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LIQUEFIED NATURAL GAS FUEL USE

BASIC TRAINING MANUAL

TO

DEPARTMENT OF TRANSPORTATION / FTA
Office of Technical Assistance and Safety

May, 1994

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16. Abstract

The Urban Mass Transportation Administration's Alternative Fuel Initiative and the Environmental Protection Agency's 1991 regulations on transit bus exhaust emissions has resulted in a number of alternative fueled transit bus research and demonstration activities. Since the chemical and physical properties for liquefied natural gas (LNG) are significantly different than for diesel fuel, a training program was needed. The purpose of this program was to inform transit agencies of the characteristics of LNG and to instruct them in the proper use and handling of the new fuel in various transit operations. This training manual describes LNG use in transit, including LNG properties, flammability, advantages, health effects, along with safety equipment and procedures, as well as operating transit vehicles with LNG.

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ABOUT ALTERNATIVE FUELS

IN THIS SECTION: **ABOUT ALTERNATIVE FUELS**

WHY ALTERNATIVE FUELS?

Gasoline and diesel fuel have a long history as the "driving force" of transportation in America.

Are alternative fuels really necessary?

The term "alternative fuel" refers to fuels other than traditional gasoline and diesel fuel. Three important factors have contributed to the increasing experimentation and use of alternative fuels, particularly in transit-type operations. They are:

1) FEDERAL AND STATE MANDATES FOR LOWERED EMISSIONS
2) REDUCING DEPENDENCE ON FOREIGN OIL
3) IMPROVED PUBLIC IMAGE

1) FEDERAL AND STATE MANDATES FOR LOWERED EMISSIONS

Nationally, the Clean Air Act of 1990 set progressively more stringent requirements for vehicle emissions. Reduced emission goals for "transit-type" vehicles have resulted in a search for fuels and combustion techniques that will meet those newly established standards. Natural gas engines have demonstrated their potential for meeting those new standards.

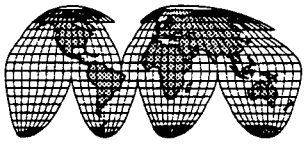
It's the law

By-products of engine combustion covered by Federal and some state laws include carbon monoxide, lead, reactive hydrocarbons, nitrogen oxides and particulate matter.

Traditional gasoline and diesel fuels have trouble meeting these new standards

2) REDUCING DEPENDENCY ON FOREIGN OIL

Natural gas is in relatively abundant domestic supply, lessening the need for dependence on potentially disruptive foreign supply.



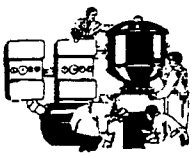
reducing dependence on foreign oil

3) IMPROVED PUBLIC IMAGE

Transit buses with no black smoke exhausting from tailpipes can only help the image of mass transit to the public.

WHAT FUELS ARE CONSIDERED ALTERNATIVE?

The desirability of any "alternative" fuel is dependent not only on its ability to meet clean air standards, but on its cost, availability, distribution network, storability, safe handling characteristics, ability to adapt to varying weather conditions, transportability, and importantly, public perception. In addition, certain fuels require extensive engine modification and differences in routine engine maintenance.



Research is continuing with alternative fuels

The following list of fuels have advantages over either traditional diesel or gasoline in reducing emissions.

- COMPRESSED NATURAL GAS (CNG)
- LIQUEFIED NATURAL GAS (LNG)
- METHANOL (M-100)
- METHANOL-GASOLINE BLEND (M-85)
- ETHANOL
- PROPANE OR LIQUEFIED PETROLEUM GAS (LPG)
- HYDROGEN
- ELECTRICITY
- BIODIESEL (SOY DERIVATIVE BLENDED WITH DIESEL)
- REFORMULATED GASOLINE

A list of alternative fuels

HOW NATURAL GAS IS USED FOR TRANSPORTATION

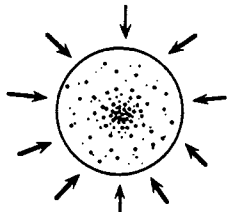
Natural gas has to be transportable to be a vehicle fuel

In its commonly used gaseous form, natural gas is much less dense than gasoline or diesel fuel. In order to carry an equivalent amount of fuel on board a vehicle, fuel storage tanks would have to be literally hundreds of times the size of conventional gasoline or diesel tanks.

Two methods have been used to increase the density of natural gas in order to make it practical as a transportation fuel.

CNG

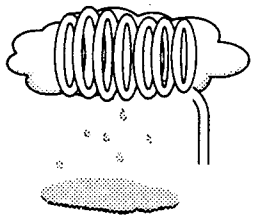
One method involves **compressing** natural gas to 3000 - 3600 p.s.i.g.. The resulting fuel is called Compressed Natural Gas (CNG). CNG is stored in reinforced tanks on the vehicle.



CNG is natural gas that is compressed

LNG

The other method involves **supercooling** the gas and turning it into a cryogenic (supercooled) liquid. At temperatures reaching -260° F (-162° C) natural gas becomes a liquid, thereby concentrating its energy into a much smaller space.



LNG is natural gas that is liquefied by supercooling

This fuel is called Liquefied Natural Gas (LNG). LNG is stored in specially insulated tanks under moderate pressure (60 to 120 p.s.i.g.).

ADVANTAGES OF NATURAL GAS AS A FUEL

Emissions are greatly reduced

Replacing traditional gasoline or diesel fuel with natural gas results in significant reduction of all of the by-products of combustion listed in the Clean Air Act of 1990. Those include significant reductions in carbon monoxide, reactive hydrocarbons, nitrogen oxides and particulate matter.

A list of natural gas advantages

A number of additional advantages include:

❶ Natural gas is relatively inexpensive

❷ Supplies of natural gas are abundant domestically

❸ A well established distribution network is already in place

❹ Natural gas is a familiar fuel for millions of people

❺ Natural gas has the highest octane rating of all traditional and alternative fuels

❻ Conventional engines can be modified to burn natural gas at moderate cost

❼ In a closed fuel(ing) system, no evaporative emissions occur

❽ Particulate emissions are almost eliminated — resulting in the disappearance of smoky exhaust

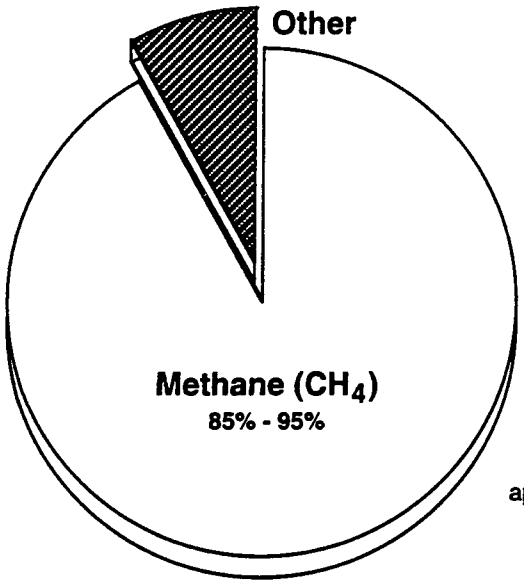
WHAT IS LIQUEFIED NATURAL GAS (LNG)?

IN THIS SECTION:

WHAT IS LIQUEFIED NATURAL GAS?

COMPOSITION OF NATURAL GAS

Natural gas is mostly **methane**. The graphic below illustrates the composition of natural gas.



natural gas is approximately 85 - 95% methane

Natural gas is mostly methane with small amounts of ethane propane CO_2 nitrogen

When natural gas is supercooled into liquefied natural gas (LNG) it is possible to decrease the presence of the other elements and increase the percentage of methane until the LNG is nearly pure methane.

