Converting Vehicles to Propane Autogas
Part 1: Installing Fuel Tanks and Fuel Lines

Scope of This Course

The purpose of this course is not to teach the user how to convert a vehicle to propane, but to enable the user to compare the basic code requirements with other technologies and installation practices and use them as appropriate.

At the time of this publication in the United States, the nationally recognized standards for vehicle conversions are found in National Fire Protection Association manual 58, *Liquefied Petroleum Gas Code* (NFPA 58). Some states have adopted additional or different code requirements. Users should check with the authority having jurisdiction in their areas to determine which requirements apply.

Please Notice

Readers of this material should consult the law of their individual jurisdiction for the codes, standards and legal requirements applicable to them. This material merely suggests methods which the reader may find useful in implementing applicable codes, standards and legal requirements.

This material is not intended nor should it be construed to:

1. *Set forth procedures which are the general custom or practice in the propane industry;*
2. *Establish the legal standard of care owed by propane distributors to their customers;*
3. *Prevent the reader from using different methods to implement applicable codes, standards or legal requirements.*

Please Notice

This material was designed to be used as a resource only to assist expert and experienced supervisors and managers in training personnel in their organizations and does not replace federal, state, or company safety rules. The user of this material is solely responsible for the method of implementation. The Propane Education & Research Council, and the Alternative Energy Division of the Railroad Commission of Texas assume no liability for reliance on the contents of this training material.

Issuance of this material is not intended to nor should it be construed as an undertaking to perform services on behalf of any party either for their protection or for the protection of third parties.

The use of specific products or manufacturers' trademarks, names or descriptions are used for reference and are not intended as an endorsement.

Caution

Always consult recognized standards (NFPA 58 or equivalent) and Original Equipment Manufacturer (OEM) installation publications when working with propane autogas systems. Pressure in fuel tanks and other propane autogas system components may exceed 300 psig.

Caution

Necessary safety precautions must be applied when installing, disconnecting or otherwise handling propane system components. Failure to apply adequate safety practices or failure to heed warnings while performing installation or repair procedures may result in serious personal injury or death to yourself or others.

Optional Unit Reviews

Review of Chapter 1

Directions: Select from the list below the response that most correctly completes each of the following statements. Write the letter of your choice in the space provided. Answers may be used more than once.

A.	-44	J.	10
B.	heavier	K.	frostbite
C.	colorless	L.	0.504
D.	1	M.	1.50
E.	1 ½%	N.	lighter
F.	24	O.	270
G.	15.5	P.	½
H.	natural gas	Q.	6
I.	NFPA 58	R.	1.5

___ 1. Propane vapor is ______ than air.

___ 2. Propane liquid weighs ______ as much as water.

___ 3. Propane expands in volume ______ times when it boils and changes from liquid to vapor.

___ 4. The specific gravity of propane vapor is ______.

___ 5. The stoichiometry ratio for propane by weight is ______:1.

___ 6. Propane is produced by the processing of crude oil and/or ______.

___ 7. Propane liquid is ______ than water.

___ 8. The boiling point of propane liquid at normal atmospheric pressure is ______ degrees F.

___ 9. The ideal air-to-fuel ratio of propane by volume is ______:1.

___ 10. The specific gravity of propane liquid is ______.

___ 11. Liquid propane can cause ______ when it comes in contact with body tissue.

___ 12. Propane liquid expands approximately ______ percent for every ______ degrees F increase in temperature.

___ 13.

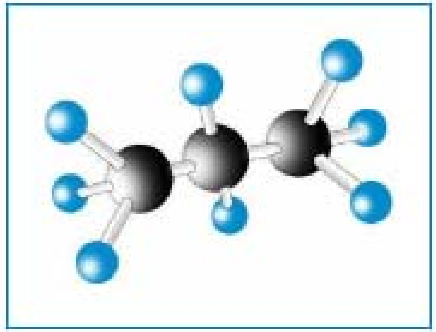
Scope of This Course

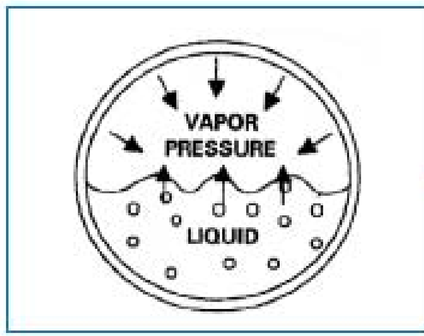
Additional references:

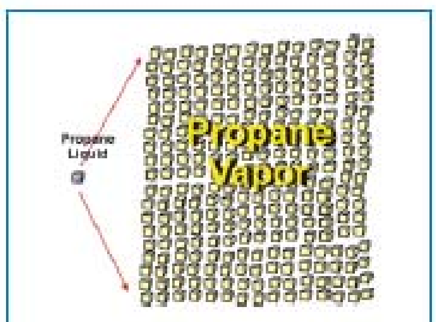
- CAN/CSA-B.149.5,Canadian Installation Code for Propane Fuel Systems and Tanks on Highway Vehicles
- EN67, the European standard for vehicles converted to LP-gas

NOTE: Canadian or European conversion standards are referenced to demonstrate that other options are available and practiced worldwide. It is the installer's responsibility to determine the appropriate practice for each individual installation.

In every aspect of a propane equipment installation, where explicit equipment manufacturers' installation instructions exist, those instructions must be followed.







Chapter One

Propane Fuel

Chapter 1: *Propane Fuel*

1.1.1 History of LP-Gas as an Engine Fuel

The use of LP-gas (liquefied petroleum gas) as an engine fuel is almost as old as the automobile itself. In the early 1900s, the main fuels available to power automobiles were gasoline and grain alcohol (ethanol). Gasoline rapidly became the overwhelming choice because of its price advantage and widespread availability, even though the refining practices of that time made it a highly volatile fuel that evaporated quickly.

Dr. Walter Snelling of the U. S. Bureau of Mines discovered a method of removing the lighter hydrocarbons from gasoline. He later identified these compounds as butane and propane, the primary constituents of LP-gas. The result improved motor gasoline and created a new LP-gas industry.

Developing practical means of separating butane and propane from crude oil and natural gas led to the first automobiles powered by LP-gas in the early 1900s.

Chapter 1: *Propane Fuel*

1.1.2 Changes in the Fuel Blend

Until World War II, LP-gas engine fuel was mainly butane. The discovery of new uses for butane, primarily in the petrochemical industry, directed most available butane away from the engine fuel market. Propane became the primary component of LP-gas engine fuel.

In 1963 the Gas Processors Association (GPA) adopted specification HD-5 for propane engine fuel. The purpose was to provide a uniform quality propane, so engines could be designed and tuned to deliver the best performance and fuel economy.

Chapter 1: *Propane Fuel*

1.1.3 Rapid Growth

The 1973 Arab Oil Embargo increased public interest in propane engine fuel. Suddenly gasoline was in uncertain supply and expensive, resulting in rapid growth of propane fuel-system retrofits in the late 1970s and early 1980s. By 1978 about 35,000 vehicles a year were being converted to propane in the U.S. By 1981 that number was nearly 250,000. In 1989 almost 4 million vehicles worldwide were powered by propane autogas.

Regulatory actions increased demand for alternative-fueled vehicles in the 1990s. Some states, such as Texas, Florida, and California, required the use of these fuels as early as 1989. With the 1990 amendments to the Clean Air Act, the United States required the use of alternative fuels in certain fleets. Although the price gap between gasoline and propane has subsequently narrowed, environ-mental concerns and cost savings continue to motivate fleets to convert their vehicles.

Chapter 1: *Propane Fuel*

1.1.4 Physical Characteristics and Properties

Like gasoline and diesel fuel, propane is a member of the hydrocarbon (HC) family. HC's are substances composed solely of hydrogen and carbon. There are thousands of HC's ranging from asphalt and heavy oils to light gases such as propane, butane, ethane, and methane, the primary component of natural gas.

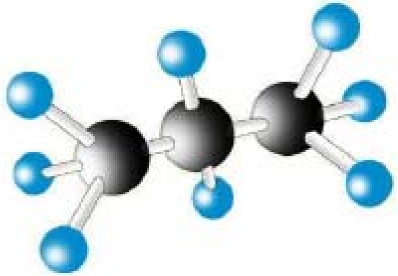


Figure 1. Propane Molecule

The number and arrangement of hydrogen and carbon atoms in a fuel's molecular structure is what gives each fuel its set of physical properties. At atmospheric pressure, propane (C3H8), butane (C4H10) and methane (CH4) are gases because of their relatively low molecular weight. At atmospheric pressure, gasoline, kerosene and diesel fuel are liquids because their molecules are much larger and heavier.

Chapter 1: *Propane Fuel*

1.1.5 Heat Content

Heating values are measured in British thermal units (Btu's). One Btu is the amount of heat required to raise the temperature of one pound of water one degree Fahrenheit.

Generally speaking, the more carbon atoms in a molecule of a given fuel, the greater its heat content or energy value.

One gallon of propane will produce 91,502 Btu's of heat energy, compared to 124,340 Btu's for one gallon of gasoline.

By weight, one pound of propane produces 21,548 Btu's, which is almost the same as gasoline.

Chapter 1: *Propane Fuel*

1.1.6 Odorant

Propane is odorless by nature, like butane or methane. An odorant, usually ethyl mercaptan, is added to give propane its distinctive, pungent smell.

The odorant acts as a warning agent so that leaks can be detected quickly.

NFPA 58 states that odorization at the rate of one pound of ethyl mercaptan per 10,000 gallons of propane has been recognized as an effective odorant. This rate allows the average person to detect a combustible mixture of air and fuel at a level of not more than 1/5 the lower flammability limit (2.1 percent fuel to air).[1]

1 NFPA 58, 2008 and 2011 editions, §4.2.1

Chapter 1: *Propane Fuel*

1.1.7 Specific Gravity

Propane liquid is lighter than water, and propane vapor is heavier than air. These physical characteristics are expressed as specific gravities.

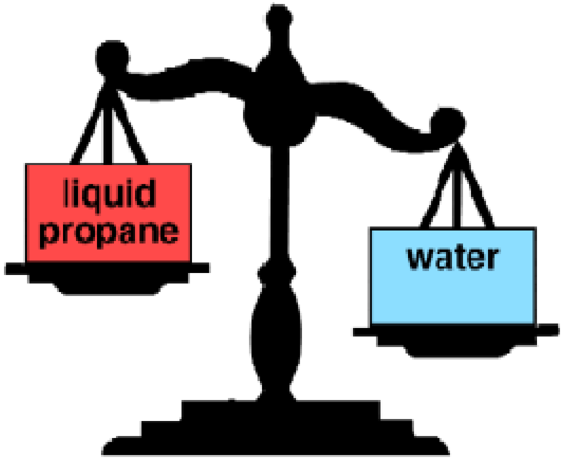


Figure 2. Propane liquid is lighter than water.

