

The spark-ignited engine (Otto Cycle) is a constant air-fuel ratio engine, and although the volume of air inside the cylinders remains constant, the density of air (MAP or Vacuum) varies according to the throttle position.

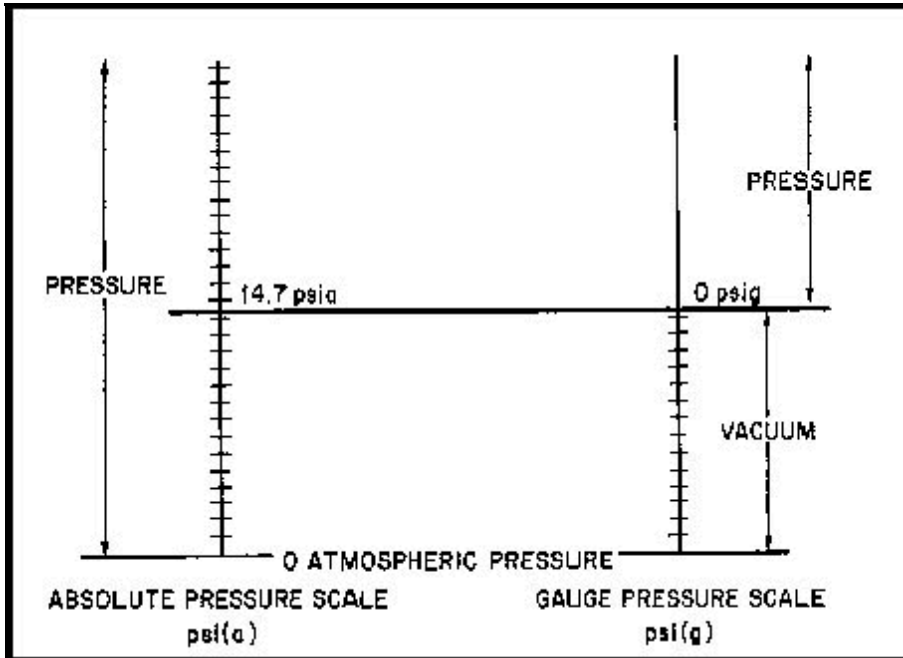


FIG. 5: 1

Absolute Pressure: Absolute Pressure is a pressure using a scale with zero starting at **zero** atmospheric pressure (PSIA)

Gauge Pressure: Gauge Pressure is a pressure using a scale with zero starting at atmospheric pressure (PSIG)
Zero PSIG = 14.7 PSIA 29.9" hg.

The Zenith Electronic Engine Management System (ZEEMS) controls both fuel delivery and the governor/throttle with an integrated throttle body and electronic control unit design. Each control system is described separately, but in actual operation, control of fuel and throttle happen simultaneously.

Fuel System:

Review of a gasoline carburetor system will aid in understanding the ZEEMS fuel system operation. Carburetors, mechanical fuel injection systems and electronic fuel injection systems all perform the same basic functions; however, the methods incorporated to perform these functions differ. The fundamental purpose of any fuel system is to measure the incoming air and mix the appropriate amount of fuel with it under all engine operating conditions.

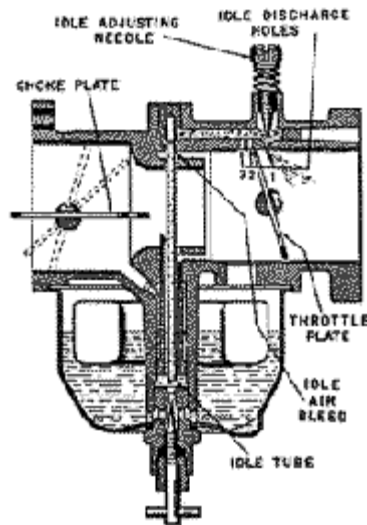


FIG. 5: 2

The carburetor performs three main functions. These functions are:

- To deliver a mixture of gas and air in a ratio that suits each condition of engine operation.
- To atomize the gasoline as it enters the intake manifold.
- To control the volume of air / fuel delivered in response to throttle position and engine operation condition.

In reality, each engine operating condition requires a circuit or mechanism to be designed into and attached to the gasoline carburetor to ensure that the engine will operate without hesitation or “flat-spot” and give maximum power with the optimum fuel economy within the levels of emissions for that model and year of engine design.

The ZEEMS fuel injection system is based on the “ speed-density” concept. The ECU uses engine RPM, IMAF, IAT and ECT to calculate the fuel required for a specific engine operating condition. By using RPM, IMAF, IAT and ECT to calculate intake manifold air density, the ECU calculates the correct fuel re-

SYSTEM OPERATION

NOTES

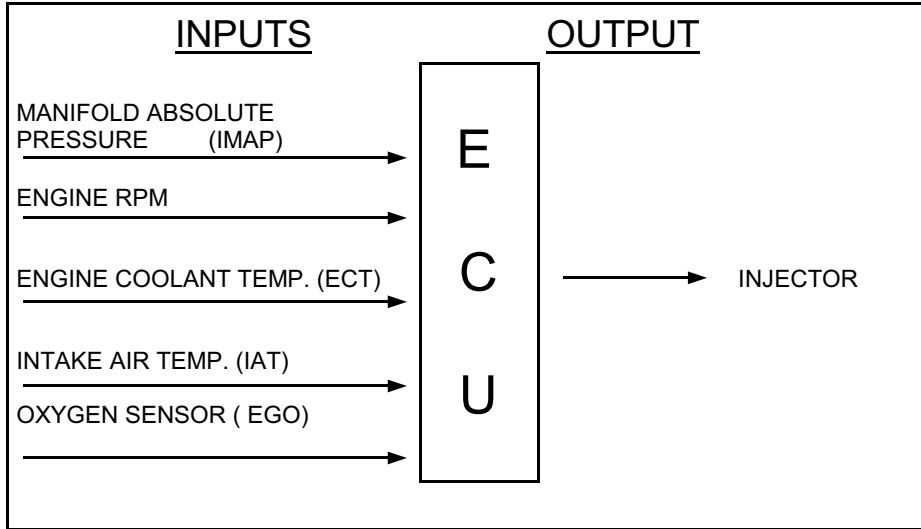


FIG. 5: 3

In the near future when exhaust catalysts are needed to make the required emission standards, an exhaust gas oxygen sensor (EGOS) will be included to make further corrections to fuel requirements to enhance exhaust catalyst efficiency.