LNG can be processed into nearly pure methane

The exact percentage of methane required is dependent on the specifications of the natural gas engine.

LIQUEFYING NATURAL GAS

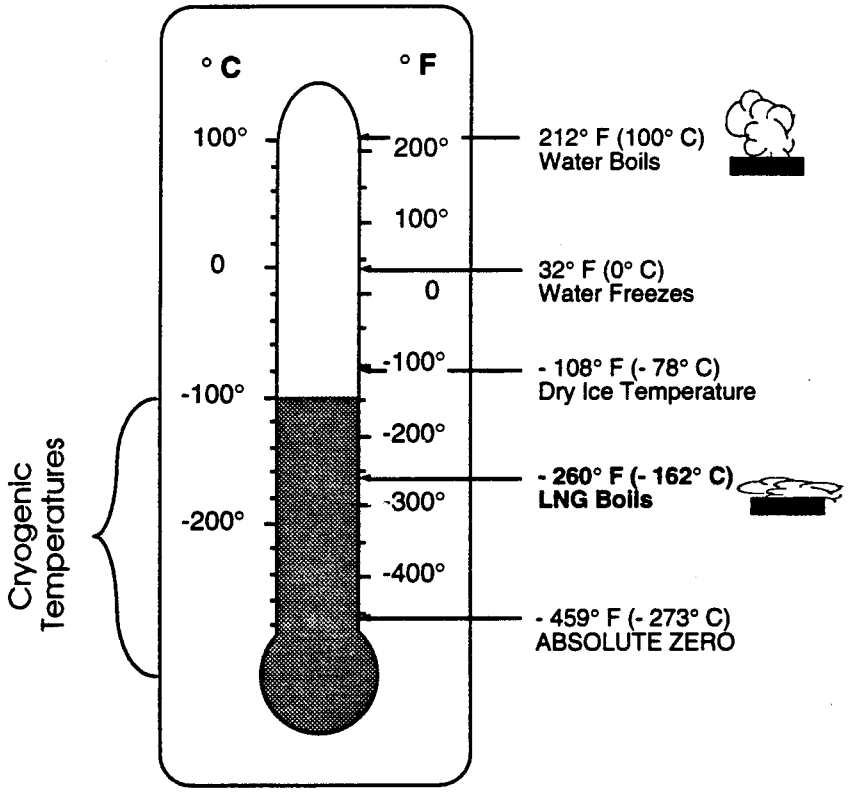
Natural gas, like other gases, will turn into a liquid when it is cooled or supercooled to a low enough temperature.

(Note: LNG is not liquefied propane (LPG). Propane liquefies under moderate pressure and is composed of different hydrocarbons than those in LNG).

The "boiling point" is the temperature at which a liquid becomes vapor

LNG is not propane

The chart below illustrates the temperature differences for the boiling point of water versus liquefied natural gas.



Below the boiling point, the product is a liquid

Super cooled fluids are called "cryogenic" liquids

IN THIS SECTION:

WHAT IS LIQUEFIED NATURAL GAS?

ODOR AND APPEARANCE OF LNG

LNG is ODORLESS

The natural gas that expands from LNG as it warms is **odorless** and cannot be smelled. If the sulfur odorant that is typically added to natural gas were added, it would generally freeze out when the natural gas was supercooled and liquefied.

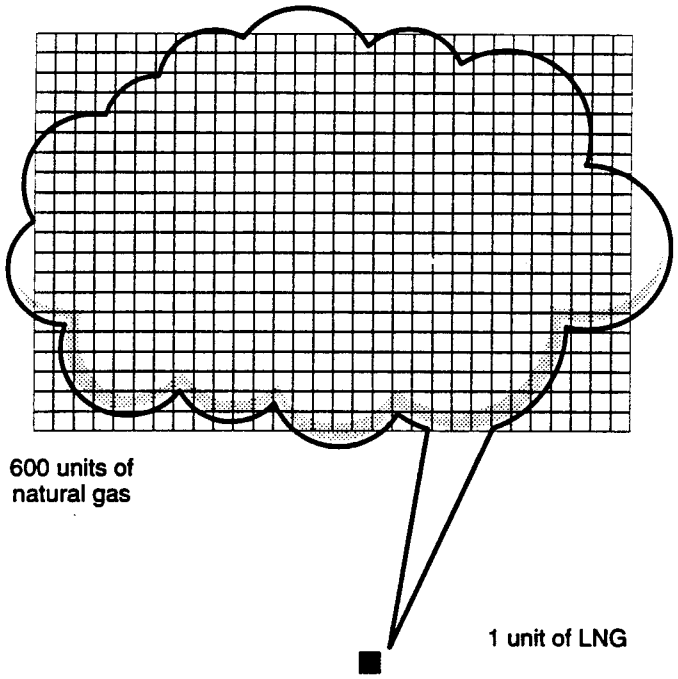
LNG looks like water

LNG has the same **clear** appearance as water.

VOLUME OF NATURAL GAS VS. LIQUEFIED NATURAL GAS

Liquefying natural gas greatly reduces its volume. About **600** units of natural gas will reduce to **one** unit of LNG when supercooled.

600 units of natural gas reduces to 1 unit of LNG

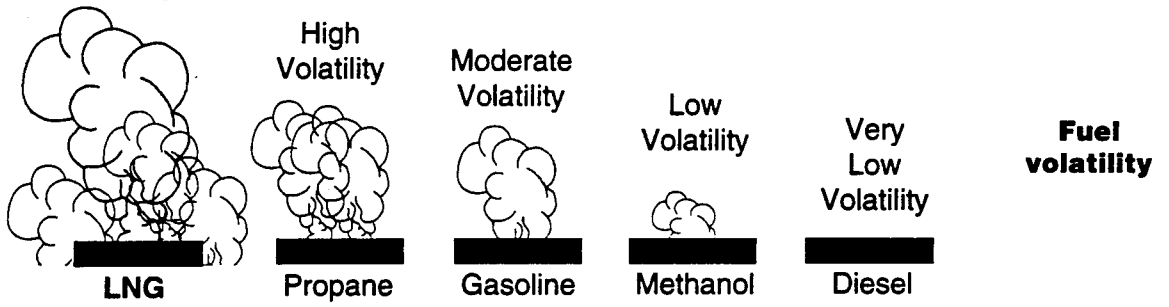


COMPARING LNG WITH OTHER FUELS

It is useful to compare LNG with other fuels. Although the charts and graphs may be labeled LNG, with few exceptions, the following comparisons are typically for natural gas (as composed primarily of methane).

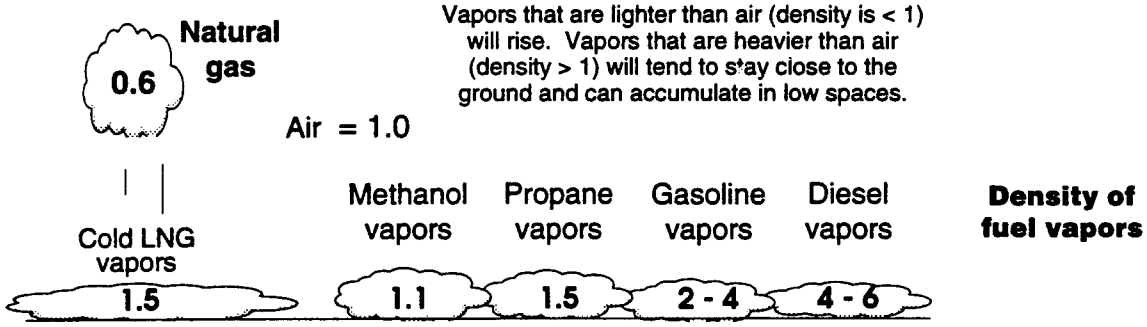
FUEL VOLATILITY

The ability of a liquid to vaporize is called volatility. Volatility is dependent on several factors, including temperature and pressure.



