Bendix ELECTROJECTOR

This manual is designed to provide the Serviceman with a basic knowledge of how the Electrojector System operates. It incorporates pictures of an Electrojector System Installation; a schematic drawing of a typical System; pictures and illustrations of the component parts of the System.

Quick Reference Index

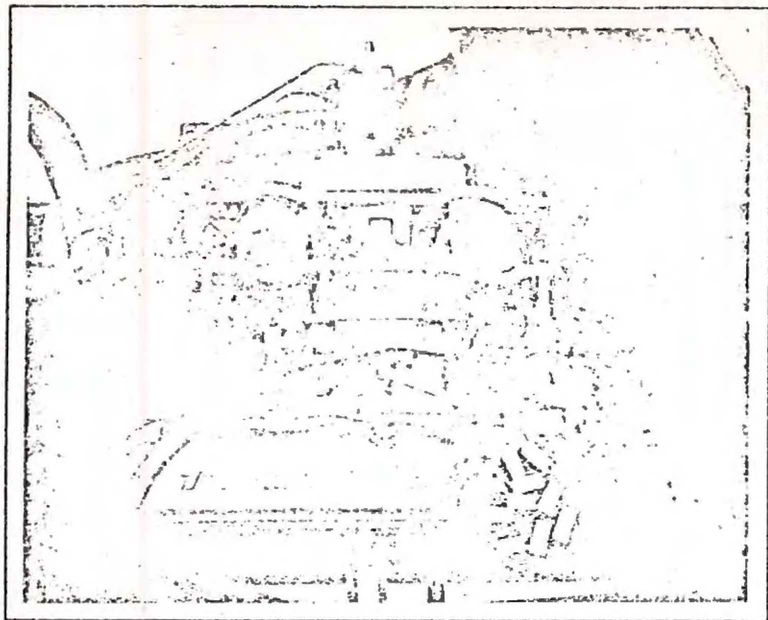
	Page No.
General Description - - -	3
Function of each Component Part - - - -	3
Glossary of Electrojector Terms - - -	8

Form No. 10-1029
Printed August, 1957

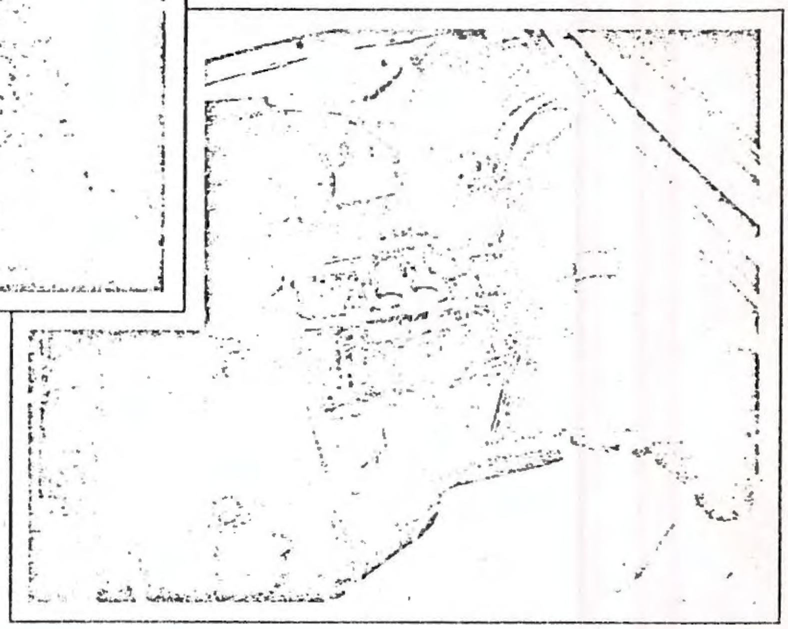
SERVICE SALES DEPARTMENT
BENDIX PRODUCTS DIVISION OF
SOUTH BEND 20, INDIANA

Bendix
AVIATION CORPORATION

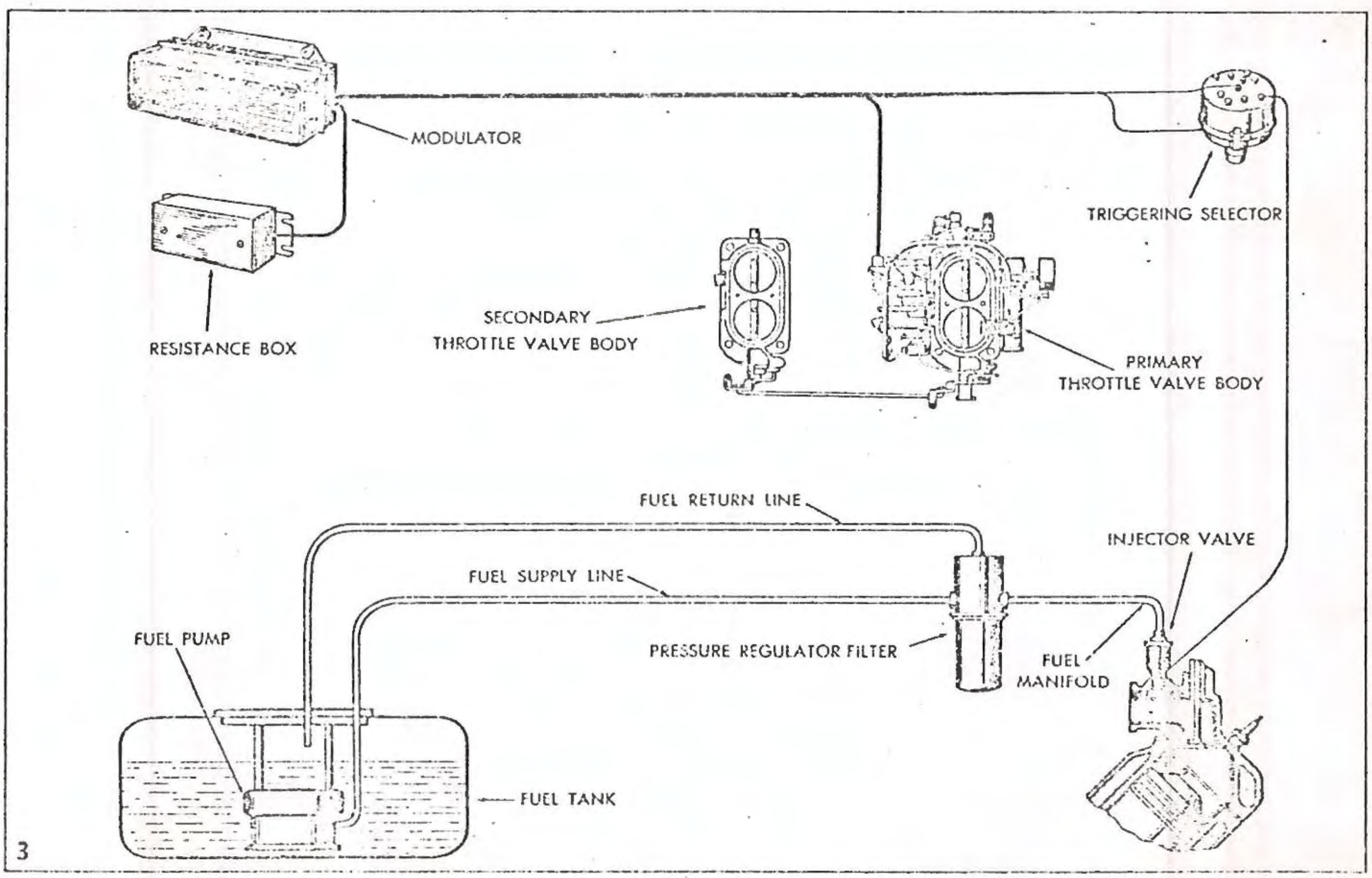
TYPICAL INSTALLATIONS OF THE ELECTROJECTOR SYSTEM



1



2



3

SCHEMATIC OF A TYPICAL ELECTROJECTOR SYSTEM

GENERAL DESCRIPTION

The Bendix Electrojector is a system which electronically controls the injection of fuel into an internal combustion engine. The Injectors are located in the engine manifold -- one for each cylinder of the engine.

Fuel for the Injectors is supplied, under a constant pressure, by an Electric Pump through a Pressure Regulator -- Filter, to a Fuel Manifold and then to each Injector.

A combination timing and distributing device, the Triggering Selector, is driven by a shaft connected to the ignition distributor. The Triggering Selector transmits an electrical signal to the Electronic Modulator, which actuates the Modulator, whose output is then returned to the selector portion of the Triggering Selector for distribution to the correct Injector Valve.

The electrical impulse to the Injector opens a valve within the Injector for a very minute period of time and the fuel is injected into the manifold. The time period of injection is measured in milliseconds.

Electrical devices in the system known as "Sensors" make the system responsive to barometric pressure, temperature, intake manifold vacuum and other factors which affect engine requirements. The Sensors affect the Modulator to provide the correct air/fuel mixture for all stages of performance, namely: starting, warm-up, idling, acceleration, varying loads and speeds.

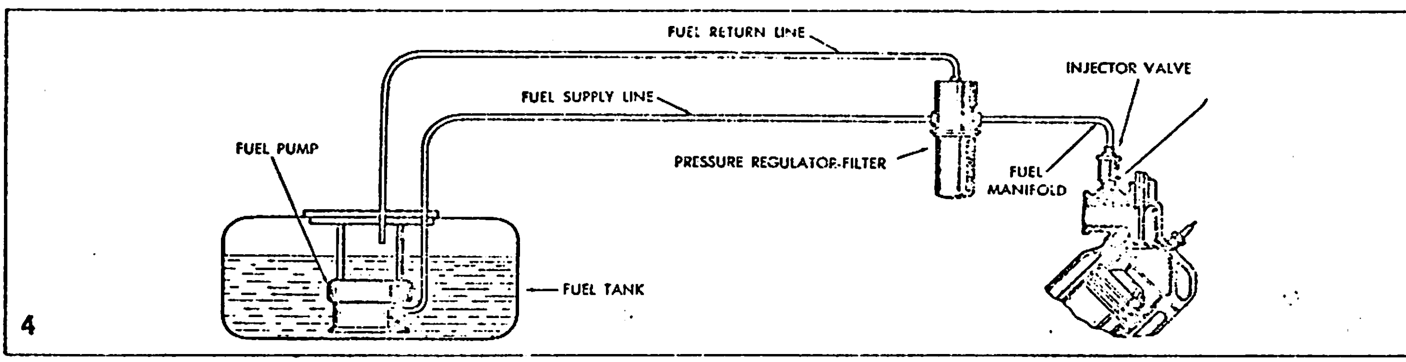
Air intake units, known as Throttle Valve Bodies, are mounted on the intake manifold. There can be either one or two Throttle Valve Bodies depending on the type of installation made on the engine. Each unit has two barrels with throttle valves. One unit is the Primary Throttle Valve Body and it carries the Sensors. The throttle valves of the Primary Throttle Valve Body are directly connected to the accelerator pedal. The Secondary Throttle Valve Body contains only the throttle valves. The throttle valves of both units are connected by a linkage. When the accelerator pedal is initially depressed from the closed position, the valves of the Primary unit only are opened and, shortly thereafter the Secondary valves begin to open so that both sets of throttle valves reach wide open position at the same time.

This completes the cycle of delivering the air and fuel into the intake manifold.

The Electrojector consists of the following three basic systems:

1. The fuel supply system
2. Injector control system
3. Sensor system

FUNCTION OF EACH COMPONENT PART

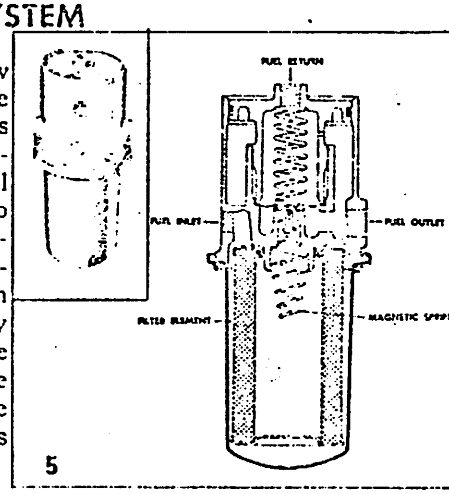


SCHEMATIC OF THE FUEL SUPPLY SYSTEM

THE FUEL SUPPLY SYSTEM CONSISTS OF:

a. Fuel Tank
b. Fuel Pump
c. Pressure Regulator-Filter
d. Fuel Manifold
e. Injectors

FUEL PUMP: An electrically operated Fuel Pump, submerged in the fuel tank, furnishes fuel to the fuel line at approximately 29 psi. The Fuel Pump is wired to two circuits; the starting switch circuit and to a pressure switch located in the oil line of the engine lubricating system. The Fuel Pump begins to operate the instant the starter switch is closed and, when the engine starts, the pressure in the oil line closes the pressure switch to take over the flow of current to the Fuel Pump. This circuit combination prevents fuel being pumped to the intake manifold and combustion chamber in case of a leaky Injector Valve when the engine is "dead" and the ignition key is left on.