The specific gravity of a liquid is defined as the weight of a given volume of the liquid compared to the weight of the same volume of water, measured at the same temperature and pressure.

The specific gravity of water is defined as 1.0. A liquid that is twice as heavy as water has a specific gravity of 2.0, and a liquid that is half as heavy has a specific gravity of 0.5. The specific gravity of propane liquid is 0.504, which means propane liquid weighs about half as much as water.

Chapter 1: *Propane Fuel*

1.1.7 Specific Gravity

Repairs must be made either outdoors or in a well-ventilated area at least 25 feet away from any sources of ignition, such as smoking materials, open flames, electrical tools and lights, and at least 35 feet away from any metal grinding or oxy-welding operation.

Fueling and venting operations must be performed only outdoors, and unauthorized personnel should be kept away from the repair area.

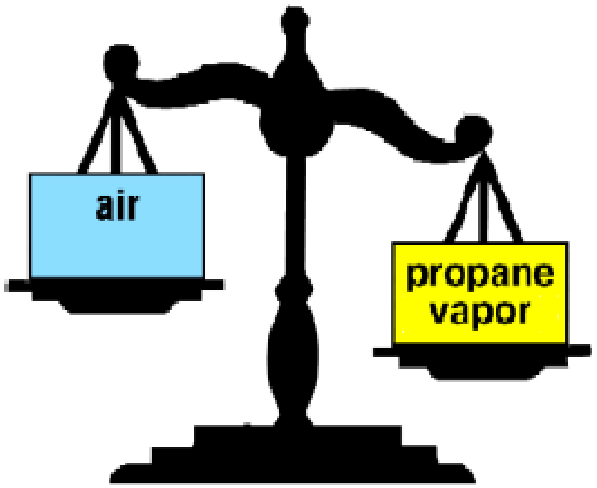


Figure 3. Propane vapor is heavier than air.

Chapter 1: *Propane Fuel*

1.1.8 Boiling Point, Temperature, and Pressure

Another important physical property of propane is its low boiling point. At standard atmospheric pressure (sea level), pure propane liquid boils (vaporizes) at any temperature warmer than -44°F. Below -44°F, propane will remain liquid at standard atmospheric pressure.

At temperatures above -44°F, propane will exist as a vapor unless it is kept under pressure, as in a container. Propane stored in a container exists as both a vapor and a liquid.

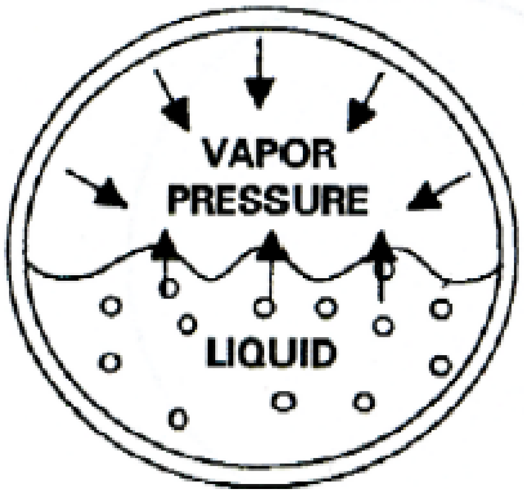
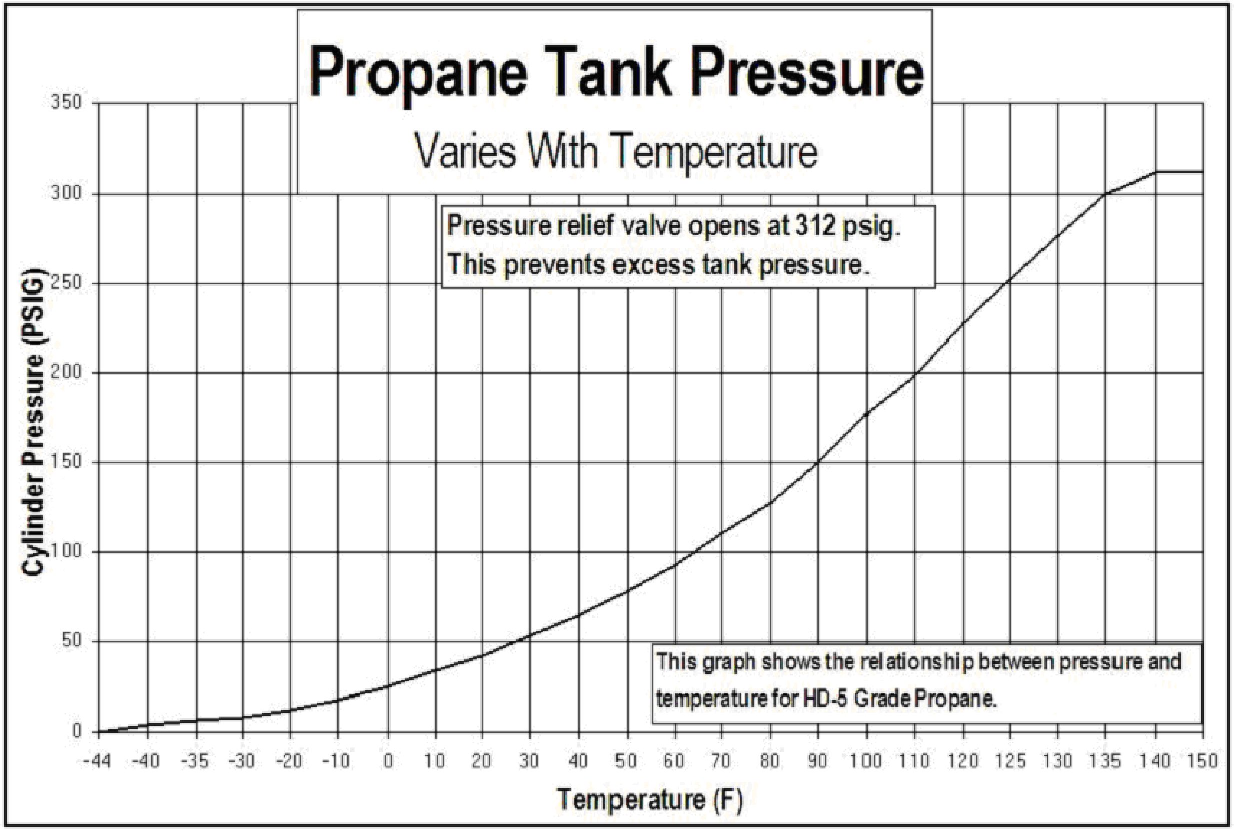


Figure 4. Propane liquid expands to 270 times its original volume when it vaporizes.

Chapter 1: *Propane Fuel*

1.1.17 Propane Fuel Containers and Fuel Lines

The vapor pressure of propane in a container varies with temperature.



Chapter 1: *Propane Fuel*

1.1.9 Expansion Ratio

If propane liquid is released into the air, it quickly vaporizes and expands to 270 times its original volume.

Therefore, a liquid propane leak can be more hazardous than a vapor leak due to the expanding vapor cloud.

Also, when liquid propane is released into the atmosphere, its rapid vaporization pulls heat from the surrounding air, causing a refrigerating effect that makes everything it touches extremely cold.

If propane liquid contacts skin or other tissues, it can cause third-degree freeze burns.

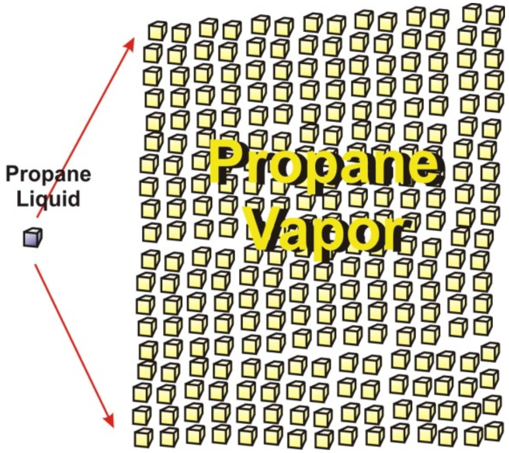


Figure 6. Propane liquid expands to 270 times its original volume when it vaporizes.

Chapter 1: *Propane Fuel*

1.1.11 Combustion Air/Fuel Ratio

Although propane vapor will burn in any mixture within its limits of flammability, combustion is most efficient and complete when there is just the right amount of fuel for the available oxygen in the air. The ideal combustion ratio for propane, also referred to as the stoichiometric[2] air/fuel ratio, is 15.5:1 by weight, i.e., 15.5 pounds of air for every pound of propane vapor.

The ratio is 24:1 by volume, i.e., 24 parts of air (96 percent) to every one part of propane vapor (4 percent).

[2] The term "stoichiometry" is used to describe complete combustion. SAE standard J1829 defines "stoichiometric air-fuel ratio" as "the mass of air required to burn a unit mass of fuel with no excess of oxygen or fuel left over." See **http://standards.sae.org/1829_200210**/.

Chapter 1: *Propane Fuel*

1.1.12 Octane Ratings

Octane ratings measure a fuel's resistance to detonation. Propane's octane rating (100-105) is higher than that of any premium gasoline.

Detonation occurs when the pressures inside the combustion chamber become too great for the fuel to burn evenly. Instead of a smoothly expanding flame front inside the cylinder, multiple flame fronts are formed and collide with one another, producing a sharp pinging or spark knock that signals detonation.

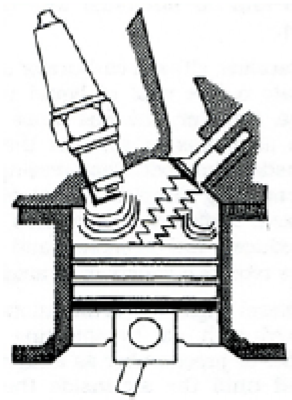


Figure 7. Detonation

Vibration created by these colliding flame fronts can quickly damage an engine.

Chapter 1: *Propane Fuel*

1.1.13 Combustion Characteristics

Propane is a vapor at standard temperature (60°F) and standard atmospheric pressure (one atmosphere or 14.7 psi absolute). Gasoline and diesel fuel are liquids under these conditions. They must be vaporized to burn well.

In a gasoline fuel system, a carburetor or fuel injector creates a fine mist of liquid fuel. To vaporize completely, the fuel must pick up additional heat as it passes through the intake manifold and enters the combustion chamber. Compressing the fuel helps the droplets of gasoline mix and vaporize. If gasoline is not completely vaporized, inefficient combustion causes higher exhaust emissions and reduces fuel economy and performance. Therefore, gasoline engines require a variety of strategies to aid cold-starting.