Once the required fuel delivery is calculated, fuel under pressure from the fuel pump is injected via the fuel injector into the air stream above the throttle plate.

The fuel injector acts as a simple on/off solenoid. The volume of fuel flow is determined by varying the length of time the injector is held open by the ECU. This is known as pulse width modulation (PWM) and is measured in milliseconds. The injector is pulsed each time a spark plug fires. Each time a plug fires and that cylinder is in the power stroke, another cylinder is in the intake stroke. Between each spark plug firing, the ECU calculates the fuel required for the next engine event based on the information provided to the ECU.

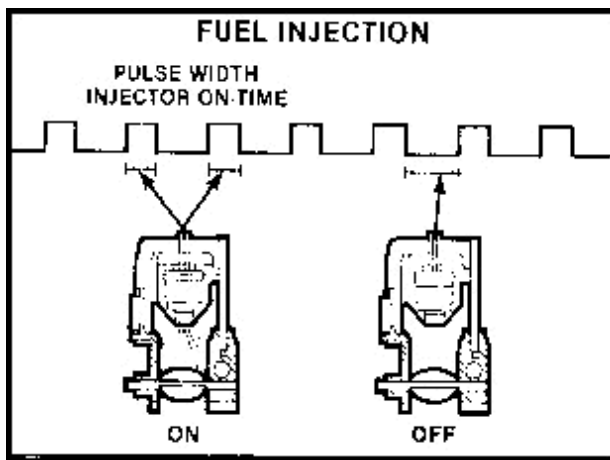


FIG. 5: 4

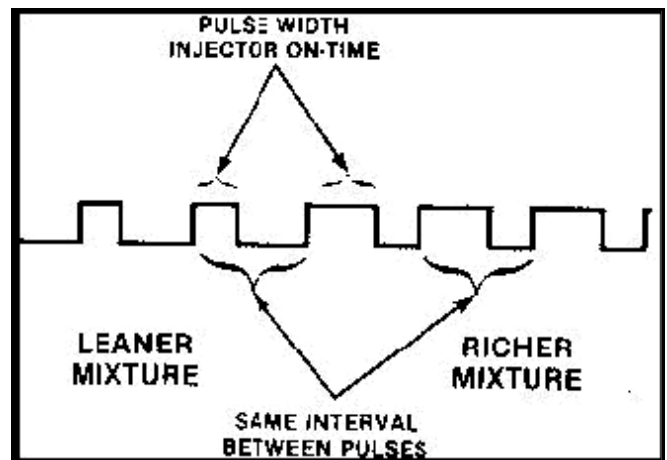


FIG. 5: 5

Pressure Sensors:

Pressure sensors monitor intake manifold pressure (which is affected by throttle position) and/or barometric pressure. They measure pressure with a silicon diaphragm that acts as a resistor. The resistor/diaphragm separates two chambers. As the pressure on the two sides of the resistor/diaphragm varies, it flexes. The flexing causes the resistance of the semi-conductor material to change its electrical resistance. The computer applies a reference voltage to one side of the diaphragm. As the current crosses the resistor/diaphragm, the amount of voltage drop that occurs depends on how much the diaphragm is flexed. By using a look-up chart, the computer can determine exactly what the pressure is to which the diaphragm is responding.

Thermistors:

A thermistor is a resistor made from a semiconductor material. Its electrical resistance changes greatly and predictably as its temperature changes. There are negative temperature coefficient (NTC) and positive temperature coefficient (PTC) thermistors. The resistance of the NTC thermistor goes down as its temperature goes up, although the resistance of the PTC type goes up as its temperature goes up. Most thermistors used in automotive systems are of the NTC type. A good example is the coolant temperature sensor. Because the resistance of the thermistor changes with temperature, the voltage drop across it changes also. The computer monitors the voltage drop across the thermistor and, using programmed values, converts the voltage drop to a corresponding temperature value.

SYSTEM OPERATION

NOTES

ZEEMS uses two different types of injectors, depending on the type of fuel. For gasoline, a pintle valve and seat injector is used. When the gasoline injector coil is energized, a pintle is lifted from a fuel seat to allow the flow of pressurized gasoline. The LPG injector incorporates a “flapper valve” design. When the injector coil is energized, a flat disc is lifted from the fuel seat allowing LPG to flow.

Gasoline Injec-

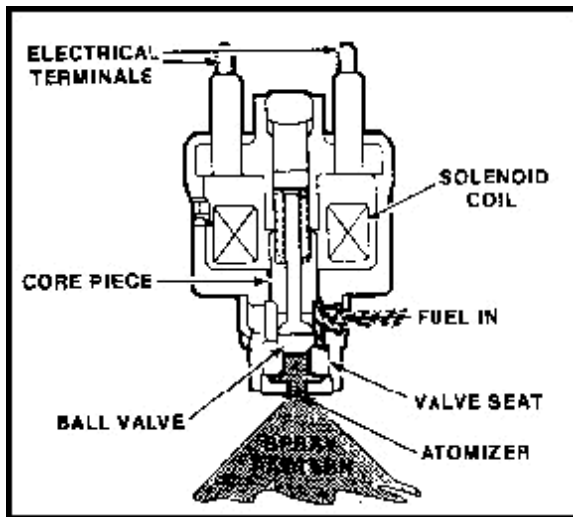


FIG. 5: 6

Propane Injec-

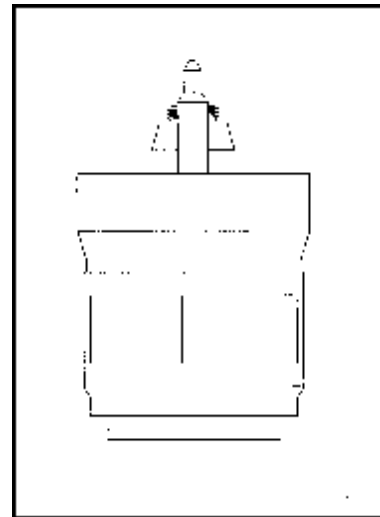


FIG. 5: 7

Ignition control & timing:

