RAILROAD COMMISSION OF TEXAS
ALTERNATIVE FUELS RESEARCH AND EDUCATION DIVISION

CONVERTING GROUNDS EQUIPMENT TO PROPANE

CONVERTING A SMALL ENGINE TO OPERATE ON PROPANE

There are generally two types of propane fuel systems:

- Liquid-fuel fed
- Vapor-fuel fed

The main differences in the two types of systems are the fuel tanks, the pressure regulators, a heat exchanger (called the "vaporizer"), and fuel shut-off devices (called the "lockoff"). The engine carburetion systems are generally interchangeable.

Liquid fuel systems typically use a forklift fuel cylinder that is removable for servicing, refueling or exchanging. This cylinder is mounted horizontally on the vehicle and secured by a retaining strap that allows easy removal. These fuel cylinders typically contain about 8.5 gallons of fuel. *Figure 1.*

Vapor fuel systems may use a 20-lb. cylinder, commonly referred to as a barbecue bottle. These cylinders are mounted vertically and secured by a retaining strap that allows easy removal.

With both of these fuel systems, the fuel tank must be removed from the vehicle for refueling.

Fig. 1. DOT horizontal cylinder

Fig. 2. Propane vaporizer.

A vapor fuel system supplies enough fuel for engines up to about 25 hp. Since the fuel is withdrawn from the tank as a vapor, the liquid propane in the tank must be able to absorb heat from the surrounding air to boil off vapor and maintain equilibrium, keeping the propane a liquid at a specific temperature and maintaining vapor pressure. A fuel tank designed for vapor service has enough surface area to maintain delivery pressures for engines up to about 25 hp.

Above 25 hp, propane fuel is generally delivered as a liquid. Since a cubic foot of liquid propane contains as much energy as 270 cubic feet of propane vapor, the volume of liquid withdrawn from the tank by a liquid-fed system is much smaller than the volume of vapor withdrawn by a vapor-fed system.

Vapor fuel systems do not need a heat exchanger, since the fuel tank absorbs heat and vaporizes the fuel before it reaches the pressure regulator. Liquid fuel systems require a heat exchanger/vaporizer to convert propane liquid to propane vapor. *Figure 2.*

With a vapor-draw system, a primary pressure regulator is mounted at the fuel tank to reduce the fuel pressure to approximately 10 psig. *Figure 3.*

Fig 3. Primary pressure regulator

Fig 4. Secondary pressure regulator (left)
Fig. 5. Fuel lockoff (right)

secondary pressure regulator is mounted near the engine to reduce the pressure to near atmospheric pressure.

Figure 4 shows the secondary pressure regulator. *(NOTE: Propane is not "pushed" into the engine; it is drawn in by the modified carburetor).*

All fuel-withdrawal systems provide a means of stopping the flow of fuel when the engine is not in operation. On both types of systems, a lockoff is installed to prevent fuel from flowing when the engine is stopped.

The lockoff is an electrically operated solenoid controlled by the ignition switch. It is recommended that the circuit be routed through an oil pressure switch that prevents any fuel movement unless there is engine oil pressure.

Some systems provide for a vacuum-operated lockoff that keeps fuel from flowing unless a vacuum is present, created by a cranking or running engine. This is shown by the arrow in Figure 4.

Liquid fuel systems include a hydrostatic pressure-relief device, usually installed at the lockoff, shown by the arrow in Figure 5. This device prevents an over-pressure condition that may damage the fuel hose if it is overheated. Hydrostatic pressure-relief devices are not used on vapor fuel systems. *Figure 5.*

CARBURETION

This first series applies specifically to engines of less than 25 bhp.

Propane carburetion is simple, often no more complicated than drilling one hole in an existing disassembled carburetor.