FUEL VAPOR DENSITY COMPARED TO AIR

Vapors that are lighter than air (density < 1) will rise. Vapors that are heavier than air (density > 1) will tend to stay close to the ground and can accumulate in low spaces.



Of the fuel vapors shown, natural gas is the only fuel vapor that rises after it warms.

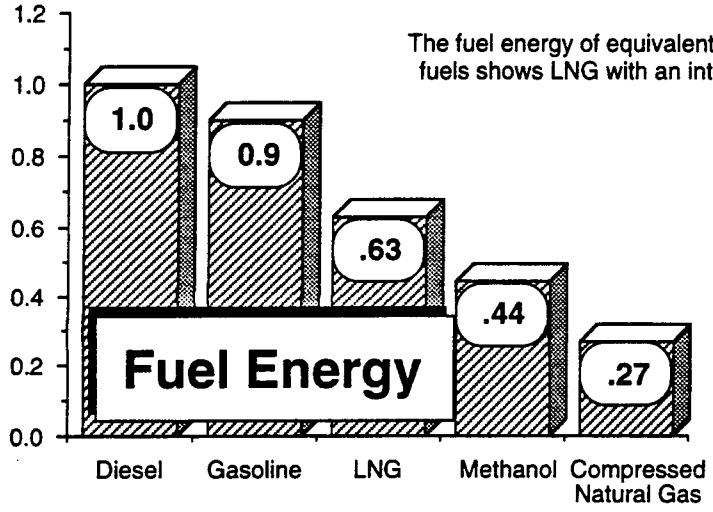
IN THIS SECTION:

WHAT IS LIQUEFIED NATURAL GAS?

COMPOSITION OF NATURAL GAS
LIQUEFYING NATURAL GAS
ODOR AND APPEARANCE OF LNG
VOLUME OF NATURAL GAS VS. LIQUEFIED NATURAL GAS
➨ COMPARING LNG WITH OTHER FUELS

COMPARING LNG WITH OTHER FUELS (con't)

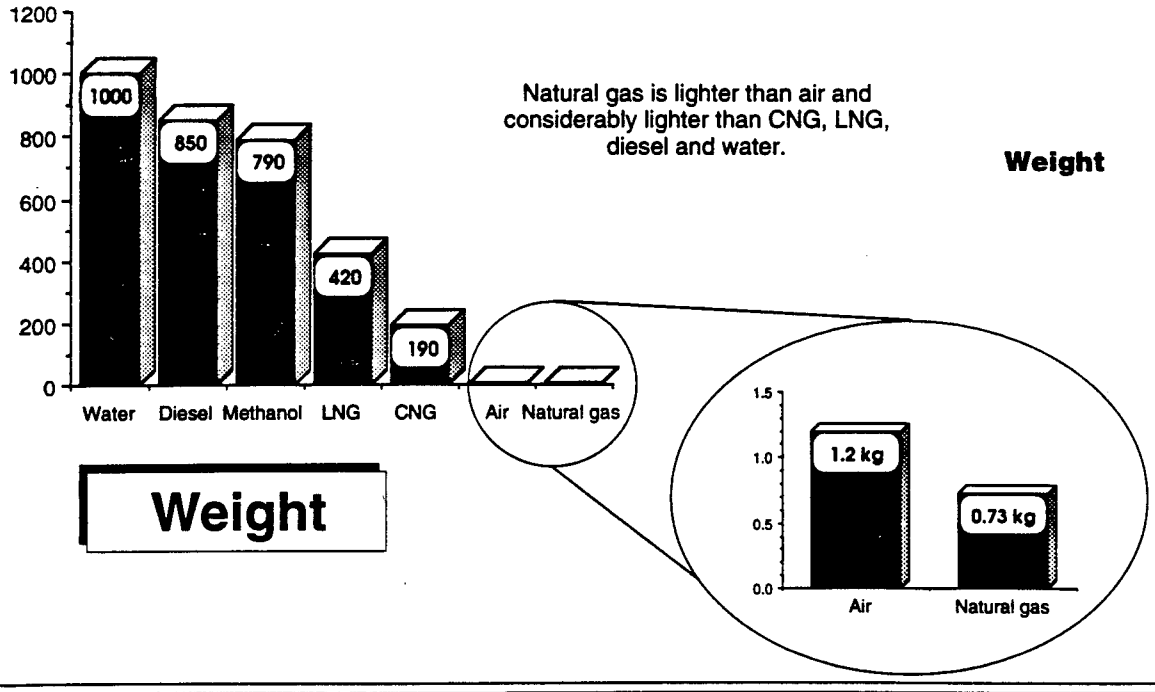
ENERGY IN A VOLUME OF FUEL



The fuel energy of equivalent volumes of these fuels shows LNG with an intermediate value.

Fuel energy

WEIGHT (in kilograms) of 1 cubic meter



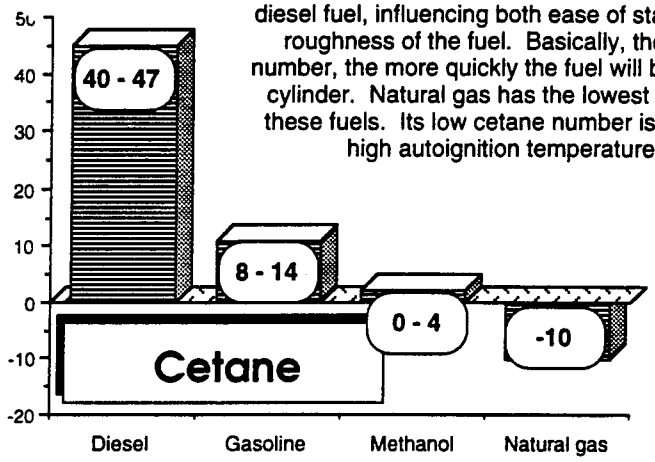
Natural gas is lighter than air and considerably lighter than CNG, LNG, diesel and water.

Weight

COMPARING LNG WITH OTHER FUELS (con't)

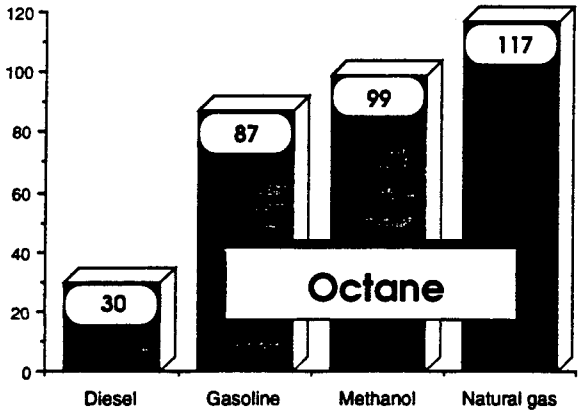
CETANE

The **cetane number** is a measure of the ignition quality of a diesel fuel, influencing both ease of starting and combustion roughness of the fuel. Basically, the higher the cetane number, the more quickly the fuel will burn upon entering the cylinder. Natural gas has the lowest cetane number of all these fuels. Its low cetane number is directly related to its high autoignition temperature (see below).