On engines that are equipped with a CKP (crankshaft position) sensor, ZEEMS utilizes the RPM, MAP and temperature sensors signals to calculate fuel rate, and to switch the ignition coil thus eliminating the need for a separate spark control module. To give optimum engine power and exhaust emissions two timing advance curves are engineered for each engine application, one for gasoline and another for propane. On dual/fuel units, the ECU stores both timing curves and controls the timing to suit the fuel being used.

On engines that are equipped with distributors ZEEMS has the capacity to control ignition timing, but this depends on the type of OEM ignition system utilized. As with DIS engines, two timing advance curves are engineered into the system.

Some units are equipped with a vacuum delay valve between the throttle body and the vacuum advance unit. This provides a momentary

Fuel Enrichment:

For optimum engine performance and emissions, the ECU will automatically increase the fuel injection rate on gasoline or propane under engine acceleration and during cold starts. This is factory

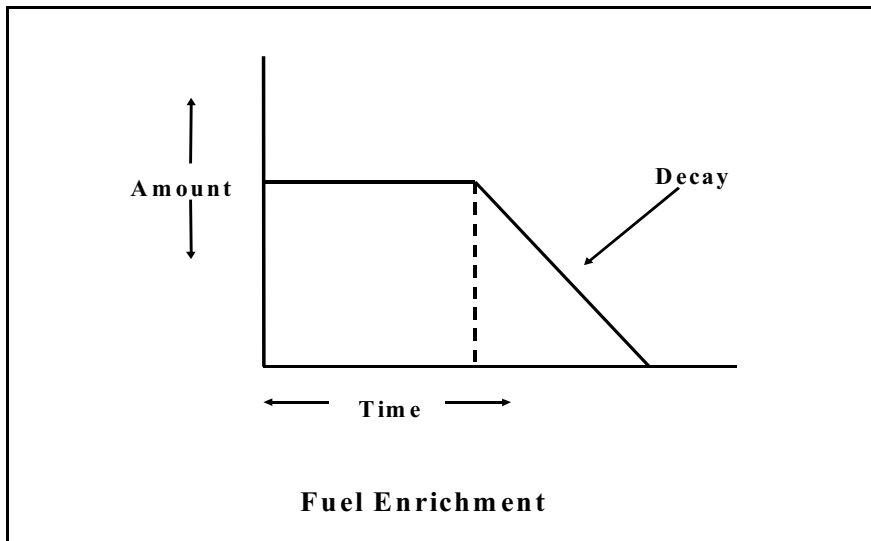
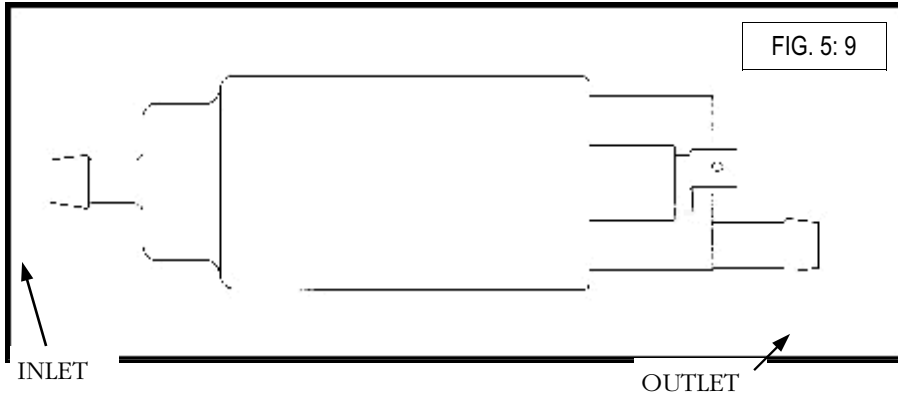


FIG. 5: 8

Fuel Pump:

To supply gasoline to the injector, ZEEMS utilizes a high capacity (16 gallons / hour) fuel pump. Depending on the machine, this will be an inline or intank pump.

INLINE GASOLINE FUEL PUMP



Note: When installing or replacing the inline pump, make sure that the outlet is connected to the terminal end of the pump. Make sure that the electrical terminals are installed correctly (large terminal +12 Volts) or the pump will run backwards.

Note: Avoid running the tank empty. Running the fuel pump without fuel for too long will damage the pump. If the machine runs out of fuel, the inline pump will need priming.

Fuel Filter:

Fuel injectors are sensitive to contaminants and require filters in the 20 – 30 micron range. The gasoline systems uses a 20 micron filter.

Gasoline Fuel Fil-

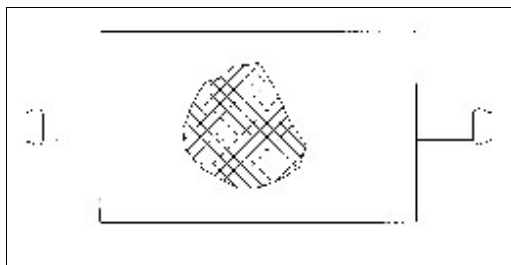


FIG. 5: 10

Pressure Regulator:

A pressure regulator, mounted in the throttle body and downstream of the injector, maintains the gasoline fuel pressure to approximately 10 psi.

Unused fuel is returned to the fuel tank via a return line from the pressure regulator. When checking gasoline pressure, make sure the engine is running.

Note: Return fuel should exit to the vapor space in the tank.

Note: Gasoline caps need to be vented.

