

PB2000-108011



Compressed Natural Gas Fuel Use Training Manual

to

**DEPARTMENT OF TRANSPORTATION / FTA
Office of Technical Assistance and Safety**

September, 1992

prepared by



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REPRODUCED BY:
U.S. Department of Commerce
National Technical Information Service
Springfield, Virginia 22161

NTIS

1. Report No. UMTA-OH-06-0056-92.1		2. PB2000-108011 		3. Recipient's Catalog No.	
4. Title and Subtitle Compressed Natural Gas Fuel Use Training Manual				5. Report Date September 1992	
				6. Performing Organization Code	
7. Author(s)				8. Performing Organization Report No.	
				10. Work Unit No. (TRAIS)	
9. Performing Organization Name and Address *Battelle Columbus Division 505 King Avenue, Columbus, Ohio 43201				11. Contract or Grant No. OH-06-0056	
				13. Type of Report and Period Covered Training Manual for CNG	
12. Sponsoring Agency Name and Address Federal Transit Administration 400 7th Street, SW Washington, DC 20590 http://www.fta.dot.gov				14. Sponsoring Agency Code DeMarco, Vincent	
				15. Supplementary Notes *And Pine & Associates, 927½ Massachusetts, Suite 4, Lawrence, Kansas 66044	
16. Abstract <p>The Urban Mass Transportation Administration (UMTA) Alternative Fuel Initiative and the Environmental Protection Agency (EPA) 1991 regulations on transit bus exhaust emissions has resulted in a number of alternative fueled transit bus demonstrations. Since the chemical and physical properties for compressed natural gas (CNG) are significantly different than for diesel fuel, a training program was needed. The purpose of this program was to inform transit employees of the characteristics of CNG and to instruct them in the proper use and handling of the new fuel in various transit operations. This manual describes CNG fuel use in transit, including CNG properties, flammability, advantages, effects on health, along with safety precautions and procedures, and operating transit vehicles with CNG.</p>					
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17. Key Words Compressed Natural Gas Use Alternative Fuel transit bus CNG - Compressed Natural Gas Use Training Manual Operations Clean Fuel Technology Flammability Safety			18. Distribution Statement Available from the National Technical Information Service/NTIS, Springfield, Virginia 22161. 703.605.6000 orders@ntis.fedworld.gov		
19. Security Classif. (of this report) unclassified		20. Security Classif. (of this page) unclassified		21. No. of Pages	22. Price NTIS

METRIC / ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in) = 2.5 centimeters (cm)
 1 foot (ft) = 30 centimeters (cm)
 1 yard (yd) = 0.9 meter (m)
 1 mile (mi) = 1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in²) = 6.5 square centimeters (cm²)
 1 square foot (sq ft, ft²) = 0.09 square meter (m²)
 1 square yard (sq yd, yd²) = 0.8 square meter (m²)
 1 square mile (sq mi, mi²) = 2.6 square kilometers (km²)
 1 acre = 0.4 hectares (he) = 4,000 square meters (m²)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz) = 28 grams (gr)
 1 pound (lb) = .45 kilogram (kg)
 1 short ton = 2,000 pounds (lb) = 0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp) = 5 milliliters (ml)
 1 tablespoon (tbsp) = 15 milliliters (ml)
 1 fluid ounce (fl oz) = 30 milliliters (ml)
 1 cup (c) = 0.24 liter (l)
 1 pint (pt) = 0.47 liter (l)
 1 quart (qt) = 0.96 liter (l)
 1 gallon (gal) = 3.8 liters (l)
 1 cubic foot (cu ft, ft³) = 0.03 cubic meter (m³)
 1 cubic yard (cu yd, yd³) = 0.76 cubic meter (m³)

TEMPERATURE (EXACT)

$$[(x - 32) (5/9)] ^\circ\text{F} = y ^\circ\text{C}$$

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm) = 0.04 inch (in)
 1 centimeter (cm) = 0.4 inch (in)
 1 meter (m) = 3.3 feet (ft)
 1 meter (m) = 1.1 yards (yd)
 1 kilometer (km) = 0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm²) = 0.16 square inch (sq in, in²)
 1 square meter (m²) = 1.2 square yards (sq yd, yd²)
 1 square kilometer (km²) = 0.4 square mile (sq mi, mi²)
 1 hectare (he) = 10,000 square meters (m²) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gr) = 0.036 ounce (oz)
 1 kilogram (kg) = 2.2 pounds (lb)
 1 tonne (t) = 1,000 kilograms (kg) = 1.1 short tons