Cetane

OCTANE



The **octane rating** is a numerical measure of the antiknock properties of a spark ignition engine fuel. Fuels with a high octane rating are more resistant to autoignition.

Natural gas has the highest octane rating of all these fuels.

Octane

Autoignition temperatures:

Natural gas	900°-1000° F	(480°-540° C)
Methanol	725° F	(385° C)
Gasoline	572° F	(300° C)
Diesel	446° F	(230° C)

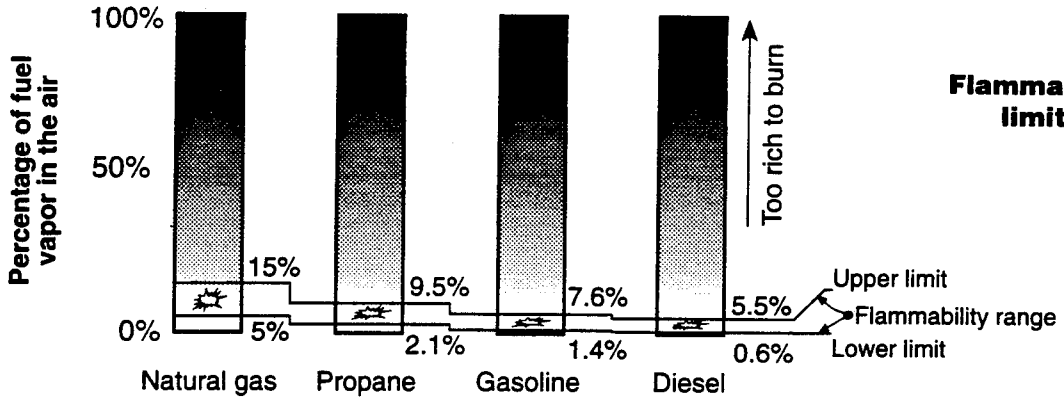
The **autoignition temperature** is the temperature at which the fuel will ignite by itself. Octane and cetane ratings are directly related to autoignition temperatures. Generally, the higher the autoignition temperature, the higher the octane rating and the lower the cetane number.

Autoignition temperatures

COMPARING LNG WITH OTHER FUELS (con't)

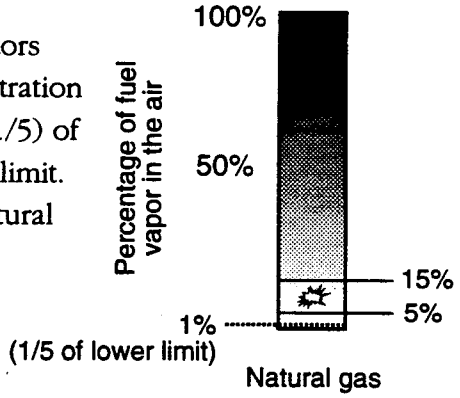
FLAMMABILITY LIMITS

Once liquid fuel has vaporized, the vapors become flammable when they are mixed with air in the proper proportions. Between the flammability limits (5% to 15% for natural gas) the vapor/air mixture will burn.



Flammability limits

- Natural gas has wider flammability limits than propane, gasoline and diesel.
- Combustible gas detectors warn when the concentration of vapors is one-fifth (1/5) of the lower flammability limit. (1/5 of 5% = 1% for natural gas).



Gas detection warning level is 1/5 of the lower flammability limit

Summary of comparison with other fuels

In summary, liquefied natural gas is an extremely cold, extremely volatile liquid. LNG that warms past -260° F (-162° C) vaporizes quickly into natural gas.

Although extremely cold natural gas vapors, like other fuel vapors at room temperature, are heavier than air, unlike the other fuel vapors, natural gas vapors will begin to rise after they warm.

Liquefying natural gas concentrates its fuel energy into a much smaller volume. Equivalent volumes of liquefied natural gas and diesel show LNG with about two-thirds (2/3) of the energy of the diesel.

The cetane rating of natural gas is low. This is because natural gas (with a high autoignition temperature) is resistant to burning in the cylinder. This high resistance to burning also results in a high octane rating for natural gas. Since natural gas has the highest octane rating of all the fuels listed, high compression engine technology is possible.

Natural gas has a flammability range of 5% - 15%. This means that a mixture of 5% - 15% natural gas with air will burn. This flammability range is the widest of all the fuels compared.

Finally, combustible gas detectors are used as an added element for safety because natural gas from LNG is odorless. These combustible gas detectors warn when vapor concentration reaches 1/5 of the lower flammability limit. For natural gas, this is 1/5 of 5% or 1% fuel vapor per volume of air.

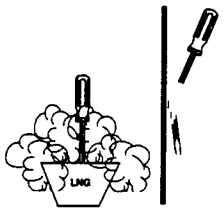
STORAGE AND FUELING WITH LNG

IN THIS SECTION: **STORAGE AND FUELING WITH LNG**

USE CRYOGENIC COMPATIBLE MATERIALS ONLY

Many materials become brittle when exposed to cryogenic temperatures. Common steels, including certain vehicle components (frame etc.), exposed to LNG can crack and break.

Materials used for the construction and repair of fuel storage and delivery systems must be approved for crogenic temperatures. This includes any SEALANTS that may be used.



Materials must be approved for cryogenic use

Materials that have been shown to be compatible with cryogenic temperatures include aluminum, copper, brass, nickel, lead, some stainless steels, teflon, certain epoxies and fiberglass.

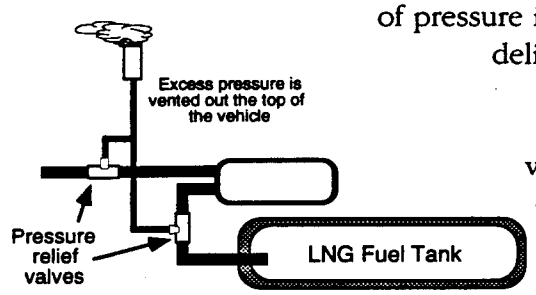
PRESSURE AND VENTING

As LNG warms past its "boiling point" of -260° F (-162° C) it forms a vapor with nearly 600 times the volume of the liquid. While the resulting pressure is beneficial in providing delivery of the fuel to the engine, during times when the vehicle is not in operation this pressure can present a problem.

Relief valves allow pressure venting

No LNG storage system is perfectly insulated and LNG will slowly vaporize with the potential to reach 14,500 p.s.i.g.. It is not practical to contain this type of pressure in the fuel storage and delivery systems.

Pressure relief valves are necessary in every closed portion of the fuel storage and delivery system.

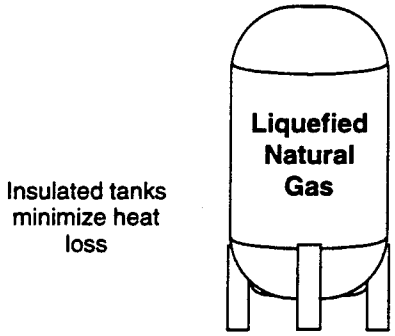


Pressure relief valves allow venting of excess pressure

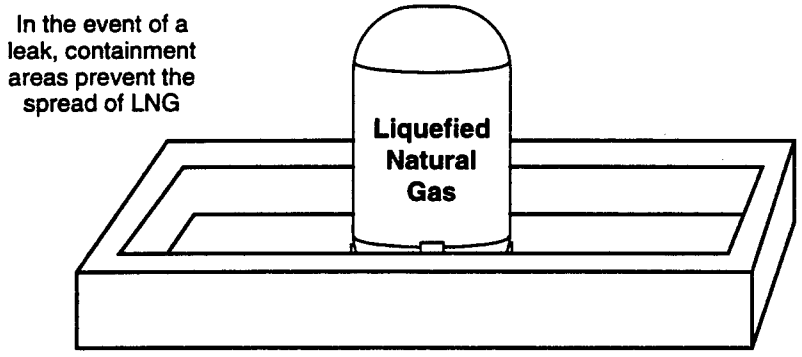
FACILITY STORAGE TANKS

LNG is typically stored above ground in vertical or horizontal vacuum insulated tanks.