Gasoline Regulator

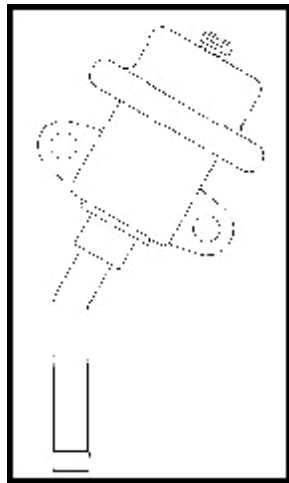


FIG. 5: 11

ZEEMS COMPONENT LOCATIONS

Gasoline System

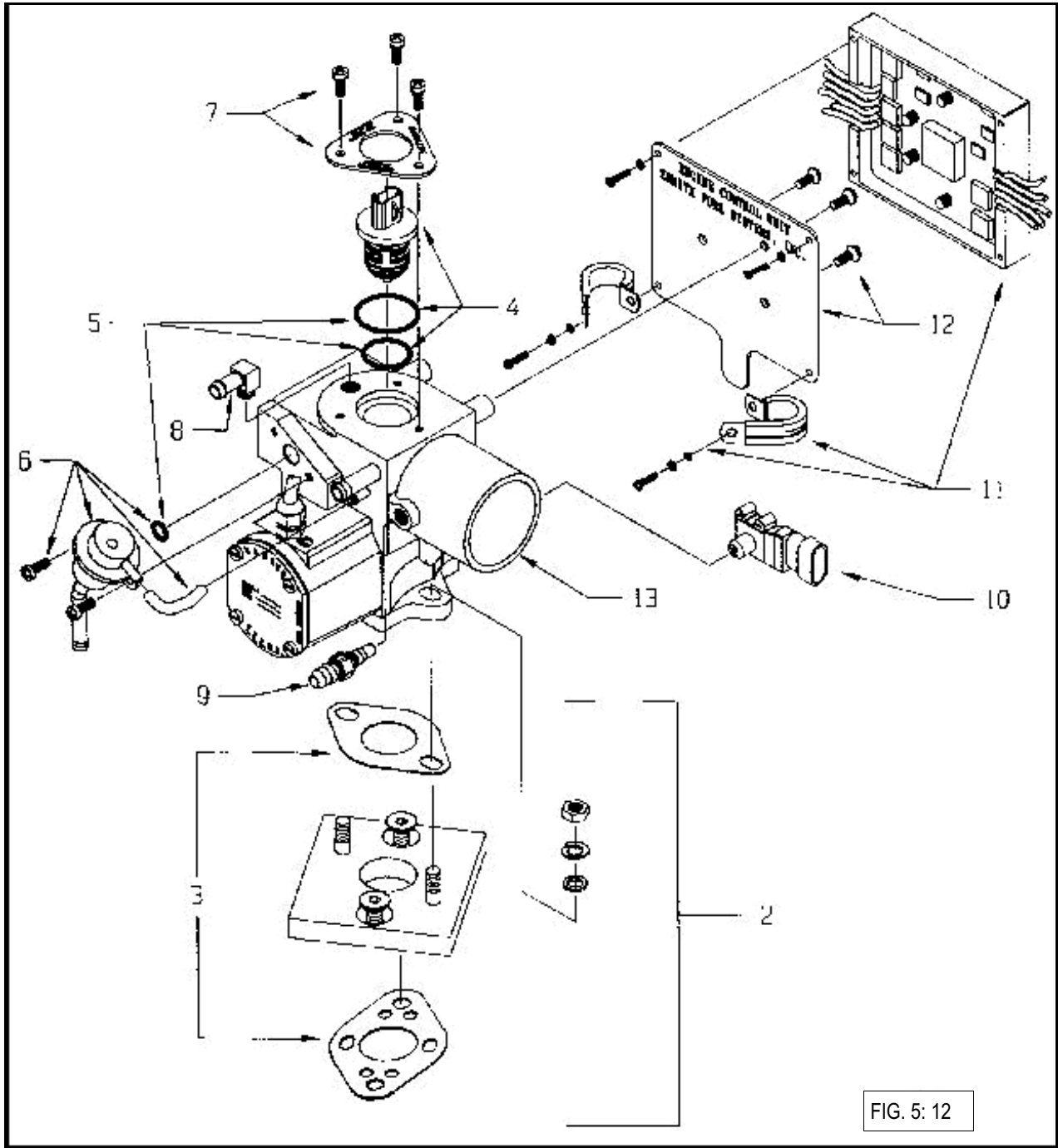


FIG. 5: 12

2 Manifold adapter

6 Fuel pressure reg.

10 IMAP sensor

3 Manifold gasket

8 Gasoline fuel inlet

11 ECU

4 Gasoline injector

9 IAT sensor

13 Throttle body with actuator

Governor Operation:

ZEEMS has an innovative state - of - the - art throttle / governor system. This is a “drive by wire” system that gives significant torque and drivability improvements to the spark ignited engine that the diesel has enjoyed for many years.

The spark ignited engine is a constant air fuel ratio engine, engine speed is maintained by controlling air flow via a throttle fly. The ZEEMS “drive by wire” system has full authority of the throttle fly and will seek to maintain a set engine speed regardless of engine load which significantly improves performance of the spark ignited engine over a conventional speed limiting governor system.

