readings in this book will be shown with a drawing of a gauge that looks like this. Note that the valve in this drawing is in the open position.



To test the K-Jetronic system, the pressure gauge installs in the line between the center of the fuel distributor and the control pressure regulator.



Many of the fuel lines in the K-system have banjo fittings at the connections. Be careful not to lose the washers when connecting the gauges—they are very difficult to replace.

Fuel Pump Relay Specifications

Application	Procedure
Fox 1975	Disconnect the airflow meter fuel pump safety connector, disconnect the three-prong connector on the back of the alternator and turn on the ignition switch.
Fox 1976-79	Place an 8 amp fused jumper between fuel pump relay socket terminals L13 and L14.
100	Disconnect the airflow meter fuel pump safety connector, disconnect the three-prong connector on the back of the alternator and turn on the ignition switch.

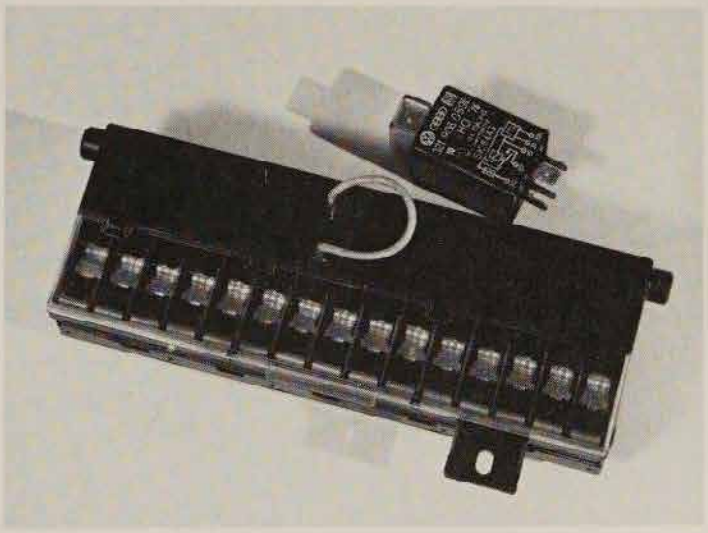
4000	Place an 8 amp fused jumper between fuel pump relay socket terminals L13 and L14.
5000	Place an 8 amp fused jumper between fuel pump relay socket terminals J39 and J40.
BMW	Place an 8 amp fused jumper between fuel pump relay socket terminals 30 and 87.
Mercedes-Benz	Place an 8 amp fused jumper between fuel pump relay socket terminals 30/51 and 87.
Porsche	
Turbo Carrera	Disconnect the airflow sensor fuel pump safety switch connector and turn on the ignition switch.
911 1973-75	Place an 8 amp fused jumper between fuel pump relay socket terminals 30/51 and 87.
911 1976-79	Place an 8 amp fused jumper between fuel pump relay socket terminals 30 and 87a.
924	Disconnect the airflow sensor fuel pump safety switch connector and turn on the ignition switch.
928	Place an 8 amp fused jumper between fuel pump relay socket terminals 30 and 87.
Saab	
To early 1977	Disconnect the airflow sensor fuel pump safety switch connector and turn on the ignition switch.
From early 1977	Place an 8 amp fused jumper between fuel pump relay socket terminals 30 and 87.
Volkswagen	
1975 Dasher only	Disconnect the airflow meter fuel pump safety connector, disconnect the three-prong connector on the back of the alternator and turn on the ignition switch.
1976-80 All models	Place an 8 amp fused jumper between fuel pump relay socket terminals L13 and L14.
Volvo	
1974-77	Disconnect the airflow sensor fuel pump safety switch connector and turn on the ignition switch.
1978-79	Obtain fuel pump test relay from the dealer and install according to manufacturer's instructions.

If all else fails in an attempt to energize the fuel pump, run a set of jumper leads from the fuel pump to the battery. Be careful about polarity between the fuel pump and battery.

With the valve on the gauge in the open position and the fuel pump running but not the engine, record the control pressure. The chart reflects what the cold control pressure should be in three typical North American climates. The temperatures listed are in degrees Fahrenheit. If the ambient temperatures listed do not reflect the temperature at which you are running the test, it will be necessary to estimate from the charts.

Cold Control Pressure Readings

Application	Pressure at 50 Deg. F. (psi)	Pressure at 75 Deg. F. (psi)	Pressure at 100 Deg. F. (psi)
Audi			
Fox 1975-77	14	24	32
Fox 1978-79	14	24	32
100	14	24	32
4000	14	24	32
5000 1978-79	14	24	32
5000 1980	14	24	32
BMW 320i	10	18	26
Mercedes-Benz			
6.9 liter	16	25	34
280 (federal)	14	21	31
280 (Calif.)	14	21	31
280 1977 (high-altitude)	17	25	33



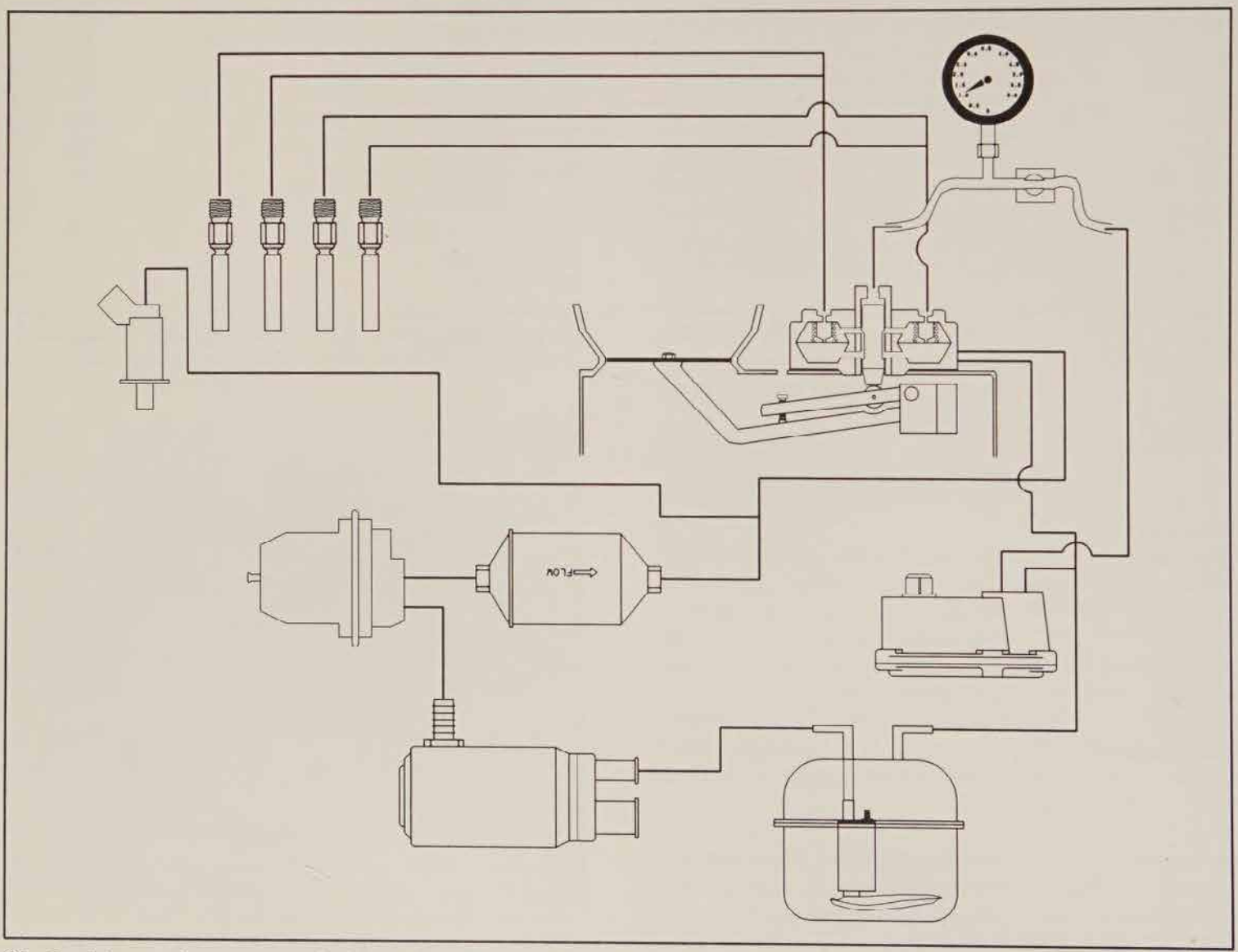
To energize the fuel pump for pressure testing on the VW and Audi products, remove the fuel pump relay. Insert a jumper across the terminals in the fuse panel that form a T. The wire shown above is a 16 amp fusible link. To avoid the possibility of damaging the car's electrical system, always use a fused wire.

Cold Control Pressure Readings

Application	Pressure at 50 Deg. F. (psi)	Pressure at 75 Deg. F. (psi)	Pressure at 100 Deg. F. (psi)
450 1976-78	19	24	34
450 1979	19	28	38
Porsche			
911 1973	15	25	35
911 1974-75	17	32	45
911 1976-77	20	32	49
911 1978-79 (Registration number 0 438 140 045)	25	32	43
911 1979 (Registration number 0 438 140 069)	21	33	47
924	16	23	32
928	17	30	44

Cold Control Pressure Readings

Application	Pressure at 50 Deg. F. (psi)	Pressure at 75 Deg. F. (psi)	Pressure at 100 Deg. F. (psi)
Turbo Carrera			
1975-77	9	22	35
1978-79	17	26	32
Saab			
99 1975-77	15	24	32
99 1978-79	15	24	32
900	15	24	32
Volkswagen			
Dasher 1976-79	16	24	32
Dasher 1980	16	24	32
Jetta, Rabbit, Scirocco to 1979	16	24	32
Jetta, Rabbit, Scirocco 1980 and later	16	24	32



Check cold control pressure with the engine not running and the valve open. The pressure for most cars is about 15-25 psi. The warmer the ambient temperature, the higher the cold control pressure will be.

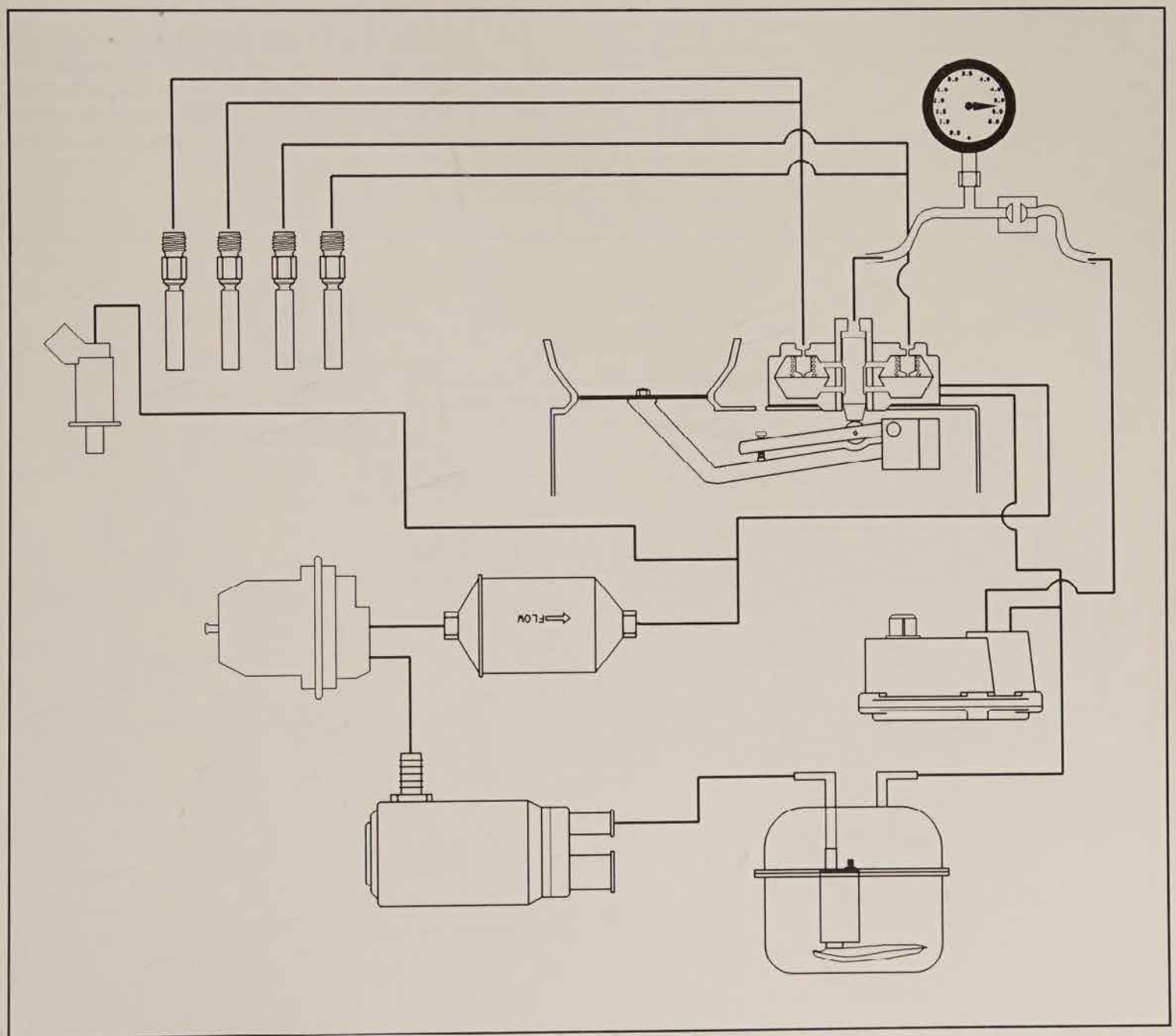
Volvo			
140	16	24	32
240 1976-77	16	24	32
240 1978-79	16	24	32
260	16	24	32

Note: All readings are plus or minus 3 psi.

Next, rotate the gauge valve to the closed position. By doing so the control pressure regulator will be isolated, thus the pressure that the gauge shows will be system pressure. Measure the system pressure and check it against the system pressure reading chart. Minor adjustments in system pressure can be made by adding or removing shims to the system pressure regulator.

System Pressure Readings

Application	Pressure (psi)
Audi	
Fox 1975-77	65-75
Fox 1978-79	65-75
100	65-75
4000	65-75
5000 1978-79	65-75
5000 1980	68-78
BMW 320i	65-75
Mercedes-Benz	
6.9 liter	75-84
280 (federal)	75-84



After checking the cold control pressure, but before starting the engine, rotate the valve to test system pressure. System pressure should not change when the ambient temperature or pressure changes. For most cars, system pressure is between 65 and 85 psi.

System Pressure Readings

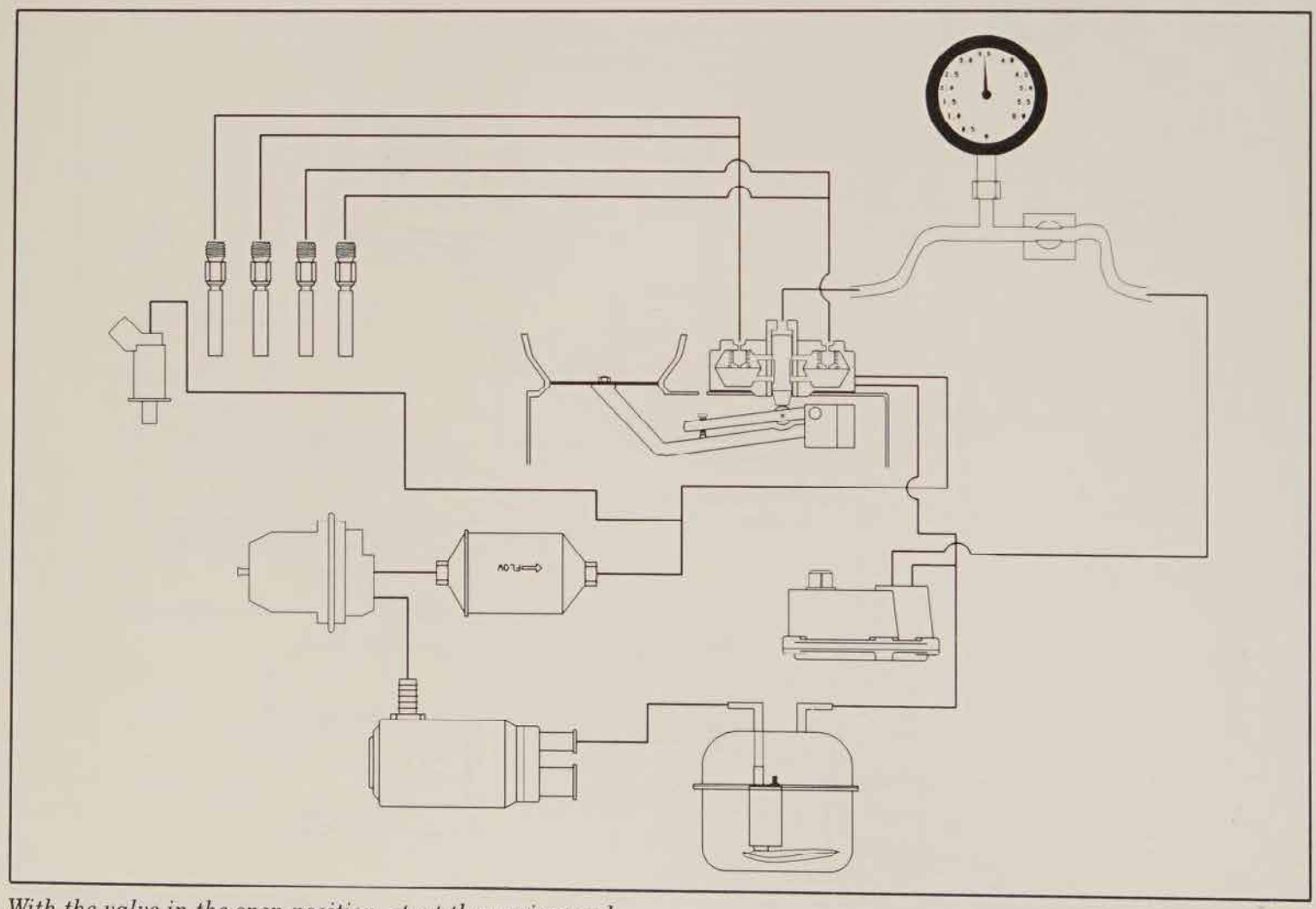
Application	Pressure (psi)
280 (Calif.)	75-84
280 1977 (high-altitude)	75-84
450 (federal and Calif.)	75-84
450 1977 (federal and high-altitude)	75-84
Porsche	
911 1973-74	65-75
911 1975	65-75
911 1976	65-75
911 1977	65-75
911 1978-79	65-75
924	65-75
928	65-75
Turbo Carrera	
1975-77	87-97
1978-79	87-97
Saab	
99 1975-77	65-74
99 1978-79	65-74
900	65-74

System Pressure Readings

Application	Pressure (psi)
Volkswagen	
Dasher 1976-79	65-75
Dasher 1980	68-78
Jetta, Rabbit, Scirocco to 1979	65-75
Jetta, Rabbit, Scirocco 1980 and later	68-78
Volvo	
140	65-75
240 1976-77	65-77
240 1978-79	65-77
260	65-77

Return the valve to the open position to measure control pressure. Reconnect the electrical connectors on the fuel pump, the control pressure regulator and the auxiliary air valve.

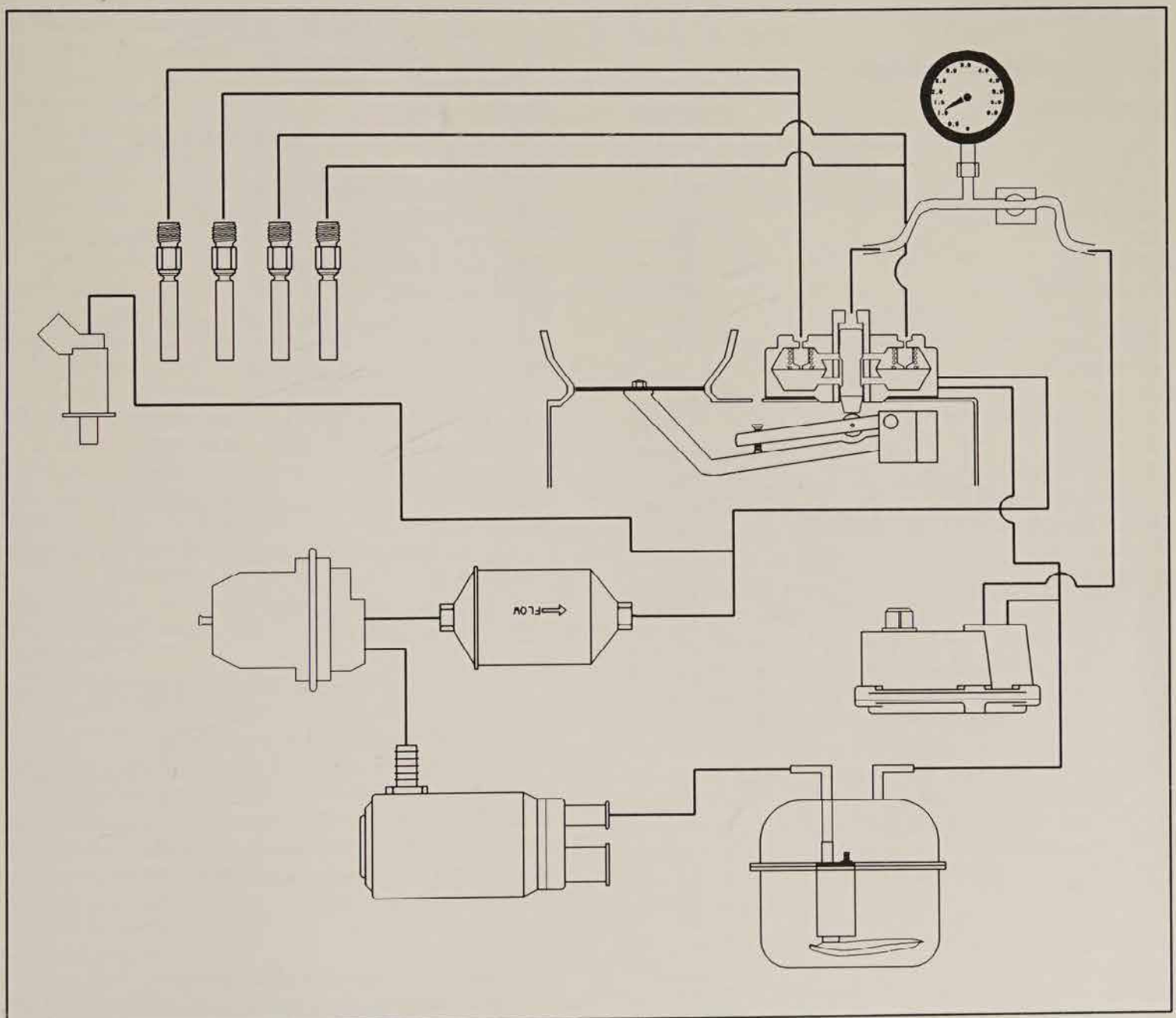
Now, start the engine and allow it to warm up. As the engine runs, the control pressure should decrease to the warm reading in about three to five minutes. After the pressure stabilizes at the warm reading, compare it to the warm control pressure chart.



With the valve in the open position, start the engine and allow the engine to warm up. When the engine is warmed up, warm control pressure should be 50-60 psi.

Warm Control Pressure Readings

Application	Pressure (psi)
Audi	
Fox 1975-77	49-55
Fox 1978-79	49-55
100	49-55
4000	49-55
5000 1978-79	49-55
5000 1980	49-55
BMW 320i	49-55
Mercedes-Benz	39-45
6.9 liter	
280 (federal)	49-55
280 (Calif.)	49-55
280 1977 (high-altitude)	44-49
450 (federal and Calif.)	52-58
450 1977 (federal and high-altitude)	49-55
Porsche	52-58
911 1973-74	
	Idle–41-44
	Part–49-55
	Full–38-44
911 1975	39-45
911 1976	39-45
911 1977	39-45
911 1978-79	39-45
924	49-55
928	41-46
Turbo Carrera	
1975-77	38-44
1978-79	49-55



When the engine is shut off, the fuel system should retain pressure for several minutes. Generally speaking, the pressure should not drop below 20 psi in the first ten to twenty minutes. Check the specs.

Saab	
99 1975-77	49-55
99 1978-79	49-55
900	49-55
Volkswagen	
Dasher 1976-79	49-55
Dasher 1980	49-55
Jetta, Rabbit, Scirocco to 1979	49-55
Jetta, Rabbit, Scirocco 1980 and later	49-55
Volvo	
140	51-57
240 1976-77	51-57
240 1978-79	51-57
260	54-59

Now shut off the engine and observe the residual or rest pressure over the next twenty minutes. The pressure should not drop below the readings on the rest pressure chart.

Rest Pressure Readings

Application	Pressure (psi)
Audi	
Fox 1975-77	23
Fox 1978-79	23
100	23
4000	23
5000 1978-79	23
5000 1980	35
BMW 320i	22
Mercedes-Benz	
6.9 liter	41
280 (federal)	41
280 (Calif.)	41
280 1977 (high-altitude)	41
450 (federal and Calif.)	41
450 1977 (federal and high-altitude)	41
Porsche	
911 1973-74	16
911 1975	16
911 1976	16
911 1977	16
911 1978-79	16
924	22
928	25
Turbo Carrera	
1975-77	22
1978-79	22
Saab	
99 1975-77	15
99 1978-79	22
900	22
Volkswagen	
Dasher 1976-79	23
Dasher 1980	35
Jetta, Rabbit, Scirocco to 1979	23
Jetta, Rabbit, Scirocco 1980 and later	35
Volvo	
140	25
240 1976-77	15
240 1978-79	25
260	25

Note: All readings are plus or minus 3 psi.

Pressure Test Analysis

In this section, I've listed some symptoms and possible causes that would likely occur on a K-Jetronic system.

Symptoms:
Cold control pressure low
Warm control pressure normal
System pressure normal
Rest pressure normal
Possible cause:
Defective control pressure regulator.

Symptoms:
Cold control pressure normal
Warm control pressure low
System pressure normal
Rest pressure normal
Possible cause:
Defective control pressure regulator.

Symptoms:
Cold control pressure high
Warm control pressure normal
System pressure normal
Rest pressure normal
Possible cause:
Defective control pressure regulator.

Symptoms:
Cold control pressure low
Warm control pressure low
System pressure normal
Rest pressure normal
Possible cause:
Defective control pressure regulator.

Symptoms:
Cold control pressure high
Warm control pressure high
System pressure normal
Rest pressure normal
Possible causes:
Restriction in the return line from the control pressure regulator.
Defective control pressure regulator.

To distinguish between these install a replacement return line on the control pressure regulator, allowing the fuel to flow into an approved fuel receptacle. If the control pressure drops, then repair or replace the return line. If the control pressure does not drop, replace the control pressure regulator.

Symptoms:
Cold control pressure normal
Warm control pressure normal
System pressure a little high
Rest pressure normal

Possible cause:
Leaking system pressure regulator.
Symptoms:
Cold control pressure normal
Warm control pressure normal
System pressure very high
Rest pressure normal
Possible causes:
Restricted return line.
Defective fuel distributor.

To distinguish between these remove the fuel distributor return line and connect a replacement line, allowing the fuel to flow into an approved fuel receptacle. If the pressure drops, repair or replace the return line. If the pressure does not drop, replace the fuel distributor.

Symptoms:
Cold control pressure normal
Warm control pressure normal
System pressure normal
Rest pressure drops below minimum
Possible causes:
Fuel pump check valve.
Leaking cold-start injector.
Leaking system pressure regulator.
Defective fuel distributor.
Defective control pressure regulator.

To distinguish between these, eliminate the possibilities one at a time by isolating the components.

Begin isolating the source of the loss of rest pressure by repressurizing the system, closing the valve between the control pressure regulator and the pressure gauge. If the pressure no longer drops, replace the control pressure regulator.

If the rest pressure continues to drop, pinch off the line between the fuel pump and the accumulator, then repressurize the system and watch the rest pressure. If the rest pressure no longer decreases, replace the fuel pump check valve.

If the rest pressure continues to drop, pinch off the line to the cold-start injector. If the rest pressure no longer drops, replace the cold-start injector.

If the rest pressure continues to drop, pinch off the return line from the fuel distributor. If the rest pressure no longer drops it is either the system pressure regulator or the fuel distributor. For either problem, replace the fuel distributor.

Symptoms:
Cold control pressure low
Warm control pressure low
System pressure low
Rest pressure normal
Possible causes:

Run the fuel pump volume test. Disconnect the fuel distributor return line and install a replacement line, allowing the fuel to flow into a measuring cup that reads in liters. Energize the fuel pump to run as described earlier. The volume of fuel that flows into and through the return line in thirty seconds should be according to the fuel flow chart. If the volume is less than the specification, inspect the inbound fuel lines and replace the fuel filter. If the flow is still not within spec, replace the in-tank filter. If the volume does not increase, run the test with the gas cap off to determine if the problem is plugged fuel tank vents. If none of these repairs increases fuel volume to specification, replace the fuel pump.

Return Line Fuel Flow

Application	Minimum Volume (cc per 30 sec)
Audi	
4000, 5000 1978-80	950
All other Audis	750
BMW 320i	750
Mercedes-Benz	
6.9 liter	1100
280 (federal)	930
280 (Calif.)	930
280 1977 (high-altitude)	930
450 (federal and Calif.)	1100
450 1977 (federal and high-altitude)	1100
Porsche	
911 1973-77	850
911 1978-79	1000
924	1050
928	1360
Saab	
Non-Turbo	750
Turbo	950
Volkswagen	750
Volvo	
140, 240 1976-79	750
260	850

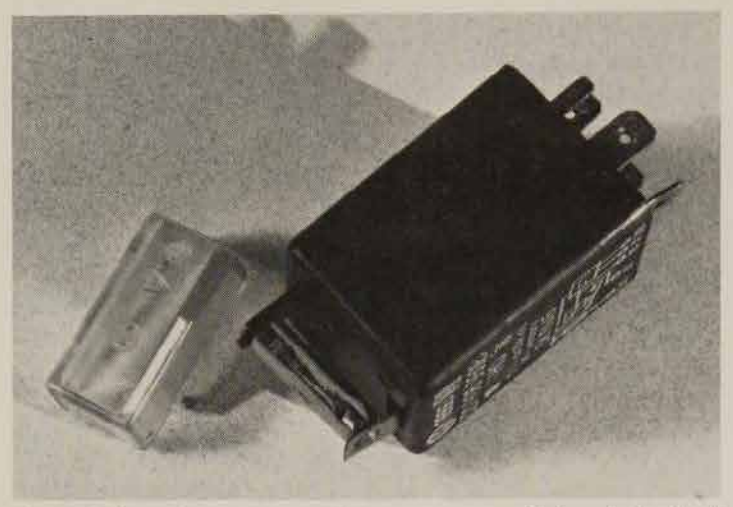
K-Jetronic Troubleshooting by Symptom

When attempting to find the cause of a driveability problem in the K-Jetronic system it is dangerous to attach symptoms to a specific component. The fuel system is a very close and symbiotic entity. The interrelationship between the various components means that a given symptom can be caused by virtually any part in the system. Therefore, in this section I will present the possible causes of a given symptom and then offer a list of components that need to be tested. Refer to earlier sections of this chapter for the test procedures related to each component.

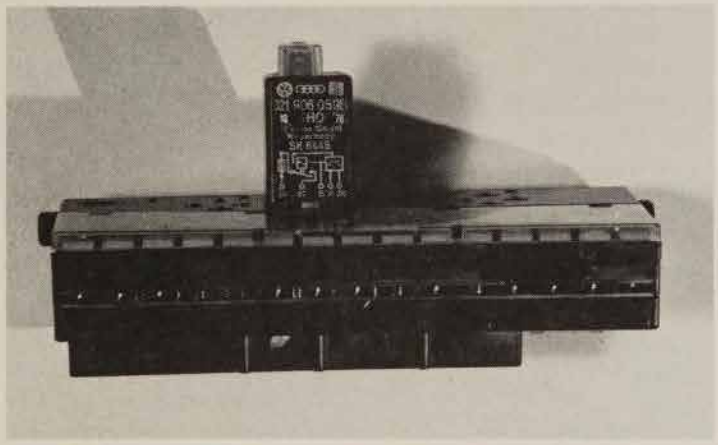
Engine Cranks but Will Not Run

Definition: Starter engages but the engine does not fire. This is a cold-starting problem.

Lack of Fuel Pressure: Test the fuel pump and pre-pump (if applicable). Perform not only a pressure test, but also a volume test.



One of the prime causes of a no-start condition is lack of power to the fuel pump. Check the fuel pump relay and the fuel pump fuse.



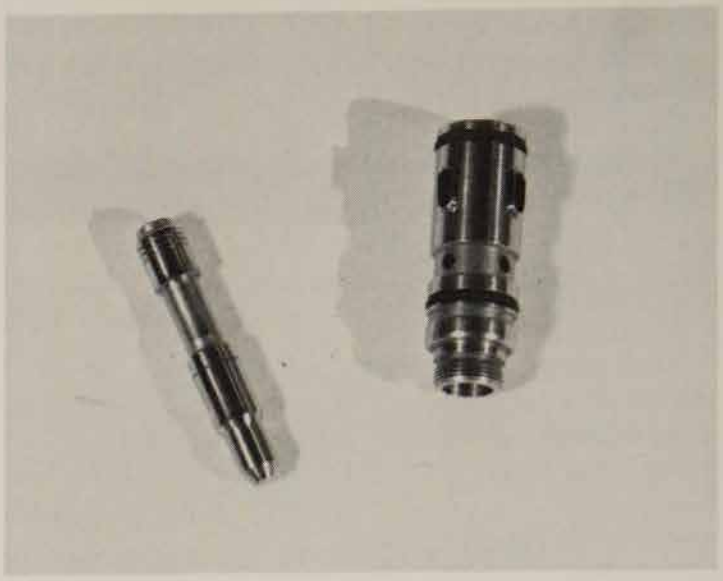
Volkswagen Rabbits from the late 1970s had a chronic problem with overheating and failure of the fuel pump circuit in the fuse panel. An alternative to replacing the fuse panel is a by-pass kit available from the dealer.

Jammed or Sticking Airflow Sensor: Remove the airflow sensor boot, loosen the center hose on the fuel distributor to relieve control pressure and using a pocket magnet, try to lift the airflow sensor plate by the center bolt. This procedure should also involve checking the sensor plate for the proper rest height and centering.

Auxiliary Air Valve Sticking: If the auxiliary air valve is not opening up, the cold engine will run if the driver keeps his foot on the accelerator. However, since the proper starting instructions for the K-Jetronic engine say not to depress the accelerator, the engine will not fire.

Cold-Start Injector Not Opening: If the cold-start injector fails to open, the net effect will be the same as the choke failing to close on a carbureted engine. The air-fuel ratio will be too lean to permit easy start-up.

Defective Thermo-Time Switch: One of the most common causes of the cold-start injector not working is a defective thermo-switch time.



