

**CHAPTER 11**  
**COMPRESSED AND LIQUEFIED NATURAL GAS FUEL SYSTEMS**

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## CHAPTER 11

### COMPRESSED AND LIQUEFIED NATURAL GAS FUEL SYSTEMS

1. SCOPE. This chapter applies to the operation and inspection of compressed natural gas (CNG) and liquefied natural gas (LNG) fuel systems. Definitions for words, phrases, and acronyms that are typically used in the installation, repair and maintenance of CNG and LNG vehicles are listed in Annex A. Main paragraphs three through nine address CNG and main paragraphs 10 through 18 address LNG.
  
2. INTRODUCTION. The information in this chapter is intended to provide general information describing the operation of CNG and LNG fuel systems and their major component parts in addition to providing inspection guidelines to determine whether such systems and their component parts are functioning properly and are in compliance with the applicable provisions of Title 13, California Code of Regulations (13 CCR), Compressed and Liquefied Gas Fuel Systems, the National Fire Protection Association Standard 52 (NFPA 52); Compressed Natural Gas Vehicular Fuel Systems Code; the NFPA 57, Standard for Liquefied Natural Gas Vehicular Fuel Systems; and the Society of Automotive Engineers (SAE) J2343, Recommended Practices for LNG Powered Heavy-Duty Vehicles.
  
3. 13 CCR SECTION 934.1 COMPRESSED NATURAL GAS – NFPA STANDARD. This section requires CNG fuel systems installed after April 1, 1994, to comply with the NFPA 52, Compressed Natural Gas Vehicular Fuel Systems, in effect at the time of installation. Specific sections of NFPA 52 are referenced in this chapter from the 2002 edition, which was effective on October 23, 2002, and is still current as of the date of this revision.
  
4. SAFETY PRECAUTIONS RELATED TO CNG FUEL SYSTEMS.
  - a. Odorization of CNG. In its pure state, natural gas is odorless, colorless, and tasteless. For safety reasons, however, an odorant called ethyl mercaptan is added, so any leak can be easily detected because of the distinct smell of this additive. Ethyl mercaptan is used because extremely small concentrations in air are easily detectable. However, maintenance and inspection personnel should not depend on odor as an indication of leaks, and should always leak test the fuel system to pinpoint leaks as the odor alone could merely indicate the vehicle has been fueled recently, possibly with some spillage at that time.
  
  - b. Toxicity of CNG. Natural gas will not harm anyone inadvertently inhaling low concentrations, near minor fuel leaks. However, heavy concentrations can cause

drowsiness and eventual suffocation, especially in confined, unventilated areas. By comparison, gasoline and diesel fuels are toxic if ingested, inhaled, or absorbed through the skin.

c. Flammability Range of CNG. Natural gas is relatively safe because it is lighter than air, causing it to quickly dissipate into the atmosphere if a leak occurs. Also, the ignition temperature of CNG is 1200° F, twice that of gasoline.

(1) CNG burns at a very narrow range of ratios of gas to air, resulting in a low likelihood of explosion. Unlike liquid fuels, which puddle if leaked, CNG rises and disperses quickly in air.

(2) The risk of fire in the presence of an ignition source exists when the ratio of air to fuel is within the product's flammability range. Fuel cannot ignite if it is mixed with too much or too little air. The flammability range for CNG is 5 percent to 15 percent volume of gas in air. For comparison, the flammability range of gasoline is 1 percent to 7.6 percent volume of gasoline in air.

d. CNG Fuel Leaks. CNG fuel containers are thicker, stronger, and less vulnerable to punctures than conventional gasoline or diesel fuel tanks.

(1) Minor Fuel Leaks. If a minor fuel leak occurs:

- (a) Eliminate all sources of ignition, e.g., drop lights, cigarettes.
- (b) Turn off engine.
- (c) Turn off all electrical devices.
- (d) Close all master CNG valves on fuel system.
- (e) Allow gas to disperse into a ventilated area.

(2) Major Fuel Leaks. If a major fuel leak occurs, e.g., fuel container(s) emptying:

- (a) Evacuate area.
- (b) Do not operate any electric overhead doors (open doors manually only).
- (c) Do not operate any electrical switches or electric heaters.
- (d) Allow gas to disperse into a ventilated area.

(3) CNG Fire.

(a) CNG and liquid fuel fires differ with respect to combustion rate and the amount of smoke produced during combustion. Gasoline and diesel fires progress violently with a high rate of heat release. Large amounts of smoke are produced during combustion, and the risk of the fire spreading or injuring exposed individuals is high.

(b) CNG fires tend to have a controlled rate of heat release, which is confined to a small area surrounding the release point. The likelihood of an individual receiving a serious burn or suffering injury from the products of CNG combustion is less when compared to gasoline or diesel fires.

(c) The potential for explosion with CNG is lower than with gasoline or diesel fuel. Because CNG is a gas (vaporizes instead of pooling), the risk of explosion outdoors is minimal. Inside a properly certified and installed CNG container, there is essentially no risk of explosion because there is no air. The principal cause of fire or explosion from CNG is fuel leakage from improperly installed or defective components.

(d) If a CNG fire occurs, stop the fire by cutting off the fuel flow if possible; then it can be put out with an extinguisher. If the fire cannot be controlled, call the fire department and identify the fire as a natural gas fire and evacuate the area immediately.

(4) Vehicle Collision.

(a) In the event of a vehicle collision, turn off the ignition switch, close the manual shut-off valve (1/4 turn valve), if so equipped, and if possible, shut off the container's individual valves.

(b) NFPA 52, 5.12.5 requires any vehicle involved in a collision or a fire causing damage to any part of the CNG fuel system to be repaired and retested before being returned to service.

(5) Advantages of CNG.

(a) CNG is readily available as a domestic energy source, is inexpensive, and generally produces lower emissions than most other alternative fuels.

(b) CNG is already in use as a viable alternative for light-duty vehicles. The American Gas Association reports over two million natural gas-powered vehicles in operation in 42 countries.

(c) CNG is cleaner burning, minimizes carbon buildup, thus increasing oil change intervals and reducing maintenance.

(6) Disadvantages of CNG.

(a) The pressure of CNG requires heavy storage containers and the containers are large, even for short-range use. These two factors reduce cargo and or passenger capacity. Consequently, maintaining reasonable cargo or passenger capacity restricts fuel container size and limits range.

(b) Lower burning British Thermal Unit (BTU) value, per equivalent gallon, than diesel. Plus, it limits engine efficiency and vehicle range.

(c) The high pressure which the CNG fuel storage system must endure requires careful design, location considerations, protection from damage, plus periodic maintenance and upkeep. Periodic container inspection is required and most containers must be replaced after 15 years, from the date of manufacture.

(d) Refueling time is dependent on the type of fueling system used and can be quite lengthy. There are two methods: (1) "slow fill," which takes from five to eight hours and is typically called "overnight" or "time-fill" refueling; and (2) "fast-fill," which takes about five to ten minutes and requires high-volume compression and special filling apparatus.

(e) There are composition variations in natural gas and the percentage of methane content from one geographical area to another. Additional processing is required to produce uniform natural gas for all areas.

(f) Natural gas has poor lubrication properties.

5. ORIGIN, TRANSPORTATION AND STORAGE OF CNG.

a. Natural Gas Origin. Natural gas is found underground where it was formed millions of years ago as organic matter (animals, plants, etc.). Natural gas is one of the most abundant fuels in nature. Natural gas collects in tiny holes in underground rock and is trapped under layers of solid rock.

(1) Natural gas is an organic compound made up of hydrogen and carbon and usually is referred to as a "hydrocarbon." Methane (CH<sub>4</sub>) is the main component of natural gas, which typically makes up 85-95 percent of the total of "pipeline quality" gas. The remainder is primarily ethane (C<sub>2</sub>H<sub>6</sub>), with smaller amounts of propane, butanes, and inert gases such as nitrogen, argon, and carbon dioxide.

(2) The combustion properties of natural gas make it an excellent fuel for spark-ignition engines. It has an ignition temperature of approximately 1,200°F, about 600° higher than gasoline. As a gas, it mixes readily and completely with air even at low temperatures, thus eliminating any need for mixture enrichment during cold starting.

(3) Natural gas has excellent antiknock properties, with an equivalent octane number in excess of 120, compared to 87 for unleaded regular gasoline and 92-93 for premium. This allows engines designed specifically for natural gas fuel to use higher compression ratios than gasoline engines, with a consequent improvement in efficiency and power output. Natural gas is not a perfectly clean burning fuel when used for internal combustion engines; however, it is considerably less polluting than gasoline.

b. Transportation and Storage of CNG. Natural gas formations are under tremendous pressure. Therefore, natural gas does not require pumping to extract it. Once natural gas exits the well, it is transported through a system of underground pipelines by “pipeline companies.”

(1) The natural gas industry in the United States has constructed more than one million miles of pipeline to transport natural gas to local distribution companies such as Pacific Gas & Electric Company, San Diego Gas & Electric Company and Southern California Gas Company in California. Pipelines are constructed and tested to operate at high pressures, and compressor stations, which normally operate at 250 to 1,000 pounds per square inch gauge (psig) pressure, are constructed every 50 to 100 miles along the pipeline to restore the pressure lost due to normal pipeline friction.

(2) The quality of pipeline natural gas can vary substantially in different areas of the country, and within California. Manufacturers and distributors of natural gas engines should accommodate this reality in designing and calibrating engines if they are to be used successfully in all areas of the state.

(3) As mentioned above, natural gas is primarily methane as it comes from the well, and it burns quite cleanly in its unprocessed state. For automotive applications, natural gas may be stored on-board the vehicle in two forms:

(a) Liquid Natural Gas. LNG utilizes the same natural gas source as CNG; however, LNG requires purification of the gas and cooling and storage below -259°F to liquefy the natural gas. Converting natural gas to liquid form allows storage of a much greater amount on the vehicle than can be achieved in the gaseous state.

(b) Compressed Natural Gas. CNG utilizes the same natural gas source as LNG; however, to achieve fill rates equivalent to liquid fuels

(such as gasoline, diesel, or LNG), CNG must be compressed to very high pressures (2,500 to 3,600 psi) in fuel storage containers.

1 The most common method of storing CNG on motor vehicles is in steel or high-strength fiberglass-wrapped aluminum cylindrical containers at up to 3,600 psi. Even at this pressure, a BTU of natural gas occupies over four times the volume of a BTU of diesel fuel. Therefore, a large storage volume (and substantial tank mass) is required if CNG vehicles are to have ranges equivalent to diesel or gasoline vehicles.

2 Gasoline and diesel are liquid fuels. When you buy those fuels at the pump, they are dispensed by the gallon, a unit of liquid measurement. However, natural gas is a vapor and not a liquid. When determining how many units of natural gas are used, the gas company measures the amount in cubic feet or in energy content expressed in BTUs. Since it is confusing to sell natural gas for vehicles by the BTU, the industry developed the gasoline gallon equivalent.

3 The measurement of energy content is used for greater accuracy in comparison of fuels. Energy content is measured in terms of BTUs. A BTU is the quantity of heat required to raise one pound of water (about one pint), one degree Fahrenheit at or near its point of maximum density.

4 One way to determine how CNG is measured is to look at how many cubic feet of CNG equal a gallon of gasoline or diesel. A good average to use is 120 cubic feet of natural gas equals one gallon of gasoline. Since diesel burns slightly hotter than gasoline, use 125 cubic feet of CNG to equal one gallon of diesel.

NOTE: For example, if there are three CNG containers on a vehicle, multiply the volume of each container by the number of containers and divide that by 120. This will give the equivalent of this quantity of CNG in gallons of gasoline.

5 A cubic foot of gas is the amount of gas required to fill a volume of one cubic foot under stated conditions of temperature and pressure. For quantifying larger amounts of CNG, a therm is used to indicate 100 cubic feet. Although the energy content in natural gas varies in different locations throughout the country, in California, one cubic foot of CNG contains approximately 1,000 BTUs of heat energy.

(4) Natural gas from the pipeline is distributed to both public and private gas distributors with fueling facilities. CNG fueling facilities generally consist of one or more gas compressors, filtration systems, compressed gas storage tanks or containers, and gas dispensing equipment.

(5) There are three basic configurations of CNG fueling stations: fast-fill, time (slow)-fill, and combination. The configuration chosen is generally determined by the fleet's fueling characteristics. Figure 11-1 illustrates one type of fast-fill refueling system, Figure 11-2 illustrates one type of slow-fill system, and Figure 11-3 illustrates a combination system.

(a) Fast-fill stations are generally used when vehicles must be refueled in a time period similar to that of gasoline or other conventional fuels. Medium and heavy duty vehicle refueling takes approximately 7 to 12 minutes. A hose and nozzle assembly dispenses gas with a quick-disconnect pipe connection inside the regular vehicle-fueling door. Generally, a dispenser is included that closely duplicates the appearance and function of a gasoline dispenser.

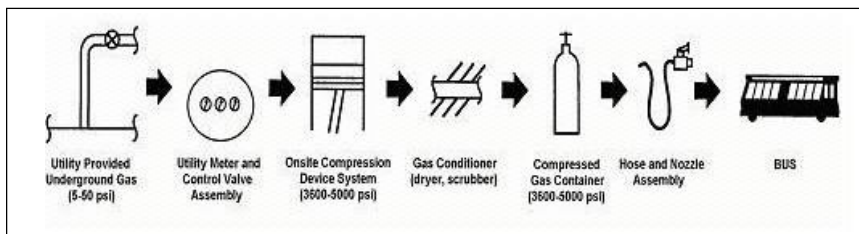


Figure 11-1. Typical Fast-Fill CNG Refueling System

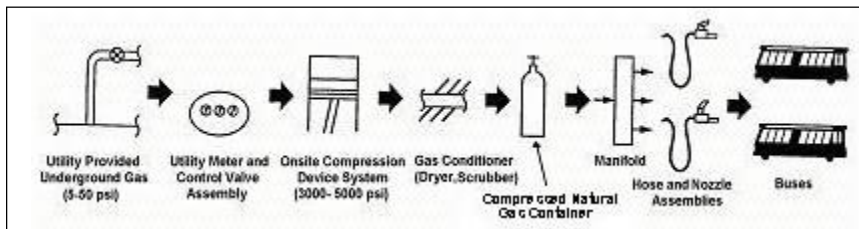


Figure 11-2. Typical Timed (Slow)-Fill CNG Refueling System

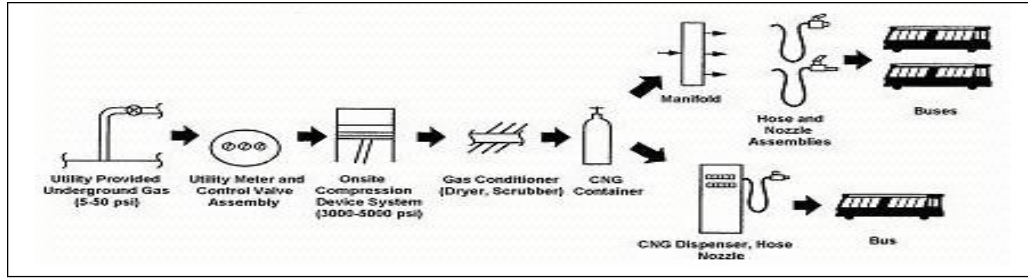


Figure 11-3. Typical Combination Fast/Slow-Fill CNG Refueling System

(b) Slow-fill stations are usually recommended when fleet vehicles operate on one fuel fill-up per day and return to a central location for a period of six to eight hours, during which they can be refueled.

(c) Combination type stations are used when some vehicles return to a central location for refueling, usually at night, and when other vehicles need to be refueled in a short period of time and cannot wait for slow-fill.

(6) As an example, when filling a 3,000-psig container, the container cannot be filled to the full capacity in cooler weather. Natural gas reacts to temperature change by expanding, so 3,000 psig of natural gas increases when the outside temperature rises. In the same respect, when CNG in a container is given a chance to cool, it loses pressure. When a container fast filled to 3,000 psig is allowed to sit overnight, its pressure may be as low as 2,400 psig in the morning. The fueling station's temperature-pressure compensating unit regulates the volume of CNG pumped into the vehicle fuel containers only at that time. Remember, CNG will continue to expand as temperature rises. Figure 11-4 shows the difference between temperature and pressure.

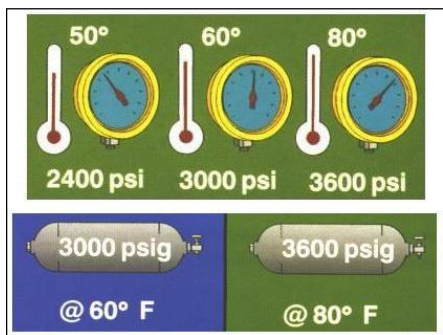


Figure 11-4. Temperature/Pressure Difference

(7) Two common alternatives for distributing CNG to fleets are mobile fueling trucks and tube trailers.

(a) Mobile fueling trucks fill directly from the pipeline, using an on-board compressor; dispensing the gas either directly into vehicles or into stationary storage vessels for subsequent slow- or fast-fill into vehicles.

(b) Tube trailers are filled with CNG at a CNG fueling station and then driven to other locations for dispensing fuel. Tube trailers can also fast-fill vehicles using a small compressor to increase gas pressure.

## 6. CNG FUEL SUPPLY CONTAINERS.

a. Manufacturing of CNG Containers. CNG containers must be designed to withstand thousands of pounds of pressure. The manufacturing begins with receipt of seamless raw-stock steel or aluminum open-end tubes. Figure 11-5 illustrates elements of a typical CNG manufacturing process.

(1) The tubes undergo a unique “flow-forming” process which reduces the wall thickness to the precise specification for a given container size, while increasing the inherent strength of the steel or aluminum.

(2) The tubes are then cut to length and subjected to a specialized metal spinning process which forms domes on both ends of the container. The spinning process also provides a method for closing the ends of the tubes which provides a boss for the container shut-off valve and end plug (if needed).

(3) After heat treating, final machining, and inspection, Type 2 (hoop-wrapped) and Type 3 (full-wrapped) containers are then “overwrapped” with a composite matrix of longitudinal fibers.

(4) After curing, the completed Type 2 or Type 3 container is pre-stressed by a method referred to as “autofrettage,” a process to achieve a required level of stress distribution which increases fatigue life of the container. Prior to completion, most container manufacturers conduct the following tests:

(a) Wall and end thickness check of each container on the assembly line.

(b) Hardness test and an interior and exterior examination for defects.

(c) Water capacity check and final visual inspection.

(5) Records of all tests conducted are completed prior to certification.

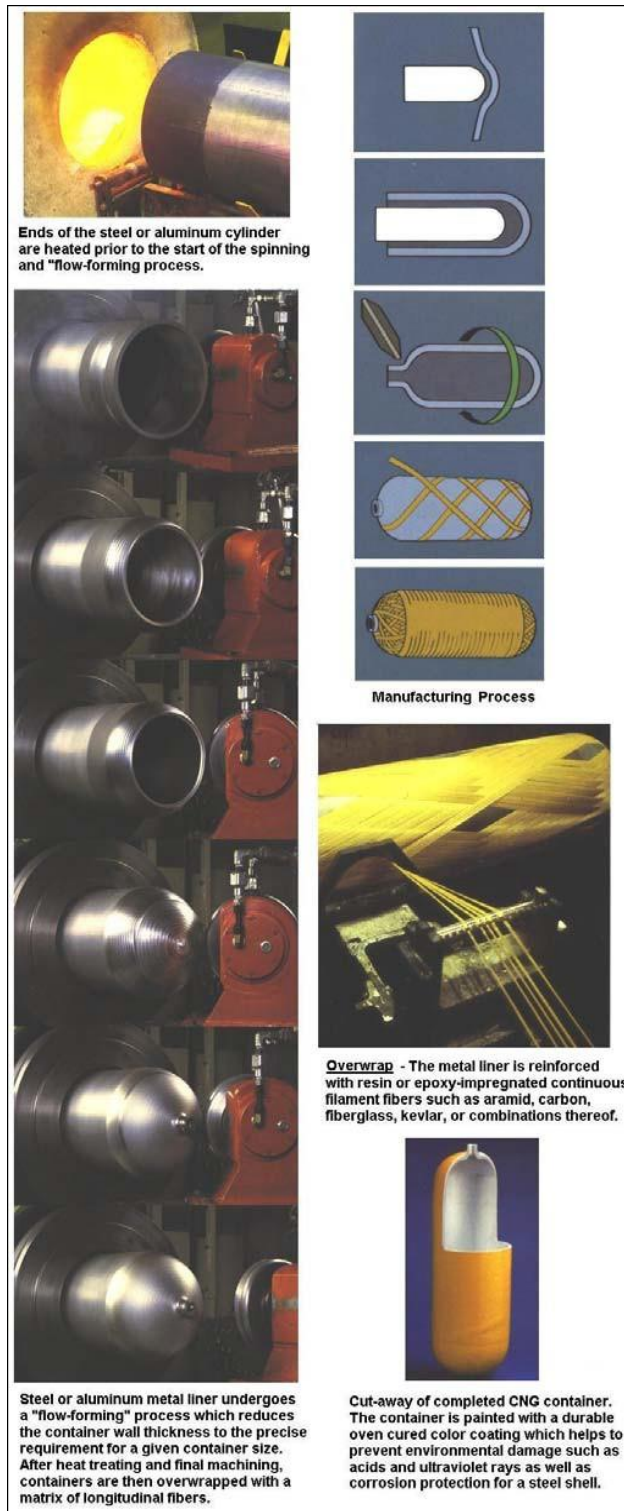


Figure 11-5. Manufacturing Process of Type 1, Type 2, and Type 3 Containers

b. Fuel Supply Container(s) Manufactured Prior to March 27, 1995.

(1) Prior to implementation of Federal Motor Vehicle Safety Standard (FMVSS) 304 (Compressed Natural Gas Fuel Container Integrity) in 1995, and the natural gas vehicle standard (NGV2) developed by the American National Standards Institute in 1992, most U. S. Department of Transportation (DOT) fuel supply containers for motor vehicles were built under specific DOT exemptions (DOT-E), which required containers to be reinspected and hydrostatically retested every three years or five years (depending on the type of container) in accordance with Title 49, Code of Federal Regulations, Section 173.34(e)(13).

(a) The California Highway Patrol (CHP), for several years, enforced the federal provisions of the exemptions applied to the DOT-E container, and required the containers to be hydrostatically retested in accordance with the exemption. However, after consulting with several CNG fuel supply container manufacturers, the Gas Research Institute (GRI), the Compressed Gas Association (CGA), and the Natural Gas Vehicle Coalition, the CHP concluded that hydrostatic testing is not necessarily the best technique for requalifying these high-pressure containers for use as a motor vehicle component. Some manufacturers contend that a hydrostatic test is a good one-time test of a container's integrity, but may also cause a permanent weakening of the container, thereby shortening its expected service life.

(b) Fleet vehicle operators should consult with the manufacturers of the CNG containers in their fleets for guidance on the type and frequency of inspection that should be conducted for each type of container.

(c) Manufacturers of motor vehicles must comply with the applicable provisions of certain FMVSSs in effect at the time of manufacture. California Vehicle Code (VC) Section 24011 prohibits a dealer from selling or offering for sale a vehicle or item of equipment that does not conform to the applicable federal standard. Additionally, the vehicle or equipment must bear a certification by the manufacturer or distributor that it complies with the applicable federal standards.

(d) A vehicle that has been converted to operate on CNG (after the first sale) does not have to comply with the provisions of the FMVSS. Vehicles that are converted to operate on a CNG fuel system must comply with the applicable provisions of NFPA 52 or the FMVSS, regarding the installation of fuel containers.

NOTE: A manufacturer, distributor, dealer, or motor vehicle repair business may not knowingly render inoperative, in whole or part, any device or element of design installed on or in a motor vehicle or item of motor vehicle equipment manufactured in compliance with applicable FMVSS.

c. Fuel Supply Container(s) Manufactured On or After March 27, 1995.

(1) On September 26, 1994, the National Highway Traffic Safety Administration (NHTSA) published a final rule addressing the safe performance of CNG containers, which took effect March 27, 1995. The final rule established a new FMVSS, No. 304, Compressed Natural Gas Fuel Container Integrity, that specifies pressure cycling, burst, and bonfire tests for the purpose of ensuring the durability, initial strength, and venting of CNG containers.

(a) The pressure cycling test evaluates a container's durability by requiring a container to withstand, without any leakage, 13,000 cycles of pressurization and depressurization at 100 percent of service pressure plus 5,000 cycles at 125 percent of service pressure. This requirement helps to ensure that a CNG container is capable of sustaining the cycling loads imposed on the container during refueling over its entire 15 year service life. Figure 11-6 illustrates a typical hydrostatic test facility.

(b) The burst test evaluates a container's initial strength and resistance to degradation over time based on a unique safety factor for determining the internal hydrostatic pressure that the container must withstand during the burst test. This requirement helps to ensure that a container's design and material are of appropriate strength for the duration of the container's life. Safety factors range from 2.25 to 3.50, depending on the container type, material, and design involved. The higher the service pressure and safety factor, the more material is needed to comply with this requirement.

Figure 11-6a illustrates a typical burst test.

(c) The bonfire test evaluates a container's ability to relieve internal pressure, due primarily to temperature rise. Each container must be equipped with a pressure relief device. The container must completely vent its contents through the pressure relief device and shall not burst while retaining its entire contents when the container is centered over the bonfire source. The flame temperature of the bonfire may not be less than 800°F (430°C). Figure 11-6b illustrates a typical bonfire test.



Figure 11-6. Typical Manufacturer's Container Hydrostatic Test

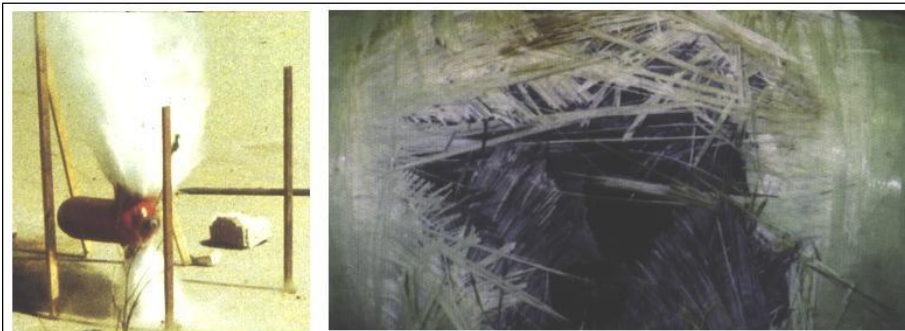
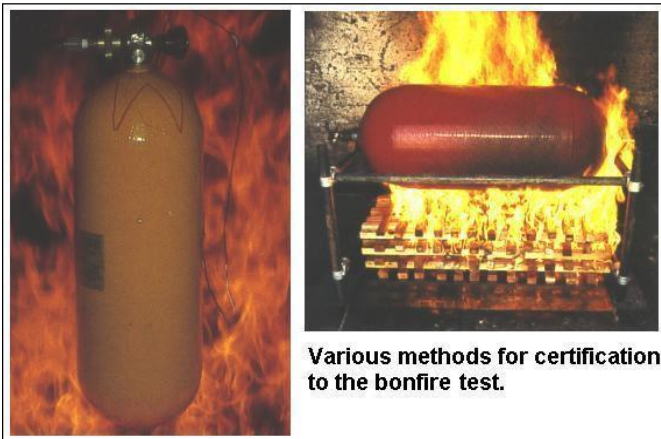


Illustration on the left shows the initial burst of a container. The illustration on the right shows the results of a burst test.

Figure 11-6a. Typical Burst Tests



Various methods for certification to the bonfire test.

Figure 11-6b. Typical Bonfire Tests

d. Types of FMVSS Containers. The new FMVSS is patterned after the American National Standards Institute's (ANSI) voluntary industry standard known as ANSI/NGV2. ANSI/NGV2 and FMVSS No. 304 specify detailed material and other requirements for four different types of containers.

(1) Type 1. A Type 1 container is a metallic (steel or aluminum), noncomposite container. Steel containers have a long history in natural gas vehicle (NGV) service. Aluminum containers, although not as common, are also used in NGV service.

(a) Steel containers are usually made of chrome-molybdenum, carbon-boron, or carbon-manganese. Aluminum containers are made of any qualifying aluminum alloy with the appropriate tempering.

(b) Generally, these containers have a service rating of 2,400 psi. Figure 11-7 illustrates a typical steel container and cross section of container. In the Type 1 design there are no composite materials and the metal supports 100 percent of the internal gas pressure.

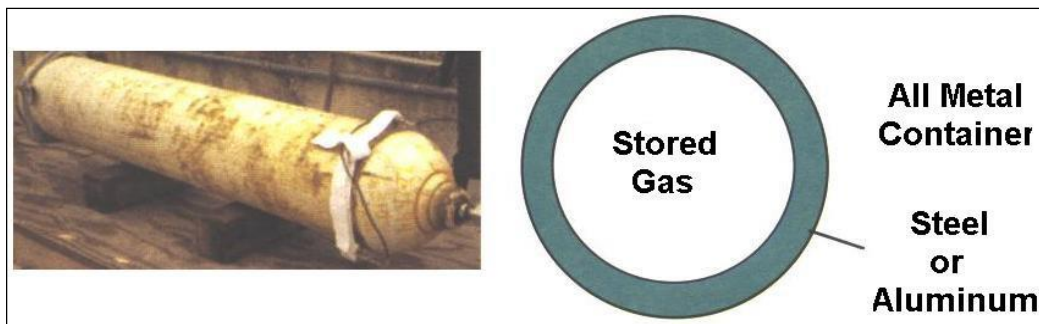


Figure 11-7. Typical Type 1 Metallic (Steel or Aluminum) Container

(2) Type 2. A Type 2 container is a metallic liner reinforced with resin impregnated continuous filament fibers such as aramid, carbon, epoxy fiberglass, E-glass, S-glass, Kevlar, vinyl ester, or certain combinations, which are wound only in the hoop or circumferential direction (hoop-wrapped).

(a) The resins are used to bind composite fibers, and are usually epoxy or polyester compounds. The container's metallic liner must have sufficient strength and thickness to carry all of the longitudinal load at the required burst pressure and must withstand 1.25 times the normal service pressure without rupture.

(b) The liner's cylinder sidewall is thinner than the Type 1 containers to reduce the weight of the container; however, the hoop-wrapped fibers provide the additional strength to compensate for the thinner metal.

(c) These containers have been in NGV service since 1989. Generally, these containers have a service pressure of 3,000 psi or 3,600 psi. In the Type 2 design the metal and composite wrap share the internal gas pressure about evenly, the load taken by metal is approximately 55 percent and the load taken by the composite is 45 percent. Figure 11-8 illustrates a typical Type 2, hoop-wrapped container and a cross section of a container. Figure 11-8a shows a cut-away of a Type 2 container.