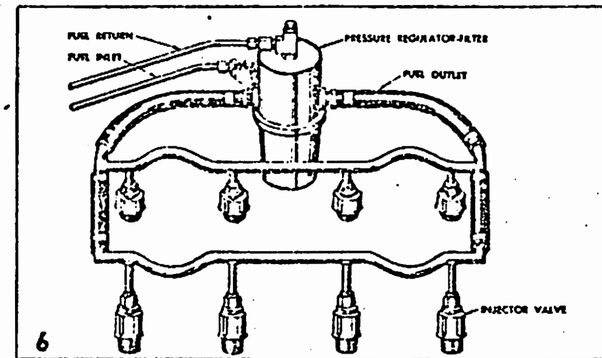
PRESSURE REGULATOR-FILTER: A combination Pressure Regulator-Filter, see Fig. 5, reduces and maintains the fuel pressure to the Fuel Manifold at 20 P.S.I., plus or minus ½ pound. It also filters the fuel. A reducer in the filter allows only a portion of the fuel to be returned to the tank via the return line. This assures that solid fuel is being maintained in the Fuel Manifold.

FUEL MANIFOLD: The Fuel Manifold, see Fig. 6, distributes the fuel from the Pressure Regulator-Filter to the individual Injectors.

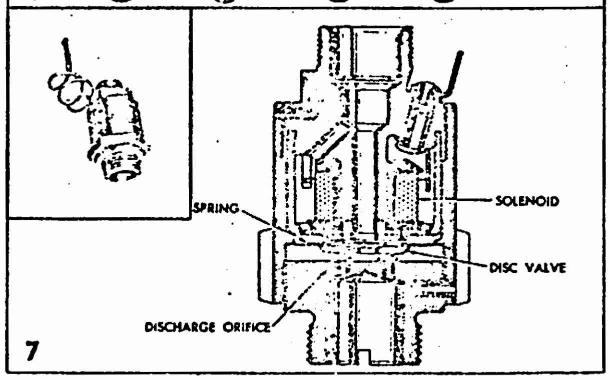
INJECTORS: The Injectors, see Fig. 7, are located in the intake manifold, directed at the intake port of each cylinder. The Injector consists of a solenoid, a disc valve, a return spring and the orifice plate. The disc valve is located between the solenoid and the orifice plate. A star-shaped flat spring holds the disc valve against the orifice plate when the valve is in the closed position. Thus, the fuel flow is cut off to the orifices by the disc valve. When the solenoid is energized by current from the Modulator, the disc valve, being made of magnetic material, is attracted towards the electromagnet, against the force of the flat spring, allowing fuel to flow through the orifices and discharging into the engine in the area of the inlet valve.

The period of time that the valve is open is controlled by the Modulator and is measured in milleseconds. A millisecond is 1/1000th of a second. The period of valve opening varies in accordance with the requirements of the engine.

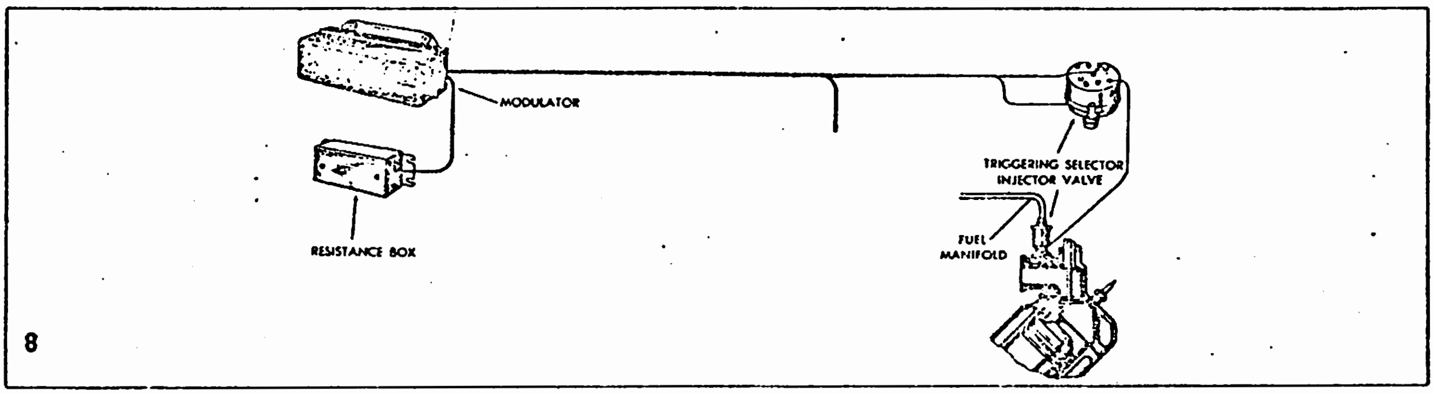
At the completion of the time period, the current to the solenoid is cut off and the spring returns the disc valve to its closed position on the orifice plate and cuts off the fuel flow.



6



7



8

SCHEMATIC OF THE INJECTOR CONTROL SYSTEM

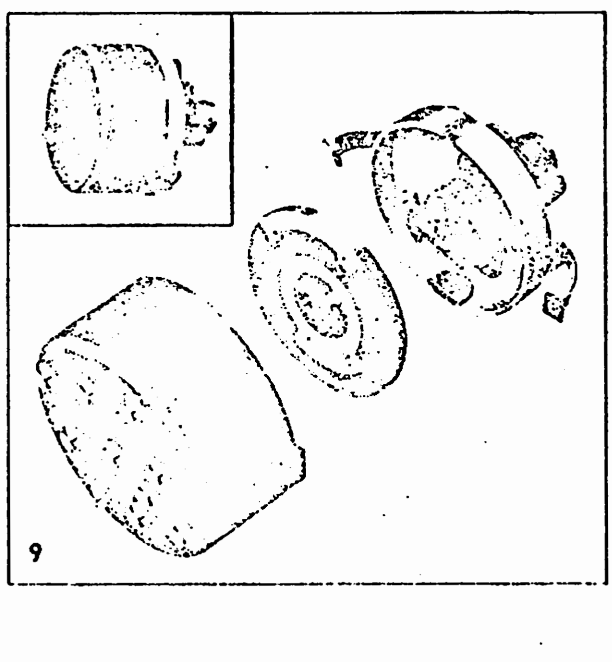
THE INJECTOR CONTROL SYSTEM CONSISTS OF:

a. Triggering Selector Unit
b. Electronic Modulator
   Altitude Compensator
   Resistance Box
c. Wiring Harness

TRIGGERING SELECTOR UNIT: The function of the Triggering Selector unit, see Fig. 9, is to "trigger" or create a voltage change in the Modulator, thereby initiating a current flow which is returned to the Triggering Selector for distribution to the correct Injector.

The Triggering Selector unit consists of a four lobed cam with two sets of breaker contact points riding on the cam. These contact points establish when the fuel injection is to begin. The unit also consists of a current distributor (rotor and cap) which connects the output of the Modulator to the proper Injector. The Triggering Selector unit is driven at one-half engine speed by a shaft connected to the engine distributor. The function of the Triggering Selector unit is not however, in any way, connected with the ignition system.

The two sets of breaker contact points are designated as set "A" and set "B." The Modulator also consists of two sets of electronic components designated as channels "A" and "B." Contact breaker set "A" is connected to the input of channel "A" and contact breaker set "B" is connected to the input of channel "B". The contact breaker points operate in



9

alternate succession. When a set of points "break," its respective channel in the Modulator switches the electrical current "ON" to the Triggering Selector unit where it is distributed to the appropriate Injector.

The rotor of the unit has two separate distributing contact surfaces, which are shaped as arcs. Each contact surface is associated with 4 brush contacts located in the distributing cap. The outer arc distributes the electrical current from channel "A" to the Injectors for cylinders 1, 4, 6, 7. The inner arc distributes the electrical current of channel "B" to the Injectors for cylinders 8, 3, 5, 2.

MODULATOR: The Modulator, see Fig. 10, turns "ON" & "OFF" the electrical current which operates the Injector. With a constant fuel pressure, the amount of fuel which an Injector injects into the engine is proportionate to the length of time which the valve is energized. The Triggering Selector points "breaking" starts the period of injection, and the condition of all Sensors, including the Altitude Compensator, modify the operation of the Modulator so that the duration of the pulse to the Injectors produces fuel flow which matches the engine requirements.

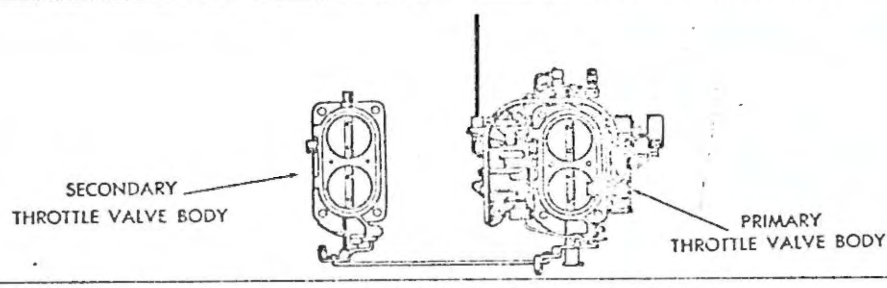
The Modulator consists of two identical electronic units which are identified as "channel A" and "channel B." Each channel of the Modulator is associated with one of the two sets of breaker contact points located within the Triggering Selector unit. Each time a set of breaker contact points open, a flow of current is turned "ON" by the channel associated with that set of points. Since the two sets of breaker contacts operate alternately, the two channels of the Modulator also operate alternately. Each time a set of points opens, an electric current is turned on by one of the two channels of the Modulator. The duration of this current is extremely short. Since the electric current is of such short duration, it is called a "pulse" of current. The period of this pulse is termed as "pulse duration." Thus, a voltage which has a duration of 3/1000ths of a second, is referred to as a 3 millisecond pulse, or as a pulse which is of 3 milliseconds duration.


10


11

RESISTANCE BOX: The Resistance Box, see Fig. 11, is a part of the Modulator Circuit. One portion of the Modulator Circuit contains resistances which generate heat. Therefore, these resistances have been installed in a separate box, with a perforated cover, which more readily dissipates the heat. The Resistance Box and the Modulator are connected through the Wiring Harness.

ALTITUDE COMPENSATOR: The Altitude Compensator is a Sensor device which automatically adjusts pulse duration for altitude changes. This device, which is part of the Modulator, is pre-adjusted, sealed and does not require any attention in the field.



12

SCHEMATIC OF THE SENSOR SYSTEM

THE SENSOR SYSTEM CONSISTS OF:

A. Primary Throttle Valve Body
   1. Manifold Vacuum Sensor
   2. Acceleration Sensor
   3. Cold-Start and Warm-Up Sensor
   4. Idle Adjustment Sensor
   5. Air Temperature Sensor

B. Secondary Throttle Valve Body

The Modulator uses two Sensor Circuits which control the pulse duration and consequently, the amount of fuel injected into the engine. One Sensor Circuit is sensitive to resistance. The more resistance that is inserted into the Sensor Circuit, the greater will be the pulse duration. The other Sensor Circuit is sensitive to voltage. The higher the voltage to the Modulator via this Sensor Circuit, the shorter will be the pulse duration from the Modulator.

The voltage-sensitive Sensor Circuit is called the Main Control Circuit and the resistance-sensitive Sensor Circuit is called the Auxiliary Control Circuit.

The Manifold Vacuum Sensor and the Acceleration Sensor comprise the Main Control Circuit. The Manifold Vacuum Sensor and the Acceleration Sensor both vary the voltage which is fed into the Modulator via the Main Control Circuit. This, in turn, varies the amount of fuel injected into the engine, according to the needs of the engine.