Since the control cylinder and control plunger are machined to close tolerances, the plunger is prone to sticking. Although this could be a result of fuel varnishing which can be cleaned off, it will usually warrant replacement of the fuel distributor.

Sticking Control Plunger: Remove the fuel distributor from the airflow sensor assembly and ensure that the plunger moves freely.

Restricted Injectors: In order for restricted injectors to cause a no-start problem these injectors would have to be severely restricted. Perform the injector equal-flow test.

Hot-Starting Problems

Definition: Engine starts only after cranking for an extended period of time (five to thirty seconds).

Loss of Rest Pressure: Run a complete K-Jetronic pressure test, paying particular attention to the rest pressure. If the rest pressure does not hold according to specification, troubleshoot the cause of pressure loss. It could be a defective fuel pump check valve, leaking cold-start injector, defective fuel distributor or faulty system pressure regulator.

Improperly Adjusted Airflow Sensor: Check airflow sensor plate for proper height, centering and binding. Remove the airflow sensor boot; loosen the center hose on the fuel distributor to relieve control pressure and using a pocket magnet, try to lift the airflow sensor plate by the center bolt. This procedure should also involve checking the sensor plate for the proper rest height and centering.

Sticking or Binding Control Plunger: Remove the fuel distributor and ensure that the control plunger is moving freely.

Leaking Injectors: Remove the injectors from the intake manifold, pressurize the system and inspect injectors for leaks.

Leaking Cold-Start Injector or Shorted Thermo-

Time Switch: Remove the cold-start injector from the intake manifold, pressurize the fuel system and inspect for leaks.
Incorrect Control Pressure: Run a complete K-Jetronic pressure test to ensure that the warm control pressure is correct.

Engine Idles Rough When Cold
Incorrect Cold Control Pressure: If the cold control pressure is too high it will limit the movement of the control plunger and therefore limit the fuel available to flow through the injectors. The engine will therefore run lean and the idle will be rough.
Auxiliary Air Valve Not Opening: If the auxiliary air valve does not open, the cold idle speed will not rise and therefore the idle will be slow and rough.
Leaking Cold-Start Valve: A leaking cold-start valve will make the engine run excessively rich, even when cold. An excessively rich running engine will tend to idle rough whether the engine is cold or warm. If the cold-start injector is leaking, the roughness will get progressively worse as the engine warms up.
Improperly Adjusted or Binding Airflow Sensor: Anytime the airflow sensor plate does not operate smoothly it can result in air-fuel ratio errors.
Unequal Injector Flow or Spray Pattern: Perform the injector flow test. Replace any injectors that are flowing an inadequate quantity or have a poor spray pattern.

Engine Idles Rough When Warm
Incorrect Warm Control Pressure: If the warm control pressure is too low or too high the air-fuel ratio will be incorrect, causing rough idle.
Leaking Cold-Start Valve: This will overfuel the engine, resulting in a rich air-fuel ratio and a rough idle.
Improperly Adjusted, Sticking or Binding Airflow Sensor: Anytime the airflow sensor plate does not operate smoothly it can result in air-fuel ratio errors.
Unequal Injector Flow or Spray Pattern: Perform the injector flow test. Replace any injectors that are flowing an inadequate quantity or have a poor spray pattern.

Engine Stalls Immediately after Starting, Warm
Warm Control Pressure: If the warm control pressure is too high the air-fuel ratio will be very lean, resulting in the engine dying.
System Pressure: If the system pressure is too high or too low, the air-fuel ratio will be incorrect. Incorrect fuel pressure can result in either a rich or lean running condition. Either condition can cause the engine to stall after start-up.

Idle Speed Too High and Cannot Be Adjusted
Check Minimum Air: If closing off the idle air bypass does not bring the idle within specs check for vacuum leaks, check the auxiliary air valve and adjust the minimum air.
Check the Auxiliary Air Valve: Remove the hoses to the auxiliary air valve and ensure that it is closing off.
Vacuum Leaks: A vacuum leak is a source of extra air entering the intake manifold after the throttle plates. As a result, a vacuum leak can cause an excessively high idle speed.

Engine Backfires in Intake
Check for Proper CO Adjustment: A lean mixture adjustment can result in a backfire under load or when starting.
Check Engine Air Tubing between Airflow Sensor and Throttle: Holes or other leaks in the tubing that runs from the airflow sensor to the throttle assembly can result in a lean air-fuel ratio. A lean ratio can result in a backfire under load or when starting.
Check for Vacuum Leaks: Vacuum leaks can result in a lean mixture, and a lean mixture can result in a backfire. One of the best techniques for locating a vacuum leak is to run a little propane around the intake system.

Engine Misfires under Load
Ignition Problems: The most likely cause of a misfire is the ignition system, regardless of the fuel system.
Inadequate Fuel Delivery (engine running lean): An insufficient supply of fuel can be the result of a binding airflow sensor or control plunger, restricted injectors, incorrect control or system pressure. Also perform an equal-flow and spray pattern test on the injectors.

Poor Power
Incorrect Tune-Up Specs or Worn Tune-Up Parts: As with a carbureted engine the most likely cause of poor power is the basic tune-up specifications of timing, dwell and air-fuel ratio. Also, worn distributor caps, spark plugs, points and plug wires can seriously impact the performance of the K-Jetronic engine.
Control Pressure Too High: High control pressure will limit the travel of the control plunger, thereby limiting the amount of fuel that can flow into the engine. When the engine begins to run lean, power can suffer.
Restricted Injectors: Restricted injectors can limit the amount of fuel that can pass through them, thereby limiting power.

Stumble or Sag on Acceleration
Sticking or Binding Airflow Sensor Plate: If the airflow sensor plate binds on the way up, fuel flow will be limited and the engine will sag or stumble.
Sticking or Binding Control Plunger: If the control plunger binds on the way up, fuel flow will be limited and the engine will stumble or sag.

Incorrect System or Warm Control Pressure: If the system pressure is too high or if the control pressure is too high (high system pressure will usually cause high control pressure) the movement of the control plunger will be limited. The engine will begin to run lean as the airflow increases. A lean running engine will sag or stumble on acceleration.
Unequal Injector Flow: Restricted injectors can limit the amount of fuel that can pass through them, thereby limiting power.

Engine Diesels
Binding or Sticking Airflow Sensor: In order for the engine to "diesel" or run-on after the engine is shut off there must be fuel entering the engine. One source of this fuel is an airflow sensor that is not dropping to the closed position as the engine is shut off.
Binding or Sticking Control Plunger: Inspect the control plunger for smooth movement without binding or sticking.
Leaking Injectors: Perform an injector flow test and inspect the injectors for proper seating when the airflow sensor drops to the rest position.
Leaking Cold-Start Injector: Remove injector, pressurize the system and inspect for leaks.

Excessive Fuel Consumption
Improperly Adjusted Air-Fuel Ratio
Leaking Injectors
Leaking Cold-Start Injector

What to Do, and When

Lack of Fuel Pressure

When there is no fuel pressure, the first thing to do is confirm that there is fuel in the tank. I have seen several methods, at various levels of sophistication, to confirm fuel quantity. Of all these methods, the best and simplest is to pour a gallon or so of fuel into the tank.

If there is an adequate amount of fuel in the tank, the next item of business is to confirm fuel pump operation. Place a mechanic's stethoscope on the fuel pump and have someone crank the engine. If the fuel pump is located inside the fuel tank, then place the stethoscope on the fuel tank. As the engine is cranked the hum of the fuel pump should be heard through the stethoscope. If no hum is heard, check electrical power to the pump.

Begin by inspecting the fuel pump fuse. If the fuel pump fuse is good, connect the alligator clip of a test light to the ground side of the fuel pump connector and probe the positive side of the fuel pump connector. If the test light goes on, then the pump is receiving power and has a good ground. If the test light fails to light up, connect the alligator clip to a good chassis ground and probe the positive terminal on the fuel pump. If the test light still fails to light up, check the fuel pump relay and inspect the fuel pump wiring harness. If the test light finally goes on, inspect the fuel pump ground.

Another reason for a lack of fuel pressure is restriction in the fuel lines or the fuel filter. Energize the fuel pump and begin loosening fittings along the fuel supply line.

USE EXTREME CAUTION THOUGH, AS THE FUEL WILL BE UNDER AS MUCH AS 100 PSI PRESSURE AND WILL TEND TO SPRAY OUT IN A FINE, HIGHLY FLAMMABLE MIST.

If there is only a small amount of pressure or volume present at a loosened fitting, inspect the components upstream of that fitting for restrictions. Restrictions are commonly found in the fuel filter and the in-tank pickup filter screen.

An obvious reason for no fuel pressure would be an external leak. Look for external leaks anywhere along the fuel lines or at the accumulator.

Jammed or Sticking Airflow Sensor

After removing the airflow sensor boot, inspect for proper adjustment of the sensor plate. Adjust as necessary. If the adjustment is OK, the binding is at the fulcrum—the only component of the K-system that can be disassembled and reassembled without damaging it.

Remove the airflow sensor assembly from the car. On each side of the sensor you will find a disc held in place by an internal snap ring. Remove the snap rings and with a small screwdriver, wobble the disc back and forth until it falls out. There is a large counterweight on the end of the airflow sensor lever; loosen the large screw that holds the counterweight in place. At the same time this will loosen the fulcrum shaft. Carefully mount the airflow sensor assembly in a vise and using a brass drift, drive the shaft out of the assembly.

Wash all the metal components in solvent, removing any varnish build-up that may have occurred over the years. Rinse the solvent off of the parts with hot water. The hot water will evaporate quickly, reducing the possibility of rusting.

Reassemble the airflow sensor using a very light film of point lube or similar lubricant. Make the sensor plate adjustments and reinstall on the car.

Auxiliary Air Valve Not Opening

There is really nothing that can be done for an auxiliary air valve that does not open, short of replacement. Be sure that the valve is not receiving power all the time and replace it.

Cold-Start Injector Not Opening

The cold-start injector is a simple, normally closed solenoid-operated valve. If the cold-start injector does not open when the engine temperature is below 95 deg. F., disconnect the cold-start injector and connect a test light across the terminals. Crank the engine. If the test light goes on, the wiring harness is good. Loosen the fuel line at the

cold-start injector and crank the engine again. If fuel leaks or sprays from the loosened line, replace the cold-start injector. If not, confirm fuel delivery to the fuel distributor and repair or replace the restricted fuel line. If the fuel line delivers fuel, then replace the cold-start injector.

If connecting the test light across the terminals and cranking the engine does not light the test light, confirm that the engine temperature is below 95 deg. F. Connect the test light alligator clip to the positive battery terminal and probe the harness connector of the cold-start injector. One of the two terminals should actuate the test light, the other should not. If neither activates the light, inspect the wire that runs from the cold-start injector to the thermo-time switch, and the one that runs from the switch to ground for an open circuit. If both wires test satisfactorily, replace the thermo-time switch.

Sticking Control Plunger

A sticking control plunger normally indicates a damaged control plunger. Simply dropping the plunger when servicing the fuel distributor might be enough to damage it. Inspect the plunger for evidence of varnishing. If the plunger continues to stick or bind, replace the fuel distributor. Care during installation will prevent damage to the new plunger.

Note: Control plungers are machined for a precise match to a given fuel distributor. Attempting to use a control plunger from another fuel distributor can result in even more severe binding or leaking.

Restricted Injectors

Restricted injectors can best be diagnosed by performing the injector flow equality test. Cleaning a restricted injector(s) can be done with an injector cleaning system. These cleaning systems range in price from about $100 to well over $1,000.

Unless you are a business specializing in fuel-injection or tune-up service, purchasing a cleaning system such as this is probably not the best use of your money. As an alternative, remove the injectors from the intake system and leave them attached to their fuel supply lines. Place them in a safe container, then activate the fuel pump as described in the section on measuring pressures. Once the fuel pump is running, lift the airflow sensor plate all the way and allow fuel to flow through the injectors at full force. Lower the sensor plate to its rest position, wait a few seconds, then slowly lift the plate between 1/8 and 1/4 in. Observe the injector spray pattern. If the pattern is good, reinstall the injectors and test drive. If the pattern is bad, replace the injectors.

Although replacing the injectors may sound drastic or expensive, for most applications a full set of injectors will probably cost less than most shops charge for injector cleaning. In any case, replacement of the injectors is usually far more effective than cleaning them.

Leaking Injectors

Remove the injectors from the intake. With the engine shut off, energize the fuel pump to run. Observe the injectors for leaking. Raise the airflow sensor plate; the injectors should spray. Drop the sensor plate; the injectors should stop spraying immediately.

If they are leaking, attempt to clean them by raising the airflow sensor plate all the way, allowing the injectors to spray at full volume for ten seconds. Retest the injectors for leaking. If they continue to leak, replace them.

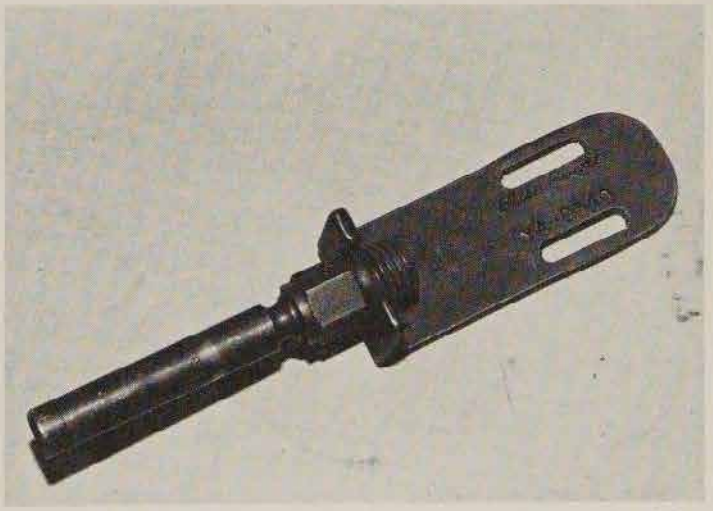
Unequal Injector Flow

Remove the injectors from the intake manifold and place each in its own graduated cylinder. Energize the fuel pump and raise the sensor plate about 1/4 in. for thirty seconds. The volume through each injector should vary by only 10 percent. If the volume is not equal, clean the injectors. If there is no improvement from cleaning, replace them.

If the flow was equal at 1/4 in., repeat the test at about half the travel of the airflow sensor plate. Again, the volumes should vary by only 10 percent.

Loss of Rest Pressure

Loss of rest pressure is one of the most common causes of one of the most common K-Jetronic symptoms. With the K-Jetronic fuel pressure gauge installed between the fuel distributor and the control pressure regulator, pressurize the system with the engine not running. Turn the valve on the fuel pressure gauge. If there now is no loss of rest pressure, replace the control pressure regulator.



To perform an unequal injector flow test, or to check for leaking injectors, it is necessary to remove the injectors from the intake manifold. Tools like this are available to make a difficult job easier.

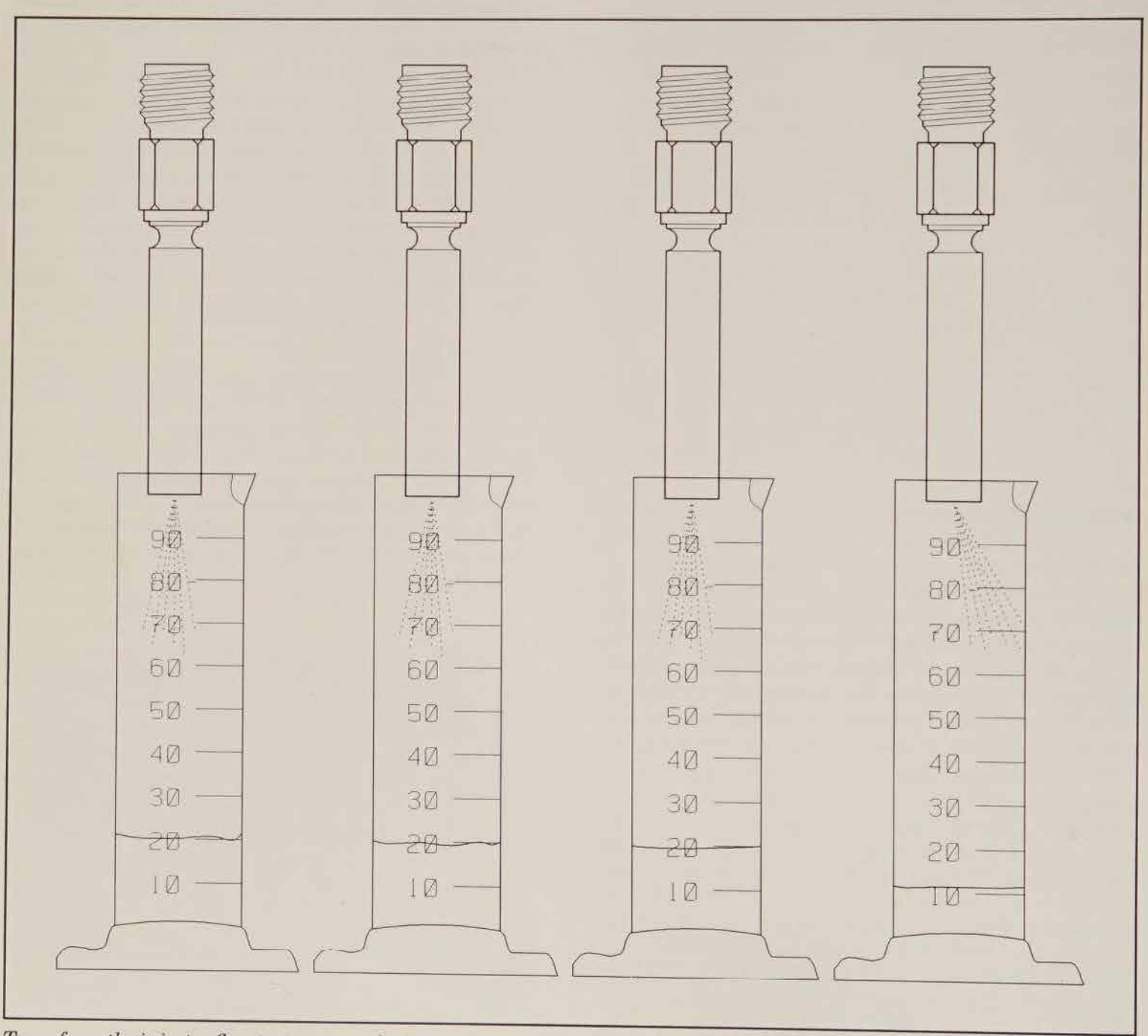
If the loss of rest pressure is not at the control pressure regulator open the valve, remove the injectors from the intake and place them in view. Remove the cold-start injector, leaving all fuel lines attached. Pressurize the system and inspect the removed components for leaking as the rest pressure drops. If there is no evidence of leaking, replace the fuel pump check valve.

Note: From personal experience, 90 percent of the time a loss of rest pressure is caused by a defective fuel pump check valve. Also, if the injectors are found to be leaking, replace the fuel distributor and retest.

Incorrect Control Pressure

High: If the system pressure is within specifications, there are only three possible causes for high control pressure: a restriction in the return line from the fuel distributor to the fuel tank, a restriction in the return line from the control pressure regulator to the fuel distributor, or a defective control pressure regulator.

Connect the K-Jetronic fuel pressure gauge with the valve in the open position so fuel can flow to the control pressure regulator. Enable the fuel pump to run with the engine not running. Carefully crack open each of the return lines (remember to use



To perform the injector flow test, remove the injectors from the intake manifold. Place each injector in a graduated cylinder. For safety, disable the primary ignition system. Energize the fuel pump by by-passing the fuel pump relay. Lift the airflow sensor plate. The flow of fuel through the injectors should be equal. If not, clean or replace the injectors.

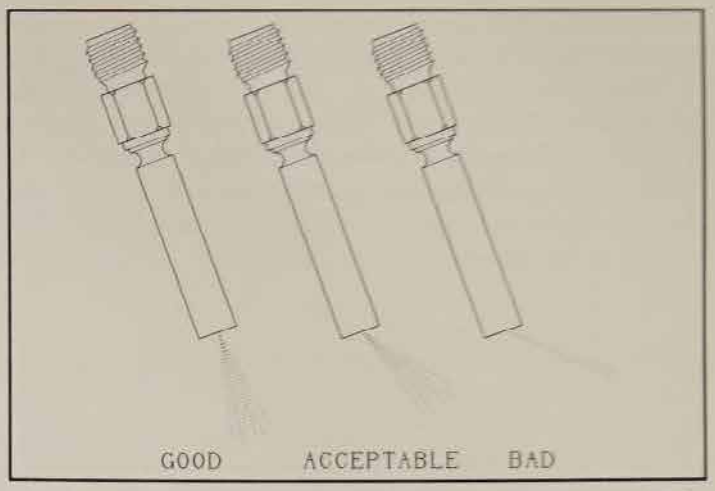
extreme caution as the fuel is highly flammable and under high pressure) and observe the control pressure. If the pressure drops, it indicates there is a restriction in that line.

If the pressure is unaffected by the opening of the return lines, replace the control pressure regulator.

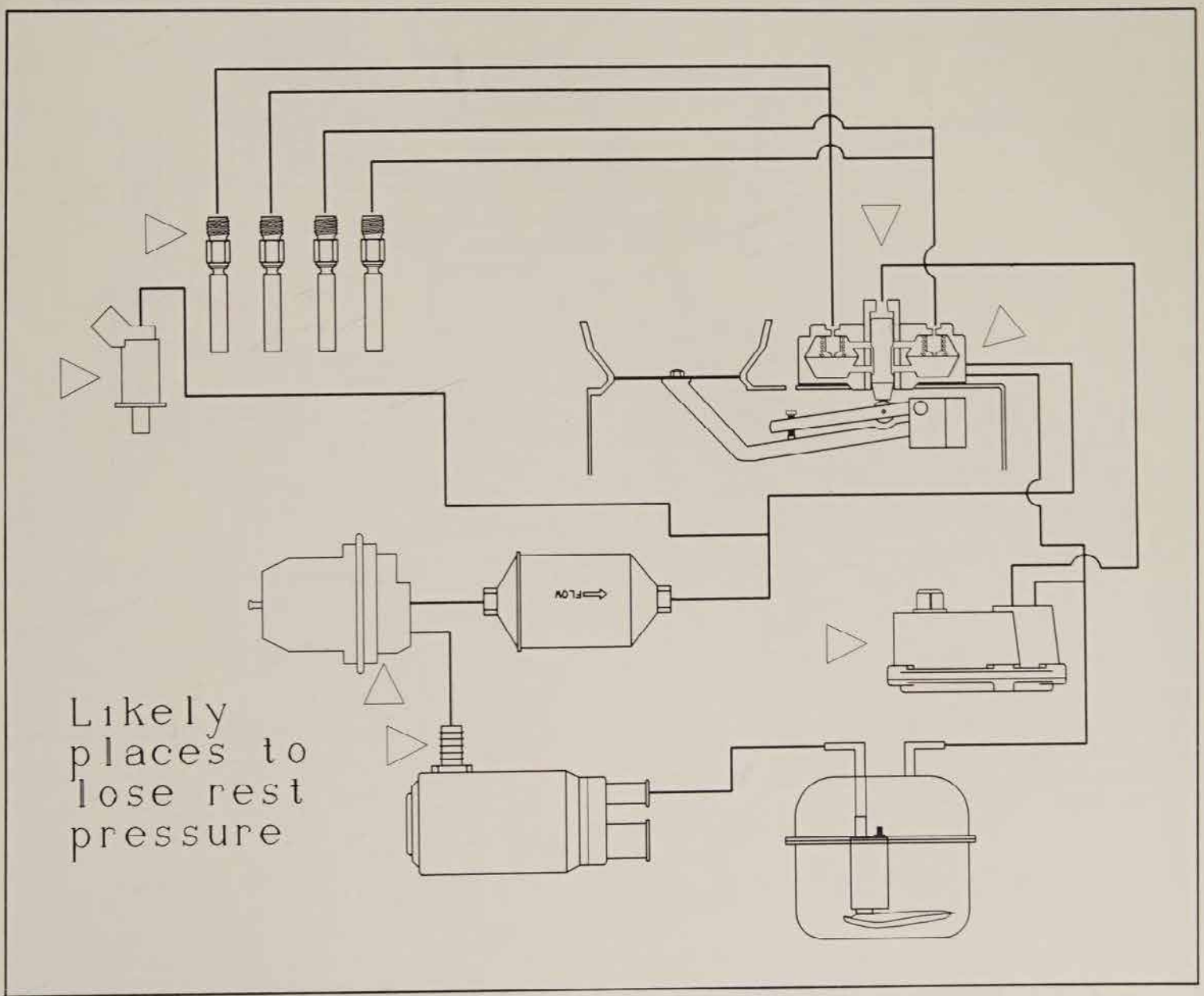
Low: If the control pressure is low, verify that the system pressure is within specification and replace the control pressure regulator.

Incorrect System Pressure

High: If the system pressure is too high, energize the fuel pump to run with the engine shut off and crack the return line loose. If the system pressure does not drop, remove the system pressure regulator from the side of the fuel distributor. Be careful not to lose any pieces. Clean the regulator compo-



Watch the spray pattern while flowing the injectors. If the spray pattern is cone shaped, then look elsewhere for the driveability problem. If the pattern is a stream, replace or clean the defective injector(s).



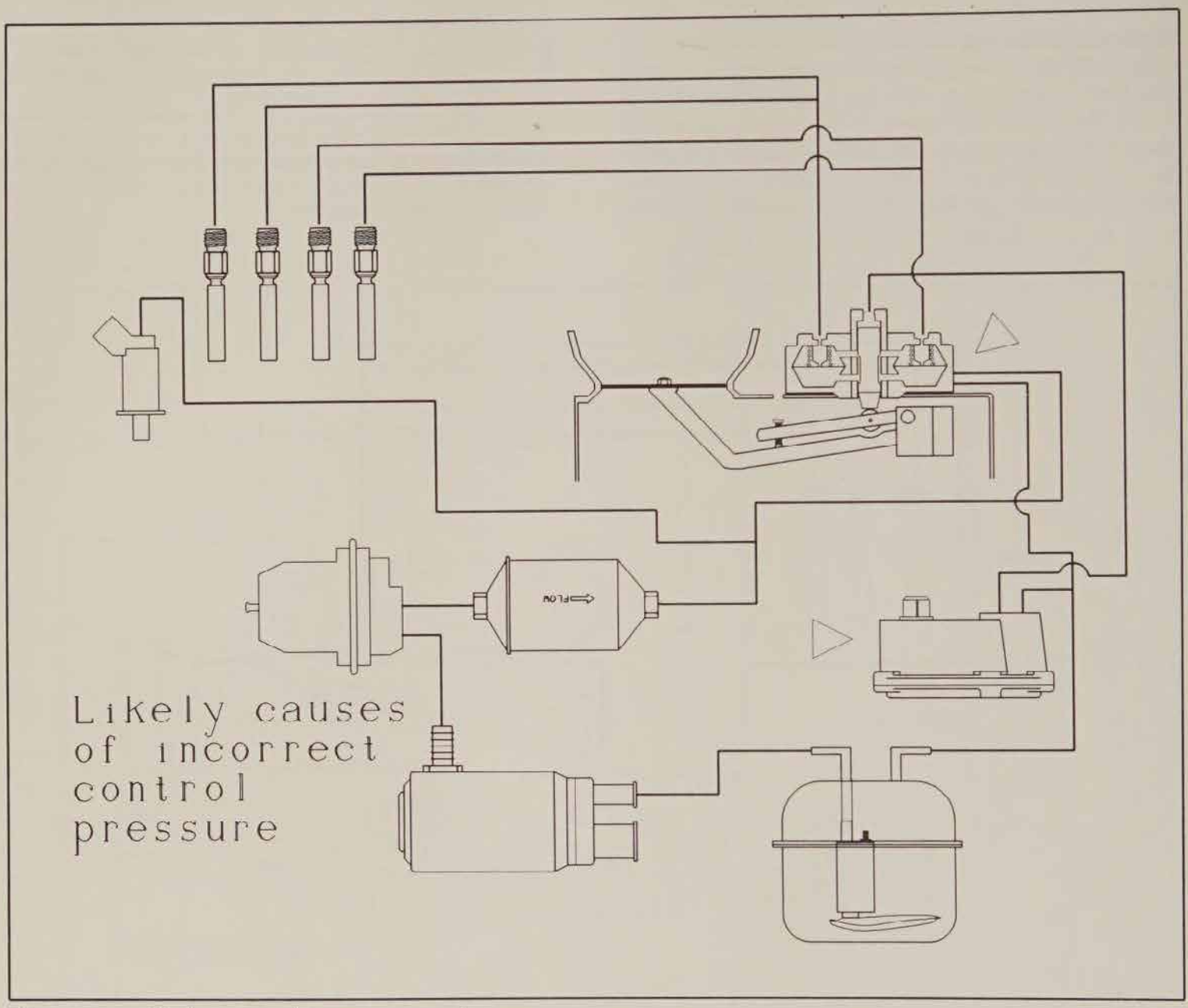
Likely places to lose rest pressure are the fuel pump check valve, the accumulator, the cold-start valve, the injectors, the fuel distributor, the system pressure regulator and the control pressure regulator.

nents with a mild solvent and reassemble. If the pressure is still high, replace the fuel distributor.

If the pressure is only a little too high, you might be able to reduce the pressure by removing adjusting shims from the system pressure regulator.

Low: If the system pressure is too low, remove the system pressure regulator from the side of the fuel distributor. Be careful not to lose any pieces. Clean the regulator components with a mild solvent and reassemble. If the pressure is still low, replace the fuel distributor.

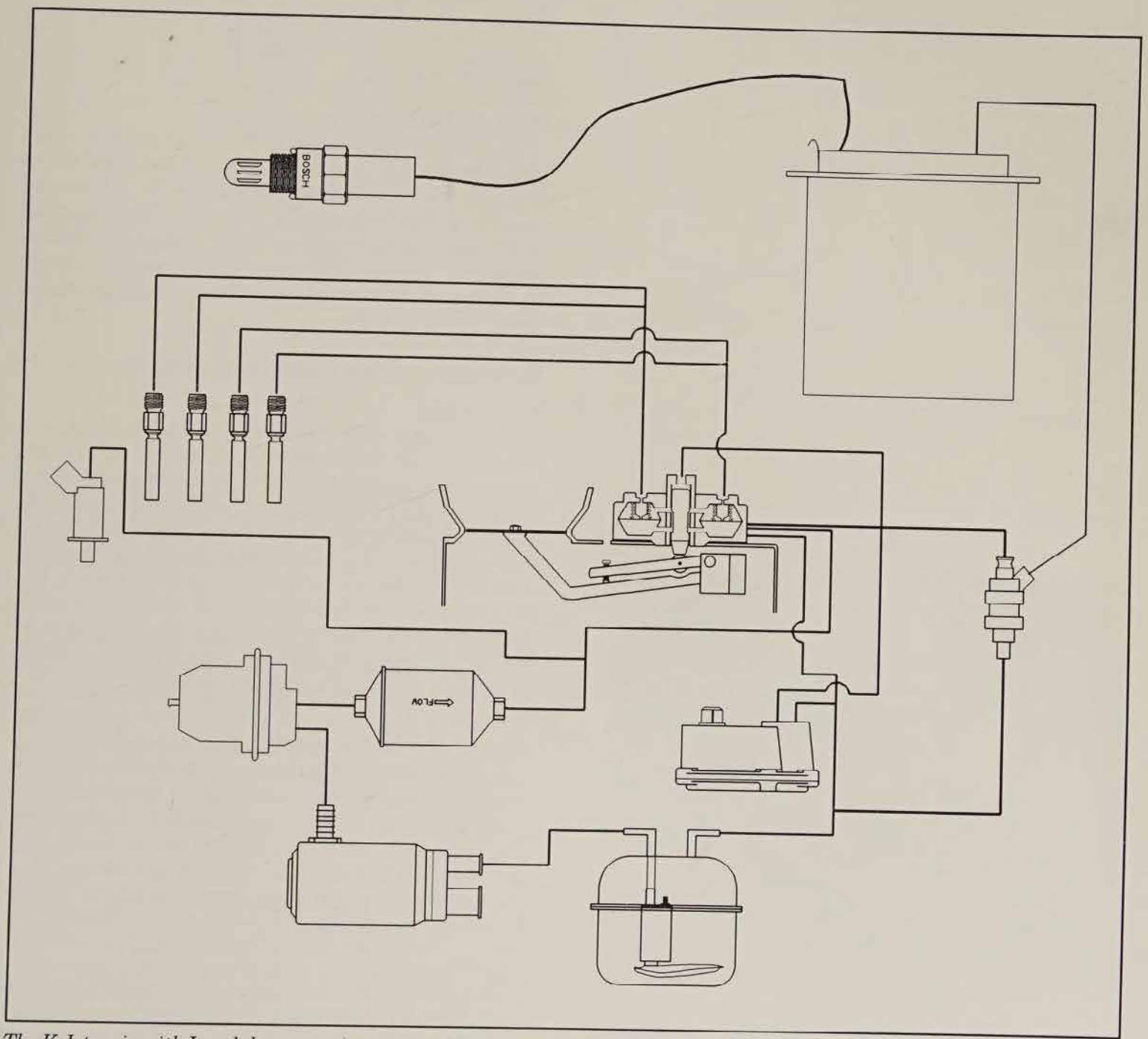
If the pressure is only a little too low, you might be able to increase the pressure by adding adjusting shims to the system pressure regulator. Good luck finding anyone who stocks them!



The two most likely causes of incorrect control pressure are the system pressure regulator and the control pressure regulator.

10

K-Jetronic with Lambda



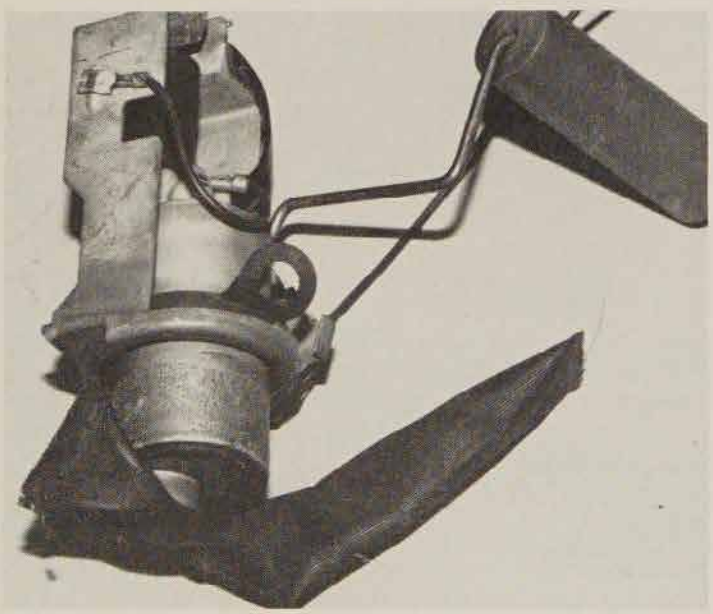
*The K-Jetronic with Lambda system is very similar to the K-Jetronic system. The primary difference is the addition of three new components: the Lambda sensor, the ECU and the frequency valve. (*Note: *The similarity of the frequency valve in this drawing to an EFI injector is realistic.)*

As emission controls grew stricter during the 1970s, the need for a more precise method to control air and fuel entering the engine became obvious. The answer to this was the oxygen feedback or Lambda control system.

