

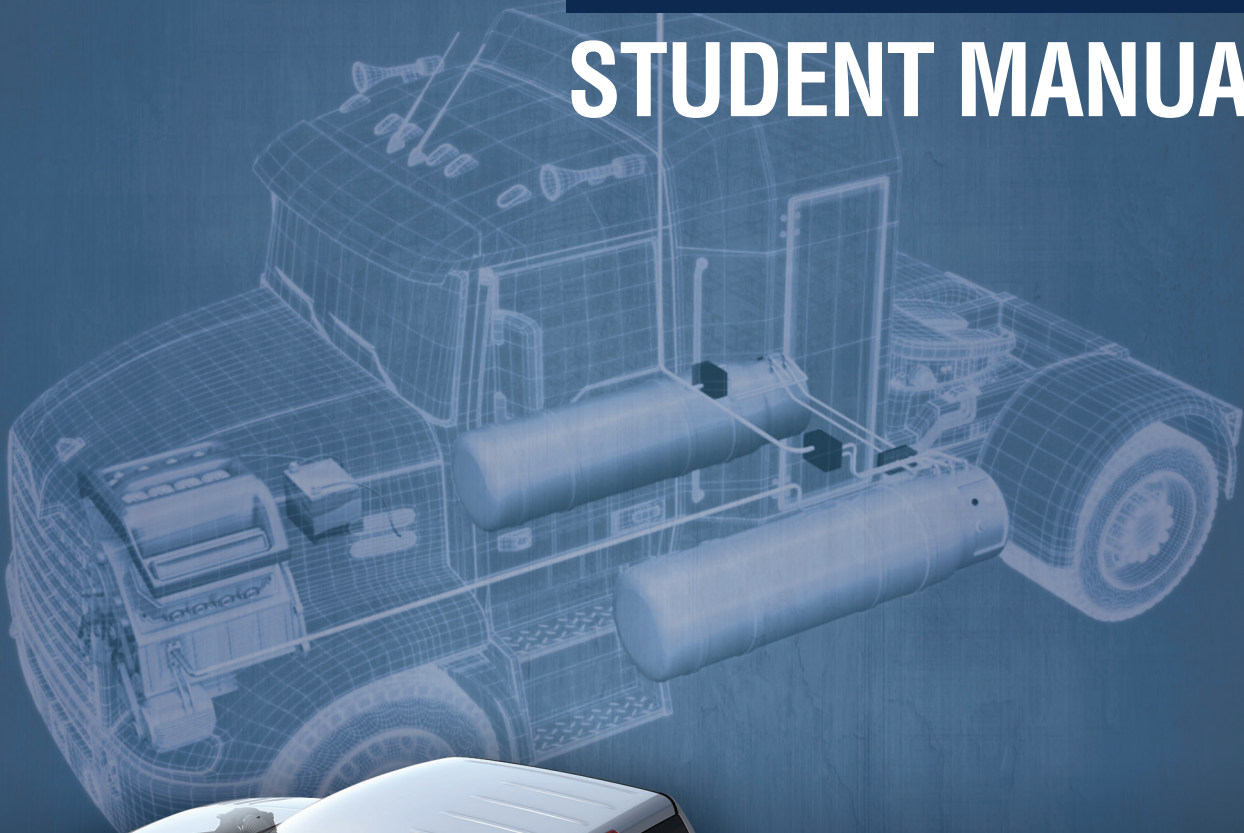


**ALTERNATIVE  
FUEL VEHICLES**  
SAFETY TRAINING PROGRAM

# Alternative Fuel Vehicle Safety Training

## Gaseous Fuel Module

# STUDENT MANUAL





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# GASEOUS FUEL VEHICLE SAFETY TRAINING PROGRAM

## **STUDENT MANUAL**

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# FOREWORD

Established in 1896, The National Fire Protection Association (NFPA) is the leading global advocate for the elimination of death, injury, property and economic loss due to fire, electrical and related hazards. Today the association delivers information and knowledge through more than 300 consensus codes and standards, research, training, education, outreach and advocacy.

Since 2010, NFPA has developed a comprehensive training program which educates first responders across the country on alternative fuel vehicle safety. Through extensive research of both the fire service and current training methodologies, NFPA has produced a highly engaging multi-media training curriculum and delivery plan consisting of instructor-led classroom courses, train-the-trainer deliveries, self-paced e-learning modules, 3-D models, training videos, a quick-reference Emergency Field Guide, which includes on-scene procedures and safety precautions, and an app. Through this program, NFPA has demonstrated its deep commitment to developing and improving safety training and standards for first responders, with regard to alternatively fueled vehicles.

This manual represents the continued efforts of the NFPA to ensure first responders are prepared for new technologies on our nation's roadways. This edition includes continued refinement of existing safety information, and the inclusion of gaseous fuel vehicles. These updates were made possible through a Department of Energy grant awarded to the NFPA in 2015.

This course was developed using current fire-rescue service best practices and incorporating instructions and guidance from auto and battery manufacturers. However, due to the inherently dangerous and unpredictable nature of rescue operations, NFPA claims no responsibility for either the manufacturer instructions contained herein, or unforeseen circumstances that may create rare exceptions to the general safety-related guidance provided.

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# **SECTION I: INTRODUCTION TO GASEOUS FUEL VEHICLES**

## **SECTION OBJECTIVES**

Following instruction, the student shall be able to:

1. Identify the two (2) most commonly used gaseous fuels
  2. Identify the typical applications for gaseous fueled vehicles
  3. Describe the difference between dual fuel and bi-fuel vehicles
-

## I. PROGRAM OVERVIEW



There has been a recent push to move away from traditional fuels, such as diesel and gasoline, especially in fleet applications. As a result, the likelihood of firefighters responding to incidents involving gaseous vehicles will increase. It is important that firefighters and other emergency responders familiarize themselves with the types of fuels utilized, as well as their impact on emergency operations.

### A. Course Goal

The course goal is to prepare first responders to operate safely at incidents involving compressed natural gas (CNG), liquefied natural gas (LNG), and liquefied propane gas (LPG) vehicles.

### B. Course Sections

Section I: Introduction to Gaseous Fuel Vehicles

Section II: Gaseous Fuel Properties

Section III: Vehicle Systems and Operation

Section IV: Fueling Stations

Section V: Initial Response Procedures “Identify, Immobilize and Disable”

Section VI: Emergency Operations

Section VII: Program Review

## II. COMMONLY USED GASEOUS FUELS

The two most common types of gaseous fuels used in vehicles are natural gas and propane. As with a gasoline or diesel powered vehicle, these fuels are burned in an internal combustion engine. Natural gas can be stored on vehicles in either its compressed (CNG) or liquefied (LNG) state. Propane will be found in a liquefied (LPG) state.



## III. VEHICLE TYPES AND APPLICATIONS



Gaseous fuel systems can be found in commercial/fleet, transit, and passenger/light duty vehicle markets. Unlike hybrid and electric vehicles, most CNG, LNG, and LPG vehicles are conventional vehicles which have gone through an upfitting process. This involves the purchase of a conventional chassis and the installation of the gaseous fueled system by a third party. It is less common to see these vehicles built entirely by the original vehicle manufacturer.

Although not as common, aftermarket kits are available that can convert conventional vehicles to run on CNG or LPG. In some instances, the parts may be substandard in construction. Also, installers may not have the appropriate qualifications and training to install the system. Required labeling may not be added due to unfamiliarity with requirements. As a result, the presence of these modifications may be unknown until much later during an incident.

#### IV. FUEL SYSTEM TYPES

It is also possible for emergency responders to encounter vehicles with both conventional fuels and gaseous fuels stored onboard. Vehicles can either be single or dedicated fueled, and be designed to run on CNG, LNG or LPG alone or multi-fueled.



Multi-fueled vehicles can be broken into two categories; in dual fuel vehicles the engine uses two fuels simultaneously to run. In bi-fuel vehicles the engine can operate on one of the two fuels at any time.