1.1.14 Emissions

All internal combustion engines produce emissions, but some fuels produce less than others. The main regulated compounds in engine exhaust are hydrocarbons (HC's), carbon monoxide (CO), and various oxides of nitrogen (NOx). Some jurisdictions also regulate emissions of carbon dioxide (CO2).

In addition to catalytic converters that treat exhaust, late-model passenger cars and most light- and medium-duty trucks have charcoal canisters that trap evaporative emissions from the gasoline fuel tank. These vapors are drawn into the engine and burned when the engine is started. Although the canisters absorb much of the fuel vapor, a saturated canister can still release raw HC's into the atmosphere. Studies indicate that HC's may account for as much as 20 percent of total emissions from a vehicle.

Propane fuel systems are sealed to maintain pressure and are therefore less likely to produce evaporative emissions.

Chapter 1: *Propane Fuel*

1.1.15 Engine Performance

Many engines perform better on propane than on gasoline. One reason is that propane mixes more readily with air. Propane's higher octane rating also allows the engine to use a more aggressive ignition timing curve at lower rpm and still resist detonation. On engines where timing is controlled by an on-board computer, some propane fuel systems use a modified OEM computer that has been reprogrammed with a new fuel and ignition timing map.

Another factor that contributes to increased performance is a denser air/fuel mixture entering the cylinders. Since propane is already vaporized when it enters the intake manifold, heating is not necessary or desirable. Lower intake temperatures promote a denser mixture for more power.

Chapter 1: *Propane Fuel*

1.1.16 Engine Maintenance and Life

Clean combustion extends spark plug life, decreases valve train wear, and reduces wear on internal engine components, thus extending engine life and reducing maintenance costs.

When sludge and acid build up as a result of combustion blow-by, especially during engine warm-up, additives in the engine oil are rapidly used up. Bearings, rings, valve guides, cam lobes, and other friction surfaces wear more rapidly as the lubricant breaks down. Propane virtually eliminates the buildup of carbon, varnish and sludge inside the engine. Fewer contaminants in the crankcase means that oil change intervals may be safely extended.

Chapter Two

Basic Safety Considerations

Chapter Three

Pre-Conversion Inspection/Validation

Chapter 3: *Pre-Conversion Inspection/Validation*

3.1 Validating a Vehicle Prior to Conversion

Vehicles being considered for conversion to propane should be carefully screened to ensure satisfactory results. Not every vehicle can or should be converted. This pre-conversion checklist will help you decide whether a vehicle is a good candidate for conversion.

Chapter 3: *Pre-Conversion Inspection/Validation*

3.1.1 Pre-Conversion Checklist

The customer should be advised that any defects in the vehicle should be remedied prior to conversion. A vehicle may be declined for conversion if the defects cannot be remedied. Customers sometimes mistakenly assume that:

- A used vehicle that has been converted to propane will be restored to like-new condition;
- Any and all existing vehicle defects will be repaired during the conversion;
- The conversion facility will repair any failure of any component after the vehicle is converted, even if the failure is not conversion related.

A pre-conversion inspection should be performed on every candidate vehicle, including new vehicles, to avoid misunderstandings or wasting time and resources on a conversion that will not work out either short- or long-term.

Chapter 3: *Pre-Conversion Inspection/Validation*

3.1.2 Converting High-Mileage Vehicles

The conversion facility should consider a thorough inspection of the engine and engine compartment, including any noises, leakage or smoke, before converting a vehicle that has accumulated more than about 60,000 miles.[1] An engine oil analysis is strongly recommended.

1 60,000 miles is a rough guideline and may not reflect the actual condition of the candidate vehicle. Conversion facilities should adopt their own criteria for determining a high-mileage vehicle.

Chapter 3: *Pre-Conversion Inspection/Validation*

3.1.2 Converting High-Mileage Vehicles

- A compression or leak-down test **<u>may</u>** be performed on high-mileage vehicles. Any compression reading that varies more than 15 percent from the highest reading should disqualify a vehicle from conversion. A wet and dry compression test may indicate where engine wear may be located.

WARNING!

Performing a compression test on a high-mileage vehicle introduces the possibility of spark plugs breaking during removal, which will then require extensive repairs.

Chapter 3: *Pre-Conversion Inspection/Validation*

3.1.2 Converting High-Mileage Vehicles

- Any vehicle that shows visible white, blue, or black smoke during starting should be disqualified from conversion. The exhaust tailpipe should not have any oily or moist dark soot or film inside the pipe. The tailpipe should be dry.
- Connect a diagnostic scan tool to the diagnostic connector port. Check and verify any current or pending diagnostic trouble codes (DTCs). Verify operation of the oxygen sensors, especially the post-catalyst sensor, to verify proper catalytic converter operation. Also inspect short-term fuel trim (STFT) and long-term fuel trim (LTFT) values. They should be near zero.

Chapter 3: *Pre-Conversion Inspection/Validation*

3.1.2 Converting High-Mileage Vehicles

- Inspect the transmission. A transmission fluid analysis is strongly recommended. Transmission servicing or fluid changes should only be performed by a qualified transmission repair facility. If the transmission is leaking fluid at the input shaft or drive shaft seals, or if it shifts roughly, these conditions should be documented.
- Inspect the cooling system. Verify the condition of the radiator, all hoses, drive belts, coolant and coolant overflow bottles. Check for visible cooling system corrosion, and verify that the engine's cooling fans are operating and cycling properly.
- Inspect the exhaust system, including manifolds, exhaust pipes, catalytic converters, mufflers and tailpipes. Verify and document any exhaust-system modifications.

Chapter 3: *Pre-Conversion Inspection/Validation*

3.1.3 Pre-Conversion Test Drive

Cold and hot temperature starting:

- Cold temperature means at least four hours since the last restart.
- Hot temperature means no more than 10 minutes since the last restart following full-temperature operation. If the vehicle has electric cooling fans, they should cycle at least once without the air conditioning being engaged. This verifies that the engine is at full operating temperature.

Chapter 3: *Pre-Conversion Inspection/Validation*

3.1.2 Vehicle Sign-In Form—All Vehicles

The first step is to clearly identify the vehicle in a sign-in form or work order. This document should include, as a minimum:

Vehicle Owner	This means the owner of the vehicle, not the driver. For example, use "South Central Utility District" or "City of Industry," not "Michael Jones," unless he is the owner of a private vehicle or fleet. If in doubt, use the name on the purchase order or contract.
Vehicle Address	May require two or more entries. The primary entry should be the billing address, or the address used on the purchase order or contract. The second address may be where the vehicle is based, e.g., a service center or utility district field office.
Vehicle Make and Model	This should clearly identify the make of vehicle, e.g., Chevrolet or Ford, and the model, e.g., C-1500 or F-150.

Chapter 3: *Pre-Conversion Inspection/Validation*

3.1.2 Vehicle Sign-In Form—All Vehicles

The first step is to clearly identify the vehicle in a sign-in form or work order. This document should include, as a minimum:

Body Style	This should identify the body type, e.g., king cab, super crew, extended cab, station wagon, SUV, CUV, cab and chassis.
Vehicle License Number	Print the license number of the vehicle. If the vehicle has not yet been issued permanent license plates, use the last 8 numbers of the VIN (see below). These numbers indicate the model year, place of manufacture, and a sequential number.
VIN	The manufacturer's permanent vehicle identification number. If the manufacturer has two identification numbers (e.g., cab and chassis, with an added utility body), the primary identification number, usually the chassis number, should be used.

Chapter 3: *Pre-Conversion Inspection/Validation*

3.2.1 Vehicle Checklist After Customer Sign-In

The checklist should include a thorough vehicle inspection, including all of the following points.

Photograph the vehicle, including the vehicle VIN tag. Photograph the vehicle from all four corners; verify any information markings (license plate, door ID number, etc.) are visible.

Document any anomalies.

Chapter 3: *Pre-Conversion Inspection/Validation*

3.2.1 Vehicle Checklist After Customer Sign-In

The conversion facility should inspect:

- All body panels for paint mismatch which might indicate an accident repair;
- All body panels for dents, scratches, blemishes, or other defects;
- All front and rear windows and door glass for scratches;
- All doors for window operation;
- All doors for latch and locking operation;
- All interior lighting;
- All exterior lighting, including headlights, tail lights turn or directional signals, backup alarms or sensors;

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Chapter 3: *Pre-Conversion Inspection/Validation*

3.2.1 Vehicle Checklist After Customer Sign-In

The conversion facility should inspect:

- Interior accessories including:
  - Air conditioning,
  - Heating,
  - Radio or other entertainment features (CD, DVD, GPS, Nav-Con), and
  - Additional communications or emergency equipment;
- Interior for upholstery stains or other interior damage or imperfections;
- Tires for manufacturer name, depth, proper rating for the vehicle, plus inspect for different size tires or tire size not appropriate for the vehicle;

Chapter 3: *Pre-Conversion Inspection/Validation*

3.2.1 Vehicle Checklist After Customer Sign-In

- **Under-Hood Modifications (Photo-Document)**
  - Additional batteries
  - Sirens
  - Alarms
  - Radio or other communication devices
  - Emergency vehicle charging or cooling system modifications
  - Customer-added performance or cosmetic changes for modifications

Chapter 3: *Pre-Conversion Inspection/Validation*

3.2.1 Vehicle Checklist After Customer Sign-In

When all items on the vehicle checklist are identified, and both the conversion facility and the customer accept the vehicle's condition and agree the vehicle should be converted to propane, the vehicle should be considered suitable for conversion and the process may begin.

Chapter Four

Tanks

Chapter 4: *Tanks*

4.1 Tanks and Tank Installations

In the U.S., all propane containers are classified as either ASME tanks or DOT cylinders.[1]

ASME and DOT containers have different physical configurations and different end-use applications. They are not interchangeable and should not be adapted or modified for end-use applications they were not designed for. Only containers that have DOT or ASME certification may be installed legally on vehicles in the U.S.

This course considers only ASME tanks. DOT cylinders are mainly used for industrial and off-road applications such as forklifts, mowers, conveyor belts, floor buffers or scrubbers.

1 NFPA 58, 2008 ed., §11.3.1.1

Chapter 4: *Tanks*

4.1 Tanks and Tank Installations

There are two types of tank installations:

Tanks are selected for a specific installation based on the propane fuel system type as specified by the conversion equipment manufacturer. Two types of tanks are currently in use:

- Open vehicle installation, where the tank is installed in the bed of a pickup truck, under a truck body, or on a school bus, or
- Enclosed vehicle installation, where the tank is installed inside a sedan, SUV or van.

Chapter 4: *Tanks*

4.1 Tanks and Tank Installations

There are also two types of tank designs:

- Vapor pressure type: Tanks that use propane's vapor pressure to push liquid fuel to the engine for conversion to vapor, for example, in a vapor fuel-injection system;
  and
- Integral pump type: Tanks that use an integral fuel pump to elevate output pressure as needed, for liquid propane fuel-injection systems.