Propane carburetors are of three types:

- Spud-in kit, in which the carburetor is modified by enlarging and opening and inserting a special propane jet. *Figure 6.*
- Venturi spacer (where the original carburetor is utilized in a dual fuel configuration, allowing either gasoline or propane to be used). With this system, a spacer is inserted between the carburetor body and the engine (for idle fuel mixtures), and another venturi spacer is installed between the carburetor and air cleaner assembly. *Figure 7.*
- Replacement by a specially designed propane carburetor, eliminating the original unit. *Figure 8.*

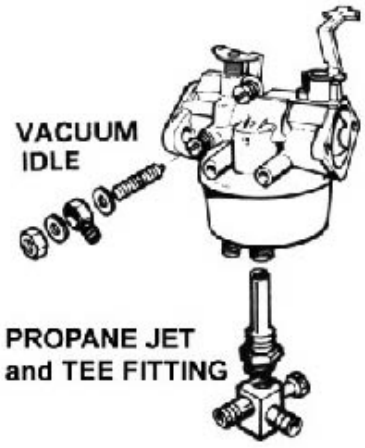


Fig. 6. Spud-in system

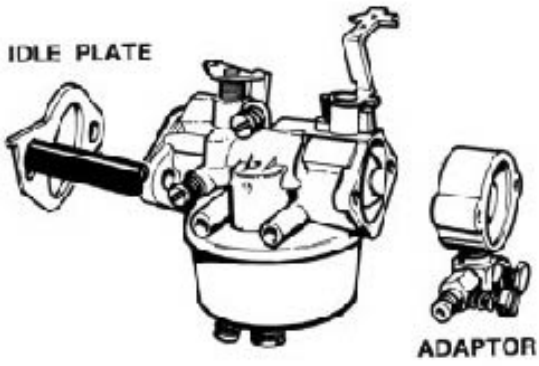


Fig. 7. Venturi spacer, dual fuel adaptor

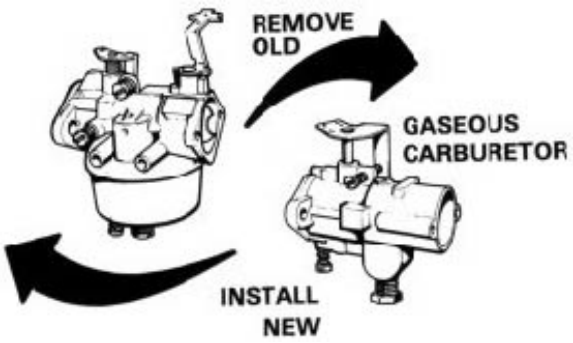


Fig. 8. Replacement carburetor

This image shows the replacement purpose-specific, gaseous fuel carburetor. The complete gasoline carburetor is removed and replaced with a vapor-fuel carburetor.

Engines 25 bhp and more

The most common carburetion system used is the Impco series 55 or series 100 carburetor with the Impco Model J or "Cobra" vaporizer.

Fig. 9. Impco series 55 carburetor

Fig. 9-A. Impco series 100 carburetor

These components are traditionally used with liquid-fueled, liquid-cooled engines. The installation and sophistication of this type of equipment are very similar to automotive applications, without the electronics.

These carburetors are a direct replacement of the original gasoline carburetor. An adapter plate is commonly required to match the carburetor to the intake of the engine. Some modification to the throttle linkage and air cleaner assembly may be required. The use of this system dictates a mono-fuel application. *Figures 9 and 9-A.*

INSTALLATION GUIDELINES

Fuel tanks

When installing a gaseous fuel conversion system or converting a gasoline-powered vehicle, one of the most challenging tasks is deciding where to install the fuel cylinder.

Points to consider when making this decision:

- The bracketry (and related framework) must be capable of supporting four times the weight of a full cylinder in each direction. (Up, down, left, right, front, back.)
- The fuel tank must remain accessible for removal and servicing. When establishing the location for the tank, remember that a full fuel tank may weigh as much as 70 lbs.
- The manual service valve must be accessible during operation.

Fig. 10. Impco Model J vaporizer. The "Cobra" is similar.