Although the bulk of this system is still comprised of the standard K-Jetronic components, a few additional components have been added and the lower chambers of the fuel distributor have been modified.

Applications for K-Jetronic fuel injection with Lambda include:

Audi
Coupe
Coupe GT
4000
4000S
4000S Quattro
5000
5000S
5000S Turbo
BMW 320i
Mercedes-Benz
280
380
450
500
Peugeot 505
Porsche
911SC
924
924 Turbo
Saab
99
900
900 Turbo
Volkswagen
Carbriolet
Dasher
Golf
Jetta
Quantum
Rabbit
Rabbit pickup
Scirocco
Volvo
Coupe
DL
GL
GLE
Turbo
240
260
260 GLE
706 GLE



The pre-pump is used on most K-Lambda cars to move fuel from the tank to the main fuel pump. This prevents vapor lock and ensures a steady supply of fuel to the system.

Hydraulic Theory

To easily troubleshoot the K-Jetronic with Lambda system one must understand two basic principles of hydraulics: (1) Pumps do not create pressure, they only supply a volume. Both wanted and unwanted restrictions in the system create the pressure. (2) Any restriction holds pressure back upstream of the restriction and causes the pressure to drop downstream.

K-Jetronic with Lambda Components

Fuel Tank

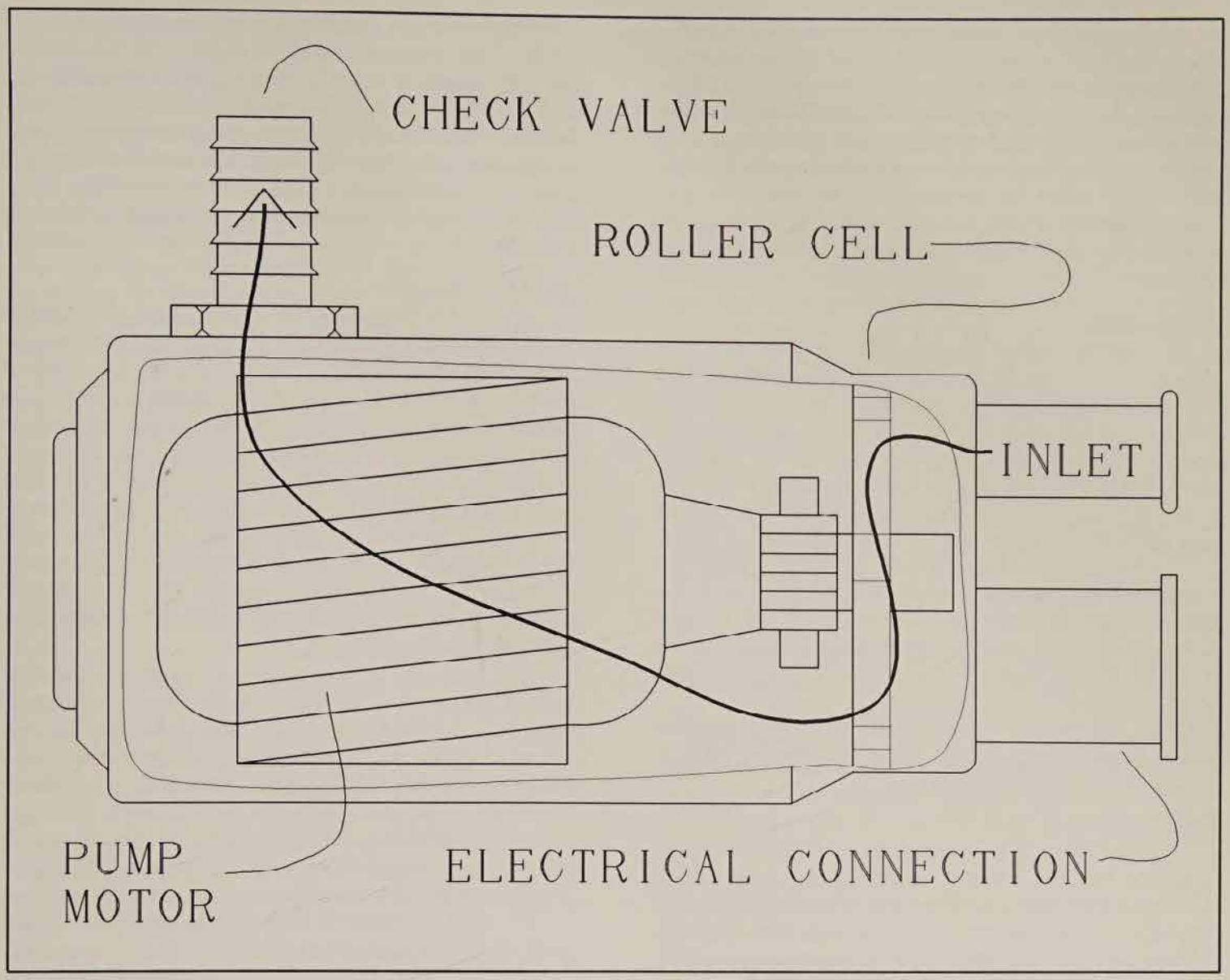
In electronic fuel-injection systems the design of the fuel tank is not critical. However, there are times when as much as 90 percent or more of the fuel pumped by the fuel pump will pass through the engine compartment, be warmed and return to the tank unused. This warm fuel needs to combine evenly with the colder fuel sitting in the tank. For that purpose the K-Jetronic with Lambda tank is designed to be narrow and deep. Baffling around the fuel pickup also reduces the possibility of fuel starvation when the car is low on fuel.

In-Tank Filter

Located on the end of the fuel pickup or in-tank fuel pump there is a sock-style filter. This filter is relatively coarse and is designed specifically to prevent damage to the fuel pump from rust, metal, dirt and sand. When the filter becomes plugged it can result in a loss of volume to the extent that system pressure will drop, causing a loss of power, hesitation and stalling.

Pre-Pump

The pre-pump is used on most post-1976 applications that do not have the main pump located in the fuel tank. This pump's job is to ensure a steady volume of fuel to the chassis-mounted main pump to prevent vapor locking. The pump is fused sep-



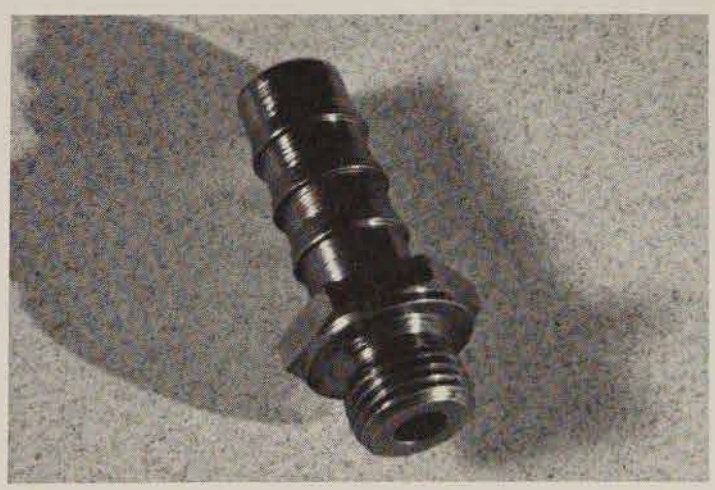
The K-Lambda fuel pump is a high-pressure, high-volume roller vane pump. These pumps are capable of sustained pressures in excess of 125 psi.

arately from the main fuel pump and on applications such as the 1976-80, the fuse is not located in the fuse panel but rather under a plastic cover beneath the carpet in the trunk.

When the pre-pump fails, the most common symptom will be a severe stumble or hesitation off idle when the fuel level is below half a tank, especially on hot days.

Fuel Pump

The fuel pump used by the K-Jetronic with Lambda system is a high-speed electrically driven roller vane pump. This type of pump delivers a high and relatively even volume to the fuel system, allowing the system to maintain an even and consistent pressure. The pump can be located in the fuel tank or on the chassis. If located in the tank, there will be no pre-pump.



The K-Lambda fuel pump has a check valve to retain fuel pressure in the system when the system is shut off. Retaining pressure until the engine is cold enough for the cold-start injector to work again is essential for easy hot restarts.

A different type of safety system is used to shut down the fuel pump in the event of a ruptured fuel line. It utilizes a relay that receives a signal from the primary ignition system. When the engine dies the primary ignition system shuts down, the relay stops sensing the signal and shuts off the fuel pump.

Typically, a defective fuel pump or fuel pump wiring system manifests itself as a no-start problem.

Accumulator

The accumulator is located close to the fuel pump. It consists of a spring-loaded diaphragm in a can and serves two purposes in the fuel system. First, the accumulator dampens or smooths out pressure pulsations created by volume fluctuations from the fuel pump. Its second job is to help maintain pressure in the system after the engine has been shut off and the fuel pump has shut down.

The most common failure of the accumulator is a ruptured diaphragm. On most applications, if the diaphragm ruptures fuel will leak out the back of the accumulator. Some applications have a hose connecting the back or dry side of the accumulator to the fuel tank.

If the accumulator diaphragm ruptures, system pressure will drop to the point where the engine will shut off and not restart.

Fuel Filter

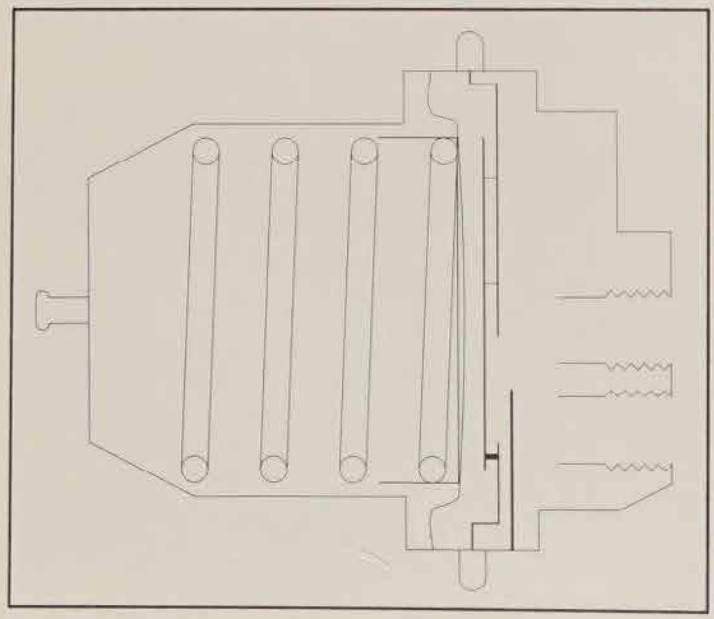
The fuel filter is important to an electronic fuel-injection system, but not nearly as important as it is to the CIS system. The injectors and the fuel distributor have some tiny openings and orifices. Consequently, very small particles can accumulate, causing severe restrictions in the fuel system.

The fuel filter on the K-Jetronic with Lambda is usually in plain sight in the engine compartment but probably has not been changed since the car has left the factory. The fuel filter is the only real protection that the injection system has against internal contamination from dirty fuel. The filter should be replaced every time the spark plugs are replaced.

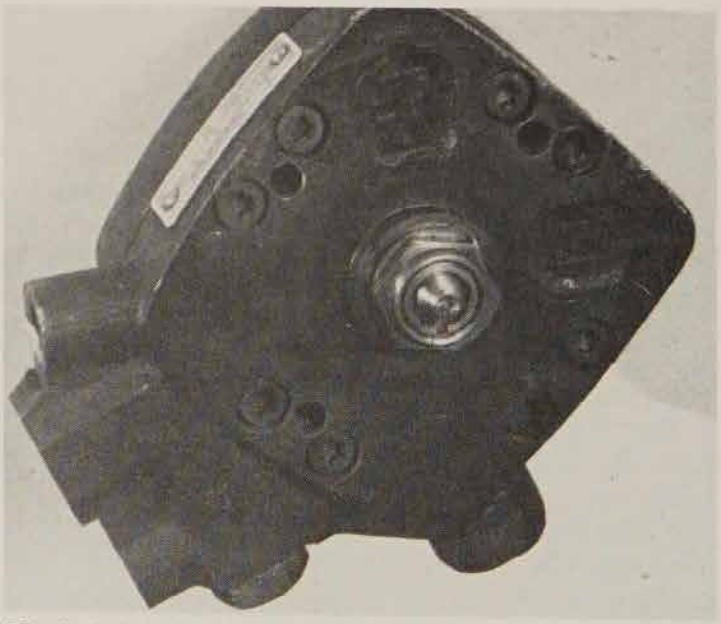
Fuel Distributor

The fuel distributor is the heart of the K-Jetronic with Lambda system. It is divided into two sets of chambers, the lower chambers and the upper chambers. These chambers are separated by a thin stainless-steel diaphragm which seals an orifice that protrudes down from the top of the upper chamber. A spring in the upper chamber applies pressure against the diaphragm, forcing it downward and opening the orifice when the pressures in the upper and lower chambers equalize. This pair of chambers is known as a differential pressure regulator. There is a differential pressure regulator for each engine cylinder.

With the fuel pump running but no air flowing into the engine, the pressure in the lower chambers is 1.5 psi higher than the pressure in the upper chambers. This pressure differential works against the tension of the spring in the upper chamber. In the center of the fuel distributor is the metering cylinder. In the center of the metering cylinder is the control plunger. A set of holes in the lower portion of the metering cylinder allows fuel to flow along a tapered area in the control plunger toward the upper chambers. If there is no air flowing into the engine the plunger will be in its lowest position, allowing no fuel to flow into the



The accumulator consists of a spring-loaded diaphragm. The job of the accumulator is to reduce noise by smoothing out pressure pulses. It also helps to maintain rest pressure when the engine is shut off.



The fuel distributor routes and meters fuel pumped by the fuel pump to the injectors.

upper chambers. As the airflow sensor plate is lifted by air entering the engine, the control plunger is lifted as well. As the plunger is lifted, metering slots adjacent to the upper portion of the control plunger are opened, allowing fuel to flow from the lower chambers into the upper chambers. The pressures in the upper and lower chambers equalize, allowing the springs to push the diaphragm downward, in turn allowing fuel to flow to the injectors. The quantity of fuel reaching the injectors is governed by how much the control plunger has been lifted and how much the metering slots have been opened.

A solenoid-operated valve resembling an electronic fuel injector is connected by a hose to the lower chambers of the fuel distributor. The frequency valve has a fixed flow rate that allows pressure in the lower chambers to be maintained at a level equal to those in the upper chamber while the engine is running. The frequency valve is sent a 60 Hz signal at a 50 percent duty cycle when all systems are working nominally. This allows the system to operate very much like a standard K-system. However, when the Lambda sensor detects a high oxygen content in the exhaust (low Lambda sensor voltage), the duty cycle to the frequency valve increases, causing the pressure in the lower chambers to decrease. This pressure reduction increases the volume of fuel allowed to flow through the upper chambers to the injectors. When the oxygen content of the exhaust decreases, the Lambda sensor voltage increases and the ECU responds by decreasing the duty cycle to the frequency valve.

Rough running and poor power are symptoms associated with a defective fuel distributor.

System Pressure Regulator

The system pressure regulator is located in the side of the fuel distributor. Its primary task is to control system pressure at about 5 bar (1 bar = 15 psi), with some variation from one application to another. The secondary task of the regulator is to close off the return line to the tank when the engine is shut off in order to maintain residual or rest pressure.

The design of the system pressure regulator prior to 1978 did not seal rest pressure adequately. Later systems incorporate a push valve with rubber O-rings to increase the valve's sealing ability.

System pressure can be adjusted to a small degree by adding or removing shims, thus altering the spring tension in the pressure regulator. These shims are not typically stock items for most dealerships, however.

Failure of the system pressure regulator normally results in a dramatic rise or drop in system pressure. Either condition will cause the engine to run extremely lean. Typical symptoms include backfiring, stalling, rough running and poor power.

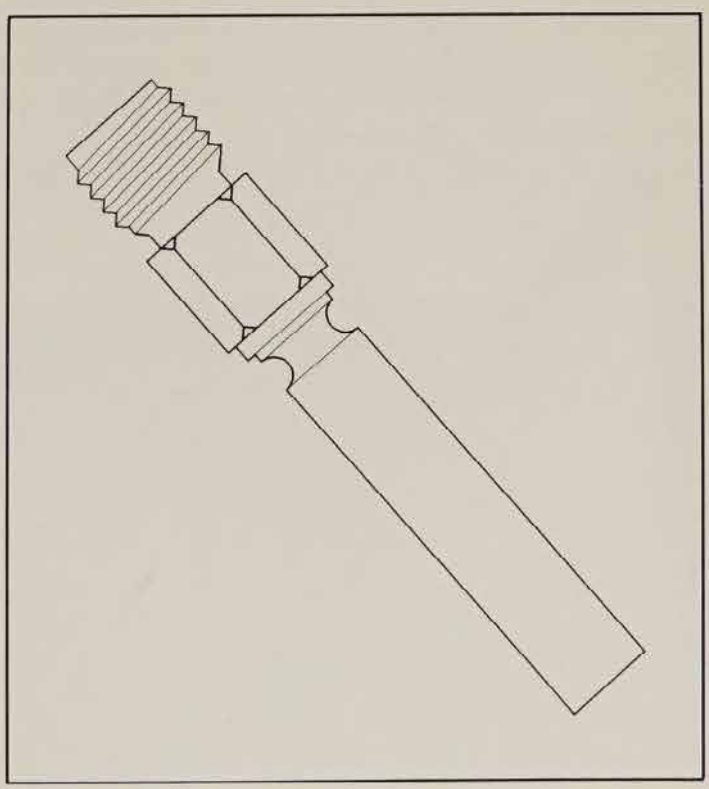
Control Pressure Regulator (or Warm-Up Regulator)

There is a tiny hole in the stainless-steel diaphragm that separates the lower chambers from the upper chambers of the fuel distributor. This hole allows fuel to flow from the lower chambers into an area above the control plunger. The control pressure regulator controls the pressure in this area, limiting the degree to which the control plunger can be lifted for a given amount of airflow into the engine. Limiting the movement of the control plunger in turn limits the richness of the air-fuel ratio. When the engine is cold the control pressure will be relatively low (around 1.5 bar), allowing greater movement of the control plunger and therefore a richer mixture. As the engine warms up the control pressure increases (to about 3.5 bar), leaning out the air-fuel ratio.

Defects in the control pressure regulator will typically cause cold-starting problems, hot-starting problems or rough running.

Injectors

The CIS system uses pressure-opened injectors. When the pressure supplied by the upper chambers of the fuel distributor to the injectors reaches approximately 3.0 bar (45 psi), the injectors open and spray fuel just above the intake valves continuously. A small disc located just above the valve in the injector vibrates as the fuel passes across it.



The K-Lambda injectors are simple, pressure-activated pop-off valve injectors. When pressure behind the injectors reaches around 50 psi they will open and spray continuously until the engine is shut off.

This helps to atomize the fuel and is responsible for the characteristic hum from the injectors.

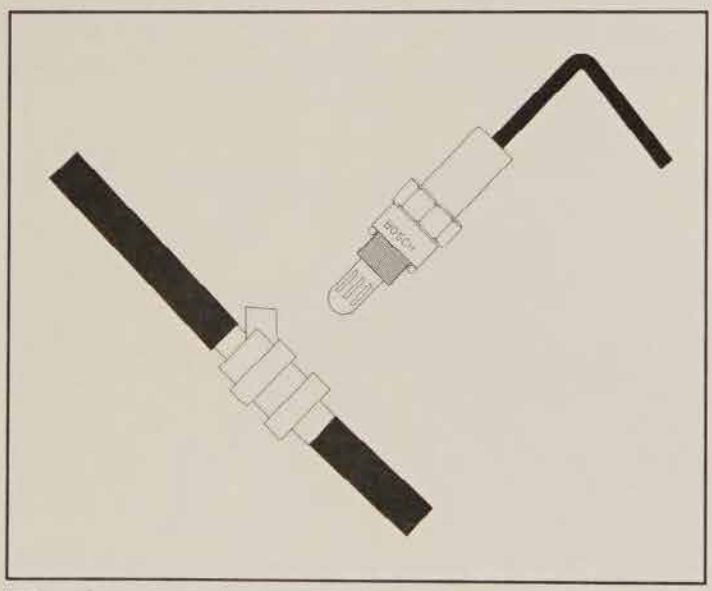
These injectors are so simple in design that nothing ever goes wrong with them, except for restrictions and leaking.

A defective injector will result in erratic engine operation, poor power and increased fuel consumption.

Cold-Start Injector

Also connected to system pressure is a solenoid-operated valve known as the cold-start injector. Since the earliest applications of the K-system were all four-cylinder, the cold-start valve picked up the nickname fifth injector. It stuck in some circles, even for six- and eight-cylinder applications.

The cold-start injector receives battery voltage whenever the starter is engaged, and is grounded through a device known as a thermo time switch. The thermo-time switch is a temperature-sensitive bimetal switch designed to provide a ground for the cold-start injector when the temperature of the engine is less than 95 deg. F. A second circuit in the thermo-time switch is an electric heating element intended to heat the bimetal as the engine is being cranked. The result is that the cold-start injector should operate only when the engine is being cranked, the temperature of the engine is less than 95 deg., and for a maximum of five to twelve seconds.



When heated to approximately 600 deg. F. the Lambda sensor becomes conductive for oxygen ions and begins to produce voltage. The sensor's output voltage is inversely proportional to the amount of oxygen in the exhaust. The ECU processes the voltage and sends a variable duty cycle signal to the frequency valve. When the oxygen content of the exhaust is high, the Lambda output voltage is low—the ECU assumes that the engine is running lean and increases the duty cycle to the frequency valve. The increase in duty cycle enriches the mixture.

Two of the most common symptoms of a cold-start injector problem are hard starting when cold because it is not operating, and a leaking injector which can cause an extremely rich running condition.

Lambda Sensor

The key component in the oxygen feedback system is the Lambda sensor. Located in the exhaust within a couple of feet of the cylinder head is a voltage-generating device that has an output between 100 and 900 mV under most operating conditions. When heated to approximately 600 deg. F., the Lambda sensor becomes conductive for oxygen ions and begins to produce a voltage. The lower the oxygen content in the exhaust, the higher the voltage. Hence, when the exhaust gases passing through the exhaust system are the result of a lean mixture the output voltage will be low; when the exhaust gases passing through the exhaust are the result of a rich exhaust condition the output voltage will be high.

For more information on the Lambda sensor, see chapter 5 on Lambda control.

Frequency Valve

The frequency valve is a normally closed, solenoid-operated valve resembling a D-Jetronic or L-Jetronic injector. Attached to the lower chambers of the fuel distributor, the frequency valve receives a variable duty cycle signal from the ECU (electronic control unit). When the Lambda sensor detects a lean running condition the ECU increases the duty cycle to the frequency valve, thereby increasing the volume of fuel through the injectors. When a rich exhaust condition (low oxygen content) is detected, the duty cycle will decrease. This duty cycle can be measured at a test connector with a dwell meter. If the test connector cannot be located, then connect the dwell meter to the appropriate ECU connector, as shown in the chart.

Frequency Valve Duty Cycle Measurement Guide

Application	ECU Test Connector Number
Audi	
1980-83 except Quattro	17 Blue/White
1983 Quattro	8 or back-probe frequency valve
BMW 320i	15 or back-probe frequency valve
Mercedes-Benz	15 Green/Brown
Peugeot 505	15 or back-probe frequency valve
Porsche	
1980 911	17 Green/White
1981-83 911	17 Green/White

1980 924 and 924 Turbo	17 Black
1981-83 924 and 924 Turbo	17 Black
Saab	
1977-80	17 Brown/White
1981-83	17 Brown/Violet
Volkswagen	
1980-83 except Quantum	17 Blue/White
1982-83 Quantum	1 or back-probe frequency valve
Volvo	17 Red

Thermal Switch

Several auto manufacturers use a thermal switch to signal the ECU when the engine is warm enough to operate at an air-fuel ratio of 14.7:1. These makes include Saab, Volvo, Peugeot, Mercedes, VW and Audi. The thermal switch is a bimetal device that closes when cold and opens when warm.

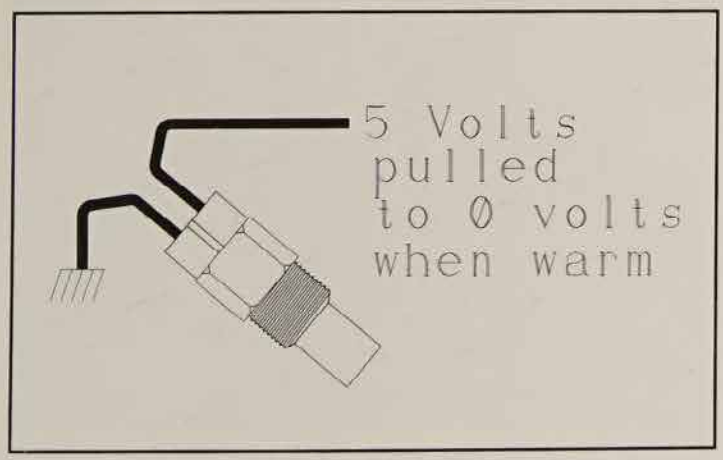
The Audi models except for the turbos have a second thermal switch to signal the ECU when the engine is overheating.

Throttle Switch

Saab, Volvo and Audi use a throttle switch to indicate wide-open throttle. This switch is open until the driver goes to wide-open throttle.

Mercedes-Benz uses not only a wide-open throttle switch but also a closed-throttle switch. The closed-throttle switch is open until the throttle is closed.

Peugeot does not use a throttle switch at all; instead, it uses a pair of vacuum switches—a yellow one that closes at 3.3 in. Hg (inches of mercury), and a green one that opens at 3.3 in. Hg. Both of these switches inform the ECU that the engine is under an extreme load.



Most K-Lambda systems use a thermal switch to indicate when the engine is warm enough to operate under Lambda control. When the engine is cold there should be 5 volts at one of the wires. When the engine is warmed up, the voltage on both wires should be zero.

K-Jetronic with Lambda Tune-Up Adjustments

For most engines equipped with the K-Jetronic with Lambda system, all of the standard ignition adjustments are made in the same way as for a carbureted engine. Spark plug gap has the same relevance, as well as ignition timing, point dwell, curb idle and so on.

Airflow Sensor Plate Rest Height

Adjust the rest height of the airflow sensor plate by adjusting the spring clip under the sensor plate. The plate should rest with the top of the plate just below the upper edge of the narrowest part of the airflow sensor venturi.

Airflow Sensor Plate Centering

The bolt in the center of the airflow sensor plate goes through a hole that is larger than the bolt. When the bolt is loosened, the plate can be moved to center it. Center the plate visually and ensure that the plate does not stick or bend in the venturi as the plate is lifted.

Adjusting Minimum Air

After completing the standard ignition system adjustments of dwell and timing, begin work on the fuel injection by adjusting the throttle plate for minimum airflow. Start up and warm the engine to operating temperature, then shut it off and visually inspect the auxiliary air valve to ensure that it has closed completely. Next, connect a tachometer and restart the engine. Close the manually adjusted idle air by-pass, and adjust the throttle stop screw so the engine just barely idles—at about 450 rpm on an eight-cylinder, 550 rpm on a six-cylinder and 650 rpm on a four-cylinder.

After completing the minimum air adjustment, ensure that the throttle does not bind in the closed position.

A throttle switch is used to tell the ECU that the throttle is wide open. When the switch indicates wide-open throttle, the ECU increases the frequency valve duty cycle to almost 100 percent for maximum enrichment.

Adjusting Curb Idle Speed

After completing the minimum air adjustment, use the manual adjustment on the idle air by-pass to set curb idle speed according to the EPA sticker under the hood. If the sticker is missing, 950 rpm is a good default setting for all applications.

Adjusting CO

The CO adjustment on the CIS system is located in the airflow sensor near the fuel distributor. A 3 mm long Allen wrench is required for the job. After completing the minimum idle and curb idle adjustments and after ensuring again that the engine is thoroughly warmed up, insert a CO exhaust gas analyzer into either the tailpipe or the sampling port located ahead of the catalytic converter, as indicated in the EPA sticker under the hood. If the EPA sticker is missing, adjust the CO to 1.5 percent ahead of the catalytic converter with the Lambda sensor disconnected.

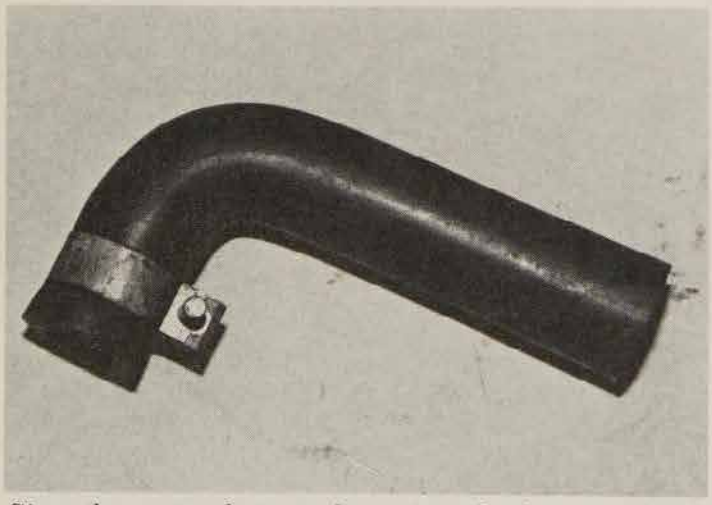
Very small movements of the 3 mm Allen wrench make an enormous difference in the CO reading. For this reason, the only practical and accurate way to adjust the CO is by using a gas analyzer.

After the CO is adjusted, recheck the idle speed.

Note: This adjustment *must* be made with the engine warm and the Lambda sensor disconnected.

Trick of the Trade

Connect a dwell meter to the Lambda signal duty cycle test connector. Start the engine and allow it to warm up. Leaving the Lambda sensor connected, adjust the 3 mm Allen wrench until the frequency valve dwell reaches about 45 deg. on the four-cylinder scale. The CO will be correct, assuming the intake, engine, ignition and tune-up parts are all in good shape.



Since the gas analyzer probe may need to be inserted at a port ahead of the catalytic converter, it may be necessary to use an adapter. This is the adapter I use for Peugeot. It is actually the exhaust tube from a 1978 260 series Volvo vacuum pump.

Component Testing and Troubleshooting

Since the K-Jetronic with Lambda system controls itself through the variation of hydraulic pressures throughout the system, the bulk of serious troubleshooting will be done by testing pressures in the system. There are six pressures that are relevant to the control of the K-Jetronic with Lambda system: operating pressures, supply pressure, system pressure, cold control pressure, warm control pressure, injector opening pressure and return line pressure.

Understanding the function and purpose of each of these pressures is essential in troubleshooting system faults. However, only four pressures are actually measured directly in the troubleshooting method. These pressures include testing pressures, cold control pressure, system pressure, warm control pressure and rest pressure.

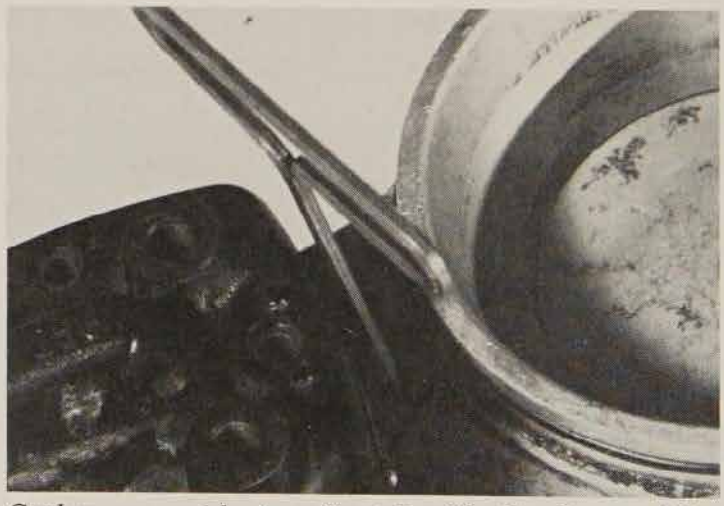
Hooking Up the Gauge

A gauge capable of reading approximately 100 psi is required to troubleshoot the K-Jetronic with Lambda system. Additionally, the hoses from the gauge must form a T. One leg of the T must be equipped with a shutoff valve.

Connect the gauge in the line that runs from the center of the fuel distributor to the control pressure regulator. The hose with the valve should be installed on the control pressure regulator side of the hose going to the gauge.

For an effective and accurate diagnosis, follow the proper operational sequence from beginning to end and diagnose your results only after the entire procedure has been completed.

Begin with a cold engine. Disconnect the electrical connectors at the auxiliary air valve and at the control pressure regulator. Then connect the



Carbon monoxide is adjusted with the 3 mm Allen wrench inserted through the hole between the fuel distributor and the airflow sensor venturi. Be sure that the Lambda sensor is dissconnected when adjusting the CO. Remember also that small movements of the Allen wrench mean big changes in CO.

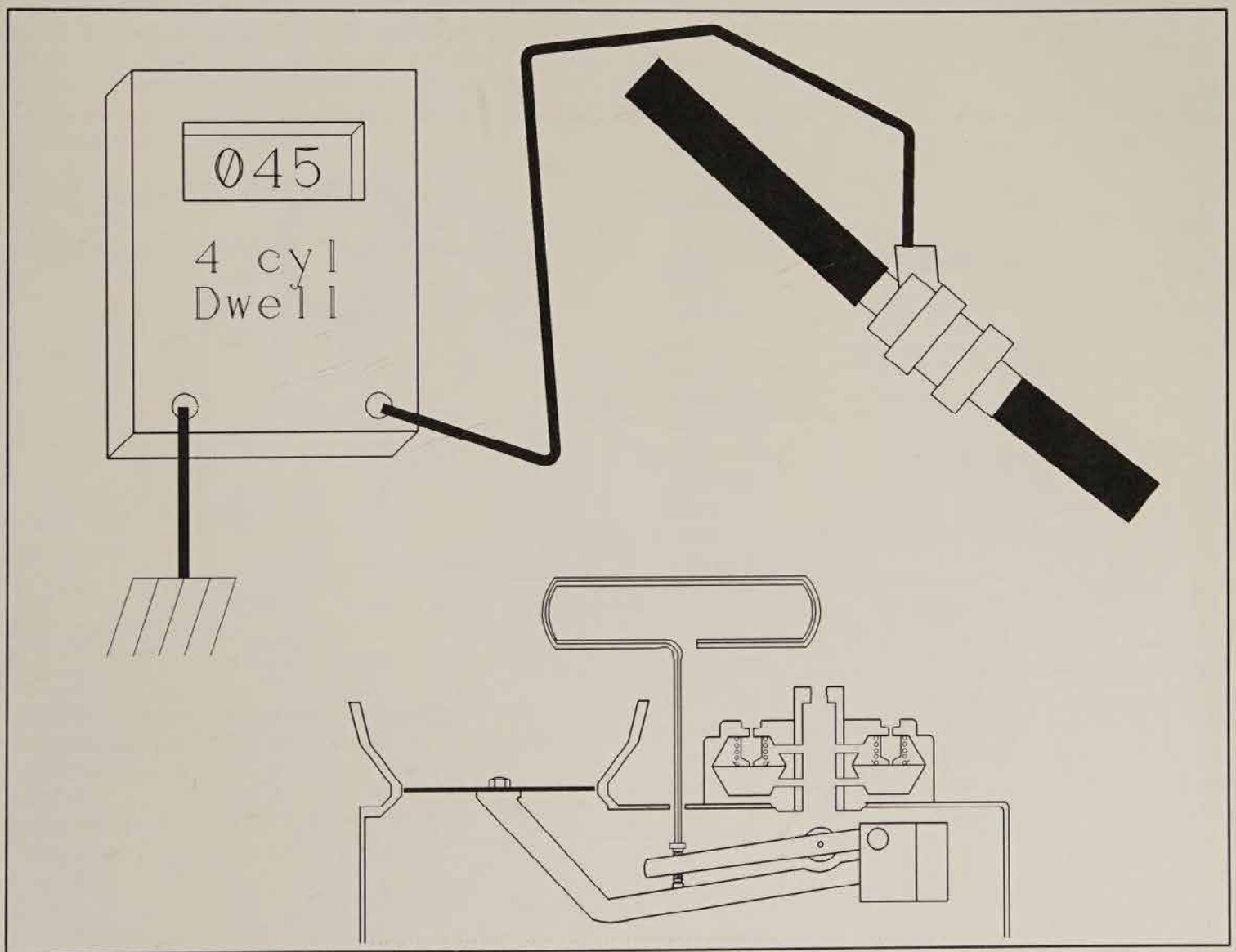
gauge. By-pass the fuel pump relay according to specifications.