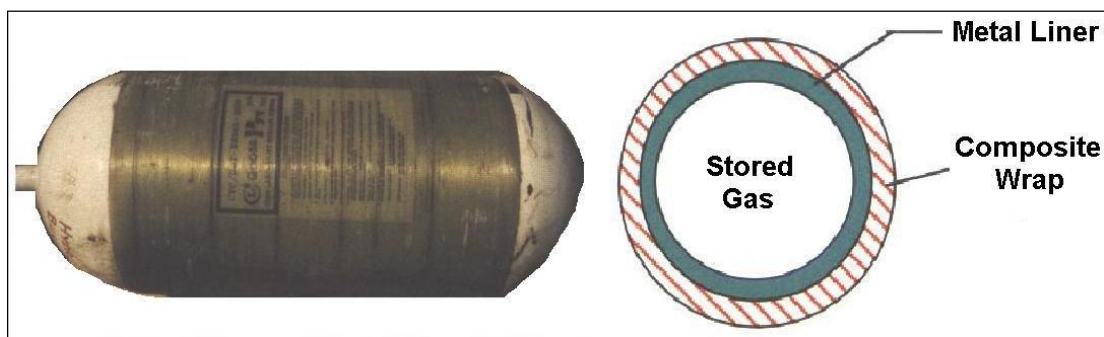


Figure 11-8. Typical Type 2 Hoop-Wrapped Container

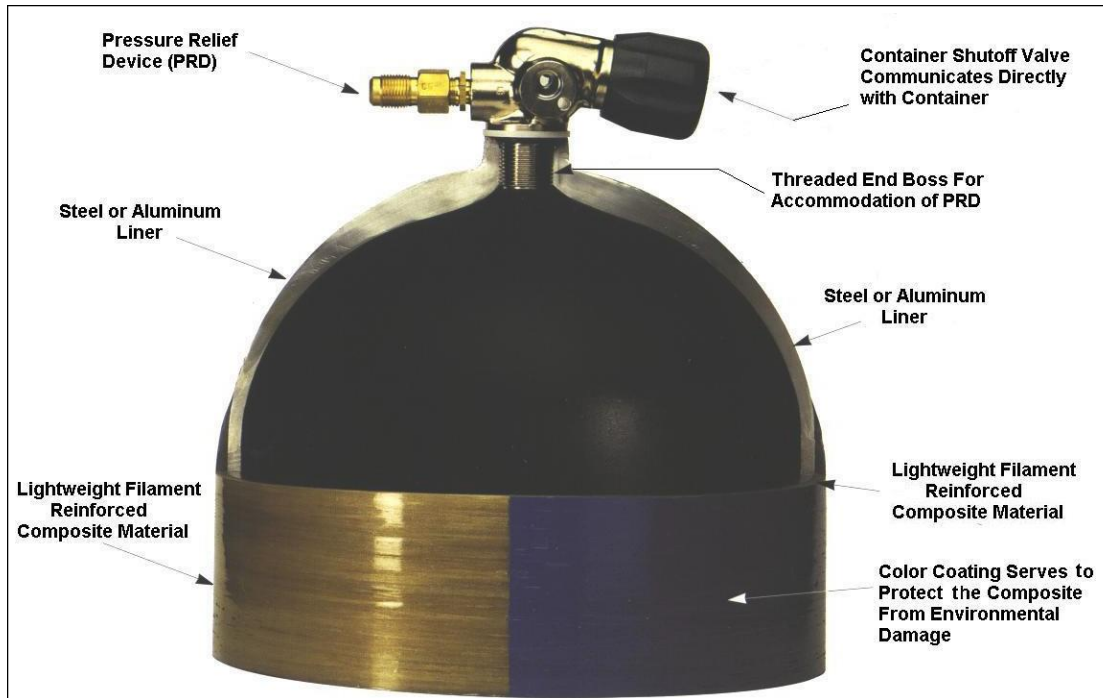


Figure 11-8a. Cut-away of a Type 2 Hoop-Wrapped Container

(3) Type 3. A Type 3 container is a metallic (steel or aluminum) liner with resin-impregnated continuous filaments such as aramid, carbon, epoxy, fiberglass, E-glass, S-glass, Kevlar, vinyl ester, or certain combinations, which are fully wrapped over the entire liner, including the domes.

(a) The metallic liner is generally load carrying but does not have sufficient strength and thickness to carry the longitudinal load at the burst pressure.

(b) These containers have been used in NGV service since 1991, and generally, have a service rating of 3,000 or 3,600 psi. Figure 11-9 shows a typical Type 3 fully wrapped container and a cross section of a container. In the Type 3 design the composite wrap takes on an increased role and holds about 80 percent of the internal gas pressure while the metal holds about 20 percent of the internal gas pressure. Figure 11-9a shows a cross-view of the container.

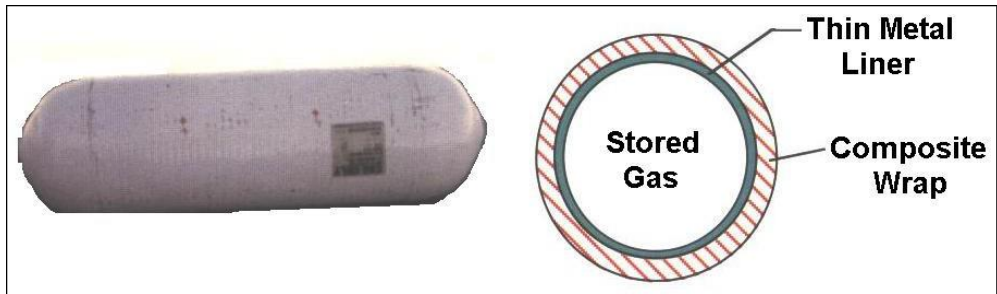


Figure 11-9. Typical Type 3 Fully Wrapped Container

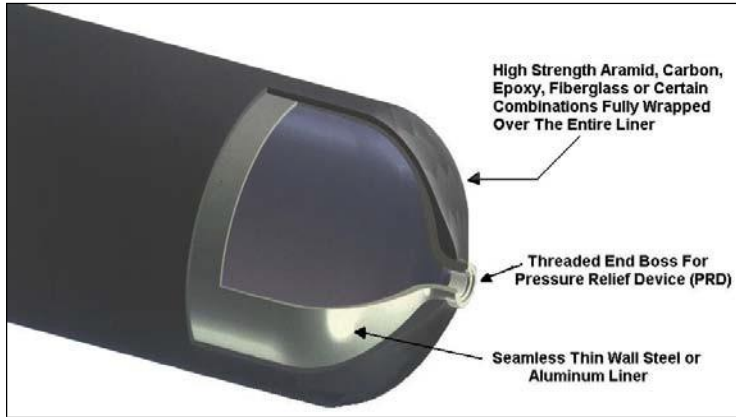


Figure 11-9a. Cross Sectional View of Type 3 Fully Wrapped Container

(4) Type 4. A Type 4 container is a non-metallic liner reinforced with resin impregnated continuous filaments such as aramid, carbon, epoxy, fiberglass, E-glass, S-glass, kevlar, vinyl ester, thermoplastic resin, or certain combinations, fully wrapped over the entire container, including the domes. The fibers are wound in either a helical or polar pattern to provide longitudinal reinforcement in a precisely oriented direction.

(a) Type 4 containers use a plastic liner usually made from high-density polyethylene (HDPE) or nylon, which is wrapped with a mixture of kevlar, carbon, or a mix of glass and carbon fibers (termed a hybrid) in an epoxy or polyester resin. The plastic liner is solely used as a gas barrier and 100 percent of the internal gas pressure is held by the composite materials.

(b) Metallic bosses, usually aluminum or stainless steel, are used to accept pressure relief devices.

(c) The containers have been in use since 1991. Generally, these containers have a service rating of 3,000 to 5,000 psi. Containers may

also be used to store nitrogen and hydrogen. Figure 11-10 shows a typical Type 4 container.

(d) One container manufacturer (Lincoln Composites) uses a patented TUFFSHELL™ feature to maximize resistance to damage. These features include: a damage resistant outer layer; impact resistant, energy absorbing materials in the dome regions; and an external coating to minimize the effect of the environment and exposure to sunlight. Figure 11-10a shows a cross sectional view of the dome region area.

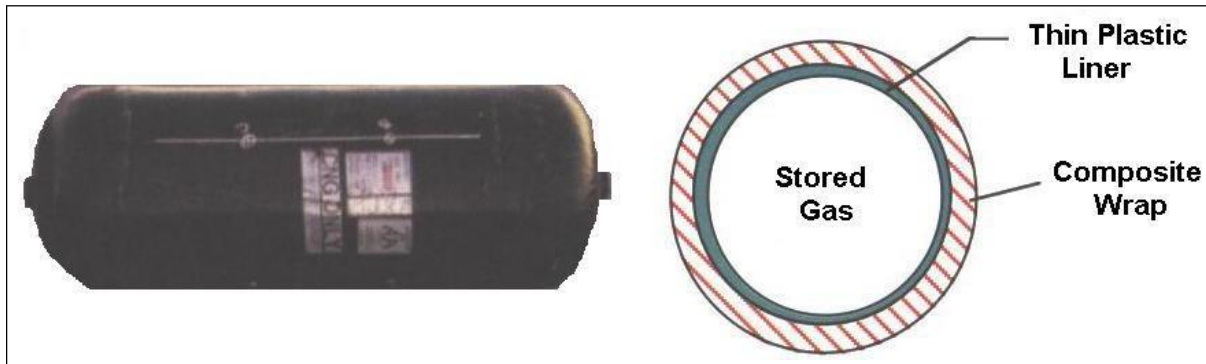


Figure 11-10. Typical Type 4 Non-Metallic Fully Wrapped Container

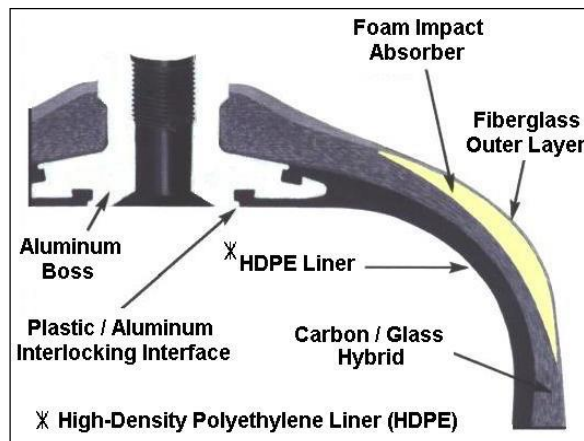


Figure 11-10a. Type 4 Container Lincoln Composite Tuffshell™ Cut-Away

e. Container Labeling Requirements. FMVSS 304, S7.4, as of October 30, 2000, specifies labeling requirements for CNG fuel containers and mandates that each container be permanently labeled with specific information.

(1) The information must be in English, in letters and numbers that are at least 1/4 inch in height, and must include the following:

(a) The statement: "If there is a question about the proper use, installation, or maintenance of this container, contact \_\_\_\_\_" inserting the CNG fuel container manufacturer's name, address, and telephone number.

(b) The statement: "Manufactured in \_\_\_\_\_." inserting the month and year of manufacture of the CNG fuel container.

(c) \_\_\_\_\_ The statement: "Service pressure \_\_\_\_\_ kPa, ( \_\_\_\_\_ psig)".

(d) The symbol "DOT," constituting a certification by the CNG container manufacturer that the container complies with all requirements of this standard.

(e) The container designation (e.g., Type 1, 2, 3, 4).

(f) The statement: "CNG Only."

(g) The statement: "This container should be visually inspected after a motor vehicle accident or fire and at least every 36 months or 36,000 miles, whichever comes first, for damage and deterioration."

(h) The statement: "Do Not Use After \_\_\_\_\_" inserting the month and year that mark the end of the manufacturer's recommended service life for the container.

(2) Any label affixed to the container in compliance with this section shall remain in place and be legible for the manufacturer's recommended life of the container. Figure 11-11 illustrates a typical manufacturer's fuel container label as required by FMVSS 304. Figure 11-12 shows a typical manufacturer's fuel container safety label.

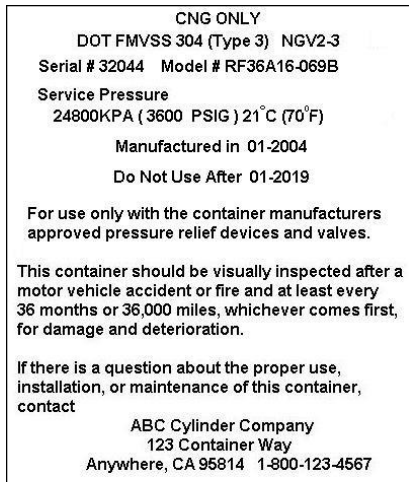


Figure 11-11. Typical Manufacturer's Fuel Container Label Required by FMVSS 304



Figure 11-12. Typical Manufacturer's Fuel Container Safety Label

7. CNG FUEL CONTAINER AND CONTAINER MOUNTING BRACKETS/STRAPS INSPECTION. Preventive maintenance and training are important elements of safety in all aspects of vehicle operation. This is also true for the operation of natural gas vehicles. General visual inspection techniques using the most current edition of CGA C-6.4, Methods For External Visual Inspection of Natural Gas Vehicle (NGV) Fuel Containers and their installations, should be applied to CNG containers and their mounting brackets/straps. Inspection personnel should have a thorough understanding of the various types of containers, and the specific allowances for damage to the specific container. Figure 11-13 illustrates some of the suggested items needed for the inspection of a CNG container. Inspection personnel should, as a minimum, have the following equipment prior to conducting a general visual container inspection: high intensity light and/or flashlight; inspection mirrors; depth gauge and tape measure;

rule/straight edge; leak test fluid acceptable for CNG and/or flammable gas detector (sniffer); the manufacturer's current inspection recommendation(s)/guidelines; and the most current edition of CGA C-6.4 for the specific container being inspected (2003 edition of CGA C-6.4 is the most current as of this revision).

NOTE: The information provided in this section is not intended to replace the container manufacturer's and/or vehicle manufacturer's guidelines.



Figure 11-13. Inspection Equipment

a. General Inspection Guidelines For All Types of Containers (Type 1 through Type 4). Containers should be clean and free of dirt or other debris, which impedes the ability to clearly determine the condition of the external surface of the container. Remember that container mounting brackets and protective shields or covers (if equipped) may have to be loosened or removed to allow a thorough inspection.

(1) Check each container to ensure that it is not in contact with, or in close proximity to, objects which could cut, gouge, or abrade the surface of the container. This includes vehicle components such as tubing and hoses, and parking brake or other cables. Generally, a minimum of 1/2 inch clearance completely around the container is recommended. Additional clearance may be required in areas where the vehicle may flex during operation.

(2) Fuel containers which are believed to have been potentially damaged by any means should be inspected immediately. Damage includes, but is not limited to:

(a) The fuel container or vehicle in which it is installed is involved in a fire or accident or is exposed to excessive heat (generally temperatures over 180°F).

(b) The container was dropped or was subjected to an impact by road debris, loose tools, or damage from vehicle cargo. Containers should not be mounted in a cargo area unless adequately protected. As an example, containers mounted behind the cab of a pickup truck should be partitioned from the cargo area to prevent damage from shifting cargo.

(c) Sudden loss of gas pressure, emission of natural gas odor, or signs of leakage.

(d) Unusual snapping or hissing noise, rattling or other indications of container looseness.

(e) Exposure to harsh chemicals, cargo leakage (chemicals), or prolonged exposure to moisture or sunlight.

(f) A fuel container which is transferred to another vehicle or which is removed from the vehicle and reinstalled or relocated to another area of the vehicle.

b. Inspection of Type 1 through Type 4 Containers. CGA C-6.4 describes three levels of damage which are evaluated and categorized as follows:

(1) Level 1 Damage. Minor container damage, which is considered acceptable. Such damage should have no adverse effects on the safety of the container and its continued use. Items such as scratched paint, nicks, or dings that have no appreciable depth or no significant quantity of frayed fibers are considered to be in this category and repair is not required.

(2) Level 2 Damage. Level 2 damage is more severe damage than Level 1 but keeps open the possibility of repair and the container being returned to service, based on the recommendations of the manufacturer and their literature. Level 2 damage may include cuts or gouges that are deeper or longer than those of Level 1. Level 2 damage requires repair, more thorough evaluation, or destruction of the container, depending on the severity.

However, the container should be removed from service and the container manufacturer's recommendations followed.

(3) Level 3 Damage. Containers with Level 3 damage shall be condemned. Damage at Level 3 is such that the container has been rendered unfit for continued service and cannot be repaired.

NOTE: CHP inspection personnel should not advise the container owner of any repairs needed or recommended for any container damage. The owner should be advised that any Level 2 or Level 3 container damage would place the container out of service; however, the container may be depressurized and isolated from the fuel system until an in-depth examination of the container is completed. The container must be repaired in accordance with the manufacturer's recommendations or replaced prior to returning the container to service on a public highway.

c. Detailed Examination of Type 1 through Type 4 Containers. Keep in mind that the guidelines provided by CGA C-6.4 and described in this chapter are general in nature. Always check with the vehicle or container manufacturer for specific damage levels of the container. Figures 11-14 through 11-21 illustrate the types and level of damage described below. Tables 1 through 3 outline acceptance, rejection, and condemning conditions for the four types of CNG containers.

(1) Cuts, Gouges, and Scratches. Cuts, gouges, or scratches less than 0.010 inch (0.254 mm) deep are defined as Level 1 damage regardless of length, number, or direction, and are generally acceptable. Cuts, gouges, or scratches equal to or greater than 0.010 inch deep (0.254 mm) are defined as Level 2 or 3 damage and are unacceptable. Level 2 damage may be reworked; however, the manufacturer's recommendations for container repair or disposal should be followed. Refer to Figures 11-14, 11-14a and 11-14b.

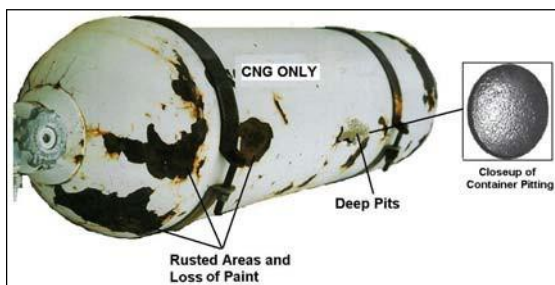


Figure 11-14. Type 1 (steel) Container with Heavy Corrosion, Pitting, and Loss of Paint

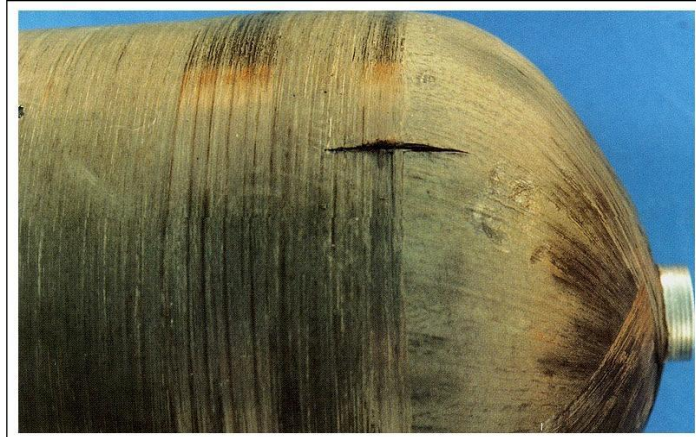


Figure 11-14a. Type 2 or Type 3 Container with Level 3 Damage Cut to Composite Wrap

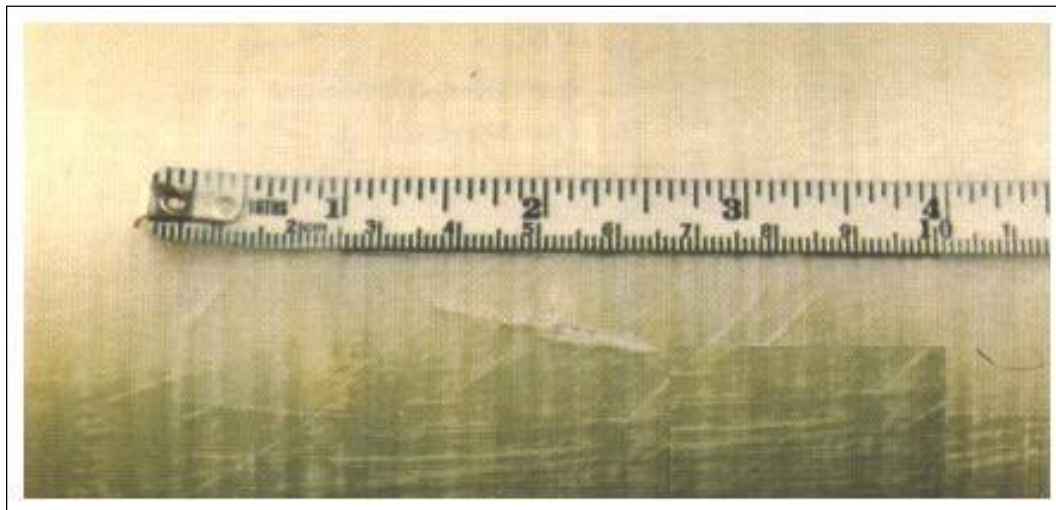


Figure 11-14b. Type 2 or Type 3 Container with Level 1 Minor Cut (acceptable)

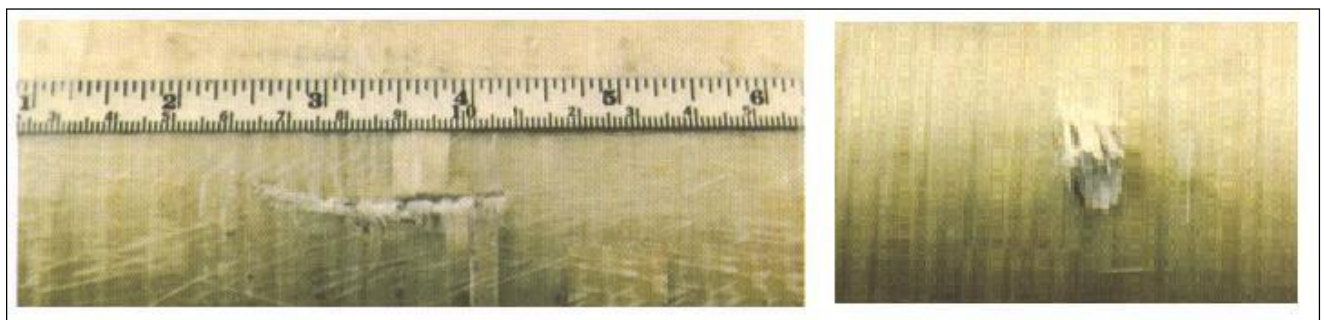


Figure 11-14c. Type 2 or Type 3 Container with Level 3 Cuts and Level 1 Scratches

(2) Abrasions. An abrasion may be the result of something chafing the surface of the container, such as a nut or bolt wedged between the container and the frame, suspension components, parking brake cable, or other vehicle components. Refer to Figures 11-15, 11-15a and 11-15b.

(a) Surfaces subjected to minor abrasion will tend to be smooth and somewhat polished in appearance. Severe abrasion will tend to appear as a group of parallel gouges or cuts as opposed to a polished surface.

(b) Abrasions or scuffs less than 0.010 inch (0.254 mm) deep (Type 2, 3, and 4 containers) are Level 1 damage, and, for the composite area of the container, are generally acceptable regardless of size, number, or direction. Abrasions greater than 0.010 inch deep are Level 2 or Level 3 damage and require guidance from the container manufacturer.

(c) Type 1 containers or the metal portions of Type 2 containers showing evidence of abrasion must be examined closely to verify that the amount of metal removed has not gone below the manufacturer's recommendations.

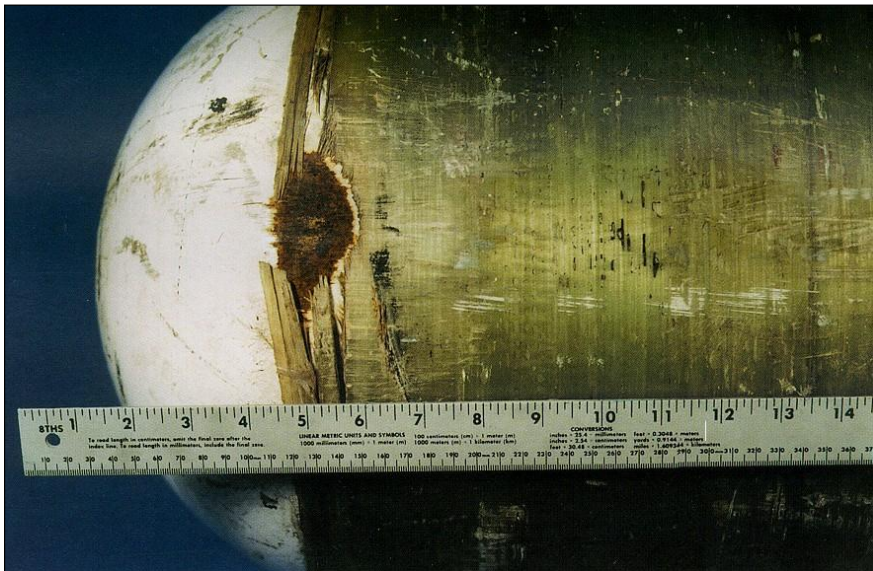


Figure 11-15. Type 2 Container with Level 1 Scuffing and Level 3 Abrasion Damage



Figure 11-15a. Type 3 Container with Level 1 Abrasion Damage from Mounting Bracket

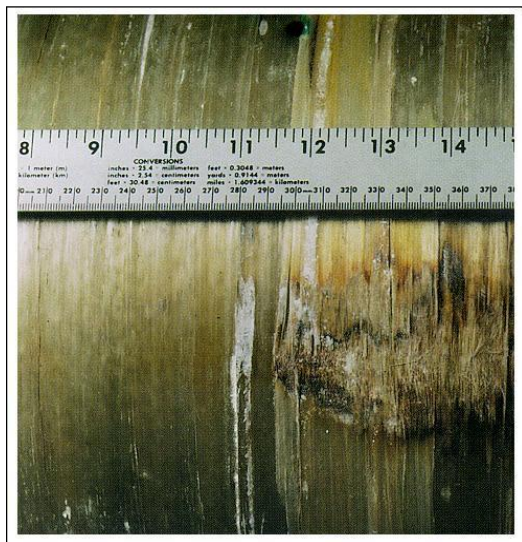


Figure 11-15b. Type 2 or Type 3 Container with Level 3 Abrasion Damage

(3) Overwrap Cracking. Matrix cracking or separation in the composite is considered Level 1 and is not generally a serious defect on a Type 2 container. This type of separation should not be confused with actual fiber breakage and damage. Additionally, the circumferential crazing parallel to the composite fibers, which occurs during some composite manufacturing process, is not harmful and should not be confused with stress corrosion cracks which are oriented perpendicular to the fibers. Figure 11-16 illustrates the cracking or separation of a Type 2 container on the left side of the photo. The right side of the illustration shows the manufacturing process of the hoop-wrapping of the container. Figure 11-16a illustrates composite overwrap cracking or “banding”

in the hoop (non-axial) direction and the left photo shows the depth of overwrap banding which could be as much as .025 inches.

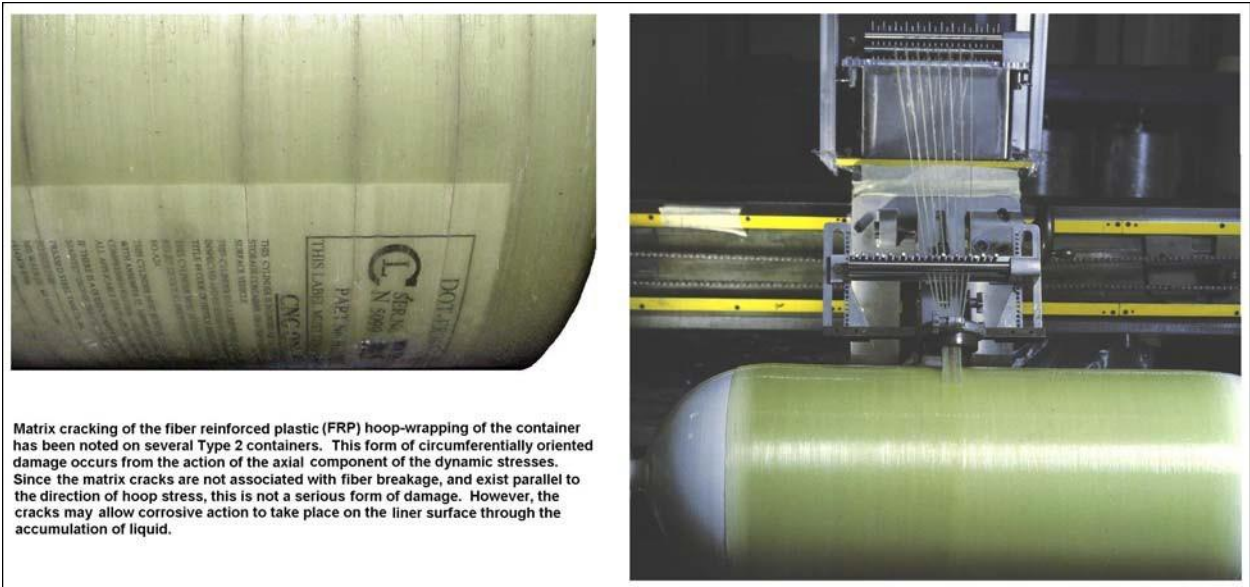


Figure 11-16. Type 2 Container Composite Cracking or Separations are Not Considered as Damage



Figure 11-16a. Type 2 Container Composite Cracking or Separations are Not Considered as Damage

(4) Chemical Damage. Generally, the materials used in the container are resistant to chemical agents under normal vehicle conditions and operating

environment. However, the container should be maintained in a clean state and should not be allowed to have prolonged exposure to moisture, corrosive agents, soaps, or automotive fluids. Generally, chemical damage will appear as an alteration of the surface such as:

(a) Corrosion, discoloration, etching, pitting, blistering, swelling, as well as composite softening, and/or resin removal. In extreme cases of chemical damage, the composite may exhibit fractures and broken or loose fibers (stress corrosion cracks). The container wall should be rigid and not deform easily. Softness of the tank wall may be evidence of severe internal or chemical attack damage and would be considered Level 2 or Level 3 damage.

(b) Minor discoloration and no material loss is defined as Level 2 damage and is considered acceptable provided the type of chemical is known. The chemical should be completely removed; the container surface cleaned, and the container manufacturer's recommendations followed.

(c) Any evidence of blistering, swelling, softening, resin removal, broken or loose fibers, stress corrosion cracks, or fractures is Level 3 damage for composite containers. Figures 11-17 and 11-17a illustrate chemical damage to a container and associated stress corrosion cracking.

(d) Metal portions of Type 2 containers exhibiting pitting, corrosion and/or oxidation (weathering), mentioned above for composite materials, is also considered Level 2 or Level 3 damage and is cause for container removal from service. Refer to Figures 11-14 and 11-15.

(e) The installation of container protective shields or covers should allow free drainage of water, or other fluids, and not cause them to have prolonged contact with the container or container mounting brackets/straps. A minimum of 0.5 inch (12.7 mm) clearance completely around the container is recommended. Additional clearance may be required in areas where the vehicle may flex during operation. Figure

11-17b illustrates a container that is secured directly to a vehicle without any clearance between the securement platform and the container.



Figure 11-17. Level 3 Chemical Damage to Container (Stress Corrosion Cracking)



Figure 11-17a. Level 3 Stress Corrosion Cracking and Chemical Damage to Container



Figure 11-17b. Container Secured Directly to a Compartment With No Clearance

(5) Corrosion. Corrosion of a metal surface involves the loss of wall thickness caused by acid or caustic materials. The following describes the different types of corrosion for Type 1 and metal portions of Type 2 containers:

(a) Isolated Pitting. Isolated pits of small diameter in small remote areas do not effectively weaken the container and may be considered acceptable Level 1 damage. Isolated pits having a depth greater than 0.035 inch (0.889 mm) is considered Level 3 damage and the container must be removed from service.