LNG is stored above ground in insulated tanks



Containment rings (usually concrete) around the facility storage tank prevent the spread of LNG in the event of a rupture or leak.

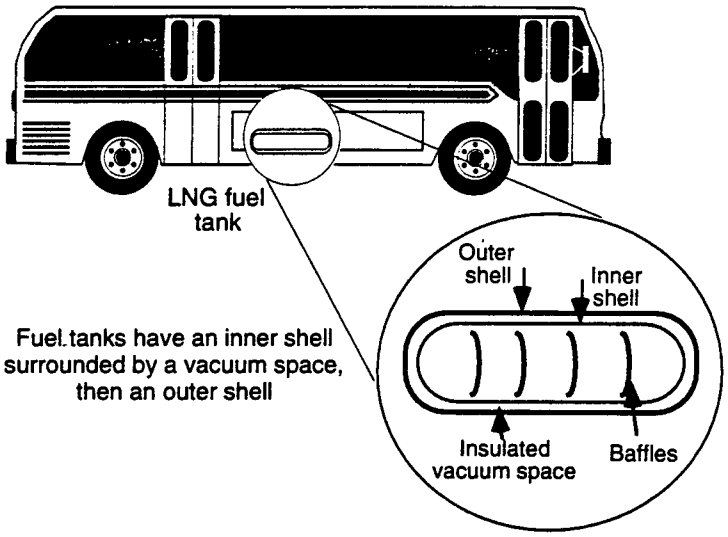


Containment areas prevent the spreading of LNG in an emergency

IN THIS SECTION: **STORAGE AND FUELING WITH LNG**

VEHICLE STORAGE TANKS

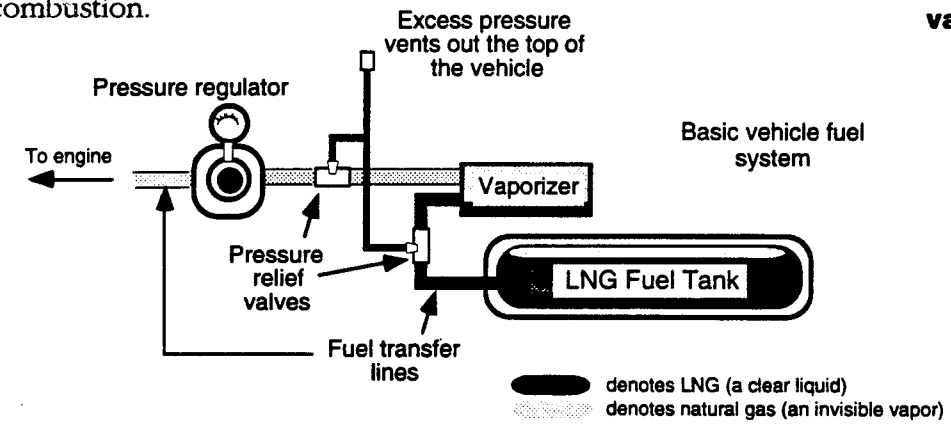
Vehicle fuel tanks consist of an inner shell surrounded by a superinsulated vacuum space enclosed in a cylindrical outer shell. Baffles in the inner tank help prevent sloshing of the fuel while the bus is in motion.



LNG can typically be stored in vehicle tanks for about a week before venting occurs

Insulated transfer lines move fuel (either by pump or via pressure difference) through a vaporizer and pressure regulator before the vaporized fuel eventually reaches the engine for combustion.

Fuel is transferred, vaporized and pressure regulated

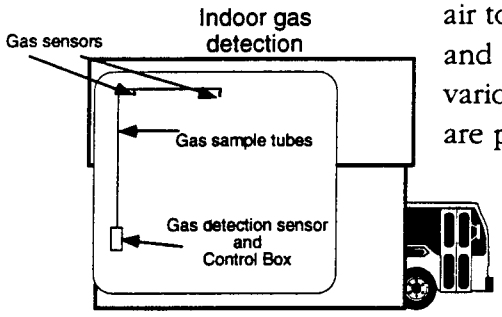


GAS DETECTION

LNG and the natural gas that vaporizes from it are **odorless**. Leak detection is therefore accomplished by the use of gas detectors. Gas detectors are devices that are capable of sensing the presence of fuel vapors in the air.

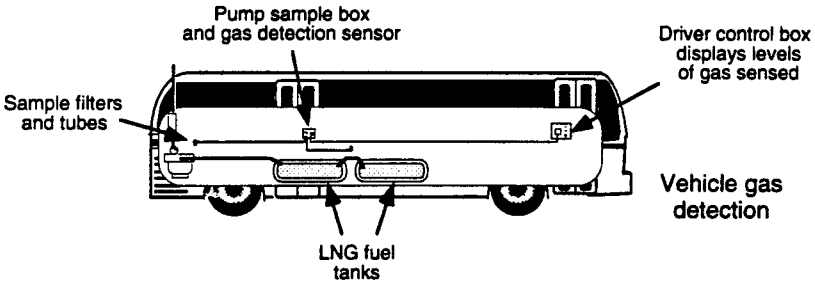
Gas leaks cannot be smelled - a gas detector must be used

The gas detector relates the concentration of vapors in the air to the flammability limits and provides a warning of various gas levels. Gas sensors are placed in ceiling areas and in other locations where vapors may be present.



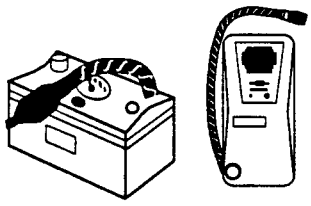
Indoor sensors are placed where vapors may be present

In the vehicle, sensors are placed throughout. Signals are fed into a control panel located in the driver's area.



Vehicle sensors are placed throughout

Portable hand-held gas detectors may be used temporarily in areas not covered by fixed gas detectors.



Portable sensors can be used anywhere

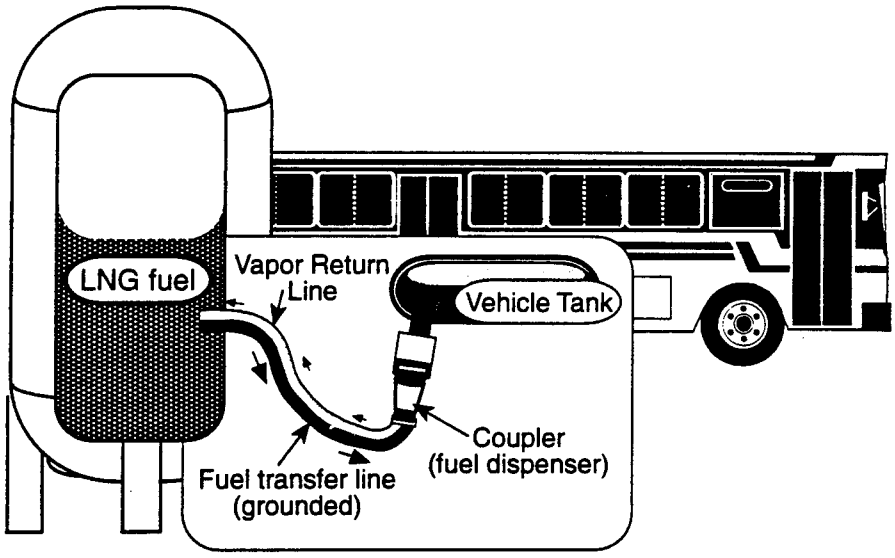
IN THIS SECTION: **STORAGE AND FUELING WITH LNG**

FUELING

Fueling consists of moving LNG from the facility storage tanks via insulated transfer lines through a coupler (fuel dispenser) to the vehicle storage tanks. All components and transfer lines are "grounded" to prevent static sparks.