Chapter 4: *Tanks*

4.1 Tanks and Tank Installations

Figure 9 shows a traditional propane autogas fuel tank installed in the bed of a pickup truck. The tank is used in liquid service to supply fuel to a vapor fuel-injection system.

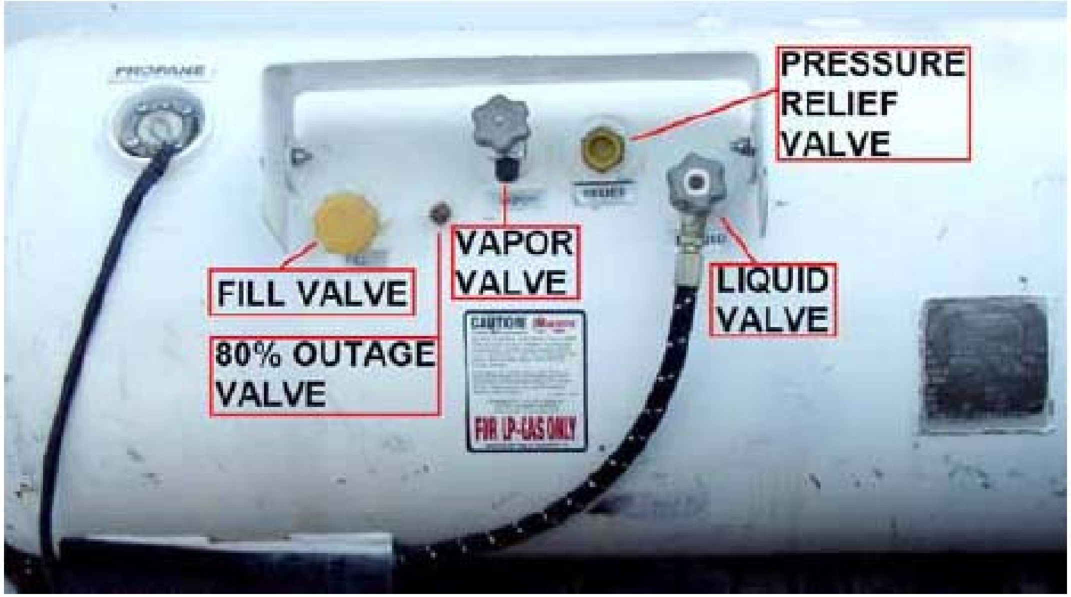
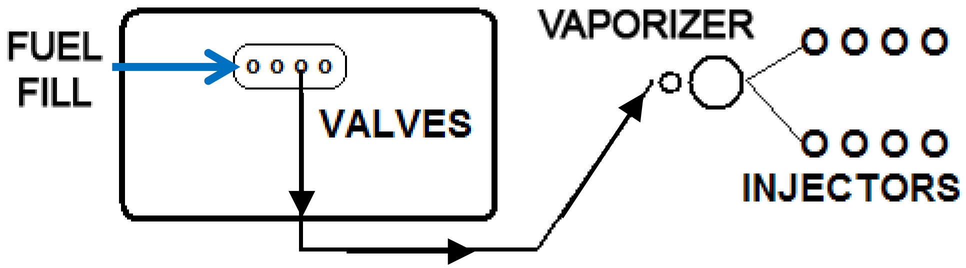


Figure 9. Propane autogas fuel tank

Chapter 4: *Tanks*

4.1 Tanks and Tank Installations



Vapor fuel injection systems use a conventional autogas tank with separate fill and service valves. The tank supplies propane liquid to a vaporizer, which changes the liquid to vapor and meters the vapor to the fuel injectors.

Chapter 4: *Tanks*

4.1 Tanks and Tank Installations

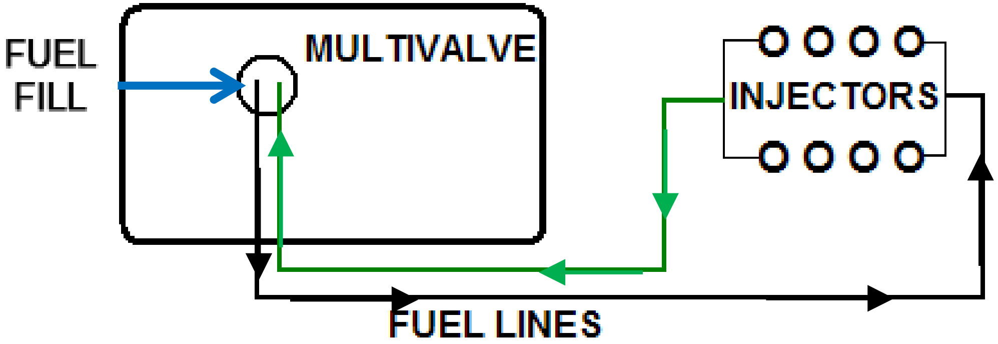
Figure 10. LPI tank valves. The valves are located under the access plate. See Figure 11.

Figure 11. LPI tank access plate

These tank valves are typical of Roush CleanTech and CleanFUEL USA Liquid Propane Fuel Injection systems. The tanks are similar to vapor service tanks, except the fuel pump is located inside the tank. Access to the fuel pump is through a flanged "multi-valve" containing switches, sensors, solenoids, and manual service valves where applicable.

Chapter 4: *Tanks*

4.1 Tanks and Tank Installations



Liquid fuel injection systems use a proprietary fuel tank with an integrated multivalve and an integrated fuel pump that supplies propane liquid to the injectors. Excess or partially vaporized fuel is returned to the tank.

Chapter 4: *Tanks*

4.2 Tank Selection

Selecting an appropriately sized tank is critical. An oversize tank will add to the vehicle's gross weight, alter its center of gravity and affect its towing and payload capacity.

CAUTION!

Fuel containers are heavy and require the use of either a jack or lift to aid in the installation. Never attempt to lift a tank unassisted.

The capacity of an ASME tank is stated on the data plate in gallons of water capacity (gallons WC). Propane capacity is 80 percent of water capacity and may not be shown on the data plate.

Chapter 4: *Tanks*

4.2.1 Size Considerations

Weight considerations are more important for bifuel (gasoline and propane) vehicles than for dedicated (propane-only) vehicles. Removing the gasoline tank for a dedicated conversion can offset the weight of the propane tank, since propane weighs about 2/3 as much as gasoline. Some upfitters, such as Roush CleanTech, size their tanks to match the vehicle's original weight classification and payload.

Chapter 4: *Tanks*

4.2.4 Tank Locations

Fuel containers may be located on, within or under a vehicle, with certain limitations (Figure 14). The basic requirements about side and ground clearance are well described in NFPA 58, Chapter 11.[6]

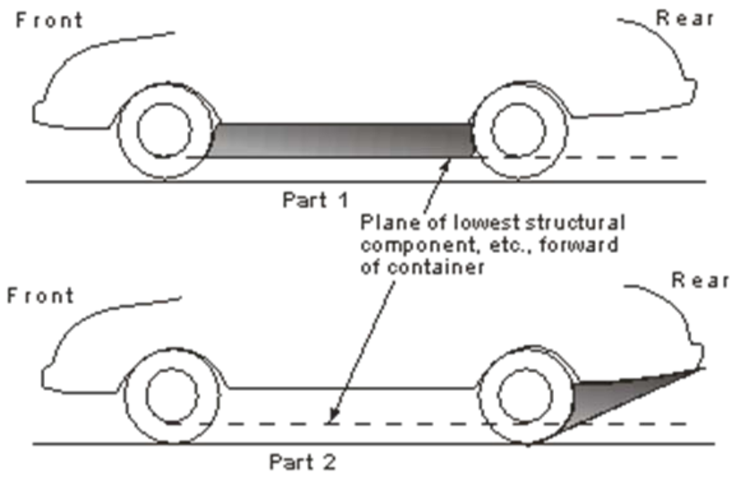


FIGURE 11.8.3.4 Container Installation Clearances.
Source: NFPA 58, *Liquefied Petroleum Gas Code* (2011)

Figure 14. Tank Clearances

6 NFPA 58, 2008 ed., §11.7 inclusive; NFPA 58, 2011 ed., §11.8 inclusive

Chapter 4: *Tanks*

4.4 Installation Requirements and Options

A propane autogas tank must be attached to the vehicle using suitable fasteners that will not jar loose, slip or rotate. The fasteners must withstand without permanent deformation a static force applied in any direction equal to four times the weight of the container filled with fuel.[9]

For example, if a full tank weighs 350 lbs., then the tank installation must withstand a static force equal to four times that weight, 1,400 lbs., in six directions—up, down, left, right, front, rear—without slippage or deformation of the fasteners. Canadian code (B149.5) requires that all brackets have a minimum strength capable of retaining the tank at a force of 20 times the weight of the full container vertically, and 8 times the weight of the full tank in any direction horizontally.

9 NFPA 58, 2008 ed., §11.7.4.1; NFPA 58, 2011 ed., §11.8.4.1

Chapter 4: *Tanks*

4.4 Installation Requirements and Options

Most propane autogas tanks manufactured in or supplied for North American use have mounting lugs or plates with pre-installed ½" NC weld-nuts. Many U.S. manufacturers and all European tanks have mounting lugs or plates with provisions for m10X1.25[10], m12X1.50, or m14X2.0 metric fasteners. NFPA 58 does not specify the size, type or grade of fasteners, which leaves the decision to the installer or engineering team. Many installers use a ½" NC grade 5 or grade 8 bolt with suitable washers and a nut to retain the bolt.

10 Most fuel system components are designed and shipped with metric fasteners. These fasteners are specified "M" for metric, followed by the diameter and thread pitch in millimeters. For example, M10X1.50 designates a metric bolt, 10 mm in diameter, with a 1.50 mm thread pitch (i.e., distance between threads). The bolt head may be marked with tensile strength grades (8.8 or 10.9) that are equivalent to U.S. grade 5 or grade 8 bolts.

Chapter 4: *Tanks*

4.4 Installation Requirements and Options

OPTION 1

Using a flat washer located under the fuel tank retaining bolt head and nut to reinforce the body or sheet metal is recommended. The material to which the tank is fastened often determines the type of retention hardware used. If the tank is mounted to a frame rail, a simple flat washer is all that is required. If the tank is mounted to sheet metal in the bed or trunk of a vehicle, a more robust means should be provided.

Figure 18. Bed-mount installation that also serves as a tank mount

In Figure 18, the tank retaining bolt (1/2” x 5” NC Grade 8) passes through the bed and the reinforcing rib, then through the frame mount. This location replaces the original bed mounting bolt. If other bolts pass directly through the vehicle bed, load-spreading fasteners should be used.

Chapter 4: *Tanks*

4.4 Installation Requirements and Options

OPTION 2

A flat plate is located under the retaining bolt heads or nuts. The location will dictate the actual size; 2” to 3” round or square plate steel is typical. The plate spreads the clamping force and distributes the load.