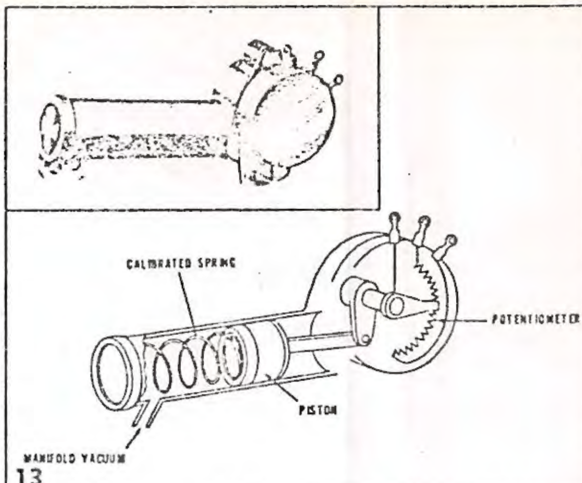
The Cold-Start and Warm-Up Sensor and the Idle Adjustment Sensor comprise the Auxiliary Control Circuit. The Auxiliary Control Circuit provides the correct fuel-air ratio during engine starting, warm up and engine idle. During normal engine operation, after the engine has warmed up and at speeds greater than idle, the Auxiliary Control Sensors have negligible effect upon the pulse duration, and consequently the fuel-air ratio.

MAIN CONTROL SENSOR CIRCUIT

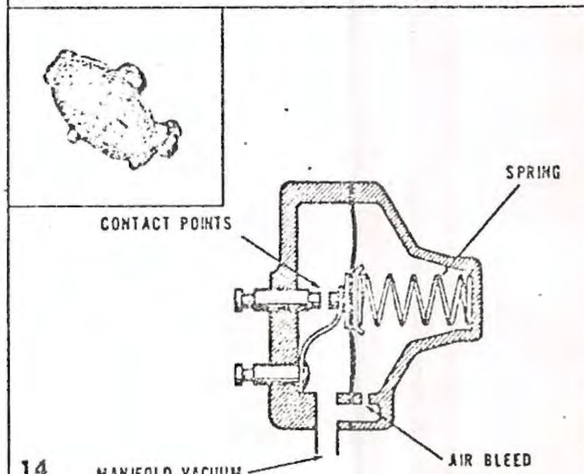
MANIFOLD VACUUM SENSOR: The Manifold Vacuum Sensor unit, see Fig. 13, is located on the Throttle Body. It consists of a potentiometer, the shaft of which is connected to a spring loaded piston by means of a crank mechanism. The cylinder, in which the piston travels, is connected to the lower portion of the Throttle Body by a channel which is open to the intake manifold vacuum. As the manifold vacuum increases, the vacuum piston moves against a calibrated spring and the sliding motion of the piston is converted into a rotary motion of the potentiometer's shaft by the crank linkage. The slider of the potentiometer picks up the control voltage to the Modulator. The rotation is toward the increased voltage position and thereby reduces the pulse duration. When the throttle is opened, the manifold vacuum decreases, allowing the calibrated return spring to move the piston in the opposite direction. The potentiometer likewise rotates in the opposite direction and thereby dcreases the voltage to the Modulator. This action increases the pulse duration and thus, the engine vacuum affects the amount of fuel injected into the engine.

ACCELERATION SENSOR: To insure a smooth uninterrupted flow of power for acceleration, additional fuel must be metered into the engine. This is accomplished through the use of the Acceleration Sensor, see Fig. 14. The Acceleration Sensor consists of a vacuum diaphragm switch which is normally in closed position. The switch is connected in series with the Manifold Vacuum Sensor. Electrically, it is located between the positive 12 volt supply and the Sensor potentiometer. When the switch is open, the potentiometer of the Manifold Vacuum Sensor is connected directly to ground . . . which causes the Modulator to produce a greater pulse duration and consequently enrich the fuel-air mixture as required for acceleration.

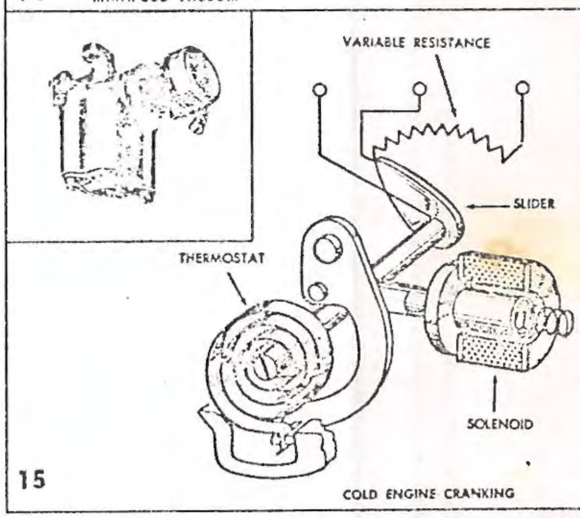
The Sensor unit consists of a diaphragm separating two halves of a chamber. One half of the chamber is connected to the engine manifold vacuum at the Throttle Body. The diaphragm contains one contact of a pair of contacts comprising the switch. The other contact is fastened to the case. An air bleed equalizes the pressure on both sides of the diaphragm. The electrical contacts within the sensor are normally closed thereby completing the circuit between positive 12 volts and the Manifold Vacuum Sensor potentiometer. When the manifold vacuum suddenly drops (as in the case of an acceleration), the pressure on both sides of the diaphragm momentarily becomes unequal . . . the air bleed hole in the diaphragm is small and restricts the flow of air that would equalize the two pressures. When the manifold pressure drops suddenly, the higher pressure is on the side of the diaphragm with the electrical contacts. The higher pressure forces the diaphragm toward the low pressure side of the chamber thus opening the electrical contacts. The air bleed in the diaphragm quickly neutralizes the pressure differential on either side and the diaphragm returns to its initial position with the contacts of the switch closed.



13



14



15

AUXILIARY CONTROL SENSOR CIRCUIT

COLD-START AND WARM-UP SENSOR: The Cold-Start and Warm-Up Sensor performs the same function as does the choke in a conventoinal carburetor . . . namely, it adds fuel for starting the engine and while it is warming up to normal operating temperatures. The warm-up enrichment is controlled by a thermostat connected to the shaft of a rheostat (or variable resistor). The action of the thermostat coil is similar to that of its counterpart in a conventional carburetor . . . as the temperature of the thermostat changes, the coil winds or unwinds thus turning the shaft of the rheostat to which it is attached. The rheostat is so arranged that, when the engine is cold, see Fig. 15, the resistance introduced into the Auxiliary Control Circuit increases the pulse duration and hence increases the amount of fuel injected into the engine. The cold start feature of this Sensor consists of a solenoid plunger connected by a lever to the outer end of the thermostat coil. When the engine starter is engaged, the solenoid plunger actuates the lever which contacts the thermostat ear and causes the thermostat to rotate an additional amount. The temperature of the thermostat determines the amount of rotation of the resistor shaft and thus controls the additional pulse duration.

When the engine fires and the starting motor is disengaged, the solenoid plunger releases the thermostat coil which initially decreases the resistance, see Fig. 16, and the pulse duration. As the engine continues to run, the thermostat tension is then only affected by the warm air from the stove on the manifold. As the tension continues to decrease, the resistance of the rheostat decreases, see Fig. 17, and, consequently, a decreased pulse duration as the engine reaches normal operating temperature.

Linkage connected to the Sensor and a fast idle cam provides fast idle position of the throttle during cold start and warm up periods.

COLD START PULSES: Normally, when the breaker contacts of the Triggering Selector open, an output pulse occurs. During the cranking period, however, in addition to the increased pulse duration due to the resistance added by the Cold Start Sensor, a circuit in the Modulator also causes two additional pulses to occur. Thus, the flow of fuel is tripled during the cranking period.

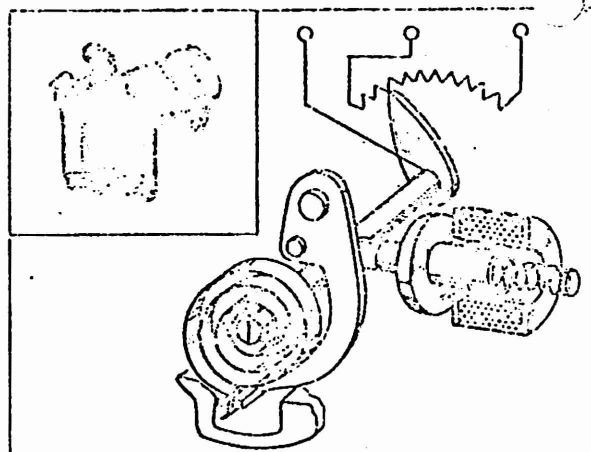
DE-LOADER: The De-loader provides an electrical means of disabling the Modulator and thereby interrupting the fuel injection while the engine is cranking with a wide open throttle. This procedure is followed in the event the engine becomes "loaded" while cranking.

The De-loader device consists of two Switches with related components located near the end of the throttle shaft. A lever attached to the throttle shaft contacts the two Switches when the throttle is in "wide open" position. The Switches are normally in the open position and are closed when the lever contacts them. When the throttle is wide open, one Switch shorts out the Cold Start and Warmup Sensor Rheostat. The second Switch, being connected to the Temperature Sensor, connects the starter relay to the Temperature Sensing Circuit when it closes and thereby introduces additional voltage. This reduces the pulse duration to an extremely low value while cranking with the throttle in the wide open position.

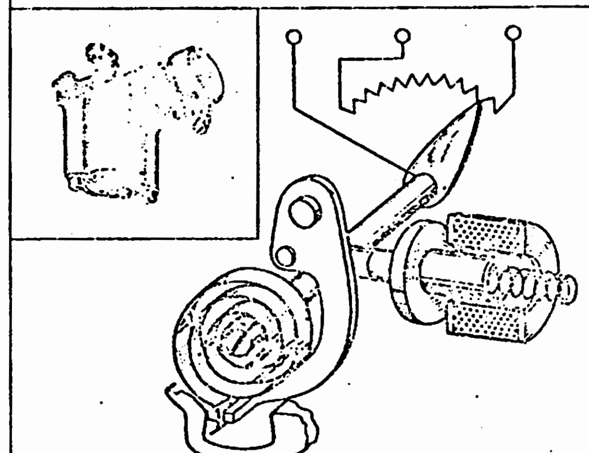
IDLE ADJUSTMENT SENSOR: The Idle Adjustment Sensor, see Fig. 18, is located on the Throttle Valve Body. Its function is similar to that of the idle system of a conventional carburetor, namely, to adjust the fuel to air ratio at closed throttle. The Idle Adjustment Sensor consists of: the Idle Adjustment Rheostat and the Idle Adjustment Switch. The Idle Adjustment Rheostat is located near the end of the throttle shaft and is connected electrically in series with the Acceleration and Manifold Vacuum Sensors which are part of the main sensor circuit. The Idle Switch is also located near the end of the throttle shaft and is actuated by a lever which is attached to the throttle shaft. During curb idle the Idle Switch is "open" and the Idle Adjustment Rheostat, being in series with the Manifold Vacuum Sensor, raises the voltage in the potentiometer circuit and thereby decreases the pulse duration from the Modulator. This then permits a range of adjustment of the rheostat to provide either a "richer" or "leaner" mixture as required by the engine.

When the throttle is opened beyond curb idle, the Idle Switch is closed and the pulse duration is then modified by the Manifold Vacuum Sensor in accordance with the engine manifold vacuum.

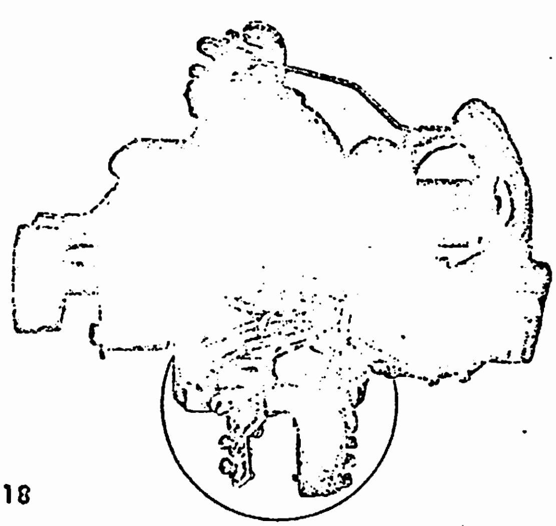
TEMPERATURE SENSOR: The Temperature Sensor, see Fig. 19, located on the primary Throttle Body and exposed to the incoming air, changes the fuel flow to compensate for air temperature changes. A decrease in the temperature requires a greater quantity of fuel and an increase requires less fuel for the proper air/fuel ratio. When a change of temperature takes place, the Temperature Sensor changes the resistance to the Modulator to increase or decrease the pulse duration and thereby change the fuel charge.