The fueling system is "grounded" to prevent sparks and "closed" to prevent the escape of vapors and liquid

A **vapor return line** allows for the return of vapors and excess LNG from the vehicle storage tanks to the facility storage tanks.



Fuel is dispensed via the grounded transfer line. Excess pressure returns to the facility tank via the vapor return line.

see section on "Safety Precautions and Procedures"

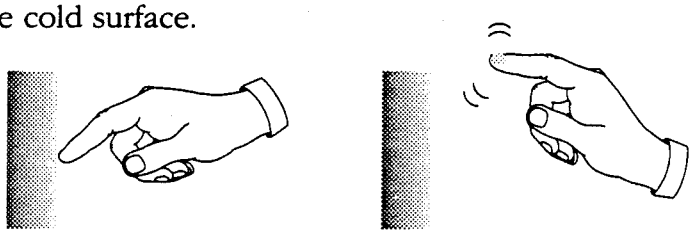
FUELING (con't)

Fueling with LNG requires certain special precautions, including the **use of protective equipment** and **attention to system integrity**.

Fuelers need to protect themselves from exposure to supercool temperatures

PROTECTIVE EQUIPMENT is necessary to prevent "cryogenic burns" that could occur if any part of the body is more than momentarily exposed to the supercooled liquid.

Touching parts of the fuel system that are extremely cold can cause the skin to stick tight and to tear when pulled away from the cold surface.



Skin can tear when pulled away from super cold material

Maintaining SYSTEM INTEGRITY means constant observance of the condition of the fueling hoses, insulation, coupler, vehicle storage tank and transfer lines, and facility equipment. **REPORT ANY EQUIPMENT CONDITION** that is not up to standard.

Report substandard equipment condition

Failure of any part of the system can generally be detected by observing icing on the surface of the component, indicating that insulation from outside temperatures is not being maintained. However, it is not uncommon for certain parts, such as the fuel dispenser, to have some ice on its surface due to moisture in the air coming into contact with the cold surface. Fog will also occur when moist air contacts cold piping.

VEHICLE OPERATION AND REPAIR

IN THIS SECTION:

VEHICLE OPERATION AND REPAIR

VEHICLE OPERATING CHARACTERISTICS

Except for the presence of gas detectors, its business as usual

STARTING	procedures may vary slightly. However, because LNG is a vapor when it reaches the engine cylinder, hot and cold start problems are greatly reduced.
ACCELERATION,	as with diesel engines, depends on the gearing of the vehicle and other factors.
EXHAUST	from any vehicle has the potential to be dangerous. Harmful emissions from LNG fueled vehicles are reduced, not eliminated. Proper ventilation is still required. One noticeable difference, however, is the absence of dark, smoky exhaust.
RESTARTING,	like starting, is not a problem due to fuel alone.
ACCIDENTS	can happen with any vehicle. Although LNG tanks are secured in a manner designed to reduce the potential for damage from an accident, it is always possible for damage to occur. (see Emergency Response - Leaks and Spills). As an added element of safety, passengers and bystanders are cautioned to remain upwind if leaks occur or if the potential for leaks exists.
GAS DETECTORS	are located on the vehicle to signal the presence of any natural gas leaks. These detectors are necessary because of the absence of a "smellable" sulfur odorant in the natural gas from LNG.
FIRE SUPPRESSION	LNG fueled vehicles contain fire suppression equipment.

QUESTIONS FROM PASSENGERS

The LNG vehicle has more safeguards than the typical diesel or gasoline fueled vehicles

Passengers may be curious about LNG as a fuel and some are likely to ask questions about it. Some passengers may even be concerned about the new technology.

LNG fuel is much cleaner burning than either traditional gasoline or diesel fuels. And for safety, LNG vehicles have onboard gas detection and fire suppression equipment.

Passengers may be curious about the new fuel

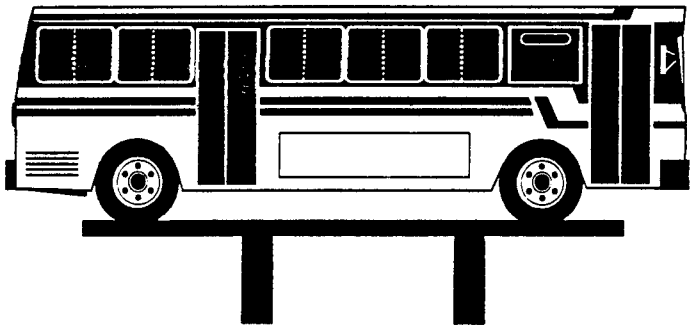
Note: Ruptured LNG tanks and transfer lines vent LNG and vapors which, although flammable and extremely cold, are not toxic.

Once LNG vapors warm, the natural gas will rise and (outdoors), will disperse quickly.

There are additional safeguards build into a LNG fueled bus that are not present with diesel or gasoline fueled buses.

LNG fuel in a vehicle tank is no more likely to burn or explode than gasoline in an automobile gas tank.

POTENTIAL HAZARDS DURING REPAIR



These hazards can be avoided by purging the fuel system first and connecting vent hoses to the building exhaust system

Generally, five categories of potential hazards exist during the repair of LNG fuel systems. Those are 1) accidental opening or damage to the fuel system, 2) pressure build-up and venting indoors, 3) cryogenic burns, 4) potential for fire, and 5) overinhalation of exhaust.

1) Accidental opening or rupture to the system

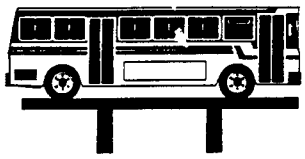
1) Accidental opening (or the rupturing) of an unpurged fuel system can result in a fire hazard and possible cryogenic burns to those persons close by who are caught unaware and unprepared.

Ruptures can occur when replacement parts, connections and sealants are not approved for cryogenic use or when parts have deteriorated through wear.

Although natural gas cannot be seen, moisture clouds (fog) and frost from LNG can

Cold natural gas vapors escaping from a rupture will accumulate in low areas until they warm. They will then rise and dissipate (outdoors). Large amounts of natural gas can accumulate in a confined environment, robbing unsuspecting occupants of oxygen. Remember, natural gas used for LNG cannot be smelled. Gas detectors are essential.

POTENTIAL HAZARDS DURING REPAIR (con't)



2) Although superinsulated fuel storage tanks can maintain cryogenic temperatures for several days, gradual warming is inevitable. As the LNG in the system "warms" above -260° F (-162° C) the pressure in the fuel tank will increase.

2) Venting of the system inside the building can be dangerous

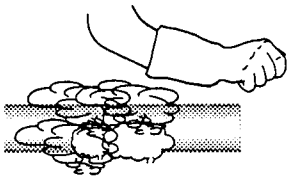
Excess pressure vents out the top of the vehicle

Eventually, natural gas will escape through pressure relief valves that vent on the top of the bus.