- The pressure relief valve must be pointed away from the operator and the engine.
- The fuel tank must be oriented in a specific position by means of a locating pin. Using this pin to orient the tank insures that if the pressure relief valve were to discharge, vapor would be directed away from the operator. Correct orientation is required by law, and most tank mounting kits provide a means of compliance (Figures 11 & 12). Also note that the pin diameter has increased from approximately 3/8″ to 1/2″ in diameter to prevent unauthorized removal of the pin. This change also necessitates a change in tanks. Newer tanks have a larger locating hole in a slightly different location.

NOTE: Applications differ. Some installations may require a redesign of bracketry and other related support framework.

Fig. 12. Tank installed with locating pin

Fig. 11. Tank locating pin

Identify a location where the fuel tank will be mounted. Verify that the fuel tank will not interfere with the normal operation of the vehicle. The fuel tank should NOT extend beyond the body (envelope) of the vehicle to avoid scraping walls or trees. If there is no suitable existing location, a metal framework must be fabricated to support the fuel cylinder.

Notice the securing latch in Figure 13. This allows fuel cylinders to be exchanged without tools.

Fig. 13. Tank securing latch

The photo below shows a fuel cylinder mounted above the engine using existing brackets for the oil cooler. *Figure 14.*

Fig. 14, showing the locating pin

Fig. 15. Installation brackets

Side detail of the fuel tank/cylinder mounting. *Figure 15.*

This photo shows custom-fabricated spacers used to mount the fuel cylinder.

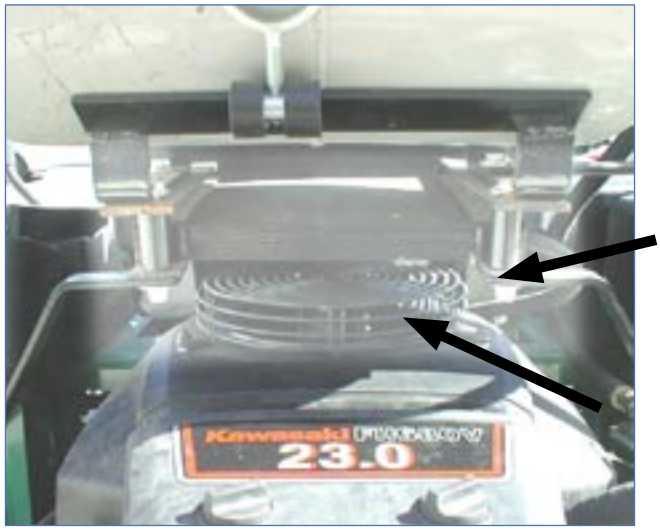


Fig. 16. Installation brackets (cont.)

Note that air flow through the oil cooler is not impeded. *Figure 16.*

INSTALLING PRESSURE REGULATORS

Fig. 17. Primary pressure regulator

Fig. 18. Secondary pressure regulator

Vapor system

The primary regulator (Figure 17) on a vapor system is usually integrated with the fuel coupling at the fuel tank. This regulator reduces the vapor pressure from tank pressure (100-200 psig, depending on the temperature) to approximately 8-14 psig, depending on the fuel system. A flexible fuel hose connects the primary regulator to the secondary pressure regulator, which may also be called the "zero governor," since it reduces the pressure output to a "zero" pressure (atmospheric pressure). It is important to remember that propane is drawn into the engine; it is not "pushed" into the engine.

The secondary regulator (Figure 18) is securely mounted to the body, engine, or chassis to minimize movement. All propane-carrying devices should be eight (8) inches from any exhaust component unless they are shielded. The exhaust may be shielded instead.

Fig. 19. Electric fuel lockoff (left)
Fig. 20. Fuel lockoff, vacuum-operated (right)

Fig. 21. Pressure regulator / vaporizer (left)
Fig. 22. Spud-In kit parts (right)

INSTALLING THE PRESSURE REGULATOR

Liquid system

With a liquid system, the fuel tank supplies liquid propane to the regulator, where it is converted to a vapor and reduced to near atmospheric pressure.