Fuel Pump Relay Specifications

Application	Procedure
Audi	
1980-83 except Quattro	Place jumper with 8 amp fuse between pin V and pin P87F of fuel pump relay harness connector.
1983 Quattro	Place jumper with 8 amp fuse between pin 30 and pin 87 of fuel pump relay harness connector.

Fuel Pump Relay Specifications

Application	Procedure
BMW 320i	Place jumper with 8 amp fuse between pin 15 and pin 87 of fuel pump relay harness connector.
Mercedes-Benz	Place jumper with 8 amp fuse between pin 30 and pin 87 of fuel pump relay harness connector.
Peugeot 505	Place jumper with 8 amp fuse between pin 20C and pin 76 of fuel pump relay harness connector.



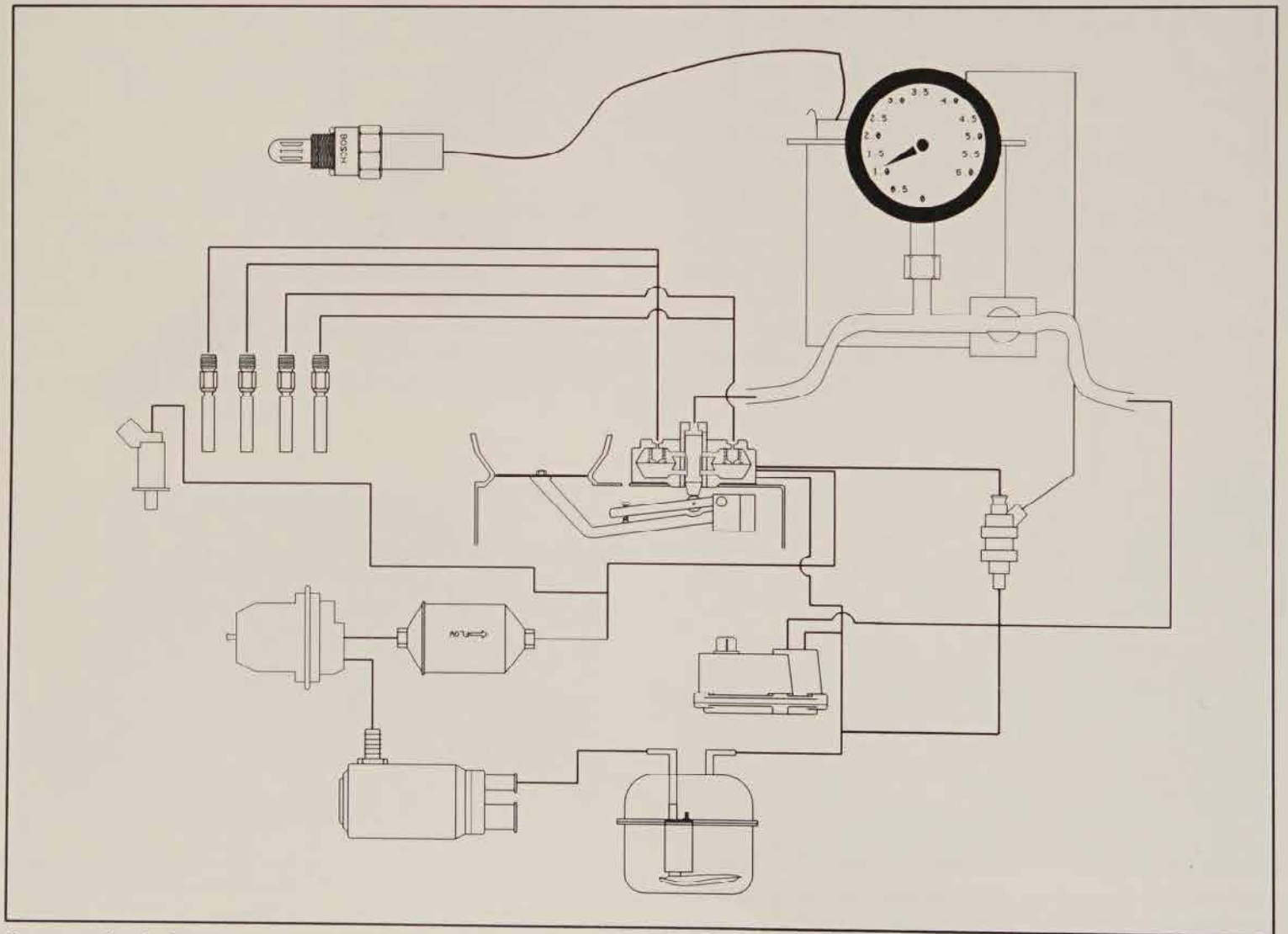
For those who do not have a gas analyzer, an accurate way to adjust the air-fuel ratio on K-Lambda cars is with a dwell meter. Set the dwell meter on the four-cylinder scale. Connect the dwell meter to the pulsed side of the frequency valve, or the duty cycle test terminal of the car. Then start the engine and allow it to warm up. With the Lambda sensor still connected, use a 3 mm Allen wrench to adjust the air-fuel ratio until the dwell meter reads 45 deg.

Fuel Pump Relay Specifications

Application	Procedure
Porsche	
1980 911	Place jumper with 8 amp fuse between pin 30 and pin 87A of fuel pump relay harness connector.
1981-83 911	Place jumper with 8 amp fuse between pin 30 and pin 87 of fuel pump relay harness connector.
1980 924 and 924 Turbo	Place jumper with 8 amp fuse between pin 30 and pin 37 of fuel pump relay harness connector.
1981-83 924 and 924 Turbo	Place jumper with 8 amp fuse between pin 30 and pin 87 of fuel pump relay harness connector.

Fuel Pump Relay Specifications

Application	Procedure
Saab	
1977-80	Place jumper with 8 amp fuse between pin 30 and pin 87 of fuel pump relay harness connector.
1981-83	Place jumper with 8 amp fuse between pin 30 and pin 87 of fuel pump relay harness connector.
Volkswagen	
1980-83 except Quantum	Place jumper with 8 amp fuse between pin 30 and pin 87 of fuel pump relay harness connector.



Connect the fuel pressure gauge in the line between the center of the fuel distributor and the control pressure regulator. Activate the fuel pump without starting the engine. With the valve open, the fuel pressure will read cold control pressure.

Fuel Pump Relay Specifications

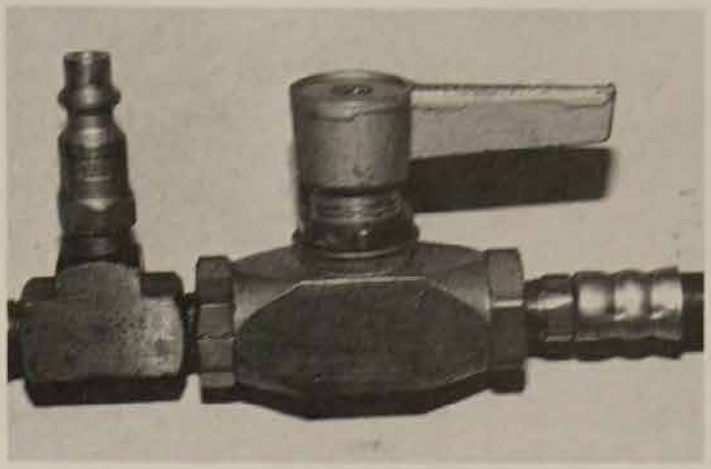
Application	Procedure
1982-83 Quantum	Place jumper with 8 amp fuse between pin 30 and pin 87 of fuel pump relay harness connector.
Volvo	Place jumper with 8 amp fuse between pin 30 and pin 87 of fuel pump relay harness connector.

If all else fails in an attempt to energize the fuel pump, run a set of jumper leads from the fuel pump to the battery. Be careful about polarity between the fuel pump and battery.

With the valve on the gauge in the open position and the fuel pump running but not the engine, record the control pressure. The chart below reflects what the cold control pressure should be in three typical North American climates. The temperatures listed are in degrees Fahrenheit. If the ambient temperatures listed do not reflect the temperature you are running the test at, it will be necessary to estimate.

Cold Control Pressure Readings

Application	Pressure at 50 Deg. F. (psi)	Pressure at 75 Deg. F. (psi)	Pressure at 100 Deg. F. (psi)
Audi			
1980-83 except Quattro	17	25	32
1983 Quattro	17	25	32
BMW 320i	17	26	35
Mercedes-Benz			
280	17	26	35
380, 450, 500	23	32	40
Peugeot			
1980 505	17	30	44
1981-85 505	25	40	56
Porsche			
1980 911	25	36	48
1981-83 911	23	36	50
1980 924	15	24	32
1980 924 Turbo	23	36	50
1981-83 924	17	32	46
1981-83 924 Turbo	28	40	56
Saab			
1977-80 non-Turbo	20	28	36
1979-80 Turbo	17	23	31
1981-83 including Turbo	24	36	52
Volkswagen			
1980-83 except Quantum	17	23	36
1982-83 Quantum	20	28	38
Volvo			
1977-80 Four-cylinder	17	25	32
1980-85 Four-cylinder	21	32	46
1978-79 Four-cylinder	17	25	32
1980-83 Six-cylinder	23	35	48
760	23	32	42

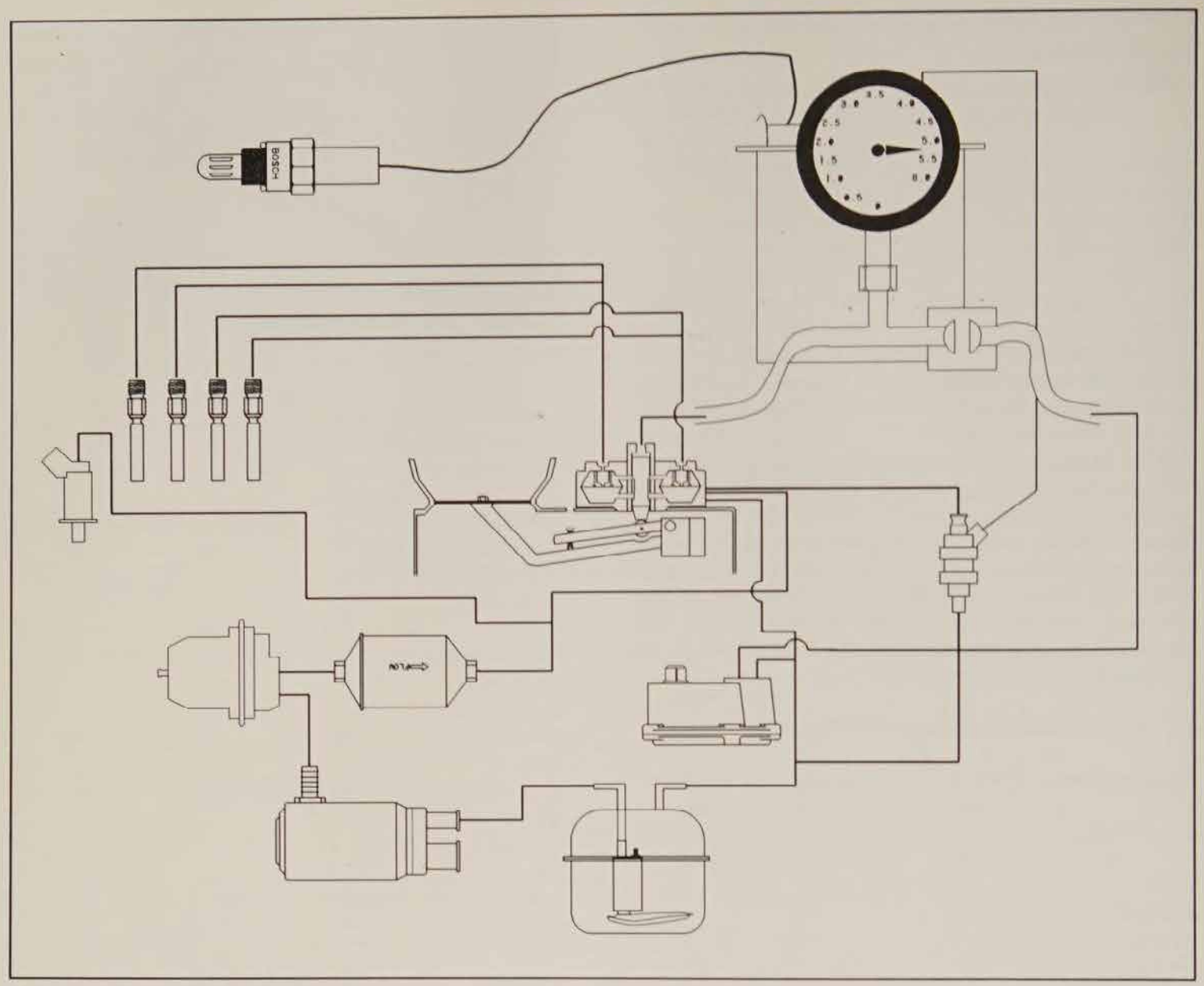


This valve in the line between the gauge and the control pressure regulator determines whether fuel can flow to the control pressure regulator.

Next, rotate the gauge valve to the closed position. By doing so the control pressure regulator will be isolated, thus the pressure that the gauge shows will be system pressure. Measure the system pressure and check it against the system pressure chart. Minor adjustments in system pressure can be made by adding or removing shims to the system pressure regulator.

System Pressure Readings

Application	Pressure (psi)
Audi 1980-85	65-75
BMW 320i	65-75
Mercedes-Benz	75-84
Peugeot 505	65-74



Close the valve to read system pressure.

Porsche 1980 911	65-75
Saab	65-74
Volkswagen	65-75
1980 and later	68-78
Volvo	65-77

Return the valve to the open position to measure control pressure. Reconnect the electrical connectors on the fuel pump, the control pressure regulator and the auxiliary air valve.

Now, start the engine and allow it to warm up. As the engine runs, the control pressure should decrease to the warm reading in about three to five minutes. After the pressure stabilizes at the warm reading, compare it to the warm control pressure chart.

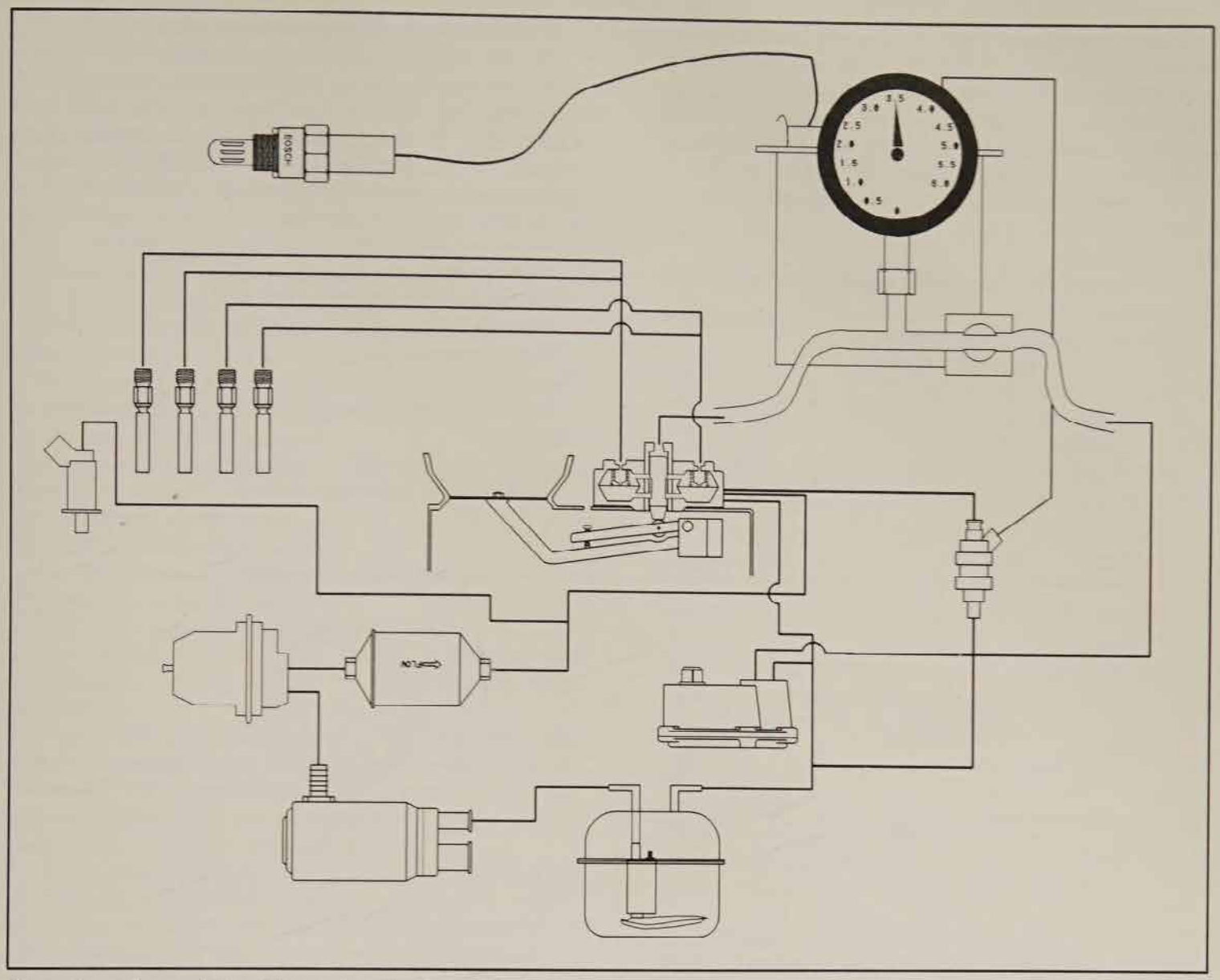
Warm Control Pressure Readings

Application	Pressure (psi)
Audi 1980-83 except Quattro	49-55
BMW 320i	39-45
Mercedes-Benz	49-55
Peugeot 505	49-55
Porsche	
1981-83 911	49-55
1981-83 924 and 924 Turbo	49-55
Saab 1977-83	49-55
Volkswagen 1980-83 except Quantum	49-55
Volvo	51-57

Now shut off the engine and watch the residual or rest pressure over the next twenty minutes. The pressure should not drop below the readings on the rest pressure chart.

Rest Pressure Readings

Application	Pressure (psi)
Audi	
1980-83 except Quattro	23



Open the valve and start the engine. As the engine runs for several minutes the control pressure should rise to about 3.5 bar, or 50 psi.

1983 Quattro	23
BMW 320i	22
Mercedes-Benz	41
Peugeot 505	22
Porsche	
1980 911	22
1981-83 911	22
1980 924 and 924 Turbo	22
1981-83 924 and 924 Turbo	22
Saab	
1977-80	15
1981-83	22
Volkswagen 1980-83 except Quantum	23
Volvo	25

Pressure Test Analysis

In this section, I've listed some symptoms and possible causes that would likely occur on a K-Jetronic with Lambda system.

Symptoms:
- Cold control pressure low
- Warm control pressure normal
- System pressure normal
- Rest pressure normal

Possible cause:
- Defective control pressure regulator.

Symptoms:
- Cold control pressure normal
- Warm control pressure low
- System pressure normal
- Rest pressure normal

Possible cause:
- Defective control pressure regulator.

Symptoms:
- Cold control pressure high
- Warm control pressure normal
- System pressure normal

Rest pressure normal

Possible cause:

Defective control pressure regulator.

Symptoms:

Cold control pressure low
Warm control pressure low
System pressure normal
Rest pressure normal

Possible cause:

Defective control pressure regulator.

Symptoms:

Cold control pressure high
Warm control pressure high
System pressure normal
Rest pressure normal

Possible causes:

Restriction in the return line from the control pressure regulator.

Defective control pressure regulator.

To distinguish between these install a replacement return line on the control pressure regulator, allowing the fuel to flow into an approved fuel receptacle. If the control pressure drops, then repair or replace the return line. If the control pressure does not drop, replace the control pressure regulator.

Symptoms:

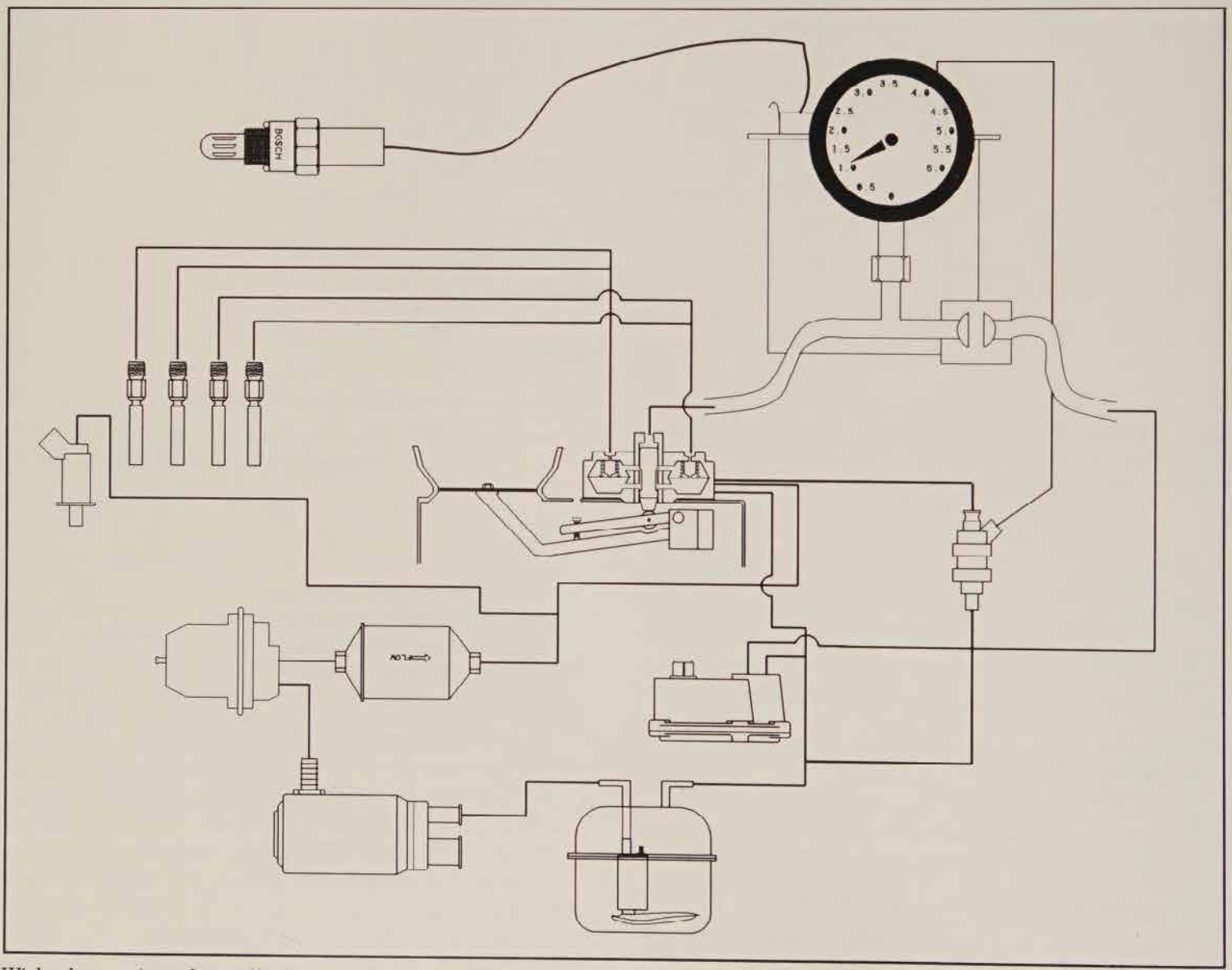
Cold control pressure normal
Warm control pressure normal
System pressure a little high
Rest pressure normal

Possible cause:

System pressure regulator misadjusted or defective.

Symptoms:

Cold control pressure normal



With the engine shut off, the control pressure should remain above 15 psi for at least twenty minutes. In this illustration, the control pressure regulator may be causing a loss of rest pressure. The valve was closed, isolating the control pressure regulator. If the rest pressure no longer falls, the problem is a leaking control pressure regulator.

Warm control pressure normal
System pressure very high
Rest pressure normal

Possible causes:

Restricted return line.
Defective fuel distributor.

To distinguish between these remove the fuel distributor return line and connect a replacement line, allowing the fuel to flow into an approved fuel receptacle. If the pressure drops, repair or replace the return line. If the pressure does not drop, replace the fuel distributor.

Symptoms:

Cold control pressure normal
Warm control pressure normal
System pressure normal
Rest pressure drops below minimum

Possible causes:

Fuel pump check valve.
Leaking cold-start injector.
Leaking system pressure regulator.
Defective fuel distributor.
Defective control pressure regulator.

To distinguish between these, eliminate the possibilities one at a time by isolating the components.

Begin isolating the source of the rest pressure loss by repressurizing the system, closing the valve between the control pressure regulator and the pressure gauge. If the pressure no longer drops, replace the control pressure regulator.

If the rest pressure continues to drop, pinch off the line between the fuel pump and the accumulator, then repressurize the system and watch the rest pressure. If the rest pressure no longer decreases, replace the fuel pump check valve.

If the rest pressure continues to drop, pinch off the line to the cold-start injector. If the rest pressure no longer drops, replace the cold-start injector.

If the rest pressure continues to drop, pinch off the return line from the fuel distributor. If the rest pressure no longer drops, it is either the system pressure regulator or the fuel distributor. For either problem, replace the fuel distributor.

Symptoms:

Cold control pressure low
Warm control pressure low
System pressure low
Rest pressure normal

Possible causes:

Run the fuel pump volume test. Disconnect the fuel distributor return line and install a replacement line, allowing the fuel to flow into a measuring cup that reads in liters. Energize the fuel pump to run as described earlier in this section. The volume of fuel that flows into and through the return line in thirty seconds should be according to the following chart. If the volume is less than the specification, inspect the inbound fuel lines and replace the fuel filter. If the flow is still not within spec, replace the in-tank filter. If the volume does not increase, run the test with the gas cap off to determine if the problem is plugged fuel tank vents. If none of these repairs increases fuel volume to specification, replace the fuel pump.

Return Line Fuel Flow

Application	Minimum Volume (cc per 30 sec)
Audi	
1980-83 except Quattro	750
1983 Quattro	850
BMW 320i	750
Mercedes-Benz	
Eight-cylinder	1100
Six-cylinder	930
Peugeot 505	750
Porsche	
1980 911	1000
1981-83 911	1100
1980 924 and 924 Turbo	1050
1981-83 924 and 924 Turbo	1100
Saab	
1977-80	750
1981-83	950
Volkswagen	
1980-83 except Quantum	750
1982-83 Quantum	850
Volvo	850

K-Jetronic with Lambda Troubleshooting by Symptom

When attempting to find the cause of a driveability problem in the K-Jetronic with Lambda system it is dangerous to attach symptoms to a specific component. The fuel system is a very closed and symbiotic entity. The interrelationship between the various components means that a given symptom can be caused by virtually any part in the system. Therefore, in this section I will present the possible causes of a given symptom and then offer a list of components that need to be tested. Refer to earlier sections of this chapter for the test procedures related to each component.

Engine Cranks but Will Not Run

Definition: Starter engages but the engine does not fire. This is a cold-starting problem.

Lack of Fuel Pressure: Test the fuel pump and prepump (if applicable). Perform not only a pressure test, but also a volume test.

Jammed or Sticking Airflow Sensor: Remove the airflow sensor boot, loosen the center hose on the fuel distributor to relieve control pressure and using a pocket magnet, try to lift the airflow sensor plate by the center bolt. This procedure should also

involve checking the sensor plate for the proper rest height and centering.
Auxiliary Air Valve Sticking: The engine will run if the auxiliary air valve does not open, providing the driver keeps his foot on the accelerator. However, since the proper starting instructions for the K-Jetronic with Lambda engine say to refrain from depressing the accelerator, the engine will not fire.
Cold-Start Injector Not Opening: If the cold-start injector fails to open, the net effect will be the same as the choke failing to close on a carbureted engine. The air-fuel ratio will be too lean to permit easy start-up.
Defective Thermo-Time Switch: One of the most common causes of the cold-start injector not working in a defective thermo-time switch.
Sticking Control Plunger: Remove the fuel distributor from the airflow sensor assembly and ensure that the plunger moves freely.
Restricted Injectors: In order for restricted injectors to cause a no-start problem these injectors would have to be severely restricted. Perform the injector equal-flow test.

Hot-Starting Problems

Definition: Engine starts only after cranking for an extended period of time (five to thirty seconds).
Loss of Rest Pressure: Run a complete K-Jetronic with Lambda pressure test, paying particular attention to the rest pressure. If the rest pressure does not hold according to specification, troubleshoot the cause of pressure loss. It could be a defective fuel pump check valve, leaking cold-start injector, defective fuel distributor or faulty system pressure regulator.
Improperly Adjusted Airflow Sensor: Check airflow sensor plate for proper height, centering and binding. Remove the airflow sensor boot, loosen the center hose on the fuel distributor to relieve control pressure and using a pocket magnet, try to lift the airflow sensor plate by the center bolt. This procedure should also involve checking the sensor plate for the proper rest height and centering.
Sticking or Binding Control Plunger: Remove the fuel distributor and ensure that the control plunger is moving freely.
Leaking Injectors: Remove the injectors from the intake manifold, pressurize the system and inspect injectors for leaks.
Leaking Cold-Start Injector or Shorted Thermo-Time Switch: Remove the cold-start injector from the intake manifold, pressurize the fuel system and inspect for leaks.
Incorrect Control Pressure: Run a complete K-Jetronic with Lambda pressure test to ensure that the warm control pressure is correct.

Engine Idles Rough When Cold

Incorrect Cold Control Pressure: If the cold control pressure is too high, it will limit the movement of the control plunger and therefore limit the fuel available to flow through the injectors. The engine will therefore run lean and the idle will be rough.
Auxiliary Air Valve Not Opening: If the auxiliary air valve does not open, the cold idle speed will not rise and therefore the idle will be slow and rough.
Leaking Cold-Start Valve: A leaking cold-start valve will make the engine run excessively rich, even when cold. An excessively rich running engine will tend to idle rough whether the engine is cold or warm. If the cold-start injector is leaking, the roughness will get progressively worse as the engine warms up.
Improperly Adjusted or Binding Airflow Sensor: Anytime the airflow sensor plate does not operate smoothly it can result in air-fuel ratio errors.
Unequal Injector Flow or Spray Pattern: Perform the injector flow test. Replace any injectors that are flowing an inadequate quantity or have a poor spray pattern.

Engine Idles Rough When Warm

Incorrect Warm Control Pressure: If the warm control pressure is too low or too high the air-fuel ratio will be incorrect, causing rough idle.
Leaking Cold Start Valve: This will overfuel the engine, resulting in a rich air-fuel ratio and a rough idle.
Improperly Adjusted, Sticking or Binding Airflow Sensor: Anytime the airflow sensor plate does not operate smoothly it can result in air-fuel ratio errors.
Unequal Injector Flow or Spray Pattern: Perform the injector flow test. Replace any injectors that are flowing an inadequate quantity or have a poor spray pattern.

Engine Stalls Immediately after Starting, Warm

Warm Control Pressure: If the warm control pressure is too high the air-fuel ratio will be very lean, resulting in the engine dying.
System Pressure: If the system pressure is too high or too low, the air-fuel ratio will be incorrect. Incorrect fuel pressure can result in either a rich or lean running condition. Either condition can cause the engine to stall after start-up.

Idle Speed Too High and Cannot Be Adjusted

Check Minimum Air: If closing off the idle air bypass does not bring the idle within specs check for vacuum leaks, check the auxiliary air valve and adjust the minimum air.
Check the Auxiliary Air Valve: Remove the hoses to the auxiliary air valve and ensure that it is closing off.
Vacuum Leaks: A vacuum leak is a source of extra air entering the intake manifold after the throttle plates. As a result, a vacuum leak can cause an excessively high idle speed.

Engine Backfires in Intake

Check for Proper CO Adjustment: A lean mixture adjustment can result in a backfire under load or when starting.

Check Engine Air Tubing between Airflow Sensor and Throttle: Holes or other leaks in the tubing that runs from the airflow sensor to the throttle assembly can result in a lean air-fuel ratio. A lean ratio can result in a backfire under load or when starting.

Check for Vacuum Leaks: Vacuum leaks can result in a lean mixture, and a lean mixture can result in a backfire. One of the best techniques for locating a vacuum leak is to run a little propane around the intake system.

Engine Misfires under Load

Ignition Problems: The most likely cause of a misfire is always the ignition system, regardless of the fuel system.

Inadequate Fuel Delivery (engine running lean): An insufficient supply of fuel can be the result of a binding airflow sensor or control plunger, restricted injectors, incorrect control or system pressure. Also perform an equal flow and spray pattern test on the injectors.

Poor Power

Incorrect Tune-Up Specs or Worn Tune-Up Parts: As with a carbureted engine the most likely cause of poor power is the basic tune-up specifications of timing, dwell and air-fuel ratio. Also, worn distributor caps, spark plugs, points and plug wires can seriously impact the performance of the K-Jetronic with Lambda engine.

Control Pressure Too High: High control pressure will limit the travel of the control plunger, thereby limiting the amount of fuel that can flow into the engine. When the engine begins to run lean, power can suffer.

Restricted Injectors: Restricted injectors can limit the amount of fuel that can pass through them, thereby limiting power.

Stumble or Sag on Acceleration

Sticking or Binding Airflow Sensor Plate: If the airflow sensor plate binds on the way up, fuel flow will be limited and the engine will sag or stumble.

Sticking or Binding Control Plunger: If the control plunger binds on the way up, fuel flow will be limited and the engine will stumble or sag.

Incorrect System or Warm Control Pressure: If the system pressure is too high or if the control pressure is too high (high system pressure will usually cause high control pressure) the movement of the control plunger will be limited and the engine will begin to run lean as the airflow increases. A lean running engine will sag or stumble on acceleration.