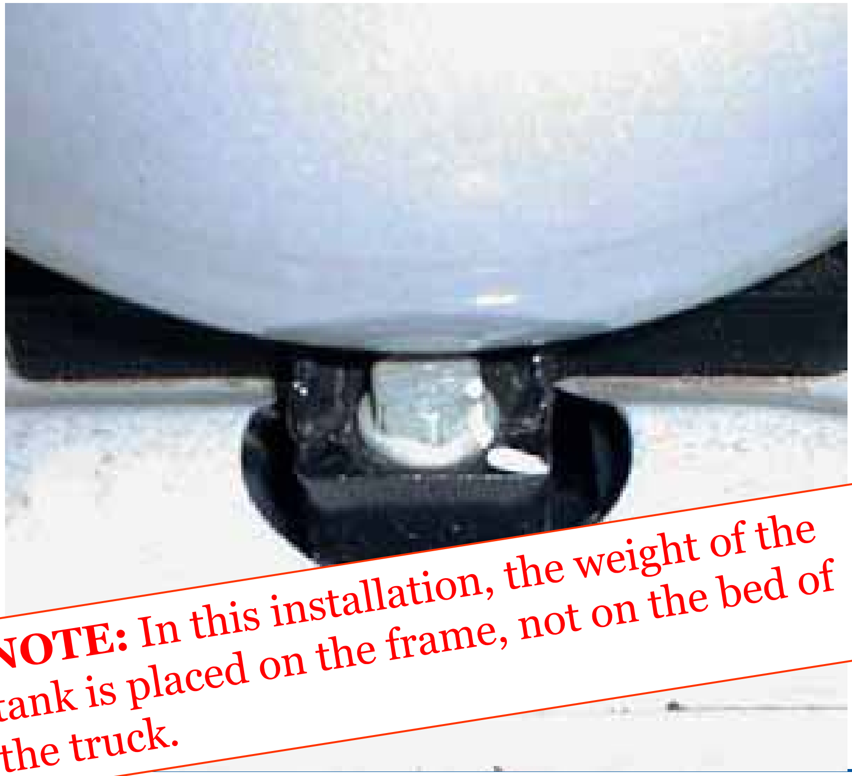
Figure19. Load-spreading washer located under vehicle bed

Figure20. Load-spreading washer located under vehicle bed

Chapter 4: *Tanks*

OPTION 3

This OEM application uses a frame-supported cradle that mounts through the bed.



NOTE: In this installation, the weight of the tank is placed on the frame, not on the bed of the truck.

Chapter 4: *Tanks*

4.4.3 Tanks Located Under the Vehicle

If the tank is located closer than 18” to any heat-producing component (exhaust system, engine, transmission, air conditioning discharge), a non-combustible baffle or heat shield with an air gap on both sides must be positioned between them.[17] The chassis or frame may serve as the heat shield. Installers may add additional protection of the tank or tank valves as needed, as long as the tank’s valves and fittings remain accessible.

Any fuel-carrying component in close proximity to a heat-producing source should be protected from radiant heat by shielding or other insulation.

[17] NFPA 58, 2008 ed., §11.7.1.3 ; NFPA 58, 2011 ed., §11.8.1.3

Chapter 4: *Tanks*

This twin manifold tank is located under the rear of a one-ton truck, where the second gasoline fuel tank was originally located. Note the shielding between the exhaust tailpipes and the rock guard protecting the tank's valves.

Chapter 4: *Tanks*

This underbody tank is located outside the frame rail on a one-ton truck. The placement of the exhaust catalyst prohibits the propane tank from being installed inside the frame rail.

4.4.3 Tanks Located Under the Vehicle

This toroidal (donut-shaped) tank is located under the rear of a ¾-ton truck, where the spare tire was located. This installation utilizes heat-reflective wrapping that shields the tank from the vehicle's exhaust tailpipe. This type of tank is also available for interior mounting and is frequently installed in the spare tire location.

Chapter 4: *Tanks*

4.4.4 Tanks Located Inside the Vehicle

Fuel tanks located inside a vehicle must have a vapor-tight barrier or seal that keeps any leakage from valves or fittings from entering the passenger compartment.[18] The barrier or seal typically takes the form of a metal box or similar apparatus that fits around the valves and fittings on the tank.

Access to the valves and fittings is gained by removing the vapor seal box access panel. Codes require that the valves be accessible without the use of tools.[19]

CAUTION

If the vapor seal enclosure retention mechanism is retained by bolts that are installed through the float-level gauge, the bolts should not be removed if the tank is pressurized. The fuel gauge O-ring may be forced out, resulting in an uncontrollable leak.

18 NFPA 58, 2008 ed., §11.8; NFPA 58, 2011 ed., §11.9

19 NFPA 58, 2008 ed., §11.7.4.3; NFPA 58, 2011 ed., §11.8.4.3

Chapter 4: *Tanks*

4.4.4 Tanks Located Inside the Vehicle

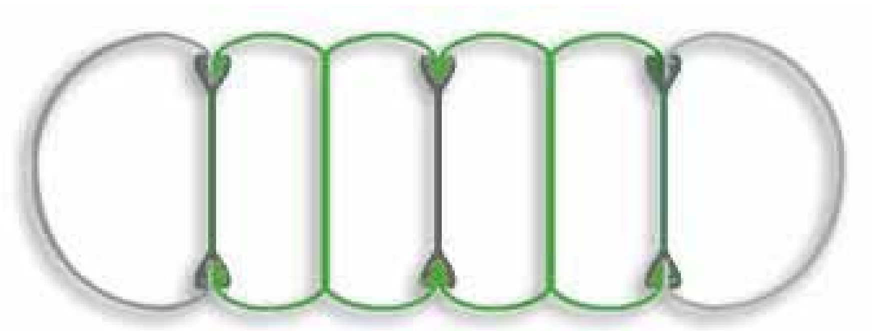
Tanks mounted inside the vehicle are required to be vented to the outside. All the valves and fittings are located inside the vapor seal box, and all related fuel lines must be routed through conduit or flexible tubing that is sealed to the tank box. In addition, the opposite end of the conduit tubing should be secured to the vehicle by a flange or other suitable fitting. This practice ensures an air-tight and gas-tight installation.

Chapter 4: *Tanks*

4.4.6 Other Tank Options

Conformable tanks may be manufactured to the specific dimensions of a vehicle and would ideally fit in the original gasoline fuel tank's location.

Fully metallic conformable tanks allow unique installations. The conformable tank is made from extruded sections that are then welded together.



Note the vapor enclosure covering the valves and fittings.

Chapter 4: *Tanks*

4.4.6 Other Tank Options

A triple conformable tank installation on a large truck

Underbody conformable tank installation

Chapter 4: *Tanks*

4.5 Tank Installation Process

If the converted vehicle is to be dedicated propane, the gasoline tank and its related support brackets and fuel lines must be removed. Safe and careful handling of gasoline should be practiced. A gasoline tank may be heavy or unwieldy, especially if the tank still contains gasoline.

A tank jack or modified transmission jack will assist in the removal process. Do not attempt to remove a gasoline tank without the aid of proper support devices or additional help.

Before drilling into any body or bed panel or in any frame section, ensure that there is sufficient clearance on the opposite side of the structure.

Chapter 4: *Tanks*

4.5 Tank Installation Process

Repeated trial fittings will probably be required, especially if only one vehicle is being converted. If more than one vehicle is being converted with the identical vehicle and tank configuration, a drilling template may be made and used during the installations. If the tank will be installed inside the trunk of a sedan, additional trial fittings may be required.

Fuel tanks usually provide at least four mounting points. Access to the two front mounting points may be difficult. For installations in a sedan, the rear seat may need to be removed to provide access. All four mounting points should be used unless the tank mounting is part of an engineered mounting system.

Other items such as sound-system components or the trunk-release mechanism may also need to be removed temporarily and later reinstalled or relocated.

Chapter 4: *Tanks*

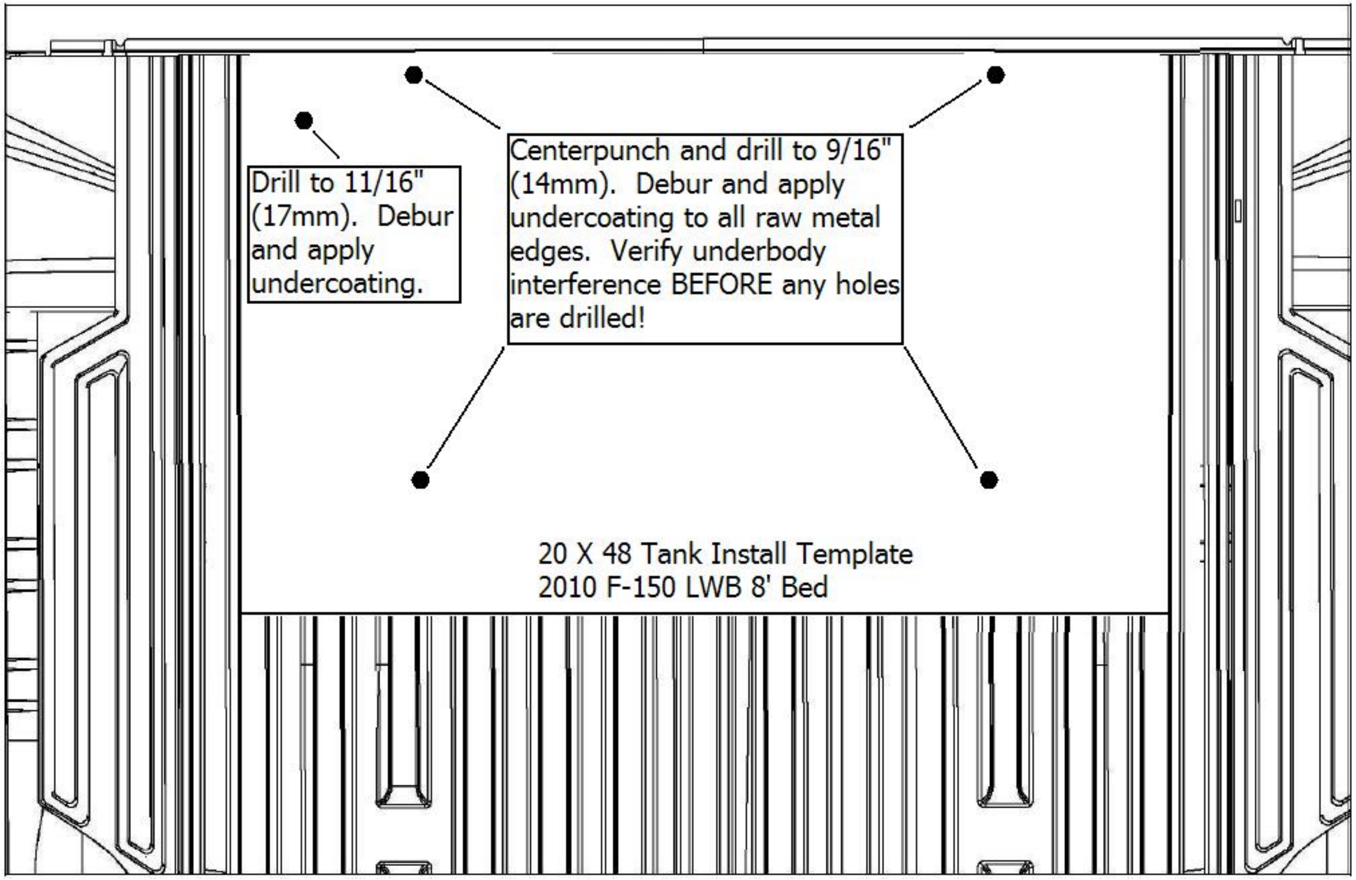
4.5 Tank Installation Process

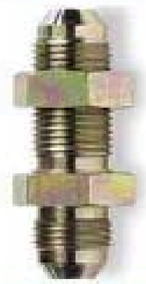
When fuel tanks are installed inside an enclosed vehicle, at least one suitably sized hole for vent-away hoses will be required. Additional holes may be required to provide routing for the vent hoses and fuel lines.