(b) Line Corrosion. Where corrosion results in a continuous pattern or when pits are connected to others in a narrow band or line, it is termed "line corrosion." This condition is more serious than isolated pitting and may be found anywhere on the container. If the deepest pit in the line corrosion is less than 0.030 inch (0.76mm) the container has Level 1 damage and may be returned to service. If the deepest pit in the line corrosion is greater than 0.030 inch (0.76 mm), the container has Level 3 damage and must be removed from service.

(c) General Corrosion. General corrosion is that which covers considerable surface areas of the container. This is also known as "broad spread corrosion." It reduces the structural strength of the container. General corrosion is often accompanied with pitting and the level of damage should be determined by using line corrosion pit depth criteria in paragraph (b) above. General corrosion that reduces the metal wall thickness by 0.030 inch (0.76 mm) or more is Level 3 damage and the container must be removed from service. Figure 11-14 illustrates pitting of a Type 1 Container.

(6) Damage to Container Ports. Impact to the ends of the container, including the valves, plumbing and pressure relief devices may cause the tank ports to be displaced into the container or cocked. Containers exhibiting this condition are considered Level 3 damage and must be removed from service.

(7) Bulges. Bulges are considered a severe structural damage where the container is deformed in an outward manner. Containers showing visual bulging have Level 3 damage and the container must be removed from service. Type 1 containers with a bow or "banana" shape are acceptable provided their shape does not interfere with proper mounting. Figure 11-18 illustrates a bulge of a Type 1 container.

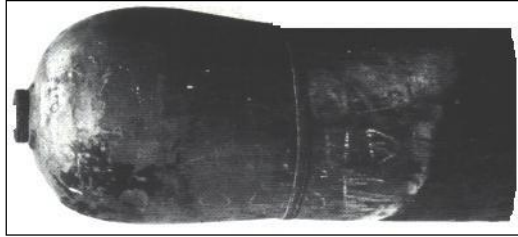


Figure 11-18. Level 3 Damage Due to Type 1 Container Bulge

(8) Impact Damage. Impact damage may be incurred during container shipping, handling or in-service use. These impacts may be the result of dropping the tank prior to installation or during container removal for maintenance or detailed inspection, a vehicle accident, road debris or an object that impacted the container. Figure 11-19 illustrates a Type 4 container with impact damage to the dome area of the container. The insert shows the type of fiber breakage that develops as a result of the impact.

(a) Impact damage for Type 3 and Type 4 composite containers differs from other forms of container damage in that the container wall may suffer more severe damage within the wall of the container than at the surface of the container, especially where the surface of the object impacting the container is blunt and relatively smooth. This is particularly true with Type 4 carbon composite containers. The surface of a composite container tends to return to its original shape after an impact and, therefore, does not dent like a Type 1 or Type 2 container.

(b) Impact damage may cause delaminations between, and fractures of, the composite layers used to construct the container. Surface damage associated with impact loading may include cutting, gouging, scraping, scuffing, chipping, puncturing, fiber breaking, loose fibers, resin cracking or change in coloration or appearance. Minor dents are considered Level 2 damage and the container manufacturer should be contacted for corrective action.

(c) Type 1 containers or metal portions of Type 2 containers with impact damage or dents greater than 0.0625 inch (1.588 mm) and/or a major diameter of the dent being 2 inch (50.8 mm) or more, or a dent that is deformed excessively or abruptly is considered Level 3 damage and must be removed from service until the manufacturer is contacted to determine the extent of damage.

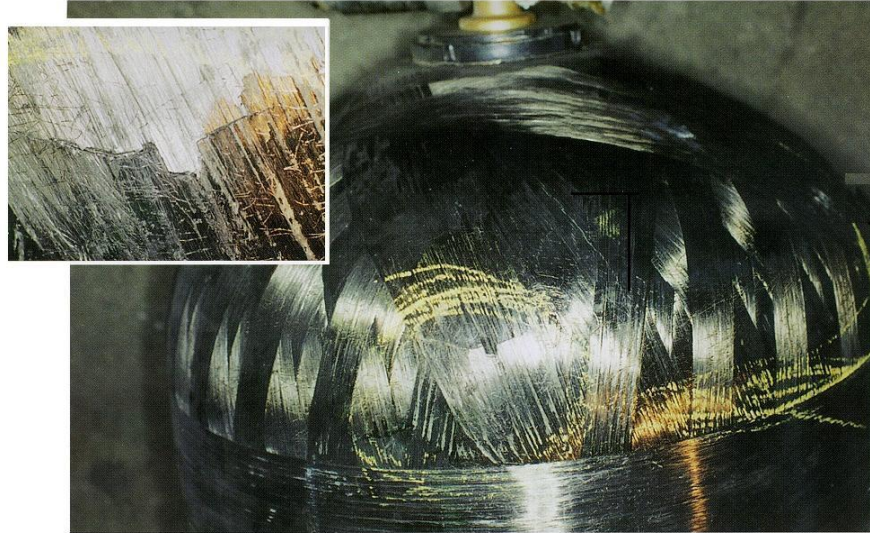


Figure 11-19. Level 3 Impact Damage to Type 4 Container

(9) Fire and Excessive Heat Damage. Generally, vehicle CNG containers have a maximum service temperature of 180° F (82.2° C) unless otherwise identified on the label. Excessive heat to a container may occur if a container is not shielded or protected from the vehicle exhaust system or a vehicle is involved in a fire, resulting in significant damage. Figure 11-20 shows Level 3 damage to a Type 4 Container.

(a) Fire damage may be evident by discoloration, darkening, charring or sooting of the surface area of the container.

(b) Severe heat or fire damage may result in resin removal and loose fibers of composite containers. Burning, charring, burning of the paint, and/or discoloration of the coating or label, plus container and/or shut-off valve (melted plastic components of valve) distortion or melting of the pressure relief device fuse plug, may be other indications of heat or fire exposure.

(c) If the vehicle is involved in an accident or fire, which causes damage to the CNG container, the container is considered to have Level 3 damage and must be removed from service. The container must be inspected, and retested in accordance with the document under which it was originally manufactured before being returned to service as required by NFPA 52,

5.12.4. Additionally, NFPA 52, 5.12.5 requires the entire fuel system to be repaired and retested before the vehicle is returned to service.



Figure 11-20. Level 3 Heat Damage to a Type 4 Container

(10) Weathering. The container may exhibit degradation of the external coating after prolonged exposure to sunlight and weathering. This may result in discoloration and/or potential deterioration of the coating on exposed surfaces. Figure 11-21 shows weather damage to a Type 4 container.

- (a) Generally, most prolonged exposure to sunlight or weathering is Level 2 damage provided there is no evidence of surface metal corrosion or loose or broken fibers.
- (b) After completion of the inspection process, the affected surface could be repaired by application of a coating in accordance with the manufacturer's recommended procedures.



Figure 11-21. Level 2 Weathering Damage to a Type 4 Container

(11) Gas Leakage. Containers, which exhibit gas leakage, must be removed from service. Gas leakage can be confirmed by use of a soapy solution or a

flammable-gas detector. If a non-ammonia and non-corrosive soapy solution is used, leakage is indicated by persistent bubbling.

(a) Some bubbling may be observed on composite containers, which can be caused by air trapped between the composite shell and the liner being forced out through the composite by the internal pressure. This condition will persist for a half-hour to several hours, depending on the pressure in the container. Figure 11-22 illustrates leak checking of container with a soap and water solution. However, a gas detector may help identify if the bubbles are air or natural gas.

(b) There have been a number of leaks reported with Type 4, full-wrapped plastic lined containers. These leaks have been caused either by pre-existing flaws in the plastic liner, flaws in the fusion weld of plastic liners, improper installation of the seal between the plastic liner and the end boss fitting, or by a combination of operating practices which resulted in negative gage pressures inside the containers followed by fast filling under low ambient temperature conditions. The low-pressure low-temperature fast-filling combination causes the liners to wrinkle and crack.

NOTE: It is important to calibrate flammable-gas detectors prior to using them to confirm natural gas leaks, since the detectors may be sensitive to normal out-gassing from composite or plastic materials, oils, other hydrocarbons, normal indoor air or even soapy solutions.

(c) When checking fuel lines for leakage, ensure that the fuel line is not damaged. Fuel lines that are damaged must be replaced. They may not be repaired (NFPA 52, 5.13.1). Figure 11-22a illustrates general locations where steel lines or fittings can leak.

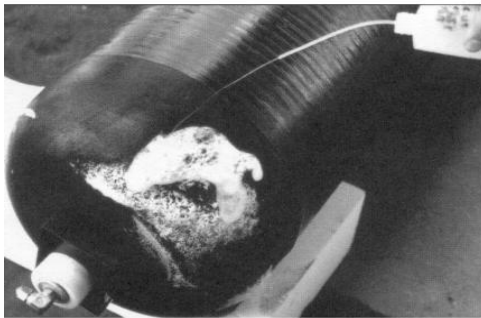


Figure 11-22. Leak Checking Container with Soapy Solution (Type 4)

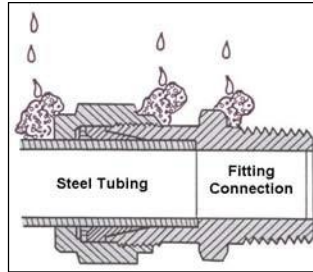


Figure 11-22a. General Locations Where Steel Lines or Fittings Can Leak

(12) Examination of Valves and Pressure Relief Devices (PRD). Each CNG container is equipped with either a manual or automatic container shut-off valve with a PRD in the port at one end of the container. Another PRD may be located in a port at the other end of the container. Containers longer than 65 inches or portions of a container that may be subjected to severe heat are generally equipped with a PRD at both ends of the container. All PRDs must be in direct communication with the contents of the container regardless of whether the container valve is open or closed. An inspection of the PRD valve and plug should include the following:

- (a) External inspection of PRDs for corrosion, damage, rust, bulging, plugging of external PRD channels, and mechanical defects; such as leakage, extrusion of fusible metal, or looseness of fusible metal triggers.
- (b) Examine the shut-off valve and PRD assemblies, including the hexagonal torque nut for damage. The valve and PRD assemblies should not be deformed or show other signs of damage. Damaged valves and PRDs must be replaced with the same type of valve and PRD recommended by the manufacturer for that type of container. There should be no rubber shavings or other evidence of seal damage at these interfaces.
- (c) Dents, gouges, and scratches equal to or greater than 0.02 inch (0.508 mm) deep, in locations other than the hexagonal torque nut, are Level 2 damage. Figure 11-23 illustrates one type of manual container valve, PRD, and fuel line.

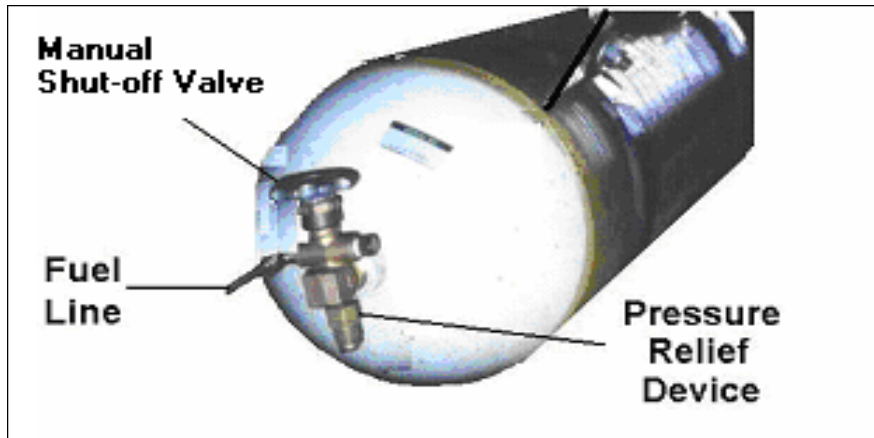


Figure 11-23. Container Shut-off Valve, Pressure Relief Device and Fuel Line

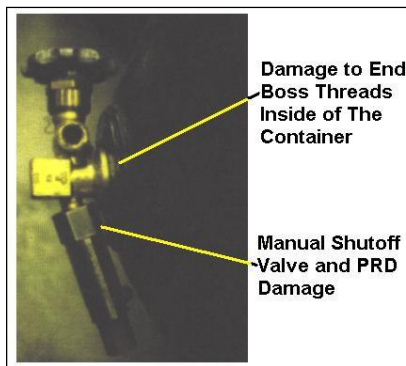


Figure 11-23a. Damaged PRD and Shut-off Valve

d. Container Inspection Interval and Examination. CNG containers must be visually inspected after a motor vehicle accident or fire and at least every 36 months or 36,000 miles, whichever comes first, for damage and deterioration. However, failure to perform preventive maintenance inspections on a regular basis or promptly (in the case of a potentially damaging incident or unusual behavior) may result in a serious accident causing severe damage, injury, or both. An inspection must be conducted if any of the following conditions exist:

- (a) Container Installation. The fuel container is transferred to another vehicle, or the container installation or mounting brackets have been moved.
- (b) Accidents and/or Heat. The fuel container or vehicle in which it is installed is involved in a fire, is exposed to excessive heat or is subjected to an impact.

(c) Chemicals and/or Excessive Pressure. The fuel container is suspected to have damage from cargo, vehicle, and/or environmental chemicals, is overpressurized, or is believed to have been damaged by any other means.

(d) Unusual Behavior. Unusual behavior may include, but is not limited to, presence of natural gas odor, unexpected loss of gas pressure, rattling, unusual snapping or hissing sounds, or other indications of looseness.

e. Container Inspection and Damage Level – All Container Types. Tables 1, 2 and 3 outline acceptance, rejection, and condemning conditions for containers. Visual inspection of the container surface is the primary means of detecting container damage. Keep in mind that the level of damage and the conditions are general in nature and inspectors should also refer to the vehicle or container manufacturer's guidelines before condemning any container.

<b>METAL CONTAINERS (Type 1 and the Exposed Metal Portions of Type 2)</b>				
<b>Container Condition</b>	<b>Level 1 Damage</b>	<b>Level 2 Damage</b>	<b>Level 3 Damage</b>	<b>Page/ParaReference</b>
<b>Abrasions</b>	No evidence of abrasions.	Minor abrasion refer to manufacturer's guidelines.	Depths that reduce wall thickness below minimum allowable referenced in manufacturer's guidelines.	Page 11-24 Para 7.c(2)  Figure 11-15 Figure 11-15a Figure11-15b
<b>Impact (dent)</b>	No evidence of impact damage or dent(s).	Minor dent(s) refer to manufacturer's guidelines.	≥2 inches (50.8 mm) diameter or ≥0.0625 inch (1.588 mm) deep.	Page 11-30 Para 7.c(8)  Figure 11-19
<b>Bulging or Bowing</b>	No evidence of bulging (banana shape acceptable) (see Level 3)  (Type 1 Container Only)	Any bulging is Level 3 damage. For minor bow refer to manufacturer.	Any visible bulge, or bowed shape which interferes with proper mounting.	Page 11-29 Para 7.c(7)  Figure 11-18
<b>Corrosion/pits</b>	<0.035 inch (0.889 mm) deep.	Refer to manufacturer's guidelines.	±0.035 inch (0.889 mm) deep.	Page 11-29 Para 7.c(5)  Figure 11-14

Table 1. Inspection Criteria Limits for Type 1 and Metal Portions of Type 2 Containers

<b>METAL AND COMPOSITE CONTAINERS (All Container Types )</b>				
<b>Container Condition</b>	<b>Level 1 Damage</b>	<b>Level 2 Damage</b>	<b>Level 3 Damage</b>	<b>Page/Para Reference</b>
<b>Cuts/gouges and scratches</b>	<0.010 inch (0.254 mm) deep.	Repair/rework may be possible, refer to manufacturer's guidelines.	≥ 0.010 inch (0.254 mm) deep. Refer to manufacturer's guidelines.	Page 11-22 Para 7.c(1)  Figure 11-14a Figure 11-14b Figure 11-14c
<b>Weathering</b>	No evidence of weathering.	Minor coating disruption and/or loss of outer coating. Repair work may be possible.	Excessive coating disruption and/or loss, refer to manufacturer's guidelines.	Page 11-32 Para 7.c(10)  Figure 11-21
<b>Chemical damage</b>	Chemical is known not to affect container type, cleans off with no residue affect.	Discoloration is minor after cleaning, no material loss, refer to manufacturer's guidelines.	Permanent discoloration, and/or loss/disruption of material, refer to manufacturer's guidelines.	Page 11-26 Para 7.c(4)  Figure 11-17 Figure 11-17a
<b>Container port damage</b>	No evidence of damage.	No evidence of damage.	Impact to the ends of the container, including valves, plumbing, PRDs that cause the tank ports to be displaced or cocked.	Page 11-29 Para 7.c(6)  Figure 11-23a
<b>Container subjected to fire, heat exposure or vehicle involved in accident</b>	Vehicle owner knows of no fire, heat exposure, or accident and no indications of such on container.	Minor fire, heat exposure, or accident damage, refer to manufacturer's guidelines.	Indications of heat damage or container impact, refer to manufacturer's guidelines.	Page 11-31 Para 7.c(9)  Figure 11-20
<b>Charring/soot</b>	No evidence of charring or soot.	Charring or soot washes off and no permanent discoloration.	Permanent discoloration or marking which appears to be exposure to excessive heat.	Page 11-31 Para 7.c(9)  Figure 11-20

Table 2. Inspection Criteria Limits for Metal and Composite Containers

<b>METAL AND COMPOSITE CONTAINERS (All Container Types ) (Cont.)</b>				
<b>Container Condition</b>	<b>Level 1 Damage</b>	<b>Level 2 Damage</b>	<b>Level 3 Damage</b>	<b>Page/Par Reference</b>
<b>Gas Leakage</b>	No leakage.	Bubble test or gas detector test negative.	Bubble test and/or gas detector confirms fuel leak.	Page 11-32 Para 7.c(11)  Figure 11-22 Figure  11-22a
<b>Labeling</b>	Required information legible and clean.	Label information missing or not legible (NFPA or FMVSS 304).	Container manufacturer, model/part number illegible or missing.  Beyond service life.	Page 11-18 Para 6.e(1)  Figure 11-11
<b>Container Valve &amp; PRD</b>	No evidence of damage to container valve or PRD.	Dents, gouges and scratches $\pm$ 0.02 inch in locations other than the hexagonal torque nut.	Refer to manufacturer's guidelines.	Page 11-34 Para 7.c(12)  Figure 11-23 Figure  11-23a

Table 2. Inspection Criteria Limits for Metal and Composite Containers (Cont.)

<b>COMPOSITE CONTAINERS (Types 2, 3 and 4)</b>				
<b>Container Condition</b>	<b>Level 1 Damage</b>	<b>Level 2 Damage</b>	<b>Level 3 Damage</b>	<b>Page/Para Reference</b>
<b>Abrasion</b>	<0.010 inch (0.254 mm) deep.	Refer to manufacturer's guidelines.	>0.010 inch (0.254 mm) deep.	Page 11-24 Para 7.c(2)  Figure 11-15 Figure 11-15a
<b>Impact (dent)</b>	No evidence of impact damage or dent(s).	Minor dent, and refer to manufacturer's guidelines.	Refer to manufacturer's guidelines.	Page 11-30 Para 7.c(8)  Figure 11-19
<b>Stress corrosion cracking (SCC)</b>	No evidence of SCC and container has not been subjected to chemical damage.	Minor discoloration, no material loss, or resin removal. No evidence of SCC.	Any evidence of blistering, swelling, softening, and resin removal, broken or loose fibers, SCC, or fractures	Page 11-26 Para 7.c(4)  Figure 11-17  Figure 11-17a

Table 3. Inspection Criteria Limits for Composite Containers (Types 2, 3, and 4)

f. General Inspection Guidelines for Container Mounting Brackets and Straps and Installation of Fuel Supply Containers (Type 1 through Type 4). The container should be mounted in a system which restrains the container securely but does not cause damage to the container or vehicle. The mounting system must allow the container to expand and contract as the internal pressure fluctuates without causing the container to be abraded. Inspection of the mounting brackets/straps and the container installation should include the following:

- (1) In accordance with NFPA 52, 5.3.10, metal clamping bands (container mounting straps) may not be in direct contact with the container. The interface between the container and mounting straps must be lined with a

rubber gasket to allow limited movement of the container in the mounting system. NFPA 52,

5.3.10 requires a resilient gasket that is designed with a non-water retaining isolator so that it does not trap liquids between the rubber and the container. Ensure that the rubber gasket is in place, has not been worn through, is in good condition, and is not allowing the metal bracket strap to chafe against the container. Figure 11-24 illustrates an example of a rubber gasket in good condition and one that is worn.

(2) NFPA 52, 5.3.4 requires the container mounting bracket to be secured to the vehicle body, bed, or frame to prevent damage from road hazards, slippage, loosening, or rotation, using a method capable of withstanding a static force in the six principal directions of eight times the weight of a fully pressurized container(s). Additionally, NFPA 52, 5.3.5 requires each fuel container in the rack to be secured to its cradle in such a manner that it is capable of withstanding a static force applied in the six principal directions of eight times the weight of a fully pressurized container(s).

(3) Although not required by NFPA 52, most manufacturers recommend that containers should not be mounted in more than two brackets each. Multiple brackets may cause chassis loads to be transferred from the vehicle frame into the container, causing stress concentrations in the vehicle frame and an increased likelihood of frame failure. Consult the container/bracket manufacturer for additional information. Figure 11-25 illustrates typical container mounting brackets.

(4) Washers or bolts should not be in contact with or in close proximity to the container. Washers may be required between the bolt and the mounting system to prevent the bolt from pulling through the mounting.

(5) Containers mounted under vehicles should be shielded against road debris impact. The 1995 edition of NFPA 52, 3-3.1 requires all containers installed on/or after August 11, 1995, to be protected with a shield to prevent damage that can occur due to road hazards, loading, unloading, direct sunlight, and use of the vehicle. Additionally, the shield must be installed to prevent contact of the shield with the container and entrapment of materials that could damage the container or its coating.

(6) The 1998 edition of NFPA 52, 3.3.2 and the 2002 edition of NFPA 52,

5.3.2 no longer require a protective shield. However, shields, if present, must be installed to prevent:

(a) Direct contact between the shield and the container.

(b) Trapping of solid materials or liquids between the shield and container that could damage the container or its coating.

(c) Contact with vehicle components such as frame members, body panels, brake lines, and so on, that may lead to container fretting or abrasion over time.

(7) Containers located less than 8 inches from the exhaust system must be shielded against direct heat (NFPA 52, 5.3.7).

(8) Inspection personnel should review NFPA 52, 5.3, (Installation of Fuel Supply Containers), to ensure the containers are in compliance with all provisions of this section. When conducting a detailed visual inspection, the inspector would generally use mirrors to conduct the inspection. However, if containers cannot be viewed by use of mirrors, the inspector may request removal of shields blocking the view of the container.

(9) Generally, container mounting brackets should be disassembled only when suspicion of potential container damage (under the bracket area) exists. Additionally, complete container removal is not normally recommended for the purpose of conducting a detailed visual inspection.

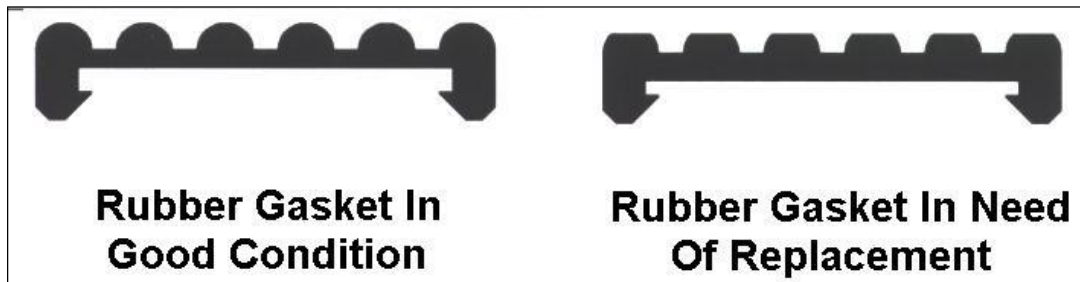


Figure 11-24. Examples of Rubber Gasket Condition

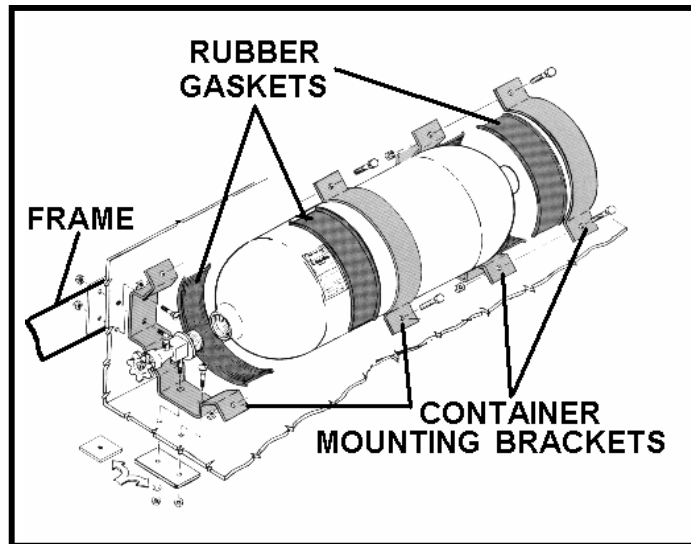


Figure 11-25. Typical Container Mounting Brackets

g. Container(s) Installed Above the Operator or Passenger Compartment. NFPA 52, 5.3.3.1 requires a container, its piping, fittings, and valves, that are installed above the operator or passenger compartment of a vehicle, to be protected from damage by:

- (1) A guard rail or similar device that is designed to absorb the impact of a collision with a stationary object when the vehicle is moving either forward or backward at 5 mph. The guard rail or similar device must be free of projections that could damage the container or its valves and fittings; and
- (2) A shield designed to absorb impacts that can occur during loading, unloading or use of the vehicle. The shield must be free of projections that could damage the container or its valves and fittings.
- (3) The top of the container and any CNG piping, fitting, valve, housing, guard rail, or shield may not be more than 13-1/2 feet above the road surface.
- (4) The container must be protected from accidental contact with overhead electrical wiring by metallic or nonmetallic covers. Figure 11-26 shows CNG containers located above the operator/passenger compartment.

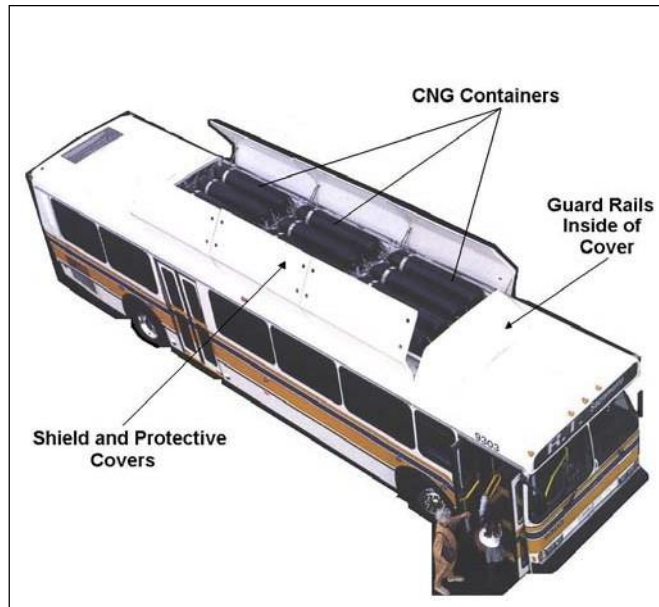


Figure 11-26. CNG Containers Located Above Operator/Passenger Compartment

h. Container Minimum Road Clearance. NFPA 52, 5.3.11, requires the minimum clearance from the road to a container, its housing, or fittings, whichever is lowest where the container is installed below the frame and between the axles of a CNG vehicle, with the vehicle loaded to its gross weight rating to be:

- (1) Not less than 7 inches for a vehicle having a wheel base less than or equal to 127 inches or;
- (2) Not less than 9 inches for a vehicle having a wheel base greater than 127 inches.
- (3) Additionally, NFPA 52, 5.3.12, prohibits containers that are installed behind a rear axle of a CNG vehicle from being installed transversely. However, containers may be installed in other orientations where the container valve and fittings are located at the end of the container most protected from a source of impact.
- (4) Containers installed under the vehicle body should be inspected for impact or abrasion damage due to stone chips, and a variety of other road debris.

The containers should also be inspected for acid attack due to road spray, and unintentional drainage (battery acid or other chemicals). Containers located in a truck bed should be inspected to ensure that any cargo shifts have not impacted the container.

8. FUEL SYSTEM COMPONENTS AND THEIR INSPECTION. In addition to the fuel supply containers mentioned above, the following fuel system components are normally found in a CNG fuel system:

a. Container Shut-off Valve. NFPA 52, 5.6.1, requires every container to be equipped with a manual valve or a normally-closed, remotely-actuated shut-off valve connected directly to the container. The container valve is designed to shut off the fuel supply from the container to the rest of the fuel system. Figure 11-27 illustrates two types of manual shut-off valves.

(1) The valve must be mounted directly in the container neck. Some container valves are equipped with an “O-ring,” which should be checked to ensure that it is not leaking.

(2) The normally-closed, remotely-actuated valve must be equipped with a means to bleed the fuel container manually. Figure 11-27a illustrates a typical electric normally-closed remotely-actuated shut-off valve with a manual lockdown and container bleed device.

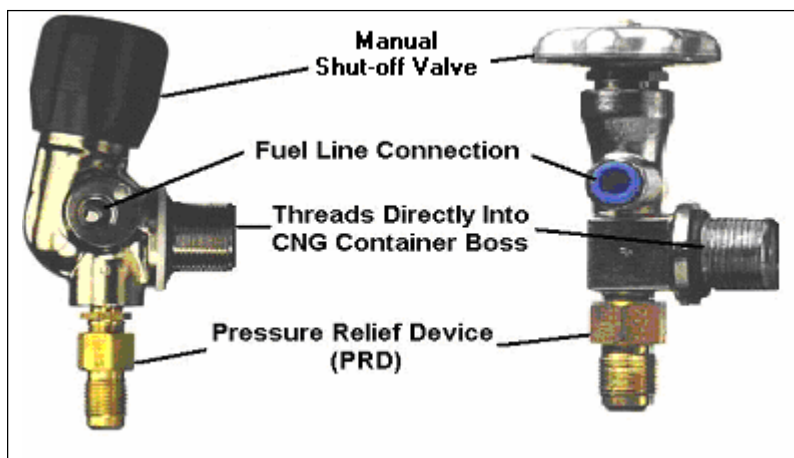


Figure 11-27. Two Types of Manual Shut-off Valves

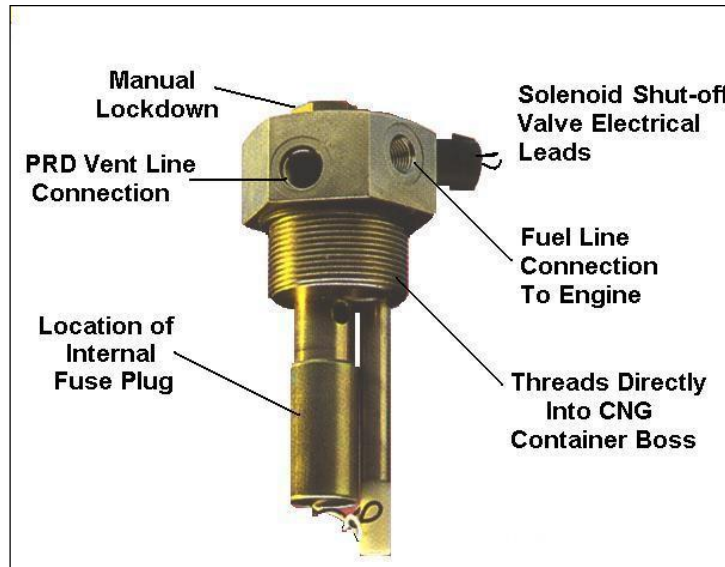


Figure 11-27a. Remotely Actuated Shut-off Valve

b. Pressure Relief Device. A PRD is fitted into the container shut-off valve. The purpose of the PRD is to melt and/or burst and release CNG from the container in the event of a fire or when internal pressure exceeds 5,000 psi. Generally, there are three ways to over-pressurize a CNG container: (1) too much CNG may be dispensed during the filling operation, (2) the temperature of the fuel may increase after filling, or (3) as the result of a vehicle fire.