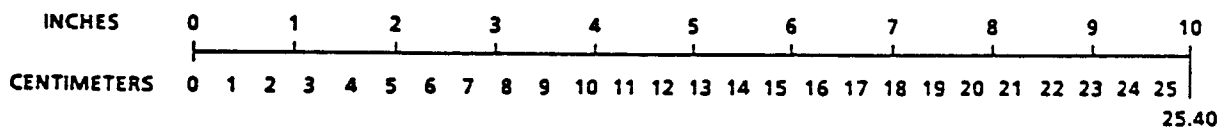
VOLUME (APPROXIMATE)

1 milliliter (ml) = 0.03 fluid ounce (fl oz)
 1 liter (l) = 2.1 pints (pt)
 1 liter (l) = 1.06 quarts (qt)
 1 liter (l) = 0.26 gallon (gal)
 1 cubic meter (m³) = 36 cubic feet (cu ft, ft³)
 1 cubic meter (m³) = 1.3 cubic yards (cu yd, yd³)

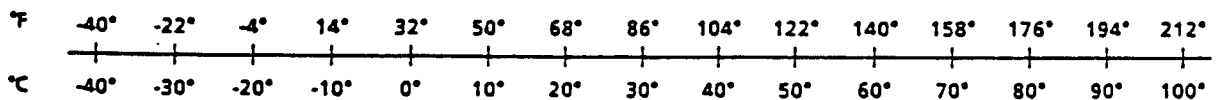
TEMPERATURE (EXACT)

$$[(9/5)y + 32] ^\circ\text{C} = x ^\circ\text{F}$$

QUICK INCH-CENTIMETER LENGTH CONVERSION



QUICK FAHRENHEIT-CELCIUS TEMPERATURE CONVERSION



For more exact and/or other conversion factors, see NBS Miscellaneous Publication 286, Units of Weights and Measures. Price \$2.50. SD Catalog No. C13 10 286.

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Alternative Fuels and Transit

Why Alternative Fuels?

Alternative fuels have the following advantages...

- > They meet state mandates for cleaner burning fuels.
- > The reduced exhaust emissions fulfill new government standards.
- > The cleaner exhaust helps to improve public transit's image to the public.

Advantages of CNG as a Fuel

CNG or Compressed Natural Gas has the following advantages as a vehicle fuel:

- Natural gas is readily abundant, domestically and globally
- A distribution network is already in place
- Its use as a vehicle fuel is proven
- Natural gas engines emit less soot than diesel engines
- CNG promises to meet long-term mandated standards for emission
- Relatively low fuel costs
- No hot or cold start problems
- Relatively high octane
- No sludge or carbon deposits in engines
- Low fuel toxicity

CNG - What is it?

CNG - What is it?

Physical Properties

- **Composition**
- **Odor/Appearance**
- Density
- High Pressure
- Fuel value
- Octane/Cetane

Flammability

- Dangers
- Luminosity
- Ignition
- Ignition temperature
- Spark assistance
- Flammability limits
- Combustible Gas Detectors

Effects on Health

- Odor threshold
- Breathing CNG
- Skin exposure
- Exhaust

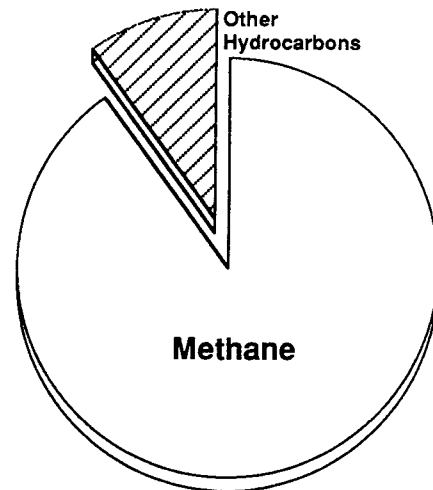
Physical Properties

Composition

Natural gas is 80 - 95% methane. The remaining vapors contains ethane, propane, butane and other hydrocarbons (combinations of hydrogen and carbon atoms).

Because natural gas is made up of "simple" hydrocarbons, it is a gas. More complicated hydrocarbons, like gasoline and diesel fuel, are liquids.