Holes should not be located in a wheel well or exposed to wheel spray or road debris. The exact location of a vent hole will depend on the application. Installing a mounting flange is recommended to provide a secure mounting location for the vent hose. This flange will be fastened over the vent hole that was previously drilled in the body panel.

Chapter 4: *Tanks*

4.5.1 Underbody Access





Chapter Five

Fuel Transfer Lines

Chapter 5: *Fuel Transfer Lines*

5.1 Standards

Federal Motor Vehicle Safety Standards (FMVSS) for automobile manufacturers include standards for protecting fuel lines from impacts and preventing leaks.[1]

FMVSS standards do not dictate the actual routing or location of fuel lines. They require only that the lines survive vehicle impacts. It is the vehicle manufacturer's responsibility to demonstrate and verify the integrity of each line through engineering studies, computer simulations or crash testing. As a result of this testing, brake and gasoline fuel lines are routed in the most protective location on a vehicle. Accordingly, these locations should also be the locations of choice for routing propane autogas fuel lines.

1 FMVSS 501.301, fuel system integrity.

Chapter 5: *Fuel Transfer Lines*

5.2 Hose Types

OPTION 1

"User-build" hose is acceptable to all jurisdictions in the U.S., but is seldom used in OEM applications and may not be approved for Canadian, European or Australian use. It is typically, but not always, identified by its quilt wrap with stainless steel reinforcement and rubberized inner lining.

Chapter 5: *Fuel Transfer Lines*

5.2 Type III Hose

OPTION 2

Type III hose is preferred by the OEM's and most industrial forklift manufacturers. This hose typically has a rubberized outer cover with a stainless steel wire braid reinforcement over a nylon inner lining.

Chapter 5: *Fuel Transfer Lines*

5.2 Type III Hose

OPTION 2

Type III hose, as required by code in Canada and used by U.S. OEM applications. It is seldom used in U.S. aftermarket conversions due to the additional cost and limited availability.

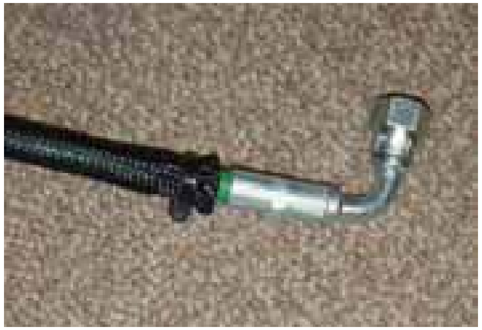
Composite hose with high-temperature silicone outer protective sleeve, installed at assembly. This hose will resist direct heat impingement from a flame or exhaust.

Chapter 5: *Fuel Transfer Lines*

5.2 Type III Hose

OPTION 2

Composite hose with an abrasion-resistant outer covering, installed after assembly.



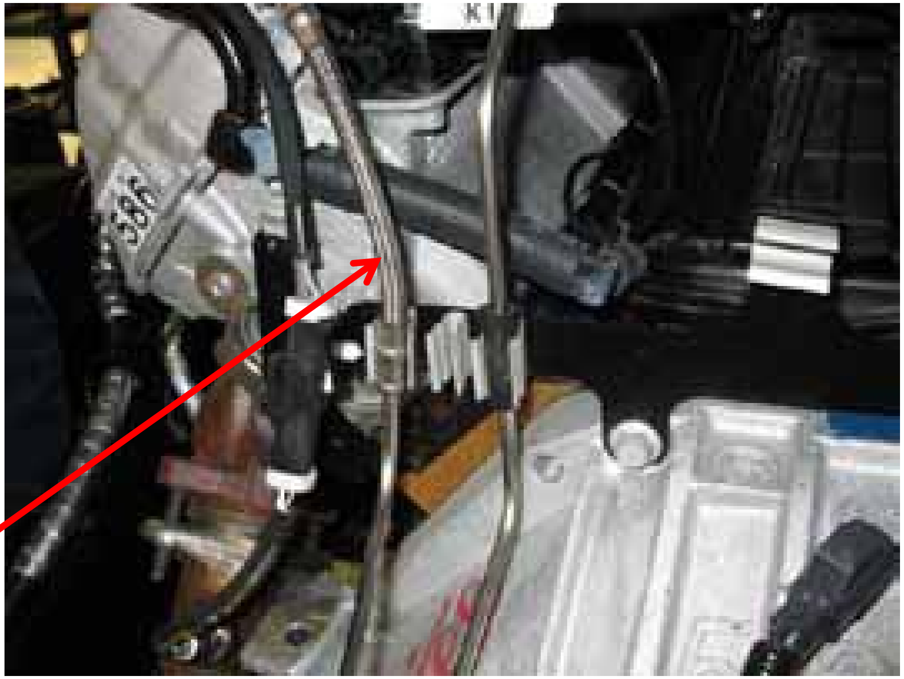
Stainless steel external braid nylon-lined flexible hoses allow for different tank configurations and a universal installation.
Stainless steel braid hoses are pre-fabricated by a certified hose manufacturer. Field repairs or modifications are not permitted.

Chapter 5: *Fuel Transfer Lines*

Rigid fuel lines do not seep, but special provision must be made to allow movement between fixed components by providing enough flexibility in the lines or a unique flexible joint. Rigid fuel lines should be protected against abrasion and road debris by a protective sheath, coating, or other abrasion-resistant protection.

OPTION 3

These metal fuel lines represent current state-of the-art technology. Both metal and composite hose/tube construction are currently used in OEM applications. Metal fuel lines are typically pre-formed and are not adaptable to different vehicle applications. These fuel lines are custom-fabricated based on wheelbase, cab and bed length. Note the flexible joint allowing some movement.



Chapter 5: *Fuel Transfer Lines*

5.3 Fuel Line Mounting and Routing

Although NFPA 58 does not specify exact fuel line locations, fuel lines should not be routed in locations where they may become damaged due to body and frame movement, road debris, tire damage, service damage, under or over frame rails, or through frame rail openings where the fuel line may become damaged due to a “scissor” action.

Routing fuel lines inside a box-type enclosed frame rail is prohibited for safety reasons. Even though such routing would protect the line from impact, heat, abrasion, and other potential damage, it would also prevent leak testing and inspection and provide no opportunity to inspect the internal box frame location for sharp edges or pinch points.

OEM’s typically prefer to route fuel lines near the existing fuel and brake lines, as they tend to be well protected from impact. Installers at the OEM level have the advantage of selecting or fabricating fuel-line retaining brackets that replicate the mounting configuration of the gasoline and brake lines. Aftermarket installers may have to use other means of ensuring a secure fuel-line routing, but if at all possible, they should attempt to follow the OEM fuel-line locations.

Chapter 5: *Fuel Transfer Lines*

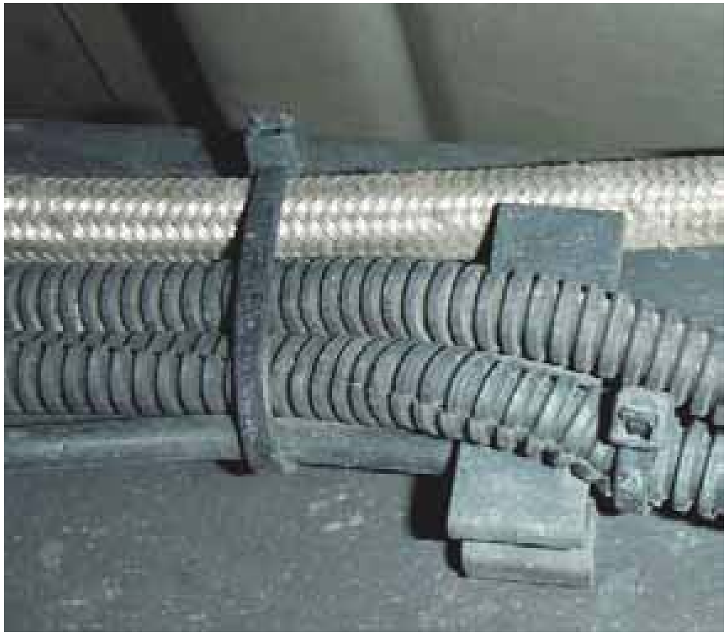
5.3 Fuel Line Mounting and Routing

Plastic zip-ties may be acceptable as long as the fuel line is securely fastened to a rigid body or chassis component and not fastened to an emergency brake cable, suspension component or axle. Zip-ties are available in several grades, colors, and heat- and UV-resistance ratings. If zip-ties are used, they should be rated for the highest heat and UV resistance available.

OPTION 1

The plastic zip-tie is satisfactory for securing fuel lines, but may deteriorate with age and exposure to heat.

This installation shows a Type III stainless steel hose with a nylon inner core routed along with the original nylon gasoline fuel hose and existing wire harness.