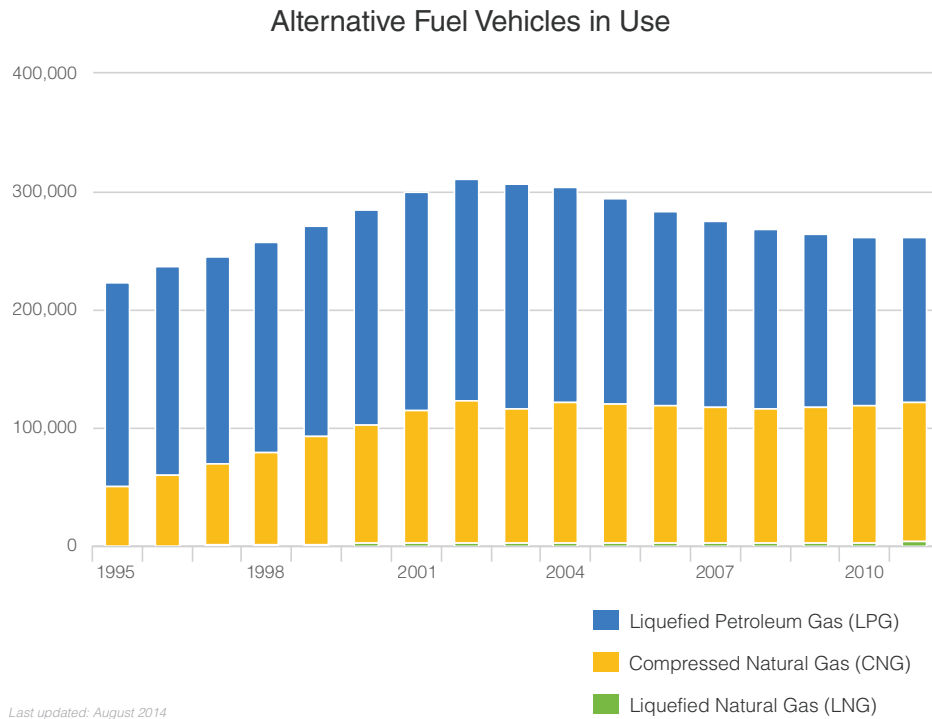
#### V. HAZARDS OVERVIEW

There are several specific hazards associated with gaseous fuel vehicles that emergency responders do not typically encounter with conventional vehicles. These include, but are not limited to, flammable gas, high pressure gas storage, and cryogenic liquids.

#### VI. VEHICLE STATISTICS

Current statistics indicate that some models of gaseous fueled vehicles are on the rise, particularly natural gas. Information on the use of gaseous fueled vehicles can be found at [www.afdc.energy.gov/data](http://www.afdc.energy.gov/data). In addition, NFPA provides information at [www.evsafetytraining.org](http://www.evsafetytraining.org)

Gaseous fuel vehicle usage data:



## VII. SECTION SUMMARY

Emergency responders should anticipate the increased use of gaseous fuel vehicles, especially natural gas, in the coming years. The key to safety and effectiveness is understanding the properties of the gas, storage and safety systems, and how they impact emergency operations involving CNG, LNG and LPG vehicles.



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# **SECTION II: GASEOUS FUEL PROPERTIES**

## **SECTION OBJECTIVES**

Following instruction, the student shall be able to describe the physical properties and hazards of:

1. Compressed Natural Gas (CNG)
  2. Liquefied Natural Gas (LNG)
  3. Liquefied Propane Gas (LPG)
-

## I. INTRODUCTION TO GASEOUS FUELS

The type of fuel and the storage state can impact an emergency response. Natural gas is stored on vehicles in both a compressed (CNG) and liquefied (LNG) state. Propane is only found in a liquefied (LPG) state.

## II. NATURAL GAS



The natural gas found on vehicles is the same that is delivered to homes and businesses. The physical properties of natural gas are:

- a. It is lighter than air and will rise upon release into the atmosphere.
- b. It has an auto ignition temperature of approximately 1,100 °F. In comparison, gasoline's auto ignition temperature is 536 °F and diesel's is 493 °F.
- c. The flammable range of natural gas is approximately 5% to 15% in air.
- d. The most likely ignition source will be an open flame or an electrical arc.

When stored in compressed state, pressures can reach up to 3,600 psi. The gas is odorized to aid in the detection of leaks. The primary hazards of CNG are flammability and high storage pressure.



To store natural gas in a liquefied state, it is cooled to  $-260^{\circ}\text{F}$  and has an approximate storage pressure of 120 psi. In this state, the primary hazards are cryogenic temperatures, the lack of odorant due its low storage temperature (additive freezes), and flammability upon conversion to a gaseous state.

The 600:1 gas from liquid expansion ratio makes it an effective form of storage. If released a cloud of vapor may be visible where the moisture in the air condenses from the low temperature of the gas. Although natural gas normally rises in air, it will sink if the gas temperature is below  $-150^{\circ}\text{F}$ . Gas at temperatures above that will rise.

### III. PROPANE



Propane (LPG) is found on vehicles in the same manner as typically encountered at a residence or business. The physical properties of propane are:

- a. Gas vapors are 1.5 times heavier than air and will sink into low areas and pool.
- b. It has an auto ignition temperature of approximately  $1,000^{\circ}\text{F}$ . In comparison, gasoline's auto ignition temperature is  $536^{\circ}\text{F}$  and diesel's is  $493^{\circ}\text{F}$ .
- c. The flammable range of propane is approximately 2% to 10% in air.
- d. The most likely ignition source will be an open flame or an electrical arc.



Propane, sometimes referred to as “Autogas.” The actual storage pressure is dependent on ambient temperatures. The primary hazards of propane include potential frostbite from liquid contact (-44 °F), pooling of heavier than air vapors, and flammability in its gaseous form.

Since propane will sink and pool in low areas, the potential for it to be found in its flammable range is more prevalent than natural gas. In addition, it should be considered a simple asphyxiant since it will displace the oxygen in that area as well.

Unlike LNG, LPG is odorized to aid in leak detection. The gas from liquid expansion ratio of LPG is 270:1. Additionally, it expands 1.5 times for every 10 °F rise in temperature.

#### IV. GASEOUS FUELS COMPARISON

Understanding the differences between the physical properties of CNG, LNG and LPG is critical and will assist in making educated decisions at an emergency scene.

	CNG	LNG	LPG
<b>Physical State</b>	Gas	Liquid	Liquid
<b>Storage Pressure</b>	3,600 psi	Approximately 120 psi	Approximately 150 psi. Actual pressure based on ambient temperature
<b>Flammable Range</b>	5% - 15%	5% - 15%	2% - 10%
<b>Auto Ignition Temp</b>	1,100 °F	1,100 °F	1,000 °F
<b>Vapor Density</b>	Lighter than Air	Lighter than Air	Heavier than Air
<b>Boiling Point</b>	N/A	-260 F	-44 F
<b>Liquefied</b>	N/A	By cooling to -260 °F	By Pressurization
<b>Odorized</b>	Yes	No	Yes
<b>Hazard</b>	Flammable Gas, High Pressure	Flammable Gas, Cryogenic	Flammable Gas

#### V. SECTION SUMMARY

Understanding the physical properties of natural gas and propane are critical to making educated decisions at an emergency incident involving gaseous fuel vehicles. The storage state also impacts the primary hazards that may be encountered by responders.

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# **SECTION III: VEHICLE SYSTEMS AND OPERATION**

## **SECTION OBJECTIVES**

Following instruction, the student shall be able to:

1. Describe the five different types of CNG cylinders responders may encounter
  2. Describe the construction of liquefied natural gas (LNG) tanks
  3. Describe the construction of liquefied propane gas (LPG) tanks
  4. Describe the function of the low voltage solenoid
  5. Identify the purpose of temperature activated relief devices
  6. Describe the safety systems that may be found CNG, LNG and LPG vehicles
-

## I. INTRODUCTION



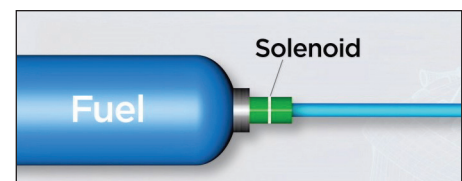
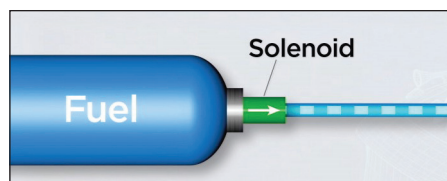
Emergency responders must be familiar with the basic storage, fuel distribution, and safety systems found on CNG, LNG and LPG vehicles. Knowing the potential locations for gas storage cylinders and tanks as well as the type of pressure relief devices is important during emergency operations. Additionally, understanding the safety devices installed on each system type better allows the responder to determine the potential hazards.