Unequal Injector Flow: Restricted injectors can limit the amount of fuel that can pass through them, thereby limiting power.

Engine Diesels

Binding or Sticking Airflow Sensor: In order for the engine to diesel or run-on after the engine is shut off there must be fuel entering the engine. One source of this fuel is an airflow sensor that is not dropping to the closed position as the engine is shut off.

Binding or Sticking Control Plunger: Inspect the control plunger for smooth movement without binding or sticking.

Leaking Injectors: Perform an injector flow test and inspect the injectors for proper seating when the airflow sensor drops to the rest position.

Leaking Cold-Start Injector: Remove injector, pressurize the system and inspect for leaks.

Excessive Fuel Consumption

Improperly Adjusted Air-Fuel Ratio: Check the CO adjustment as previously described.

Leaking Injectors: Remove the injectors from the cylinder head. Energize the fuel pump and watch the injector tips for evidence of dripping. If a drop forms, falls from the tip of the injector and is replaced by another drop, replace the offending injector.

Leaking Cold-Start Injector: Remove the cold-start injector from the cylinder head. Energize the fuel pump and watch the tip for evidence of dripping. If a drop forms, falls from the tip of the cold-start injector and is replaced by another drop, replace it.

What to Do, and When

Lack of Fuel Pressure

When there is no fuel pressure, the first thing to do is confirm that there is fuel in the tank. I have seen several methods, at various levels of sophistication, to confirm fuel quantity. Of all these methods the best and simplest is to pour a gallon or so of fuel into the tank.

If there is an adequate amount of fuel in the tank, the next item of business is to confirm fuel pump operation. Place a mechanic's stethoscope on the fuel pump and have someone crank the engine. If the fuel pump is located inside the fuel tank, then place the stethoscope on the fuel tank. As the engine is cranked the hum of the fuel pump should be heard through the stethoscope. If no hum is heard, check electrical power to the pump.

Begin by inspecting the fuel pump fuse. If the fuel pump fuse is good, connect the alligator clip of a test light to the ground side of the fuel pump connector and probe the positive side of the fuel pump connector. If the test light goes on, then the pump is receiving power and has a good ground. If the test light fails to light up, connect the alligator

clip to a good chassis ground and probe the positive terminal on the fuel pump. If the test light still fails to light up, check the fuel pump relay and inspect the fuel pump wiring harness. If the test light finally goes on, inspect the fuel pump ground.

Another reason for a lack of fuel pressure is restriction in the fuel lines or the fuel filter. Energize the fuel pump and begin loosening fittings along the fuel supply line.

USE EXTREME CAUTION THOUGH, AS THE FUEL WILL BE UNDER AS MUCH AS 100 PSI PRESSURE AND WILL TEND TO SPRAY OUT IN A FINE, HIGHLY FLAMMABLE MIST.

If there is only a small amount of pressure or volume present at a loosened fitting, inspect the components upstream of that fitting for restrictions. Restrictions are commonly found in the fuel filter and the in-tank pickup filter screen.

An obvious reason for no fuel pressure would be an external leak. Look for external leaks anywhere along the fuel lines or at the accumulator.

Jammed or Sticking Airflow Sensor

After removing the airflow sensor boot, inspect for proper adjustment of the sensor plate. Adjust as necessary. If the adjustment is OK, the binding is at the fulcrum—the only component of the K-system with Lambda that can be disassembled and reassembled without damaging it.

Remove the airflow sensor assembly from the car. On each side of the sensor you will find a disc held in place by an internal snap ring. Remove the snap rings and with a small screwdriver, wobble the disc back and forth until it falls out. There is a large counterweight on the end of the airflow sensor lever; loosen the large screw that holds the counterweight in place. At the same time this will loosen the fulcrum shaft. Carefully mount the airflow sensor assembly in a vise and using a brass drift, drive the shaft out of the assembly.

Wash all of the metal components in solvent, removing any varnish build-up that may have occurred over the years. Rinse the solvent off of the parts with hot water. The hot water will evaporate quickly, reducing the possibility of rusting.

Reassemble the airflow sensor using a very light film of point lube or similar lubricant. Make the sensor plate adjustments and reinstall on the car.

Auxiliary Air Valve Not Opening

There is really nothing that can be done for an auxiliary air valve that does not open, short of replacement. Verify that the valve is not receiving power all the time and replace it.

Cold-Start Injector Not Opening

The cold-start injector is a simple, normally closed solenoid-operated valve. If the cold-start injector does not open when the engine temperature is below 95 deg. F., disconnect the cold-start injector and connect a test light across the terminals. Crank the engine. If the test light goes on, the wiring harness is good. Loosen the fuel line at the cold-start injector and crank the engine again. If fuel leaks or sprays from the loosened line, replace the cold-start injector. If not, confirm fuel delivery to the fuel distributor and repair or replace the restricted fuel line. If the fuel line delivers fuel, then replace the cold-start injector.

If connecting the test light across the terminals and cranking the engine does not light the test light, confirm that the engine temperature is below 95 deg. F. Connect the test light alligator clip to the positive battery terminal and probe the harness connector of the cold-start injector. One of the two terminals should activate the test light, the other should not. If neither activates the test light, inspect the wire that runs from the cold-start injector to the thermo-time switch. If this is good, inspect the one that runs from the switch to ground for an open circuit. If both wires test satisfactorily, replace the thermo-time switch.

Sticking Control Plunger

A sticking control plunger normally indicates a damaged control plunger. Simply dropping the plunger when servicing the fuel distributor might be enough to damage it. Inspect the plunger for evidence of varnishing. If the plunger continues to stick or bind replace the fuel distributor. Care during installation will prevent damage to the new plunger.

Note: Control plungers are machined for a precise match to a given fuel distributor. Trying to use a control plunger from another fuel distributor can result in even more severe binding or leaking.

Restricted Injectors

Restricted injectors can best be diagnosed by performing the injector flow equality test. Cleaning a restricted injector(s) can be done with an injector cleaning system. These cleaning systems range in price from about $100 to more than $1,000.

Unless you are a business specializing in fuel-injection or tune-up service, purchasing a cleaning system such as this is probably not the best use of your money. As an alternative, remove the injectors from the intake system and leave them attached to their fuel supply lines. Place them in a safe container, then activate the fuel pump as described in the section on measuring pressures. Once the fuel pump is running, lift the airflow sensor plate all the way and allow fuel to flow through the injectors at full force. Lower the airflow sensor plate to its rest position, wait a few seconds, then slowly lift the plate between 1/8 and 1/4 in. Observe the injector spray pattern. If the pattern is good, reinstall the injectors and test drive. If the pattern is bad, replace the injectors.

Although replacing the injectors may sound drastic or expensive, for most applications a full set of injectors will probably cost less than most shops charge for injector cleaning. In any case, replacement of the injectors is usually far more effective than cleaning them.

Leaking Injectors

Remove the injectors from the intake. With the engine shut off, energize the fuel pump to run. Observe the injectors for leaking. Raise the airflow sensor plate; the injectors should spray. Drop the sensor plate; the injectors should stop spraying immediately.

If they are leaking, attempt to clean them by raising the airflow sensor plate all the way, allowing the injectors to spray at full volume for ten seconds. Retest the injectors for leaking. If they continue to leak, replace them.

Unequal Injector Flow

Remove the injectors from the intake manifold and place each in its own graduated cylinder. Energize the fuel pump and raise the sensor plate about ¼ in. for thirty seconds. The volume through each injector should vary by only 10 percent. If the volume is not equal, clean the injectors. If there is no improvement from cleaning, replace them.

If the flow was equal at ¼ in., repeat the test at about half the travel of the airflow sensor plate. Again, the volumes should vary by only 10 percent.

Loss of Rest Pressure

Loss of rest pressure is one of the most common causes of one of the most common K-Jetronic with Lambda symptoms. With the K-Jetronic fuel pressure gauge installed between the fuel distributor and the control pressure regulator, pressurize the system with the engine not running. Turn the valve on the fuel pressure gauge. If there now is no loss of rest pressure, replace the control pressure regulator.

If the loss of rest pressure is not at the control pressure regulator open the valve, remove the injectors from the intake and place them in view. Remove the cold-start injector, leaving all fuel lines attached. Pressurize the system and inspect the removed components for leaking as the rest pressure drops. If there is no evidence of leaking, replace the fuel pump check valve.

Note: From personal experience, I have found that 90 percent of the time a loss of rest pressure is caused by a defective fuel pump check valve. Also, if the injectors are found to be leaking, replace the fuel distributor and retest.

Incorrect Control Pressure

High: If system pressure is within specifications, there are only three possible causes for high control pressure: a restriction in the return line from the fuel distributor to the fuel tank, a restriction in the return line from the control pressure regulator to the fuel distributor or a defective control pressure regulator.

Connect the K-Jetronic with Lambda fuel pressure gauge with the valve in the open position so fuel can flow to the control pressure regulator. Enable the fuel pump to run with the engine not running. Carefully crack open each of the return lines (remember to use extreme caution as the fuel is highly flammable and under high pressure) and observe the control pressure. If the pressure drops, it indicates there is a restriction in that line.

If the pressure is unaffected by the opening of the return lines, replace the control pressure regulator.

Low: If the control pressure is low, verify that the system pressure is within specification and replace the control pressure regulator.

Incorrect System Pressure

High: If the system pressure is too high, energize the fuel pump to run with the engine shut off and crack the return line loose. If the system pressure does not drop, remove the system pressure regulator from the side of the fuel distributor. Be careful not to lose any pieces. Clean the regulator components with a mild solvent and reassemble. If the pressure is still high, replace the fuel distributor.

If the pressure is only a little too high, you might be able to reduce the pressure by removing adjusting shims from the system pressure regulator.

Low: If the system pressure is too low, remove the system pressure regulator from the side of the fuel distributor. Be careful not to lose any pieces. Clean the regulator components with a mild solvent and reassemble. If the pressure is still low, replace the fuel distributor.

If the pressure is only a little too low, you might be able to increase the pressure by adding adjusting shims to the system pressure regulator. Good luck finding anyone who stocks them!

11

KE-Jetronic System

The KE-Jetronic system, also known as the CIS-E system, was introduced during the early 1980s in response to tightening emission control regulations. Like the K and the K-Lambda systems, the heart of the KE-system is both the airflow sensor and fuel distributor. The injectors are standard K-system injectors. The control pressure regulator has been replaced by electronic components, however.

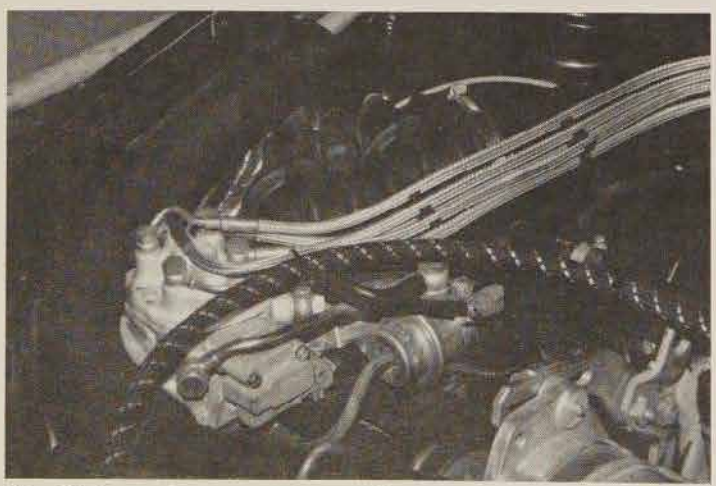
KE-Jetronic system applications include:

Audi	Volkswagen
Coupe GT	Cabriolet
4000S	Golf
4000S Quattro	Jetta
5000S	Quantum
5000S Turbo	Scirocco
Mercedes-Benz	
190E	

Fuel Components

Fuel Tank

There is nothing unusual about the KE-system's fuel tank. It has the standard outlet and return line.



The K-Jetronic system is an effort to integrate electronic fuel-injection sensors with a mechanical fuel-injection system.

Fuel Pump

The fuel pump is a high-pressure, high-volume, roller vane electric pump—standard to the Bosch arsenal of fuel-injection components. Unlike the electric fuel pumps used on carbureted engines, this pump supplies a steady pressure and volume of fuel to the injection system.

When the fuel pump fails, the engine dies and will not restart. In some cases, a failing pump will sound louder than normal. Unfortunately, this does not necessarily indicate if and when failure will occur.

Accumulator

The accumulator smooths out pressure pulsations created by volume fluctuations of fuel to the injection system. On the KE-system the accumulator is teed off of the line running between the fuel pump and the accumulator.

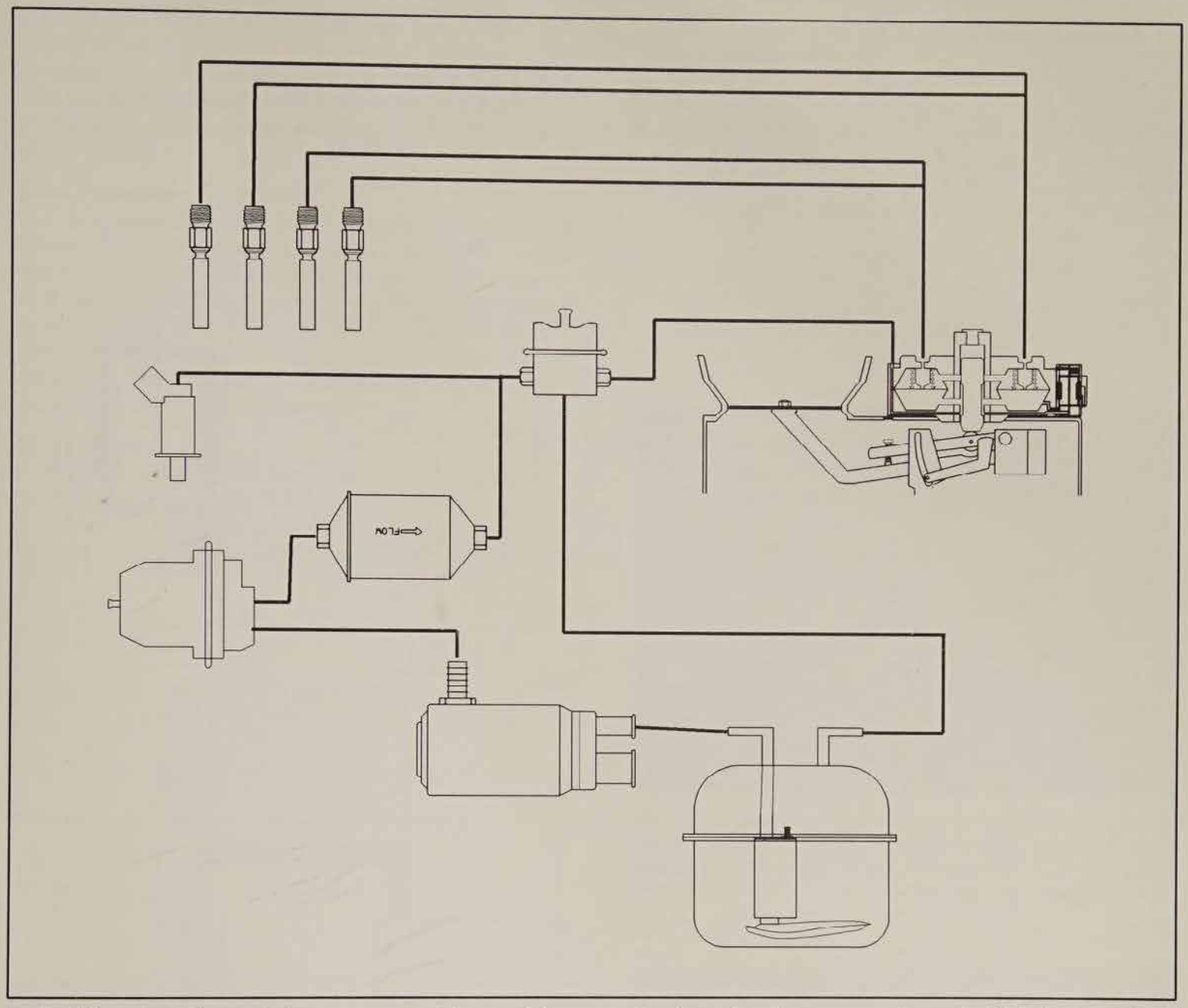
The accumulator is a simple device consisting of a spring-loaded diaphragm in a can. There are only two possible failures related to this unit: the diaphragm can rupture, or the spring can break.

If the diaphragm ruptures, the engine will not start and the accumulator will leak. On some applications the accumulator has a hose to allow fuel escaping from the system through a ruptured diaphragm to return to the tank. It is necessary on these applications to remove the hose to determine if the diaphragm is ruptured. The hose will normally be moist with fuel, but if the accumulator is defective, fuel will run out of the hose.

If the spring in the accumulator breaks, the diaphragm will normally rupture. If the diaphragm does not rupture, the engine will still start and run. However, a broken spring will cause an increase in noise from the fuel pump, or erratic engine performance.

Fuel Filter

The fuel filter must be serviced at regular intervals. Precision machining in the fuel distributor and the injectors requires good fuel filtration. A



In the KE-system, the control pressure regulator used in the K and K-Lambda systems is replaced by a system pressure regulator. Thus, the warm-up enrichment function is replaced by a computer-controlled electrohydraulic actuator.

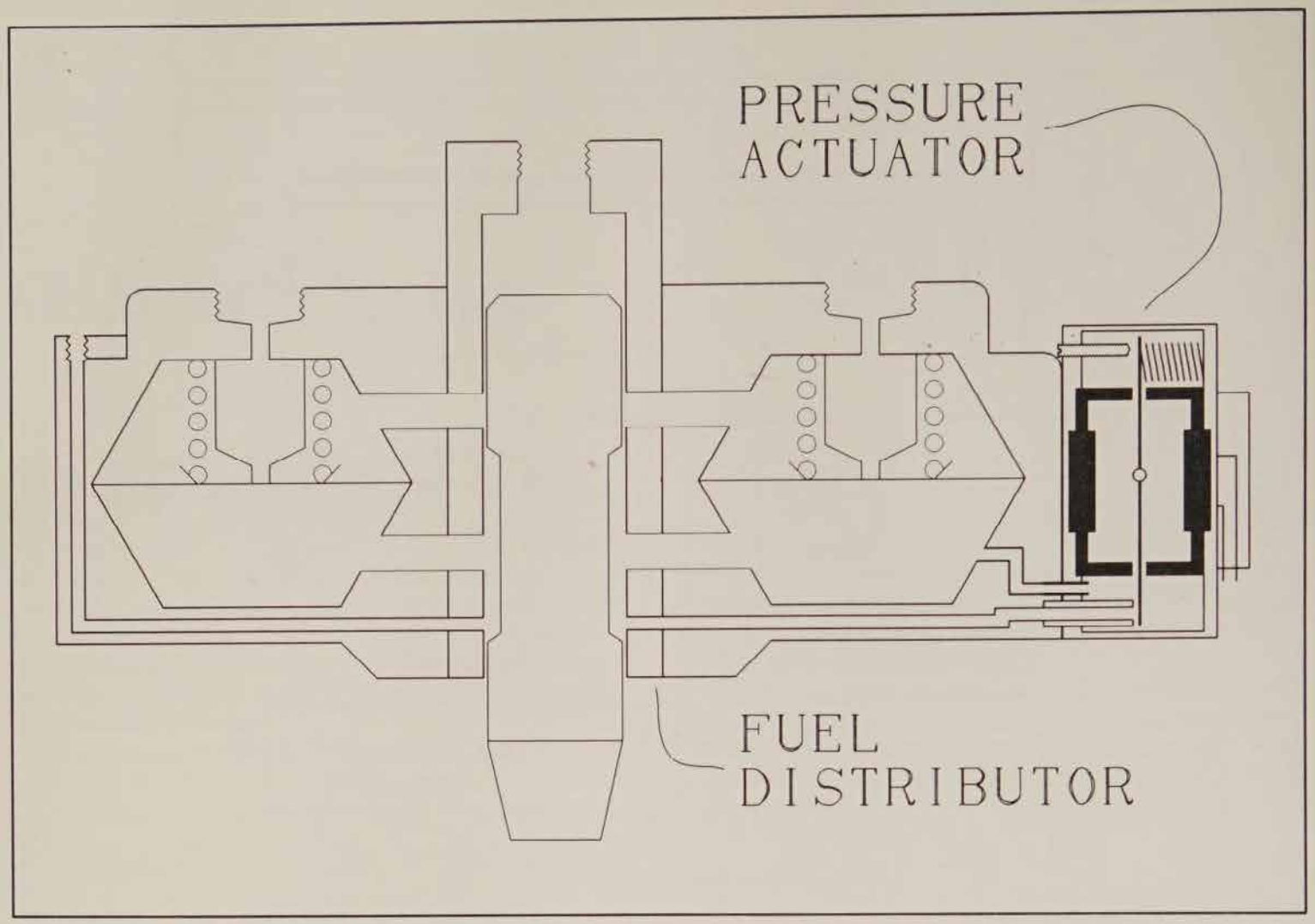
restricted fuel filter can result in poor engine performance, hesitation and stumbling.

Fuel Distributor

The fuel distributor is the heart of the KE-Jetronic system. It has four major parts: the control plunger and cylinder, the upper chambers, the lower chambers and the differential pressure regulator (electrohydraulic actuator).

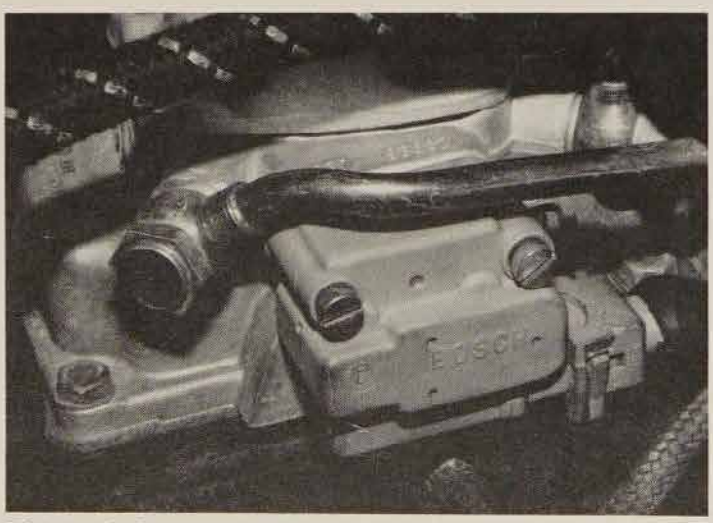
Under pressure from the fuel pump, fuel flows into the control cylinder. When the engine is shut off and no air is flowing into the engine the plunger is in its lowest position, keeping fuel from flowing into the upper chambers and onto the injectors. The fuel then travels on to the differential pressure regulator, or as it is often referred to, the electrohydraulic actuator.

On the Volkswagen GTI the fuel pump, accumulator and fuel filter are located under the car in front of the rear axle.



The electrohydraulic pressure regulator mounts on the side of the fuel distributor. When this unit is removed the O-rings should be replaced.

The electrohydraulic actuator consists of a valve on a reed located between magnets. An electromagnet is located in the device so it can either increase or decrease the effect of the magnetic field. As the magnetic field changes, the reed can flex back and forth, thereby changing the size of the valve opening. Varying the size of the opening varies the amount of fuel entering the lower chambers of the fuel distributor, thus altering the lower chamber pressure. A thin stainless-steel diaphragm separates the lower from the upper chamber. When the pressure in the lower chamber rises the diaphragm is deflected up, restricting the flow of fuel to the injectors. When the lower chamber pressure decreases the diaphragm is deflected down, increasing the fuel flow to the injectors.



This is the location of the electrohydraulic actuator on the Volkswagen GTI.

Increasing the current through the electromagnet lowers the pressure in the lower chambers of the fuel distributor, enriching the mixture. Reversing current increases lower chamber pressure and reduces or even shuts off fuel flow to the injectors. The current flow through the electrohydraulic actuator will be high when the engine is cold, and decrease as the engine warms up. On deceleration the current flow is reversed to lean out the mixture or shut off the fuel.

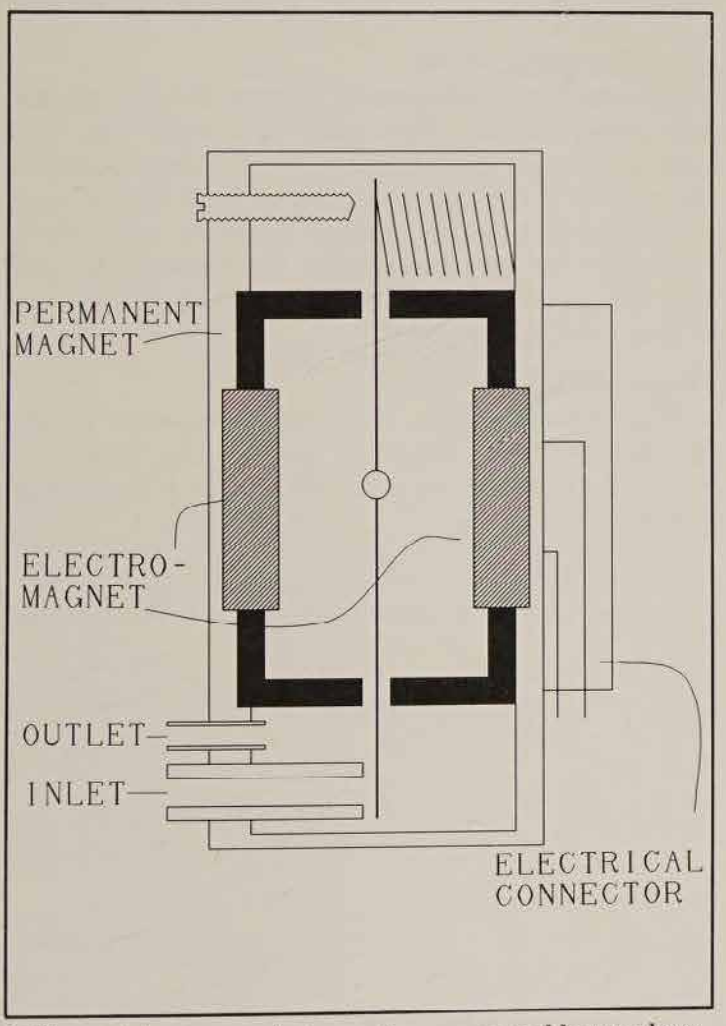
The main control of fuel through the injectors is through the lifting of the control plunger and opening slits, or passageways, between the lower and upper chambers. As the airflow sensor is lifted by air flowing into the engine the control plunger is lifted as well.

Fuel Pressure Regulator

A fuel pressure regulator maintains a constant pressure in the control cylinder and the upper chambers of the fuel distributor. In addition to the fuel lines, a vacuum line connects the fuel pressure regulator to the intake system. Changes in air pressure within the intake system cause an increase in fuel pressure. When the fuel pressure increases, the mixture enriches.

Fuel Cooler

In order to maintain a constant fuel temperature in the tank, many applications place a fuel cooler in the return line. This cooler is in the form of a hollow canister which dissipates much of the heat that the fuel retains as it passes through the engine compartment.



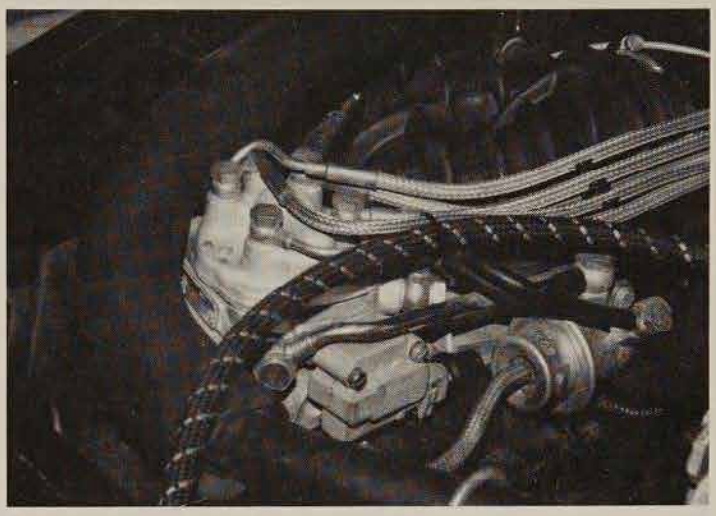
Differential pressure between the upper and lower chambers is controlled by varying the strength of an electromagnet. The polarity of the electromagnet works against that of a permanent magnet to control the pressure differential between the upper and lower chambers. This controls the flow of fuel to the injectors, and therefore the air-fuel ratio.

Injectors

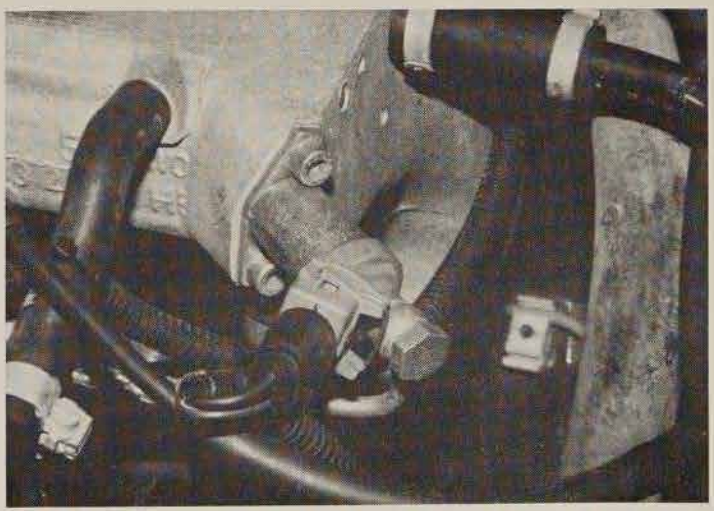
An injector is basically a spring-loaded pop-off valve. When fuel pressure to the injector exceeds 3 bar (45 psi) the spring opens, allowing fuel to flow into the intake system just ahead of the intake valve.

Cold-Start Valve

The KE-system uses an extra injector controlled by a thermo-time switch to enrich the mixture for



In this view, the system pressure regulator is mounted next to the fuel distributor. Note the vacuum line from the end of the regulator to the intake manifold. This provides for enrichment when the engine is under load.



The cold-start injector and thermo-time switch work as a team to enrich the mixture for cold starting. When the ignition key is in the crank position the injector (also called a cold-start valve) receives 12 volts. If the temperature of the engine is less than 95 deg. F., the thermo-time switch will ground the cold-start injector. Fuel should spray through the injector when the engine is cranked cold, but not when the engine is running or the temperature is greater than 95 deg. F.

cold starting. The cold-start valve operates only while the engine is being cranked, engine temperature is less than 95 deg. F., and for a maximum of twelve seconds.

Air Components

Throttle Valve

The throttle valve is connected to the accelerator pedal through a linkage and cable. The valve controls the amount of air permitted to enter the engine and therefore engine rpm.

Airflow Sensor

As with other K-systems, the volume of air entering the intake system is measured with an airflow sensor. The sensor consists of a plate connected to a lever and mounted in a venturi. When air passes into the engine to be used in combustion, it lifts the sensor plate. As the plate is lifted the lever is lifted; as the lever is lifted the plunger is lifted. As fuel flows from the control cylinder to the upper chambers of the fuel distributor the stainless-steel diaphragm is moved downward, allowing fuel to flow to the injectors.

Idle Speed Air Valve

The idle speed air valve may be controlled either manually or by computer.

The manually controlled electric bimetal auxiliary air valve dates back to the 1970s, and increases the amount of air entering the engine when cold. This is used in conjunction with a thumbscrew valve.

An electric motor controlled by the CIS-E computer opens and closes a throttle air by-pass valve. When the engine is cold the valve opens, increasing the idle speed. As the engine warms, the idle speed actuator closes to decrease the idle speed. Should engine wear or other factors affect the idle speed of the engine, the computer will signal the controller to adjust accordingly.

Electrical Components

Cold-Start Valve, Thermo-Time Switch

The cold-start valve is powered by 12 volts from the start position of the ignition switch. When engine temperature is less than 95 deg. F. the bimetal switch in the thermo-time switch grounds the cold-start valve. When the ignition key is turned to the start position 12 volts are applied to the cold-start injector, the solenoid opens the valve and extra fuel is sprayed into the intake manifold. An electric heater is also powered when the key is in the start position. As the engine is cranked, the heater heats the bimetal switch until it opens. As a result, the cold-start valve will spray fuel only when engine temperature is less than 95 deg. and only for a maximum of five to twelve seconds.

Fuel Pump

The KE-Jetronic system's fuel pump is a roller vane pump driven by a high-speed DC (direct current) motor.

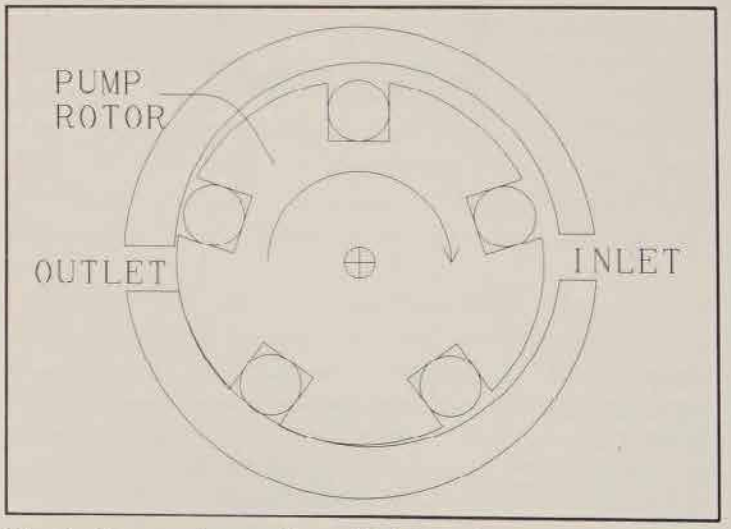
Auxiliary Air Valve

The intake air by-pass device is used to control idle speed at idle. Two types are used. The first uses a bimetal strip to close a valve as the engine warms up. The strip is heated by both engine heat and electricity. The second consists of a valve controlled by a bi-directional DC motor. The system computer controls the movement of the valve to control the idle speed.

Power Relay

The system power relay applies power to the ignition system, the fuel pump, the cold-start valve, the electric idle control valve and the system computer.

The airflow sensor is basically a plate sitting in a venturi. As air enters the engine to be used in combustion, the plate rises, lifting the control plunger in the fuel distributor.



The fuel pump is a roller cell driven by an electric motor in excess of 3500 rpm. The pump can produce a pressure of over 125 psi.

Electronic Components

Airflow Sensor Potentiometer

A potentiometer is located in the airflow sensor to inform the system computer of the volume of air entering the engine. As the volume of air increases, the voltage output of the sensor increases as well. The computer, sensing an increase in airflow, can alter the current to the pressure actuator and therefore increase the fuel flow into the engine.