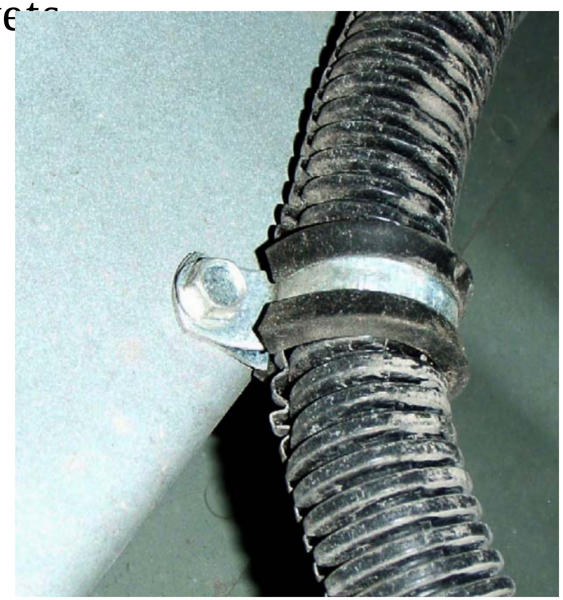


Chapter 5: *Fuel Transfer Lines*

5.3 Fuel Line Mounting and Routing

OPTION 2

The Adel-type clamp originated in the aviation industry. These clamps have rubber insulators around a metal band and are secured to a body or frame member by self-tap screws or click-type rivets.



Chapter 5: *Fuel Transfer Lines*

5.3 Fuel Line Mounting and Routing

An alternative is to position fuel lines in locations that would be used by the OEM if they were designing the fuel system, e.g., paralleling the positions of gasoline, diesel and brake lines and electrical cables. Fuel lines should not pass between body panels, under the frame rail, between the frame and body, or through a frame rail.

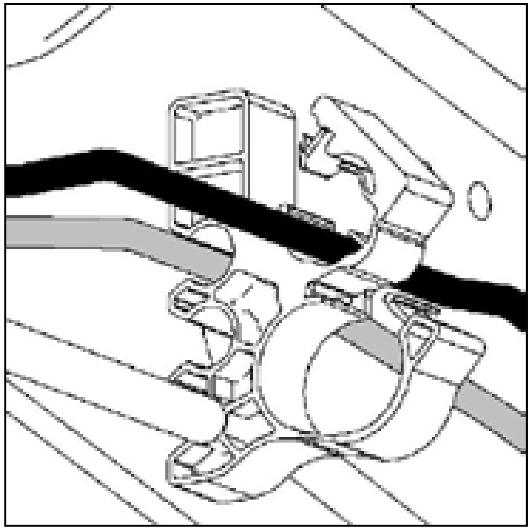


Figure 57 Existing fuel line clip

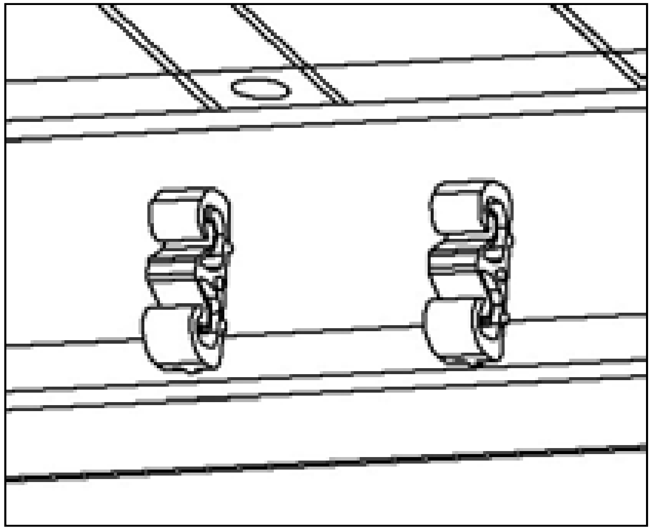


Figure 57 Clip supplied by the manufacturer

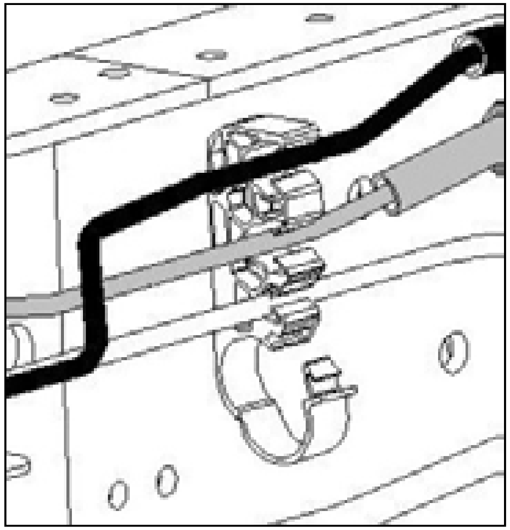


Figure 57 Existing fuel line clip

Chapter 5: *Fuel Transfer Lines*

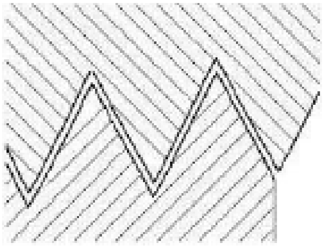
5.3 Fuel Line Mounting and Routing

If a grommet is used to prevent abrasion damage to any hose, ensure that the grommet is sealed with a suitable adhesive material such as silicone or weather-stripping adhesive.

Another alternative is to use a bulkhead fitting where a fuel line must pass through a body panel, truck bed or frame rail. Although a grommet meets the base standards, it provides no positive anchor. A grommet will always shift or slip, placing the hose or fuel line directly against a metal body panel or frame member where the line may become damaged and eventually fail.

A bulkhead fitting serves as an anchor for the fuel line and prevents rubbing and abrasion.

The fitting shown at right allows for 3/8" SAE 45° flare fittings to be attached.



Chapter Six

Fuel-Line Connectors

Chapter 6: *Fuel Line Connectors*

In North America, the SAE 45° flare fitting is the most common fitting connector used for couplings that may have to be removed for service. A tapered pipe thread is used for permanently installed fittings. Some OEMs elect to use a compression coupling, while others use a spring seal high-pressure fitting similar to an OEM gasoline or diesel fuel-filter fitting. The SAE 45° flare fitting may be reused indefinitely, as long as the mating surfaces are free from any defect from manufacturing or handling. Flare fittings may also be called "adapter couplings," since most of them adapt a pipe-thread fitting to a flare fitting.

Industrial and high-performance AN[1] 37° flare fittings with an appropriately rated engine-fuel hose may be acceptable, as long as there is no chance of cross-fitting the SAE 45° flare with the AN 37° flare fitting. These fittings are not compatible, and leakage will occur.

[1] The abbreviation derives from an Army-Navy specification pre-dating WWII.

Chapter 6: *Fuel Line Connectors*

Many European installations currently use a single-ferrule compression fitting on a steel tube (6mm, 8mm or 10mm outside diameter, Figure 61). However, composite fuel lines using proprietary fittings are increasing in popularity.

U.S. and NFPA 58 standards do not specify which fuel-line connector must be used, only that they meet the required service pressure.[2]

[2] NFPA 58, 2008 ed., §11.6.2.2 and §5.9.6.4(A-D); NFPA 58, 2011 ed., §11.7.2.2 and §5.9.6.4 (A-E)

Chapter 6: *Fuel Line Connectors*

6.1 Tapered Thread Fittings and Sealants

Thread taper specifications for National Pipe Thread (NPT)[3] fittings are shown in threads per inch, the amount of taper (degrees or inches per foot), and the angle or pitch of the threads. The basic design of the tapered pipe thread fitting, however, does not provide a positive torque value seal and is the most frequent source of leaks at fittings.

As the fitting is tightened, small voids will remain in the peaks and valleys of the threads. If not properly assembled, the joint will leak. Even if all necessary precautions are used, leaks can still occur at these joints.

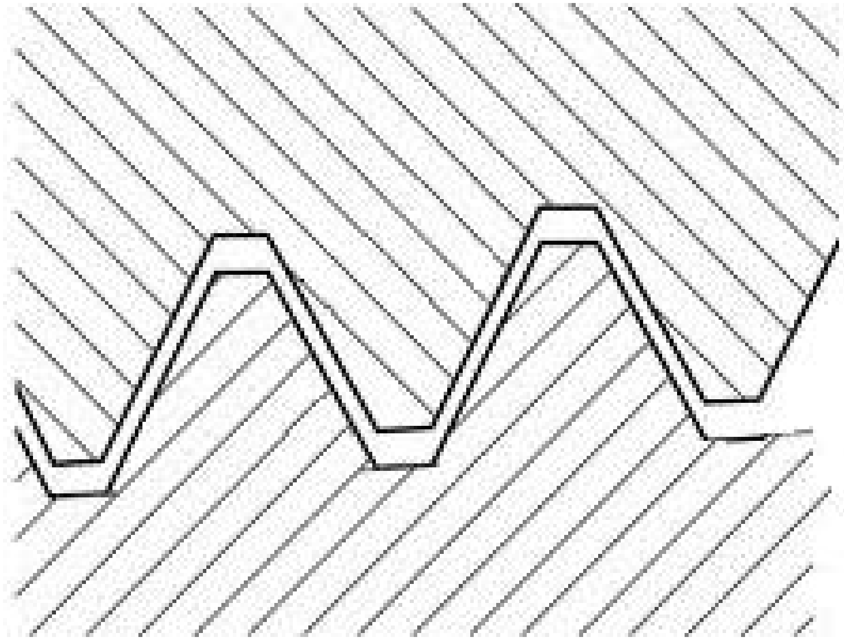
[3] ANSI/ASME B1.20.1-1983 (R1992)

Chapter 6: *Fuel Line Connectors*

6.1 Tapered Thread Fittings and Sealants

National Pipe Thread

Figure 62 illustrates how the gap between the male and female threads can lead to leakage if a thread sealant is not used.

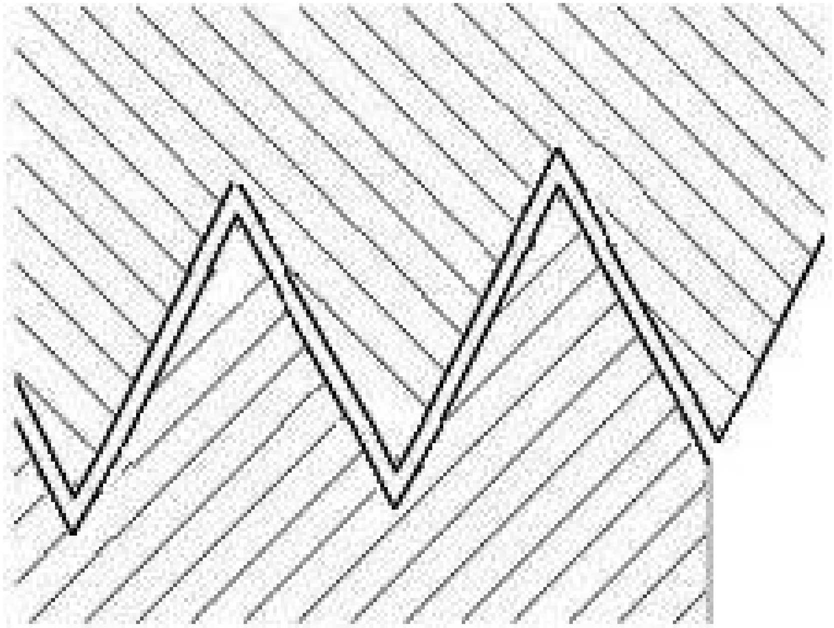


Chapter 6: *Fuel Line Connectors*

6.1 Tapered Thread Fittings and Sealants

National Gas-Pipe Thread (Dry-Seal Thread)

In Figure 63 the gap between the male and female threads is minimized. The thread will deform as it is tightened, as metal is forced into the peaks and valleys of the corresponding fittings. A thread-seal compound is still recommended for lubrication during assembly. Upon disassembly, the threads are usually damaged and may not reseal effectively if reassembled.