CNG is natural gas that is compressed in order to fit enough gas in a given volume to be practical as a portable fuel supply. Even when compressed, natural gas is not a liquid.



Odor/Appearance

Natural gas is **ODORLESS, COLORLESS, AND TASTELESS**. An odorant (trace amounts of an organic sulfur compound) is added to aid in the detection of leaks.

However, persons exposed to natural gas odor for a long period of time can find that the smell is no longer noticeable.

CNG - What is it?

Physical Properties

Composition
 Odor/Appearance
•Density
 High Pressure
 Fuel value
 Octane/Cetane

Flammability

Dangers
 Luminosity
 Ignition
 Ignition temperature
 Spark assistance
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 Combustible Gas Detectors

Effects on Health

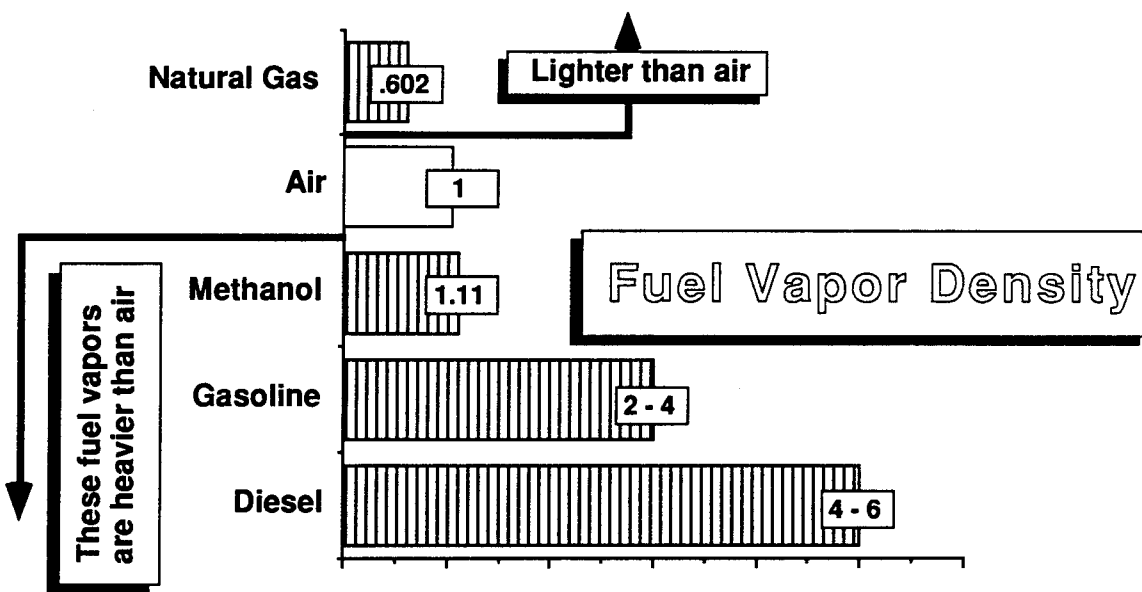
Odor threshold
 Breathing CNG
 Skin exposure
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Physical Properties (con't)

Density

Methane, or natural gas, is lighter than air because it is less “dense” than air. Vapors that are less dense than air will tend to rise when released.

The density of natural gas compared to other fuel vapors is shown below.



CNG - What is it?

CNG - What is it?

Physical Properties

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 Density
 •High Pressure
 Fuel value
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Effects on Health

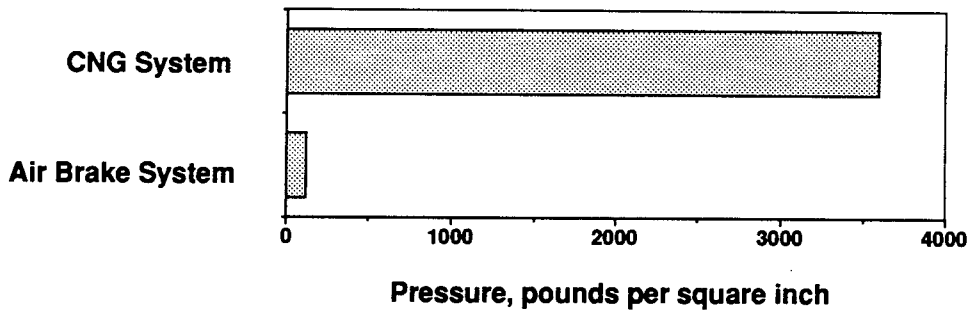
Odor threshold
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Physical Properties (con't)

High Pressure

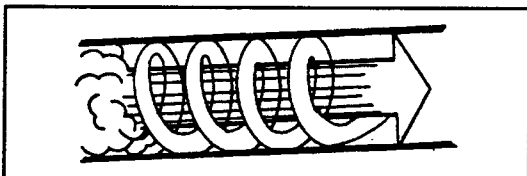
Compared to liquids, gases are not as dense. In order to get enough natural gas into vehicle fuel tanks, it must be compressed to a high pressure - often to 3600 pounds per square inch (psi).