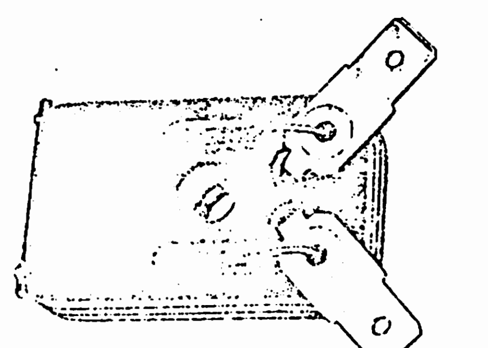
16 ENGINE WARM UP



17 NORMAL OPERATING TEMPERATURE



18



19

GLOSSARY OF ELECTROJECTOR TERMS

FUEL SUPPLY SYSTEM

Fuel Manifold — Distributes the fuel from the pressure regulator-filter to the injectors.

Fuel Pump — Delivers the fuel from the supply tank to the fuel line at approximately 29 (P. S. I.)

Injector — An electrically operated valve which opens and closes to discharge the fuel into the intake manifold. There is one injector for each cylinder.

Pressure Regulator-Filter — Maintains a constant pressure of 20 pounds-plus or minus one-half pound per square inch (PSI) — to the injector valves. It also filters the fuel to the injector valves.

INJECTOR CONTROL SYSTEM

Altitude Compensator — Modifies the pulse duration in accordance with the requirements for altitude conditions. (Located in the modulator)

Base Pulse Duration — The duration of the electrical pulse established by the modulator.

Breaker Contact Points — Break the circuit delivering the electrical current to the modulator.

Cold Start Pulse — A triple pulse which takes place during the cranking period of cold starts.

Increased Pulse Duration — The additional pulse which is created by the modulator upon receipt of a signal from the sensors.

Millisecond — One one-thousandth (1/1000) of a second. The period of injection is measured in milliseconds.

Modulator — Receives a signal from the triggering selector and initiates an electrical current that is modulated by the sensors. It sends an output current to the Triggering Selector for delivery to the injectors.

Pulse Duration — The unit of time which an injector is energized by the electrical current from the modulator.

Resistance Box — Contains resistance units for the modulator.

Rotor — A plastic disc in the triggering selector unit with electrical contact surfaces for transmitting the electrical current to the injectors.

Timing — The regulation of the transmittal of the electrical current from the Triggering Selector to the Modulator.

Triggering Selector — Performs a two-fold function: a) the triggering portion controls the time to "trigger" or send an input electrical current to the modulator. b) the distributing portion receives the output current from the modulator and transmits it to the correct injector.

Triggering Selector Cap — Completes the circuit between the triggering selector and the injectors. In conjunction with the rotor, it delivers the electrical current to the proper injector.

SENSOR SYSTEM

Acceleration Sensor — Momentarily increases the pulse duration for acceleration. It is controlled by manifold vacuum.

Cold-Start and Warm-Up Sensor — Increases the pulse duration for cold starts. It is controlled by a solenoid and a thermostat. It also modifies the pulse duration during the warm up period and controls the fast idle cam.

De-Loader — Provides a manual means to re-position the cold start sensor to reduce pulse duration when throttle is in full open position during the cranking period. This is used in case engine becomes loaded while cranking.

Idle Adjustment Sensor — Provides manual adjustment of the pulse duration for correct air/fuel mixture at idle speed.

Manifold Vacuum Sensor — Modifies the pulse duration in accordance with engine manifold vacuum.

Potentiometer — A device for dividing voltage.

Primary Throttle Valve Body — One unit in a compound installation having 2 throttle valve bodies. It controls air flow to the intake manifold and also carries the sensors.

Rheostat — A device for altering the resistance in a circuit.

Secondary Throttle Valve Body — One unit in a compound installation having 2 throttle valve bodies. It controls air flow but does not carry any sensors.

Sensor Circuit — A group of two or more sensors wired together; however, each sensor independently modulates the pulse duration.

Temperature Sensor — A resistor, sensitive to temperature changes. It modifies the pulse duration in accordance with temperature of inlet air in primary throttle valve body.

FUEL INJECTION

GENERAL

A completely new fuel injection system, an adaptation of the Bendix "Electrojector," has been made available as an extra-cost feature on the Chrysler 300 D for 1958. It is a new approach to solving the ever-present problem of fuel delivery and has resulted in providing a number of advantages that heretofore have proved elusive, or are expensive to build into a carburetor.

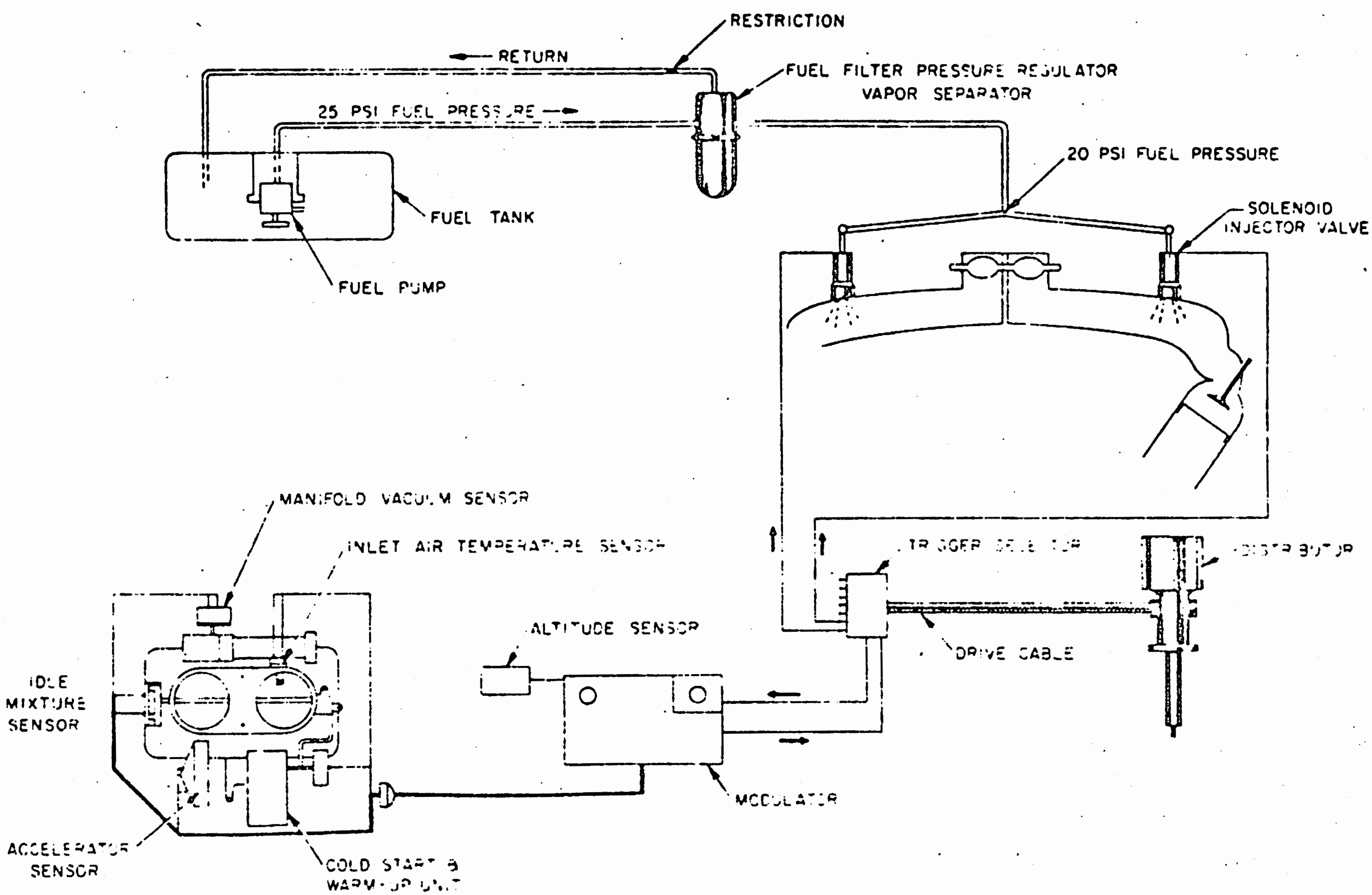
In fuel injection, taking fuel directly into the engine at the intake ports promotes improved cold starting and quicker warm-up. By this means, fuel travels through very short open passages and is not subject to the condensing effect of the entire length of the cold intake manifold. Therefore, the proper fuel-air mixture ratios can be more easily maintained, resulting in a gain in performance during this period.

Damp-weather stalling during engine warm-up as a result of throttle blade icing is another problem that has been eliminated by the adoption of fuel injection. Since the fuel is not introduced above the throttle blades, where it must pass by the blades and through a venturi with its inherent refrigerating effect (due to the pressure drop and consequent rapid fuel vaporization), the temperature of the throttle blades does not fall low enough to cause air-borne moisture to freeze on the blades and restrict the flow of air.

"Faulting" during cornering and rapid acceleration or braking is another hard-to-correct idiosyncrasy of carbureted engines which is eliminated by using fuel injection. Since fuel bowls are not required, fuel injection is not subject to the interruptions in fuel flow which affect carburetors under some driving conditions. Due to a tendency for the fuel to "pile up" on one side or the other of the bowls, in some instances it may actually uncover the carburetor main metering passages, but more often merely spills into the manifold resulting in an over enrichment of the fuel-air mixture. With fuel injection, an uninterrupted supply of fuel guarantees a smooth flow of power whatever maneuvers are undertaken by the car.

DESCRIPTION

The new fuel injection system is unique in that it is electrically operated, with electronic control of the quantity of fuel that is metered into the engine. In general, it is a system wherein fuel is supplied at



INJECTION TIMING AND INJECTOR ACTUATING ELEMENTS constant pressure and metered into the cylinders by electrically-operated injector valves. The length of time that each valve remains open to admit fuel is controlled by an electrical pulse whose length is adjusted electronically to give optimum engine performance.

Air to be combined with the metered fuel is provided through two throttle bodies. The primary throttle only is used initially to give a "softer" pedal and better low-speed control for most city driving; the secondary throttle is used only during fast acceleration. The secondary throttle is so linked that its blades begin to open after the primary throttle blades have opened 30 degrees and both reach full-open at the same time.

The functions performed by the new fuel injection system separate naturally into three main groupings: the Fuel Supply System to furnish fuel at constant pressure, the Injector Control System to control the metering of the fuel, and the Sensor System to regulate the Injector Control System so that the quantity of fuel metered will give the best performance for the atmospheric and engine operation conditions that exist at the time.

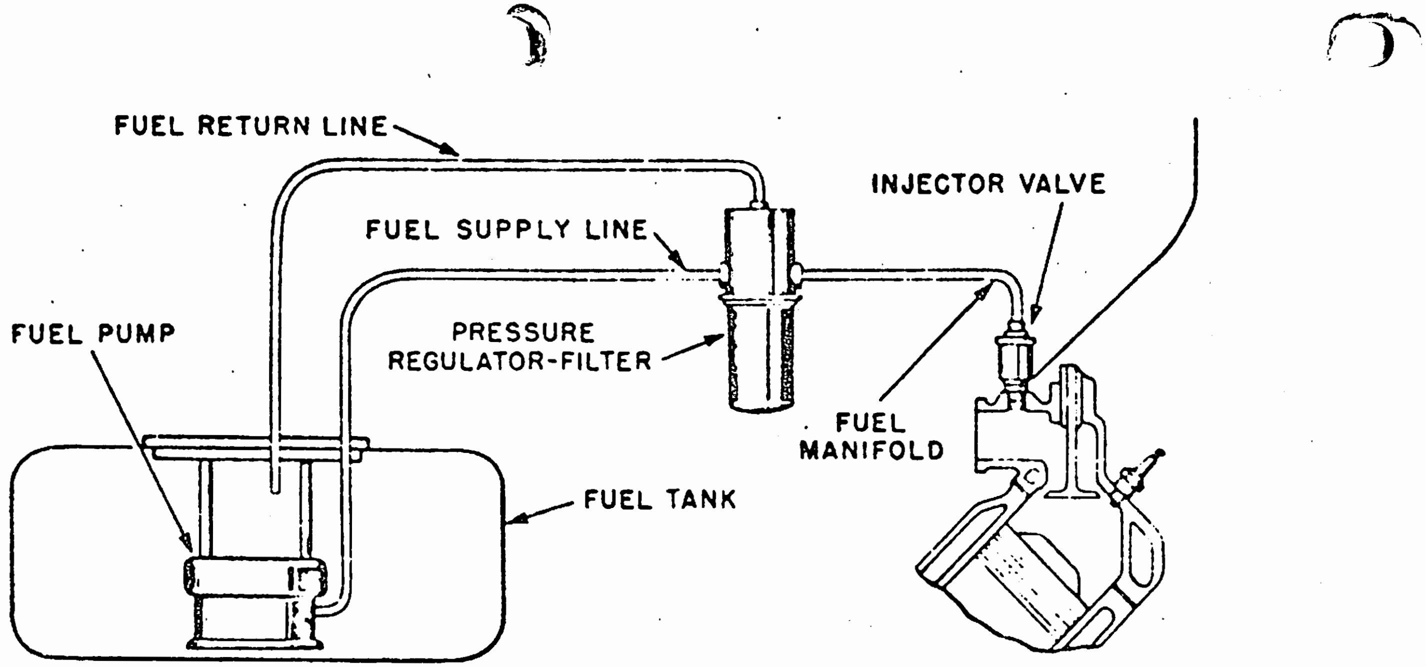
FUEL SUPPLY SYSTEM

The fuel supply system has the very important function of providing fuel at constant pressure to each injector valve. Not only must the fuel flow be continuous--that is, free from vapor, air, and dirt--but it must be delivered at a very closely controlled constant pressure in order to give predictable engine performance, and the pressure must be high enough to ensure an adequate supply of fuel for all operating speeds.