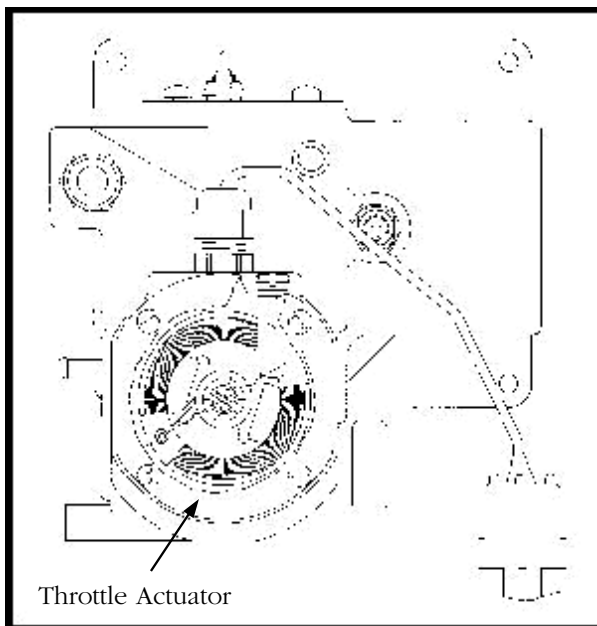


FIG. 5: 13

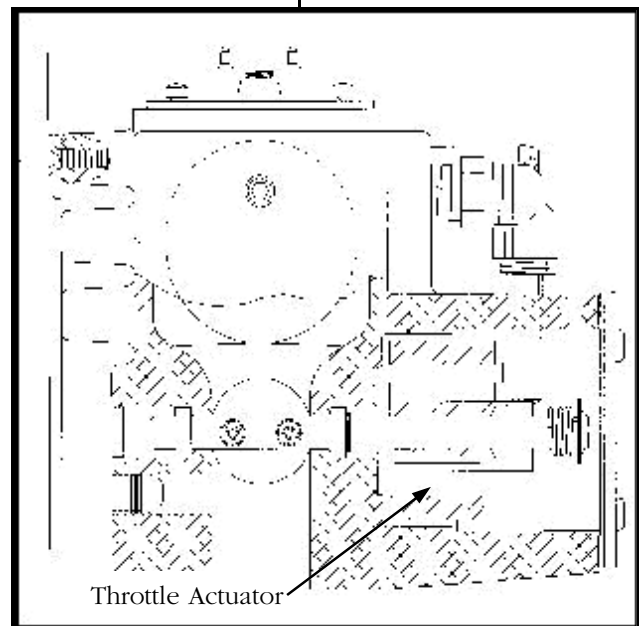


FIG. 5: 14

An electric actuator controls the throttle plate. With no voltage applied to the throttle / governor control, the throttle is closed against the throttle stop. The mechanical throttle stop is set at an RPM below normal idle, typically around 500 RPM.

The ECU receives a voltage input from either a multi position speed switch mounted on the dash, or throttle pedal driven potentiometer

With 12 volts DC applied, the throttle is wide open. The ECU controls the throttle opening by pulsing the voltage between 0 and 12 volts to obtain an average applied voltage and opening.

Governor operation

When the operator calls for an increase/decrease in speed, the ECU compares the current engine RPM to the desired engine RPM. The ECU applies a pulse width to the throttle actuator to increase/decrease engine RPM accordingly. Once the desired RPM is obtained and a demand for increased/decreased engine load is called for, the ECU will command the actuator to open or close the throttle fly without operator interference maintaining a constant engine RPM.

The ECU governs engine RPM with a proportional-integral-derivative (PID) controller. This type of controller allows much faster governor response than conventional mechanical governors. Control to idle or maximum engine RPM occurs very rapidly with minimum RPM undershoot/overshoot. For optimum machine performance under all operating conditions, the governor is calibrated specifically for each engine application.

Because no two machines are exactly alike, the ECU has the ability to “learn” and adjust the throttle stop for improved idle quality and low speed governing. After a period of extended, uninterrupted engine idle at normal operating temperature, the ECU will reprogram idle parameters to correct idle speed and improved decelerations. After the initial factory installation, it is unlikely that the ECU will need to “learn” its base setting.

Note: The throttle plate mechanical idle stop setting must still be checked and adjusted. Check particular engine specifications.

Failsafe Modes:

If any electrical failure to the throttle control occurs, the throttle will return to the mechanical idle stop position.

If for any reason engine RPM exceeds the maximum limits, fuel delivery is interrupted.

The gasoline fuel pump or LPG lock-off will disengage in 2 – 4 seconds if the ignition key is on and there is no secondary ignition pulse to the ignition coil.

Engine start sequence:

There is no need to depress the throttle pedal to “set the choke” or provide fuel for cold start. Depressing the throttle pedal has no effect until the engine is running. The ECU opens the throttle to a predetermined position for starting.