This is 30 times the pressure in an air brake system! For this reason, CNG fuel tanks are approximately 3/4 inch thick.



This high pressure allows much more natural gas to be put into the fuel tank. But it also means that there is a large force on high pressure components.

The compressed gas acts like a spring.



If a fuel system component fails, this pressure can be released suddenly and forcefully.

CNG - What is it?

- Physical Properties
 Composition
 Odor/Appearance
 Density
 High Pressure
 •Fuel value
 •Octane/Cetane

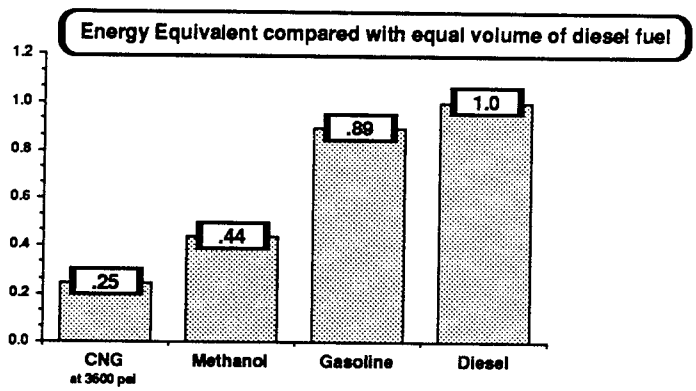
- Flammability
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 Flammability limits
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- Effects on Health
 Odor threshold
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Physical Properties (con't)

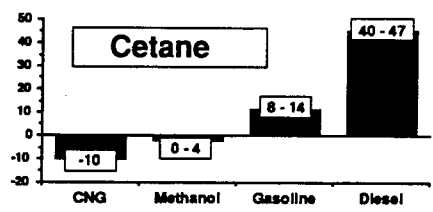
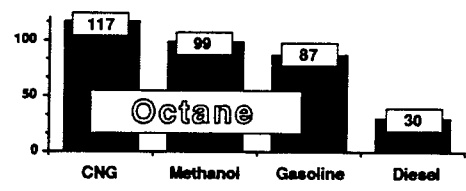
Fuel value

Compared to methanol, gasoline, and diesel fuel, CNG has less energy per volume.



Octane/Cetane

The higher the octane rating of a fuel, the less the fuel will “knock.” CNG has the highest octane rating when compared to methanol, gasoline, and diesel fuel.



CNG also has the lowest “cetane” number. The lower the cetane number, the greater the delay between when the fuel enters the cylinder and when it begins to burn. This is because CNG also has the highest ignition temperature.

CNG - What is it?

CNG - What is it?

Physical Properties

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Density
High Pressure
Fuel value
Octane/Cetane

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•Luminosity
•Ignition
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Skin exposure
Exhaust

Flammability

Dangers

As with any fuel, the use of natural gas requires awareness of potentially hazardous situations.

- > As with any fuel, natural gas is **FLAMMABLE** and **FIRE** is a danger.
- > In a confined area, **UNDER CERTAIN CONDITIONS**, natural gas could cause an **EXPLOSION**.

Luminosity

The flame of burning natural gas is clearly visible.



Ignition

For a fuel to burn, it must...

- 1) be vaporized. CNG is always a vapor. The fuel must also...
- 2) be within its ignition limits - the proper proportions of oxygen and fuel vapors and finally,
- 3) it must have an ignition source.

Ignition sources for natural gas are...

- Sparks caused by electrical equipment (like grinding wheels) or static electricity.
- Hot surfaces are less of a danger for natural gas than for other fuels, but can still cause ignition.
- Open flames will cause any fuel vapor/oxygen combination within its ignition limits to ignite.



CNG - What is it?