To accomplish these tasks, the fuel supply system has been equipped with a fuel pump that is completely submerged in the tank, a pressure regulator-filter to remove air and vapor and to regulate fuel into a manifold at constant pressure, a manifold to distribute to each injector, and an injector at each cylinder to meter a controlled quantity of fuel into the engine.

Fuel Pump

New for passenger cars, an electric-motor-driven fuel pump submerged in the gas tank has been adopted for use with fuel injection. It is a thin-vane, positive displacement pump which delivers fuel to the pressure regulator-filter at a pressure of from 25 to 33 psi.



FUEL SUPPLY SYSTEM

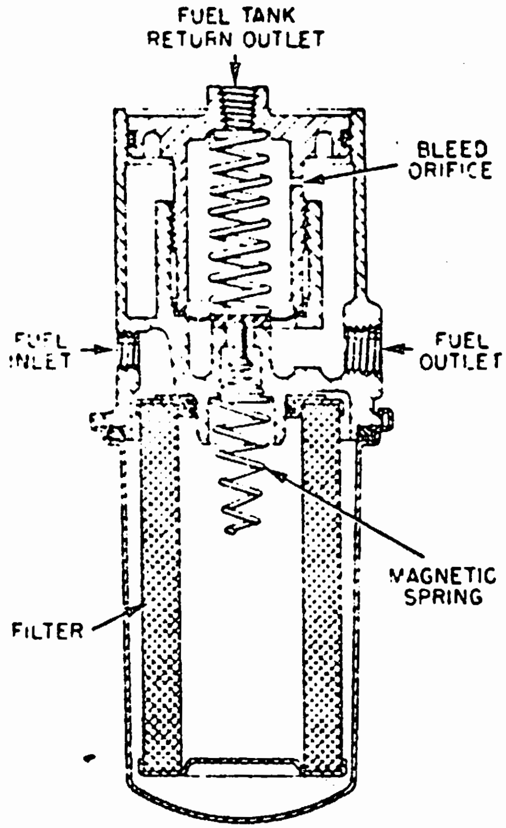
(61)

Since this new pump "pushes" fuel from the tank to the engine, the fuel lines are always pressurized, maintaining a higher boiling point of the fuel and thus reducing the formation of vapors. And, since the pump is submerged, it is not likely that air will be drawn into the lines.

The circuit for the fuel pump motor incorporates a safety precaution against flooding should the engine stall or the ignition key be turned on with the engine not operating. The fuel pump motor will begin to operate only when the car is being started. Once the engine is running, current to the pump motor is maintained via the ignition circuit by the closing of a pressure switch in the main engine oil gallery when the oil pressure has built up. And, as long as the engine continues to operate, the pump will deliver fuel to the system. However, should the engine stall, the drop in oil pressure will release the switch and stop the pump from operating.

Pressure Regulator-Filter

A pressure regulator-filter located in the engine compartment, a part of the fuel supply system, has three



PRESSURE REGULATOR-FILTER

important functions. It must filter from the fuel received from the pump any particles that could affect the rate of flow in any way; it must eliminate any air and fuel vapor that might collect; and it must dispense the fuel at a very closely controlled pressure of 20 psi. In order to maintain proper engine performance at all operating speeds with fuel injection, fuel pressure must be controlled very accurately, for any unforeseen changes in the pressure will cause considerable variation in the power output of the engine.

Fuel from the pump first passes through an extremely fine micronic filter which takes out any particles greater than 5 microns in diameter (a micron is one millionth of a meter), then past a magnetized wire spring to attract any minute metal particles which the filter could not stop. This fine filtering is necessary to prevent a build-up in the injector valve or orifices which might change the rate of fuel flow. The valves are solenoid-operated and their magnetic fields could attract unfiltered magnetic particles to the valve surfaces.

As the fuel flows through the pressure regulator-filter, the fuel pump pressure acts against a diaphram. Any pressure in excess of 20 psi overcomes a regulator valve spring and pulls the valve towards its seat to limit the flow, thus maintaining an outlet pressure of 20 psi. The diaphram area is quite large in relation to the area of the regulator valve, thereby assuring very accurate control of the outlet pressure--not more than plus or minus one-half pound.

Before the fuel exits from the pressure regulator-filter, it passes through a chamber where any vapors or air are trapped at the top and bled into a fuel tank return line. In this manner, only "solid" fuel is dispensed to the injector valves.

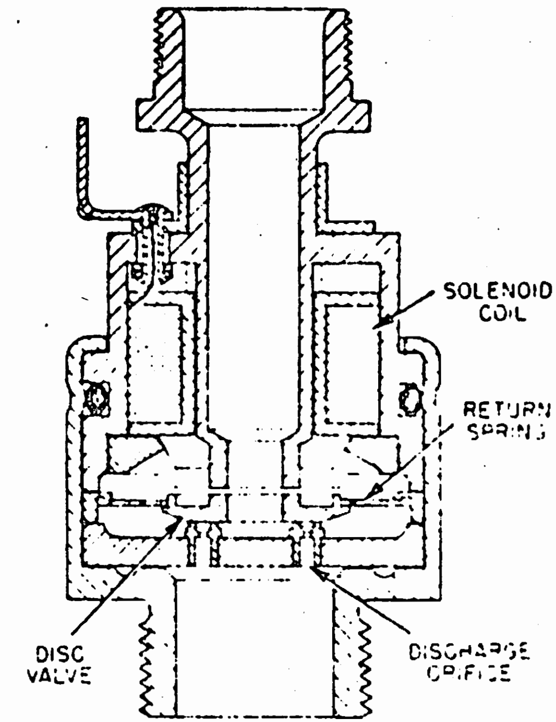
Fuel Manifold

From the pressure regulator-filter, the pressurized fuel is piped to the injector valves by a manifold system. The manifold consists of two "runner" tubes, one for each bank of four cylinders, from which short "feeder" tubes connect to each injector valve. The runners are interconnected by flexible hoses fore and aft. The entire system has been designed to take advantage of the dynamics of pulsations resulting from the extremely rapid opening and closing of the injector valves. Consequently, the selection of the proper manifold line diameters and the placing of flexible interconnectors play an important part in getting optimum engine performance, since space limitations bar the use of a very large manifold which would achieve the same result.

(21)

Injectors

The injector has the job of metering a calibrated quantity of fuel into the intake manifold at the intake port. This is done by opening the injector valve for a specific length of time as determined by an injector control system.



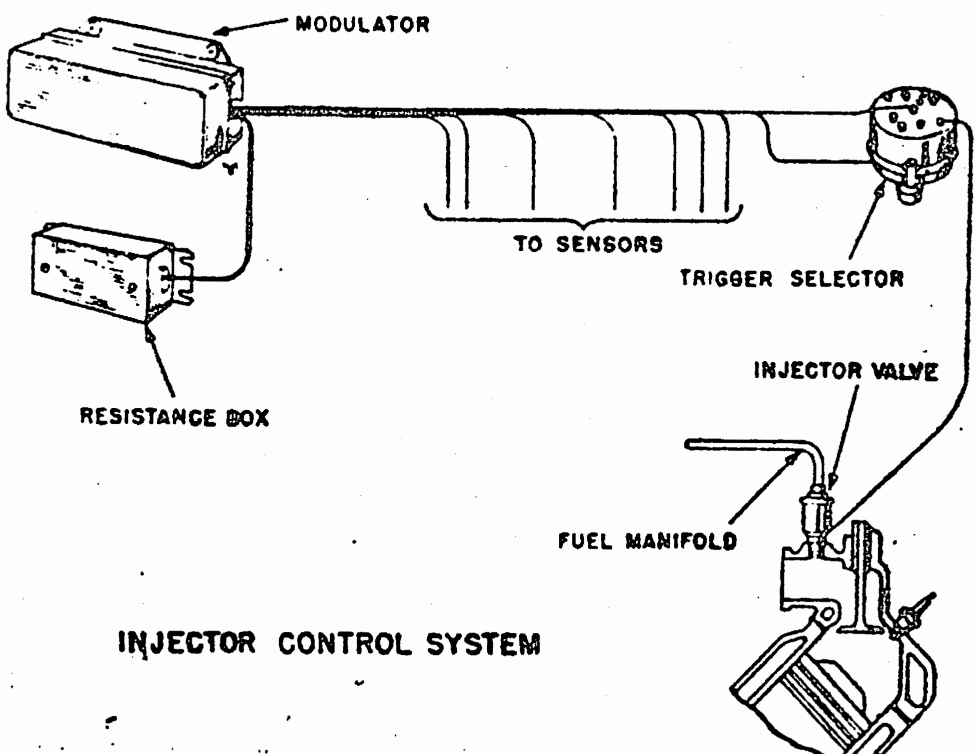
INJECTOR VALVE

Each injector valve is solenoid-operated and is activated by an electrical pulse received from the injector control system. As a valve disc is pulled away from its seat electromagnetically, six small orifices are opened to the pressurized fuel. As soon as the electrical pulse has been cut-off, a very high rate flat spring returns the valve disc to its seat, shutting off the flow of fuel. This is an extremely rapid operation, the valve being designed to stay open from 1.0 to 4.3 milliseconds (thousandths of a second).

(22)

INJECTOR CONTROL SYSTEM

The injector control system has the function of so regulating the amount of fuel metered into each cylinder that the engine gives its desired performance under the existing conditions. This is accomplished by distributing to each injector an electrical pulse that is timed by a trigger selector to coincide with each engine intake stroke, and its duration controlled electronically by a modulator and a system of sensors.



INJECTOR CONTROL SYSTEM

Trigger Selector

The trigger selector has a dual function as part of the injector control system; first, it triggers the modulator into operation and, second, it receives an electrical pulse from the modulator and distributes it to the proper injector.

The triggering action is quite similar to the action of the ignition distributor, and the trigger-selector is driven at the same speed as the distributor by a flexible cable from the distributor shaft. A four-lobe cam operates two sets of breaker points so that, alternately, one of two modulator channels is triggered. A measured electrical pulse returned from the modulator then is distributed via a segmented commutator to the proper injector.

Modulator

The modulator, which is located in front of the radiator, electronically develops pulses of current whose duration is calibrated according to the existing atmospheric and engine operating conditions. Each pulse then actuates an injector valve, holding it open for the duration of the pulse to provide the correct amount of fuel for the desired engine performance.

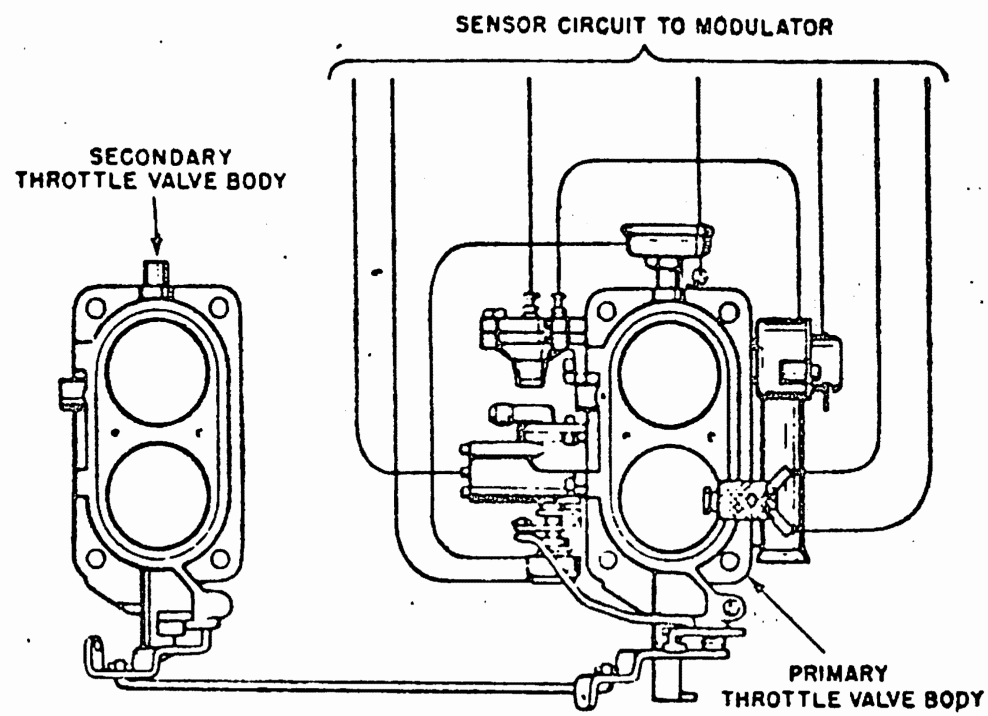
There are two complete electronic channels in the modulator, each of which develops calibrated electrical pulses to regulate the fuel supply to separate sets of four cylinders. As either channel is triggered, a pulse of current whose duration is determined by the combination of the modulator and sensor circuitry, is returned to the trigger selector to be distributed to the proper injector.