The fuel must also pass through an electric or vacuum-operated fuel solenoid that controls the fuel.

The electric fuel lockoff *(Figure 19)* should be controlled by either a vacuum switch or an oil pressure switch that prevents the solenoid from being energized unless the engine is either cranking or running.

A typical vacuum-operated lockoff is shown in Figure 20.

The regulator/vaporizer on a liquid fuel system is mounted on either the engine or the vehicle chassis. The unit must have access to engine coolant, which provides heat to the vaporizer to convert the fuel from liquid to a vapor. *Figure 21.*

.This regulator reduces the fuel pressure from tank pressure of about 100-200 psig, depending on temperature, to approximately atmospheric pressure. (Remember that here, too, propane is drawn, not "pushed," into the engine.) The vaporizer requires a vacuum signal of approximately 1.5" of water column to start a flow of fuel.

The regulator/vaporizer is securely mounted to minimize movement. As with the vapor regulator, all propane-carrying devices should be 8 inches from any exhaust component unless the devices or the exhaust is shielded.

INSTALLING THE CARBURETION SYSTEM

Vapor system

After the method of conversion is determined (spud-in, venturi adaptor, or replacement), follow the manufacturer's instructions.

The following text gives a general overview of each conversion process. All physical modifications should be considered permanent. The photographs are of a specific model of carburetor, but the modifications are similar for almost all carburetors.

Spud-in kit

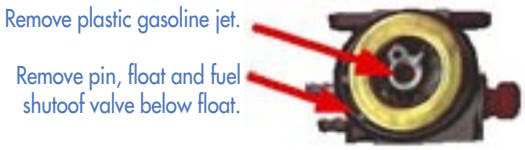
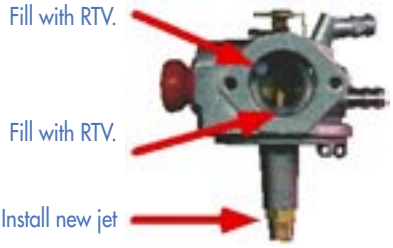
The main task in modifying the carburetor is to replace the existing gasoline fuel delivery tube (the red plastic tube) with a brass propane delivery tube. *Figure 22.*

To do this requires removing and disassembling the gasoline carburetor and drilling out the opening in the carburetor where the old jet was located. The new brass jet, and some other fittings and a valve assembly, will take the place of the gasoline delivery jet. (NOTE: Some models do not require additional drilling.)

Another brass fitting (the slow-running fitting) will be replaced with a larger, hollow fitting that serves as a vacuum feedback port to the vacuum-controlled flow regulator or tee control valve.

Unused air passages that are only required for gasoline fuel use will be sealed with RTV silicone.

CARBURETOR CONVERSION STEPS

Step One After removing, cleaning, and disassembling the carburetor, remove the float chamber and plastic cap over vacuum fitting location.	
Step Two Remove the gasoline jet, float and fuel shutoff valve.	
Step Three Enlarge the location of the fuel delivery jet to accept the new propane jet. Seal unused passages.	
Step Four Install propane delivery jet and seal unused vents and air passages.	
Step Five Seal unused gasoline fuel inlet.	

Install the fuel supply fitting to the propane jet. This fitting frequently has fuel mixture adjustments for both idle and power load levels.

Reassemble the carburetor, governor linkage, choke (if equipped) and air cleaner assembly.

Connect the necessary fuel supply hoses and clamps.

Extra parts may be discarded, since the engine will now operate only on propane.

WHAT DOES IT LOOK LIKE WHEN THINGS ARE HOOKED UP?