Though the cold vapors will flow downward, after the natural gas warms it will be lighter than air and can accumulate in unvented ceiling areas where contact with non-approved electrical equipment and heaters can cause ignition.

3) Cryogenic burns are the result of unprotected skin contact with escaping liquid and the "boiling" of supercold fuel vapors near the opening.

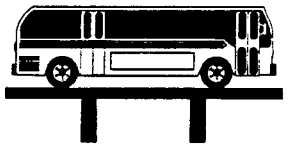
The severity of a cryogenic "burn" is a result of the length of time and magnitude of skin exposure to the supercold liquid or vapors.



Very brief skin exposure is not harmful

3) Cryogenic burns can result from skin (or eye) contact with LNG or escaping vapors near the opening

POTENTIAL HAZARDS DURING REPAIR (con't)



4) When fuel escapes in sufficient quantities, the potential for fire exists when an ignition source is present.

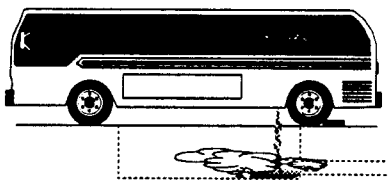
4) Natural gas can accumulate in unvented ceiling areas

Even static electricity can ignite fuel vapors.

LNG and cold natural gas vapors pool in low areas prior to warming and rising

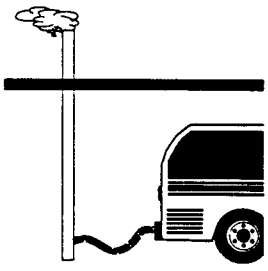
The potential for fire exists in unvented ceiling areas where natural gas will accumulate AND in low spots where the rapidly vaporizing liquid fuel can pool.

It is important to recognize the danger of LNG seeping into pits or sewer systems while vaporizing into flammable gas.



Since LNG and its vapors are **odorless**, gas detectors are a critical part of fire prevention strategies.

5) Over-inhalation of exhaust fumes can occur when idling vehicles are not properly vented to the outside. LNG as a fuel results in greatly reduced emissions, not the elimination of emissions. Exhaust hoses are still needed.



5) Exhaust still needs to be properly vented outside

SAFETY PRECAUTIONS AND PROCEDURES

IN THIS SECTION: **SAFETY PRECAUTIONS AND PROCEDURES**

SAFETY PRECAUTIONS AND PROCEDURES

CRYOGENIC BURNS

safety

CRYOGENIC BURNS

- Skin contact with LNG, boiling vapors, or cold metal surfaces can cause **frost burns**. Frost burns are not actually burns, but the victim feels symptoms similar to those of a burn.
- LNG contact with unprotected eyes can cause blindness.
- Touching exposed, extremely cold metal can cause the skin to stick to the metal and to tear when pulled away.

MINIMUM PROTECTIVE CLOTHING TO BE WORN WHEN **FUELING**

- ✔ **Full face shield (not glasses)**
- ✔ **Full length, loose fitting gloves***
- ✔ **Full length apron**
- ✔ **Heavy footwear**
  (wear trousers OUTside of boots)

The severity of a cryogenic burn is dependent on the length and magnitude of exposure to supercooled liquid or vapors. Brief skin exposure (of a couple of seconds at a time) is not harmful.

* Loose fitting gloves are recommended so that the wearer can fling them off if cryogenic fluid spills inside the cuffs.

IN THIS SECTION: **SAFETY PRECAUTIONS AND PROCEDURES**

SAFETY PRECAUTIONS AND PROCEDURES

LEAKS AND SPILLS

safety

LEAKS AND SPILLS

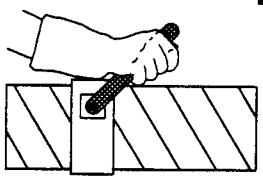
The primary dangers from leaks and spills are:

- the potential for cryogenic burns, should exposure occur
- the possibility of fire if the fuel comes into contact with an ignition source
- large leaks within a confined space can lead to asphyxiation (suffocation) due to the cutoff of oxygen in the area
- spills of sufficient quantity on steel vehicle components can cause cracks

IF LEAKS OR SPILLS OCCUR

- ✔ **Continue to prevent any ignition source from entering the area. This includes no cigarettes, electrical equipment and no open flames.**
- ✔ **Small leaks and spills will vaporize and dissipate.**
- ✔ **If practical, locate the source of a continuing leak. If properly trained and authorized, isolate and shut off the source of the leak or spill. PROPER VENTILATION IS REQUIRED.**
- ✔ **For a large leak on a vehicle, tow the vehicle outdoors. Inspect vehicle components for cracks.**
- ✔ **Follow company procedure for reporting leaks and spills.**

See next page for what happens when large leaks or spills occur



Shut off the source of a leak if possible

IN THIS SECTION:

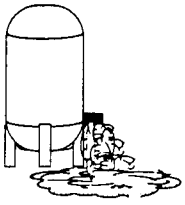
SAFETY PRECAUTIONS AND PROCEDURES

CRYOGENIC BURNS

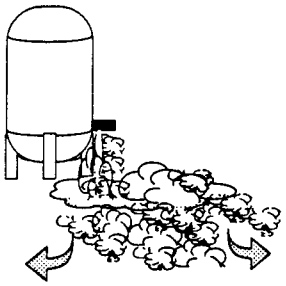
➨ LEAKS AND SPILLS

FIRE HAZARDS

When large leaks and spills occur:

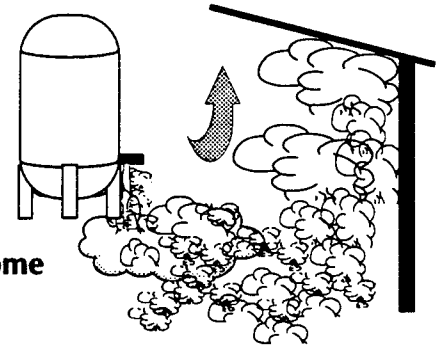


LNG flows from a break or crack in the system.



The liquid LNG and supercold LNG vapors spread rapidly along the ground or floor. They warm as they spread.

The LNG and heavy cold vapors will settle in low areas (like maintenance pits).



As the cold vapors warm, they eventually become lighter than air and will rise.

This natural gas can accumulate in unvented overhangs, ceiling areas or near the roof in vehicles.

SAFETY PRECAUTIONS AND PROCEDURES

FIRE HAZARDS

safety

FIRE HAZARDS

Fuel vapor, mixed in the proper proportion with air (oxygen) is **flammable**. Natural gas that is venting from a pressurized tank or fuel line has the potential to flame like a torch if exposed to an ignition source.

FIRE SAFETY RULES **✔Keep all ignition sources away**

- ➤ Do not strike matches or smoke
- ➤ Do not operate welding or cutting tools
- ➤ Do not use tools that generate sparks
- ➤ Do not operate non-approved electrical equipment

no smoking

no open flames

no hot surfaces

no sparks

Unless properly trained and authorized to be in the area of a recurring leak or spill, stay away.

Be aware that leaks are NOT detectable by smell! You must rely on gas detectors.

LNG vapors (which consist of cold natural gas) are heavier than air and will flow to low areas such as maintenance pits. After the vapors warm, they will rise, accumulating in non-vented ceiling areas inside buildings or near the roof area in vehicles.

If fire occurs, extinguishing the fire may not be desirable because of the possibility of re-ignition.

Do not use water on an LNG fire.

LNG vapors, mixed in the proper proportion with air, are flammable.

Natural gas that is venting under pressure can flame like a torch if ignited.

Clouds of (natural gas) fuel vapor will burn very rapidly.