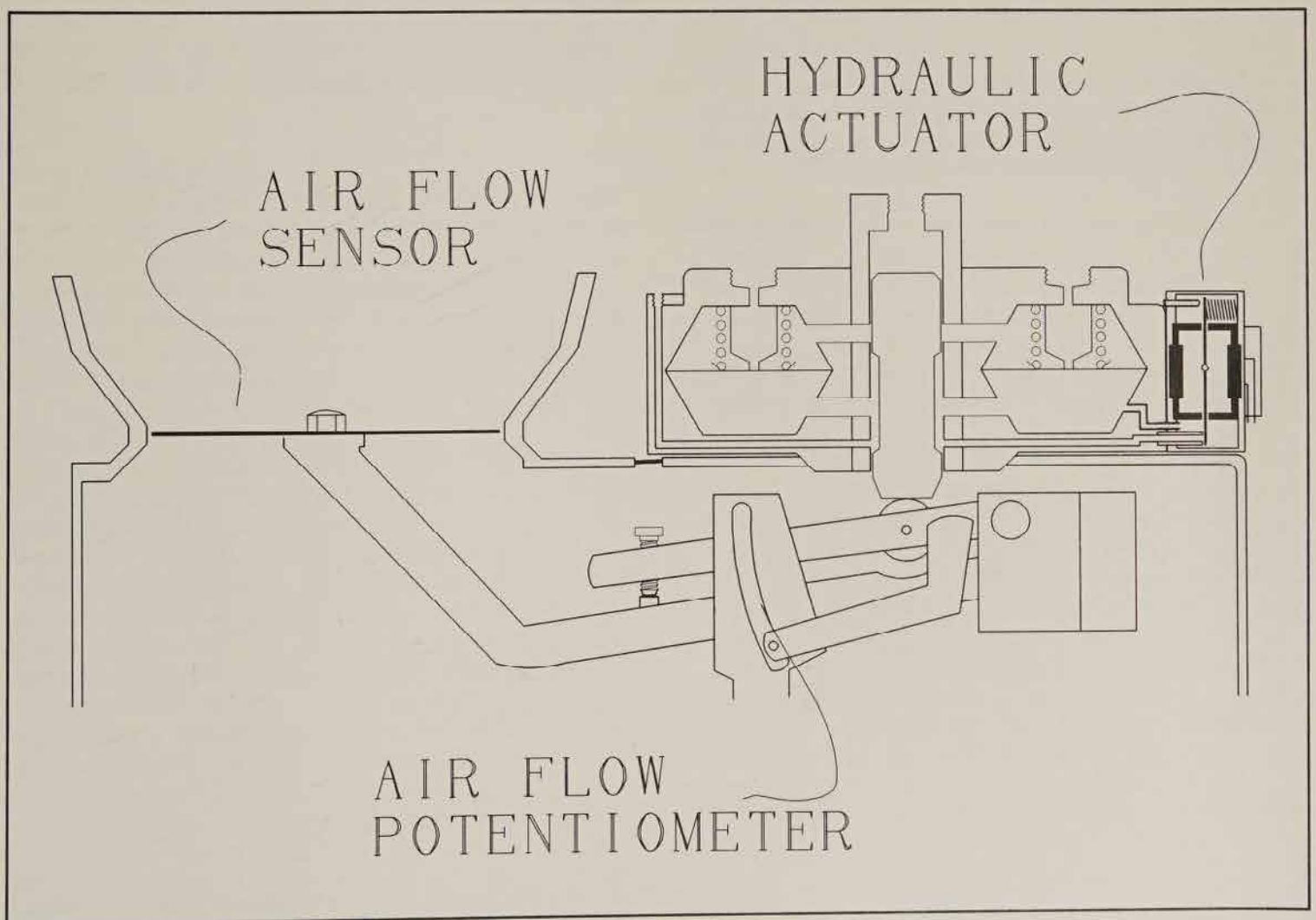
Electrohydraulic Actuator

The electrohydraulic actuator consists of a valve on a reed located between magnets. An electromagnet is located in the device, so it can either increase or decrease the effect of the magnetic field. Altering the current flow through the electromagnet alters the magnetic field. Therefore, as the field changes the reed can flex back and forth, changing the size of the valve opening. Varying the size of the opening in turn varies the amount of fuel entering the lower chambers of the fuel distributor. This alters the lower chamber pressure and therefore the air-fuel ratio.

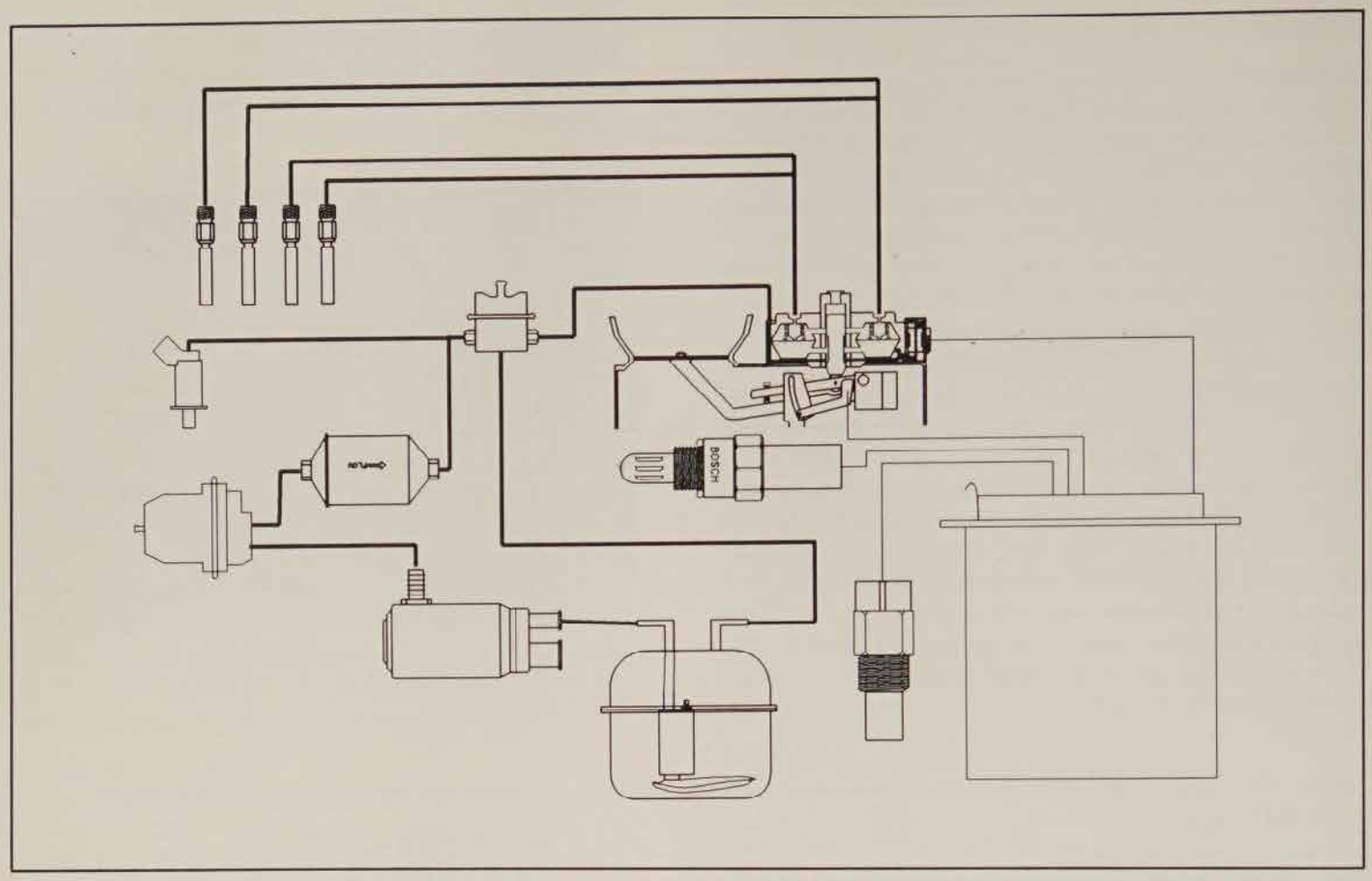
Coolant Temperature Sensor

The coolant temperature sensor is a major input to the system computer. The sensor consists of a

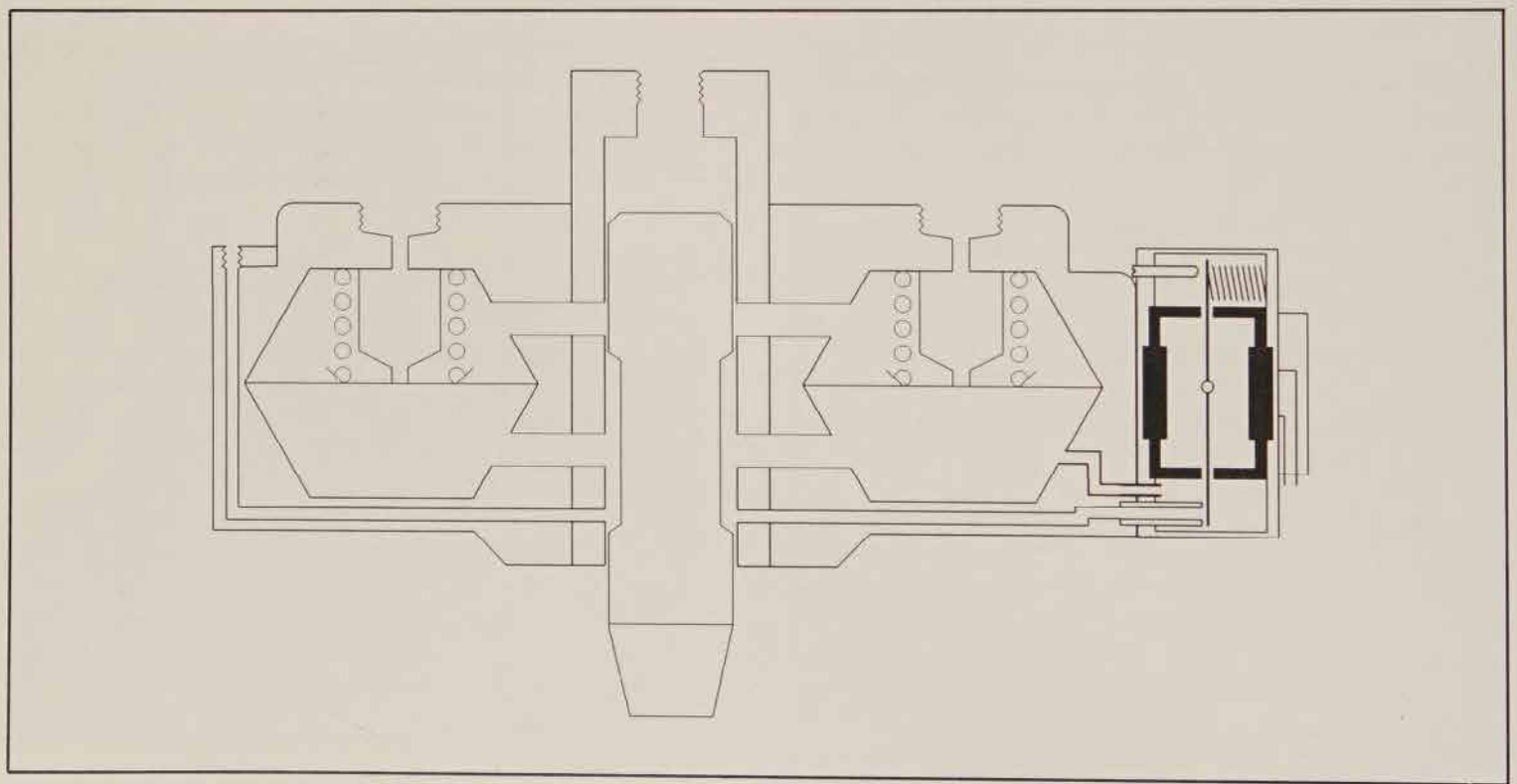
Idle speed in the KE-system is controlled by the ECU. The unit shown above is the idle speed actuator used on the Volkswagen GTI.



A potentiometer in the airflow sensor sends a variable voltage signal to the ECU. The ECU then knows the volume of air entering the engine.



The KE-system input sensors to the ECU are the coolant temperature sensor, the airflow sensor potentiometer, the Lambda sensor and a wide-open throttle switch.



During engine warm-up the coolant sensor input to the system computer causes the computer to increase the current flow through the electrohydraulic actuator, enriching the mixture. As the engine warms up the current drops, leaning out the mixture. When the engine reaches operating temperature the coolant sensor gives way to the Lambda sensor.

temperature-sensitive resistor called a thermistor. As the coolant temperature increases, the resistance of the sensor drops.

The computer increases the current flow to the pressure actuator when the engine is cold, and slowly decreases it as the engine warms up. Additionally, this sensor is used to signal the system computer that the idle speed needs to be higher to compensate for cold engine operation.

Throttle Switch

The throttle switch is a two-contact switch. One set of contacts is closed when the throttle is closed. The other set is closed when the throttle is wide open.

Lambda Sensor

The CIS-E system uses a Lambda sensor to monitor exhaust gases. When a lean exhaust condition is detected, the Lambda sensor sends a low voltage (less than 0.5 volt) to the system computer. The computer responds by increasing the current flow through the electrohydraulic actuator, which decreases the lower chamber pressure and enriches the mixture.

When the engine begins to run rich, the Lambda sensor voltage increases. The system computer reduces the current flow through the electrohydraulic actuator and the injection system leans out.

How CIS-E Works

When the engine is cranked, air begins to flow into the engine. The airflow lifts the sensor plate which, in turn, lifts the control plunger in the fuel distributor. When the plunger is lifted, fuel flows from the lower chambers of the distributor through the metering slits into the upper chambers and off to the injectors. As the airflow changes the position of the plunger changes, thereby altering the amount of fuel entering the engine.

When the engine is started the cold-start valve will spray for about five to ten seconds. If the temperature of the engine is greater than 95 deg. F., the cold-start injector will not operate.

During engine warm-up the coolant sensor input to the system computer causes the computer to increase the current flow through the electrohydraulic actuator, enriching the mixture. As the engine warms up the current drops, leaning out the mixture. When the engine reaches operating temperature the coolant sensor gives way to the Lambda sensor.

During normal, warm operation the airflow sensor lifts the fuel distributor control plunger proportionally to the volume of air entering the engine. As the plunger is lifted, fuel flows through the metering slits from the lower to the upper chambers of the fuel distributor. If the pressures in the lower chamber are equal to or lower than the pressure in the upper chambers, then the diaphragm separating the upper and lower chambers is deflected downward and fuel can flow to the injectors. When the pressure inside the injectors exceeds 30 psi the injectors will open and fuel will flow into the intake manifold. The Lambda sensor signals the system computer to alter the current through the electrohydraulic actuator in order to trim and correct the air-fuel ratio.

The throttle switch is used in conjunction with the airflow sensor potentiometer to signal the system computer about engine load. If the system computer detects an increasing airflow and a wide-open throttle, the current through the electrohydraulic actuator is increased, the Lambda sensor is ignored and the mixture is enriched. When the throttle switch indicates a closed throttle and the airflow potentiometer indicates a decreasing airflow, the current through the electrohydraulic actuator is reversed. This reversed current cuts off fuel flow.

KE-Jetronic Adjustments

Because of the computer control of air-fuel ratio and idle speed, the number of manual adjustments on the KE-Jetronic system is limited.

Audi and Volkswagen

Seven adjustments need to be made on Audi and Volkswagen applications to accommodate the KE-system. During a normal tune-up these adjustments do not need to be tested. Should any major injection components such as the fuel distributor be replaced, however, these adjustments should be checked. They should also be checked if a driveability or fuel economy problem is present. These adjustments include: basic plate lever adjustment, sensor plate and lever centering, sensor plate rest position, sensor plate free play, airflow sensor potentiometer, throttle valve housing and throttle switch adjustment.

Basic Plate Lever Adjustment: Remove the fuel distributor from the airflow sensor housing. Using a depth gauge, measure the distance between the top of the housing and the roller on the plate lever. The distance should be 0.74 to 0.75 in. (18.9–19.1 mm). If an adjustment needs to be made, use a 3 mm Allen wrench to adjust the mixture screw.

Sensor Plate and Lever Centering: Remove the 6 mm bolt in the center of the airflow sensor plate. Coat the bolt with locking compound. Then reinstall the bolt, finger tight. Carefully center the plate by either eye-balling it or using a 0.004 in. feeler gauge. Tighten the 6 mm bolt. If the plate cannot be centered it may be necessary to remove the airflow sensor assembly from the car; turn it upside down and center the lever on its fulcrum shaft. When the sensor plate is centered, in order to verify that the plate and lever do not bind try to lift the plate by placing a magnet on the center bolt.

If the magnet easily lifts the lever and plate without sticking or binding, then the adjustment is complete.

Sensor Plate Rest Position: The top side of the airflow sensor plate should rest about 0.07 to 0.08 in. below the top edge of the narrowest part of the venturi cone. Although this sounds like a highly precise adjustment, you need only ensure that the top of the sensor plate rests just below the top edge of the narrowest part of the venturi. If the adjustment is incorrect, open or close the wire clip around the leaf spring just below the sensor plate.

Sensor Plate Free Play: The next adjustment to make is for the distance between the control plunger and the roller on the airflow sensor lever. Before checking this, the basic plate lever adjustment must be correct. Connect an ammeter in series with the electrohydraulic actuator. Verify that the current is between 4 and 16 milliamps. If the current is less than 4 milliamps, allow the engine to cool down before continuing. If the current is greater than 16 milliamps, warm the engine before continuing.

Crank the engine for ten seconds to build up fuel pressure. Lift the sensor plate until some resistance is felt. There should be some free play, but no more than 0.078 in. If this adjustment is not correct, remove the fuel distributor and verify the basic plate lever adjustment. If this adjustment is correct, adjust the control plunger stop screw.

Airflow Sensor Potentiometer: After verifying the basic lever adjustment, airflow sensor plate centering, sensor rest position and free play, the airflow sensor potentiometer adjustment can be made. Connect a high-impedance voltmeter to potentiometer terminal number 17. With the sensor plate in the rest position the voltage should be 0.2 to 0.3 volt. As the sensor plate is lifted, the voltage should increase smoothly to about 7.0 volts. If the increase in voltage is not smooth, replace the potentiometer. If the voltage specifications are incorrect, loosen the mounting screws and adjust.

Throttle Valve Housing: The minimum throttle adjustment is done with a thin piece of paper. Loosen the throttle plate stop screw and place the paper between the stop screw and the throttle. Adjust the screw until it barely pinches the paper. Then remove the paper and tighten the screw an additional half turn.

Throttle Switch: Connect an ohmmeter across the terminals of the closed-throttle switch. Continuity should be gained just before the throttle is closed.

Next, connect an ohmmeter across the terminals of the wide-open throttle switch. Continuity should be gained just before the throttle is wide open.

Mercedes-Benz

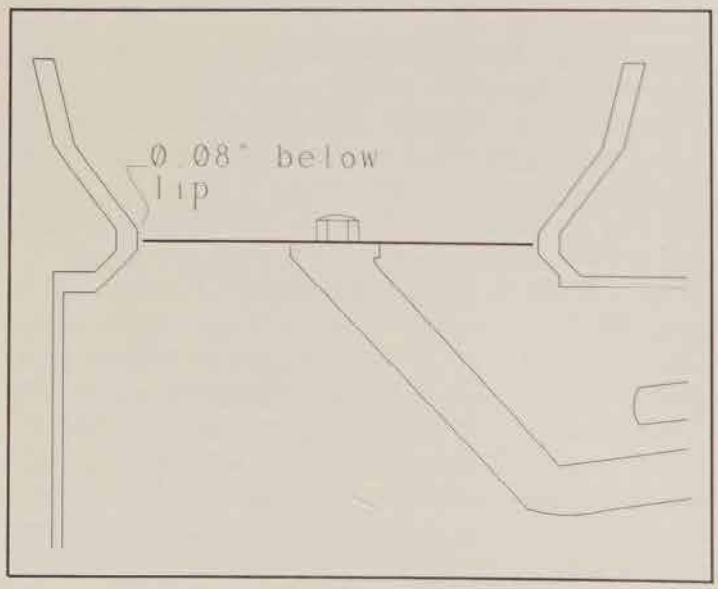
Two adjustments need to be made on Mercedes-Benz applications: airflow sensor plate adjustment, and airflow sensor potentiometer adjustment.

Airflow Sensor Plate Adjustment: Pressurize the fuel system. This can be done by removing the fuel pump relay and placing a jumper wire with a 16 amp fuse between terminals 7 and 8.

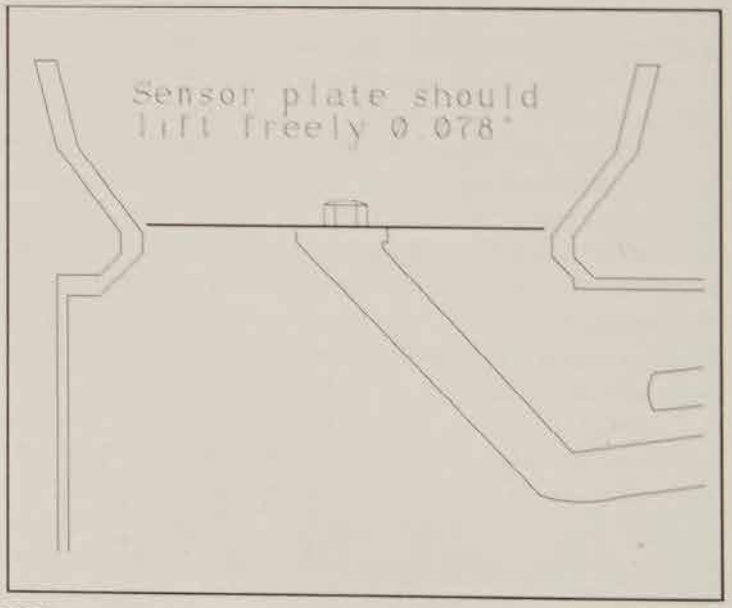
The airflow sensor plate should be centered in the narrowest part of the venturi. This usually means a gap all the way around the airflow sensor of about 0.002 in. If the sensor plate is not centered, loosen the center bolt and adjust. The sensor plate should not bind when pressed down.

The rest position of the sensor plate should place the top of the sensor plate 0.008 in. below the top edge of the narrowest part of the venturi.

The distance between the airflow sensor lever and the bottom of the control plunger (free play)



On Volkswagen-Audi products the top side of the airflow sensor plate should rest 0.08 in. below the upper edge of the narrowest part of the venturi.



Volkswagen-Audi sensor plate free play.

should be 0.040 to 0.080 in. If gently lifting the sensor plate does not reveal this tolerance, then adjust the free play by driving the guide pin up or down as required.

Airflow Sensor Potentiometer Adjustment: There should be between 3,200 and 4,800 ohms of resistance between terminals 14 and 18 of the airflow potentiometer when the airflow sensor is at rest. There should be between 560 and 1,060 ohms from terminal 14 to terminal 17. The reading should increase to between 3,760 and 5,640 when the sensor plate is lifted to its highest point. Adjust if necessary.

Troubleshooting the KE-Jetronic System

Of all the Bosch systems, the KE-system may be the most confusing to troubleshoot. The system combines electronics with mechanical fuel flow control. An analysis of driveability symptoms may point to either a mechanical or electronic problem, or not distinguish between the two. What follows is a logical sequence for analyzing any driveability problem.

Verify Engine Condition

Run a compression test and/or cylinder leakage test. Check the valve adjustment and camshaft condition. Then verify the condition of the ignition system. If all of these test satisfactorily, then check the injection system.

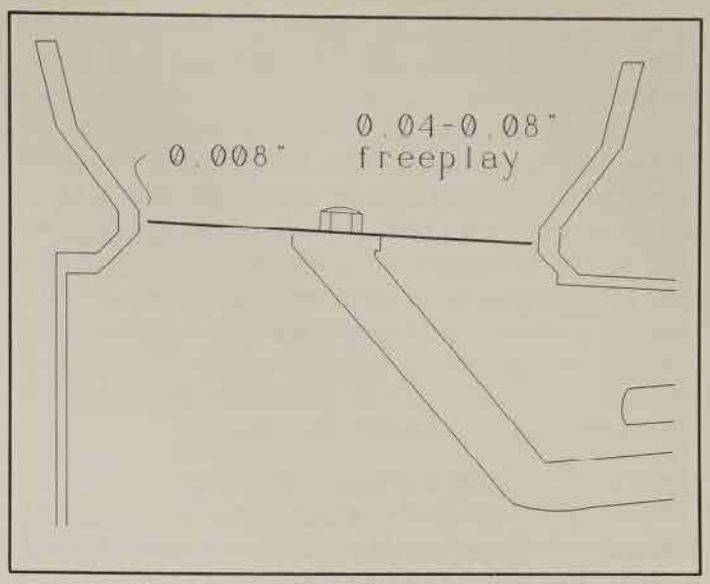
Test Fuel Pressure

As in all fuel-injection systems, any thorough system test must begin with fuel pressure. Connect a pressure gauge between the cold-start valve and the port on the lower chambers of the fuel distributor. Disconnect the electrical connector on the electrohydraulic actuator. Then activate the fuel pump. The pressure indicated should be between 75 and 82 psi.

If the pressure is low, check the fuel pump volume. The pump should be able to deliver 0.5 gpm (gallons per minute) or more. If the volume is low, check the fuel filter (including the one in the tank) and the line for kinks. If the pressure is low but the volume is acceptable, replace the system pressure regulator.

If the fuel pressure is high, disconnect the return line from the system pressure regulator and repeat the test. Ensure that the fuel from the regulator is captured in an approved fuel container. If the fuel pressure remains high, replace the pressure regulator. If the pressure drops, clean or repair the return line.

The next step is to measure lower chamber differential pressure, or the difference between the pressure in the lower chambers of the fuel distributor and system pressure. This measurement is done in two steps. The first step is to simulate pressure in the lower chambers with no correction based on engine temperature and exhaust oxygen.



Mercedes-Benz sensor plate adjustments.

Disconnect the electrical connector on the differential pressure regulator and close the valve on the pressure gauge. Activate the fuel pump; the differential pressure should be between 2.9 and 7.0 psi. If the pressure does not meet these specifications, disconnect the return line from the lower chambers of the fuel distributor. A volume of approximately five ounces per minute should flow through the return line. If the pressure is wrong but the flow is correct, replace the differential pressure regulator. If the flow is incorrect, replace the fuel distributor.

If the first part of the test yields the correct pressure, then reconnect the differential pressure regulator with an ammeter in series, and proceed with the second part of the test. The second step is to simulate the differential pressure of a cold engine. Disconnect the coolant temperature sensor and place a 15,000 ohm resistor across the terminals. Activate the fuel pump. Differential pressure should be between 10.0 and 17.5 psi. The ammeter should read between 50 and 80 milliamps.

If the pressure is wrong but the current is correct, replace the differential pressure regulator.

If both the ammeter and pressure readings are incorrect, check the resistance through the differential pressure regulator. If the resistance is greater than 21.5 ohms or less than 17.5 ohms, replace the differential pressure regulator.

If the resistance reading is correct, check the ECU power and grounds. Also check the ground for the temperature sensor. If these are OK, replace the ECU.

Test Rest Pressure

Rest or residual pressure is a measurement of the KE-system's ability to retain pressure after the engine has been shut off. Open the valve on the

pressure gauge and energize the fuel pump for about thirty seconds. Shut off the fuel pump and monitor the pressure for ten minutes. The pressure should not drop below 38 psi. If the pressure drops too low, remove the differential pressure regulator (electrohydraulic actuator) and inspect the O-rings. If the O-rings are functioning properly, or the pressure continues to drop when the test is repeated after replacement, pinch off the system pressure regulator return line. Repeat the test. If the pressure holds, replace the system pressure regulator. If the pressure still falls, replace the electrohydraulic actuator.

Check Pre-pump Delivery Volume

Some KE-injection systems use a pre-pump. When the symptoms include sagging, hesitation or stumbling, the delivery rate of this pump should be checked. The minimum flow rate is about one pint in twelve seconds.

Check Main Pump Delivery Volume

Main pump delivery volume should be approximately 0.5 gpm.

Test Injectors for Equal Flow

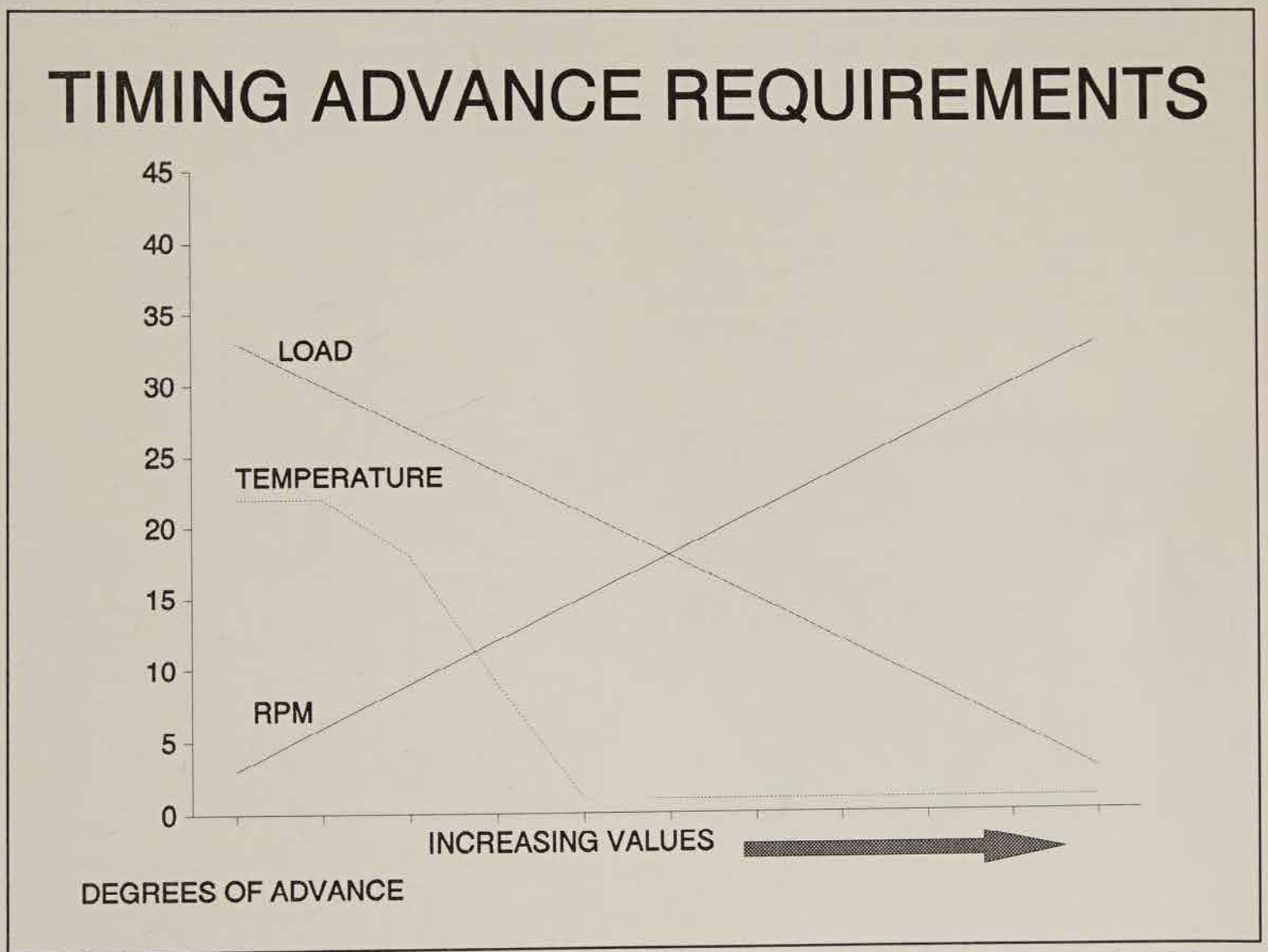
The injector equal-flow test is an effort to determine how much contamination or restriction there is in the injectors. Remove the injectors from the intake manifold, leaving them attached to the fuel lines. Place the nozzle of each injector in a graduated cylinder; energize the fuel pump. Lift the airflow sensor plate and place the tip of a screwdriver under the edge of the plate. Flow the injectors for about thirty seconds, then pull the screwdriver out. The volume of fuel that flowed through each injector should vary by only 10 percent.

Replace any injector that flowed 10 percent less than the others. If all injectors pass this test, repeat the test with the airflow sensor plate lifted about 3/4 in. Again, the quantity that flowed through each injector should be within 10 percent of each other. If any injector flows 10 percent less than the rest, replace the injector.

12

Motronic System

The Motronic system incorporates computerized timing control with fuel injection to provide a complete engine control package. In the early 1980s automotive emission control laws throughout the world became tougher. In the United States, manufacturers began to address these



As engine rpm increases, the need for additional timing advance is required so that the burn in the combustion chambers can end by the correct number of degrees ATDC. A cold engine can tolerate, and needs, more timing advance so that the slow-burning cold air-fuel charge can complete combustion by the correct number of degrees ATDC. As the engine load increases the chance of detonation increases, thus the timing must be retarded. The Motronic system is designed to handle these varying demands for timing advance.

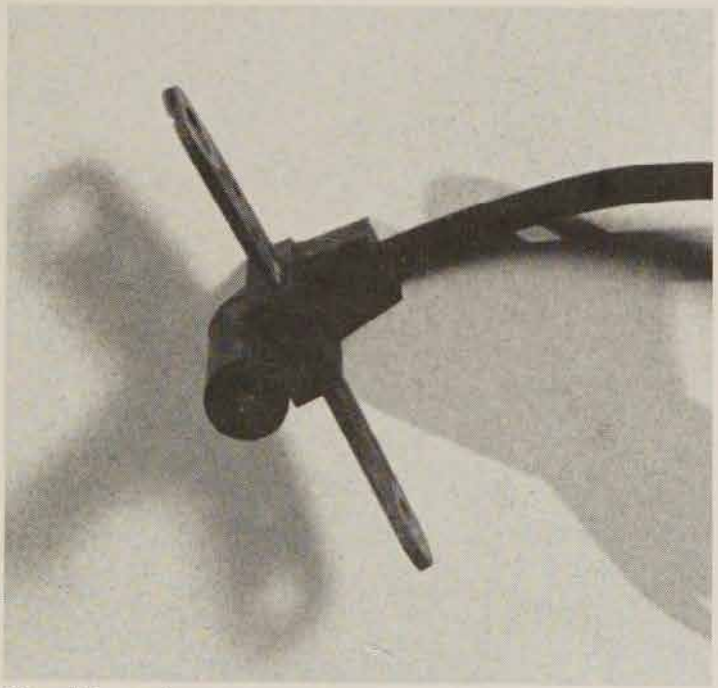
concerns by using complicated and highly integrated computer-based engine management systems. Not only were these systems more complex than those in the past, car manufacturers were now free to select an injection system from Bosch, a timing control system from Motorola and an emission device management system from United Technologies, for example. The result is engine compartments on many European cars that are a virtual potpourri of electronics.