SYSTEM OPERATION

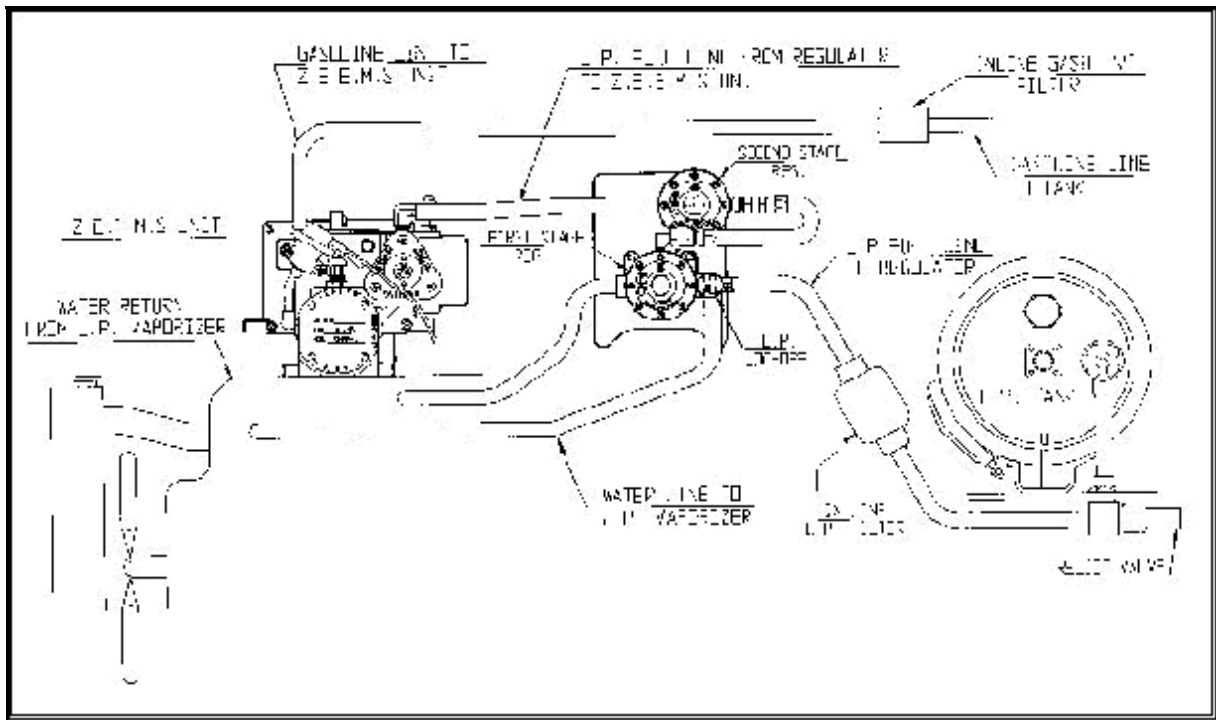


FIG. 5: 15

Operational sequences of the propane fuel system:

1. Liquid propane, at approximately 100 psi (70°F), flows from the tank through the service line. The hydrostatic relief valve is located in the service line fitting. Its function is to relieve pressure at 450 psi that could occur if the liquid in the service line were to be heated by a fire, etc.
2. Fuel then passes to a filter (20 micron) and through a shut off valve. This is commonly known as a “lock off.” This device prevents fuel from flowing to the rest of the system unless it is activated by 12 volts from the ECU.

Propane Fuel Filter

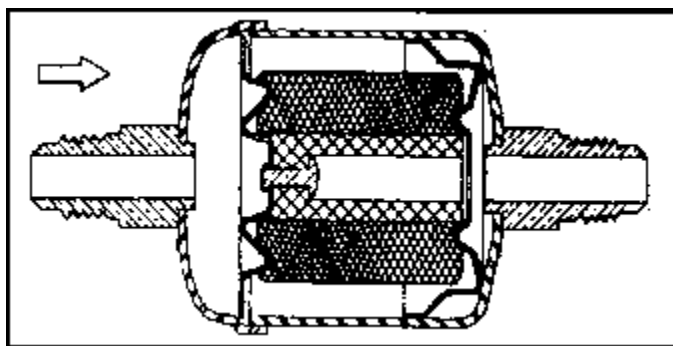


FIG. 5: 16

NOTES

Operational sequences of the propane fuel system:

From the shut off valve, fuel enters the primary vaporizer regulator (converter). Gas pressure is reduced to 25 -35 PSI and changes from a liquid to vapor state. Engine coolant flows through this device to aide fuel vaporization. Fuel then enters the secondary pressure regulator where gas pressure is reduced to 24 psi for delivery to the injector.

Note: When making pressure adjustments on propane, pressure tests are made with the engine off, lock off energized by use of jumper wire.

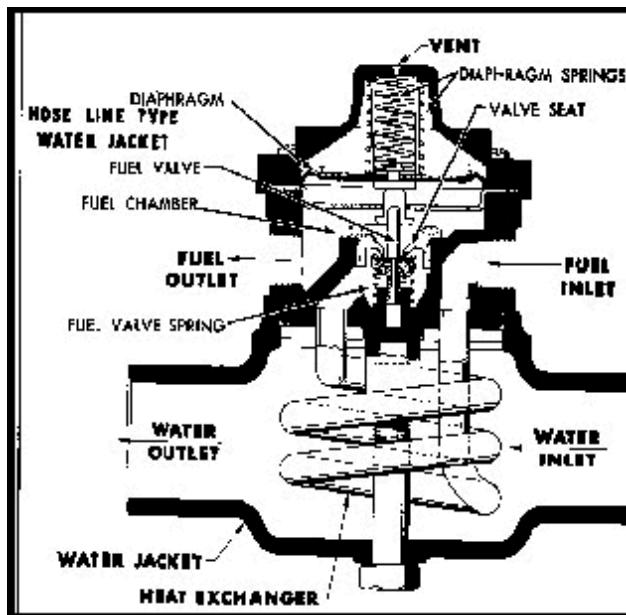


FIG. 5: 17

PROPANE FUEL SYSTEM

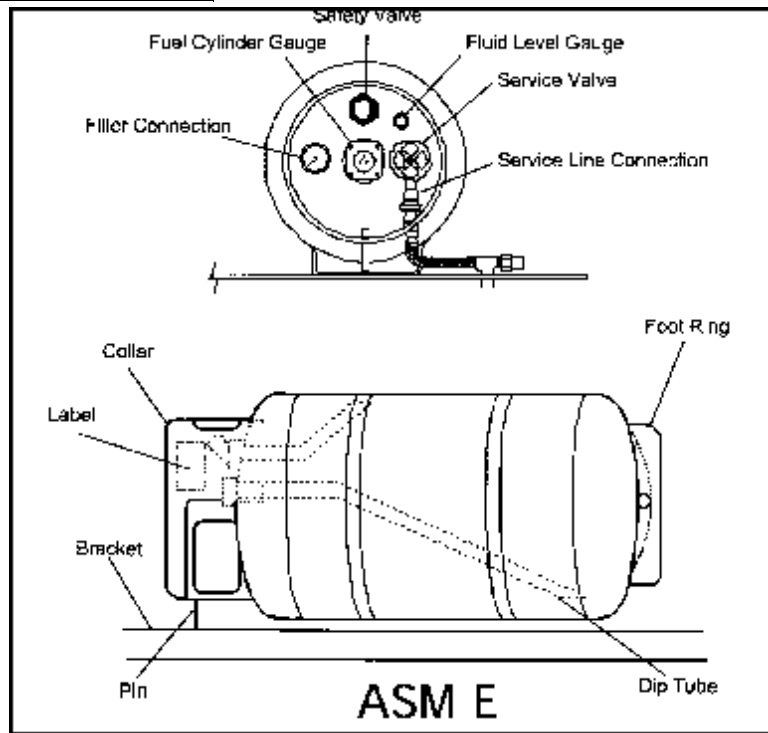


FIG. 5: 18

Propane Tank:

Due to the difference in physical properties between propane and gasoline, the propane fuel tank is vastly different in construction and operation than its gasoline counterpart.