(1) Categories of PRD. Generally, there are three categories of PRDs currently being used in the CNG industry:

(a) Thermally Activated. These devices are activated only by high temperatures (157° F to 220° F). The design generally contains a fusible material that will melt when it reaches a specific temperature releasing CNG through a vent hole. Figure 11-28 illustrates a typical thermally activated PRD. Note the grainy fusible material present in the barrel of the PRD plug.

(b) Series Combination. These devices are activated by high temperature and high pressure. The design generally has a fusible material that is backed by a pressure burst disk. Figure 11-28a illustrates a typical series combination PRD. The holes near the top of the PRD (and inside) are filled with a fusible material. Also, not seen, is an internal burst disk that will burst due to the force of gas pressure.

(c) Parallel Combination. These devices are activated by either high temperature or high pressure. The design generally has two vent

paths, one of which is protected by a fusible material and the other by a pressure burst disk. Figure 11-28b illustrates a typical parallel combination PRD. Note the two different (parallel) vent connections.

NOTE: NFPA 52, 4.5.1(a) requires the device to comply with CGA S-1.1, Pressure Relief Device Standards, Part 1, Cylinders For Compressed Gas; or with DOT and TC specifications, standards, exemptions, or special permits; or ANSI/IAS NGV2, Basic Requirements for Compressed Natural Gas Vehicle (NGV) Fuel Containers; or International Approval Services (IAS) U. S. Requirement 5-96, Basic Requirements for Natural Gas Vehicle (NGV) Fuel Containers.

(d) There are various designs and locations for PRDs. Although PRDs are required to “directly communicate” with the fuel, they can be located on the shut-off valve external to the container or on the shut-off valve inside the container. Figure 11-28c shows several different designs of PRDs. Figure 11-28d shows a PRD designed to be installed external to the container and Figure 11-28e shows a PRD designed to be installed internal to the container.



Figure 11-28. Typical Thermally Activated PRD



Figure 11-28a. Typical Series Combination (thermal and pressure) Activated PRD



Figure 11-28b. Typical Parallel Combination (thermal and pressure) Activated PRD



Figure 11-28c. Several Different Designs of Pressure Relief Devices

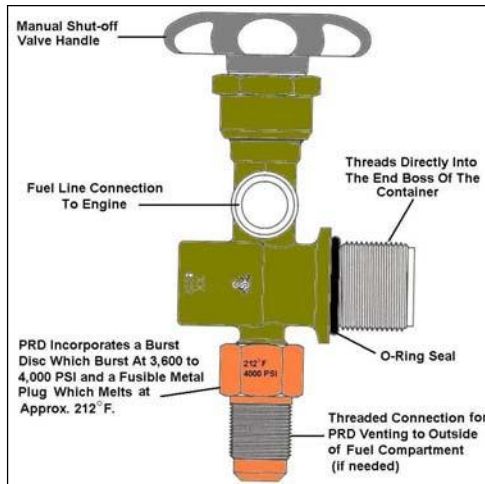


Figure 11-28d. Pressure Relief Device (External Fuse Plug)

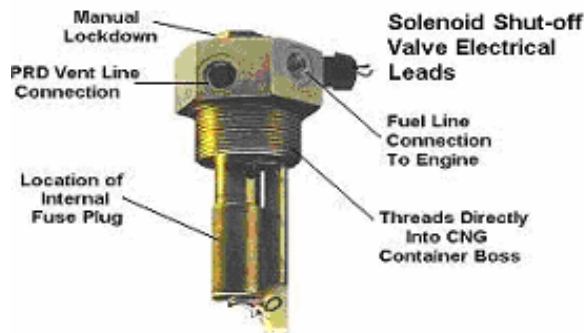


Figure 11-28e. Pressure Relief Device (Internal Fuse Plug)

(2) NFPA Requirements for PRDs. Some of the other requirements inspectors should look for when inspecting PRDs are:

(a) Each container must be fitted with one or more pressure relief devices (NFPA 52, 4.5.1).

(b) The PRD must be in direct communication with the fuel and shall be vented to the atmosphere by a method that can withstand the maximum pressure that results (NFPA 52, 4.5.1(2)).

(c) PRDs may not be fitted with lifting devices (NFPA 52, 4.5.2.2).

(d) PRD adjustment, if external, shall be provided with a means for sealing the adjustment to prevent tampering by unauthorized persons.

If at any time it is necessary to break such a seal, the valve shall be removed from service until it has been reset and sealed (NFPA 52, 4.5.2.2).

(e) PRDs and connections between pressure-carrying components installed within a closed compartment shall be vented to the outside of the vehicle (NFPA 52, 5.4.1).

(f) Each CNG container shut-off valve that has a PRD internal to the valve, must be stamped or otherwise permanently marked on the valve body to indicate the service ratings of the PRD (NFPA 52, 4.9.4). However, container valves incorporating integral pressure relief devices marked in accordance with NFPA 4.5.1, shall not require additional marking.

(3) CGA Standards for PRDs. CGA S-1.1, Pressure Relief Devices Standards, Part 1, Cylinders for Compressed Gases (1989 Edition), contains several different methods a manufacturer of PRDs may use to identify the PRD.

(a) CGA, S-7.1. "Suitable markings shall be provided to identify the manufacturer of the pressure relief device." The following sections are the manufacturer's options:

(b) CGA, S-7.2. "When rupture disks and pressure opening parts are designed to be replaced as individual parts, they shall be marked to indicate the rated burst pressure (when used in conjunction with the proper mating part), the flow capacity, and the manufacturer. Suggested methods of marking are as follows:"

(c) CGA, S-7.2.1. "Stamp with manufacturer's name or trademark and rated burst pressure or identifying part number on the part containing the pressure opening."

(d) CGA, S-7.2.2. "Ink or otherwise mark the number on the rupture disk or apply some other code mark to facilitate determination of burst pressure range and the proper mating part."

(e) CGA, S-7.2.3 "When rupture disk and pressure opening parts are combined in a factory assembled pressure relief device designed to be replaced as a unit (CG-1, CG-4, or CG-5), the assembly shall be externally marked to indicate the rated burst pressure, flow capacity, manufacturer, and yield temperature if applicable."

NOTE: As mentioned above, there are various types of PRDs. As an example, a “CG-1” is a rupture disk; a “CG-2” is a fusible plug utilizing a fusible alloy with a yield temperature not over 170°F, nor less than 157°F; a “CG-3” is a fusible plug utilizing a fusible alloy with a yield temperature not over 220°F, nor less than 208°F; a “CG-4” is a combination rupture-disk/fusible-plug device, utilizing a fusible alloy with a yield temperature not over 170°F, nor less than 157°F; and a “CG-5” is a combination rupture-disk/fusible-plug device, utilizing a fusible alloy with a yield temperature not over 220°F, nor less than 208°F. Ultimately, it is the PRD manufacturer’s responsibility to provide the proper device suitable to the type of pressure to which the CNG container is expected to perform.

(f) CGA, S-7.3. “Fusible metal pressure relief devices (CG-2 or CG-3) shall be externally marked to indicate yield temperature and manufacturer.”

(g) CGA, S-7.4. “Pressure relief valves shall be marked to indicate:

1Manufacturer.

2The set pressure for which the valve is set to start-to-discharge.

3 The flow rating pressure in pounds per square inch gauge (psig) at which the flow capacity of the valve is determined.

4The flow capacity in cubic feet per minute of free air.”

(h) CGA S-1.1, S-7.5. “All markings required in 7.2 through 7.4 inclusive may be coded. Code designations shall be determinable from the manufacturer.”

NOTE: Inspection personnel who question a PRD code designation may have to refer to the vehicle and/or CNG container manufacturer for further information.

(4) Inspection of Container Valves and Pressures Relief Devices. As mentioned above, all PRDs must be directly connected to the container or container valve in a manner that ensures the PRD can vent the contents of the container regardless of whether the container valve is in the closed or open position (NFPA 52, 4.5.1). Figure 11-29 illustrates a container in an enclosed compartment where the PRD is not vented to the outside of the

compartment. Inspection of the container valves and PRDs should include the following:

- (a) Verify the PRD in use with the container is suitable for the container type and the container manufacturer has approved the PRD (NFPA 52, 4.5.1).
- (b) The container valve and PRD assemblies should not be deformed or show other signs of damage. Damaged valves and/or PRDs must be replaced (NFPA 52, 5.13.3). Check the interface between the valve and the container port; and the PRD and container port; and all connections and O-rings for leakage.
- (c) Inspect all valves and PRDs for corrosion, damage, rust, bulging, plugging of external PRD channels, and mechanical defects, such as leakage or extrusion of fusible metal. Generally, dents, gouges or scratches that are 0.02 inches (0.508 mm) deep in locations other than the hexagonal torque nut call for removal and replacement of the PRD (refer to the manufacturer's recommendations).
- (d) Check the PRD to determine if it has an external adjustment. If so, NFPA 52, 4.5.2.2, requires a means for sealing the adjustment to prevent tampering by unauthorized persons. Additionally, if the seal is broken, the PRD must be removed from service until the manufacturer or other competent person has retested and sealed the PRD.
- (e) Ensure the PRD is in compliance with the remaining requirements of NFPA 52, 5.13.4.
- (f) Ensure replacement PRDs are installed in accordance with the manufacturer's guidelines.
- (g) Multiple container installations should be arranged so discharge from the pressure relief device on one container will not impinge on another container. Some manufacturers install a ½ inch stainless steel tube "pipe-away" to redirect the pressure relief device flow. (This is not a requirement of NFPA 52).

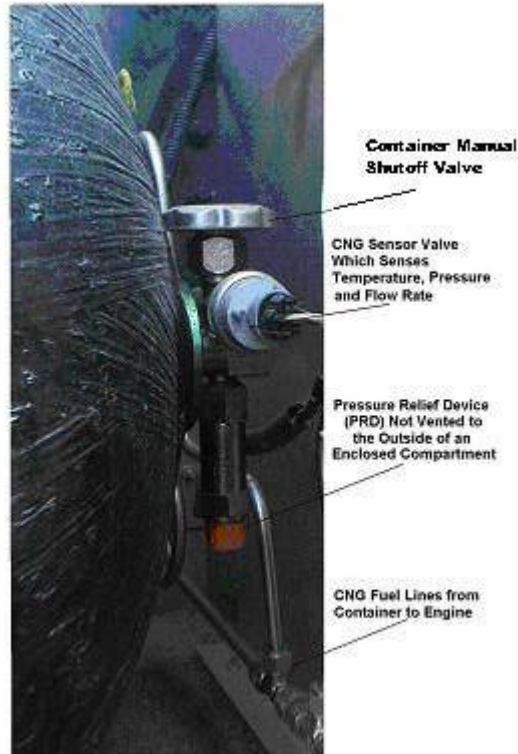


Figure 11-29. PRD Not Vented to the Outside of an Enclosed Compartment

c. Venting Systems. All pressure relief devices and connections between pressure-carrying components, including plugs in the ends of containers with openings in each end, which are installed within a closed compartment must be vented to the outside of the vehicle in a suitable location (NFPA 52, 5.4.1). Figure 11-30 illustrates a linear, low density polyethylene-type enclosure, and Figures 11-30a and 11-30b show an equally gastight alternate enclosure, both of which are vented directly to the outside of the vehicle.

- (1) The venting system for the discharge of pressure relief devices (pressure relief device channels) shall be constructed of metallic tubing with threaded, compression, or flare fittings and shall be secured at the outer end.
- (2) The vent or vents for the venting system may not exit into a wheel well or into the engine compartment (NFPA 52, 5.4.3).
- (3) The vent may not restrict the operation of a container pressure relief device or pressure relief device channel (NFPA 52, 5.4.4).
- (4) Vent outlets must be protected by caps, covers, or other means to keep foreign objects, water, dirt, and insects from collecting in the lines.

Additionally, the protective devices may not restrict the flow of gas (NFPA 52, 5.4.5).

(5) The neck of the container and all CNG fittings within the compartment must be enclosed in a gastight enclosure made of linear, low density polyethylene having a minimum thickness of eight mils or an equally gastight alternate enclosure vented directly to the outside of the vehicle (NFPA 52, 5.4.6).

(6) When PRDs are located in a vehicle compartment capable of accumulating natural gas, a container must be installed so the following conditions are met (NFPA 52, 5.4.7):

1 The PRD, for the protection of the container, is installed in the same vehicle compartment as the container.

2 The discharge from the PRD is vented to the outside through an electrically conductive tube or hose, which shall be in accordance with the following:

a Secured at intervals in such a manner as to minimize the possibility of damage, corrosion, or breakage of either the vent line or the PRD due to expansion, contraction, vibration, strains, or wear and to preclude any loosening while in operation.

b Having a burst pressure of at least 1-1/2 times the pressure in the vent that results from activation of the PRD.

c The vent line should not lose its gas-carrying ability when exposed to 590° C for 20 minutes.

3 The vent opening is not blocked by debris thrown up from the road, such as snow, ice, mud, and so forth, or otherwise affected by the elements.

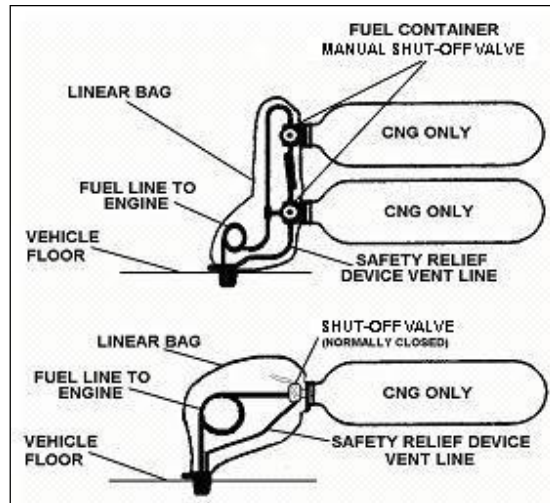


Figure 11-30. Gastight Enclosure (linear, low density polyethylene)

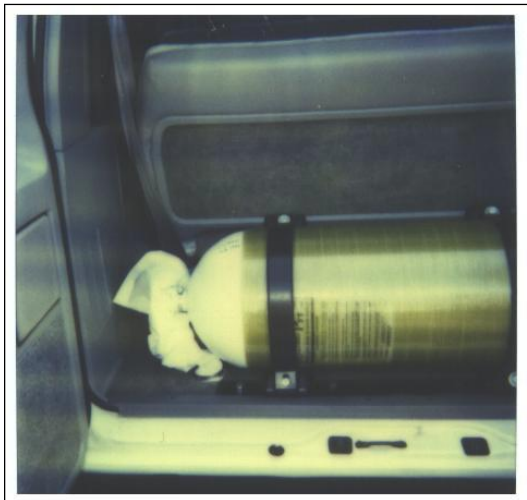


Figure 11-30a. Typical Gastight Vent Located Inside a Small Bus

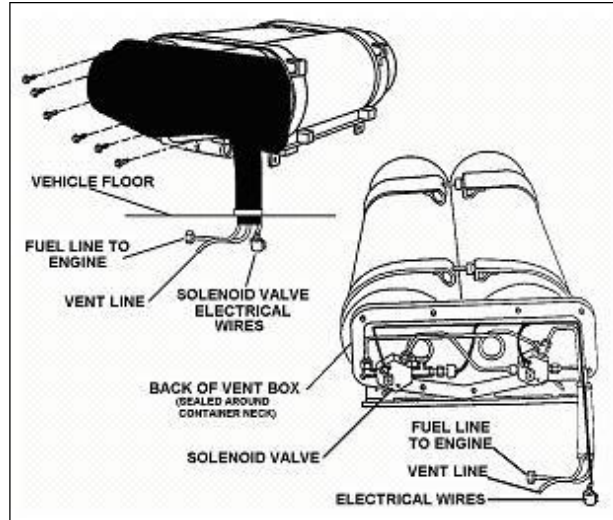


Figure 11-30b. Gastight Enclosure (equally gastight alternate)

(7) If the PRD is plumbed back from the valve or end plug toward the middle of the cylinder as shown in Figure 11-30c, it must be mounted securely to the cylinder surface in a manner that causes no abrasion to the cylinder surface. All plumbing from the valve or end plug to the PRD and PRD outlet plumbing must be rated for the required service pressure and must not restrict the PRD relief flow (NFPA 52, 5.4.2). Figure 11-30d illustrates the mounting securement of one type of PRD which does not meet the above requirements. In this particular case, the inspector found the securement mounting bracket loose and the protective rubber gasket was slipping out of the securement bracket.

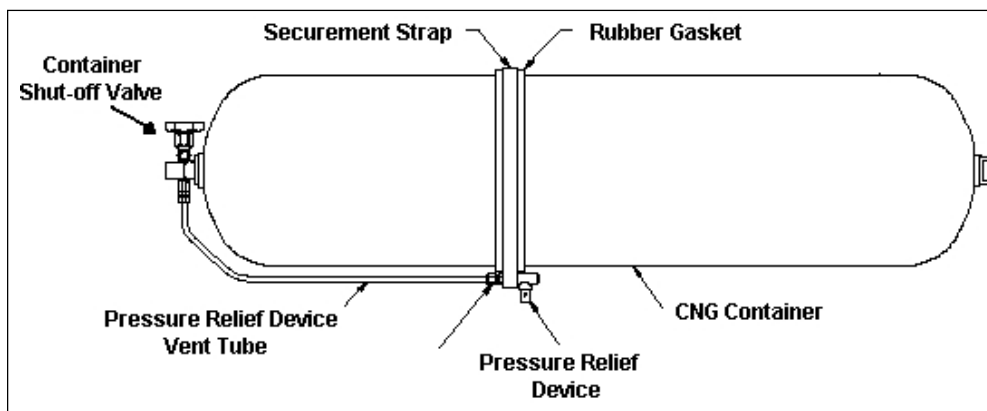


Figure 11-30c. PRD Plumbing Back on Cylinder



Figure 11-30d. PRD Securement Bracket and Rubber Gasket Loose

d. Fuel Lines. The fuel lines connect the fuel fill receptacle to the fuel containers and the fuel containers to the pressure regulator. Generally, fuel lines are made from annealed seamless stainless steel (tubing) or flexible metal lines. Flexible metal hose is usually constructed with a combination of annular corrugated 316L stainless steel tube with a 321 stainless steel braid which provides a strong, flexible design.

(1) Hose, metallic hose, flexible metal hose, tubing, and their connections must be suitable for the most severe pressures and temperatures expected under normal operating conditions with a burst pressure of at least four times the service pressure (NFPA 52, 4.10.2). The fuel lines and all other high pressure components must withstand a hydrostatic test of four times their service pressures. Given a service pressure of 3,000 psi, the high-pressure components must be able to withstand pressures up to 12,000 psi.

(2) Fuel lines must have the maximum practical clearance from the engine exhaust system (NFPA 52, 5.5.5). Generally, the fuel lines should be at least eight inches away from a heat source. Some manufacturers use a heat shield and/or wrap the fuel line in a braided ceramic fiber type material that is heat resistant when they cannot locate the fuel line or container more than eight inches away from a heat source. Figure 11-31 illustrates a vehicle exhaust system that is closer than eight inches from the CNG container. However, the exhaust system is wrapped with a ceramic fiber material that acts as a "shield." As long as the container does not show any heat damage there is no violation.

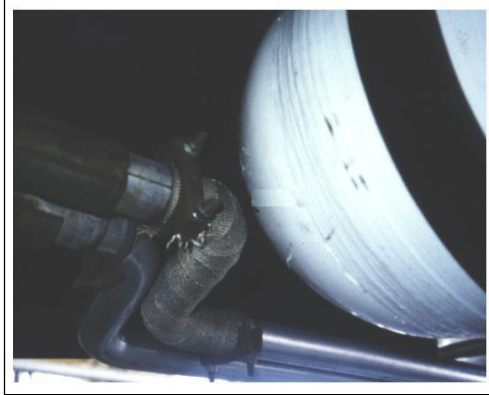


Figure 11-31. Exhaust System Less Than 8 inches from CNG Container

(3) Fuel lines are required to be mounted, braced, and supported to minimize vibration and must be protected against damage, corrosion, or breakage due to strain or wear. Additionally, the fuel line should be supported at least every 24 inches; however, NFPA 52, 5.5.6 does not require it. Generally, fuel lines have “stress (vibration) loops” that are placed in the fuel line wherever it connects to another component, and are approximately three inches or more in diameter. Securement clamps may not be attached to vibration loops, which are intended to absorb any tension or compression forces exerted on the fuel line during the normal operation of the vehicle. Do not measure the length of the vibration loop when measuring the 24 inch support points. Figure 11-31a shows a typical vibration loop.

(a) To avoid twisting or flexure of a flexible metal hose, the hose should be installed so that flexing takes place in one plane only, and in the plane of bending. Figure 11-31b illustrates the correct and incorrect methods of installing a typical hose.

(b) Sharp bending of flexible metal hose must be avoided. There are many ways a hose can be subjected to recurring sharp bends as a result of improper installation. Figure 11-31c illustrates a few examples of the correct and incorrect bend radius.

(c) A CNG fuel system, which uses a flexible metal hose to absorb movement, must be properly supported to prevent breakage due to strain or wear (NFPA 52, 5.5.7). Additionally, the hose should not be compressed or stretched, and the direction of motion should be perpendicular to the centerline (axis) of the hose. Figure 11-31d shows the correct and incorrect methods of installation.

(4) A bend in piping or tubing is prohibited where such a bend weakens the pipe or tubing (NFPA 52 5.5.8). Figure 11-31e illustrates three fuel lines that are not acceptable and one that is acceptable. Fuel lines should be inspected in accordance with NFPA 52, 4.8 (Fuel Lines), and NFPA 52, 5.5 (Installation of Piping).

(5) Fuel line and/or pipe joint or connections must be located in accessible locations (NFPA 52, 5.5.9). Additionally, fuel lines must be checked to ensure they are in compliance with NFPA 52, 4.8.

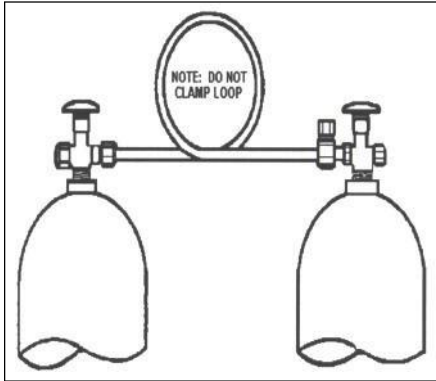


Figure 11-31a. Stress (Vibration) Loop

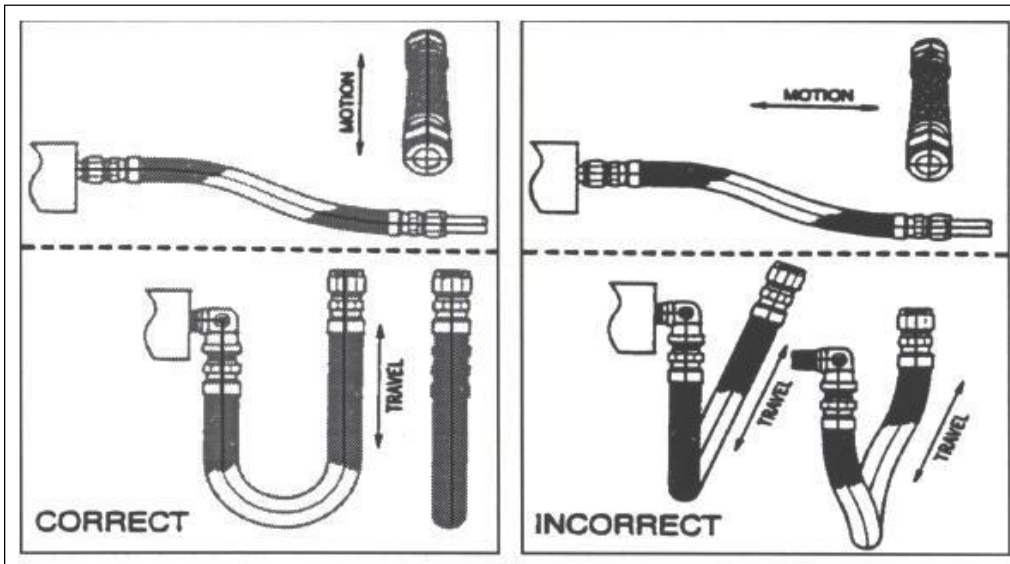


Figure 11-31b. Twisting or Flexure of Flexible Metal Hose

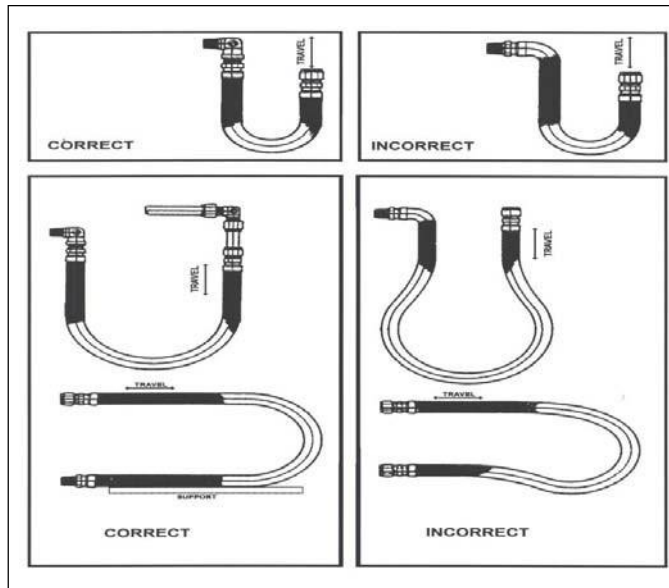


Figure 11-31c. Correct and Incorrect Methods of Bending for Flexible Metal Hose

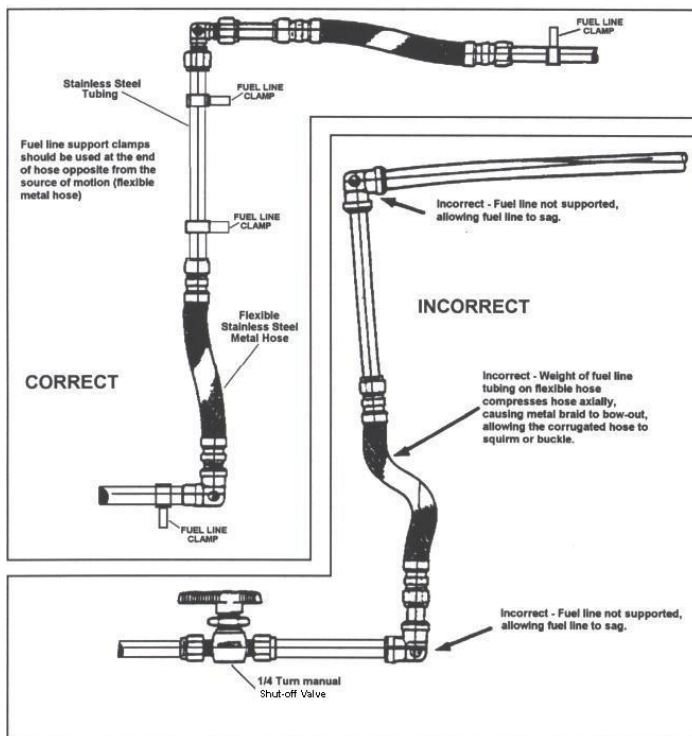


Figure 11-31d. Correct and Incorrect Methods of Supporting Flexible Metal Hose

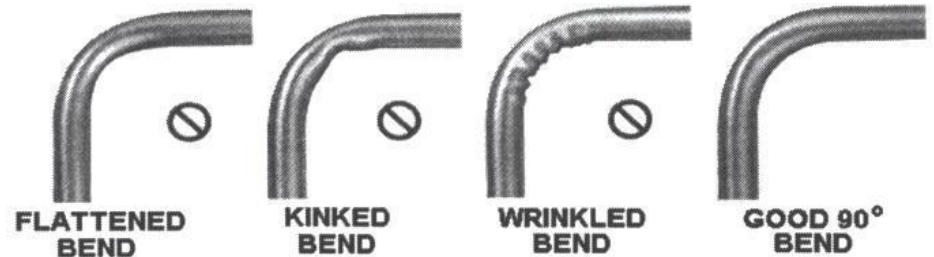
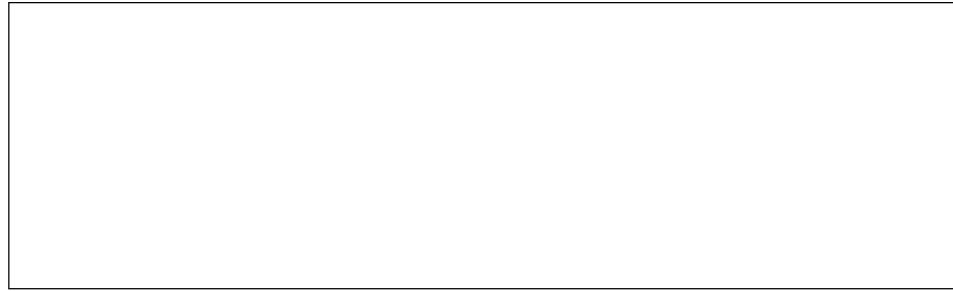


Figure 11-31e. Fuel Line Bending

e. Vehicle Fueling Connection. Each vehicle is equipped with a fueling connection for filling the CNG containers with natural gas from a dispenser. There are no specific locations for the fueling connection, and they may be found on the front of the vehicle, the rear, or the left or right side. Figure 11-32 shows a typical fuel connector. The vehicle fueling connection must comply with the following NFPA sections:

- (1) Vehicle fueling connection devices must be listed in accordance with ANSI/AGA NGV1, Standard for Compressed Natural Gas Vehicles (NGV) Refueling Connection Devices. The use of adapters is prohibited (NFPA 52, 4.11). Additionally, the fueling receptacle must be installed in accordance with the manufacturer's instructions (NFPA 52, 5.9.2).
- (2) The fueling system must be equipped with a backflow check valve that prevents the return flow of gas from the container(s) to the filling connection. The backflow check valve must be mounted to withstand the breakaway force specified in NFPA 52, 6.11.8.
- (3) NFPA 52, 5.11.8 requires a breakaway device to be installed at every dispensing point. The device must be arranged to separate using a force not greater than 150 lbs. when applied in any horizontal direction.
- (4) FMVSS 303, Fuel System Integrity of Compressed Natural Gas Vehicles, S5.3, requires each CNG vehicle to be permanently labeled, near the vehicle refueling connection, with the information specified in sections S5.3.1 and S5.3.2. The information must be visible to a person standing

next to the vehicle during refueling, in English, and in letters and numbers that are not less than 3/16 inch in height.