Here the system is shown before being installed on an engine. *Figure 23.*

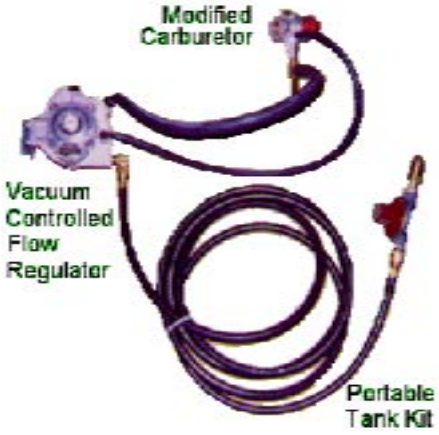


Fig. 23 System mockup

The modified carburetor is connected via two hoses to the vacuum-controlled flow regulator. The hose connected to the bottom of the carburetor delivers propane gas to the new jet.

The second, smaller hose is connected to the side of the carburetor where the vacuum fitting has been installed. The other end connects to the vacuum control feedback port on the flow regulator. On some systems, the smaller hose is connected to a tee fitting that supplies fuel during the idle position.

The third hose from the vacuum flow regulator should be connected to a propane tank using the special 12-psi regulator included in the tank portability kit.

Installing the venturi spacer kit

This type of system allows for the original carburetor to be retained and provides for either gasoline or propane operation (not at the same time).

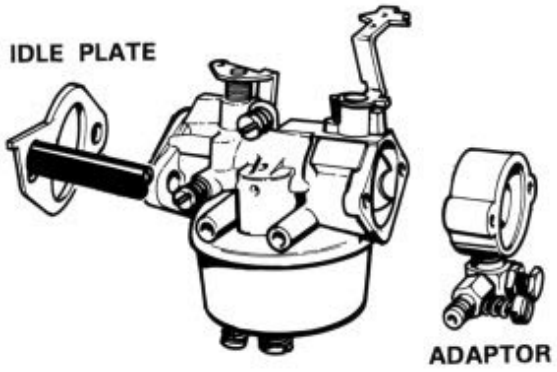


Fig. 24. Spacer plate and adaptor

Remove the carburetor and install the supplied idle spacer plate between the carburetor and the engine (Figure 24). Reinstall the carburetor. Install the spacer venturi between the air filter and carburetor. Retain with longer bolts. Some fabrication may be required to secure the air filter housing to the engine—see below. Connect the fuel supply hoses as described above.

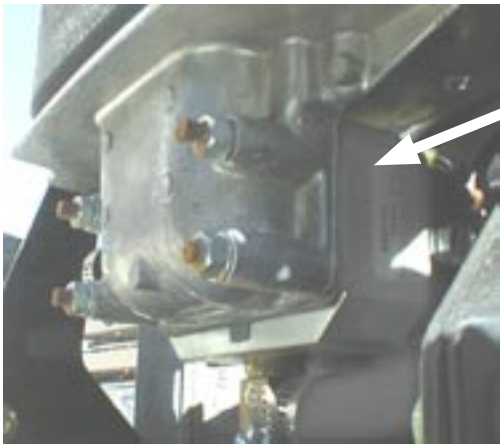


Fig. 25. Adapter between carburetor and air filter

In the photo above, the arrow indicates the spacer adapter between the air cleaner housing and the carburetor body *Figure 25.*

Fig. 26. Vapor hose connection

The photograph below shows the vapor hose entering the adapter. *Figure 26.*

This application allows for a bi-fuel usage, changing back and forth from propane to gasoline. When operating in a bi-fuel condition, since there is no gasoline in the fuel bowl, the gasoline components' gaskets and seals may deteriorate and cause future problems.

Fig. 27. Liquid fuel for a vapor system

Figure 27 shows a liquid fuel supplied carburetion system. Notice the electric lockoff at the top right and a secondary lockoff at the inlet to the low-pressure regulator. On larger engines, the vaporizer is a single combined unit that must be plumbed into the engine's cooling system to help vaporize the liquid propane. On the unit shown above, the vaporizer is an air-heated unit that absorbs necessary heat from the ambient air and the airflow from the engine-cooling fan. For this reason, it is placed in close proximity to the engine. This unit is limited to about 25 bhp. Since it uses ambient air to provide heat for the vaporizer, it may freeze up in cold, damp conditions.