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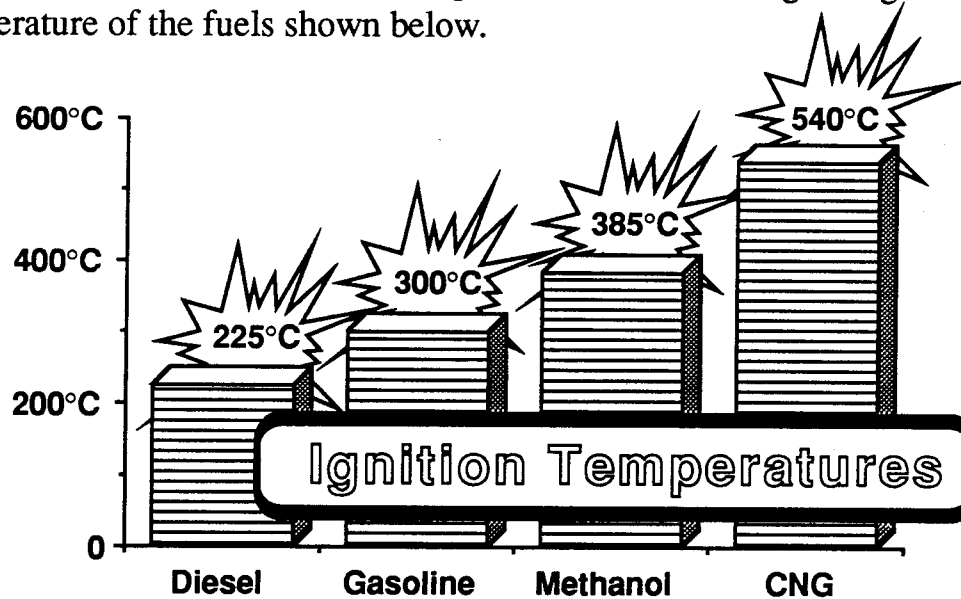
Effects on Health

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Flammability (con't)

Ignition temperature

Ignition temperature is the temperature at which the fuel, when mixed in the proper proportion with air, can ignite. CNG has the highest ignition temperature of the fuels shown below.



Spark assistance

High pressure, like that found in an engine cylinder, can create a high temperature. Autoignition can be used in an engine if the fuel will ignite quickly enough at these temperatures. Because CNG will not ignite easily, it requires spark assistance to ignite in an engine cylinder. Some natural gas engines use diesel fuel to provide a pilot flame.

CNG - What is it?

CNG - What is it?

- Physical Properties
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 Fuel value
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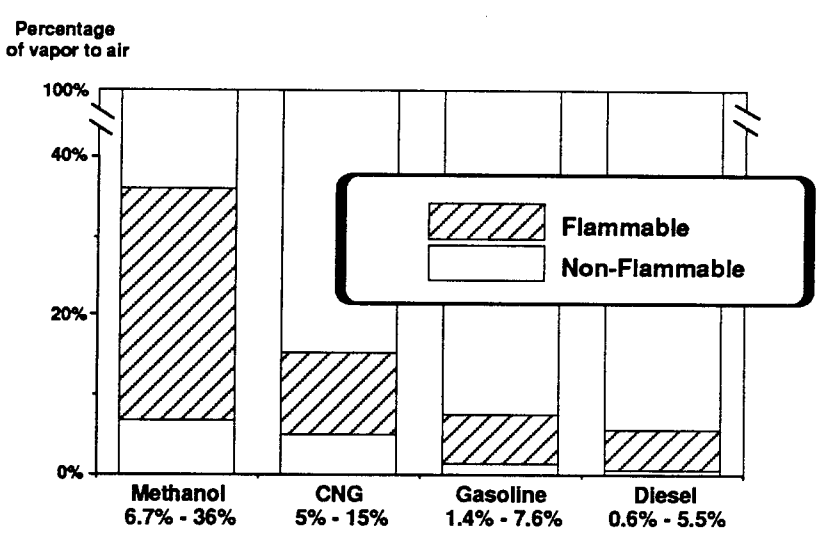
- Flammability
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 Ignition
 Ignition temperature
 Spark assistance
 •Flammability limits
 •Combustible Gas Detectors

- Effects on Health
 Odor threshold
 Breathing CNG
 Skin exposure
 Exhaust

Flammability (con't)

Flammability limits

Flammability limits are extremes where combustion can occur. At the upper limit, there is not enough air for the mixture to burn. At the lower limit, there is not enough fuel to burn. The fuel will burn at any mixture in between. Compared with methanol, gasoline and diesel fuel, CNG is flammable over a wider range than gasoline and diesel, but not as wide a range as methanol.