Chapter 6: *Fuel Line Connectors*

6.1 Tapered Thread Fittings and Sealants

As there is no positive stop when the tapered pipe thread fitting is fully assembled, the fitting is tightened using the installer's own "feel," which will change depending on the material used (brass, steel, stainless steel) and which thread-sealing compound is applied (sealant tape, liquid or paste thread seal, or an anaerobic thread seal, such as Loctite 565, 567, 569, 592 or equivalent). Anaerobic thread sealer cures in the absence of air and serves as a thread lock.

Liquid, paste, or putty-type thread sealers fill the voids with a heavy paste compound that may be mixed with bulk fiber filler such as Rectorseal 5 or Rectorseal T plus 2 or Permatex 14D or equivalent.

Chapter 6: *Fuel Line Connectors*

6.1 Tapered Thread Fittings and Sealants

Thread sealing compound should never be installed on flare threads or flare nut surfaces.

Thread Sealant Alternatives

OPTION 1 Soft or medium setting fibrous filler

OPTION 2 Liquid or paste thread seal with PTFE (Teflon) paste thread seal

OPTION 3 Anaerobic thread sealer/thread lock

Chapter 6: *Fuel Line Connectors*

6.2 Fuel Line Fittings

OPTION 1

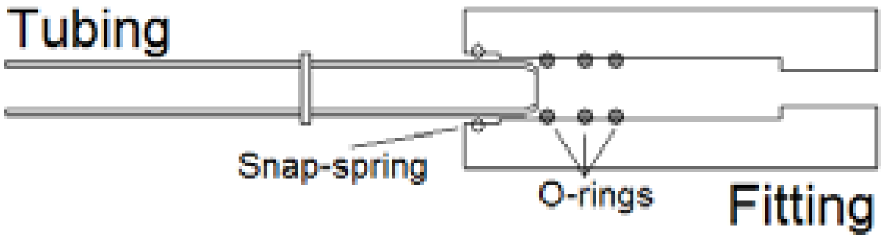
SAE 45° flare fittings incorporate a surface seal connection at the 45° flare face. The tube sealing surface must be concentric and absolutely free of burrs. Any scratches or surface irregularities will result in a leak.

Chapter 6: *Fuel Line Connectors*

6.2 Fuel Line Fittings

OPTION 2

Roush CleanTech LPI fuel lines fit into a specially designed socket that uses O-rings to form the seal and prevent leakage. This formed fitting requires special tools to release the connection, but closely resembles a conventional gasoline or diesel fuel line fitting. This fitting allows for some rotation, which prevents stress on the fuel line and fitting.



Chapter 6: *Fuel Line Connectors*

6.3 Additional Fuel Line Requirements

A hydrostatic pressure relief valve must be installed in each section of fuel line where propane can be isolated between positive closing shutoff valves.[5] When both the engine lockoff solenoid and the tank solenoid or manual shutoff valve are closed, liquid propane can become trapped in the line. To prevent damage to the fuel line due to a temperature increase and high pressure resulting from expanding propane,[6] the hydrostatic pressure relief valve will momentarily open to relieve the fuel-line pressure.

This valve should not be located under the hood where the released fuel may be drawn into the engine or exposed to exhaust-system heat. The recommended location is underbody, where the valve will discharge away from the vehicle and any other heat-producing components. No legal requirements dictate the location of the hydrostatic pressure relief valve, but the valve should be in a secure location that directs any potential discharge away from any heat source, including inside the engine compartment.

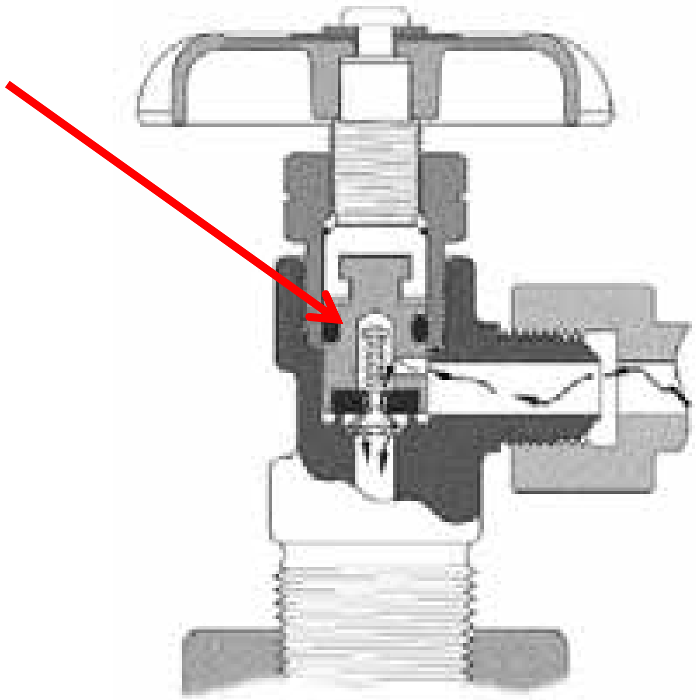
5 NFPA 58, 2008 ed., §11.9.2 inclusive; NFPA 58, 2011 ed., §11.10.2 inclusive

6 Propane liquid expands 1 percent for every 6°F rise above 60°F.

Chapter 6: *Fuel Line Connectors*

6.3 Additional Fuel Line Requirements

Some tanks' liquid service valves have an integrated hydrostatic pressure-relief valve. Some such valves are identified by the letter "H" in the valve model number. The integral hydrostatic valve (Figure 66, red arrow) allows excess pressure to return to the tank if the manual service valve is closed and there is excess pressure in the downstream line.

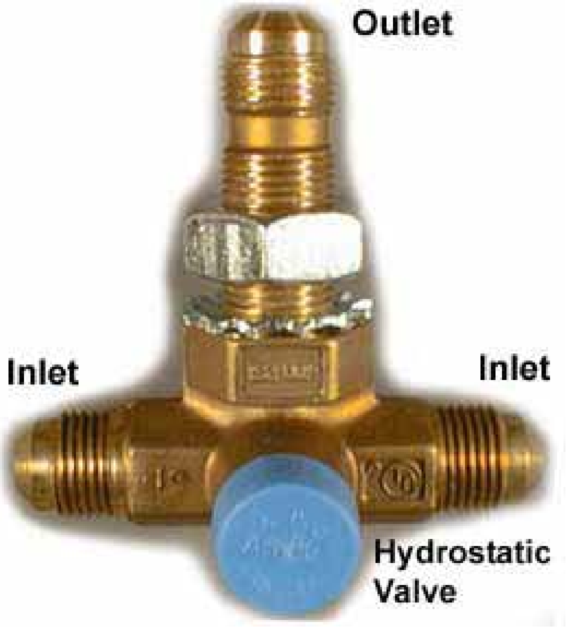


Chapter 6: *Fuel Line Connectors*

6.3 Additional Fuel Line Requirements

Multiple tanks may be filled from one location, since each tank has a double back-flow check fill valve that also prevents tank cross-filling. In addition, each tank has an automatic stop-fill device that limits the amount of fuel in each tank to a maximum of 80 percent liquid fill.

If two or more tanks supply fuel to an engine, a series of check valves must be incorporated to prevent cross-feeding of one tank to another, which could result in an overfill condition of one of the tanks. This "check-tee" incorporates a bulkhead fitting, two inlets with integral check valves, and a hydrostatic pressure relief valve. Fuel will flow from the tank with the highest pressure (warmest tank) until the pressure is equalized.



Chapter 6: *Fuel Line Connectors*

6.3 Additional Fuel Line Requirements

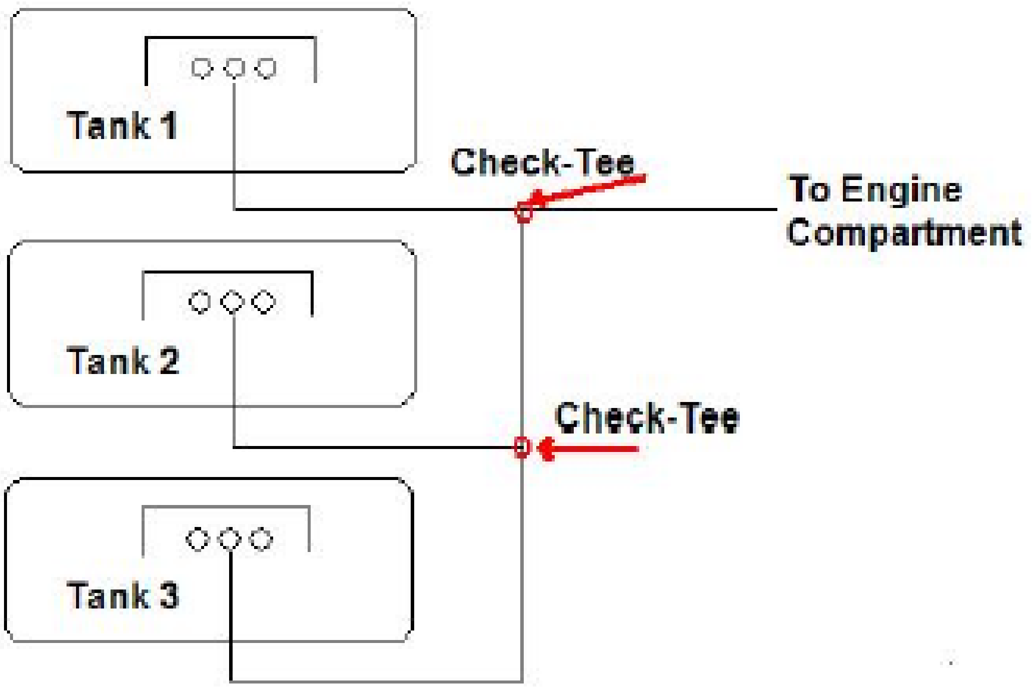


Figure 67. Multiple tanks configured for vapor fuel injection system

Appendices

Appendix A: Material Safety Data Sheet

Appendix B: On-Board Diagnostics (OBD I and II)

Appendix C: Pre-Conversion Guidelines

Appendix D: Purging Propane Autogas Tanks With a Vacuum Pump

Appendix E: Glossary

Q & A