(a) FMVSS 303 S5.3.1. The statement: "Service pressure \_\_\_\_\_ Kpa ( \_\_\_\_\_ psig)."

(b) FMVSS 303 S5.3.2, the statement: "See instructions on fuel container for inspection and service life."

NOTE: FMVSS 303 applies only to passenger cars, multipurpose passenger vehicles, trucks, and buses that have a gross vehicle weight rating (GVWR) of 10,000 pounds or less and use CNG as a motor fuel. However, the standard also applies to school buses, regardless of weight, that use CNG as a motor fuel.

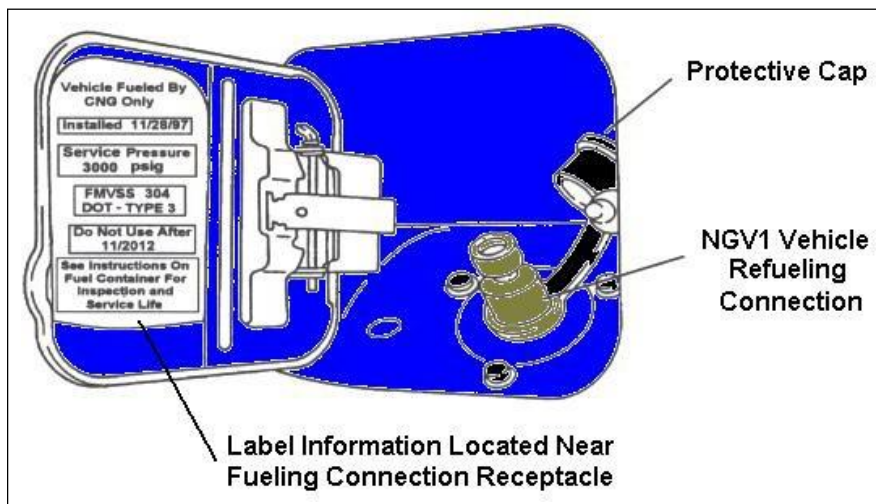


Figure 11-32. Typical CNG Fueling Connection

f. Shut-off Valve. In addition to the manual or normally-closed remotely-actuated shut-off valve connected directly to the fuel container, NFPA 52, 5.6.2 requires an additional manual shut-off valve, or a normally-closed automatically controlled shut-off valve. The purpose of this valve is to stop the flow of fuel from the CNG containers to the engine compartment in the event of an accident or fire. Figure 11-33 shows a typical manual shut-off valve and Figure 11-33a shows a typical normally-closed automatically controlled shut-off valve.

(1) The manual shut-off valve (if so equipped) must be located in an accessible location and must not have more than 90 degrees (1/4 turn) rotation from the open to the closed positions (NFPA 52, 5.6.2).

(2) The valves must be securely mounted and shielded or installed in a protected location to minimize damage from vibration and unsecured objects (NFPA 52, 5.6.2.1).

(3) The valve must be marked with the words “MANUAL SHUT-OFF VALVE.” Weather-resistant decals or labels must use blue or black luminous letters on a white or silver background (NFPA 52, 5.6.2.2). If the valve is immediately behind an access door, and the door is marked “MANUAL SHUT-OFF VALVE,” the valve itself does not have to be marked.

(4) If the valve is a normally-closed automatically controlled shut-off valve, it does not have to be marked, nor does the location, if behind an access door, have to be marked.



Figure 11-33. Typical Manual 90 Degree (1/4 Turn) Shut-off Valve



Figure 11-33a. Typical Normally-Closed Remotely-Actuated Shut-off Valves

g. Engine Fuel Shut-off Valve. In addition to the manual shut-off valve, or a normally-closed automatically controlled shut-off valve described above, every CNG fuel system is required to have a shut-off valve that automatically prevents the flow of gaseous fuel to the engine when the engine is not running, even if the ignition switch is in the “on” position (NFPA 52, 5.6.3). Figure 11-34 illustrates one type of fuel shut-off valve in current use. Figure 11-34a shows another type of fuel shut-off device commonly referred to as a mechanical fuel “lockoff” device, which is commonly used in older CNG fuel systems.

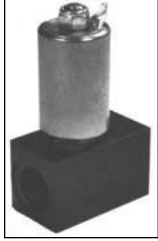


Figure 11-34. Typical Engine Fuel Shut-off Valve

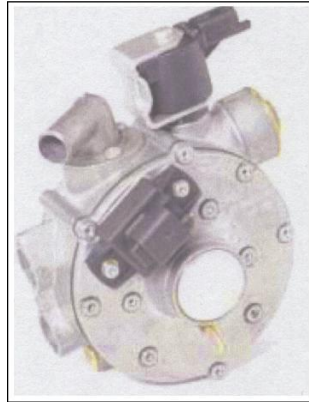


Figure 11-34a. Mechanical Fuel Lockoff Device Used on Older CNG Fuel Systems

h. Pressure Regulator(s). An automatic pressure reducing regulator(s) is required to be installed in every fuel system to reduce the fuel container pressure to a level consistent with the service pressure required by the gas-air mixture in the CNG fuel system (NFPA 52, 5.8.1). CNG systems vary in the types and number of regulators used. Generally, there are three basic types of pressure regulator systems commonly found in CNG vehicles:

(1) A two-regulator system, which uses a high-pressure (referred to as a primary or first stage) regulator to reduce the CNG container pressure from 3,000 or 3,600 psi to between approximately 80 and 180 psi. Figure 11-35 illustrates one type of high-pressure regulator. The other regulator is a low-pressure (secondary) regulator that further reduces the pressure to atmospheric pressure. Figure 11-35b shows a typical low-pressure regulator. The system is typically used with an air valve type mixer and can be “open-loop” (no oxygen sensor input is used to control air-fuel mixture) or “closed-loop” (oxygen sensor input is used by an electronic fuel controller to maintain optimum air-fuel mixtures).

(2) A single regulator system, which has one regulator with three stages to reduce the CNG container pressure to slightly above atmospheric pressure at idle and slightly less than atmospheric pressure at all other engine

speeds. Figure 11-35c illustrates a typical single-type pressure regulator. This system is generally used with a venturi type mixer and can also be open-loop or closed-loop.

(3) A fuel injection system employs a single (high pressure) regulator, which also reduces pressure from the CNG container to approximately 130 psi. The fuel then flows to a metering valve body (low pressure) that electronically controls the amount of fuel that is delivered to the engine through injectors. Figure 11-35d shows a typical pressure regulator used with a fuel injection system. Fuel injection systems are always closed-loop systems, and generally use exhaust gas oxygen sensor inputs (plus additional inputs such as CNG container temperature and pressure, fuel system temperature and pressure, manifold air temperature and absolute pressure, engine coolant temperature, exhaust back pressure and other sensors) to control optimum air-fuel ratios.

(a) NFPA 52, 5.8-2, requires pressure regulators to have a means to prevent regulator malfunctions due to refrigeration effects. Most regulators use the engine cooling system, which generally provides enough heat to prevent regulator “freeze-up.”

(b) Low-pressure chambers (regulator) must provide for overpressure relief or be able to withstand the service pressure of the upstream (high) pressure chamber (NFPA 52, 4-7.2).

(c) Pressure regulators must be installed so that their weight is not placed on, or supported by, the fuel lines (NFPA 52, 5-8.3).

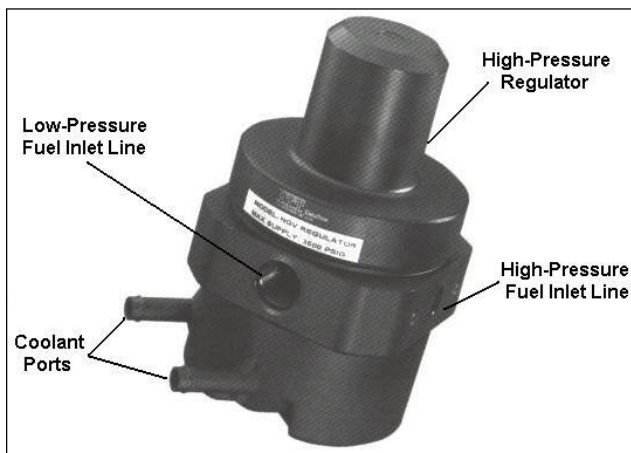


Figure 11-35. Typical High-Pressure Regulator

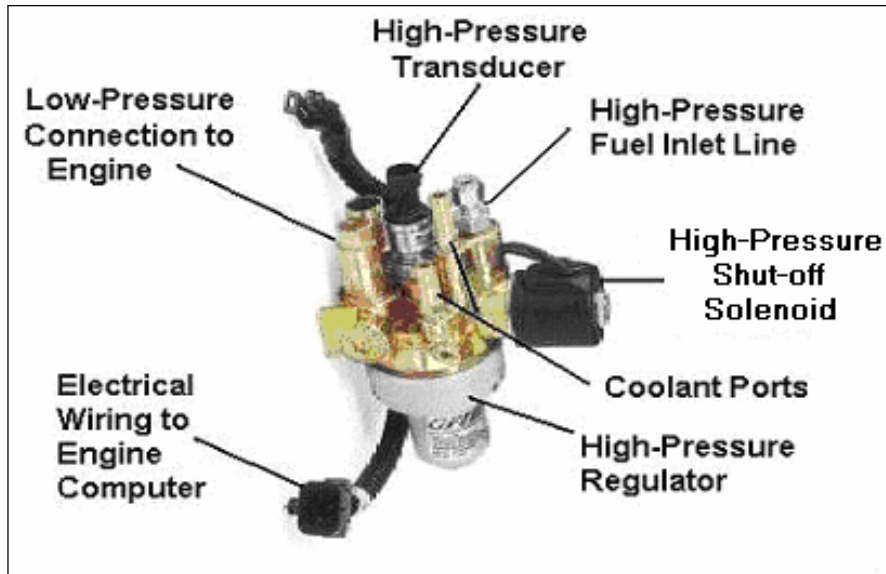


Figure 11-35a. Typical High/Low-Pressure Regulator



Figure 11-35b. Typical Low-Pressure Regulator (Older Style)

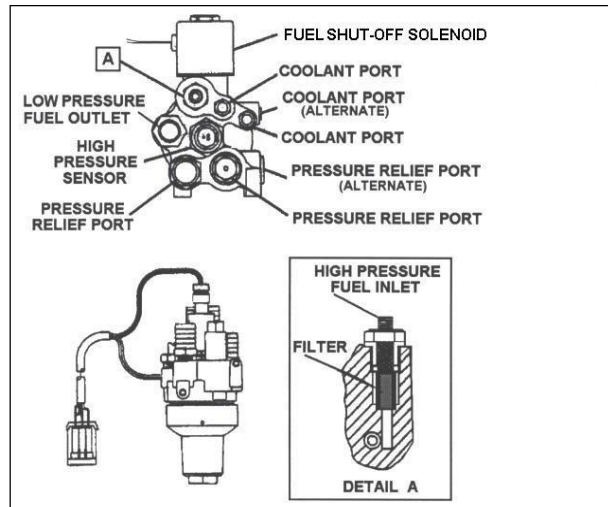


Figure 11-35c. Single-Type Pressure Regulator

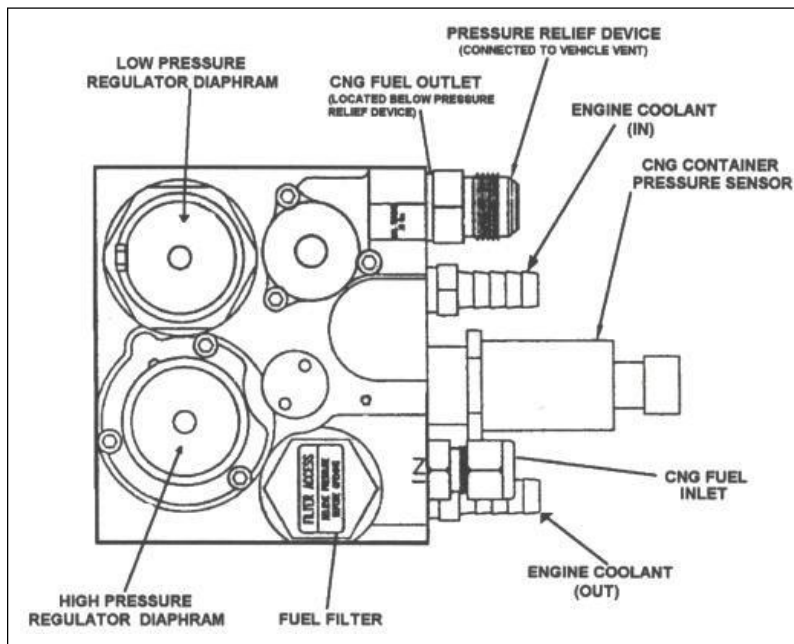


Figure 11-35d. Single-Type Pressure Regulator Used With Fuel Injection Systems

- i. Pressure Gauge and Fuel Gauge. The fuel pressure gauge and/or fuel gauge indicates the amount of fuel remaining in the fuel container(s). Figure 11-36 illustrates a typical pressure gauge and figure 11-36a shows a typical CNG fuel gauge.

(1) A pressure gauge is not required in a CNG fuel system; however, if it is installed, it must meet the requirements of NFPA 52, 4.6 and 5.7.

(2) A fuel gauge, which is similar to the type used in gasoline or diesel powered vehicles, is commonly found in CNG vehicles. This type of gauge does not show pressure, but reads empty to full.



Figure 11-36. Pressure Gauge (0 to 5,000 PSI)

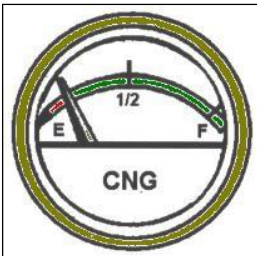


Figure 11-36a. Typical Fuel Gauge

j. Labeling. Section 27909 VC states that: “Any vehicle which carries liquefied petroleum gas fuel or natural gas, in a tank attached to a vehicle, in any concealed area, including trunks, compartments, or under the vehicle, shall display on the exterior of the vehicle the letters “CNG,” “LNG,” “LPG,” whichever type fuel is utilized, in block letters at least one inch high. The letters shall be of contrasting color and shall be placed as near as possible to the area of the location of the tank. Any vehicle fueled by liquefied petroleum gas fuel or by natural gas may also comply with this section by displaying on each side of the vehicle words or letters at least 0.25 inch high indicating that the vehicle is fueled by liquefied petroleum gas or natural gas. It is unlawful to dispense liquefied petroleum gas fuel or natural gas into any tank in a concealed area of any vehicle registered in California, unless the vehicle complies with the requirements of this section.”

(1) NFPA 52 Labeling Requirements. In addition to VC 27909, NFPA 52,

5.11.2 requires each vehicle to be identified with a weather-resistant, diamond-shaped label located on an exterior vertical surface on the lower

right rear of the vehicle (e.g., on the trunk lid of a vehicle so equipped, but not on the bumper of any vehicle) inboard from any other markings. The label must be a minimum of 4-3/4 inches long by 3-1/4 inches high. The marking must consist of a border and the letters "CNG" (1-inch minimum height centered in the diamond) of silver or white reflective luminous material on a blue background. Figure 11-37 shows the required label.

(2) Unodorized CNG Label. NFPA 52, 4.2.1.1, Gas Composition, requires CNG introduced into the fuel system to have a distinctive odor potent enough for its presence to be detected down to a concentration in air of not over one-fifth of the lower limit of flammability. The CHP, Commercial Vehicle Section, has issued several exemptions to the provisions of NFPA 52, provided the bus meets the following requirements:

(a) Each vehicle subject to this exemption shall be equipped with a methane gas detection system which shall warn of the presence of methane gas in the engine compartment, driver's compartment and passenger compartment.

(b) At a minimum, the methane gas detection system shall provide a warning before the methane gas concentration reaches the lower explosive limit. Such warning shall be plainly audible and visible to the driver before entering the driver's compartment and while seated in the normal driving position.

(c) The gas detection system shall function at all times, whether or not the engine is operating, when the vehicle is operated or parked on public roadways or other areas accessible by the public.

(d) In the event the gas detection system does not function properly (including false detection), the bus shall immediately be placed out-of-service and shall not be operated on a public highway until repairs have been completed and the system is re-calibrated in accordance with the manufacturer's instructions.

(e) Each bus shall be labeled with the words "UNODORIZED" immediately above or below the required CNG-fueled vehicle diamond-shaped label. The "UNODORIZED" label shall be a minimum one-inch in height and of silver or white reflective luminous material. Figure 11-37a illustrates the type of CNG label required under the exemption.



Figure 11-37. CNG Label Required by NFPA 52



Figure 11-37a. CNG Label Authorized for Unodorized CNG

k. Fuel Filter. CNG fuel systems are not required to have a fuel filter; however, many systems contain a fuel filter. The filter is designed to protect engine components against contaminants that may come from CNG compressors and storage facilities. It is specifically designed to remove oil, water, and solid contamination from compressed natural gas. Figure 11-38 shows a typical in-line fuel filter.

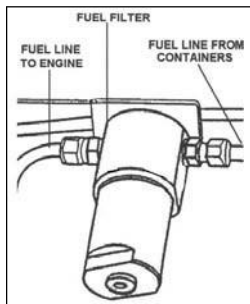


Figure 11-38. Typical Fuel Filter

9. OPERATION OF CNG FUEL SYSTEM. Figure 11-39 illustrates the typical location of various natural gas vehicle components on one type of CNG fuel system which operates as described below:

a. Fuel System Entry. CNG enters the vehicle through the vehicle fueling connection (1). The pressure gauge (2) indicates the fill pressure. After passing through the one-way check valve (3), the gas then enters the vehicle fuel containers (4), where it is stored at approximately 2,400 to 3,600 psi. Note that the fuel line from the filling connection to the fuel container is hidden by the fuel line from the container to the engine compartment (7).

b. Valves. When fuel is needed, the gas flows out of the containers through the container's manual or automatically-closed valve (5), and past the pressure relief device (PRD) (6). The PRD is a safety device that releases gas harmlessly into the atmosphere if the pressure and/or temperature exceed the CNG container manufacturer's safety design.

c. Fuel Lines. After the gas flows through the container valve and PRD, it enters a stainless steel high-pressure fuel line (7), and through the manual (1/4 turn valve) or automatic fuel shut-off valve (8).

d. Regulators. The fuel then flows through the engine fuel shut-off valve or lockoff device (9), and then into the high-pressure regulator (10). From the high-pressure regulator, the fuel flows into the low-pressure regulator (11).

e. Engine. The fuel then enters the metering valve (12), the fuel injectors (13) (if so equipped), and then enters the gas/air mixer (14). The fuel is introduced into the engine generally at the throat of the intake manifold, and finally enters the engine and is combusted.

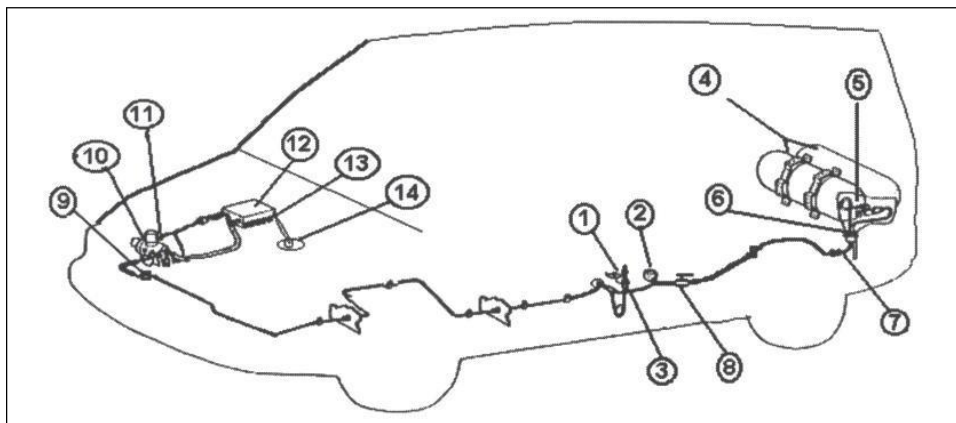


Figure 11-39. Location of Fuel System Components

10. LIQUEFIED NATURAL GAS FUEL SYSTEMS. The following information in Sections 10 through 18 pertains to the operation and inspection of LNG fuel systems.

a. 13 CCR SECTION 935, Liquefied Natural Gas. This section requires LNG fuel systems installed after January 1, 2000, to comply with the NFPA 57, Liquefied Natural Gas Vehicular Fuel Systems, 1996 edition or the Society of Automotive Engineers (SAE) Standard J2343, Recommended Practices for LNG Powered Heavy-Duty Trucks, January 1997 edition.

b. 13 CCR Section 935(b), Additional Requirements. All LNG fuel systems complying with the NFPA Standard 57, 1996 edition, or the SAE Standard J2343 January 1997, shall also comply with the following:

(1) Wherever the word "should" appears in either the NFPA Standard 57, 1996 edition, or the SAE Standard J2343 January 1997, it shall be understood to set forth mandatory requirements.

(2) Every motor vehicle equipped with an LNG fuel system shall be equipped with a methane gas detection system which shall warn of the presence of methane in the engine compartment, drivers compartment, and any passenger compartments. At a minimum, the methane gas detection system shall provide a warning before the methane gas concentration reaches the lower explosive limit. Such warning shall be plainly audible and visible to the driver before entering the driver's compartment and while seated in the normal driving position. The gas detection system shall function at all times, whether or not the engine is operating, when the vehicle is operated or parked on public roadways or other areas open to the public.

(3) The LNG container shall meet the drop test requirements of SAE J2343 January 1997 or equivalent.

(4) Fuel tanks shall be oriented and mounted in accordance with the tank manufacturers recommendations and in a location designated by the vehicle manufacturer, in the location normally utilized for liquid (gasoline or diesel) fuel containers for that make and model of vehicle, or as determined by a qualified engineer. Fuel tanks shall not be mounted above any driver or passenger compartment, unless a spill pan is installed between the fuel tanks and the compartment, with a liquid capacity equal to at least the capacity of the largest single fuel tank of a multiple-tank installation consisting of three or more fuel tanks, but not less than one-quarter the fuel capacity of the containers located above the compartment and capable of preventing liquid from entering the interior or dripping into any window, door or emergency exit way. Spill pans shall be designed in such a manner that rain water is not retained. The spill pan drain shall not be directed into any

confined space, the engine compartment, muffler area, battery box, or other hazardous location.

(5) Every motor vehicle equipped with an LNG fuel system shall bear a label, located at or near the fueling connection, that shall include:

(a) Identification of the vehicle as an LNG-fueled vehicle; and

(b) The maximum allowable working pressure of the vehicle fuel container.

(6) The NFPA Standard specifies that certain systems and components shall be approved by the authority having jurisdiction. The CHP has jurisdiction over these regulations but does not approve individual systems or components. Users and installers are responsible for the use of proper components and for their proper installation, as specified in the applicable standard.

## 11. ORIGIN, TRANSPORTATION, AND STORAGE OF LIQUEFIED NATURAL GAS (LNG).

a. Natural Gas Origin. Natural gas is a fossil fuel composed primarily of methane, along with other hydrocarbons such as ethane, propane, and butane, and inert gases, such as nitrogen. Before liquefying natural gas, substances that would freeze during the liquefaction process, such as water, carbon dioxide, sulfur, and some of the heavier hydrocarbons must be removed. The gas is then cooled to about -260° F at atmospheric pressure.

(1) Some manufacturers of LNG go a step further by removing almost all non-methane constituents, making LNG that is 99 + percent pure methane. The combustion properties of natural gas make it an excellent fuel for spark-ignition engines. It has an ignition temperature of approximately 1,000° F, about 600° higher than gasoline. As a gas, it mixes readily and completely with air even at low temperatures, thus eliminating any need for mixture enrichment during cold starting.

(2) Natural gas has excellent antiknock properties, with an equivalent octane rating of 130, compared to 87 for unleaded regular gasoline and 92-93 for premium. This allows engines designed specifically for natural gas fuel to use higher compression ratios than gasoline engines, with a consequent improvement in efficiency and power output. Natural gas is not a perfectly clean burning fuel when used for internal combustion engines; however, it is considerably less polluting than gasoline and diesel.

b. Liquefaction. At most facilities where LNG is made, natural gas is cooled gradually, usually in stages, to transform it into liquid. The cooling process is not unlike the cooling process used in common refrigerators or air conditioners. The big difference is that natural gas is cooled to around  $-260^{\circ}$  F.

(1) There are several different methods that can be used to cool natural gas to this temperature. Most require that the gas be cleaned of constituents, such as water and carbon dioxide, that would freeze during the liquefaction process and, thereby, plug or foul equipment. Most common refrigerators and air conditioners use a gaseous refrigerant such as Freon in a two-stage cooling process. In the first stage, the refrigerant is compressed to a high pressure, which, in turn causes its temperature to rise. Water or possibly air is then circulated through the compressed refrigerant in coiled tubes to cool it down and condense the refrigerant into liquid.

(2) In the second stage, the compressed liquid coolant is then relieved of its pressure (expanded). In so doing, it boils back into a gas, absorbing heat from its surroundings and thereby cooling the air within the air conditioner or refrigerator. The vaporized refrigerant is then returned back to the compressor where it starts the first stage again. The primary difficulty with this system for natural gas is that few refrigerants can cool a substance to  $-260^{\circ}$  F. For this reason, natural gas is commonly liquefied in multiple stages (called a cascade system) or with multiple refrigerants (called a mixed-refrigerant system).

(3) Natural gas can also be liquefied using what is called the expanded cycle, where natural gas under high pressure is expanded rapidly; thereby cooling the gas to the point where some LNG can be recovered.

c. Transportation of LNG. LNG is transported by truck, rail or ship. Billions of gallons of LNG are transported on-board oceangoing tankers that travel from major natural gas production regions to major markets. Smaller barges have also been designed to carry LNG for shorter distances. LNG has been transported over-the-road for more than 35 years.

d. Storage of LNG (Containers). LNG utilizes the same natural gas source as CNG; however, this gas requires purification of the gas and cooling and storage below  $-259^{\circ}$  F for liquification. Converting natural gas to liquid form allows storage of a much greater amount on the vehicle than can be achieved in its gaseous state. The LNG storage container, like most cryogenic containers, is generally made of stainless steel and is designed as two pressure vessels, one inside of the other, similar to that of a thermos bottle.

## 12. SAFETY OF LNG FUEL SYSTEMS.

a. Physical Properties. When natural gas is cooled to a temperature of  $-259^{\circ}$  F, it liquefies at ambient pressure to a colorless, odorless, and tasteless liquid. Liquefaction of natural gas leads to the formation of LNG which consists primarily of methane, with minor quantities of ethane, propane, other higher hydrocarbons, nitrogen, and other trace components. Methane volume fraction may vary between 95 percent and 99 percent.

(1) Due to its low temperature, a spill of LNG onto any surface at room temperature results in immediate boiling of the liquid and emanation of natural gas vapors at the LNG boiling point temperature ( $-259^{\circ}$  F).

(2) Because the composition of LNG varies, depending on the source of natural gas collection, the boiling temperature at atmospheric pressure also varies slightly. Also, methane evaporates preferentially from LNG leaving a liquid which progressively becomes richer in higher hydrocarbons. This process, called "weathering," also occurs even when LNG is contained in an insulated fuel tank.

(3) The boiling temperature also varies with pressure. The critical temperature of methane is  $-117^{\circ}$  F; hence, in order to maintain pressurized methane in a liquid state, the temperature of the methane must remain lower than the critical temperature of  $-117^{\circ}$  F.

b. Odorization of LNG. Unlike CNG, there is no odorant (ethyl mercaptan) added to LNG. Therefore, for safety reasons, 13 CCR 935(b)(2) requires every motor vehicle equipped with an LNG fuel system to also be equipped with a methane gas detection system which shall warn of the presence of methane in the engine compartment, drivers compartment, and any passenger compartments. SAE J2343, 4.9, separately requires a methane gas detection system in a truck cab and engine compartment.

c. LNG Frostbite. Extreme cold temperatures can cause frostbite injury. Accidental contact with cryogenic liquid or cold issuing gas may cause a freezing injury similar to frostbite.

(1) Protect your eyes and cover the skin where the possibility of contact with the liquid, cold pipes, cold equipment components, or cold escaping gas exists.

(2) Safety goggles or a face shield should be worn around vehicles equipped with a LNG fuel system. Clean, insulated gloves that can be easily removed and long sleeve shirts are recommended for hand and arm protection.

(3) Cuffless trousers should be worn outside boots or over the shoes to shed spilled liquid. If clothing is splashed with liquid or otherwise saturated, the clothing will be highly flammable and easily ignited. Saturated clothing should be removed as soon as possible.

d. Toxicity. Natural gas will not harm anyone inhaling low concentrations near minor fuel leaks. However, heavy concentrations can cause drowsiness and eventual suffocation, especially in confined, unventilated areas. By comparison, gasoline and diesel fuels are toxic if ingested, inhaled, or absorbed through the skin.

e. Flammability Range of LNG. Natural gas is relatively safe because it is lighter than air, causing it to quickly dissipate into the atmosphere if a leak occurs. The ignition temperature of LNG is 1,000° F, as compared to 428° F for gasoline and 437° F for diesel fuel.

(1) LNG is a cryogenic liquid, chilled to a temperature of -259° F, and in its liquid form cannot burn or explode. At this temperature, the vapor is denser than the surrounding air. The methane vapor must warm to -180° F to reach neutral buoyancy in air with a temperature of 40° F. During the interval between vaporization and neutral buoyancy conditions, the methane vapor will behave like other heavier-than-air vapors and will pool on the ground.

(2) Once neutral, the natural gas will begin to disperse into the atmosphere. Consequently, within minutes after a small spill or leak, the danger of fire passes, provided the spill or leak occurs where the vapor can escape without reaching an ignition source.

(3) The risk of fire in the presence of an ignition source only exists when the ratio of air to fuel is within the product's flammability range. Natural gas cannot ignite if it is mixed with too much or too little air. The flammability range for natural gas is 5 percent to 15 percent volume of gas in air. In comparison, the flammability range of gasoline is 1 percent to 7.6 percent volume of gasoline in air.

(4) Since LNG is a very cold liquid, spills and leaks are highly visible. As LNG vaporizes, the cold gas freezes water vapor in the atmosphere around it causing a white vapor cloud. The flammable perimeter of the air-gas mixture generally coincides with the perimeter of this cloud.

f. LNG Fuel Leaks. LNG fuel containers are thicker, stronger, and less vulnerable to punctures than conventional gasoline or diesel fuel tanks. However, leaks can occur on both the vapor and liquid side of the fuel system which could include the following:

(a) Leaks in Gas Piping (Discharge of Pressure Relief Valve). Leaks resulting in the release of cold gas can occur in the piping associated with liquefaction, storage, and vaporization of natural gas.