SENSOR SYSTEM

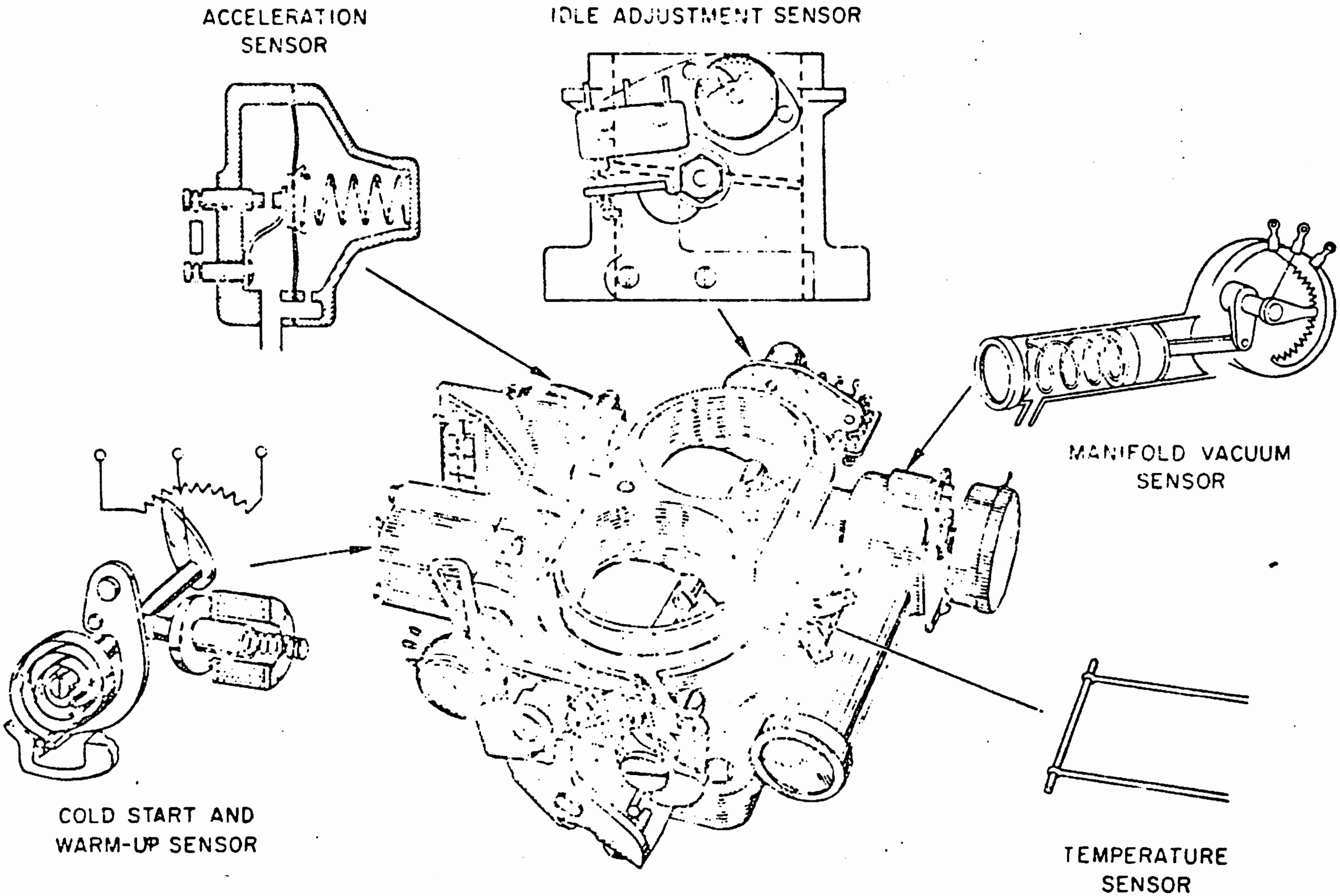
The basic sensor for fuel injection is the trigger selector whose rotation is directly tied to engine speed. It dictates how often the injector valves open, hence the quantity of fuel delivered. All other sensors merely modify this basic rate of fuel delivery. These other sensors consist of resistance units, each of which is affected by one of the various atmospheric or engine operation conditions, and whose values are combined into the modulator electronic circuits to control the duration of each electrical pulse developed.

Altitude Compensator

The altitude compensator is located in the modulator and is a sensor that adjusts part of the modulator electronic circuit to vary the length of the electrical pulse to give correct fuel-air mixtures at different altitudes. It is a bellows type aneroid barometer that regulates a rheostat in response to changes in air pressure.



SENSOR SYSTEM



PRIMARY THROTTLE BODY AND SENSORS

(25)

Temperature Sensor

The temperature sensor is located on the primary throttle body and is exposed to intake air. It is composed of a thermister which changes its resistance radically in an inverse direction as the temperature varies; that is, the resistance of the thermister decreases as the temperature increases. (This is unique in that the resistance of most metals increases as their temperature rises.) This adjustment of resistance, in conjunction with that of the altitude sensor, helps to determine the duration of the electrical pulse.

Manifold Vacuum Sensor

The manifold vacuum (load) sensor has the primary function of adjusting the amount of fuel delivered so that it corresponds to the throttle position or to the load against which the engine is pulling. It is located on the primary throttle body and consists of a potentiometer--a variable resistance placed in a circuit to control voltage--whose "tap" (moveable arm) is linked to a spring-loaded piston, one side of which is open to manifold vacuum.

As the engine load decreases, such as after a car has reached the top of a hill, the manifold vacuum increases and pulls the piston against its spring. This movement of the piston rotates the tap of the potentiometer, reducing its resistance to decrease the voltage in the modulator circuit. The result, then, is a shorter electrical pulse with a consequent decrease in the amount of fuel delivered to the engine.

As the load on the engine increases, manifold vacuum decreases and permits the spring to move the piston in the opposite direction. Resistance in the circuit therefore is increased, resulting in additional fuel metered into the engine to handle the increased engine load.

Acceleration Sensor

The acceleration sensor is located on the primary throttle body and its circuit is in series with that of the manifold vacuum sensor. It is the means by which an extra supply of fuel is provided to take care of a sudden demand of the kind that occurs when the car is accelerated.

This sensor is a vacuum-operated switch which normally is closed. When the manifold vacuum drops suddenly (car being accelerated) the pressure on one side of a diaphram rises, so that the diaphram moves, opening the switch. This action immediately adds a fixed resistance to the resistance of the potentiometer in the manifold vacuum sensor, resulting in a voltage increase in the modulator circuit. This makes the duration of the electrical pulse longer to provide an enriched fuel-air mixture to meet the suddenly increased engine requirements. A bleed hole in the diaphram allows the pressures on both sides to equalize so that a spring can return the diaphram rapidly to its initial position, closing the switch and taking the added resistance out of the circuit.

Idle Sensor

The idle sensor is located on the primary throttle body with its circuit also in series with the manifold vacuum sensor. It consists of a manually-adjusted resistance which is added to the circuit when the throttle blades are in the idle position. In this instance, the resistance is located in the circuit differently so that it reduces instead of increasing the voltage of the modulator circuit, thereby shortening the electrical pulse and reducing the amount of fuel metered during idle.

Cold-Start and Warm-Up Sensor

The cold-start and warm-up sensor, as its name implies, adjusts the duration of the electrical pulse to provide the necessary fuel enrichment during cold starting and during warm-up to normal engine operating temperatures. It consists of a thermostatic coil at the primary throttle body which positions a rheostat according to the engine temperature, and a solenoid-operated plunger which is linked to turn the thermostatic coil an additional amount when the solenoid is energized during starting.

The thermostatic coil is so located as to assume the temperature of the engine and adjust itself, and the rheostat, accordingly.

As the car is started, a circuit to the solenoid is completed, causing the plunger linkage to contact an "ear" on the thermostatic coil and rotate it further than its position as determined by engine temperature. The added resistance to the modulator circuit increases the duration of the electrical pulse, resulting in the fuel enrichment necessary for starting.

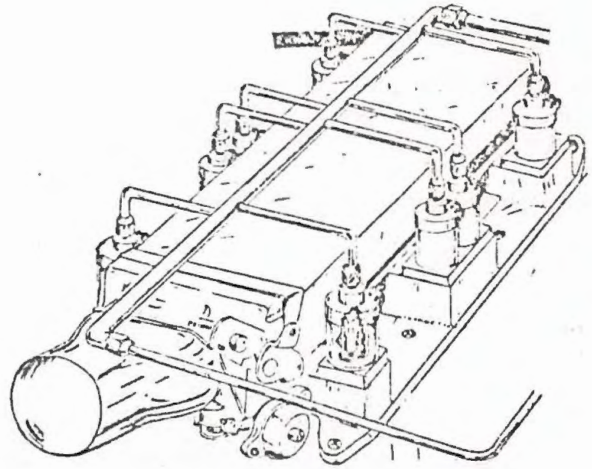
After the engine has started and the starting motor has been disengaged, the solenoid becomes de-energized and the plunger releases the thermostatic coil to return to its initial position. The thermostatic coil then is heated gradually by fresh air piped through the exhaust manifold, causing it to turn the rheostat and decrease the resistance in the modulator circuit. This decreases the duration of the electrical pulse progressively during the warm-up period, so that the fuel flow decreases until the fuel-air mixture for normal engine operating temperatures is reached.

To avoid flooding should the engine fail to start immediately, or to clear it out in case of flooding, the accelerator pedal can be depressed fully, closing two micro switches. During cranking this completes a circuit to the modulator which reduces the pulse length to a point where the injector valves will not open to deliver fuel. Raising the accelerator slightly permits the micro switches to open, cancelling this special circuit so that the injectors will function normally.

(27)

THE

Bendix Electrojector



Bendix AVIATION CORPORATION ELMIRA, N. Y.

ECLIPSE MACHINE DIVISION

Bendix Electrojector

QUESTIONS AND ANSWERS

QUESTION: What is the Electrojector?

ANSWER: It is a revolutionary new method of fuel injection for internal combustion engines. It is new because it is electronically controlled and electrically actuated. It provides timed intake port injection through a low pressure, common rail system, responsive to intake manifold pressure, and other engine requirement signals.

QUESTION: How is the Electrojector electronically controlled?

ANSWER: Engine requirement signals are electrically transmitted to an Electronic Modulator. It combines them with timing signals from a Distributor-Breaker Unit, and transmits measured pulses to an amplifier, which then sends stronger pulses through the Distributor-Breaker Unit to the individual solenoid injector nozzles. The time duration of the nozzle opening is controlled by these pulses, regulating the amount of fuel delivered at each power stroke of the engine.

QUESTION: Does the Electrojector require a metering type high pressure pump?

ANSWER: No. The low pressure system uses a motor driven electrical pump, maintaining 20 lbs. per square inch pressure.

QUESTION: What does the term "common rail" mean?

ANSWER: A common rail system is a fuel system to which all injectors are directly connected. It is a single closed circuit line running from the tank through a filter to all injectors, and back to the tank. A restriction in the return line helps to maintain constant fuel pressure.

QUESTION: How is the system timed?

ANSWER: The system is timed by electrical triggering originating in the D-B Unit assembled in the distributor.

QUESTION: Are these the same units used for ignition timing?

ANSWER: No. The standard distributor cap and rotor are removed. The Distributor-Breaker Unit, (D-B Unit), consisting of a separate set of breaker points, and a distributing commutator, is mounted on the base of the regular distributor, as well as a separate rotor. Then the standard rotor and cap are replaced, and the distributor contains two sets of timing components. The height of the distributor is increased about one inch.

QUESTION: What is required of a fuel injection system?