## II. GASEOUS VS CONVENTIONAL VEHICLES



Gaseous fuel vehicles have much more in common with traditional vehicles than electric or hydrogen fuel cell vehicles. Like a conventional vehicle, a fuel is used in an internal combustion engine to generate the power for propulsion. The primary difference is the fuel type and storage method.

A key design feature that is found in CNG, LNG and LPG vehicles is the use of a low voltage solenoid to control the flow of fuel from the cylinder or tank. The valve is opened when low voltage current is supplied to the solenoid and closes when it is removed. Although not common, in some instances the deployment of supplemental airbags will cause the solenoid to automatically close and shut the flow of fuel.



### III. COMPRESSED NATURAL GAS (CNG) VEHICLE SYSTEMS

#### CNG Storage

Compressed natural gas is stored on vehicles at pressures up to 3,600 psi. There are five types of cylinders that are typically found in use.

<b>Type I</b>	<ul style="list-style-type: none"> <li>All metal construction, generally steel, similar to industrial cylinders</li> </ul>
<b>Type II</b>	<ul style="list-style-type: none"> <li>Mostly steel or aluminum with a fiber-reinforced polymer overwrap</li> <li>Wrap can be glass, carbon or basalt fiber</li> <li>Metal vessel and wound composite materials share about an equal structural load</li> </ul>
<b>Type III</b>	<ul style="list-style-type: none"> <li>Metal liner, typically aluminum, with full carbon fiber composite overwrap</li> <li>Composite materials carry the structural load</li> </ul>
<b>Type IV</b>	<ul style="list-style-type: none"> <li>No metal is used in construction</li> <li>A thermoplastic polymer liner is overwrapped with carbon fiber or hybrid carbon/glass composite filaments</li> <li>The structural load is carried by the composite overwrap</li> </ul>
<b>Type V</b>	<ul style="list-style-type: none"> <li>All composite construction</li> <li>Carbon fiber or hybrid carbon/glass fiber is wound over a collapsible mandrel used to provide shape.</li> <li>Composite material carries all the structural load</li> </ul>

Type I and II cylinders are heavier due to the incorporation of metal in their design. Type III, IV and V cylinders weigh less and are more attractive in applications where weight is an issue. They have an overwrap that is a low conductor of heat, resulting in a nominal rise in content pressure when exposed to heat/fire. This wrap typically ignites at 650 °F. These are two important concepts to consider when discussing the differing types of pressure relief devices and safety systems used on these cylinders.



CNG cylinders are designed to be very rigid and absorb impact energy. They are significantly stronger than gasoline or diesel tanks. However, carbon fiber and other composite materials used as overwrapping can be degraded by sunlight and are typically shielded, or placed in an area out of direct sunlight.

All cylinders exposed to a heat source or fire must be inspected before being placed back into service. This is especially the case with cylinders that incorporate composite materials in their design, as they do not regain their strength after cooling.

The mounting locations of CNG cylinders vary depending on the size and type of vehicle:



- On passenger cars and light duty vehicles, they are usually mounted in the trunk or where the gasoline/diesel tank would normally be located. They can also be found mounted in the bed of pickup trucks.



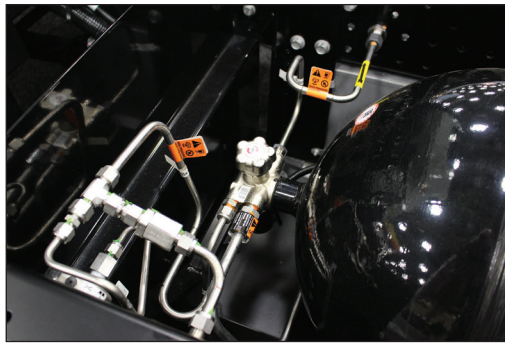
- On medium/heavy duty vehicles they are generally mounted on the frame rails or behind the cab. They can also be mounted horizontally on the roof of refuse trucks.



- On transit buses they are typically located on the roof. Light duty and passenger vehicles can incorporate any of the five (5) types of cylinder designs. Heavy/Medium duty trucks and buses will typically use Type III, IV and V cylinders due to their lighter weights.

### CNG Distribution

The fuel is distributed from the cylinder(s) to the engine compartment via stainless steel gas lines and in some instances, flexible hose. These fuel lines are typically not found in standard extrication cut points.



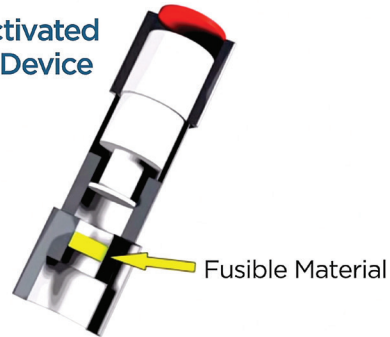
When multiple cylinders are present, they are connected via a manifold for supply and refueling purposes. On each cylinder there is typically a manual valve. This valve is typically used for service work and may not be easily accessible to first responders for use in an emergency.

### CNG Safety Systems

CNG cylinders are equipped with pressure relief devices to prevent containment failure in the event the cylinder is exposed to fire or high heat. Since composite cylinders will experience very little pressure increase when exposed to a fire, they are equipped with temperature activated pressure relief device(s) (TPRD) instead of reseatable pressure relief devices

(PRDs). The TPRDs are designed to relieve the cylinder pressure before the structural overwrap can fail due to the heat of a fire.

**Temperature Activated  
Pressure Relief Device  
TPRD**



There may be one or more TPRDs mounted on each cylinder which will activate between 220 °F and 240 °F. Unlike traditional relief devices, they do not reset as the pressure reduces, and the entire contents of the cylinder are vented. There is no standardized vent location or direction, and each cylinder may vent individually or through a manifold to a single location. Some light duty vehicles may also have a pressure activated rupture disk.

In some light duty vehicles, a crash or air bag deployment may shut the solenoid and stop the flow of fuel from the cylinder(s). In medium and heavy duty trucks and buses there may be a ¼ turn manual shut off valve.

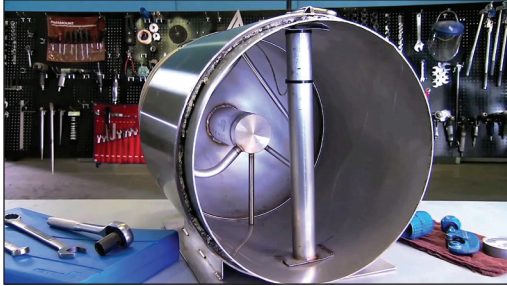
On transit buses, a fire suppression system will be found in the engine compartment which will discharge dry chemical into the compartment in the event of a fire. Although not required, they may also be equipped with gas detection systems that will sound an alarm to alert the driver to stop and evacuate the vehicle.



## IV. LIQUIFIED NATURAL GAS (LNG) VEHICLE SYSTEMS

LNG is most commonly used in medium and heavy duty vehicles, although it may be used for other applications.

### LNG Storage



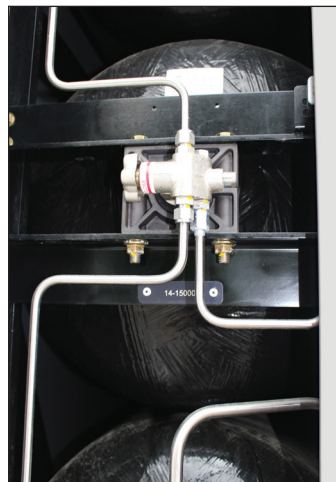
LNG is contained in a double walled stainless steel tank with a super insulated vacuum space, similar in nature to a Dewar flask with the inner tank acting as the pressure vessel. It is designed to maintain LNG at  $-270^{\circ}\text{F}$  for 7 to 10 days. The construction makes the tank very strong and resistant to damage from external sources.