Fig. 28. Installed system

This is the completed system (Figure 28). Notice that all the equipment is securely mounted and located within the confines of the engine cage.

INSTALLATION USING A REPLACEMENT CARBURETOR ASSEMBLY

When a pre-configured kit is purchased, most of the necessary hardware is included:

- Carburetor
- Vaporizer (often assembled to a bracket with the fuel lockoff)
- Connecting hoses
- Vapor hose
- Tank mounting brackets and clamps
- Bulkhead fitting with hydrostatic relief valve
- Fuel pump blockoff plate

Fig. 29. Complete carburetion system

One of the easiest methods of converting equipment to operate on propane is to replace the original carburetor with a carburetor specifically designed for propane use. When using one of these carburetors, there is no option of a dual-fuel application.

INSTALLATION PROCEDURES

Remove the existing carburetor, fuel pump, and fuel line. Block the fuel line to prevent leakage. Many operators of mowers and industrial equipment choose to remove the gasoline tank, or convert it to a carry-all container by cutting open the top section. If the gasoline fuel tank is left on the vehicle, it must be drained.

Install the supplied fuel pump blockoff plate, if equipped, or fabricate one using a fuel pump gasket as a template. If the fuel pump is not removed, loop the suction and discharge lines together with rubber tubing and secure with clamps. This prevents the internal components of the fuel pump from drying out.

Insure that the related vaporizer mounting hardware is securely fastened to resist vibration. The use of additional brackets and other support material may be necessary. When installing a vaporizer, it is recommended that it be mounted below the liquid level of the radiator top tank to insure a constant supply of coolant. The vaporizer should be placed so that the vapor outlet is at the bottom of the unit (as shown in the photo above) to prevent accumulation of oils and sediment. On the Model "J" and "Cobra," the outlet is selectable by removing a 3/8" plug and installing the appropriate fitting.

Install the coolant hoses with proper fittings. Splice into existing hoses and extend them to the vaporizer. (NOTE: The flow of coolant is not directional.) If the vehicle is NOT equipped with hoses, locate existing plugs or taps in the engine block, water pump, or radiator, and install the proper fittings. On rare occasions, the water pump must be removed and the housing drilled and tapped for a coolant supply fitting.

Install the replacement carburetor and connect the proper throttle linkage. The installation of a choke is not needed with propane conversions. The throttle linkage will frequently require some modification to duplicate the action of the original linkage.

These carburetors are designed for the Impco Model "J" or "Cobra" vaporizer.

Impco series "55" carburetor

Impco series "100" carburetor

Electric fuel lockoff

Impco Model "J" vaporizer, "Cobra" similar

Connect the vapor hose from the vaporizer to the carburetor. Route the hose so that it is as short as possible and does not interfere with any moving parts. Secure with clamps.

Connect a rubber hose from the small brass fitting at the base of the carburetor to the vacuum fitting at the fuel filter lockoff. This allows for operation of the fuel lockoff when sufficient vacuum is created by a cranking or running engine and acts as a safety device when the engine stops.

Identify a suitable location a position for the bulkhead fitting. This fitting should be positioned so if the hydrostatic pressure relief valve were to discharge, it would vent away from the engine, exhaust, and the driver.

NOTE: The fitting must NOT be located in the engine compartment. If it were to discharge, it should discharge away from the engine, the engine intake or exhaust, and the operator.

Fig. 30. Hydrostatic pressure relief valve

Connect the propane supply line from the fuel tank quick-connect fitting to the bulkhead fitting, then to the fuel filter lockoff.

PREPARING FOR FIRST-TIME OPERATION

1. Perform a visual inspection and verify that all fuel-carrying fittings and connections are secure and tight.

2. Open and then close the fuel supply valve. This will pressurize the fuel system for leak testing.

3. Apply an approved liquid leak-detection solution liberally over each fitting. If a leak is detected, immediately depressurize the fuel system and perform necessary repairs. Use an electronic combustible gas leak detector if a liquid leak mixture is not available. Repair any leaks before proceeding.