1 As with other cold-gas releases, discharge through a relief or safety valve can usually be detected by the formation of a visible vapor cloud. When several relief valves are manifolded together, moisture condensed directly on one valve body can indicate which one is venting.

2 When a PRD discharges, the reason for the discharge could be the result of a failure of a control valve, liquid or cold vapor trapped in a line between two closed valves, a barometric pressure change, or numerous other causes.

(b) Vaporization of Spilled LNG. When LNG is initially spilled on the ground or any other warm surface, it boils violently resulting in vaporization.

1 If the spill continues, a pool of LNG will accumulate and the boiling rate will decrease to a relatively constant value. The boiling rate is initially controlled by the rate at which heat is transferred by convection through a layer of gas that exists between the ground and the LNG liquid.

2 As the difference in temperature between the ground and the LNG decreases, this layer disappears. Then, the rate at which heat is conducted directly from the ground to the liquid becomes a controlling factor in the rate at which the liquid vaporizes.

3 Among the other sources of heat affecting the boiling of LNG are solar radiation and circulation of the air above the pool. After the ground has frozen and sub-cooled sufficiently, solar radiation and circulation of air above the LNG spill may control the boiling rate.

(c) Insignificant Leaks (Diffusion). Leaks smaller than 1/2 cubic centimeters per minute (cc/min) are so small and diffuse so rapidly that they can be ignored. The leaks are characterized by a series of uniform-size tiny (smaller than a pinhead) bubbles that emerge from the leak. This might show up immediately as a chain of tiny bubbles (1/2 cc/min) or as foam around the leak up to five minutes after the fitting is sprayed with bubble test solution. In either case, the leaks are not flammable and will not accumulate inside of vehicle compartments. Figure 11-40 illustrates a diffusion leak.



Figure 11-40. Insignificant Leak (Diffusion)

(d) Nonflammable Leaks. Leaks smaller than 25 cc/min are not flammable in air. They are characterized by a stream of bubbles that grow in size and flow away from the leak. Typically the bubbles range in size from 1/8-inch to 3/8-inch in diameter. The bubbles do not burst at the site of the leak, but will flow away from the leak and burst downstream as they dry out. In a ventilated environment, even in still air, they pose no flammability hazard. Figure 11-40a illustrates a nonflammable leak.



Figure 11-40a. Nonflammable Leak

(e) Small Flammable Leaks. Leaks between 25 cc/min and 100 cc/min are flammable in still air. If ignited the flame ranges in size from less than 1/16th of an inch tall, sustainable only in dead calm conditions to a flame the size of a normal cigarette lighter flame. This size of leak is characterized by bubbles that grow and burst at the site of the leak before they can flow away from it. Generally, these leaks pose no hazard in moving air, or in well ventilated compartments, but could accumulate inside of small and poorly ventilated enclosed spaces. These leaks are typically caused by poor piping design or poor piping support that puts strain on the joints. Fuel system leaks of 25 cc/min or greater are considered unsafe and a violation of Vehicle Code (VC)

Section 24002(a) and should be placed out-of-service under the provisions of 13 CCR 1230(a).

(f) Small Fuel Leaks. If a small fuel leak occurs:

1 Eliminate all sources of ignition, e.g., drop lights, cigarettes.

2 Turn off the engine.

3 Turn off all electrical devices.

4 Close all master LNG valves on the fuel system using protective gloves, face shield, and other protective equipment.

5 Allow the gas to disperse into a ventilated area.

(g) Large Fuel Leaks. If a large fuel leak occurs, e.g., fuel container(s) emptying:

1 Evacuate the area.

2 Do not operate any electric overhead doors (open doors manually only).

3 Do not operate any electrical switches or electric heaters.

4 Allow gas to disperse into a ventilated area.

g. LNG Fire.

(1) LNG and liquid fuel fires differ with respect to combustion rate and the amount of smoke produced during combustion. Gasoline and diesel fires progress violently with a high rate of heat release. Large amounts of smoke are produced during combustion, and the risk of the fire spreading or injuring exposed individuals is high.

(2) LNG fires tend to have a controlled rate of heat release, which is confined to a small area surrounding the release point. The likelihood of an individual receiving a serious burn or suffering injury from the products of LNG combustion is less when compared to gasoline or diesel fires.

(3) The potential for explosion with LNG is lower than with gasoline or diesel fuel. In its vapor (gaseous) form, there is minimal risk of explosion outdoors. Inside a properly certified and installed LNG container, there is essentially no risk of explosion because there is no air. The principal source

of fire or explosion from LNG is fuel leakage from improperly installed or defective components on the vapor side of the connections.

(4) If an LNG fire occurs, stop the fire by cutting off the fuel flow if possible; then it can be put out with an extinguisher. If the fire cannot be controlled, the fire department should be called and you should identify the fire as a natural gas fire and evacuate the area immediately.

h. Vehicle Collision.

(1) NFPA 57, 2-13.2 requires any vehicle involved in a collision or a fire causing damage to any part of the LNG fuel system to be repaired and retested before being returned to service.

i. LNG Weathering. As mentioned in paragraph 4(a) above, one of the problems associated with typical LNG is separation or distillation of its components (ethane and propane) when heat is added. This is called “weathering,” a term commonly used to describe the enrichment of LNG as methane (LNG primary constituent) boils to vapor.

(1) Methane (CH<sub>4</sub>) vaporizes more rapidly than the other hydrocarbons in LNG because it has the lowest boiling temperature.

(2) Theoretically, if LNG containing methane, ethane (C<sub>2</sub>H<sub>6</sub>), and propane (C<sub>3</sub>H<sub>8</sub>) were poured into an ordinary open barrel, the liquid methane, with a boiling temperature of -259° F, would boil to vapor first, leaving behind an ever-enriching concentration of the heavier hydrocarbons as it vaporized.

(3) Once most of the methane has boiled off and the remaining liquid has warmed to above -117° F, the ethane would boil to vapor and so forth until all of the gaseous hydrocarbons vaporized.

(4) In an insulated LNG fuel tank, the weathering effect is slowed dramatically, especially if the tank is very well insulated and sealed. If colder LNG is later added to the tank, the methane vapor should recondense into liquid.

(5) Vaporized LNG from a vehicle fuel tank that has exceeded its hold time will vent through one or more pressure relief valves. Should the tank vent methane vapor for many days or weeks, the residual liquid might contain significantly higher percentages of heavier hydrocarbons than the original LNG. This enriched LNG might then damage a vehicle’s engine.

j. Advantages of LNG.

(1) LNG has all of the combustion advantages of CNG, is readily available, clean burning and generally produces lower emissions than alternatives, with the exception of CNG.

(2) An engine will operate just as easily on LNG as it does on CNG. Though one is stored by compressions and the other by cryogenics, both are derived from natural gas.

(3) The range of an LNG vehicle is greater than that of CNG due to the fuel density which is more than twice that of CNG.

(4) The LNG fuel system pressure is less than 100 psig as compared to 3,000 psig in a CNG fuel system.

(5) LNG provides almost pure methane (99+percent) with excellent engine fuel performance characteristics.

k. Disadvantages of LNG.

(1) Direct contact to the skin or mucous membrane with liquefied product or cold vapor may cause freeze burns and frostbite. Signs of frostbite include a change in the color of skin to gray or white, possibly followed by blistering. Skin may become inflamed and painful. Personal protection must be worn when refueling an LNG vehicle (gloves, face shield, and apron).

(2) Maintaining the super-cool temperature requires large, heavy, highly insulated tanks which limit the weight of the cargo carried.

(3) Equipment to super-cool and liquefy gas is expensive to purchase, operate, and maintain.

(4) Generally, LNG can be kept in a vehicle's insulated storage tank for 7 to 10 days. After that, it must be bled off to maintain the cold temperature required to hold the gas in liquid form.

(5) The bleed-off process releases hydrocarbons, which in turn, requires treatment to avoid direct release into the atmosphere.

(6) Natural gas has poor lubrication properties.

13. LNG FUEL SUPPLY CONTAINERS (Fuel Tank).

a. LNG Vehicle Fuel Tank. The LNG fuel tank is a cryogenic container that is designed as two separate pressure vessels, one inside the other. Figure 11-41 illustrates a typical LNG fuel tank.

(1) The inner vessel stores the cold LNG in its liquid form and is wrapped with multiple layers of noncombustible insulation and reflective foil (super-insulation), then sealed within the outer vessel.

(2) The space between the inner and outer vessels is then evacuated to produce a superior insulation system. The outer vessel and its support system are designed to withstand the stresses associated with over the road vehicles.

b. LNG Vehicle Fuel Tank Specifications. Generally, vehicle fuel tanks are designed and built to one of two different specifications. For sizes up to 119 gallons, the inner pressure vessel is designed and built to the U. S. Department of Transportation (DOT) 4L specification. Fuel tanks of 120 gallons or more are built to the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code Specifications. NFPA 57, 2-3.1 requires vehicle fuel containers to be designed, fabricated, tested, and marked in accordance with DOT 4L or ASME specifications. SAE J2343, 4.2, has similar requirements.

(1) The inner vessel is protected from over pressurization by two safety relief valves. The first to open is the primary relief valve. It is designed to safely vent excess pressure in the inner vessel due to normal heat leak through the insulation and support system, or accelerated heat leak due to loss of vacuum or a fire condition. The secondary relief valve, with a higher set point, provides protection in the event the primary relief valve malfunctions or is blocked.

(2) The outer vessel is protected from over-pressurization by an annular space evacuation plug. In the event of an inner leak into the outer vessel, the evacuation plug will open and safely vent off any excess pressure. In the event of an exterior leak into the annular space and the vacuum is lost, sweat or frost will show on the outer vessel.

(3) All fuel system plumbing components are located on one end of the vessel and are protected from damage by a protection ring or a shroud.

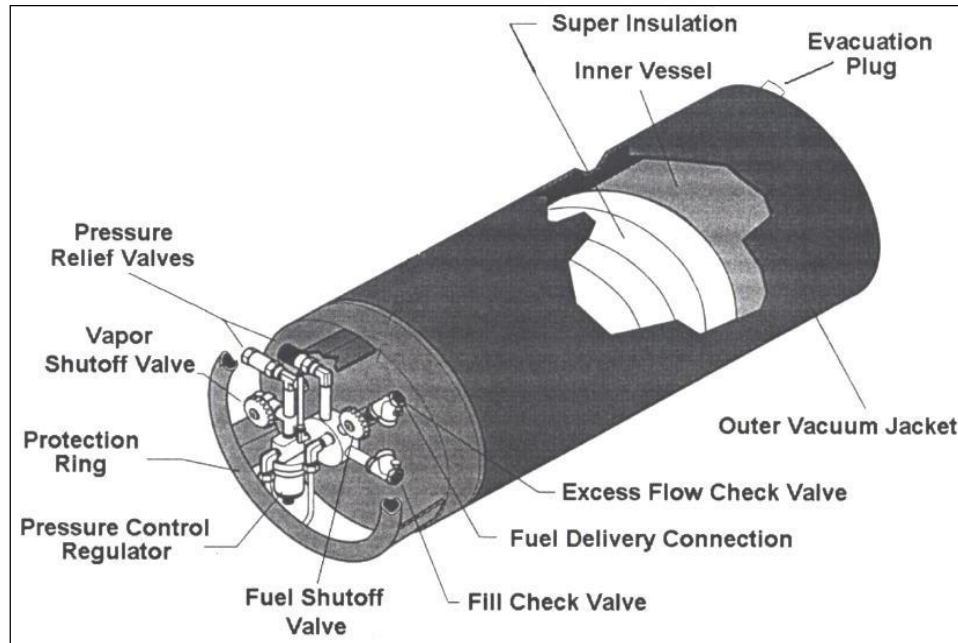


Figure 11-41. Typical LNG Vehicle Fuel Tank

c. Container Labeling Requirements NFPA 57. NFPA 57, 2-3.8, specifies labeling requirements for LNG fuel containers and mandates that each container be permanently labeled (decals or stencils are acceptable) with the following information:

(1) Total Water Capacity of the container in gallons.

(2) The words “FOR LNG ONLY” in letters not less than one inch high and visible after installation.

(3) Markings must designate whether all inlets and outlets, except the relief valves and gauging devices, communicate with vapor or liquid space.

(4) The container vapor shut-off valve must be marked “VAPOR SHUT-OFF VALVE,” and the liquid shut-off valve must be marked “LIQUID SHUT-OFF VALVE.” Identification of the markings may not be obscured by “frosting.”

d. Container Labeling Requirements SAE J2343. SAE J2343, 4.2.11, requires the tank to be labeled with the following data:

(1) Design Code.

(2) Service Pressure.

- (3) Serial Number.
- (4) Capacity in Water Gallons.
- (5) Manufacturer's Name or Trademark.
- (6) Certification Date (Tested/Inspected).
- (7) LNG Symbol (Blue and White Diamond).
- (8) All tank connections must be adequately labeled as to their function.

e. Description of Fuel Tank Filling Procedures. LNG fuel tanks are designed to be filled from several different fuel sources such as a permanent filling station, temporary fueling facility, or a portable fuel tank. The LNG fuel tank has a 230 psig Primary Relief Valve on its inlet line. Therefore, the delivery pressure of the fuel station should be 225 psig or less. Although there are several different procedures to fill a LNG fuel tank, only two will be described in this chapter. Figure 11-41a illustrates a tank before filling and after filling. Figure 11-41b describes how a typical LNG fuel tank works and Figure 11-41c describes the safety features of a typical LNG fuel tank.

(1) Normal Fueling. The LNG fuel tank is designed to be top filled through a single fill hose with no vent return. This is accomplished by spraying sub-cooled LNG into the vapor space the tank. The cold liquid condenses the vapor and creates space for itself inside the tank eliminating the need to vent product. Since this will result in a 100 percent fill, a small tank (ullage tank) inside the main tank guards against overfilling. Figure 11-41d illustrates the typical fueling of a truck tractor and Figure 11-41e illustrates safety equipment associated with LNG fueling. Figure 11-41f illustrates the typical fueling of a bus.

- (a) A typical fill sequence would involve connecting the fill hose to the tank's fill coupler. Next, the fuel station attendant opens the station's fill valve and monitors the flow or line pressure as the fill progresses.
- (b) Initially, at the start of the fill, there is a brief pressure spike as the fill piping cools down. The flow and pressure then remain stable during the remainder of the fill.
- (c) When the tank becomes full, the pressure rapidly spikes up to the station's delivery pressure and the flow rate falls off dramatically. The reason the flow does not immediately go to zero is because of the ullage tank.

(d) The ullage tank has a small opening (relative to the main full line). Once the main tank is full there will still be a small flow (typically 1-2 gallons per minute (gpm)) into the ullage tank. When a rapid pressure rise or a flow drop is observed the tank is full and the station fill valve should be shut off.

(e) Even though it is still possible to put more liquid into the tank by continuing to fill the ullage tank, the ullage tank is there to allow for fuel expansion and standby time. If the ullage tank is completely filled, the hold time will be zero and the primary relief valve will open almost immediately after the fill.

(f) If the fill is stopped at the onset of the rapid pressure rise/flow decay, when the ullage tank is empty, the tank will have about a week of standby time even if the vehicle is not driven. Most permanent fuel stations automatically monitor and perform these functions so the fuel operator's only duty is to connect and disconnect the fuel hose and press the fuel start button.

(2) Vent Filling. Although the preferred method of fueling is via a single hose top fill, it is possible to vent fill the tank. This procedure is usually used when pressure transferring fuel out of a temporary fueling facility or portable fuel tank. Figure 11-41g illustrates a typical vent-connection filling on a bus.

(a) If the fueling facility or portable fuel tank product (LNG) is vented to the atmosphere, it should be directed to a vent stack discharging to a safe location.

(b) The vehicle tank must be vented slowly if it is above its normal operating pressure, so that liquid is not drawn out of the Pressure Control Regulator into the vent gas stream.

(c) Care must also be taken to monitor vehicle fuel tank pressure so that at the end of the fill it arrives at its normal operating pressure.

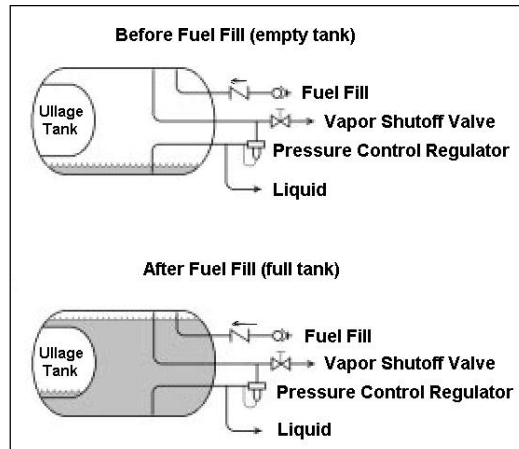


Figure 11-41a. Fuel Tank Before and After Filling

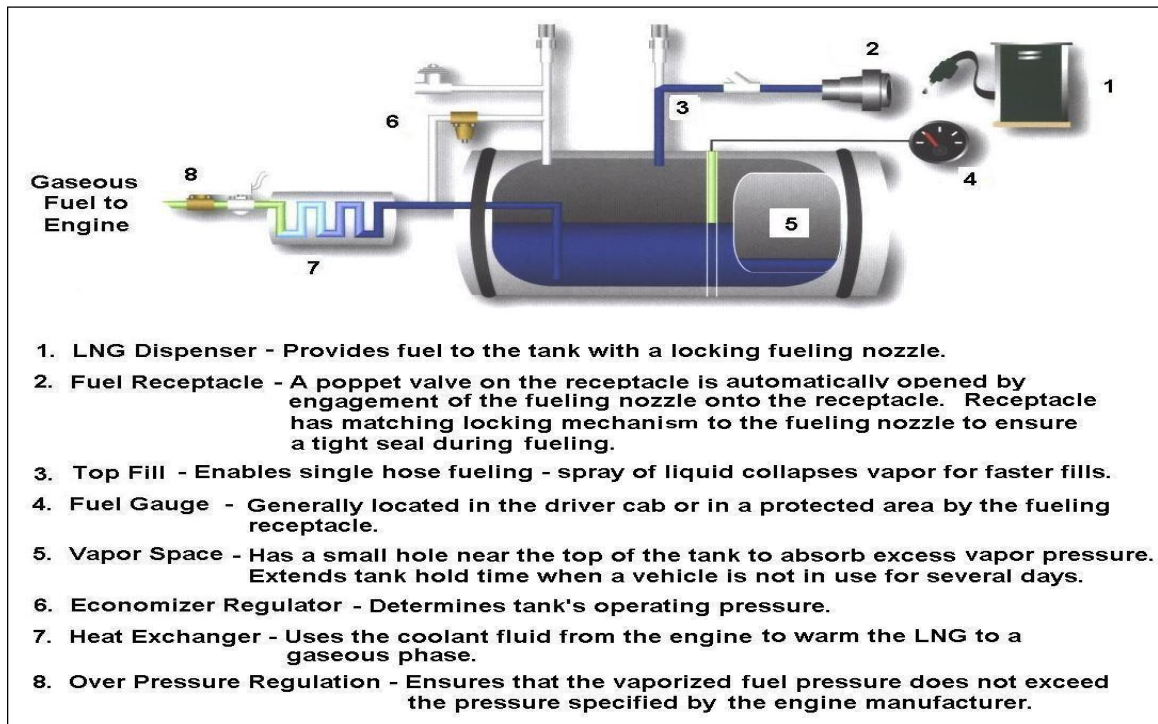


Figure 11-41b. Filling the LNG Fuel Tank

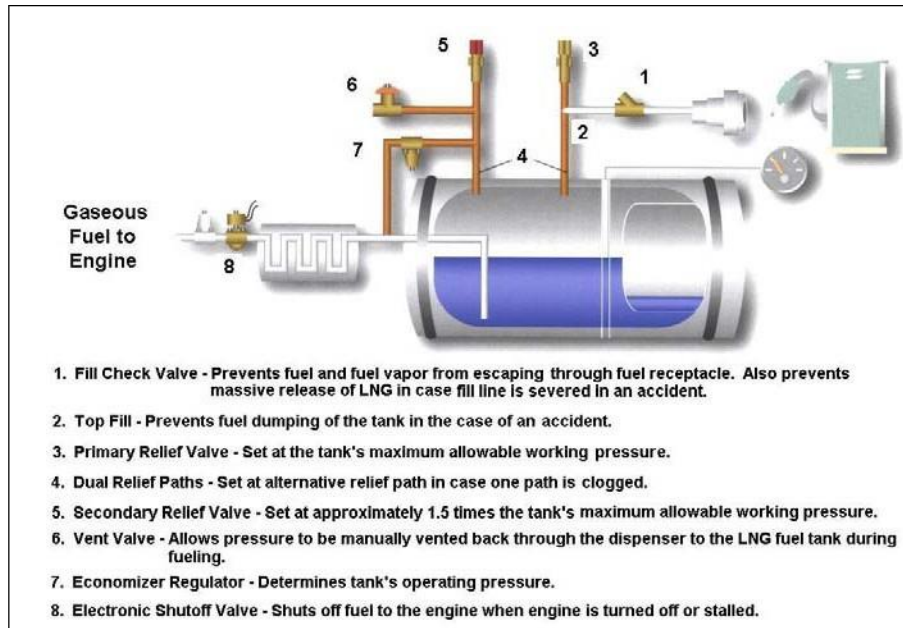


Figure 11-41c. Fuel Tank Safety Features



Figure 11-41d. Typical Fueling Connection on a Truck Tractor



Figure 11-41e. Safety Items Associated with LNG Fueling

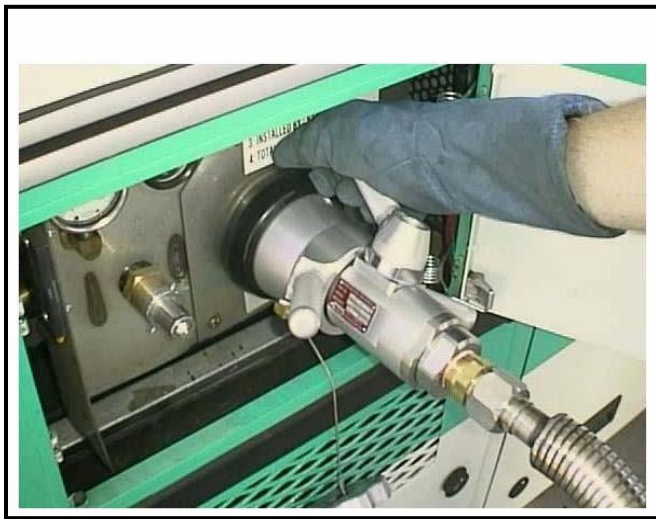


Figure 11-41f. Typical Fueling Connection on a Bus

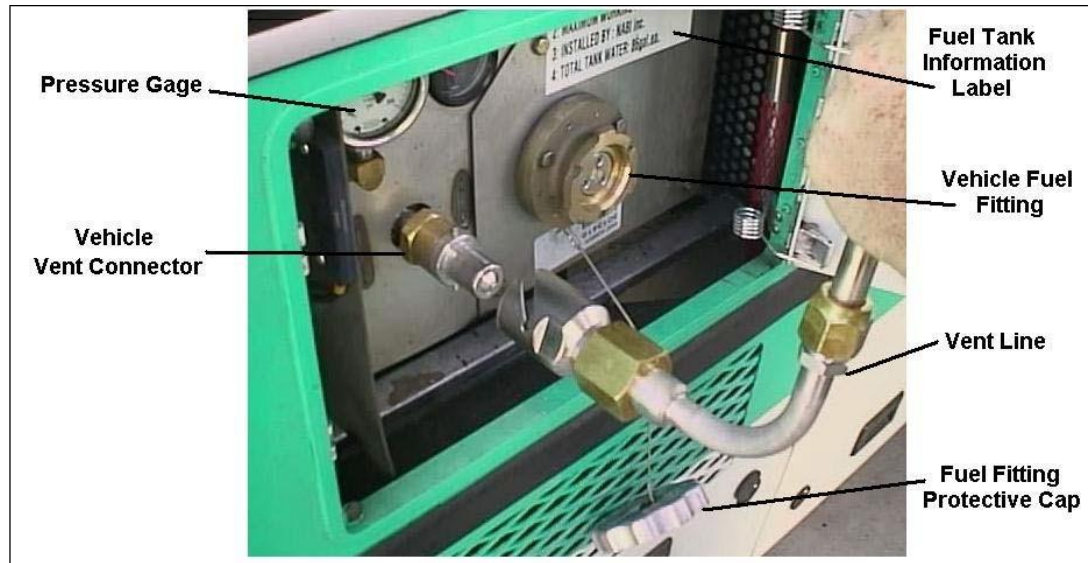


Figure 11-41g. Typical Fueling Vent Connection on a Bus

14. FUEL SYSTEM COMPONENTS AND THEIR INSPECTION. 13 CCR 935 incorporates by reference the NFPA Standard 57, 1996 edition, and the SAE Standard J2343, 1997 edition. LNG fuel systems installed after January 1, 2000, must comply with either one of the identified standards in addition to requirements set forth in 13 CCR 935(b). CHP inspection personnel use the CHP 354 (Liquefied Natural Gas (LNG) Vehicle Fuel System Inspection Checklist dated 10-98) when inspecting fuel systems installed to comply with NFPA 57. Inspection personnel use the CHP 354A (Liquefied Natural Gas (LNG) Vehicle SAE Fuel System Inspection Checklist dated 11-00) when inspecting fuel systems installed to the SAE Standard.

a. Different Fuel Tank Configurations. There are several different fuel tank configurations used in the truck and bus industry. Generally, trucks and truck tractors use a “shrouded” style fuel tank configuration which is illustrated in Figure 11-42. Most buses use a “headring” style fuel tank as shown in Figure 11-42a. Regardless of the style of fuel tank most of the plumbing components located on the tank have the same function.

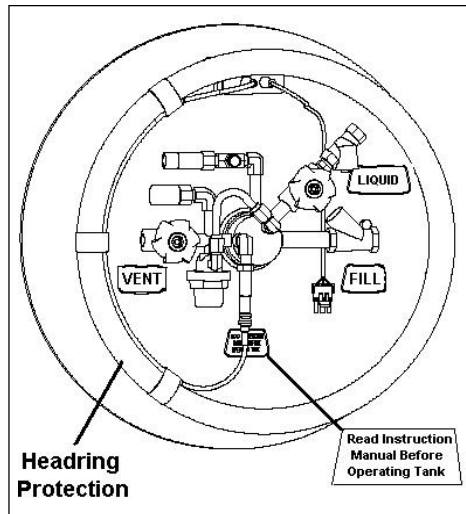


Figure 11-42. Bus Style Heading Tank

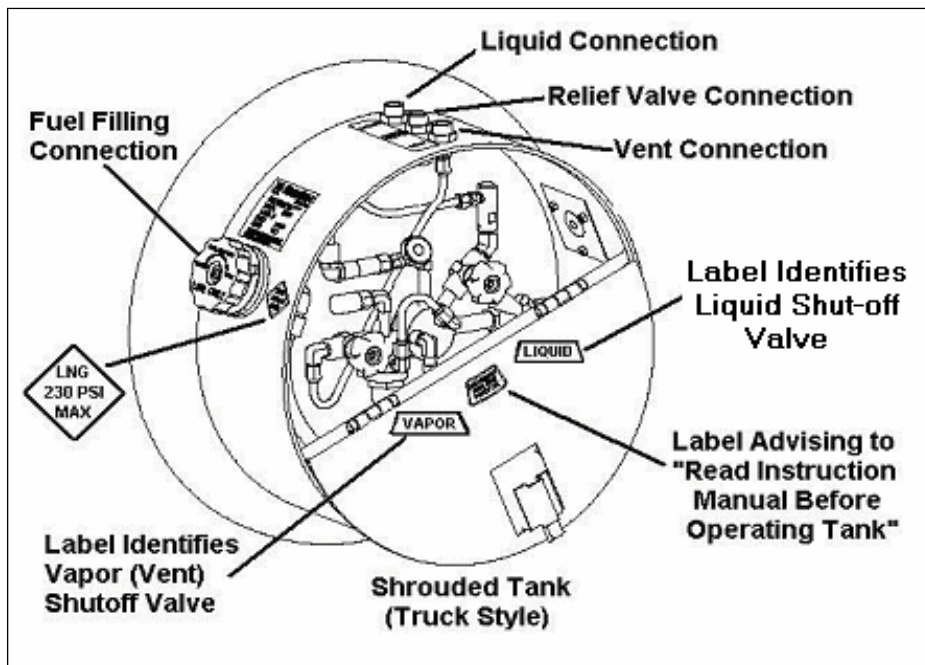


Figure 11-42a. Truck/Truck Tractor Style Shrouded Tank

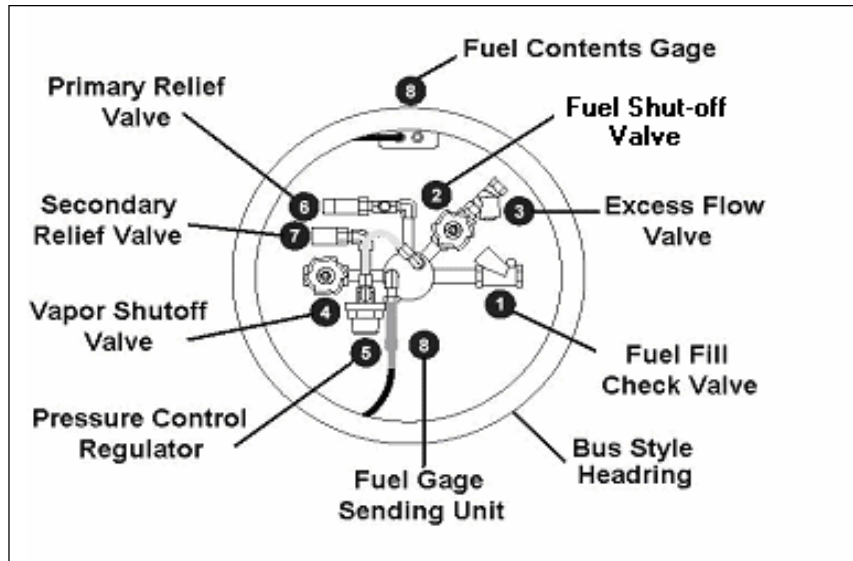


Figure 11-42b. Bus Style Heading Tank Components

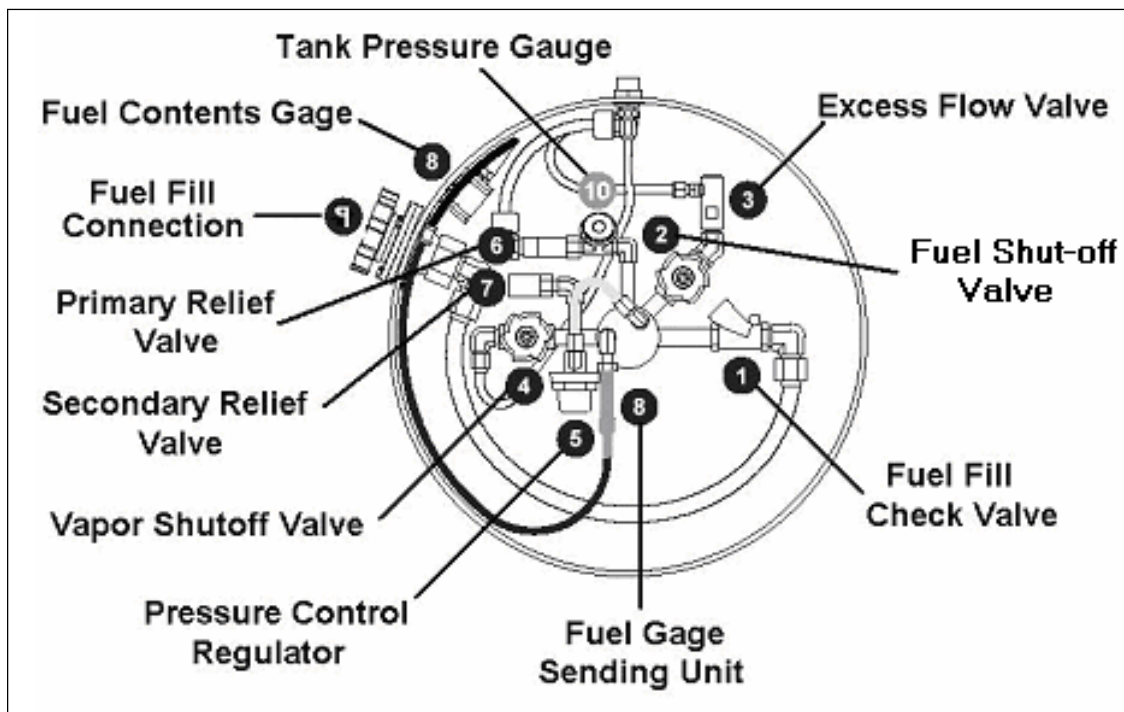


Figure 11-42c. Truck/Tractor Style Shrouded Tank Components

b. Function of Common Components. The item numbers listed below describe the function of common components which are illustrated in Figures 11-42b and 11-42c depending on whether the fuel tank is a “shrouded” or “heading” style

container. The following fuel system components are normally located on the fuel tank in an LNG fuel system:

(1) Fuel Fill Check Valve. The fuel fill line check valve is a bronze swing check with a soft seat. Its function is to prevent backflow through the fill line in the event of a fuel coupler failure or vehicle accident. It relies on tank pressure to seal and despite the soft seat should not be regarded as a positive shut-off valve. The fill check valve connects to a top fill line inside of the fuel tank. Figure 11-42d illustrated a typical fuel fill check valve.