If a cloud of fuel vapor burns in a confined area, like inside a building or vehicle, an explosion will likely occur.

Even though LNG is very cold, pools of liquid LNG will also burn, just like a pool of gasoline or other flammable liquids.

EMERGENCY RESPONSE

IN THIS SECTION:

EMERGENCY RESPONSE

CRYOGENIC BURNS
EXPOSURE TO NATURAL GAS
FIRE SUPPRESSION
LEAKS
SPILLS
FIRST AID

ABOUT THE EMERGENCY RESPONSE PROCEDURES ON THE FOLLOWING PAGES

Use the following procedures as a guideline only

The following general procedures are offered as a guideline only.

Emergency response procedures require a great deal of information that is site specific, such as location of first aid and fire equipment, staff and local authority notification procedures, reporting, training, and assignment of responsibilities.

These procedures are offered as a guideline and should not be considered complete. However, they provide useful information that may be incorporated into the final emergency response procedures.

As always, the most effective method for dealing with the potential for emergencies is active attention to **prevention.**

IN THIS SECTION:

EMERGENCY RESPONSE

CRYOGENIC BURNS

Note: Cryogenic burns may result not only from contact with the supercooled liquid itself, but also from the extremely cold vapors that boil from the liquid. Extremely cold metal can also cause "burns" when it is touched and "freeze" the skin to its surface. Tearing of the skin can occur when it is withdrawn.

First Aid for Cryogenic burns

SYMPTOMS:

The victim will feel no pain from the frozen tissues. The affected skin area will appear waxy. After the skin warms, swelling occurs. The affected area will then feel painful. More severe burn areas will blister.

First Aid for Cryogenic Burns

- Remove any clothing that may restrict blood flow to the affected area.
- DO NOT RUB frozen skin. Rubbing the affected area may damage the tissue.
- Alcoholic beverages and smoking decrease blood flow to the frozen tissues and should be prohibited.
- As soon as is practical, thaw the affected area by immersion in warm water. Circulating warm water between 105° F and 115° F (40° C to 46° C) is best. Avoid the use of dry heat.
- For a large exposure, totally immerse the victim in a warm water bath and provide supportive treatment for shock.
- Cover thawed areas with sterile dressing and protective covering.
- Warm drinks and food may be given to the victim.

IN THIS SECTION:

EMERGENCY RESPONSE

EXPOSURE TO NATURAL GAS

Note: Natural gas is not toxic. However, the odorless natural gas vapors from LNG can accumulate in a confined area and displace oxygen. Asphyxiation (suffocation) could result in a confined area.

Natural gas is not toxic, but it is flammable

Large amounts of natural gas can displace oxygen in a confined area, causing suffocation

RECOMMENDATION:

Indoor gas detectors need to be well maintained and regularly tested.

Use a portable combustible gas detector to check the air in any confined space before and during work. If the portable gas detector shows the presence of gas, provide adequate ventilation until the area is safe to work in.

First Aid for Overexposure to Natural Gas

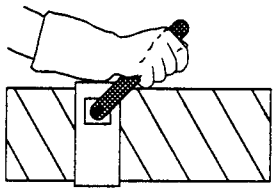
- If and when it is safe to enter the area, move the victim to an area of fresh air.
- If safe to do so, ventilate the confined area immediately, and keep all potential ignition source away.
- The use of alcoholic beverages and smoking by the victim should be prohibited.
- Contact medical personnel if breathing is abnormal or if the victim had been unconscious.
- Note: Do not enter into or remain in a saturated area, even to administer first aid, without adequate ventilation or supportive breathing equipment.

IN THIS SECTION:

EMERGENCY RESPONSE

FIRE SUPPRESSION

Note: Shutting off the source of natural gas is the most practical way to suppress a natural gas fire. Small LNG fires will likely burn out quickly. Often the best action is to allow the fire to burn.



The best way to extinguish a natural gas fire is to cut off the flow of gas

DO NOT spray water directly onto an LNG fire. The water will make the LNG vaporize more rapidly and will cause the fire to flare up.

RECOMMENDATION:

Shut off the source of natural gas if possible.

Small fires will burn out quickly. Extinguishing a fire presents the added risk of re-ignition.

Fire Suppression for Natural Gas Fires

- If possible and safe to do so, shut off the source of the natural gas.
- If unable to shut off the flow of natural gas, consider the danger of possible re-ignition before attempting to extinguish the fire.
- **ABC rated dry chemical extinguishers are recommended** to extinguish natural gas fires. Application should be to the base of the fire.
- Contact fire personnel for larger fires.
- Minimize the opportunity for the fire to spread.

IN THIS SECTION: EMERGENCY RESPONSE

LEAKS

Note: Leaks are detected in one of four ways:

1) gas detectors,
2) hearing the "hissing" of the leak,
3) observing frosting at the point of the leak,
4) feeling coldness on the outer shell of an insulated tank.

Leaks are detected by gas detectors, noise, or frosting at the leak area

Natural gas from small leaks will rise and dissipate (outdoors).

Larger leaks may fill confined areas, robbing occupants of oxygen and creating an explosion hazard.

RECOMMENDATION:

Do not bring leaking equipment inside any building unless authorized to do so. Maintain adequate ventilation and prevent ignition sources from entering the area.

Do not repair leaks under pressure. This includes using a wrench to tighten a joint. Doing so can cause the leak to worsen.

In the Event of a Natural Gas Leak

- Shut down equipment immediately.
- Provide adequate ventilation.
- Remove and prevent the entry of ignition sources into the area.
- Prevent unauthorized personnel from entering the area.
- Notify responsible staff of the position of the equipment and location of the leak.

IN THIS SECTION: **EMERGENCY RESPONSE**

SPILLS

Note: Spills represent a relatively dangerous condition because of the large volume of natural gas generated from the liquid and because of the added element of extreme coldness.

Spills are dangerous because of the presence of flammable gas and the extreme coldness

Exposed to room temperature, LNG from spills will vaporize rapidly, releasing enormous amounts of natural gas (600 parts gas to 1 part liquid).

The liquid and nearby vapors will rapidly freeze whatever surface they come into contact with.

Spills release enormous volumes of flammable gas

RECOMMENDATION:

Response to a leak needs to focus initially on removal of ignition sources, containing the leak, and providing adequate ventilation.

In the Event of a LNG Spill

- Remove and prevent the entry of any source of ignition.
- Provide adequate ventilation.
- Contact response personnel.
- Stay away from the liquid and nearby vapors without protective equipment.

IN THIS SECTION:

EMERGENCY RESPONSE

CRYOGENIC BURNS
EXPOSURE TO NATURAL GAS
FIRE SUPPRESSION
LEAKS
SPILLS
➨ FIRST AID

FIRST AID
First Aid Procedures
SUMMARY

☞ Remember to USE CAUTION — flammable vapors may be near

1) Remove the person from the area of LNG contamination.

- Remove slowly to avoid tearing frozen flesh.
- If vapors are present, if possible, shut off source and/or remove the person from the area.

2) If asphyxia (suffocation) is suspected and breathing has stopped.

- Call 911 and administer CPR.

3) If cryogenic exposure has caused injury or a burn.

- Remove any clothing saturated with LNG or clothing that is restricting the flow of blood.
- Place the frozen area in comfortably warm water or use hands or body contact to warm the affected area. DO NOT rub the area and DO NOT use dry heat.

4) Transport the affected person to a medical facility.

- Damage to the tissue cannot be determined by visual observation alone.

5) Avoid alcoholic beverages and tobacco products.

- Alcohol and tobacco impair blood flow to the frozen area and MUST BE AVOIDED.