Combustible Gas Detectors

Many CNG installations have combustible gas detectors. Because natural gas is lighter than air, these gas detectors are usually located on the ceiling and are usually set to sound an alarm at 1/5 of the lower flammability limit.

Combustible gas detectors provide an extra margin of safety by warning of fuel leaks.

CNG - What is it?

CNG - What is it?

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Combustible Gas Detectors

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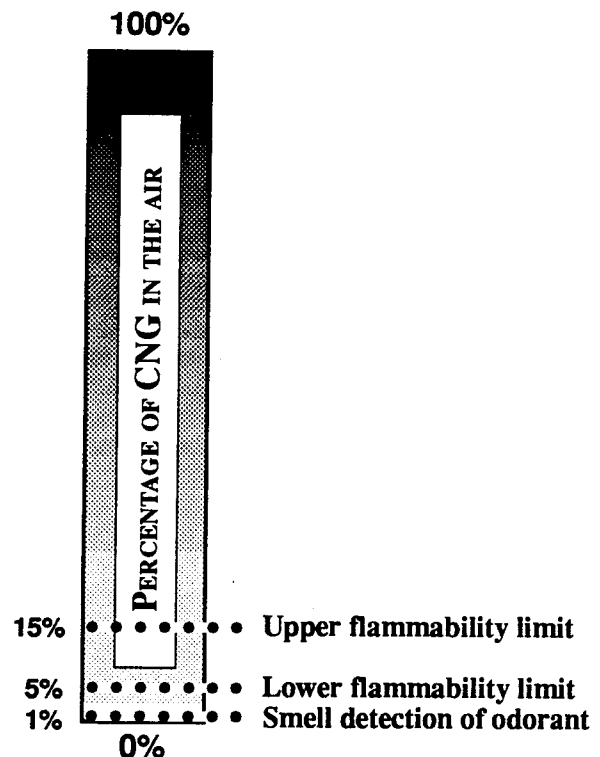
Effects on Health

Odor threshold

The average person can detect the presence of the sulphur odorant when the natural gas concentration is about 1% of the surrounding air. (This level is determined by an established formula of 1/5 of the lower flammability limit of natural gas, which is 5%). 1/5th of 5% is 1%.

At a concentration of 1%, most people should detect the sulphur odor. 1% is well below the level which would be considered either flammable or suffocating.

However, persons exposed to natural gas odor for a long period of time often find that the smell is no longer noticeable.



CNG - What is it?

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Density
High Pressure
Fuel value
Octane/Cetane

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Ignition temperature
Autoignition
Flammability limits
Combustible Gas Detectors

Effects on Health

Odor threshold
•Breathing CNG
•Skin exposure
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Effects on Health (con't)

Breathing CNG

Natural gas is considered to have low levels of toxicity because less than 1% of it consists of hydrocarbons considered to be toxic. Even with the sulfur odorant, the toxicity of CNG is still low.

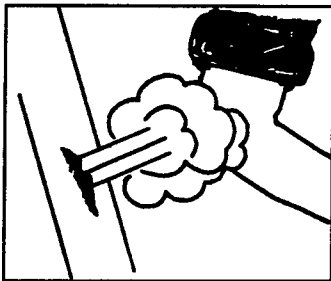
However, as with all fuels, excessive exposure should be avoided.

In a confined area, large quantities of natural gas can displace oxygen. A person in the confined area is at risk of suffocation due to lack of oxygen.

This could lead to eventual suffocation for persons in the area who fail to seek fresh air.

Skin exposure

No chemical danger exists from the exposure of natural gas to skin.



However, natural gas that is compressed to be used as a transportable vehicle fuel is under high pressure.

Concentrated high pressure releasing of the gas directly on the skin could cause skin injury.

CNG - What is it?Physical Properties

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Odor threshold
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 •Exhaust

Effects on Health (con't)**Exhaust**

It is not wise to stay in the vicinity of engine exhaust. This includes engines that burn alternative fuels. Always use exhaust ventilation when running an engine indoors.

Although CNG produces fewer harmful emissions than conventional fuels, the cumulative effects of engine exhaust can still be dangerous.