LNG tanks are roughly the size of a diesel saddle tank and can be found mounted on frame rails, or in some instances behind the cab. When multiple tanks are present, they are connected via a manifold for supply and refueling purposes.

### LNG Distribution

Stainless steel lines are used to distribute the natural gas and may contain a liquid or gas, depending on their location within the system. LNG is routed through a vaporizer warming it to ambient temperature, resulting in a phase change from a liquid to a gas. Pressure relief valves can be found in the sections carrying natural gas in both its liquid and gaseous state. When multiple tanks are present, they are connected via a manifold for supply and refueling purposes. Fuel lines are typically not found in standard extrication cut points.



## LNG Safety Systems



Unlike CNG cylinders, LNG tanks use spring activated reseating pressure relief devices (PRDs) that can operate multiple times as necessary. The PRDs are piped away from the tank, typically vertically. There are two separate relief devices incorporated into the system. The first PRD activates at approximately 225 psi; the second PRD activates at approximately 350 psi. Both reset once the pressure drops to approximately 210 psi. Each release is typically one diesel gallon equivalent.

Since LNG cannot be odorized, combustible gas detection sensors are installed in the vehicle. The initial alarm is activated between 20% – 30% of the LEL and an additional visual and audible alarms will activate at 50% to 60% of the LEL.



## V. LIQUIFIED PROPANE GAS (LPG) VEHICLE SYSTEMS

LPG fuel systems are most commonly found on light and medium duty vehicles. In some applications, they can also be found on heavy duty vehicles.

### LPG Storage

Generally, the maximum service pressures for LPG tanks is 250 psi and 315 psi. Typical storage pressure is approximately 150 psi, depending on ambient temperatures. In some applications a Siamese, two tanks connected together, may be used.

LPG tank mounting locations are generally based on the vehicle type and application. In light duty vehicles they are located in the trunk, the pickup bed, or in the standard fuel tank location under the vehicle. In medium and heavy duty vehicles they are mounted on the inside or outside of the frame rails. Since propane is heavier than air, tanks are not mounted on the roof.



### LPG Distribution

Propane, both in its liquid and gaseous state, is piped through fuel lines. The lines can contain moderate to low pressure liquid or gas, depending on its location within the vehicle. Different system designs allow for the use of propane in its liquid or gaseous state in the engine cylinders.

## LPG Safety Systems



LPG systems utilize a standard spring operated pressure relief device which is typically set to operate between 250 and 315 psi, depending on the tank. This PRD resets once a safe operating pressure has been reached.

### VI. SECTION SUMMARY

A solid understanding of gaseous fuel vehicle systems, including fuel storage, distribution, and safety devices allow for more effective decision-making and ensures safe practices at an emergency scene involving these vehicles.

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# **SECTION IV: FUELING STATIONS**

## **OBJECTIVES**

Following instruction, the student shall be able to:

1. Describe the differences between fast and time-fill CNG stations
  2. Identify the fuel storage pressures for CNG, LNG and LPG fueling facilities
  3. List four (4) safety systems encountered at a gaseous fueling facility
-

## I. INTRODUCTION

As the push continues to move away from gasoline and diesel fuel, especially in fleet applications, there will be a greater need for facilities to refuel these vehicles. As a result, there will be private and public fueling locations and the addition of gaseous fuels to existing stations. The preplanning of facilities in your response area should be a priority.

## II. COMPRESSED NATURAL GAS FUELING STATIONS



CNG stations can fall into one of two categories, time and fast fill. Time-fill stations are designed to take natural gas from the existing infrastructure and compress it into the vehicle's storage cylinder(s). The fill time is measured in hours, typically overnight. These stations can typically be found in fleet applications such as trash or delivery trucks, and in small residential home fueling appliances. There is typically no large volume fuel storage on site unless it is combined with a fast fill station.



Fast fill stations may use natural gas from the existing infrastructure or it may be shipped in. The gas is stored in steel (most common) or composite cylinders at pressures up to 5,000 psi. Fill times are measured in minutes, and depending on the number of cylinders the vehicle has, it can be similar to filling a conventionally fueled vehicle.

The number and size of cylinders depends on the needs of the facility. Steel cylinders will have standard pressure relief devices; composite cylinders will have both standard and temperature pressure relief devices.

### III. LIQUIFIED NATURAL GAS FUELING STATIONS



LNG facilities utilize a fast fill system and refuel vehicles in a matter of minutes. The LNG is typically shipped in and stored onsite in double walled tanks with a super insulated vacuum space to maintain cryogenic storage temperatures. The site has a typical storage volume of 15,000 to 30,000+ gallons depending on the needs of the facility. Storage tanks are pressurized to 20-40 psi.

LCNG (Liquefied/Compressed Natural Gas) facilities have the ability to fill both LNG and CNG vehicles. The LNG is converted back to a gas by sending it through a vaporizer for warming. The gas is then compressed into CNG and stored for later use. While odorant should be added during the conversion process, it is not always done.

### IV. LIQUIFIED PROPANE GAS FUELING STATIONS



LPG filling stations also use a fast fill system and refuel the vehicles in a matter of minutes. Storage tanks are of a single wall steel construction and their capacity can range in size, depending on the volume that the station handles. Storage pressures are approximately 150 psi, depending on ambient temperatures. The liquid LPG is pumped into the vehicle



In addition to the standard safety systems, LNG facilities are required to have gas detection capabilities, since LNG is not odorized. Upon their activation, the flow of fuel stops and electrical sources are isolated. There is also a berm around the storage tank to contain any liquid spills.

Some stations may have systems in place to stop the flow of fuel in the event it becomes dislodged in a collision. These are not required in single fuel stations but must exist in multi-fuel stations.

## VI. SECTION SUMMARY

Gaseous fuel refilling stations are becoming more popular as the demand increases. Emergency response personnel need to familiarize themselves with those facilities that are in their area. To conduct a search of fueling stations in your area go to <http://www.afdc.energy.gov/locator/stations/>. Since there is a potential for some private stations not to be listed on this site, check with your local building officials to determine if any additional facilities have been installed or are pending application approval.



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# **SECTION V: INITIAL RESPONSE PROCEDURES**

## **SECTION OBJECTIVES**

Following instruction, the student shall be able to:

1. Describe the size-up procedures and scene hazards of an incident involving gaseous fuel vehicles
  2. Positively identify a gaseous fuel vehicle using visual clues and NFPA *Alternative Fuel Vehicle Emergency Field Guide (EFG)*
  3. Identify and describe proper immobilization techniques
  4. Identify vehicle disabling methods and techniques
-

## I. INTRODUCTION

Responses to any type of incident involving a vehicle, especially those running on an alternative fuel, should follow the *Identify, Immobilize, Disable (IID)* process. First the vehicle must be properly identified by looking for labels and badging, or design features unique to that particular vehicle. Next, the vehicle must be immobilized to prevent accidental movement while emergency responders are interacting with it. Finally, it must be disabled. Proper shutdown procedures must be followed to ensure the vehicle is in a safe state to operate around.

## II. INTIAL RESPONSE PROCEDURES



Initial actions are similar to those used in incidents involving conventional vehicles. As always, scene safety is of the utmost importance at any emergency response. Ensure that there is a safe working environment for response personnel by using the proper PPE, high visibility clothing, proper apparatus placement, and traffic devices.

The first step in this process is to conduct a thorough scene size-up. While conducting a survey of the scene, always attempt to identify the type of vehicle(s) involved. If unsure and the driver is responsive, ask for additional information. Also, identify the presence and location of vehicle occupant protection systems (airbag, pre-tensioner, etc.) and determine the appropriate course of action.