The Motronic system was introduced in 1982 on the BMW 500, 600 and 700 series models. Later use of the Motronic system includes Saab and Volvo. The system combines a fuel-injection system such as L or LH with timing control functions. The theory of computerized timing control is that as engine speed increases there is a need to ignite the fuel earlier, thus the crankshaft covers more degrees of rotation in a given period of time. Assume, for instance, that at 1000 rpm the crankshaft rotates 10 deg. in three milliseconds. Let us also say that the required time for complete combustion is also three milliseconds. Since the usable energy of combustion begins to dissipate approximately 10 deg. after top dead center (TDC), combustion should be complete by this time. Therefore, at 1000 rpm ignition should occur at TDC for combustion to be completed by 10 deg. after top dead center, or ATDC.

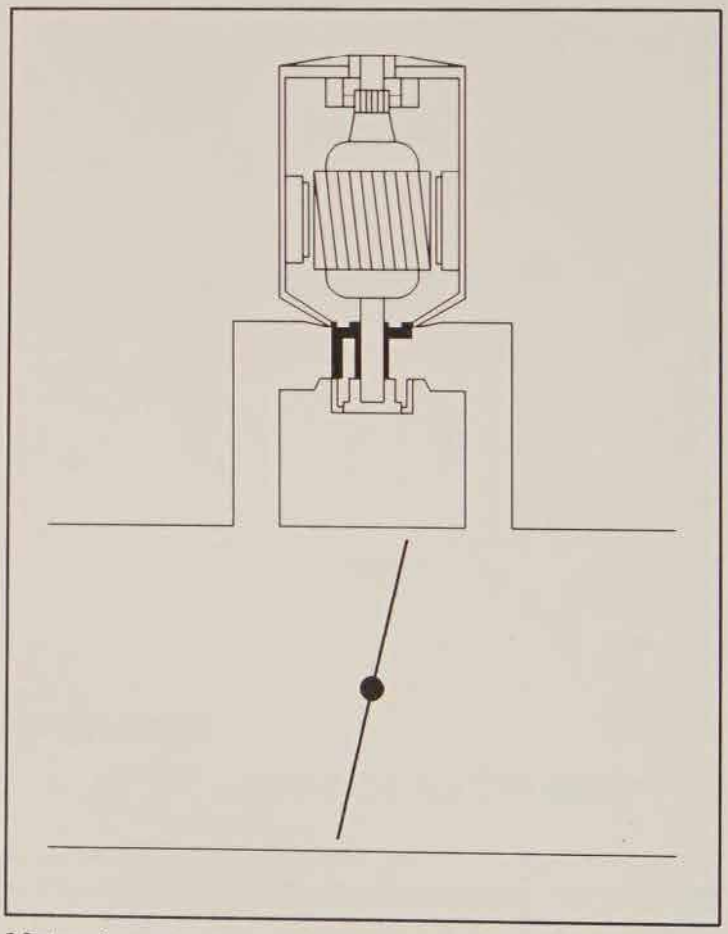
As the engine speed increases, the crankshaft covers more degrees of rotation. As engine speed increases, however, the time required for complete combustion remains the same. At 2000 rpm the crankshaft rotates 20 deg.; therefore, ignition must occur 10 deg. before top dead center (BTDC). At 3000 rpm ignition must occur 20 deg. BTDC.

The job of controlling ignition timing would be simple if engine speed were the only consideration. As the load on the engine increases, however, the tendency of the engine to detonate increases as well. Thus as engine load increases, the timing must be retarded to decrease the possibility of detonation. Since a cold engine is less likely to detonate than a hot engine, the computer allows additional advance when the engine is cold.

Using inputs from the coolant temperature sensor, a crankshaft reference sensor and an engine speed sensor, the Motronic system not only controls fuel delivery but also ignition timing. The computer also must calculate engine load. Engine load is calculated by monitoring the engine speed, the volume of air entering the engine and the position of the throttle. These sensors feed their signals into a digital computer that analyzes the information, producing a timing control signal. The computer changes the input signal from the crankshaft reference sensor into a square wave. It then changes the duty cycle of the square wave, sending this signal to the coil driver circuit to alter ignition timing.



The Motronic system uses two magnetic reluctance pickups to measure the speed and position of the crankshaft. These pickups can be tested with either an ohmmeter or an AC voltmeter.



Motronic systems use an automatic idle speed motor to control airflow around the throttle plates when the throttle is closed.

Ignition timing is controlled through a programmed bit-map within the computer. As engine speed increases, the timing advances in the bit-map. As engine load increases, the timing is retarded.

Troubleshooting the Motronic System

Troubleshooting the Motronic system is a two-step procedure. If the problem is related to running too rich or too lean, the fuel-injection portion of the system should be checked. If the problem is lack of ignition, or that the ignition timing is not changing, then test the Motronic timing control system.

Coolant Temperature Sensor

Disconnect the harness on the coolant temperature sensor. Test the voltage on each wire. If there is only one wire it should have 5 volts or more. If there are two wires, one will have 5 volts or more while the other has zero volts. If neither wire reads 5 volts or greater, repair the open circuit back to the computer. Connect a voltmeter to the voltage-carrying wire of the sensor harness and plug the harness back in to the sensor. If the voltage now reads less than the open-circuit voltage, but more than zero, the circuit is good. If the voltage remains at the open-circuit level, check for an open in the sensor and the ground wire.

Throttle Switch and Airflow or Air Mass Meter

The throttle switch and air measurement sensor are instrumental in determining the load on the engine. If the symptom is detonation, these sensors could be at fault. However, the role that the sensors play in controlling fuel-injection is more critical than the role they play in controlling ignition timing. A defect in one of these devices is more likely to show up in the form of an air-fuel ratio problem than a timing control problem.

Engine Speed and Crankshaft Reference Sensor

If the engine starts, these sensors must be good. When the symptom is a no-start, disconnect the sensor wiring harness from the sensor, connect an AC voltmeter and crank the engine. The voltmeter should read between 0.5 and 1.0 volt at cranking speed. If either sensor fails to produce this signal, it should be replaced.

13

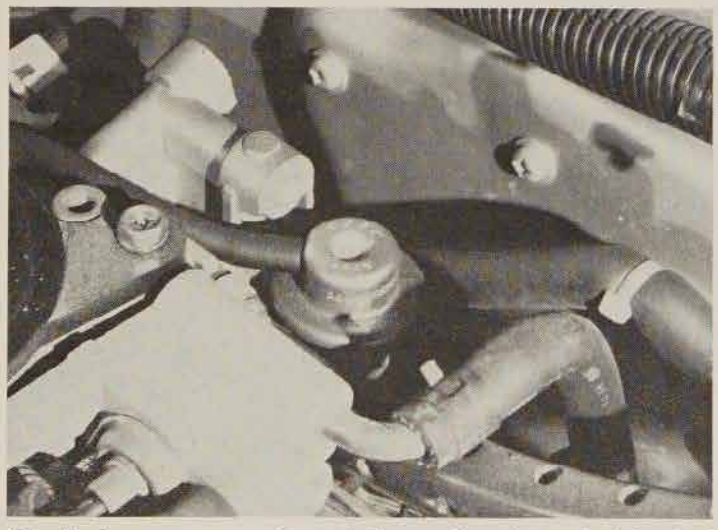
The Asian Connection

The first Japanese car to be mass-produced with fuel injection was the 1975 Datsun 280Z. The injection system that Datsun used was the Bosch L-Jetronic. From these early days and on into the 1980s and 1990s more and more Japanese manufacturers have adopted fuel injection. Today there are virtually no Japanese imports on the United States market equipped with a carburetor. During these years the Japanese manufacturers modified and refined, and eventually evolved their unique fuel-injection systems based on Bosch systems. This section covers the operation and repair of Japanese and Asian fuel-injection systems that do not fit into the standard Bosch categories.

Honda Fuel-Injection System

Honda-programmed fuel injection (PGM-FI) is used on the following applications:

Acura	Honda
Integra	Accord
Legend Coupe	Civic
Legend Sedan	Prelude



The fuel pressure regulator is located at the end of the fuel rail. Pressure is regulated at 36 psi.

Fuel Pressure

When troubleshooting any electronic fuel-injection system, the first thing to check is fuel pressure. Tee a fuel pressure gauge to the inbound line to the fuel rail. The fuel pressure at an idle should be about 36 psi.

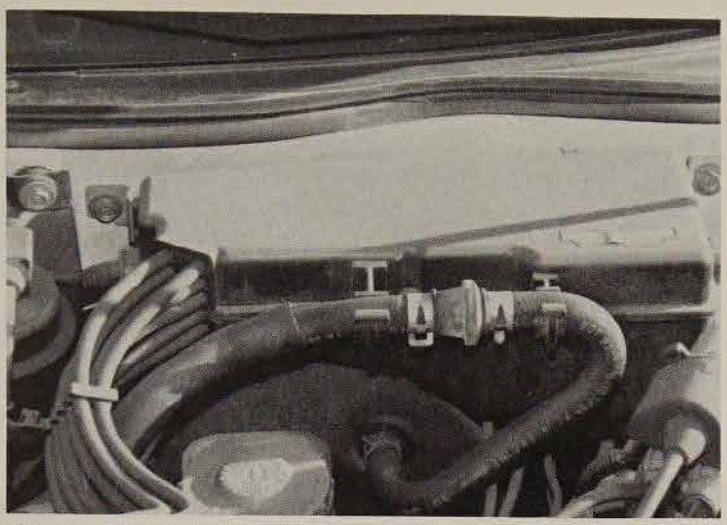
Sensors and Their Testing Procedures

Manifold Air Pressure (MAP) Sensor: The primary input sensor for the control of air-fuel ratio is a manifold air pressure sensor, often referred to as the MAP sensor. This sensor is located in a control box along with the fast-idle control solenoid, the automatic transmission idle control solenoid, the cold advance solenoid and the idle mixture adjustment sensor.

The MAP sensor has three wires connected to it. A 5.0 volt reference leaves computer terminal C15 to supply a reference voltage to the MAP sensor; terminal C14 supplies system ground for the sensor. The manifold air pressure signal is carried to terminal C11 of the PGM-FI control unit (computer). When the pressure in the manifold is low, such as at an idle, the sensor output voltage will be high (4.5 volts or so). When the pressure in the manifold increases, the voltage drops. At wide-open throttle, or with the key on and the engine off, the output voltage of the sensor should be about 0.5 volt.

Atmospheric Pressure Sensor: Knowing the manifold pressure alone is not enough when the computer is trying to calculate engine airflow. The manifold pressure with the engine running will vary for a given amount of airflow as the altitude varies. The computer compares the atmospheric pressure sensor reading to the MAP reading. It assumes that as these two pressure readings get closer together it is because there is a greater amount of air entering the engine.

Terminal C13 provides a 5.0 volt reference to the atmospheric pressure sensor. Terminal C12 is the ground. The atmospheric pressure reading is delivered to the computer at terminal C9. The voltage at



On the Honda PGM-FI system, the manifold and atmospheric pressure sensors are located in a box on the firewall.

terminal C9 should be 2.75 to 3.0 volts with the key in the on position.

Coolant Temperature Sensor: The coolant temperature sensor is a negative temperature coefficient (NTC) thermistor. As engine temperature increases, the resistance of the sensor drops. The computer uses the information from the coolant sensor to determine how much the injector pulse width should be increased to enrich the mixture during warm-up. For instance, at 95 deg. F. the resistance will range between 980 and 1,340 ohms; at 176 deg. F., resistance will be from 220 to 350 ohms.

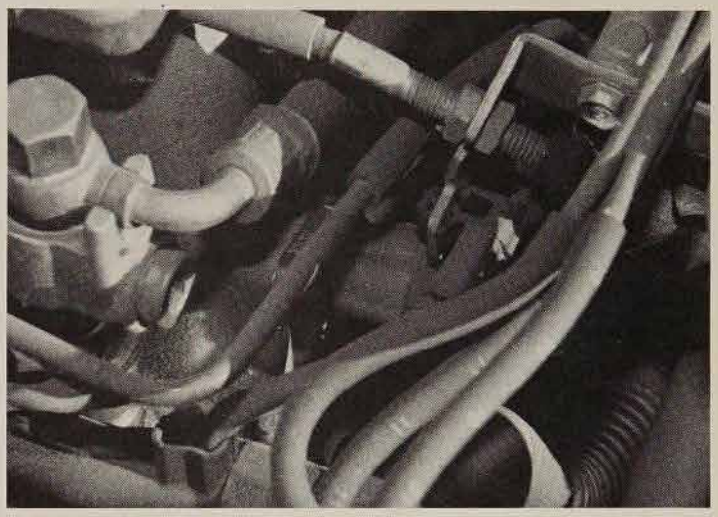
Air Temperature Sensor: Like the coolant sensor, the air temperature sensor is an NTC thermistor. This sensor tells the computer the density of the air based on air temperature so that the proper amount of fuel can be added. Thus the colder the air, the denser the air, the greater amount of fuel is required for a given volume.

Idle Mixture Adjuster Sensor: This sensor is a lot like the human appendix, it serves no identifiable purpose—at least not on cars delivered to North America. Yet, should this sensor fail, it can seriously affect the engine's air-fuel ratio.

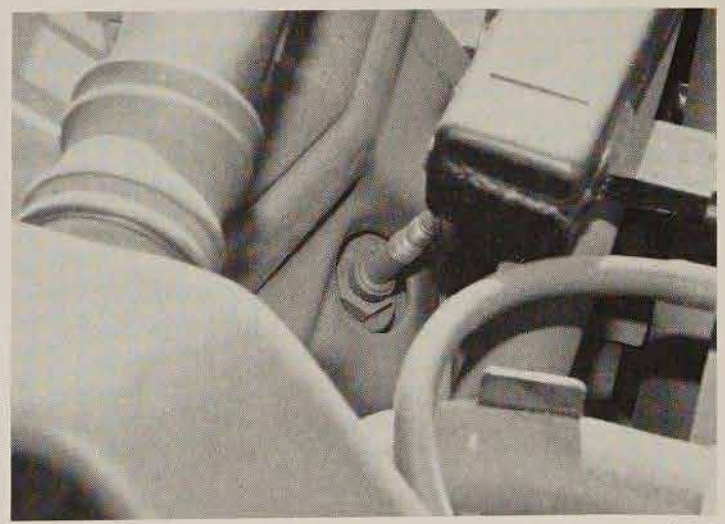
Test the idle mixture adjuster sensor with an ohmmeter. Disconnect the B and C connectors of the computer and measure the resistance between terminals B20 and C12; resistance should be anywhere between 250 and 6,200 ohms.

Crank Angle Sensor and TDC Sensor: The crank angle sensor and the TDC or top dead center sensor are actually two sections of one component located in the distributor. If the car should fail to start, disconnect the sensors from the vehicle wiring harness. There are two pairs of connectors—a horizontal pair and a vertical pair. The resistance across the horizontal pair should be 650 to 850 ohms; the resistance across the vertical pair should be 650 to 850 ohms. The resistance between either terminal of the horizontal pair and either terminal of the vertical pair should be greater than 100,000 ohms. If any of these resistances are out of spec, the entire unit must be replaced.

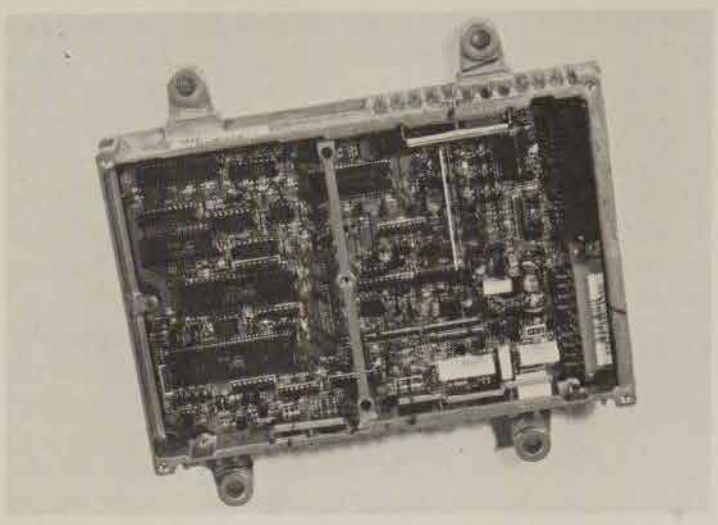
Throttle Angle Sensor: The throttle angle sensor is a potentiometer. Disconnect the sensor from the vehicle wiring harness. Connect an analog ohmmeter to the parallel terminals of the harness connector. Noting the resistance, slowly open the throttle. The resistance should gradually and smoothly increase until wide-open throttle. At wide-open throttle, the resistance on the 1985 Accord and 1986-88 Civic should be 3,200-7,200 ohms; on the 1986 Accord and 1986-88 Prelude it should range between 4,000 and 6,000 ohms. If the resistance is



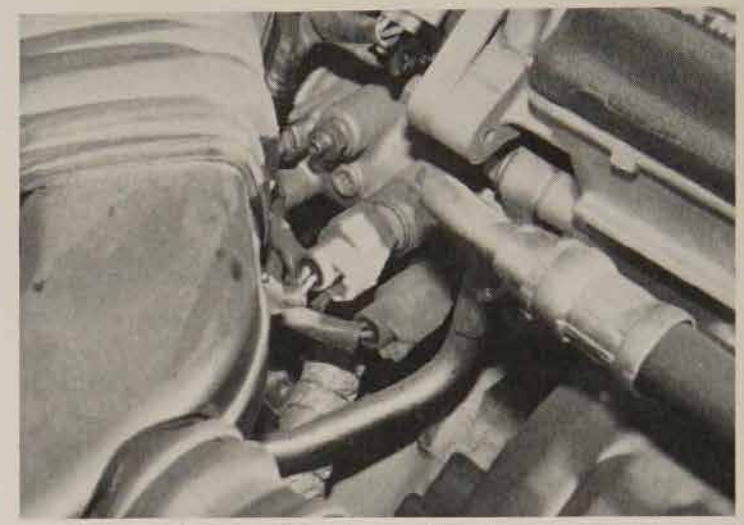
Before adjusting the throttle angle sensor be sure that there is slack in the throttle cable and that the throttle does not stick or bind in the closed position.



The Lambda sensor is located in the exhaust manifold close to the cylinder head. When heated to approximately 600 deg. F. the sensor becomes conductive for oxygen ions and begins to produce a voltage. The sensor's output voltage is inversely proportional to the amount of oxygen in the exhaust.



The PGM electronic control unit has the ability to analyze information coming from the various sensors to detect problems. The ECU also stores codes for problems that are detected. The technician can read the fault codes through light emitting diodes on the ECU.



Code 6 stands for a defective coolant temperature sensor.

out of this specification or if the resistance change is not smooth, replace the sensor.

Note: The throttle angle sensor is factory preset and cannot be adjusted.

Lambda sensor: Lambda sensor is the term Bosch uses for the sensor that most manufacturers, including Honda, call an oxygen sensor. Honda uses a standard platinum-zirconium oxide sensor. This sensor produces a voltage between 0 and 900 mV (millivolts).

To test the Lambda sensor, connect a high-impedance voltmeter to the sensor output wire. Start the car and warm the engine; run the engine at 2000 rpm for two minutes. Snap the throttle to about 4000 rpm, then release. Shut off the engine and note the sensor voltage. It should be less than 400 mV. If it is, disconnect the MAP sensor vacuum hose from the throttle body and plug the throttle body vacuum port. Then connect a hand-held vacuum pump to the MAP sensor, raise the engine speed to 3500 rpm and note the Lambda sensor voltage. The voltage should now be greater than 600 mV. If either of these voltages is incorrect, replace the Lambda sensor.

EGR Lift Sensor: The only other sensor that would figure significantly into a driveability problem would be the EGR (exhaust gas recirculation) valve lift sensor. This is also a potentiometer. With the key on but the engine off, connect a high-impedance voltmeter to terminal C8 of the computer. Then connect a hand-held vacuum pump to the EGR valve and apply vacuum. Monitor the EGR lift sensor voltage. The change in voltage should be simultaneous with the change in vacuum.

Troubleshooting Honda Fuel Injection

The Honda fuel-injection system has the ability to self-diagnose. When a fault is detected, a warning light in the instrument panel comes on. The computer then delivers a code through either one or four light emitting diodes on the ECU. The Civics and 1985 Accords have four LEDs numbered 1, 2, 4 and 8 from right to left. If there is a problem in the fuel-injection system, the ECU will turn on as many as three LEDs. If 1 and 4 are on, then the ECU has stored a code five (1 + 4). If 1, 2 and 8 are on, the ECU has stored a code eleven. The 1986-88 Accords and Preludes use a single LED. If the ECU has detected a problem in the fuel-injection system, the LED will flash the code. The stored code is equal to the number of flashes. Since this code repeats itself, there is a pause of about two seconds between repetitions. Although the two groups' vehicles differ in their methods of presenting the codes, the codes do not differ.

Troubleshooting Honda Fuel Injection

Code	Accompanying Symptoms	Defective Circuit
1	No detectable problem or rough idle	Disconnected O_2 sensor Secondary ignition misfire Faulty O_2 sensor Lean air-fuel mixture
2	No symptom or no-start	Faulty ECU
3	Fouled spark plug	Disconnected MAP sensor

Troubleshooting Honda Fuel Injection

Code	Accompanying Symptoms	Defective Circuit
	Engine stalls frequently	Faulty wiring to MAP sensor
	Hesitation	Faulty MAP sensor
4	No symptom or no-start	Faulty ECU
5	Fouled spark plug	Disconnected vacuum hose to MAP sensor
	Engine stalls frequently	
	Hesitation	
6	High idle speed when cold	Disconnected coolant sensor
	High idle speed	Open or short in coolant sensor wiring
	Hard starting at cold temperature	Faulty coolant temperature sensor
7	Hesitation or stumbling	Disconnected throttle sensor
	High idle speed	Open or short in throttle angle sensor wiring
	Cold idle speed too low	Faulty throttle angle sensor
8	Engine does not rev up	Short or open in crank angle sensor wire
	High idle speed	Induction from secondary ignition into crank angle sensor wiring harness
	Erratic idling	Faulty crank angle sensor
9	Same as for code 8	Same as for code 8
10	High idle speed	Disconnected air intake sensor
	Erratic idle when very cold	Open or short in air intake sensor harness
		Faulty intake air temperature sensor
11	No symptom or no-start	Faulty ECU
12	Engine stalls frequently	Disconnected EGR control
	Erratic or unstable low speed	Shorted or open EGR control
	No symptom	Faulty EGR control system
13	Poor power at high altitude	Disconnected atmospheric pressure sensor
	Hard cold starting at high altitude	Shorted or open atmospheric pressure sensor wiring
		Faulty atmospheric pressure sensor

No LED(s)

If the car will not start, the dash warning light is off and the LED(s) is not illuminating, check power and ground to the ECU. If the power and ground connections are alright, replace the ECU.

If the dash warning light is on, whether the car starts or not and the LED(s) is not illuminating, check the ground to the ECU. If the ground is OK, check the instrument panel and its wiring. If the instrument panel checks out, replace the ECU.

Diagnosis by Symptom

Many problems that can occur in the Honda fuel-injection system may affect driveability and will not set an ECU code. In such cases, follow this procedure:

Step 1. Check the tune-up components: Inspect the spark plugs, distributor cap, rotor and plug wires. Also check for vacuum leaks, the battery and the charging system. Since the voltage that supplies power to the logic circuits of the computer begins at the alternator, the condition of the charging system is critical.

Step 2. Test fuel pressure: Connect a fuel pressure gauge to the inbound line to the fuel rail. With the fuel pump relay by-passed and the engine not running the fuel pressure should be roughly 43 psi. With the engine running the pressure should be 36 psi.

If the pressure is too high, check the fuel rail return line for restrictions. If the return line is clear, replace the fuel pressure regulator.

If the pressure is lower than the specification, replace the fuel filter and inspect the inbound line to the fuel rail for evidence of restriction. Retest the fuel pressure. If the pressure remains low, replace the fuel pump.

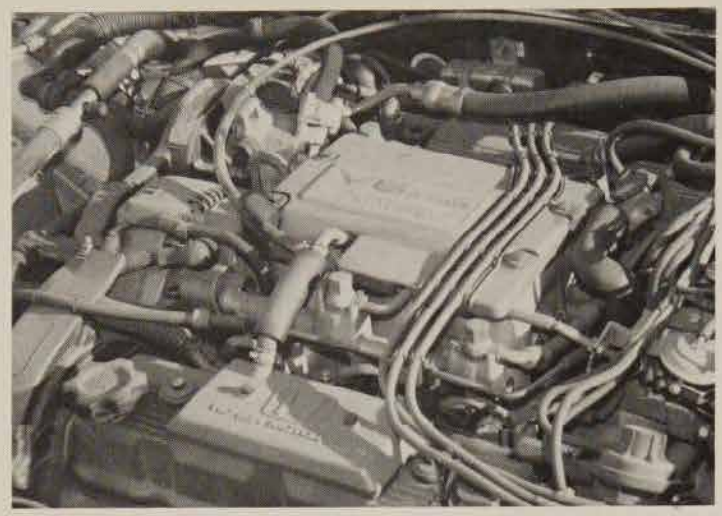
Step 3. Test the electric sensors: Follow the procedure described earlier in this chapter.

Step 4. Clean the injectors.

Step 5. If the problem persists after these tests have been completed, run through the test procedure again—something was missed.

Acura Fuel-Injection System

Since Acura and Honda share a parent company, their fuel-injection systems are very similar. Follow the troubleshooting procedures recommended for Honda, and interpret the codes with the blinking LED method used on the Prelude. When the warning light on the instrument panel is illuminated, a code has been stored in the ECU memory. The LED on the ECU will flash the numerical code, pause two seconds, then repeat over and over. For example, code 4 would consist of four consecutive flashes. Use the troubleshooting codes chart to interpret the Acura codes.



The Acura PGM-FI system is a close cousin to the Honda system. Although the engine compartment looks much more cluttered, the components and their functions are basically the same as Honda.

Acura Troubleshooting Codes

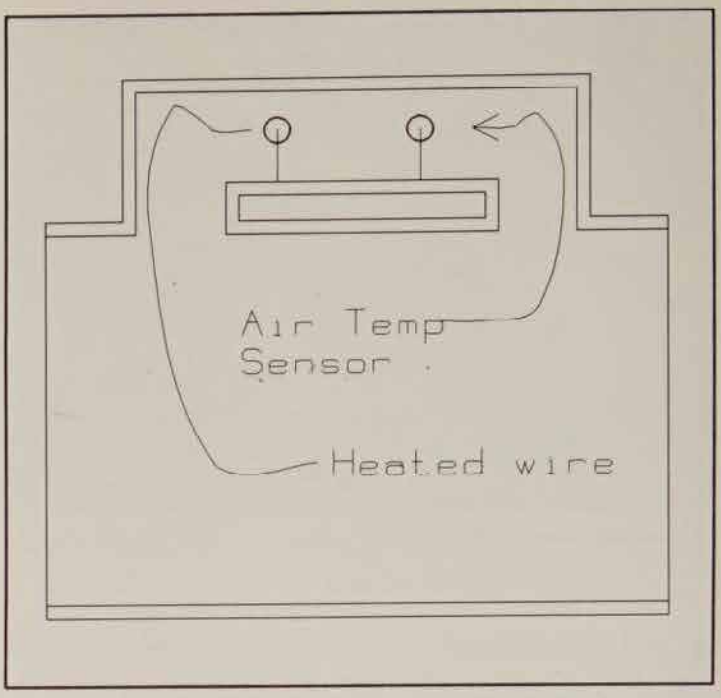
Code	Circuit Indicated
0	Electronic control unit (ECU)
1	Front oxygen content
2	Rear oxygen content
3	Manifold absolute pressure (MAP)
4	Crank angle sensor
5	Manifold absolute pressure (MAP)
6	Coolant temperature sensor
7	Throttle angle sensor
8	Top dead center (TDC) position sensor
9	Cylinder number 1 position is erratic
10	Intake air temperature sensor
11	Idle mixture adjuster
12	Exhaust gas recirculation (EGR) valve position sensor
13	Atmospheric pressure sensor
14	Electronic idle speed control
15	Ignition module signal to the ECU
17	Vehicle speed sensor
18	Ignition timing adjustment

Isuzu I-TEC Fuel-Injection System

The Isuzu I-TEC fuel-injection system application includes the Isuzu Impulse and Impulse Turbo.

Airflow Sensor

The airflow sensor for I-TEC fuel injection is located in the air cleaner. Its concept is the same as the Bosch LH-Jetronic air mass meter. A heated wire located in the sensor is heated to a fixed temperature above that of the incoming air. The temperature of the incoming air is measured by a thermistor. The heated wire is then cooled by air flowing through the sensor. As the wire cools, the sensor must increase the current flowing through the wire to maintain its temperature. The output



Isuzu uses a mass airflow sensor similar to the Bosch air mass meter. The air temperature sensor and mass airflow sensor are located in a by-pass channel outside the main channel of airflow. This eliminates restriction in the sensor.

signal is a voltage directly proportional to the increase in current, and therefore directly proportional to the airflow.

There are three wires connected to the airflow sensor. The red wire carries 12 volts of power to the sensor. The black provides a ground. The white wire carries a variable voltage signal back to the ECU.

In the event of a diagnostic code (61 or 62) for the airflow sensor, test the red wire for voltage and the black wire for ground. If these two wires are good, test the variable voltage output on the white wire. If there is no output signal, check the connection at the sensor. If the connection at the sensor is good, replace the sensor.

Coolant Temperature Sensor

The coolant temperature sensor is a negative temperature coefficient thermistor. Thus, its resistance should decrease as the temperature increases.

Coolant Temperature Sensor Resistance

Coolant Temperature (deg. F.)	Resistance (ohms)
14	7,000-12,000
50	3,000-5,000
68	2,000-3,000
122	700-1,000
176	200-400

A 5 volt reference voltage is carried to the coolant temperature sensor through a brown and white

wire. A black wire supplies ground for the sensor. As engine temperature increases, sensor resistance decreases. The decrease in resistance between the brown and white wire and ground causes the 5 volt reference to be pulled down. The ECU then measures the voltage on the brown and white wire to determine the coolant temperature. An open anywhere in the circuit, including the black ground wire, will cause the ECU to believe that the engine is cold.

Crank Angle Sensor

The crank angle sensor is a double Hall Effects sensor. Located in the distributor, this sensor produces a square wave as the distributor rotates. There are four wires connected to this sensor. The red wire carries 12 volts from the main power relay. The black wire is a ground. If the power and ground are good, the white wire and the green wire should be sending pulses to the ECU when the engine is cranked.

Confirm power and ground with a voltmeter and an ohmmeter, respectively. Connect a digital dwell meter to the green wire at terminal 1 of the ECU and crank the engine. Repeat the procedure at the white wire connected to terminal 12. If the dwell meter fails to detect a signal at either wire, inspect the wire back to the distributor. If the wire is good, replace the crank angle sensor.

Throttle Position Sensor

The turbocharged Isuzus use a potentiometer-type throttle position sensor mounted on the throttle shaft. This sensor is a variable resistor. The ECU supplies the sensor with a 5 volt reference along the red wire. A black wire is ground for the potentiometer, and the throttle position signal is carried along the black and red wire.

When the throttle is closed the signal sent back to the ECU is less than 2 volts. As the throttle is opened the voltage should gradually increase to greater than 4 volts.

There are three important tests to perform on this sensor: closed-throttle voltage, wide-open throttle voltage, and smooth voltage transition from closed to wide-open throttle. Check the latter voltage with an analog voltmeter.

Throttle Switch

All Isuzu fuel-injection applications, including the turbo, use a two-contact switch to notify the computer when the throttle is wide open and at an idle. This switch is mounted on the throttle shaft.

To test the throttle switch, disconnect the throttle. Using an ohmmeter, there should be continuity between two terminals of the switch in the closed-throttle position and between two other terminals in the wide-open throttle position.

Lambda Sensor

Comprised of platinum electrodes separated by a layer of zirconium dioxide ceramic, the Lambda sensor is used with virtually all modern fuel-injection systems.

When the exhaust gases have heated the sensor to 600 deg. F., the sensor becomes conductive for oxygen ions and a voltage is generated. The sensor begins to respond to the percentage of oxygen in the exhaust gases. When the engine runs rich the oxygen content of the exhaust gases is extremely low. This low oxygen content results in a high-output voltage, about 900 mV. When the engine runs lean the oxygen content of the exhaust is high. When the oxygen content is high the output voltage of the Lambda sensor is low, about 100 mV.

The easiest way to test the Lambda sensor is to connect a high-impedance voltmeter to the sensor output wire. The voltage should be toggling up and down across a neutral, or crossover point.

If the voltage is always above 450 mV, create a vacuum leak while carefully watching the sensor voltage. If the voltage remains high, replace the Lambda sensor.

If the voltage is always below the 450 mV crossover point, blow propane into the intake manifold from an unlit propane torch. If the sensor voltage remains low, replace the sensor.

Keep in mind, though, that the Lambda sensor very seldom causes a driveability problem with any vehicle. If the testing is being done for any condition other than poor fuel economy, the fault is probably not with the Lambda sensor.

Outputs and Engine Control Devices

Auxiliary Air Regulator: Problems with the idle speed at either hot or cold, but not both are often caused by the auxiliary air regulator. Consisting of a bimetal strip operating an air by-pass valve, the air regulator is heated both electrically and by engine heat. As the bimetal strip is heated the air by-pass valve closes, reducing the idle speed of the engine.

If the engine idles properly when cold but too fast at operating temperature, the valve is remaining open. If the engine idles properly at operating temperature but idles slowly, or dies when cold, the valve is not opening.

A simple way to test the auxiliary air valve is by visual inspection: It should be open when cold, closed when hot. If the regulator fails to close, verify that there is 12 volts to one terminal of the unit and a good ground on the other.

Fuel Pressure Regulator: The chart shows preferred fuel pressures for Isuzu applications.

Isuzu Fuel Pressures

Engine Type	Speed and Condition	Pressure (psi)
G200Z	Idle with vacuum to regulator disconnected	35.6

Isuzu Fuel Pressures

Engine Type	Speed and Condition	Pressure (psi)
4ZC1-T	Idle with vacuum to regulator disconnected	42.6
G200Z	Idle with vacuum to regulator connected	28.4
4ZC1-T	Idle with vacuum to regulator connected	35.6
G200Z	Engine off, fuel pump running	35.6
4ZC1-T	Engine off, fuel pump running	42.6

Dropping Resistors: To limit the current flow through the injectors, Isuzu uses resistors in series with the injectors. Should one of these resistors burn open the injector in series with it will stop working. If the driveability symptom is a lack of power or rough idle, test these resistors with an ohmmeter. The resistance should be 5-7 ohms.

Injectors: The injectors are a solenoid-operated valve. The solenoid windings should have a resistance of 2-3 ohms.

Troubleshooting Isuzu Fuel Injection

The Isuzu electronic control unit has the ability to detect circuit defects within the fuel-injection system. When a defect is detected, the ECU stores a code related to the defective circuit.

To obtain these codes, apply 12 volts to the test connector located next to the ECU. When the ignition switch is turned to the run position without starting the engine, a two-digit code will flash through the Check Engine light. A code forty-three, for example, would appear as four blinks followed by a pause, then three more blinks; a code twenty-two would appear as two blinks, a pause, then two more blinks. Use the troubleshooting chart to interpret Isuzu codes.