4. Be sure the mower blades or accessories are disengaged. Start the engine and allow it to run at approximately 1/3 throttle. Slight adjustments of the idle mixture screw (the smaller of the two screws) may be necessary to keep the engine running. On the vapor draw systems using a venturi or spacer block, the idle mixture screws counterclockwise for a rich mixture. On liquid draw systems where the carburetor is replaced, turn the idle mixture adjustment screw counterclockwise for a lean fuel mixture.

5. Slowly decrease the idle speed until the manufacturer's recommended speed is reached. Adjust the idle fuel mixture screw) for smoothest idle.

6. Move the throttle to full governed speed. Adjust the larger fuel mixture screw for maximum speed. This adjustment will need to be repeated when the unit is in operation to allow for a loaded engine mixture adjustment. Allow the engine to return to idle speed and verify the idle mixture. Adjust as necessary.

7. Connect an exhaust gas analyzer to the engine and adjust the idle fuel mixture for a carbon monoxide (CO) reading at the lowest possible position (approximately 0.5%). The engine must be at operating temperature to set the fuel mixtures accurately.

8. If an exhaust gas analyzer is not available, adjust for smoothest lean/best idle. Set the fuel mixtures with an exhaust gas analyzer at the earliest possible opportunity.

NEW SYSTEMS

The newest fuel systems incorporate fuel injection for small engines. This is necessary because of the tightening air quality issues requiring reduced production of carbon monoxide and oxides of nitrogen. One such system is shown at the bottom of this page.

Installation of this system varies with the application. Because fuel injection meters fuel in direct proportion to the airflow, each system is application-specific, meaning that injectors, pressure regulators, and electronic control modules cannot be interchanged between different applications.

DESCRIPTION OF THE SYSTEM

This system utilizes the speed density method of calculating the proper amount of fuel needed for ideal combustion. Speed density consists of these three things:

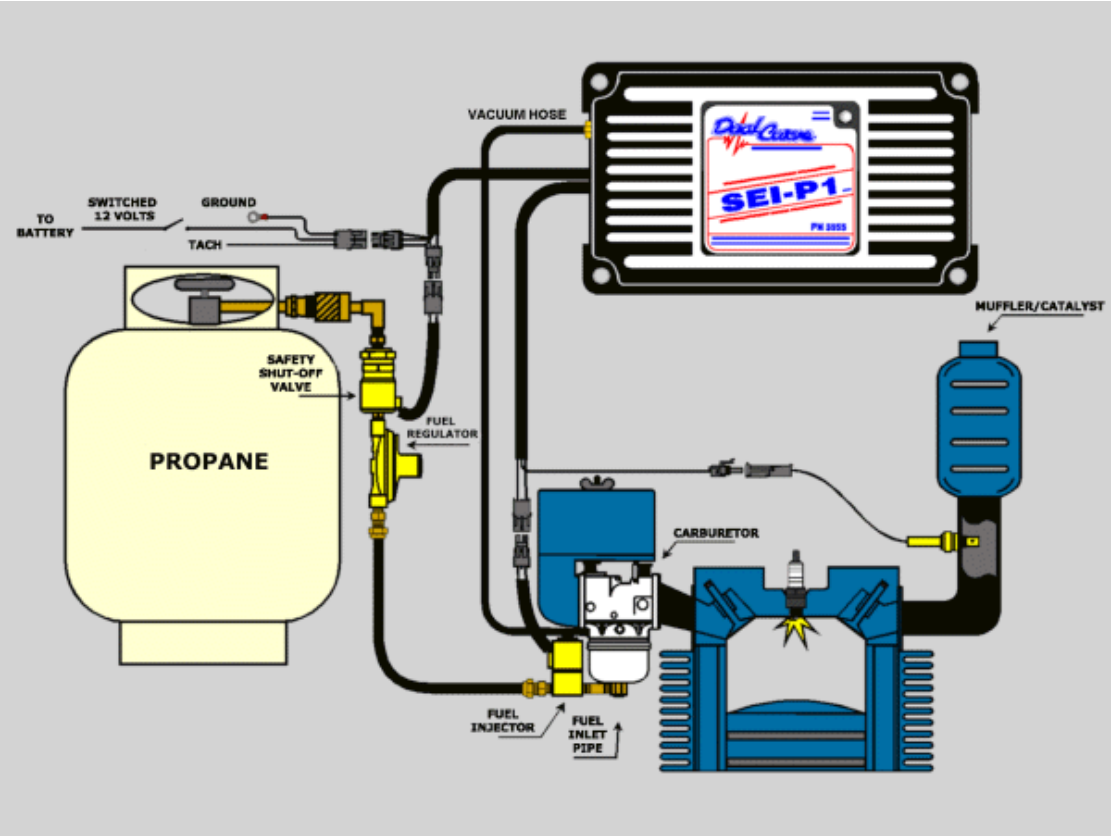
1. Engine displacement
2. Engine RPM
3. Engine load, as measured by vacuum.