(a) NFPA 57, 2-12.4.5, requires a backflow check valve to prevent the return flow of LNG from the container(s) to the filling connection. The check valve may be integral to another component in the system, such as the vehicle fueling connector.

(b) SAE J2343, 4.2.5, requires a secondary check valve independent of the fueling connector to be fitted between the fueling connector and the fuel tank.

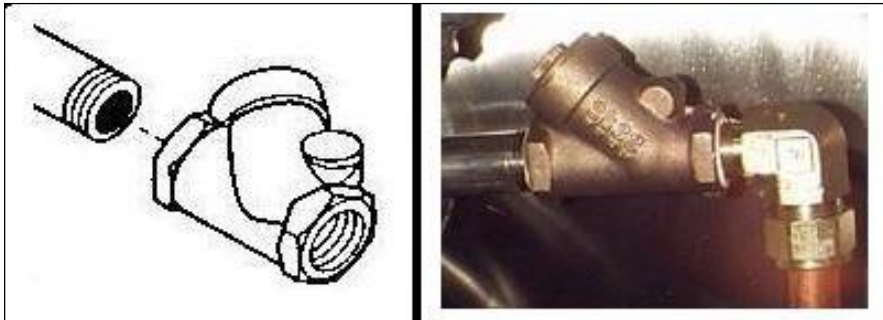


Figure 11-42-d. Fuel Fill Check Valve

(2) Fuel Shut-off Valve. The fuel shut-off valve (liquid valve) is a bronze globe valve with a soft seat. Its function is to provide a positive shut-off of the fuel line for service and maintenance operations. The fuel shut-off valve connects to the liquid withdrawal line at the bottom of the tank and to the vapor withdrawal line at the top of the tank through the pressure control regulator. The fuel shut-off valve is open for normal vehicle operation. Figure 11-42e illustrates a typical shut-off valve used for the fuel tank liquid and vapor supply lines.

(a) NFPA 57, 2-12.1.12, requires manual shut-off valves for liquid and vapor fuel to be readily accessible and operable without the use of tools. The valve location shall be marked with the words “MANUAL SHUT-OFF VALVE” and must be visible from outside the vehicle. Decals or stencils are permitted.

(b) SAE J2343, 4.2.7, requires a shut-off valve for each line which supplies fuel to the engine. The valves must be located at the fuel tank and be appropriately labeled "LIQUID SHUT-OFF VALVE" for liquid supplies and "VAPOR SHUT-OFF VALVE" for vapor supplies. If the valves are manual, a label for the closed direction or rotation is required.

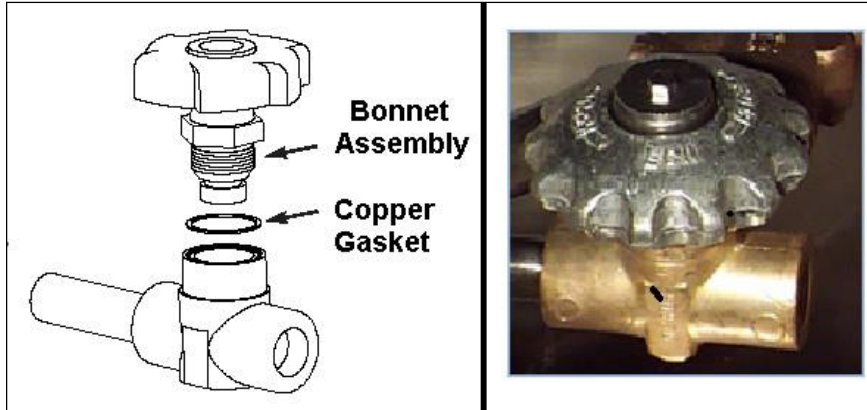


Figure 11-42e. Fuel (Liquid and Vapor) Shut-off Valve

(3) Vapor Shut-off Valve. The vapor shut-off valve (vent valve) is a bronze globe valve with a soft seat. Its function is to provide a positive shut-off of the vapor withdrawal line for service and maintenance operations. The valve connects to the vapor withdrawal line at the top of the tank. The vapor shut-off valve is closed for normal vehicle operation. Figure 11-42e shows a typical vapor shut-off valve which is the same type of valve described in paragraph (2) (fuel shut-off valve) above. The NFPA and SAE requirements are also the same as mentioned in paragraph (2).

(4) Excess Flow Valve. The excess flow valve is a specialized check valve with a hard metal seat designed to cut off fuel flow if it exceeds a certain limit. Its function is to protect the fuel line between the tank and heat exchanger against uncontrolled fuel release in the event of a vehicle accident. It is not designed to protect piping downstream of the heat exchanger, which is the function of the automatic fuel shut-off valve. The excess flow valve is not a positive shut-off valve. Its hard seat allows a small flow to pass by in order to allow the valve to automatically reset when the fuel shut-off valve is closed. Figure 11-42f illustrates a typical excess flow valve.

(a) NFPA 57, 2-10.4, requires each vaporizer (heat exchanger) to be equipped with an excess flow valve sized for not less than 120 percent of the rated flow capacity of the vaporizer.

(b) SAE J2343, 4.2.8, requires an excess flow valve for each line which supplies fuel to the engine. The valve(s) must “trip” on a fuel line failure and must be oriented so as to minimize the effect of road vibration on the valve action.



Figure 11-42f. Excess Flow Valve

(5) Pressure Control Regulator. The pressure control regulator (economizer) is a bronze pressure reducing valve that is open at pressures above its setpoint and closed at pressures below its setpoint. Its function is to allow vapor to flow into the fuel line during vehicle operation to reduce the fuel-vapor pressure to a predetermined setpoint. It is assisted in its operation by an internal check valve in the fuel pickup line providing a 2 psi bias pressure to aid vapor flow. The setpoint of the regulator is nonadjustable, being set at the time of manufacture. Flow through the regulator is not directional; it will be an open valve whenever the fuel line pressure is above its setpoint. Figure 11-42g illustrates one type of pressure control regulator (economizer).

(a) NFPA 57, 2-12.5, requires a pressure control regulator to be installed between the vehicle fuel container and the engine to regulate the pressure of the fuel delivered to the engine. Additionally, pressure regulating equipment must be installed so that its weight is not placed on, or supported by, the attached lines.

1 SAE J2343, 4.4, does not require a pressure control regulator, however, if a pressure regulator is used it must be protected from damage by road debris and from other mechanical damage by reasonable means. Additionally, the low side of the pressure regulator must be fitted with a relief device and the relief valve

outlet must be piped above the truck cab per the requirements of the primary fuel tank relief valve (see 4.2.2).



Figure 11-42g. Pressure Control Regulator

(6) Primary Pressure Relief Valve. The primary pressure relief valve, commonly known as the primary PRD, is a brass cryogenic relief valve set at the maximum allowable working pressure (MAWP) of the fuel container. Its function is to vent product to atmosphere if the tank pressure exceeds the MAWP. It is connected to the top fill line thereby providing additional safety against over pressurizing the tank during filling operations. The primary PRD is equipped with a pipeaway adapter to permit piping the vent gasses to a safe location on the vehicle. Figure 11-42h shows a typical primary PRD.

(a) NFPA 57, 2-4.2, requires the primary and secondary pressure relief valves to communicate directly with the vapor space of the fuel container. Additionally, PRDs that discharge to the atmosphere must be vented outside the vehicle. All discharge lines and outlets must be installed as follows:

1 PRD discharge lines must be metallic and have a minimum melting point of 1,500° F. However, the 2002 edition of NFPA 57, 4-4.3(1) requires PRD lines to be suitable for the pressure and temperature of the discharge fluid, but does not specify that the

discharge lines be metallic or have a specific melting point. The lines no longer have to be metal in accordance with the 1996 edition of NFPA 57, 2-4.3(a). The CHP recognizes the 2002 edition of NFPA 57 by allowing discharge lines to be other than metallic. Figure 11-43h shows a plastic “pipe-a-way” line being used on the vent connection.

2 Discharge lines and adapters must be sized, located, and secured to meet the required relief discharge capacity and to minimize possibility of physical damage. (NFPA 57, 2-4.3(b)).

3 Discharge lines must be able to withstand the pressure of the relief vapor discharge when the relief device is in the full-open position. (NFPA 57, 2-4.3(c)).

4 A means must be provided (e.g., loose-fitting caps) to minimize the possibility of the entrance of water or dirt into either the relief device or its discharge line and to drain any water that does accumulate in the discharge line. (NFPA 57, 2-4.3(d)).

5 The outlet of the discharge line must be fitted with a device or configured to prevent the formation or accumulation of any ice that could prevent the relief device from operating at required capacity. (NFPA 57, 2-4.3(e)).

6 The relief valve discharge from fuel containers shall be directed upward or downward within 45 degrees of vertical; shall not impinge directly on the vehicle fuel containers, the exhaust system, or any other part of the vehicle; and shall not be directed into the interior of the vehicle (NFPA 57, 2-4.4(f)). Figure 11-42i illustrates a typical PRD discharge line on a truck tractor.

7 The discharge line from the PRD on all buses must be located at the rear of the vehicle, directed upward, and extended to the top of the vehicle roof. (NFPA 57, 2-4.3(g)). Figure 11-42j illustrates a typical PRD discharge line on a bus.

(b) SAE J2343, 4.4.4, also requires fuel containers to be equipped with PRDs or Pressure Control Valves required by the code (DOT or ASME) under which the containers were designed and fabricated.

1Rupture discs may not be used.

2 Each PRD must be labeled with the manufacturer's name, part number, and set pressure.

3 Each PRD must have separate inlet connections which communicate directly with the vapor space of the fuel container.

4Each PRD must have a separate outlet.

5 The primary PRD must be piped to a vent stack which extends above the cab of the truck.

6The vent stack should be suitable for LNG service.

7 Primary and secondary PRD outlets must be protected from fouling by dirt, debris, snow, ice, and/or water.

8 The vent stack must be sized to prevent flow restriction due to pressure drop.

9 Gas exiting the vent stack or secondary relief valve must not impinge on enclosed areas, other vehicles, engine intakes, or engine exhausts.

10 In the case of dual tanks, the primary PRD outlet piping for each fuel container may be manifolded to a common outlet stack.

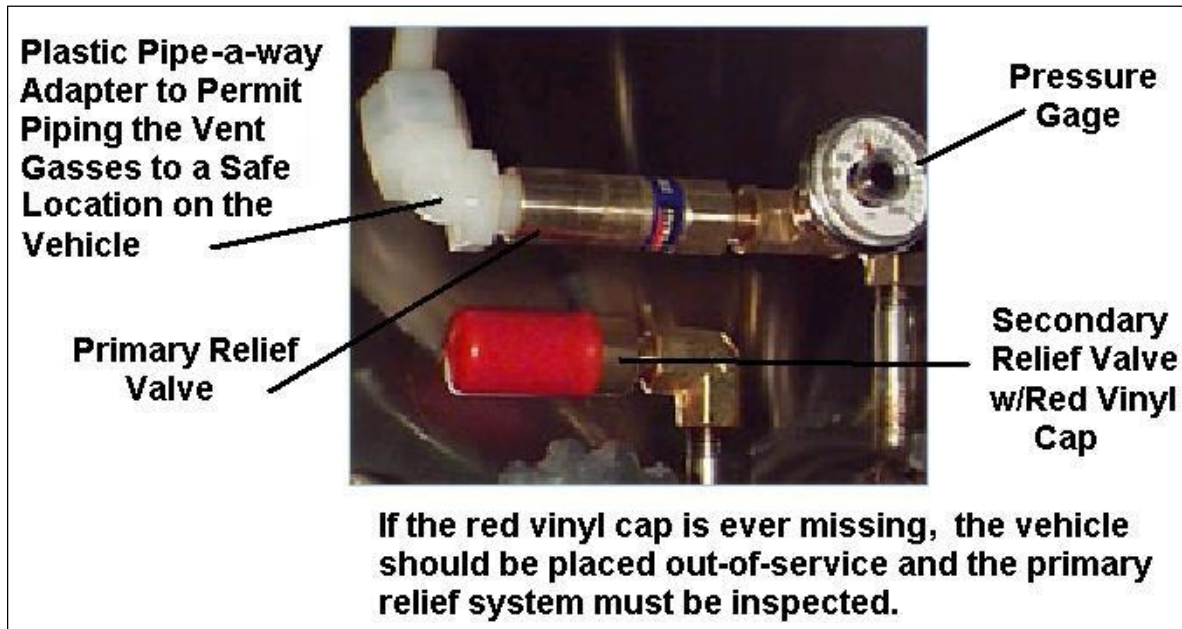


Figure 11-42h. Pressure Relief Device (PRD)

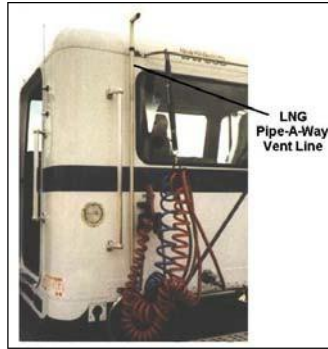


Figure 11-42i. Typical Location for Pressure Relief Device on a Truck Tractor



Figure 11-42j. Typical Location for Pressure Relief Device on a Bus

(7) Secondary Pressure Relief Device (PRD). The secondary PRD is a brass cryogenic relief valve set at 1.5 times the maximum allowable working pressure of the tank. Its function is to vent product to atmosphere to prevent a catastrophic failure of the tank in the event of a malfunction of the primary PRD or line. It is connected to the vapor withdrawal line providing a secondary relief path for the tank. It is protected from debris by a red vinyl cap and should never be piped away. Since this is the last line of defense for the tank if the red vinyl cap is ever missing, the vehicle should be placed out-of-service until the primary relief system is inspected and the problem corrected. Figure 11-42h shows a typical primary and secondary PRD. The NFPA and SAE requirements for the secondary PRD are the same as listed for the primary PRD in paragraph (6) above.

(8) Fuel Contents Gage and Sending Unit. The LNG fuel tank comes equipped with an electronic fuel contents gage. The gage consists of two parts: the fuel gage sender and a dash mounted fuel gage. The gage sender comes mounted to the fuel tank. Its function is to convert the

electronic signal to a signal compatible with the dash mounted gage. It is a solid state, sealed unit which accurately reflects the actual mass of the product in the tank and is unaffected by product state, pressure, or temperature. The dash mounted fuel gage is a standard automotive type gage calibrated to the sender. Figure

11-42k illustrates one type of fuel gage and sending unit.

(a) NFPA 57, 2-3.2, requires containers to be equipped with a device, or devices that provide an indication of when the container is filled to the maximum allowable liquid level.

(b) SAE J2343, 4.2.3, required each tank system to have a liquid level gauging device which can be read from the cab of a heavy-duty truck. Accuracy must be within + or - 1/8 capacity.

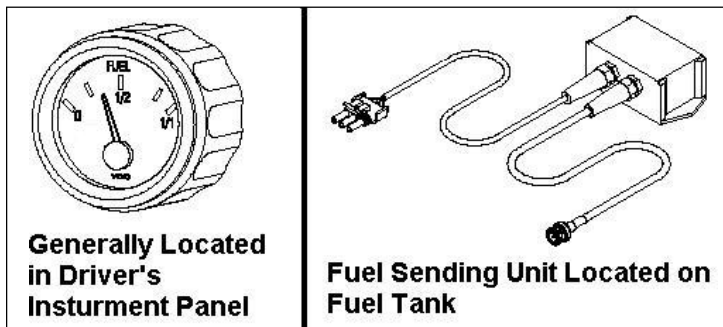


Figure 11-42k. Fuel Contents Gage and Sending Unit

(9) Fuel Fill Fitting. The function of the fuel fill fitting is to provide a connecting point to the refueling station that permits a cryogenic pressure transfer to occur. The fuel fill fitting incorporates a positive shut-off device to prevent fuel leakage when disconnected. Figure 11-42l shows a typical fuel fill fitting on the vehicle and the fuel connector from the fuel station pump.

(a) NFPA 57, 2-12.9, requires the fueling receptacle on the vehicle fuel system to be firmly supported and must:

- 1 Receive the fueling connector and accommodate the service pressure of the vehicle fuel system;
- 2 Incorporate a means to minimize the entry of dust, water, and other foreign material; and
- 3 Be suitable for any corrosive conditions that are anticipated.

(b) NFPA 57, 2-12.9.2, requires the fueling receptacle to be mounted to withstand a breakaway force such that the breakaway device specified in NFPA 57, 3-4.1.4, operates before the receptacle separates from the vehicle fuel system. The receptacle must be installed in accordance with the manufacturer's instructions.

(c) SAE J2343, 4.2.5, requires a fueling connection with a dust cap to preclude the introduction of dirt to the fuel system. A secondary check valve independent of the fueling connector must be fitted between the fueling connector and the fuel container. The fueling connector must be rated for the maximum allowable working pressure of the fuel container and must be installed in accordance with the manufacturer's recommendations. The fueling connector must withstand the breakaway forces generated by the fueling station breakaway device. Recessed or flush-mounted refueling connections must be provided with a spill path which directs liquid back outside the vehicle body. Fueling connections must be labeled "LNG only."



Figure 11-42l. Fuel Fill Fitting

(10) Pressure Gage. The fuel container pressure gage is generally located on the PRD tee at the 12 o'clock position on the plumbing manifold on shrouded tanks as illustrated in Figure 11-42m. The pressure gage alerts the person fueling the container of the actual pressure inside the fuel container. If the fuel container pressure is too high, it can be vented back to the fueling station through the LNG dispenser.

(a) NFPA 57, 2-5.1, requires fuel containers to be equipped with a pressure gauge connected to the container at a point above the maximum liquid level.

(b) SAE J2343, 4.2.4, requires fuel containers to have a pressure gage that can be read locally. The gage pressure range must be at least 1.2 times the maximum allowable working pressure. The gage opening must be no larger than 0.055 inches and must connect above the maximum liquid level.



Figure 11-42m. Typical Pressure Gauge Located on the PRD Tee

(11) Evacuation Port. The evacuation port is located on the nonplumbing head of the fuel containers. Its function is to provide a re-sealable connection for evacuating the container. Its secondary function is to provide a pressure relief path in the event of a product leak in the vacuum space. The plug should not be removed because it will cause the container to lose vacuum. There are no NFPA or SAE requirements regarding the evacuation port. Figure 11-42n illustrates the location of the evacuation port.

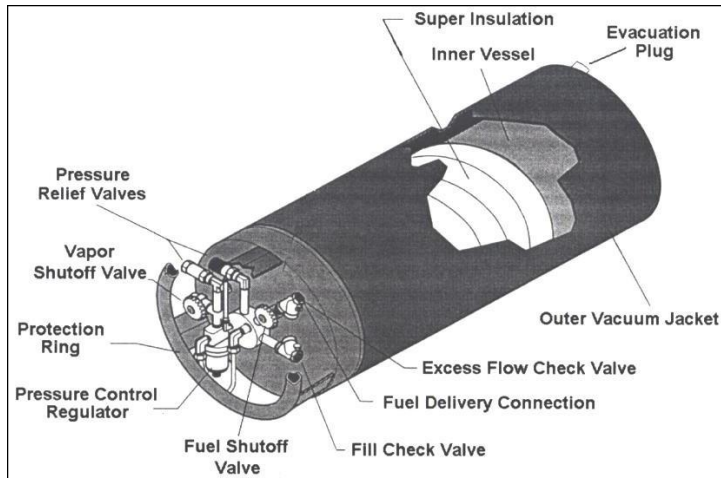


Figure 11-42n. Location of Evacuation Port on End of LNG Container

**15. ADDITIONAL COMPONENTS OF THE LNG FUEL SYSTEM AND THEIR INSPECTION.** The following components are not part of the fuel container; however, they are part of the LNG fuel system:

a. Heat Exchanger. The fuel exists in the fuel container as both a cold liquid and cold gas. It can be withdrawn from the fuel tank in either liquid form or as a mixture of liquid and gas. The function of the heat exchanger (vaporizer) is to vaporize the cryogenic liquid fuel and deliver it as a warm gas to the engine. The vaporizer is located between the fuel container and the engine and generally mounted within eight feet of the fuel container. The vaporizer is connected to engine coolant which flows around the vaporizer coils which contain fuel. As the LNG enters the vaporizer, the heat from the coolant converts it to gas by warming it. The gaseous fuel can then be supplied to the engine. The coolant flow should be plumbed in the same direction as the LNG flow. The vaporizer does not affect the fuel pressure. It simply raises its temperature and turns the fuel from a liquid to a gas. Figure 11-43 illustrates a typical vaporizer which is available in different sizes and configurations.

(1) NFPA 57, 2-10.2, requires vaporizers to be marked permanently at a readily visible point to indicate the maximum allowable working pressure of the fuel-containing portion of the vaporizer.

(a) NFPA 57, 2-10.3, requires vaporizers to be designed for a working pressure at least equal to the maximum discharge pressure of the pump or pressurized supply system, whichever is greater.

(b) NFPA 57, 2-10.4, requires each vaporizer to have a PRD sized for not less than 10 percent of the rated flow capacity of the vaporizer and NFPA 2-10.5 requires the discharge valve, its piping components, and

the PRDs installed upstream of the discharge valve to be suitable for operation at a LNG temperature of -260° F.

(c) NFPA 57, 2-10.6, prohibits engine exhaust gases to be used as a direct source of heat to vaporize fuel. Additionally, if the engine exhaust is used, it must be used via an indirect heating system.

(2) SAE J2342, 4.3, requires the following:

(a) The vaporizer must have the capacity to vaporize LNG completely at maximum engine fuel flow rates with minimum coolant design temperature.

(b) The fuel side of the vaporizer must be rated at the maximum allowable working pressure.

(c) Provisions must be made for bleeding air from the coolant side of the vaporizer.

(d) The vaporizer must be mounted as close to the fuel tank manifold as possible.

(e) The vaporizer must be protected from damage by road debris and from other mechanical damage by reasonable means.

(f) The vaporizer must be labeled for the intended service.

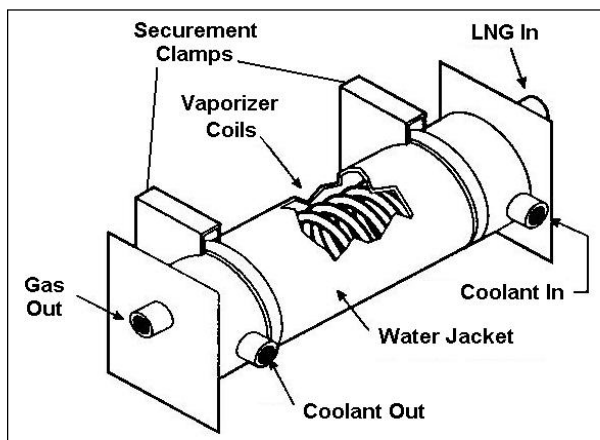


Figure 11-43. Heat Exchanger (Vaporizer)

b. Automatic Fuel Shut-off Valve. The function of the automatic fuel shut-off valve is to shut off the fuel flow to the engine when the ignition is switched off. It also may be activated by out of limit sensors on the engine or fuel system. Generally, the

shut-off valve is located at the warm gas outlet of the vaporizer. Figure 11-43a illustrates the typical installation of an automatic fuel shut-off valve.

(1) NFPA 57, 2-12.4.3, requires a positive shut-off valve to be installed in the fuel supply line at the inlet to the fuel pressure regulator. The shut-off valve must close automatically and prevent the flow of fuel to the engine when the ignition switch is in the off position, in the accessory position, or when the engine is not running and the ignition switch is in the on position.

(2) SAE J2343, 4.5, requires automatic shut-off valves to be rated at the maximum allowable working pressure of the fuel container or pressure regulator. Shut-off valves must fail to the closed position on loss of power regardless of orientation (e.g., mounted at any angle) or available pressure differential. The automatic shut-off valve must also close on loss of ignition or loss of engine operation. Valves must be protected from damage by road debris and from other mechanical damage by reasonable means.

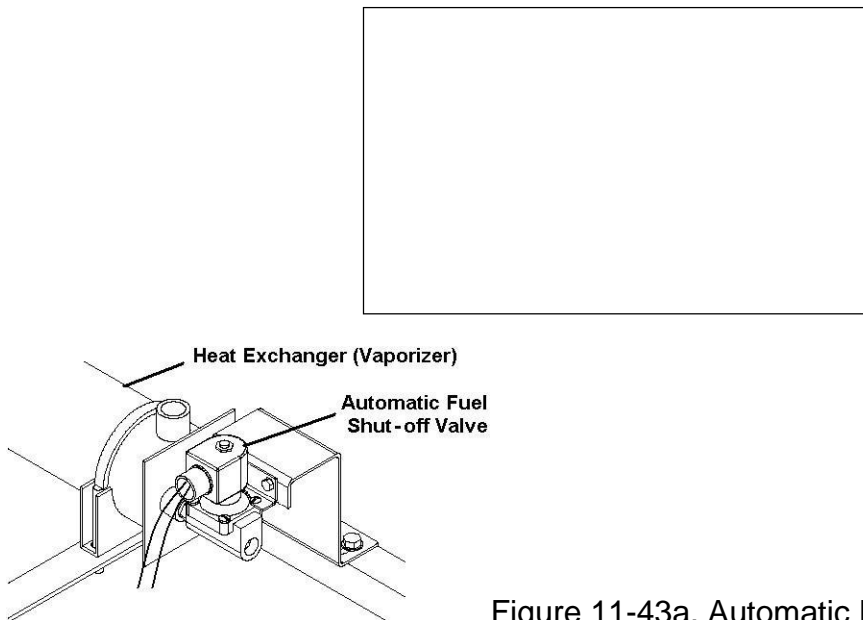


Figure 11-43a. Automatic Fuel Shut-off Valve

c. Overpressure Regulator. Some natural gas engines are unable to accept pressure up to the maximum allowable working pressure of the fuel tank. The fuel systems on these engines need to be equipped with an overpressure regulator to keep the operating pressure within acceptable limits for the engine. The regulator is generally mounted in the engine fuel line downstream of the vaporizer and automatic shut-off valve.

(1) It works in conjunction with the pressure control regulator on the fuel container to establish the fuel systems operating pressure window. The pressure control regulator on the fuel tank is set to the normal operating pressure of the engine.

(2) The over pressure regulator is set to a maximum operating pressure of the engine. The settings on these two regulators assure that the engine will always see pressures within its operating range. Generally, if an overpressure regulator is used it must be set at least 25 psig above the pressure control regulator on the fuel container to avoid transient low pressure spikes on acceleration.

(3) NFPA and SAE regulations do not address the overpressure regulator. Figure 11-43b illustrates one type of overpressure regulator.

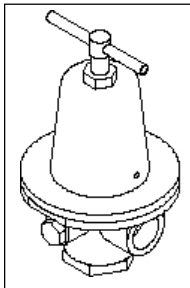


Figure 11-43b. Overpressure Regulator

d. Fuel Filter. Debris commonly enters the fuel container in two ways. It is carried into the fuel container during refueling from either dirty fill connectors, unfiltered fuel, or parts that are not properly cleaned prior to reassembly during maintenance operations. Although fuel is commonly filtered at the gas dispenser, experience has demonstrated that filters in the vehicle fuel system can reduce the likelihood of damage to regulators, valves and other key system components by capturing damaging contaminants. Figure 11-43c illustrates one type of fuel filter.

(1) NFPA 57 does not require a fuel filter in an LNG fuel system.

(2) SAE J2343, 4.11, requires a gas filter(s) which can be isolated from the fuel supply container to be installed in the vehicle fuel system. The filter(s) must be shielded from excessive radiant heat and road debris by reasonable means. The filter(s) must be rated at the maximum allowable working pressure of the fuel supply (fuel container or pressure regulator).

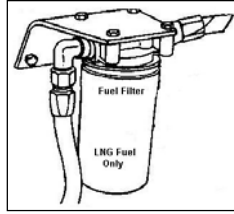


Figure 11-43c. LNG Fuel Filter

e. Fuel Lines. Pipe, tubing and fittings provide conduits for transfer of natural gas within the LNG fuel system at various pressures and flow rates. Several different pressure, temperature and fluid conditions exist within an LNG fuel system, ranging from low-pressure, to moderate pressure cryogenic LNG, and gaseous compressed gas at ambient temperatures. A number of fittings are used to connect various pieces together; these fittings include tees, reducers, straight unions, right angle unions and adapters (e.g., to change from threaded connections to compression connections). In many LNG fuel systems, the actual connection to the tubing is either a “flare” fitting or a “compression” fitting which are illustrated in Figure

11-43d. Fuel lines can be either metallic or nonmetallic suitable for LNG service. However, a bend in piping or tubing is prohibited where such a bend weakens the pipe or tubing. Figure 11-43e illustrates three fuel lines that are not acceptable and one that is acceptable.