Upon arrival conduct a 360 degree review of the scene. Common hazards that can be readily identified as being a concern at any incident are:

- Traffic
- Downed power lines
- Fuel spills or other HAZMAT
- Environmental hazards (ice, flooding, extreme temperatures, etc.)
- Fire
- Unstable vehicles

There are several specific hazards associated with gaseous fuel vehicles that emergency responders do not typically encounter with conventional vehicles. These include, but are not limited to, flammable gas, high-pressure gas storage, and cryogenic liquids.



The initial response actions at an incident involving gaseous or any other type of vehicle involves the *identify, immobilize, disable* (IID) process.

### III. IDENTIFY THE VEHICLE

The first step in the IID process is *Identify*.

It can often be difficult to identify gaseous fuel vehicles from a distance. Always assume that all vehicles are alternatively fueled (AFVs) until positive confirmation of the vehicle type can be made. To ensure safety, emergency responders should approach the vehicle at a 45 degree angle.

There are several resources that can be utilized to appropriately identify the vehicle:

#### Driver



The driver may be the best resource in determining the vehicle type. Consider that commercial/transit drivers may have received additional training on the vehicle.

## Badging and labeling

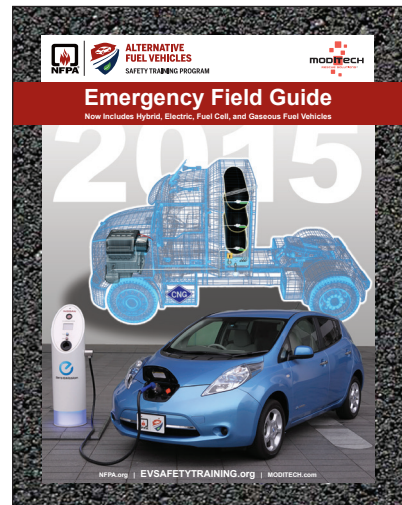


Badging and labeling is another means of identification and can be helpful when approaching the vehicle. Labels that visually indicate a vehicle runs on CNG, LNG or LPG are the most helpful. There may be other labels advertising that a vehicle is alternatively fueled such as references to “green” or “environmentally friendly” fuels. Although labels and badging can be an excellent indicator of the presence of a gaseous fuel vehicle, damage to a vehicle from a crash or fire can hide or destroy those markings. Also, although not required, there may be labels or other indicators on the dash.

## Design features

The identification of design features, systems, and components that indicate a vehicle is not conventionally powered are also helpful. The features of CNG, LNG and LPG vehicles respectfully will be addressed.

**NFPA *Alternative Fuel Vehicle Emergency Field Guide*** is another helpful resource that can aid in the identification process.



## Identification – CNG Vehicles

CNG vehicles can range from passenger cars to over the road trucks. They are required to have a label on the right rear of the vehicle/cab and may also be found at the fueling port. This label is a blue diamond shape with the letters “CNG” in white lettering. Although not required, there may be other types of labels indicating the vehicle operates on CNG.



CNG cylinders can be found on the vehicle in a variety of locations.

Light duty vehicles are typically standard production models that have been upfitted with gaseous fuel components. Cylinders in cars are generally found in the trunk space and are not visible from the exterior. They may, however, be visible in the bed of pickup trucks.



On medium and heavy-duty trucks the most prominent design features are the cylinder and cylinder cabinets. Cylinders are typically mounted on the frame rails or horizontally behind the cab area. Most often they will be found in protective covering to prevent exposure to sunlight.

Buses and refuse trucks may have a raised roofline concealing the cylinders.

## Identification – LNG Vehicles



LNG is generally used to fuel larger vehicles such as over-the-road and refuse trucks. They are required to have a label on the right rear of the vehicle/cab and at the fueling port. This will be a blue diamond shaped label with the letters “LNG” in white lettering. Although not required, there may be other types of labels indicating the vehicle operates on LNG.



The stainless steel tanks are typically mounted along the frame rail in the same vicinity where a diesel saddle tank would normally be located. Although less common, tanks may also be mounted behind the cab.



There may also be indicators found in the cab that will identify the vehicle as running on LNG, including gas detection displays or indicators. The gas alarm indicators, in some instances, will also be located on the outside of the cab near the driver's door as well.

## Identification – LPG Vehicles



LPG is typically limited to passenger and medium duty vehicles such as school buses and delivery trucks, but there are some heavy duty applications in use with municipal trucks. They are required to have a label on the right rear of the vehicle/cab consisting of a black diamond shaped label with the word “PROPANE” in white lettering. Although not required, there may be other types of labels indicating the vehicle operates on LPG.

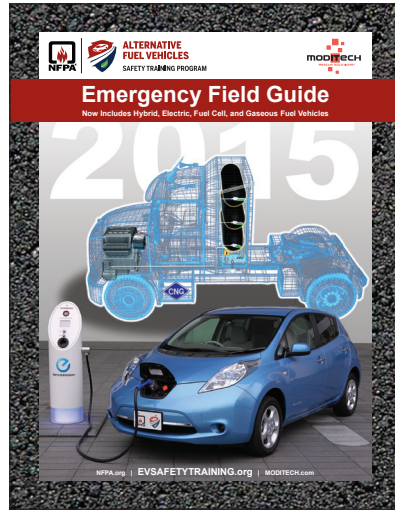


In passenger cars, design features such as LPG tanks may not be visible from the exterior of the vehicle. The tanks in cars are generally found in the trunk space which prevents using the design feature for identification. They may also be found under the vehicle in the vicinity of where the gas tank would be located. Typically these are standard production model vehicles that have been upfitted with gaseous fuel components.



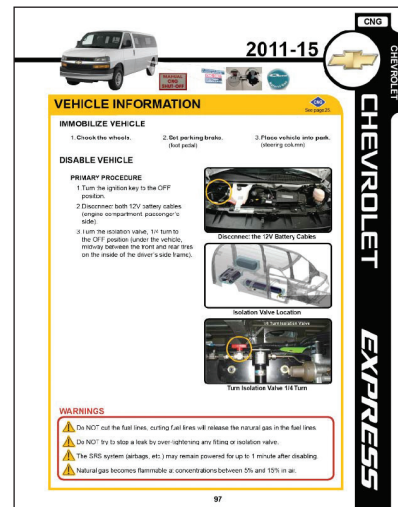
Tanks on pickup trucks may be visible in the bed. On medium/heavy trucks and school buses they are typically mounted on the inside or outside of the frame rails. In some instances though, it is possible to find tanks mounted behind the cab in medium and heavy-duty truck applications.

## NFPA Alternative Fuel Vehicle Emergency Field Guide (EFG)



The *NFPA Emergency Field Guide* can aid in identification of gaseous fuel vehicles. It is a consolidated quick reference guide for AFVs compiled from manufacturer data. It contains the most critical response information in model-specific guides as well as general guidance pages. The simple to use guide addresses the following:

- Identification
- Shutdown procedures
- Danger areas
- System diagrams
- Firefighting practices
- Submersion procedures



### Identification summary

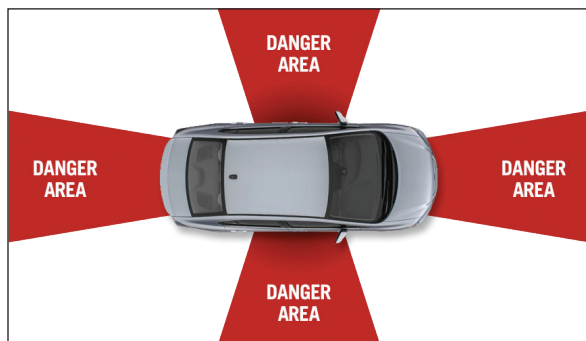
Use all available information to determine if a vehicle operates on a gaseous fuel. If indicators are not immediately visible, take the time to determine whether the vehicle uses CNG, LNG or LPG fuel. In the absence of a visible label or badge, for example, where extensive damage occurs in areas that badging would normally be found, continue to look for additional clues. Regardless of vehicle type, fire or crash damage may

obscure identification so extra caution must be used when approaching a scene.

#### IV. IMMOBILIZE THE VEHICLE

The second step in the Initial Response Actions: *Immobilize*

Since it can be difficult to identify a gaseous fuel vehicle from a distance, especially a light duty one, first responders should approach all vehicles as if they were some type of AFV until positive identification can be made.