The engine displacement is determined and fixed into the computer circuitry. Engine RPM is a direct indication of the amount of air passing through the engine. Engine load is measured by the vacuum present between the throttle blade and the intake valve. High manifold vacuum levels at low engine RPM indicate low load. Decreasing vacuum levels indicate an opening throttle, which indicates increasing engine load.

Measuring vacuum can also provide an indication of air filter restriction and make necessary fuel adjustments for compensation.

An oxygen sensor provides additional information to the computer. By measuring the amount of oxygen present in the exhaust after combustion, the computer can make small trimming changes in the fuel mixture. This provides consistent fuel mixtures for a variety of engine load conditions and environmental changes.

Fig. 31. Small Engine Fuel Injection (SEFI) schematic



INSTALLATION

The fuel injection system typically consists of these major components:

1. Pressure regulator
2. Fuel lockoff solenoid
3. Fuel injector (with adapter)
4. Oxygen sensor
5. Electronic control module

Fig. 32. SEFI components

The original carburetor is removed, cleaned, and disassembled. Either a spacer plate is installed between the carburetor and engine for the vacuum fitting location, or the throttle body is drilled and tapped for the vacuum fitting.

The carburetor body is drilled (in the same location as the vapor carburetor spud installation shown above) for the appropriate fitting. The fuel injector is threaded to this fitting. The assembly is reinstalled on the engine, connecting any wiring or necessary linkages for throttle and governor control.

A fuel line is connected from the pressure regulator to the fuel injector. This fuel line carries fuel pressure in the 8 to 15 psi range and should be of the appropriate material as required by code or supplied in the conversion kit.

The exhaust pipe is drilled to 5/8" (16mm) using a step-drill bit, and either the weld-in bung is welded or the clamp-on adapter is installed using the provided insulator seal and worm clamps. The oxygen sensor is then installed.

The electronic control module is mounted in a location which provides ventilation, but not in an area which may be exposed to moisture or water from vehicle washing or rain. It should also be mounted in a location away from engine heat. All wiring should be routed away from any moving components (fan blades, belts, accessories) and away from exhaust pipes and manifolds. Installing the module only requires the connection of two wires: ignition positive (not from the coil) and a good engine ground. The remaining wiring is terminated with the proper terminals and should not require any significant modification. If any wiring is required to be modified, use good electrical wiring repair practices (rosin core solder, heat shrink tubing, proper mechanical connections, etc.)

SETTING UP THE FUEL INJECTION SYSTEM

This system requires no preliminary tuning or adjustments. It is self-compensating for wear and fuel-quality variations. Special care must be taken to insure that no liquid propane enters the pressure regulator. It is recommended that the fuel tank be mounted vertically to prevent accidental liquid fuel withdrawal.