Isuzu Troubleshooting Codes

Code	Circuit Affected	Probable Cause
12	Primary ignition	Engine not running—normal
13	Lambda sensor	Output steady at crossover voltage
14	Coolant sensor signal too low	Wiring to coolant sensor shorted to ground Coolant sensor shorted
15	Coolant sensor indicating too cold	High resistance in coolant sensor wiring High resistance in coolant sensor
16	Coolant sensor circuit open	Open in coolant sensor wiring harness Open in coolant sensor
21	Throttle switch contacts both applied	Wires in wiring harness to throttle switch shorted together Contacts in switch shorted together
22	Starter signal to ECU missing	Open circuit in starter signal to ECU
23	ECU ignition driver transistor	Wire between ECU and ignition module appears to be grounded
25	Vacuum switching valve system	Wire between ECU and vacuum switching system appears to be open or shorted to ground
33	Injector output driver	Wire from ECU to injectors open or shorted to ground
35	Open to ignition system	Open circuit to ignition module
41	Crank angle sensor	No input from crank angle sensor Crank angle sensor indicating an rpm slower than actual engine speed
43	Idle circuit of throttle switch	Idle contacts appear to be closed even at high engine speeds
44	Lean exhaust indication	Defective O_2 sensor Misfire in secondary ignition Vacuum leaks Exhaust leaks Restricted injectors
45	Rich exhaust indication	Defective O_2 sensor High fuel pressure Leaking injector
51	Defective ECU	
52	Defective ECU	
53	Defective driver circuit in ECU	
54	Defective driver circuit in ECU	
55	Defective ECU	
61	Airflow sensor signal too low	Open in sensor wiring harness to airflow sensor Harness to airflow sensor grounded Defective airflow sensor

Isuzu Troubleshooting Codes

Code	Circuit Affected	Probable Cause
62	Signal from airflow sensor too high	Defective airflow sensor
63	No signal from vehicle speed sensor	Defective wiring to vehicle speed sensor Defective vehicle speed sensor
64	Defective injector driver transistor	Defective ECU
65	Wide-open throttle contact of ignition switch closed even at low engine speeds	Defective throttle switch Short in wiring harness to throttle switch
66	Excessive or insufficient signal from knock sensor	Open, short or ground in wiring harness to knock sensor Defective knock sensor
71	Throttle position sensor	Open, short or ground in wiring harness to throttle position sensor Defective throttle position sensor
72	EGR vacuum switching system	Open or ground in ECU wiring to EGR vacuum switch
73	Defective EGR vacuum switch driver transistor	Defective ECU

Nissan Throttle Body Injection System

In addition to the Datsun/Nissan systems covered in the L-Jetronic section, the manufacturer also uses a throttle body injection system on trucks and lower-priced applications. This system uses one or two injectors located in the throttle assembly to fuel the entire engine.

Airflow Meter

The Nissan throttle body injection system uses a mass airflow meter that mounts on the side of the throttle assembly. This heated wire sensor is similar to the LH-Jetronic air mass meter. Bolted to the side of the throttle body assembly, a small portion of the air flowing into the engine to be used in combustion passes through the air meter. Since this percentage of air entering the system is constant, the amount of air entering the engine can be estimated.

To test the airflow meter, check the voltage with the engine idling at terminal 31 of the ECU. At an idle the voltage should be approximately 1.6 volts. As the engine speed increases, this signal voltage should also increase. If the voltage is incorrect, confirm power ground for the sensor. If there are 12 volts to the sensor and a good ground, verify that the wire between the sensor and the ECU are not damaged. If all these items test positively, replace the airflow meter.

Water Temperature Sensor

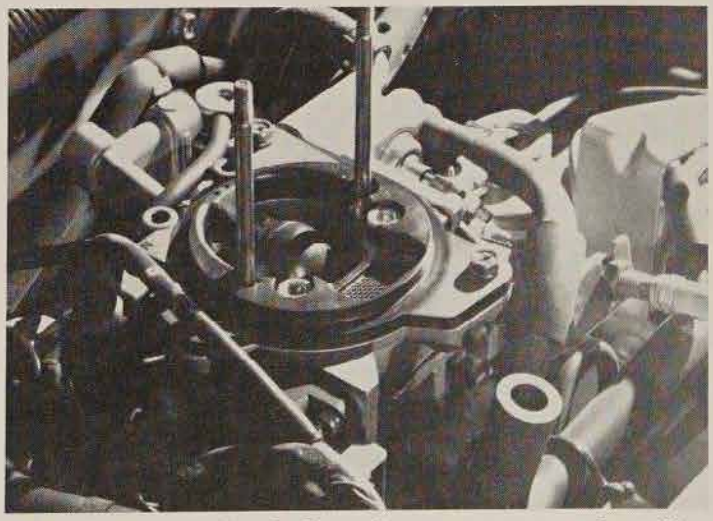
The water temperature sensor is a resistor whose resistance drops as its temperature increases. To test the circuits, probe each wire connected to the sensor. One wire should read zero volts while the other should read between 0.1 and 4.5 volts. If the voltage on the second wire is zero, look for an open or ground on the wire back to the computer. If the voltage on the second wire is 5.0, look for an open circuit between the point being measured and ground. If the voltage is between 0.1 and 4.5 volts, use the water temperature sensor resistance chart to confirm that the sensor has the proper resistance.

Water Temperature Sensor Resistance

Engine Temperature (deg. F.)	Resistance (ohms)
14	8,500-9,500
68	2,300-2,700
122	770-870
176	300-330

Air Temperature Sensor

The air temperature sensor signals the computer about the density of the air. As air temperature increases, the air becomes less dense. When air



In addition to the L-Jetronic system covered earlier, Nissan also uses a throttle body injection system on many of its pickup and Sentra models.

density decreases, less fuel is required for a given volume. A defective air temperature sensor can result in the engine running too rich, consequently, performance and fuel economy can suffer. Test the air temperature sensor as indicated for the water temperature sensor.

Throttle Position Sensor

The throttle position sensor sends a voltage to the ECU indicating throttle position. When the throttle is closed this voltage is low; as the throttle approaches wide open, the output of the sensor approaches 5 volts.

There are three wires connecting this sensor to the ECU. One wire should carry the 5 volt reference to the sensor. A second wire should provide a ground for the sensor. The third wire carries the signal from the sensor to the ECU.

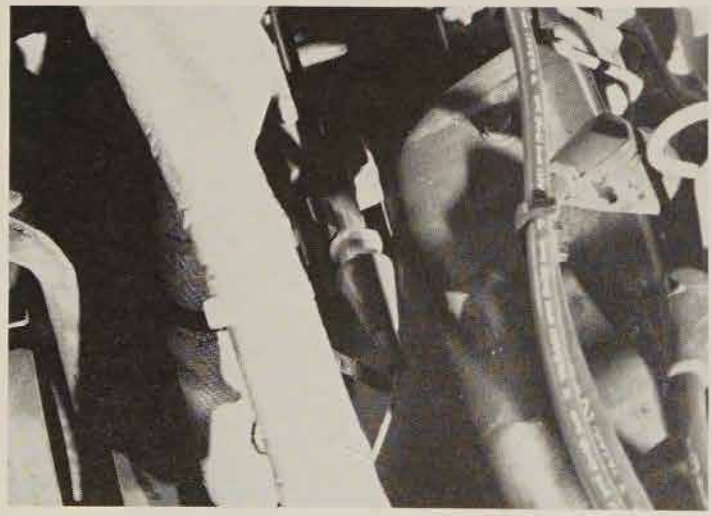
EGO Sensor

The EGO or exhaust gas oxygen sensor is a standard platinum-zirconium Lambda sensor. When the engine is running lean, it produces between zero and 450 mV. When the engine is running rich, it produces between 450 and 900 mV.

Crankshaft Position Sensor

Some of the Nissan throttle body injection systems use a unique crankshaft position sensor. Most of today's fuel-injection systems use a Hall Effects or reluctance pickup to sense engine rpm and synchronize the injectors. Nissan uses an optical sensor. This device uses two light emitting diodes and two photodiodes. A disc with slots rotates between them. As the slots pass between, a pulse that is directly proportional to the speed of the engine is created.

There are four wires going into the crankshaft position sensor. One wire should have 12 volts anytime the ignition switch is in the on position. The second wire is grounded. The third wire is connected to a digital tachometer. When the engine is cranked, an rpm reading greater than zero should be displayed. Repeat this for the third wire. If the power coming in is adequate and the ground is good but either one of the signals is missing, replace the crankshaft position sensor.



This connector is the most common style used to connect the Lambda sensor to the ECU wiring harness, including most European applications.

Mitsubishi Fuel-Injection System

Karmon Vortex Airflow Sensor

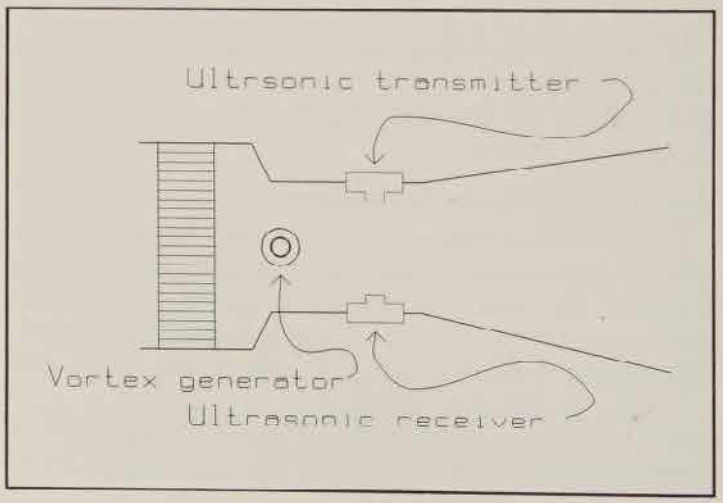
The Mitsubishi fuel-injection system features one unique component: the air flowing into the engine is measured by a Karmon Vortex airflow sensor. In this sensor a vortex is generated by air flowing past a vortex generator. The sensor then measures the frequency of these vortices as a measurement of the airflow rate.

Basically, the Karmon Vortex sensor consists of a tube. Located on one wall of the tube is an ultrasonic generator. On the opposite wall is an ultrasonic receiver. Since the propagation of the ultrasonic waves is perpendicular to the airflow, the vortices tend to accelerate the waves. Since the acceleration of these waves is proportional to the velocity of airflow, the sensor is able to accurately measure the mass of air entering the engine.

To test the airflow sensor, connect a voltmeter to terminal 2 or A2 of the ECU (whichever it has, depending on the application). The voltage at an idle should be 2.7 to 3.2 volts. If the signal is outside of this range, inspect the connections and wiring before replacing the airflow sensor.

Coolant Temperature Sensor

The Mitsubishi coolant temperature sensor is a negative temperature coefficient (NTC) thermistor. Use the coolant temperature sensor chart when testing the sensor. Note that the readings are given in voltages. These voltages are checked by connecting the meter to the ECU terminal 6 on the 1987 and later models. For the earlier models the terminal is A7.



Coolant Temperature Sensor Readings

Engine Temperature (deg. F.)	Voltage at Terminal 6 or A7 (volts)
32	3.4-3.6
68	2.5-2.7
104	1.7-1.9
176	0.6-0.8

If the voltage readings are outside of these specifications, inspect the connections and wires before replacing the sensor.

Intake Air Temperature Sensor

This is also an NTC thermistor. The ECU test terminal for this sensor is A4 on applications prior to 1987, and terminal 4 on applications 1987 and later. Refer to the intake air temperature chart for specs.

Intake Air Temperature Sensor Readings

Ambient Air Temperature (deg. F.)	Voltage at Terminal A4 (or 4) (volts)
32	3.4-3.6
68	2.5-2.7
104	1.7-1.9
176	0.6-0.8

Throttle Position Sensor

The throttle position sensor for the Mitsubishi fuel-injection system is a potentiometer. When the throttle is in the closed position the voltage at terminal 1 (A1 on models prior to 1987) should be between 0.4 and 1.5 volts. As the throttle is opened to wide-open throttle the voltage should gradually increase to between 4.5 and 5.0 volts.

Idle Position Switch

The idle position switch signals the ECU that the throttle is in the closed position. This tells the ECU to control the speed of the engine with the idle speed control motor. When the throttle comes to rest it contacts the nose of the idle speed motor. The plunger of the idle speed motor moves back slightly, closing the idle position switch.

A7 is the ECU terminal for applications prior to 1987. For 1987 and later applications the terminal is 7. When the throttle is closed the voltage at terminal A7 (or 7) should be zero to 0.5 volt. When the throttle is opened, this voltage should increase to battery voltage.

Pressure Sensor

The turbocharged applications use a pressure sensor to detect and control the level of boost in the intake manifold. When the ignition switch is in the run position, but the engine is switched off, the voltage at ECU terminal A17 (or 17) should be between 1.5 and 2.6 volts. When the engine is idling this voltage is decreased to between 0.2 and 1.2 volts. If the signal is outside of this range, inspect the connections and wiring before replacing the pressure sensor.

Lambda Sensor

The Lambda sensor produces a signal that ranges from 0.1 to 1.0 volt when the engine is warmed up and running. If the Lambda sensor voltage is low, there is extra oxygen in the exhaust system. If the sensor voltage is high, there is a low oxygen content in the exhaust. See chapter 5 on the Lambda sensor for more testing information.

14

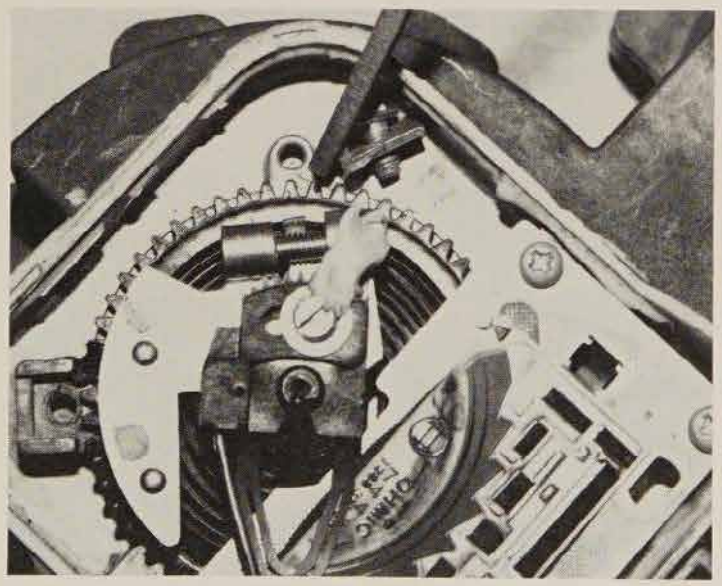
Fuel-Injection Performance Modifications

Modifying the L-Jetronic System

Whenever modifying a late-model car that will continue to be used on the street, always check with the local emission control officials. What is legal within one jurisdiction may be a violation in another.

One nice thing about fuel injection is that unless wild modifications have been made on the engine —nonstreet-legal modifications—almost everything needed to improve fuel system performance is already there.

Engine and intake manifold modifications are both simple and difficult for the injection system to deal with. The primary problem is that the airflow meter typically peaks in output at stock airflows around 3000 to 3500 rpm. This means that a modified engine will begin to run lean as the engine approaches these speeds.



One way to reduce restriction imposed by the airflow meter flap is to reduce the spring tension on the flap. Remove the screw and lock plate from the geared spring holder and rotate the holder to reduce spring tension. Be aware, however, that this procedure may affect a car's air-fuel ratio, emissions and its street-legal status.

Contrary to what many believe, the goal of performance modifications is to get more *air* into the engine, not more fuel. If fuel were the key to power, then increased performance could be as simple as raising the fuel pressure by crimping the fuel pressure regulator return line with a pair of vise grips. To get more power, the engine first needs to be modified to accept the additional air.

The premise is that the airflow meter is, by design, a restriction to airflow. Changes in engine design, camshaft configuration and intake and exhaust manifold design may be defeated by the airflow meter. In some cases, using a large airflow may improve the dilemma. Unfortunately, this is not as easy as it sounds. An airflow meter designed for one application may not directly interchange with another from that same manufacturer. For racing modifications, where time and money are no object as a rule, several airflow meters could be tried.

When installing an airflow meter that was not designed for the car you are modifying, you must first verify that the resistance of the airflow meter potentiometer changes at about the same rate as the original. Should the resistance or change in resistance differ from the original, it will alter the air-fuel ratio. If the difference leans the mixture, detonation and loss of power will occur. If the change enriches the mixture, the engine could flood and be robbed of power.

After checking the resistance values, the next step is to check the sensor terminals against the car's wiring harness. Match the wiring schematic of the donor application against the wiring schematic of the receiving car. There are as many as seven wires involved: ground for the potentiometer, reference voltage for the potentiometer, signal from the potentiometer, air temperature, 12 volt power supply, fuel pump relay input and fuel pump relay ground.

As long as the terminals match the car wiring harness for number and function, the wires within the harness can be moved to match the new sensor.

Caution: Should the 12 volt power wire (if there is one) be connected to the wrong sensor terminal, it could destroy both the sensor and the ECU.

The second restriction to airflow is the throttle body assembly. To correct this, begin by removing the throttle assembly. Any competition-oriented machine shop could enlarge the throttle bore and replace the throttle plates. Enlarging a 2.00 in. bore by 0.05 in. increases the airflow capacity through the bore by about 5 percent. Translated into cubic feet per minute (cfm), on a 2.8 liter engine this could be an increase of 10 cfm. The increase would not even be noticeable, however, unless every ounce of airflow was already being used.

A much more impressive alternative is the big-bore throttle assembly marketed by Weber. This unit provides a lot of bang for the buck.

Once the problem of airflow is solved, another issue to deal with is getting more fuel into the engine at the right time. As was stated earlier, getting an increased amount of fuel into the engine is easy; getting an increased amount of fuel *at the right time* is more difficult.

Upon initial acceleration, the L-Jetronic system first starves for fuel. This is for two related reasons.

First, the flap restricts air flowing into the engine. Second, the pressure must change in the column of air between the airflow meter and the throttle plates. The cure for both problems is the same. Under the plastic cover of the airflow meter is the spring that holds the flap shut. The tension on this spring is calibrated to ensure that EPA standards are maintained. Reducing the spring tension by one notch (or more) can reduce the off-idle hesitation. Be aware that air-fuel ratio at all engine speeds will be affected; therefore, fuel economy will be affected as well.

Extra fuel is also needed as the engine rpm increases to over 3000 under load—the system pressure is unable to be pushed through the injector. Increasing the fuel pressure will overcome this problem. Micro Dynamics markets a rising-rate fuel pressure regulator to relieve this problem. As the engine load increases, the manifold pressure increases. A vacuum line between the rising-rate regulator and the intake manifold reports this increase. Although this occurs with the stock pressure regulator as well, the stock regulator either has the pressure at the idle level or at the power level. Therefore, the stock regulator is unable to increase pressure too early. The rising-rate regulator follows manifold pressure in a linear fashion. So when the demand for fuel is there, the pressure increases enough to match that demand.

Modifying the LH-Jetronic System

As of this publication, the LH-system is not used on cars that are considered hot-rod material. There are Volvo and Saab enthusiast groups interested in performance, but the bulk of owners were seeking solid, dependable transportation when they bought their vehicles. As a result, the market share for Volvo and Saab performance parts is too small for most performance parts manufacturers to become involved. The other major user of the LH-system is Porsche. Although Porsche builds performance into its cars at a level to satisfy most people, Porsche also owns too small a market share to justify performance component manufacture. Thus, if improvements are to be made in the performance of the LH-system, it will need to be modifications to the existing components.

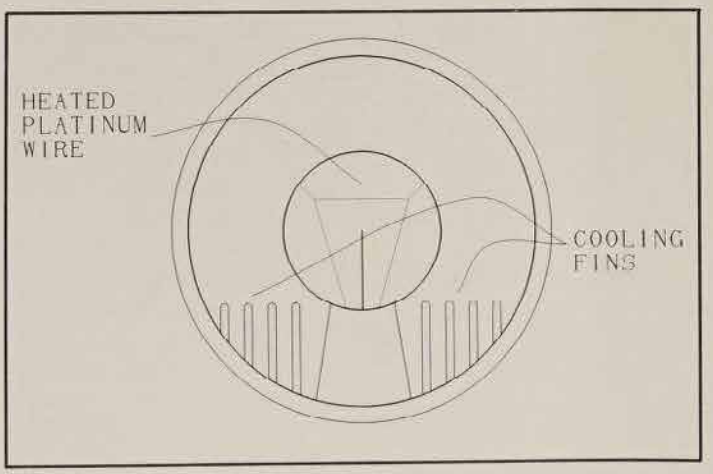
The air mass meter does not have the airflow-restricting flap that the L-system has. There are, however, screens at each end of the air mass sensor that impede airflow. Removing these screens will yield a considerable increase in airflow.

The LH-system shares the top-end fuel-starving problem with the L-system, however. But this problem is easily solved with a rising-rate fuel pressure regulator.

Modifying the K-Jetronic System

Most K-Jetronic systems have the ability to deliver all the fuel required for most power increase modifications suitable for the streets. The trick is to get more air into the engine. Like the flap of the airflow meter, the airflow sensor plate on the K-Jetronic system is a serious restriction to airflow. Modifying the airflow sensor is difficult, however, since the sensor plate is one of the most essential components of the K-system. For different cars and engines these sensors come in different bore diameters. Using an airflow sensor from a car with a bigger bore will allow increased airflow.

For most applications the diameter of the airflow sensor plate is more than large enough to meet the

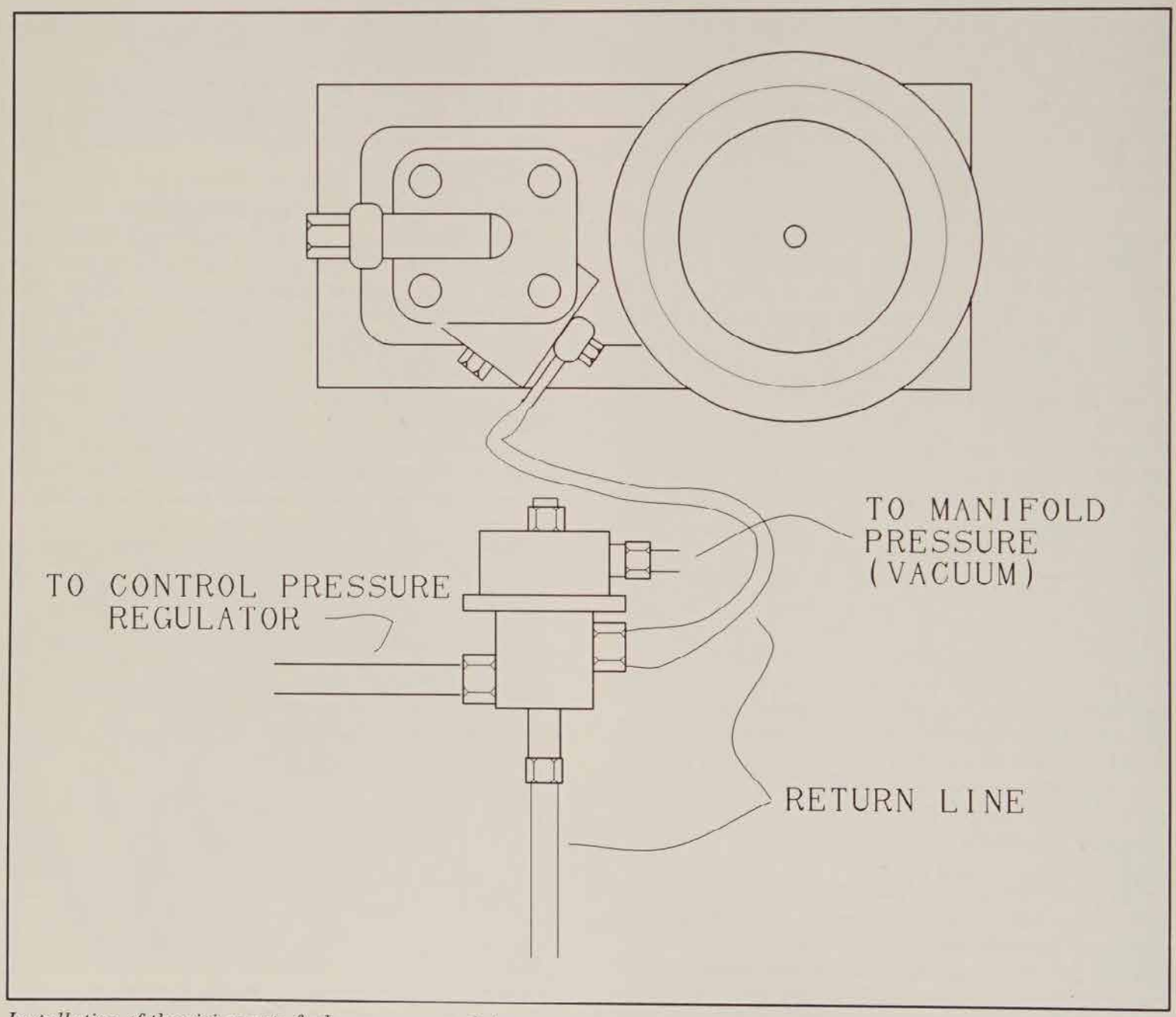


The air mass meter does not have the airflow-restricting flap that the L-system has. There are, however, screens at each end of the air mass sensor which impede airflow. Removing these screens will yield a considerable increase in airflow.

needs of the stock or lightly modified engine. Therefore, as in the L-Jetronic system, the single modification that would yield the greatest increase in performance would be the Weber big-bore throttle body kit. The results of adding this part can be astounding. I first installed one in 1984. A customer wanted increased performance from his Volkswagen Scirocco. Two weeks later he returned with all four of the transmission mounting bolts broken.

When the increased airflow is achieved, there must be extra fuel. The need for extra fuel can be met by simply enriching the mixture with the 3 mm Allen screw. This enriches the mixture throughout the airflow band.

If flat spots or hesitations are detected, the demand for more fuel can be met by installing a load-sensing system pressure regulator. These regulators, such as the one marketed by Micro Dynamics, will vary the system pressure as engine load changes. These regulators are fully adjustable for system pressure. Additionally, a vacuum line runs from the regulator to the intake manifold. As the engine load increases, the rising manifold pressure causes the system pressure to increase. As the system pressure increases, the mixture enriches.



Installation of the rising-rate fuel pressure regulator on the K-Jetronic system.

Index

Acura fuel injection system, 165
Acura fuel injection system, troubleshooting, 166
Air filter, replacement, 36, 38
Air mass meter, 88, 91
Air pump, 29
Air temperature sensor, 169
Air valve, auxiliary, 52, 70, 91, 108, 152
Air-fuel ratio, 5, 37
Airflow meter, 21, 64, 70, 169
Airflow sensor, 109, 153, 166
Alcohol contamination, 39
Ammeter, inductive, 10
Ammeter, shunt, 10

Battery, 5
Bosch D-Jetronic system, 19, 39, 44-63
Bosch D-Jetronic system, testing, 56-63
Bosch D-Jetronic system, troubleshooting, 55
Bosch D-Jetronic system, tune-up adjustments, 53
Bosch K-Jetronic system with lambda, 129-147
Bosch K-Jetronic system with lambda, testing and troubleshooting, 136-147
Bosch K-Jetronic system with lambda, tune-up adjustments, 135-136
Bosch K-Jetronic system, 34, 101-128
Bosch K-Jetronic system, performance modifications, 173
Bosch K-Jetronic system, testing and troubleshooting, 113-128
Bosch K-Jetronic system, tune-up adjustments, 110-113
Bosch KE-Jetronic system, 148-158
Bosch KE-Jetronic system, adjustments, 155-157
Bosch KE-Jetronic system, troubleshooting, 157
Bosch L-Jetronic system, 21, 64-86, 162
Bosch L-Jetronic system, performance modifications, 172
Bosch L-Jetronic system, testing, 77-86
Bosch L-Jetronic system, troubleshooting, 76-77
Bosch L-Jetronic system, tune-up adjustments, 71-76
Bosch LH-Jetronic system, 87-100
Bosch LH-Jetronic system, performance modifications, 173
Bosch LH-Jetronic system, testing, 95-100
Bosch LH-Jetronic system, troubleshooting, 95
Bosch LH-Jetronic system, tune-up adjustments, 92-95
Bosch Motronic system, 159-161
Bosch Motronic system, troubleshooting, 161

Catalytic convertor, 30
Circuits, defects in, 12
Cold-start injector, 51, 70, 91, 107, 134
Cold-start switch, 152
Compression, 37
Coolant temperature sensor, 89, 153, 161, 166, 169, 170
Crank angle sensor, 167, 170

Dead cylinder testing, 40
Distributor cap, replacement, 36, 38
Dwell meter, 16, 24, 33

Electrohydraulic actuator, 153
Electromagnetics, 6
Electronic Control Unit (ECU), 30, 38, 49, 68, 89
Electronics, basics of, 5-25
Electrostatic Discharge (ESD), 12
Emissions, 26-30
Engine modifications, 29
Engine speed and crankshaft reference sensor, 161
Exhaust Gas Recirculation (EGR) sensor, 170
Exhaust Gas Recirculation (EGR) valve, 29, 34

Frequency valve, 134
Fuel accumulator, 104, 132, 148
Fuel control pressure regulator (warm-up regulator), 107, 133, 151
Fuel cooler, 151
Fuel distributor, 105-107, 132-133, 149
Fuel filter, 69, 90, 104, 132, 148
Fuel filter, in-tank, 49, 68, 89, 103, 130
Fuel filter, replacement, 36, 38, 50
Fuel pre-pump, 103, 130
Fuel pressure gauge, 34
Fuel pump, 50, 68, 89, 103, 131, 148, 152
Fuel rail, 51, 69, 91
Fuel system pressure regulator, 50, 69, 90, 107, 133
Fuel tank, 102, 130, 148
Fuel, evaporation, 29

Hall Effect, 8
Hall Effects sensor, 22
Honda fuel injection system, troubleshooting, 164
Honda programmed fuel injection (PGM-FI), 162
Hydraulic theory, 102, 130

Idle air by-pass, 53, 71, 92, 109
Idle position switch, 171

Idle speed air valve, 152
Idle stabilizer, 91
Induction, 6
Injector pulser, 34
Injectors, 51, 69, 91, 107, 133, 151
Intake air temp sensor, 171
Isuzu fuel injection system, troubleshooting, 168
Isuzu I-TEC fuel injection system, 166

Karmon vortex airflow sensor, 170
Kettering, Charles F., 16
Kirchhoff's Law, 14

Lambda sensor, 5, 24, 32, 39, 42, 67, 89, 134, 155, 167, 171
Lambda sensor, contamination, 42
Lambda sensor, testing, 25, 43
Linear Variable-Differential Transformer (LVDT), 20, 48

Manifold Absolute Pressure (MAP) sensor, 19
Manifold Pressure Control (MPC) system, 44
Mitsubishi fuel injection system, 170
Motor, DC, 7
Motor, stepper, 7

Negative Temperature Coefficient (NTC) thermistor, 46
Nissan throttle body injection system, 169

Ohm's Law, 13
Ohmmeter, 10, 32
Optical sensor, 23
Oscilloscope, 10, 24, 34

Positive Crankcase Ventilation (PCV) valve, 29
Potentiometer, 19
Power relay, 152
Pressure sensor vacuum hose, 52
Pressure sensor, 48, 171

Resistors, 11

Solenoid, 8
Spark plug, replacement, 36, 38
Spark plug, wear, 37
Spark plugs, heat range, 37

Tach signal, 88
Tachometer, 32
Temperature Sensor I, 46, 65
Temperature Sensor II, 46, 65
Test light, 32
Thermal switch, 135
Thermistor circuits, 18
Thermistors, 17
Throttle microswitch, 18
Throttle Position Sensor (TPS), 19, 167, 170, 171
Throttle switch, 18, 47, 66, 89, 135, 155, 161, 167
Throttle valve, 152
Trigger points, 45, 66
Troubleshooting tools, 31-35

Vacuum gauge, 34
Vacuum pump, hand-held, 34
Vacuum switch, 89
Variable Reluctance Transducer (VRT), 22
Voltmeter, AC, 9
Voltmeter, analog, 9, 31
Voltmeter, digital, 9, 31

Watts, 11
Waves, amplitude, 15
Waves, duty cycle, 16
Waves, frequency, 15
Waves, pulse width of, 16
Waves, sine, 14
Waves, square, 14

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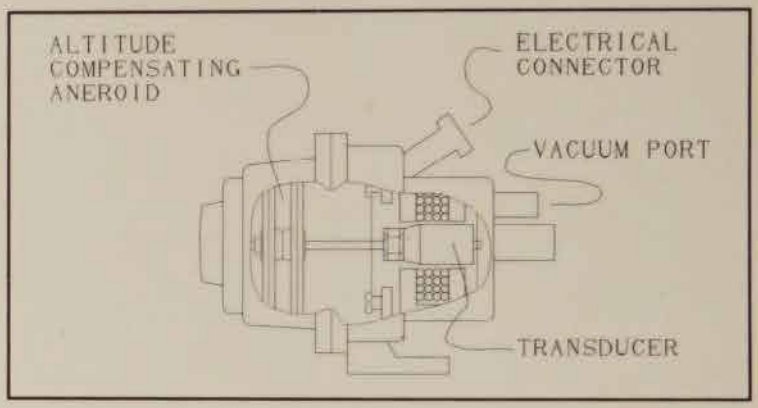
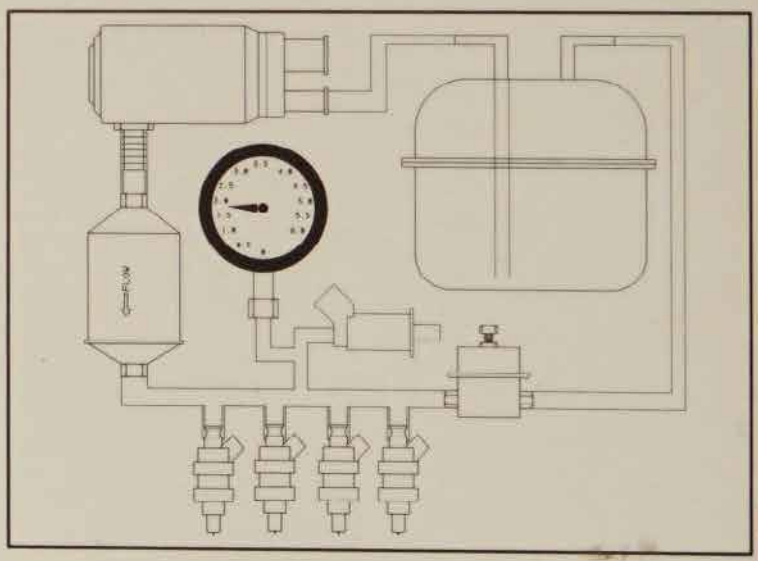
HOW TO TUNE & MODIFY BOSCH FUEL INJECTION





Bosch was a legendary pioneer of fuel injection technology, and today supplies sophisticated injection systems for some of the world's finest cars, including luxury sedans, high-performance sports cars and fuel-efficient daily commuters.

How to Tune & Modify Bosch Fuel Injection is a comprehensive, step-by-step manual on how to troubleshoot and repair systems from the early D-Jetronic setup to today's advanced Motronic system. The easy-to-follow information on inspecting, testing, tuning and repairing various Bosch systems is accompanied by 250 illustrations, charts and photos.

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