The 45° approach angle should be used for all vehicles. In terms of protection from AFVs, it allows responders to avoid two potential concerns. First, with the potential silent movement issue with HEVs and EVs the vehicle's travel paths are avoided. Secondly, with gaseous fuel vehicles, it provides a level of safety from potential venting and failure of onboard fuel cylinders and tanks.

When approaching vehicle fires, it may be impossible to fully identify its fuel type, so extra precautions should be taken. If the vehicle is identified as being powered by CNG, maintain a safe distance and do not attempt to immobilize or disable it. Proper handling of vehicle fires is addressed in the firefighting portion of the program.

This process of preventing movement is essentially the same as with conventional vehicles and needs to occur at every incident whether or not the vehicle is an AFV. It consists of the following steps:

- Chock wheels with appropriately sized wheel chocks.



- Engage the parking/emergency brake, which may be a hand or foot brake, a low voltage controlled brake, or a spring break, depending on the type of vehicle.
- Place the vehicle into park or neutral, depending on transmission and vehicle design.

## V. DISABLING THE VEHICLE

The final step in the Initial Response Actions: *Disable*

This procedure should occur at any crash and before an emergency responder interacts with the vehicle. It is typically done in the same manner as conventional vehicles. Confirm procedures with the NFPA EFG or the manufacturer's ERG.



The disabling procedures consist of two steps; turn the vehicle's ignition off and disconnect the low voltage battery. Turning the ignition off stops the engine and closes the fuel solenoid, stopping the flow of fuel. Disconnecting the battery disables supplemental restraint systems (SRS) and prevents the vehicle from being accidentally restarted.



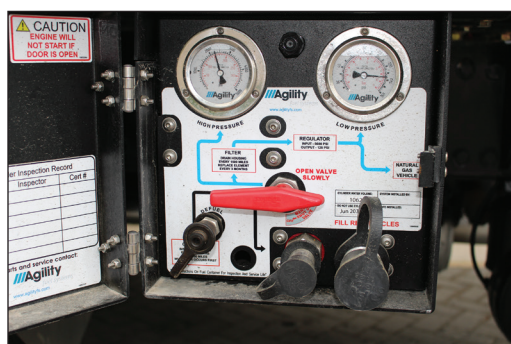
In some instances, the vehicle may be equipped with a proximity key, although this is not typical on trucks and buses. If equipped with this type of key, remove it from the vehicle and keep it at least 16' away. The ignition

system is disabled when low voltage power is removed, so if the key cannot be found it is rendered inactive once the battery is disconnected.



The 12v battery may be located under the hood, in the trunk, in other more obscure locations such as under seats or in a wheel well. 24v batteries can be found in trucks and buses and may have a battery switch to disconnect the batteries from the low voltage system. If a switch is not present and you need to cut the negative cable, be sure to cut the one going to the chassis ground, not the one connecting the two batteries.

### Controlling Fuel Flow



Turning off the vehicle's ignition closes the low voltage solenoid on the fuel system and shuts down the flow of fuel. If equipped, using the vehicle's  $\frac{1}{4}$  valve will also ensure that fuel is shut down from the system. Remember that the tanks/cylinders are still pressurized even if the flow of fuel has been controlled. This also is the case after PRDs and TPRDs have activated. Not all of the cylinders or tanks may have vented.

## VI. SECTION SUMMARY

The *identify, immobilize, disable* process should be used at all incidents involving vehicles to identify the presence of an AFV, ensure that it is appropriately secured from movement, and properly disabled. Be sure to use all of the methods outlined in this section to attempt to properly identify a gaseous fuel vehicle.

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# **SECTION VI: EMERGENCY OPERATIONS**

## **SECTION OBJECTIVES**

Following instruction, the student shall be able to:

1. Identify and describe four (4) emergency response concerns specific to gaseous fuel vehicles.
  2. Determine the appropriate actions for extinguishing fires in LNG and LPG vehicles.
  3. Identify the primary concern of CNG vehicle fires and describe the appropriate technique for mitigation of the fire.
  4. Identify and describe the proper procedures for handling incidents at CNG, LNG and LPG fueling stations.
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## I. INTRODUCTION

With both vehicles and filling stations, the emergency procedures identified for spills and fires can vary between the types of fuels involved. Storage pressures, physical properties of the fuel, and cylinder/tank construction can all impact recommended emergency response procedures.

## II. EMERGENCY RESPONSE PROCEDURES



When responding to any type of incident involving gaseous fuels, department SOPs should be followed. Approach all alternative fuel vehicles at a 45° angle for safety. All members should don appropriate PPE for the incident. The use of combustible gas indicators (meters) is critical when operating at an incident involving gaseous fuels.

Always treat cylinders/tanks as being pressurized, even if there is evidence that the PRD or TPRD has been activated. Not all of the cylinders/tanks may have been vented, or the PRD may have reset following an adequate release of product to reduce the pressure to a safe level.

Additional items to consider:

- Control all ignition sources such as flame or electrical arcing.
- If there is damage in the immediate area of the cylinder/tank operate under the assumption that the cylinder/tank is damaged as well.
- Unlike gas leaks in a structure, which has an essentially unlimited supply of fuel, the extent of the release in a vehicle is dependent upon the size of the cylinders/tanks and is therefore limited.
- Always notify tow operators arriving on scene of the type of vehicle that they will be transporting so they can take appropriate precautions.

### III. CRASHES AND EXTRICATIONS



Extrication operations generally remain the same as a conventional vehicle. Gaseous fuel components are not typically found in standard cut point areas. As always, expose the area prior to cutting operations to ensure there are no potential obstacles to the operation.

Standard stabilization methods are acceptable for use on gaseous fuel vehicles, however, be sure not to place stabilizing equipment against cylinders/tanks or fuel lines. Also, a hoseline staffed by firefighters in full PPE should be deployed for safety purposes.

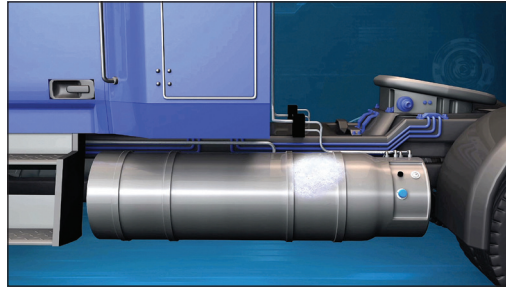
#### **CNG vehicle crash**

There are some specific considerations for CNG vehicles in crash/extrication type incidents. Roof mounted cylinders, such as those found on transit buses, may slightly alter the vehicle's center of gravity and should be considered during stabilization operations.

Other considerations include:

- Cylinders are designed to maintain structural integrity following significant impacts.
- Always be aware, that physical damage could result in containment failure and the release of a gas stored at 3,600 psi.
- Damaged fuel lines can also result in a gas release, typically at a lower pressure.
- Because natural gas rises, the flammable range is typically not found away from release point unless the vehicle is in an enclosed space and the gas can collect.

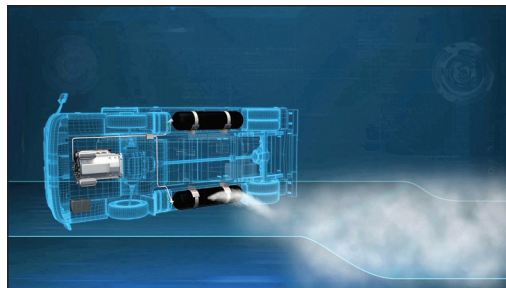
### LNG vehicle crash



LNG tanks are very strong due to the double wall construction and will resist puncturing. If frost appears on a damaged tank, there may be an actual leak or it may just be frost forming from moisture in the air contacting the inner wall of the tank. This can occur if the outer wall is breached. Even if the tank gauge reads zero, there may still be liquid present in the tank.

Typically, LNG will not leave the tank in a liquid state because it vaporizes so quickly. It will exit as a gas and rise in air. In the event of a leak, gas detection systems should activate and alarm, however, they will be disabled after low voltage current is shut down during the disabling process. If a spill were to occur firefighting PPE will provide limited splash protection from exposure to cryogenic LNG.