In order to keep the fuel in its liquid state at normal atmospheric temperatures, propane is stored under pressure hence the tank is constructed to ASME standards. The maximum working pressure of the tank is 312 psi . The pressure in the tank will vary according to the outside air temperature e.g. 110 psig @ 70 deg. F. and 52 psig @ 32 deg. F .

Because the fuel is under pressure, no fuel pump is required to move fuel to the engine compartment. To prevent over pressurizing the tank, it is only filled to 80% of its total capacity.

1 Liquid Service valve:

Located in the end of the tank, this valve will remain fully open during normal operation and is shut when stored indoors or when the system is under repair.

There is an excess flow device in the base of this valve. Its function is to close off fuel flow should the fuel line be severed. **Note:** Turn service valve on slowly. This will prevent premature excess flow valve operation, if fuel line is empty. For proper seating, this valve should always be opened completely. This will allow the proper seating of the top O-ring.

NOTES

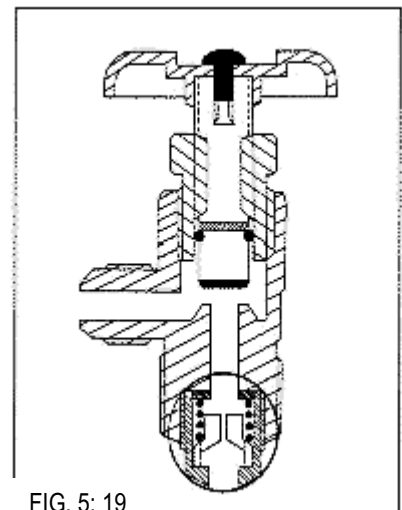


FIG. 5: 19

2 Relief Valve:

The relief valve is preset by the manufacturer to activate at 375 psig . Tank pressure will rise when the liquid expands. This can be caused by overfilling the tank, an external heat source, e.g.: fire, etc. The valve will close when pressure drops

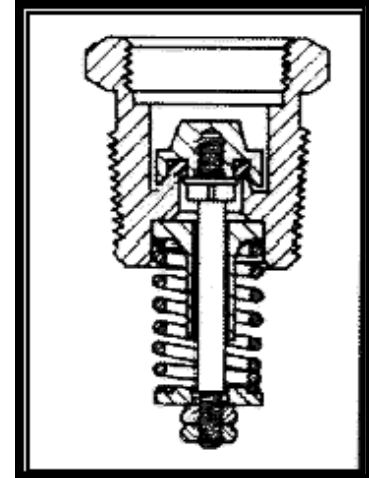


FIG. 5: 20

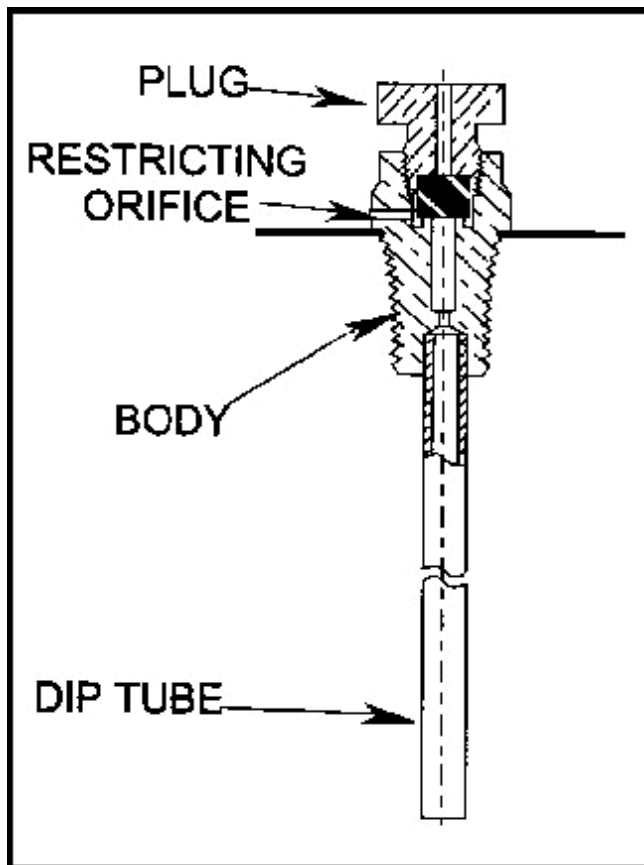


FIG. 5: 21

3 Outage Valve.

This valve is also called the 80% liquid level valve. This device when opened, allows gas (vapor) to escape as the tank is being filled . When the liquid level reaches 80% , liquid spills out the valve, indicating that the tank is filled to the correct level.

PROPANE FUEL SYSTEM OPERATION

NOTES

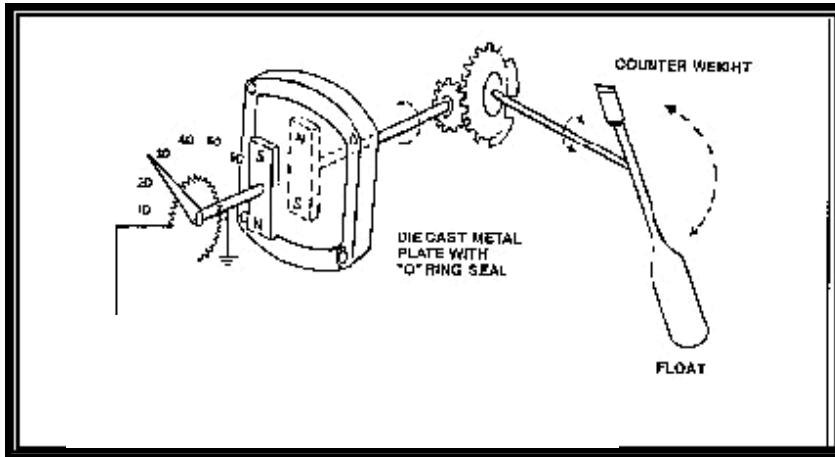


FIG. 5: 22

The sight gauge is designed so that there is no physical connection between it and the float. The fuel level is transmitted from the float via a shaft which has a permanent magnet attached. As the magnet rotates, the magnetic field causes the gauge needle to move to the