ANSWER: Any fuel system, whether carburetor or fuel injection, must meet certain engine requirements. They are:

1. Optimum air to fuel ratio under varying loads and speeds.
2. Starting enrichment tapering off during warm-up.
3. Idling enrichment to compensate for exhaust gas dilution.
4. Load enrichment for full power at full throttle.
5. Acceleration enrichment to avoid momentary lean-out.
6. Fast idle during warm-up.

QUESTION: How does the Electrojector meter or measure the fuel?

ANSWER: Fuel metering is primarily controlled by intake manifold pressure, or vacuum. This includes necessary enrichment for full throttle or full load operation.

QUESTION: Does the Electrojector use a conventional choke as used on carburetors?

ANSWER: No. Starting and warm-up enrichment demand is signaled by an electronic sensor which measures engine temperature. Fast idle during warm-up is provided by a conventional fast idle cam and thermostat, as used with carburetors.

QUESTION: What is necessary for idling?

ANSWER: An electric switch, actuated by throttle position, signals for idle range enrichment.

QUESTION: What about acceleration?

ANSWER: Acceleration enrichment demand is signaled by a throttle actuated mechanism or by a rapid change in manifold pressure. The duration of acceleration enrichment is determined by the Electronic Modulator in accordance with engine requirements.

QUESTION: Does the Electrojector supply any other requirements?

ANSWER: Yes. In addition to meeting all the requirements listed, highly desirable cut-off during deceleration and automatic altitude compensation are provided by the Electrojector.

QUESTION: How is cut-off during deceleration accomplished?

ANSWER: When the piston in the manifold pressure sensing device reaches the extreme position during deceleration, fuel is automatically cut off. This prevents smog, which is a considerable problem in many cities.

QUESTION: What is automatic altitude compensation and how is it effected?

ANSWER: Automatic altitude compensation is desirable because of thinner air at higher altitudes. A Bendix device, called an aneroid, is used in weather balloons to measure atmospheric pressure, which is a measure of altitude. A signal from this device to the Electronic Modulator maintains a constant air to fuel ratio, regardless of altitude. Without this compensation, serious enrichment results, affecting performance and economy.

QUESTION: Are other automatic compensations possible with the Electrojector?

ANSWER: Yes. Compensation for ambient air temperature can be had by using an electronic sensor in the throttle body opening or other available location. This is optional at the discretion of the vehicle manufacturer.

QUESTION: What are the components of the complete system?

ANSWER: They are:

1. A throttle body, similar to a carburetor throttle body. The throttle body contains most of the sensing units.
2. The Distributor-Breaker Unit.
3. The Electronic Modulator.
4. A Solenoid Injector Nozzle for each cylinder.
5. Electronic sensors for sensing of engine and intake air temperatures.
6. The Altitude Compensator.

In addition, separate Bendix divisions offer the following items, which are optional:

7. A motor driven non-metering electrical pump, offered by Eclipse Machine Division, Elmira, New York.
8. Conventional fuel and air filters, offered by Skinner Division, Detroit, Michigan.
9. A suitable wiring harness, offered by Scintilla Division, Sidney, New York.

QUESTION: Describe the fuel injector nozzle.

(30)

ANSWER: The fuel injector consists of a solenoid coil in a case. The core of the coil contains a valve on a plunger, backed up by a spring, which keeps the valve on the seat until the solenoid pulls it open, upon the signal from the Electronic Modulator. The nozzle orifice is large enough to eliminate dirt problems encountered in other fuel injection systems.

QUESTION: Describe the throttle body.

ANSWER: It is a casting similar to a carburetor throttle body. It contains the familiar carburetor butterfly valve on a throttle shaft. Installed in the throttle body are the Fast Idle Cam and Thermostat, the Acceleration Enrichment Control, the Intake Manifold Pressure Sensor and Deceleration Cut-Off, and the Idle Range Enrichment Control.

QUESTION: How does the Intake Manifold Pressure Sensor operate?

ANSWER: The Intake Manifold Pressure Sensor consists of a piston in a tube, with a calibrated spring pushing against it. It has an opening to manifold pressure at one end, and an opening to atmosphere at the other end of the tube. Variations in the comparison between intake manifold pressure and atmosphere cause the piston to move one way or the other in the tube. This action varies the resistance of a potentiometer, and sends a signal to the Electronic Modulator.

QUESTION: How does the Electronic Modulator interpret all these signals coming to it, and develop a signal which will accurately reflect engine requirements?

ANSWER: The Electronic Modulator contains a multi-vibrator circuit, and an amplifier. All the sensing signals, and the timing signal are combined in the multi-vibrator circuit to develop a pulse signal which will open the injectors the precise amount of time required to deliver the exact amount of fuel required by engine conditions at that instant. The amplifier raises the outgoing signal to a current sufficient to operate the solenoid valve in the injector. The entire action is instantaneous.

QUESTION: How do all these things happen so fast?

ANSWER: Electricity acts with the speed of light, 186,000 miles per second, and the Electrojector is electronic. Precise synchronism of delivery of metered fuel with engine demands provides the maximum of performance, power and economy. The Electrojector eliminates mechanical and hydraulic lag, providing the ultimate in engine response.

QUESTION: Does the Electrojector, like some other electronic devices, require a warm-up period?

ANSWER: Transistors, unlike vacuum tubes, which require warm-up time, have no filament, and require no warm-up. Transistors have almost unlimited life expectancy, and make extremely small current demands.

QUESTION: Is horsepower improved by the Electrojector?

ANSWER: Yes. Tests indicate an increase of about 10% in horsepower. Improvements in manifold design will extend this gain. But more important than horsepower increase is the improvement in torque characteristics. A typical engine reaches peak torque at 2400 RPM or about 50 MPH with a four-barrel carburetor. The same torque is atttained at 1200 RPM, or about 25 MPH with Electrojector, and an overall increase in peak torque at all speeds is provided. Getaway and maneuverability are improved, adding to safety in traffic, as well as better over-all response to driver demands.

QUESTION: Is road economy improved?

ANSWER: Yes. The uniform cylinder-to-cylinder mixture provided by the Electrojector allows leaner mixtures. There is no need to over-supply nearby cylinders to avoid starving more distant cylinders, as with carburetion. Tank economy is greatly improved, especially during cold weather, because of rapid engine warm-up. Carburetor systems, in cold weather, run rich for as much as ten miles of operation, and seldom reach full lean position within four or five miles. Electrojector reaches full lean position within one mile.

QUESTION: What are the principal advantages of fuel injection compared to carburetion?

ANSWER: They are:

1. Increased Power.
2. Higher torque, with peak torque reached at 300-500 lower RPM.
3. Improved fuel economy results from uniform distribution of fuel.
4. Quicker Cold Starting and Warm-Up.
5. Wider Latitude in Fuels.
6. More Room Under the Hood.
7. Faster, Livelier Response to the Throttle.
8. Lower Body Silhouette Possible.
9. Gas Velocity at Low Speeds is maintained by Higher Volumetric Efficiency.
10. No "Cold Muffler" on Dual Exhaust Systems.
11. No Need for Manifold Heat.
12. Lower Intake Temperature allows higher compression and earlier spark without detonation.
13. No throttle valve icing.
14. No cornering or hill angle effects.
15. Better All-Round Performance.

QUESTION: What are the advantages of the Electrojector compared to other fuel injection systems?

ANSWER:

Lower Cost.

Fewer Moving Parts.

No Special Pump Drive from the Engine is Required.

No Critical Filtering Required.

No Surge or Inertia Effects, as in a pulsating high pressure line.

No Vapor Lock

Easier Adaptation and Assembly Line Installation.

Quieter Operation.

Low Electrical Requirements.

No Ultra-Precision "Millionth-of-an-Inch" machining required.

Plus another important feature:

The Electrojector system is self-priming and requires no bleeding. This is in contrast to pressure pump systems, which often are completely upset by the presence of air or vapor in the lines.

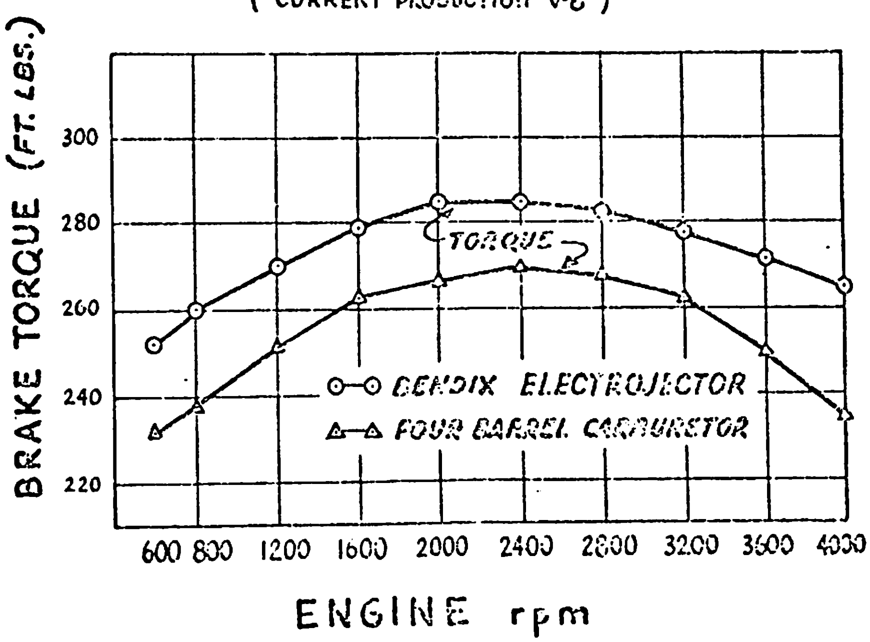
QUESTION: Is the Electrojector system now available?

ANSWER: Product designs, laboratory tests, and road tests have reached the stage where the next step is adapting the system to individual engine requirements. Vehicle manufacturers are now testing the system in their laboratories and proving grounds. Announcements by vehicle manufacturers will provide the best indication of availability of the Electrojector system.

QUESTION: Does the Electrojector have application possibilities other than for passenger cars?

ANSWER: Certainly. Already inquiries are flooding in from manufacturers of trucks and busses, light aircraft, marine and stationary engines, and others. The list of advantages will apply with greater impact when the economic gains provided by Electrojector are measured in commercial applications. The more miles a vehicle is driven, the greater the saving. In addition, road time will be decreased because vehicles will be more maneuverable, get away faster, and will be able to take grades faster. All of these advantages point to almost universal application possibilities.

TYPICAL TEST RESULTS
(CURRENT PRODUCTION V-8)



SERVICING THE BENDIX ELECTROJECTOR

For the operation of an internal combustion engine, it is necessary to supply fuel and air, in the proper proportions, to match the requirements of the engine during the various stages of operation. This basic requirement is necessary, if either carburetion or fuel injection is used for metering the fuel into the engine.

In addition to the proper metering of fuel, it is also essential that the ignition system be maintained in good operating condition and that all components, which are adjustable, such as: ignition timing, distributor point setting, spark plug gap, etc., are set in accordance with factory specifications.

The Service Analysis of the Electrojector, covered in the following pages, has been developed on the basis that all components of the ignition system are in proper working condition. This should be definitely established before any attempt is made to service the components of the Electrojector System.

THE BATTERY OF THE VEHICLE SHOULD HAVE AN OUTPUT VOLTAGE OF 12.5 VOLTS MINIMUM WITHOUT LOAD. The voltage should be checked with a battery test meter. Good cables with clean, tight connections should be assured at all times.

ELECTROJECTOR

SERVICE MANUAL NUMBER 2

(FOURTH REVISION)

(34)

This manual is designed to provide the Serviceman with Service Analysis and Test Procedure information on the Electrojector System.

The copy has been simplified by the use of a standard page format with columns under these headings:

CONDITION

REASON

CAUSE

DETERMINED BY

CORRECTION

To use the manual, follow this procedure: 1) determine the malfunction of the engine such as "Failure To Start - Engine Cranks But Does Not Fire" 2) find this situation in the column headed "Condition" 3) read across the page for service information to correct the malfunction.

Bendix ELECTROJECTOR SERVICE ANALYSIS

NOTE: Before starting a Service Analysis on the Electrojector, make certain that all other components of the engine are in proper operating condition. The battery should have a minimum of 12.5 volts.