### LPG vehicle crash



Significant damage to a LPG cylinder can result in a release. It is important to control ignition sources as leaking propane gas will collect in low areas and may reach concentrations within its flammable range. In some cases, it is possible to disperse the vapors with hose line.

## IV. VEHICLE FIRES



Responders should initially attempt to identify the type of fuel and if the cylinder or tank is involved, as this will dictate the appropriate tactics. Depending on the extent of the fire, however, it may be difficult or impossible to make an accurate identification prior to the start of extinguishment operations. Also, when dealing with a gaseous fuel vehicle it should always be assumed cylinders are pressurized. Responders should also be aware that CNG vehicles may require special tactics, depending on the extent of the fire involvement.



Upon arrival, firefighting personnel should conduct a scene size-up and establish a perimeter as soon as possible. If safe to do so, the vehicle should be immediately chocked to prevent accidental movement. Next, determine if the cylinder or tank is directly involved in, or being impinged by fire. This will dictate the appropriate strategy and tactics. Never attempt to extinguish a fire fueled by an active gas leak unless the flow of the gas can be shut down. Protect surrounding exposures until the fuel supply is exhausted.

Small fires that are not near a fuel cylinder or tank should be handled the same as a typical vehicle fire. However, keep in mind the properties

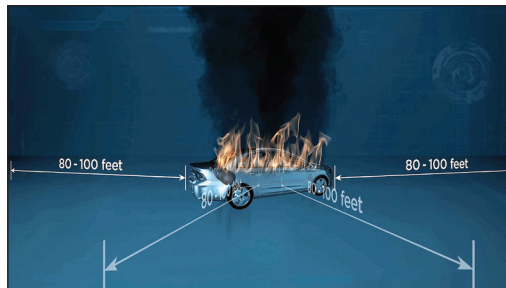
and the storage methods of the fuel while operating around it. Changing conditions may require a change in tactics, especially in CNG vehicles.



Post fire it is recommended to contact the fleet service personnel or manufacturer for information on vehicle inspection, storage and disposal. Always assume the cylinders or tanks are under pressure. Be sure to advise tow operators about the type of gaseous fuel system onboard so trained personnel can take the appropriate steps to prepare it for storage or disposal.

### **CNG vehicle fires**

If the fire in the CNG vehicle is small, and remote enough from the cylinder location that there is no potential for flame or heat impingement, then extinguish it normally. Be aware, however, that fire exposure may not always be apparent. At no time should water be applied directly to the cylinders as it can prevent the TPRDs from functioning properly.



In the case of more significant fire, or if the cylinders are already involved, do not approach the vehicle. Establish a safe perimeter of at least 80 to 100 feet and allow it to burn while protecting any exposures. Any attempts to extinguish the fire, especially if water is applied to the cylinders, may

prevent the temperature activated relief device from working properly and could result in catastrophic container failure.



Also, once activated, it may take 10-15 minutes for the high-pressure release to subside and up to 30 minutes to fully discharge, depending on the size of the tanks involved. In the majority of cases the gas is ignited and causes a high velocity jet fire. The jet fire may blow itself out and reignite more than once during the event.

### **LNG vehicle fires**



LNG vehicle fires can be extinguished using standard tactics unless fire is being fueled by an active leak. In that case, protect exposures and allow it to burn. Typically, the tanks are so well insulated that even if the vehicle becomes fully involved, there will likely be very little pressure increase inside the tank. If there is an increase, the pressure relief device will activate and bleed off the excess pressure, resetting itself when complete. Application of water to the tanks will not prevent the PRDs from working properly.

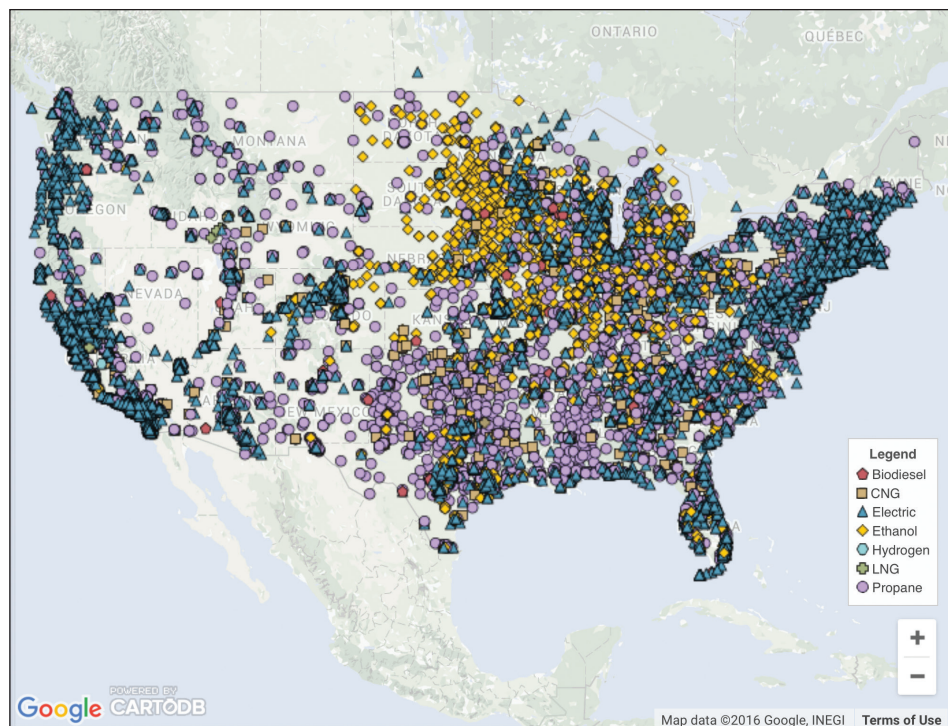
## LPG Vehicles



Fires involving LPG vehicles can be extinguished using standard LPG and vehicle firefighting techniques. In the event of fire impingement on the tanks, be sure to apply copious amounts of water to keep them cool. If tanks are not kept cool there is a potential for a Boiling Liquid Expanding Vapor Explosion (BLEVE). It may also occur if the PRD is unable to maintain a safe pressure. If a sufficient water supply is not available, evacuate to a safe distance and allow the fire to burn while protecting exposures.

## V. FUELING STATION INCIDENTS

Emergency responders must prepare for an incident at fueling stations prior to one occurring. Fire departments should conduct preplanning visits to determine the layout of the facility, the types of fuels present, including conventional ones, and any specific safety measures in place.



To aid in the identification of alternative fuel facilities, the US Department of Energy (DOE) has a database of alternative fuel stations on their website. It is searchable and can be used to determine what facilities are in the response area and includes contact information. The web address is <http://www.afdc.energy.gov/locator/stations/>

### Incident Size up

Upon arrival at an incident at a fueling station perform a scene size-up while securing the area from unauthorized personnel. Look for DOT placards, NFPA 704 symbols and other signage which can assist in the identification of the fuels and hazards involved. Also, contact should be made with facility personnel as soon as possible to determine the potential type and scope of the incident. Full PPE and SCBA should be worn during all investigations or responses due to the nature of gaseous fuels.



The control of hazards should be a priority. This can be accomplished by activating the emergency shut down devices (ESD) or attempting to stop any leaks from a remote valve or control. Attempts to control ignition sources should be made as well.

### Fires

Allow fires to burn if fed by an active leak. Extinguishing the fire prior to controlling the leak is not advised as it will potentially lead to a spread of the leaking product. Hose streams should initially be used to protect potential exposures. The actual container construction will dictate if water can be used to cool it. It is not advisable to use water on some types of cylinders.