- (1) NFPA 57, 2-12.3.1, requires manifolds and connecting fuel containers to be fabricated and installed to minimize vibration, and to be installed in a protected location or shielded to minimize damage from unsecured objects.
- (2) NFPA 57, 2-12.3.2, requires piping and tubing to be installed, supported, protected, and secured in such a manner as to minimize the possibility of damage, corrosion, or breakage due to expansion, contraction, vibration, strains, or wear, and to preclude any loosening while in transit.
  - (a) NFPA 57, 2-12.3.3, requires piping and tubing passing through a panel or structural member to be protected by grommets or similar devices that must snugly fit the piping or tubing and the hole in the panel or structural member.
  - (b) NFPA 57, 2-12.3.4, requires piping or tubing that passes through the floor of a vehicle to be installed in a location to enter the vehicle through the floor, directly beneath, or adjacent to, the container. If a branch line is required, the tee connection must be located in the main fuel line under the floor and outside the enclosed vehicle space.

(c) NFPA 57, 2-12.3.5, prohibits a fuel connection between a tractor and trailer or other over-the-road vehicle units.

(3) NFPA 57, 2-12.3.6, requires a pressure relief valve to be installed in each section of piping or tubing in which LNG can be isolated between shut-off valves so as to relieve the pressure. The pressure relief valve may not have a setting greater than the maximum allowable working pressure of the line it protects.

(4) SAE 4.7 requires piping to be shielded from radiant heating which exceeds its temperature limitations. The number of fittings and threaded pipe connections must be kept to a minimum, must be suitable for the intended service and must be included in the vibration/durability and corrosion testing. All piping and tubing must be protected from damage from road debris by reasonable means, protected from other mechanical damage, and be adequately supported. Vent stack connections must allow sufficient flexibility to accommodate differential movement. All cryogenic piping must be protected against blocking LNG between valve sections by hydrostatic relief or other suitable means.

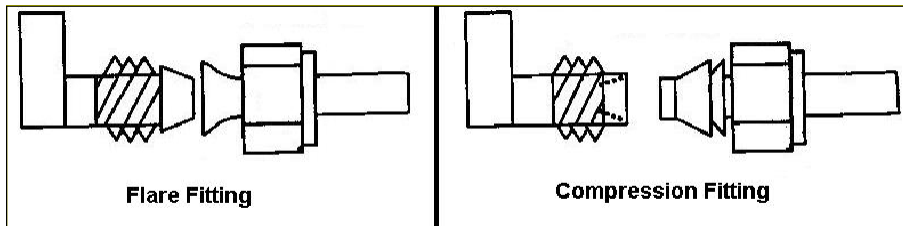


Figure 11-43d. Tube Fitting for Vaporized LNG

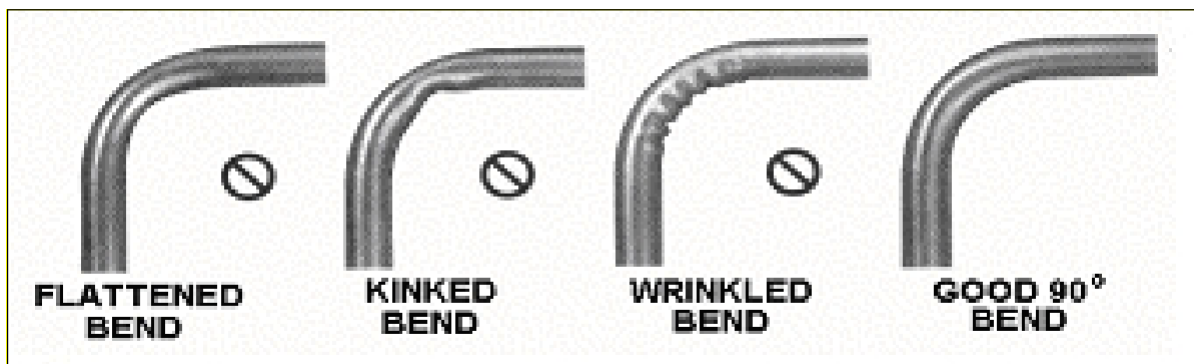


Figure 11-43e. Fuel Line Bending

**16. FUEL CONTAINERS MOUNTED IN INTERIOR OF VEHICLES AND/OR CLOSED COMPARTMENTS.**

Fuel containers mounted in the interior of vehicles and/or an enclosed compartment must be installed so that any fuel released from container appurtenances will not affect an area communicating directly with the driver or passenger compartment, or with any space containing radio transmitters or other spark-producing equipment. Fuel containers mounted inside vehicles and/or an enclosed area must be sealed and vented to the outside of the vehicle.

- a. Fuel Containers Installation. NFPA 57, 2-12.2.2, requires fuel containers to be installed and fitted so that no gas from fueling operations can be released inside the passenger compartment. This is to be accomplished by permanently installing the fueling connection outside the passenger compartment of the vehicle in a location protected from physical damage and dislodgement. NFPA 57, 2-12.2.3, requires enclosures, structures, seals, and conduits used to vent enclosures to be fabricated of materials designed to resist damage, blockage, or dislodgement caused by the movement of articles carried in the vehicle or by the closing of luggage compartment enclosures or vehicle doors, and requires the use of tools for removal.
- b. Gas Detection System (NFPA and SAE). NFPA 57, 2-12.2.4, and SAE J2343, 4.9, both require a gas detection system. However, 13 CCR, Section 935, Liquefied Natural Gas, contains additional requirements for LNG fuel systems which are above and beyond the requirements of either the NFPA or SAE requirements.
- c. Gas Detection System Requirements (13 CCR). 13 CCR, Section 935(b), requires every motor vehicle equipped with an LNG fuel system to be equipped with a methane gas detection system.

- (1) The system must warn of the presence of methane gas in the engine compartment, drivers compartment, and any passenger compartment. At a minimum, the methane gas detection system must provide a warning before the methane gas concentration reaches the lower explosive limit.

- (2) Such warning device must be both audible and visible to the driver before entering the driver's compartment and while seated in the normal driving position. The gas detection system must function at all times, whether or not the engine is operating, when the vehicle is located in areas open to the public.

**17. FUEL CONTAINER INSTALLATION, ORIENTATION, SUPPORTS, MOUNTING AND INSPECTION.** Visual inspection is currently one of the best available methods for verifying integrity of fuel containers and should be carried out on a routine basis. However, fuel containers should not be removed from the vehicle because removal and reinstallation may cause damage where none was present. Figure 11-44 illustrates a

typical fuel container location for a truck tractor and Figure 11-44a illustrates a typical location for fuel containers on a bus.

a. Fuel Container Location 13 CCR Requirements. 13 CCR, Section 1235(b)(4), requires fuel containers to be oriented and mounted in accordance with the container manufacturers recommendations and in a location designated by the vehicle manufacturer, in the location normally utilized for liquid (gasoline or diesel) fuel containers for that make and model of vehicle, or as determined by a qualified engineer.

(1) Fuel containers may not be mounted above any driver or passenger compartment, unless a spill pan is installed between the fuel containers and the compartment with a liquid capacity equal to at least the capacity of the largest single fuel container of a multiple container installation consisting of three or more fuel containers, but not less than one-quarter the fuel capacity of the containers located above the compartment and, capable of preventing liquid from entering the interior or dripping into any window, door, or emergency exit way.

(2) Spill pans shall be designed in such a manner that rain water is not retained. The spill pan drain shall not be directed into any confined space, the engine compartment, muffler area, battery box, or other hazardous location.

b. Fuel Container Location NFPA 57 Requirements. NFPA 57, 2-12, addresses the installation of vehicle fuel containers and container appurtenances and requires the following:

(1) NFPA 57, 2-12.1.1, requires vehicular components or subsystems that can fail on exposure to LNG temperatures and create a safety hazard to be protected from LNG exposure.

(2) NFPA 57, 2-12.1.2, allows fuel containers to be located within or below the driver or passenger compartment, provided all connections to the container(s) are external to, or sealed and vented from, the compartment.

(3) NFPA 57, 2-12.1.3, requires fuel containers to be located in a place and in a manner to minimize the possibility of damage to the container and its fittings. Containers located in the rear of the vehicles, where protected by bumpers or vehicle structure, are considered to be in conformance with this requirement. If a container is installed within 8-inches of the engine or exhaust system, it must be shielded against direct heating.

(4) NFPA 57, 2-12.1.4, requires fuel container markings to be visible after the container's permanent installation on a vehicle. A portable lamp and mirror may be used when reading markings.

(5) NFPA 57, 2-12.1.5, requires fuel container valves, appurtenances, and connections to be protected to prevent damage due to incidental contact with foreign objects.

(6) NFPA 57, 2-12.1.6, prohibits fuel containers from being mounted ahead of the front axle or beyond the rear bumper on motor vehicles. No part of the container or its appurtenances may protrude beyond the sides or top of any vehicle where the container can be struck or punctured.

(7) NFPA 57, 2-12.1.7, requires fuel containers to be installed to provide as much road clearance as practical. The minimum clearance from the road to the container, its housing, or its fittings, whichever is lowest, shall not, with the vehicle loaded to its gross weight rating, be less than that defined by the vehicle manufacturer's own design. This clearance must be measured as follows:

(a) Fuel containers installed between axles must comply with NFPA 57, 2-12.1.7(a), or shall not be lower than the lowest point on a structural component of the body, frame or sub-frame, if any engine or transmission component (including the clutch housing or torque converter housing) is located forward of the container.

(b) Containers installed behind the rear axle and extending below the frame must comply with NFPA 57, 2-12.1.7(b), or must not be lower than:

1 The lowest point of a structural component of the body, engine, or transmission component (including clutch housing or torque converter housing) located forward of the container; and

2 The lowest point of a straight line extending rearward from each wheel at the point where the lowermost portion of the wheel rim contacts the ground directly below the center of the axle to the lowest and most rearward structural interference (e.g., bumper, frame). Where there are two or more rear axles, the projections must be made from the rearmost axle.

(c) NFPA 57, 2-12.1.7(c), indicates where an LNG fuel container is substituted for the fuel container installed by the original manufacturer of the vehicle (whether or not that fuel container was intended for LNG), the LNG fuel container either must fit within the space in which

the original fuel container was installed or must comply with 2-12.1.7(a) or (b).

(8) NFPA 57, 2-12.1.8, requires fuel containers to be mounted securely to prevent their jarring loose, slippage, or rotation. Fuel containers must be secured to the vehicle body, bed, or frame by means capable of withstanding the loads defined in 2-3.3 (Fuel Container Structural Integrity) which are as follows:

(a) The fully pressurized fuel container (filled to its maximum filling volume with LNG), together with valves, enclosures, and all other items that normally are mounted and attached thereto and mounted by its normal means of attachment, must be capable of withstanding, without loss of contents, a static force in the six principle directions, equal to eight times the weight of the fuel container plus its contents.

(b) The fuel container, the plumbing, and the mounting attachments must be capable of withstanding the effects of shock, vibration, and acceleration encountered in normal service.

(9) NFPA 57, 2-12.1.9, prohibits the fuel container weight from being supported by outlet valves, manifolds, or other fuel connections.

(10) NFPA 57, 2-12.1.10, requires the mounting system to be designed to minimize fretting corrosion between the container and the mounting system.

(11) NFPA 57, 2-12.1.11, prohibits the fuel containers from being installed so as to adversely affect the operating characteristics of the vehicle.

(12) NFPA 57, 2-12.1.12, requires the manual shut-off valves on the fuel container for liquid and vapor to be readily accessible and operate without the use of tools. The valve location must be marked with the words "MANUAL SHUT-OFF VALVE" which must be visible from outside the vehicle. Decals or stencils are permitted.

c. Fuel Container Location SAE J2343 Requirements. SAE J2343, 4.2.10, requires fuel container internal supports be designed to be "fail safe" and be tested in accordance with industry requirements. Testing must be consonant with and in conformance with applicable federal, state, and local requirements.

(1) Fuel containers must be oriented and mounted in accordance with the manufacturer's recommendations.

(2) Containers mounted within eight inches of exhaust or other heat sources must be shielded from radiant heating.

(3) The fuel container shall not be supported by piping and/or piping connections. The fuel containers must be mounted so that no portion of the fuel container projects forward of the front axle or behind the rear axle.

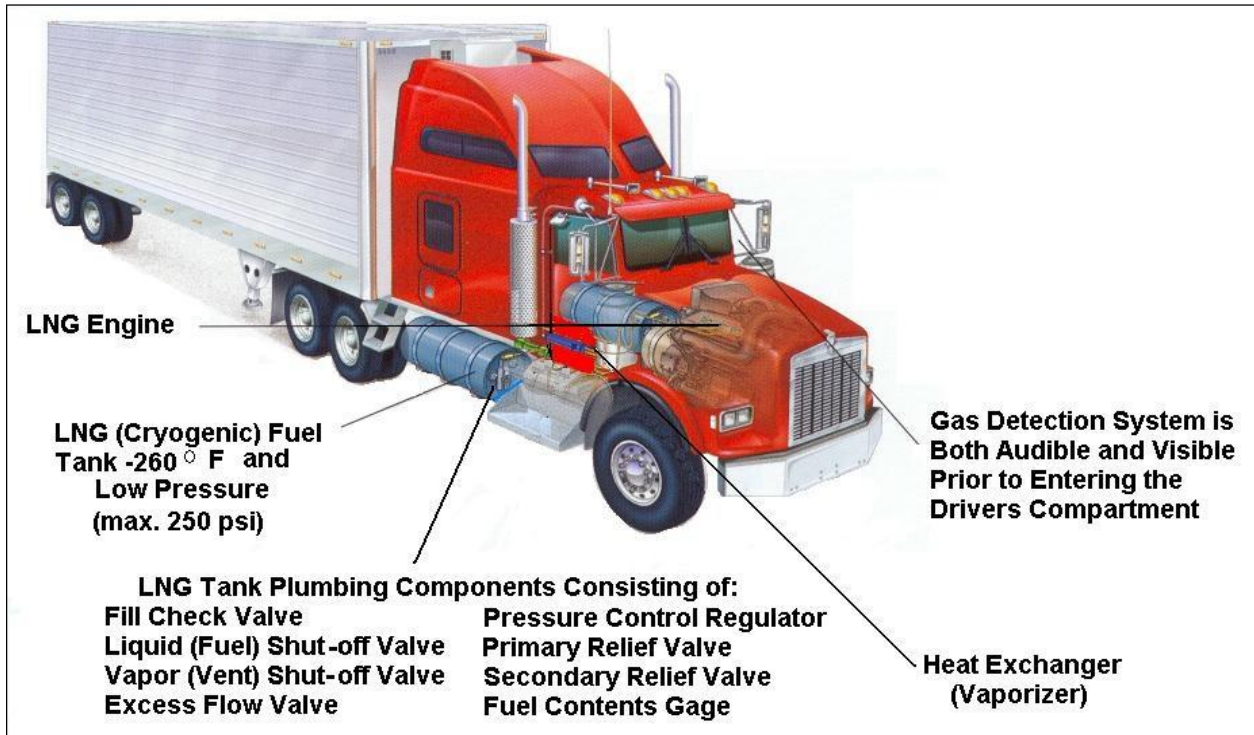


Figure 11-44. Location of Major Fuel Container Components on a Truck Tractor

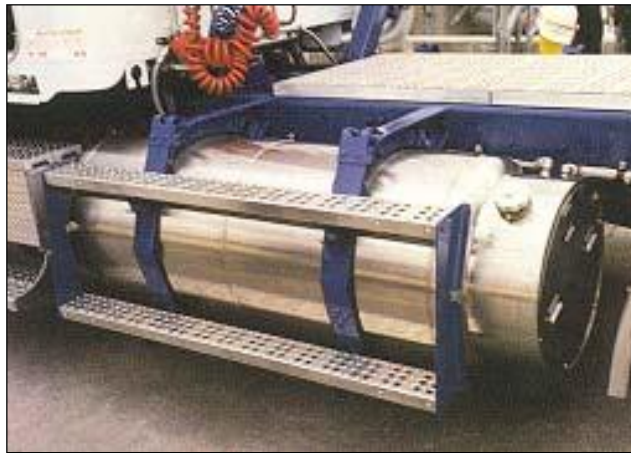


Figure 11-44a. Typical Location of Fuel Container on a Truck Tractor



Figure 11-44b. Typical Location of a Fuel Container on a Bus

18. **LABELING**. Section 27909 VC states that: “Any vehicle which carries liquefied petroleum gas fuel or natural gas, in a container attached to a vehicle, in any concealed area, including trunks, compartments, or under the vehicle, shall display on the exterior of the vehicle the letters “CNG,” “LNG,” “LPG,” corresponding to the type of fuel utilized, in block letters at least one inch high. The letters shall be of contrasting color and shall be placed as near as possible to the area of the location of the container. Any vehicle fueled by liquefied petroleum gas fuel or by natural gas may also comply with this section by displaying on each side of the vehicle words or letters at least 0.25 inch high indicating that the vehicle is fueled by liquefied petroleum gas or natural gas. It is unlawful to dispense liquefied petroleum gas fuel or natural gas into any container in a concealed area of any vehicle registered in California, unless the vehicle complies with the requirements of this section.”

a. **13 CCR and NFPA 57 Requirements**. In addition to VC 27909, 13 CCR 935(b)(5) and NFPA 57, 2-12.8.1, requires a vehicle to bear a durable label located at the fueling connection receptacle that must include:

- (1) Identification as an LNG-fueled vehicle, and
- (2) The maximum allowable working pressure of the vehicle fuel container.

(3) NFPA 57, 2-12.8.2, also requires each vehicle to be identified with a weather-resistant, diamond-shaped label located on an exterior vertical surface on the lower right rear of the vehicle (e.g., on the trunk lid of a vehicle so equipped, but not on the bumper or tailgate of any vehicle) inboard from any other markings. The label must be a minimum of 4-3/4

inches long by 3-1/4 inches high. The marking must consist of a border and the letters "LNG" (1-inch minimum height centered in the diamond) of silver or white reflective luminous material on a blue background. Figure 11-44c shows the required label.

b. SAE Requirements. SAE J2343, 4.2.11, requires each fuel container to be labeled with the following minimum data: Design Code, Service Pressure, Serial Number, Capacity in Water Gallons, Manufacturer's Name or Trademark, Certification Date and LNG Symbol (Blue and White Diamond). All container connections must be adequately labeled as to their function.



Figure 11-44c. LNG Label Required by NFPA 57 and SAE J2343

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## ANNEX A

### GLOSSARY OF CNG AND LNG FUEL SYSTEMS TERMINOLOGY TERMS COMMON TO CNG FUEL SYSTEMS

The definitions in this annex are not intended to be all-inclusive but to cover words, phrases, abbreviations, and acronyms that are typically used in the installation, repair and maintenance of CNG vehicles. Some of the terms may have different meanings when used in other contexts.

Abrasion Damage. Damage to a container caused by wearing, grinding, or rubbing away of the container material by friction.

Acoustic Emission Test. A form of nondestructive container inspection.

Alternative Fuel. An alternative to gasoline or diesel fuel which is not produced in a conventional way from crude oil, e.g., CNG, liquid petroleum gas (LPG), LNG, ethanol, methanol, hydrogen.

Appliance. Any apparatus or fixture that uses or consumes CNG furnished or supplied by a CNG gas system to which it is connected or attached.

Aramid Fiber. One of the types of reinforcement fibers used in the container's composite overwrap.

ASME Code. The American Society of Mechanical Engineers' Boiler and Pressure Vessel Code.

ASME Container. Any CNG container/cylinder manufactured to the specifications of the American Society of Mechanical Engineers in effect at the time of fabrication.

Bi-Fuel or Dual Fuel. A system that can operate on either of two fuels, but not a mixture of fuels, such as gasoline and CNG, or diesel and CNG.

Blunt Impact. A forceful blow to the surface of the container which does not cut, gouge or significantly indent the surface. This type of impact may induce damage such as delamination, which may not be readily apparent by visual examination.

Brake Horsepower. The horsepower output of an engine. The term brake horsepower is derived from the use of a brake or dynamometer to measure the engine's power output.

British Thermal Unit (BTU). The quantity of energy required to raise the temperature of one pound of water one degree Fahrenheit at or near 39.2° F.

Bulkhead. An upright partition separating compartments, such as an engine firewall.

Burst Disc or Rupture Disc. A safety device commonly used on high pressure cylinders to relieve overpressure of the container. The burst disc is designed to rupture when subjected to a predetermined pressure level.

Bypass. A separate passage which permits a liquid, gas, or electric current to take a path other than that normally used.

Capacity. The water volume of a container in standard cubic feet (cf). One gallon equals .13368 cubic foot.

Carbon Fiber. One of the types of reinforcement fibers used in the composite overwrap.

Carburetor. The device in an engine fuel system that mixes fuel with air and supplies the combustible mixture to the intake manifold for varied speed and load conditions of the engine.

Check. To verify that a component, system, or measurement complies with regulations or specifications.

Check Valve. A valve that opens to permit the passage of air or fluid in one direction only, or operates to prevent (check) some undesirable action.

Composite Container. A container fabricated of two or more materials that interact together to facilitate the container design criteria. Examples include fiberglass composites fabricated from glass fibers and epoxy resin, or carbon composites, fabricated from carbon fibers and epoxy resins.

CNG Fuel System. A system of safety devices, cylinders, piping, fittings, valves, regulators, gauges, relief devices, vents, and installation fixtures for use on a motor vehicle fueled by compressed natural gas.

Container (CNG). When used as a motor fuel, natural gas is stored aboard a vehicle in cylindrical containers at a pressure of approximately 3,000 psi. Among terms used to describe CNG fuel containers are tanks, containers, cylinders, and high pressure vessels. They will be referred to as “containers” throughout this publication.

Container Appurtenances. Devices connected to container openings for safety, control, or operating purposes.

Container Valve. A valve connected directly to a container outlet. Used to isolate the container from the rest of the fuel system.

Condemned Container. A container that must be removed from service. Repairs cannot be performed that will assure acceptable container performance.

Corrosion Damage. A process that refers to the oxidation of materials primarily in wet environments, or by a corrosive material.

Crazing. Hairline cracking of the resin, giving it an opaque, “frosty” appearance.

Cut Damage. This type of damage is caused by a sharp object in contact with a composite surface.

Cylinder. A container constructed, inspected, and maintained according to DOT specifications; Transport Canada (TC) regulations; American National Standards Institute/American Gas Association (ANSI/AGA), Natural Gas Vehicle (NGV2); or Canadian Standards Association (CSA) B51, Boiler, Pressure Vessel and Pressure Piping Code standards. Referred to as “containers” throughout this chapter.

Delamination. A form of container damage in which a separation develops between layers of the composite materials. This type of damage usually results from excessive internal pressure exerted on a weakened portion of the container.

Domes. The curved end portions of the fuel container.

Epoxy. A type of resin used in the composite wrap to protect the fibers and hold them together.

External/Exterior Coating. A surface treatment or the clear/colored coating applied to the container for environmental protection and appearance.

Fast Fill. A CNG refueling facility that can refuel a vehicle in just a few minutes.

Fiber. The load-carrying portion of the overwrap consisting of continuous filaments. The reinforcing fibers provide the majority of the container’s strength.

Fiberglass. A general term referring to glass fibers used to create a composite for reinforcement for container strength.

Filament Winding. An automated process used for orienting strands of high strength fibers and plastic resin to construct composite containers.

Filter. A device through which air, gases, or liquids are passed to remove impurities.

Fuel Line. The pipe, tubing, or hose, including all related fittings on a vehicle, through which CNG passes.

Full-Wrapped Container. The reinforcement of a filament and resin system applied over the entire liner including the domes, if so equipped.

Galvanic Corrosion. Corrosion that may occur when different materials are in direct contact with each other.

General Corrosion. Corrosion which covers considerable surface area of a container. It reduces the structural strength and is often accompanied by pitting.

Helical Wrap. A method by which the layers in the composite overwrap filament are wound to provide additional longitudinal strength for both the cylindrical and dome regions of the container. The strands of reinforcing fibers are oriented at an angle to the longitudinal axis of the container.

Hoop-Wrapped Container. Winding of filament in a substantially circumferential pattern over the cylindrical portion of the CNG container liner so that the filament does not transmit any significant stresses in a direction parallel to the container's longitudinal axis. Hoop winding generally leaves both container liner heads exposed.

Hydrostatic Test. A test performed on a container where the container is pressurized hydraulically to at least 1.5 times the service pressure and the container volume expansion is used to determine its condition.

Impact Damage. Damage caused by dropping or by a blow from another object. Impact damage may be at the surface, internal to the structure, or both.

Isolated Pitting. Pits of various depth and diameter which stand alone, as opposed to appearing in a group, as in line corrosion or general corrosion. Isolated pits of small diameter and shallow depth do not effectively weaken the container.

Kevlar. An organic fiber (nylon) used for reinforcement.

Kilo Pascals (kPa). A metric measure of pressure. One pound per square inch (psi) is equal to 6.9 kPa.

Line Corrosion. When pits are connected in a narrow band or line, such a pattern is termed "line corrosion." This condition is more serious than isolated pitting.

Liner. The internal component of the composite container which prevents leakage of gas through the composite structure and to which an overwrap is applied.

Lockoff. The device in a air-fuel system that prevents fuel from entering the converter or secondary regulator when the engine is not running.

Longitudinal Wrap. Fibers running in the general direction of the long axis of the container.

Manifold. The assembly of piping and fittings used for interconnecting containers.

Manual Shut-Off Valve. A quick-closing, manually operated valve, located downstream of all fuel supply containers on the vehicle.

Metallic Hose. A hose in which the strength of the hose depends primarily upon the strength of metallic parts; it also may have metallic liners and or covers.

Mounting Brackets and/or Straps. The devices used to secure fuel containers in a vehicle. The bracket and/or straps are specially designed to restrain containers without causing damage and to accommodate container expansion caused by changes in internal pressure.

Nonload Bearing. Parts of the container which do not support a pressure load. An example is the plastic liner in all-composite containers whose purpose is to prevent gas leakage.

Overwrap. Refers to both the fibers and the resin as a combined unit. Permeation. Process by which gas diffuses through a plastic liner.

Pitting. Type of localized corrosion that occurs in metals.

Polyethylene. A type of plastic material used in liners in all-composite containers. Known as PE (polyethylene) or HDPE (high-density polyethylene).

Ports. The openings at the ends of the container in which pressure relief devices, valves, and blank plugs are installed.

Pressure Relief Device. A device installed in the container or integrated with a valve which will release the contained gas in specific emergency conditions. The device may be pressure and or temperature activated, and is used to prevent the pressure from rising above a predetermined maximum; thereby, prevent the rupture of a normally or partially charged container when subjected to a standard fire test.

Pressure Relief Device Channels. The passage or passages beyond the operating parts of the pressure relief device through which fluid must pass to reach the atmosphere.

Pressure Vessel. A container or other component designed in accordance with the ASME Code.

Primary Regulator. A regulator in CNG systems that reduces the pressure of CNG coming from the container to around 100 psig. Also known as “first-stage regulator” or “high-pressure regulator.”

Rejected Container. A container that must be removed from service and evaluated further before final disposition.

Resin. The material (typically epoxy or polyester) which is used to bind the fibers together and protects the fibers from environmental effects and provides a means to accomplish load transfer among fibers.

Road Debris. Materials such as small rocks, stones, or gravel that have the potential to damage containers.

Service Pressure. The settled pressure at a uniform gas temperature of 70° F and full gas content. It is the pressure for which the equipment has been constructed, under normal conditions. Also referred to as nominal pressure.

Shielding. Structure designed to protect a container from road debris or other forms of attack that may damage the container.

Sidewall. The cylindrical portion of the container that does not include the domes.

Slow-Fill. A type of refueling in which the cylinders are filled slowly over a period of hours. Since the CNG in the vehicle container(s) has time to cool during the refueling process, the vehicle container(s) can be filled more completely than with fast-fill refueling.

Sources of Ignition. Devices or equipment which, because of their modes of use or operation, are capable of providing sufficient thermal energy to ignite flammable compressed natural gas-air mixtures when introduced into such a mixture or when such a mixture comes into contact with them and that will permit propagation of flame away from them.

Stress Corrosion Cracking. A form of cracking that occurs as a result of a combination of stress and a corrosive environment.

Supply Line. The pipe, tubing or hose, including all related fittings on a vehicle through which CNG passes.

Thermal Trigger. The portion of a thermally activated pressure relief device which is activated by excessive heat input.

Water Capacity. The volume of water, in pounds or gallons, at 60° F required to fill a container.

Working Pressure. The pressure at which the equipment was designed to function, or if conditions have changed, the maximum pressure allowed at specified temperatures.

## TERMS COMMON TO LNG FUEL SYSTEMS

The definitions in this annex are not intended to be all-inclusive but to cover words, phrases, abbreviations, and acronyms that are typically used in the installation, repair and maintenance of LNG vehicles. Some of the terms may have different meanings when used in other contexts.

ANSI. American National Standards Institute. ASME. American Society of Mechanical Engineers.

Container. A vessel used to store fuel on board a motor vehicle. Commonly referred to as a Fuel Tank.

Container (Fuel Tank) Appurtenances. Items connected to container openings needed to make a container a gastight entity. These include, but are not limited to, pressure relief devices; shut-off valves, backflow check, excess flow check, and internal valves, liquid level gauges, pressure gauges, and plugs.

Design Operating Pressure. The pressure at which the LNG equipment or container is designed to operate during normal use.

DOT. U. S. Department of Transportation.

Fail-safe. A term used to describe design features that provide for the maintenance of safe operating conditions in the event of a malfunction of control devices or an interruption of an energy source.

Family of Containers. A group of containers related by the following common characteristics or properties: same manufacturer, same insulation system and materials, same inner support system, mounted in the same manner with piping components in the same or similar orientation, constructed with the same material types of the same strength and a volume not greater than 100 percent of the test container provided that the inner and outer vessels are of the same thickness as the test container.

Fixed Liquid Level Device. A device that indicates when the container is filled to its maximum permitted filling volume.

Fuel Dispenser System. All the pumps, meters, piping, hoses, and controls used for the delivery of LNG to, and the removal of vapor from a vehicle.

Fueling Connector. A device that connects the fueling dispenser hose or arm to the vehicle fuel filling system for the transfer of LNG or vapor. This device includes shut-off valves.

Fueling Facility. A facility that dispenses LNG into vehicles for use as an engine fuel.  
Fueling Receptacle. The mating part of the fueling connector mounted on a vehicle.

Heat Leak. Sometimes referred to as “weathering” is the vaporization process in fuel tanks, where the cryogenic liquid, because of the addition of heat, turns into vapor; thus, increasing pressure inside the fuel tank.

Ignition Source. Any item or substance capable of an energy release of the type and magnitude sufficient to ignite any flammable mixture of gases or vapors.

Labeled. Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation that maintains periodic inspection of production of labeled equipment or materials, and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

LOX. Liquefied Oxygen. LNG. Liquefied Natural Gas.

Maximum Allowable Working Pressure (MAWP). The highest pressure which can occur within a system prior to operation of the protection relief valve.

Pressure Regulator. Any device used to reduce pressure (independent of flow) exclusive of engine control regulators.

Pressure Relief Device. A device designed to open in order to prevent a rise of internal fluid pressure in excess of a specified value; generally, due to emergency or abnormal conditions. This device can be of a re-closing or other type, such as one having a rupture disc or fusible plug that requires replacement after each use.

Pressure Vessel. A container or other component designed in accordance with the ASME Boiler and Pressure Vessel Code.

Ullage. The amount that a container lacks of being full.

Ullage Space. The volume of a container which is not full of liquid.

Vaporizer (Heat Exchanger). A device other than a container that receives LNG in liquid form and adds sufficient heat to convert the liquid to a gaseous state.