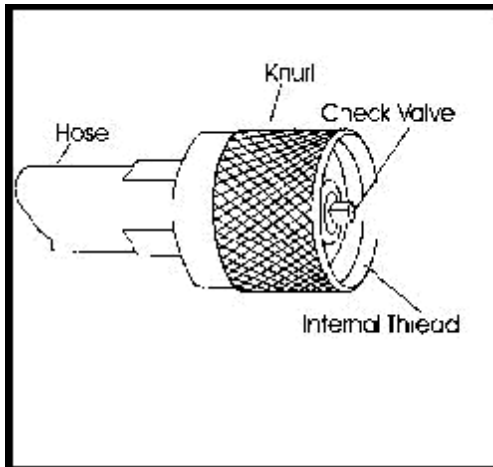


FIG. 5: 23

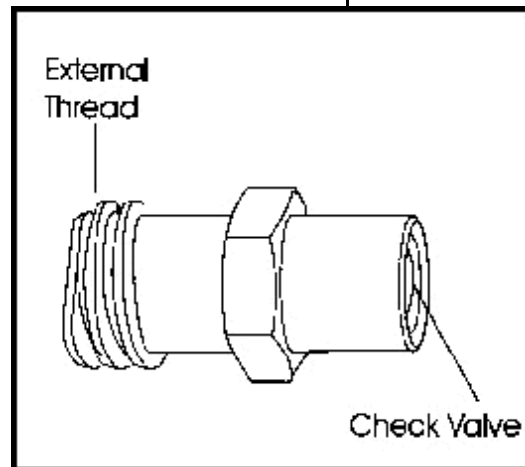


FIG. 5: 24

Quick Disconnect Couplings:

To aid in connection and disconnection the liquid service valve has a male ACME quick connect coupling. This coupling and its female counterpart, that is attached to the fuel supply line, are equipped internal check valves. When connected the checks open and allow gas to flow.

The male coupler has two seals. One, an "O" ring and the other a flat ring; both are replaceable and should be checked periodically.

Safety considerations: Exercise caution and common sense when replacing fuel lines. Also, remember that even as a gas, propane is heavier than air and any leaks in a system will tend to pool in low spots.

PROPANE FUEL SYSTEM OPERATION

NOTES

Dual Fuel:

The Zenith dual fuel system is unique in the fact that it is two separate fuel systems contained in the same throttle body.

The system has two - Injectors

Fuel VE tables

Ignition timing tables

Idle self learn tables

There is no special procedure to follow when changing from one fuel to the other. The engine can be idling or at load. The ECU automatically switches to the appropriate tables and switches the LPG lock-off or gasoline fuel pump on or off.

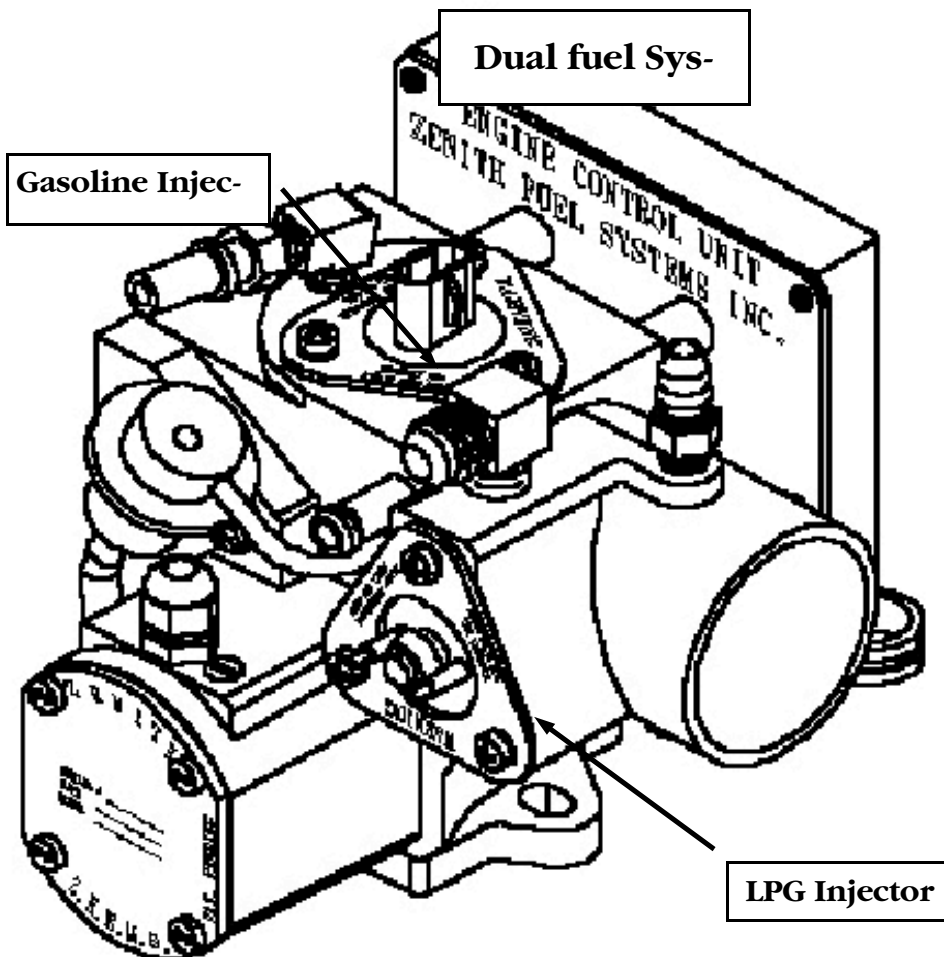


FIG. 5: 25