### CNG Fueling Stations

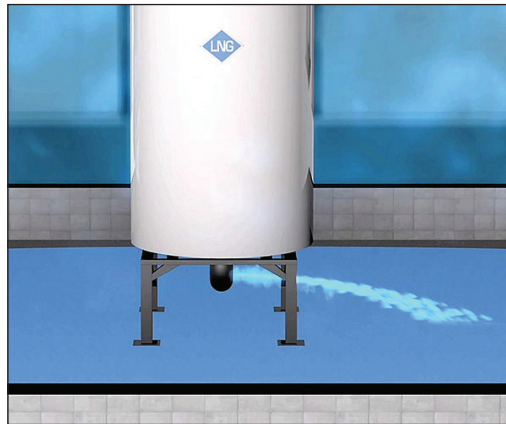
Leaking gas will be highly audible due to the high storage pressures of up to 5,000 psi. Leaks will typically be from a small diameter pipe fitting rather than the cylinder itself, and can most likely be stopped by activating

the ESD and shutting the flow of fuel. Due to its physical properties any leaking natural gas will rise and dissipate. If the release from the TPRD is ignited, it will create a jet fire due to the high-pressure release. In that event, establish at least a 100' perimeter and protect exposures.



In the event of a fire, use water to extinguish impinging fires and to cool any steel storage cylinders. *DO NOT* use water on composite cylinders because of the potential for TPRDs to fail to activate. If the TPRD activates, the bleed down time may take significantly longer than vehicles. Composite cylinders are not commonly found in fixed facility locations where the weight of the cylinder is not an issue. They are predominantly found in vehicles where the light cylinders result in increased fuel economy.

### LNG Fueling Stations



Small leaks from LNG tanks are likely to be in gaseous state due to the speed of the phase change from a liquid. Large leaks may start off as a liquid and will be contained by the berm. In the event of a release of liquid, keep in mind that LNG is a cryogenic causing freeze injuries to bare skin upon contact. Firefighting PPE and SCBA will provide some level

of protection against splash hazards and should be worn when operating near a release. LNG stations will have gas leak detection because it is not odorized, but personnel should still use combustible gas meters during any investigation. LCNG stations should be handled in a manner commensurate with both CNG and LNG recommendations. Keep in mind that there is likely non-odorized gas present.

The application of water is recommended for fires impinging on storage tanks as well as on the tanks to cool them. When cooling the tanks, do not apply water onto any leaked LNG because it will warm the LNG, speeding the release of natural gas.

### **LPG Fueling Stations**

Any propane leaks will pool into low areas and into any containment areas. Be sure to control potential ignition sources and activate the ESD to prevent the flow of fuel from the tank itself.

In the event of fire, extinguish fires impinging on the tank(s) and cool the tanks directly with water. Use at least 500 gpm or more depending on the size and number of tanks. If the duration and frequency of the relief valve activation increases, then it may not be able to adequately relieve pressure.

## **SECTION ACTIVITY 6.1 EMERGENCY OPERATIONS**

### **Directions to the Students:**

You are going to be shown a series of three videos, each showing a realistic scenario. You will be given a few moments to do a scene size-up and determine the answers to the following questions:

1. What are the hazards present?
2. What are your initial response actions?
3. What steps would you take to fully mitigate the situation?

Because it is often difficult to identify alternative fueled vehicles from a distance, approach all vehicles as if they are AFVs until positive identification can be made.

### Scenario 1

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A CNG-powered city bus is travelling down a city street. The driver pulled over when a fire was discovered in a rear wheel well of the bus. The bus stopped on the right shoulder of the street. All passengers were able to exit the bus. There are building exposures on the right side of the bus. The fire intensified and broke out the windows, eventually exposing the CNG cylinders on the roof.



#### Dispatch: Reported city bus fire

- Busy downtown street
- 4:00 pm on a Tuesday

#### On Arrival

- A CNG-powered transit bus with fire showing from the passenger compartment
- All passengers have exited the bus
- There are building exposures on the right side of the vehicle
- Flames are exposing the CNG cylinders on the roof
- Traffic is still driving by

#### Recommended Responses

- What are the hazards present?

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- What are your initial response actions?

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- What steps would you take to fully mitigate the situation?

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### Scenario 2

**An LNG-powered tractor-trailer is parked in a fenced-in truck yard with several other tractor-trailers. A passerby called 911 reporting a gas leak at the facility. There is an audible hissing noise intermittently coming from one of the trucks.**



**Dispatch:** A caller reports the sound of a gas leak at a local trucking company.

- 10:00 am on a Sunday
- Vehicle is a Peterbilt LNG tractor
- Vehicle is unoccupied, business appears closed

**On Arrival**

- Intermittent escaping gas cloud is seen from a vent on one truck
- Business is closed
- Area is fenced in and the gate is locked

**Recommended Responses**

- What are your initial response actions?

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- What are the hazards present?

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- What steps would you take to fully mitigate the situation?

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### Scenario 3

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A bi-fuel F-150 pickup truck is traveling down a wet road under rainy conditions with light traffic. There is a white propane tank visible toward the front of the bed, underneath a toolbox. The vehicle loses control on a wet road and strikes a tree on the passenger side, just behind the cab. There are two occupants in the vehicle. The driver is conscious and alert, and the passenger is unconscious and requires extrication.



**Dispatch:** Single vehicle accident, pickup truck versus a tree

- 3:00 pm, just after a rain shower
- Vehicle is a Ford F-150 bi-fuel pickup (gasoline and LPG)
- Two occupants in the vehicle

#### **On Arrival**

- Vehicle impacted a tree on the passenger side, just behind the cab
- The driver is conscious and alert
- The passenger is unconscious, but breathing
- Both occupants are wearing seatbelts

#### **Recommended Responses**

- What are your initial response actions?
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- What are the hazards present?

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- What steps would you take to fully mitigate the situation?

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# **SECTION VII: PROGRAM REVIEW**

## I. INTRODUCTION TO GASEOUS FUEL VEHICLES

Emergency responders should anticipate the increased use of gaseous fuel vehicles, especially natural gas, in the coming years. Gaseous fuel vehicles can run on a single fuel type or a combination of traditional and gaseous fuels. The key to safety and effectiveness is to understand the properties of the gas, storage and safety systems and how it impacts emergency operations involving CNG, LNG and LPG vehicles.

## II. GASEOUS FUELS PROPERTIES

Understanding the physical properties of natural gas and propane are critical to making educated decisions at an emergency incident involving gaseous fuel vehicles. The state that it is stored in also impacts the primary hazards responders may encounter. For example, natural gas will rise and dissipate while propane will sink and collect.

## III. VEHICLE SYSTEMS AND OPERATION

A solid understanding of gaseous fuel vehicle systems, including fuel storage, distribution and safety devices allow for more effective decision-making and ensures safe practices at an emergency scene involving these vehicles. This is especially the case when firefighting operations involve composite CNG cylinders and temperature activated pressure relief devices, since TPRDs can be negatively impacted by the application of water.

## IV. FUELING STATIONS

Gaseous fuel refilling stations are becoming more popular as the demand increases. Emergency response personnel need to familiarize themselves with those facilities that are in their area. To conduct a search of fueling stations in your area go to <http://www.afdc.energy.gov/locator/stations/>. There is a potential for some private stations not to be listed on this site so you should also check with your local building officials to determine if any additional facilities have been installed or are pending application approval. Preplanning operations should also provide firefighters with a familiarity of the site, the types of fuels involved and safety procedures in place.

## V. INITIAL RESPONSE PROCEDURES “IDENTIFY, IMMOBILIZE AND DISABLE”

The *identify, immobilize, disable* process should be used at all incidents involving vehicles as it not only helps to identify the presence of an AFV, it also ensures that it is appropriately secured from movement and disabled. To properly identify the vehicle, speak with the driver, look for labels and badges, and observe of the design features such as tank construction and location and finally reference the NFPA’s EFG. Next the vehicle must be immobilized by chocking, setting the parking brake, and disengaging the transmission. Lastly, shut off the vehicle’s ignition and disconnect the low voltage battery. Be sure to use all of the steps outlined in the IID process to make the vehicle safer to work around.

## VI. EMERGENCY OPERATIONS

Many response procedures for gaseous fuel vehicle incidents remain the same as incidents involving conventional vehicles. There are, however, some noted differences for both vehicles and fueling stations that are unique to gaseous fuels. Storage pressures and the physical properties of the fuel and cylinder/tank construction can impact recommended emergency response procedures.