CONDITION	REASON	CAUSE	DETERMINED BY	CORRECTION
		FUEL SUPPLY SYSTEM		
Failure to start - engine cranks but does not fire.	No fuel being delivered to injector valves.	1. Fuel pump inoperative.	1. Operate starting motor and listen for sound of pump operating.	
		a. Blown fuse	a. Visual inspection	a. Replace fuse
		b. Defective wiring or loose connections.	b. Visual inspection and ohmmeter check.	b. Tighten connections or replace wiring.
		c. Defective fuel pump or clogged inlet screen.	c. Energize circuit and check with voltmeter. (Test Proedure No. 1)	c. Service or replace fuel pump if necessary.
		2. Restriction in delivery of fuel.		
		a. Clogged filter element	a. Visual inspection	a. Clean or replace element.
		b. Defective pressure regulating valve.	b. Install pressure guage at output connection or port. (Test Procedure No. 1)	b. Replace pressure regulator-filter assembly.
		3. Empty or low tank level.		
		INJECTOR CONTROL SYSTEM		
	Injector valves not operating.	1. Injector control system inoperative.	1. Energize cranking circuit and listen for "clicking" of injector valves. (Test Procedure No. 3.)	

CONDITION	REASON	CAUSE	DETERMINED BY	CORRECTION
Continued)		a. Blown fuse to modulator.	a. Visual inspection.	a. Replace fuse, if necessary.
		b. Loose connections in electrical system.	b. Visual inspection and ohmmeter check of wiring and connections (Test Procedure No. 2)	b. Insure tight connections. Replace defective wiring if necessary.
		2. Defect in triggering selector unit.		
		a. Flexible drive shaft defective.	a. Ohmmeter test of breaker point operation.	a. Replace drive shaft if necessary.
		b. Breaker contact points inoperative	b. Ohmeter test at trigger connections.	b. Adjust points or replace triggering selector unit if necessary.
		c. Loose connections.	c. Visual inspection or ohmmeter check.	c. Insure tight connections.
		d. Restricted movement, or damaged brushes.	d. Visual inspection and voltmeter test at output connections.	d. Insure free movement of brushes or replace unit if necessary.
		e. Damaged cap or rotor.	e. Visual inspection. Refer to Test Procedure No. 4 for all checks.	e. Replace unit if necessary.
		3. Modulator not functioning		
		a. Blown fuse.	a. Visual inspection.	a. Replace fuse.

(36)

(37)

CONDITION	REASON	CAUSE	DETERMINED BY	CORRECTION
(Continued)		b. Defective resistance box.	b. Ohmmeter Test. (Test Procedure No. 6)	b. Replace if necessary.
		c. Defective modulator.	c. Check with new unit. (Test Procedure No. 5)	c. Replace unit if necessary.
		SENSOR SYSTEM		
	Sensor system defective	1. Loose junction plug or connections.	1. Visual inspection.	1. Insure tight connections.
		2. One or more sensors defective.	2. Ohmmeter check at junction plug. (Test Procedure No. 7)	2. Replace throttle valve body if necessary.
		a. Short or open circuit in temperature sensor	a. Ohmmeter check. (Test Procedure No. 12)	a. Replace throttle valve body if necessary.
		b. Defective cold start rheostat.	b. Ohmmeter check (Test Procedure No. 11)	b. Replace throttle valve body if necessary.
Engine starts - fails to run or runs poorly at low speeds but runs at speeds beyond idle range.	Fuel-air mixture excessively rich or lean.	1. Maladjustment of idle sensor rheostat.	1. Heavy "roll" of engine indicates adjustment too rich. Faltering engine indicates adjustment too lean.	1. Adjust idle sensor Replace throttle valve body, if necessary.
		2. Maladjustment of idle switch.	2. Operate throttle and check switch operation (Test Procedure No. 7)	2. Adjust switch.
		3. Cold start sensor stuck in high resistance position. (Cold starting position)	3. Manually checking sensor linkage for free travel and also free rotation of shaft. (Test Procedure No. 11)	3. Clean all external parts to make certain of free operation. Replace throttle valve body, if necessary.

CONDITION	REASON	CAUSE	DETERMINED BY	CORRECTION
2. (Continued)		4. Open circuit to to manifold vacuum sensor.	4. Voltmeter check of manifold vacuum sensor. (Test Procedure No. 8.)	4. Insure tight connections. Replace throttle valve body, if necessary.
		5. Excessive fuel pressure to injector valves.	5. Check output pressure of regulator. (Test Procedure No. 1)	5. Replace regulator, if necessary.
3. Engine runs - in low speed range but operates poorly beyond idle range.	Insufficient fuel flow to the injector valves.	1. Fuel pump not operating properly.		
		a. Defective wiring to fuel pump.	a. Visual inspection or check with ohmmeter	a. Replace wiring, if necessary.
		b. Defective pump or restricted delivery from pump.	b. Check pump output pressure (Test Procedure No. 1.)	b. Service or replace if necessary.
		2. Restriction in delivery of fuel from filter.	2. Install pressure guage in regulator. (Test Procedure No. 1.)	2. Remove any restriction. Clean filter element.
		3. Manifold vacuum sensor maladjusted.	3. Check adjustment of manifold vacuum sensor. (Test Procedure No. 8.)	3. Adjust sensor or replace throttle valve body, if necessary.
		4. Open circuit between manifold vacuum sensor and ground.	4. Voltmeter check. (Test Procedure No. 8)	4. Correct defect or replace throttle valve body if necessary.
4. Lack of Power at High Speeds.	Insufficient fuel to engine.	1. Breaker contact points not properly adjusted, or dirty.	1. Check by feeler gauge.	1. Adjust points. Replace triggering selector, if necessary.

(39)

CONDITION	REASON	CAUSE	DETERMINED BY	CORRECTION
(Continued)		2. Manifold vacuum sensor potentiometer maladjusted.	2. Test operation of manifold vacuum sensor. (Test Procedure No. 8.)	2. Adjust potentiometer. Replace throttle valve body, if necessary.
		3. Restriction in delivery of fuel from filter.	3. Install pressure gauge in regulator and follow Test Procedure No. 1.	3. Remove any restriction to fuel filter. Clean filter element.
		a. Defective pump or restricted delivery.		
		b. Clogged filter element		
		4. Defective temperature sensor.	4. Ohmmeter check (Test Procedure No. 12)	4. If sensor is defective replace throttle valve body.
Poor Acceleration - occasionally backfires through air cleaner on sudden accelerations.	Lack of fuel enrichment during acceleration.	1. Sticking contact points of acceleration sensor, or ruptured diaphragm of acceleration sensor.	1. Test lamp. (Test Procedure No. 9.)	1. Replace throttle valve body, if necessary.
		2. Misadjusted manifold vacuum sensor.	2. Follow Test Procedure No. 8.	2. Readjust sensor. (Test Procedure No. 8)
Loss of fuel economy.	Excessive fuel being delivered to engine.	1. Failure of pressure regulator to control pressure of fuel delivered to injector.	1. Install pressure gauge in regulator (Test Procedure No. 1.)	1. Replace regulator, if necessary.
		2. Leaking injector valves.	2. Observe condition of spark plugs. Remove suspected injector valve and check for leaks. (Test Procedure No. 3.)	2. Replace injector valve, if necessary.

CONDITION	REASON	CAUSE	DETERMINED BY	CORRECTION
(Continued)		3. Lack of manifold stove heat flowing to thermostat.	3. Removing heat tube and checking for clear passage.	3. Remove restriction
		4. Cold start sensor stuck in cold position.	4. Manually checking sensor linkage for free travel and also free rotation of shaft. (Test Procedure No. 11)	4. Clean all external parts to make certain of free operation. Replace throttle valve body, if necessary.
		5. Cold start sensor out-of-adjustment.	5. Manual and ohmmeter check. (Test Procedure No. 11)	5. Readjust. (Test Procedure No. 11)
		6. Manifold vacuum sensor out of adjustment.	6. Voltmeter check. (Test Procedure No. 8)	6. Readjust (Test Procedure No. 8)
		7. Idle adjustment sensor maladjusted.	7. Heavy "roll" of engine.	7. Adjust idle sensor. Replace throttle valve body, if defective.
		8. Maladjusted minimum pulse width control.	8. Pulse width meter.	8. Test Procedure #5.
Poor starting.				
Requires considerable cranking.	Insufficient fuel being delivered during the cranking period.	1. Fuel pump not operating properly (would allow warm engine to start).	1. Check operation of pump with jumper wire or ohmmeter (Test Procedure No. 1)	1. Service pump or replace, if necessary.
		a. Blown fuse.	a. Visual inspection of fuse.	a. Replace fuse, if necessary.
		b. Open circuit in wires to fuel pump.	b. Continuity check with ohmmeter.	b. Restore continuity.

(40)

CONDITION	REASON	CAUSE	DETERMINED BY	CORRECTION
(Continued)		2. Restriction in delivery of fuel from filter.	2. Install pressure guage in regulator. (Test Procedure No. 1.)	2. Remove any restriction. Clean filter element.
		3. Low pressure from regulator.	3. Install fuel pressure guage. (Test Procedure No. 1.)	3. Replace regulator, if necessary.
		4. Cold start phase of cold start and warm up sensor not operating.	4. Manually checking sensor linkage for free travel. (Test Procedure No. 11.)	4. Clean all external parts. Replace throttle valve body, if necessary.
		a. Open circuit or poor connection to cold start solenoid.	a. Visual check on condition of connection. 12 volts should be present during cranking.	a. If no voltage is observed, correct the open circuit.
		b. Defective cold start solenoid.	b. Energize circuit and observe movement of linkage.	b. Replace throttle valve body if necessary.
		5. Modulator		
		a. Triple triggering circuit inoperative due to poor connections.	a. Voltmeter check at center pin of brown modulator connector.	a. Insure good contact. If no voltage is observed, make continuity check of wiring leading to center pin from starting motor relay.
		b. Failure of modulator box.	b. By substitution with good modulator.	b. Use new unit, if trouble is eliminated.

(41)

CONDITION	REASON	CAUSE	DETERMINED BY	CORRECTION
Engine starts and fails.	Insufficient fuel after engine cranking stops.	Defective lubricating oil pressure switch.	Placing jumper wires across terminals of oil pressure switch eliminates false starts.	Replace defective switch.
Poor warm-up performance.	Improper air/fuel ratio during warm-up period.			
	A. Too rich.	a. Heat tube or manifold stove clogged, preventing circulation of warm air.	a. By removing heat tube and making physical check.	a. Remove restriction.
		b. Cold start sensor mechanism not operating freely or stuck in one position.	b. Operating linkage by hand and checking for free movement for entire travel.	b. Clean all affected parts to make certain of free operation.
		c. Air leak at heat tube connection.	c. Physical check.	c. Insure good heat tube connection.
	B. Too lean.	a. Cold start sensor mechanism not moving freely or stuck in one position.	a. Operating linkage by hand and checking for free movement for entire travel.	a. Clean all affected parts to make certain of free operation.
Rough Engine Performance.				
Low Speed (Also refer to condition No. 2)	Excessive fuel being delivered to engine.	1. Leaking injector valve.	1. By process of elimination of injector valves. (Test Procedure No. 3.)	1. Replace faulty injector valve.

(42)

SERVICE ANALYSIS

CONDITION	REASON	CAUSE	DETERMINED BY	CORRECTION
(Continued)		2. Idle sensor maladjusted.	2. Heavy "roll" of engine	2. Adjust sensor for proper air/fuel mixture. (Test Procedure No. 10.)
High Speed (Also refer to conditions No. 3 and 4)	Insufficient fuel being delivered to engine.	1. Triggering selector points maladjusted.	1. Visually examine point condition and check point setting. (Test Procedure No. 4)	1. Adjust points. Replace triggering selector, if necessary.
		2. Clogged fuel filter.	2. Visually check filter element.	2. Clean filter element.
		3. Loss of fuel pump pressure.	3. Install pressure gauge in regulator. (Test Procedure No. 1.)	3. Correct defect or replace fuel pump.
		4. Lean valve.	4. By process of elimination of injector valves. (Test Procedure No. 3.)	4. Replace faulty injector valve.
All Speeds	Engine firing on only 4 cylinders.	1. Loss of one channel of modulator due to:		
		a. Loose connection on channel post of triggering selector cap.	a. Assure tight connections.	a. Restore operation of missing channel.
		b. Failure of triggering selector unit.	b. Ohmmeter check. (Test Procedure No. 4.)	b. Adjust points. Replace triggering selector if defective.
		c. Defective modulator.	c. Test with a good spare unit.	c. Replace modulator, if necessary.

(43)

CONDITION	REASON	CAUSE	DETERMINED BY	CORRECTION
(Continued)	Engine firing on less than 8 cylinders.	1. Loose connection on triggering selector unit or at injector valve connections.	1. Ohmmeter check or by process of elimination of valves.	1. Insure tight connections.
		2. Two or more wires to triggering selector cap interchanged.	2. Visual inspection. (Test Procedure No. 3 and 4)	2. Correct mis-wiring.

(44)