Although specific emissions data are still being evaluated, CNG exhaust contains very little SOOT compared to diesel exhaust.

ALDEHYDES, such as formaldehyde, are still present in CNG exhaust but can be controlled by engine design and proper tuning.

NITROUS OXIDES are still present, as in gasoline and methanol exhaust, but reactive HYDROCARBONS, which contribute to smog, are greatly reduced.

Safety Precautions and Procedures

Safety Precautions and Procedures

General

•Precautions

Fire

•CNG fire risks

Fire Safety Rules
Fire response

Accidents

Accident procedures-Facilities
Accident procedures-Vehicle

Inhalation

Avoiding exposure
Treatment

General

Precautions

As mentioned earlier, the three potential dangers of natural gas are...

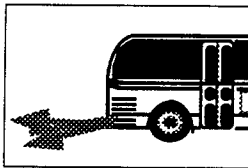
- ◇ Fire
- ◇ High Pressures
- ◇ Health Hazards

All of the following rules and procedures are designed to protect against these dangers.

Fire

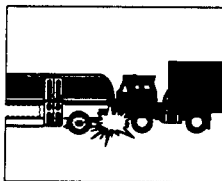
CNG fire risks

From vehicle system failures



Because fuel is stored in strong high pressure tanks, the threat of casual leaks is greatly reduced. On the other hand, because of the high pressure, leak rates could be high if a leak does occur.

From traffic accidents



Because several tanks are required in order to store enough fuel to make CNG use practical, connecting lines are necessary. This increases the vulnerability of the system to damage from severe collision. The risk of exposure to an ignition source is no greater for CNG than for diesel fuel, but due to the high pressure of the system, a fire which results from a collision could be severe.

Safety Precautions and Procedures

General
Precautions

Fire
•CNG fire risks
Fire Safety Rules
Fire response

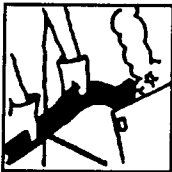
Accidents
Accident procedures-Facilities
Accident procedures-Vehicle

Inhalation
Avoiding exposure
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Fire (con't)

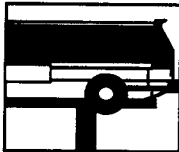
CNG fire risks (con't)

During fueling



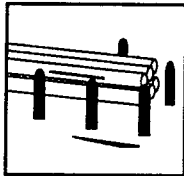
Because of the need for flexible connections and disconnect fittings with seals, the probability of slight leaks during fueling is relatively high. However, because CNG fueling is usually done outdoors, the gas vapors will tend to rise and dissipate. Even for larger leaks, the lack of an ignition source will minimize the possibility of fire.

During maintenance and repair



During procedures to repair fuel leaks and depressurize fuel tanks for maintenance, a location outdoors or inside an explosion-proof facility is recommended. The absence of ignition sources minimizes fire probability.

On-site fueling facility



CNG fuel facilities require a connection to the natural gas supply system, a compressor, a prime mover for the compressor, a CNG storage facility called a "cascade" and a fueling hose. Extra measures to provide protection from collision damage with above-ground portions and inadvertent damage to underground pipes is recommended. Strategically placed shut-off valves are essential to minimize risks. Some bus designs use interlock switches to prevent the bus from being started while the fueling hose is connected.

The Threat of Fire in Tanks

The CNG is compressed inside tanks without air. Since there is no air in the tanks, there is NO CHANCE of fire or explosion occurring inside a sealed tank.

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Fire (con't)

Fire Safety Rules

Keep all ignition sources away from natural gas

- Do not strike matches or smoke cigarettes.
- Do not operate welding or cutting tools in the immediate area.
- Do not use tools that generate sparks, like grinding wheels, in the immediate area.
- Do not operate electrical equipment which is not approved for use near flammable gases.



Ensure that fueling connections are secure and fittings are properly locked.

Know the location of all shut-off valves.

- At the dispenser.
- At the compressor.
- At the control panel.
- On the vehicle.

Safety Precautions and Procedures

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CNG fire risks
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•Fire response

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•Accident procedures-Facilities
Accident procedures-Vehicle

Inhalation
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Treatment

Fire (con't)

Fire response

■ Assess the situation.

The most practical way to extinguish a CNG fire is to **shut off the source of gas**. Where shutting off the flow of gas is not possible, such as on a wrecked vehicle, consider extinguishing the fire.

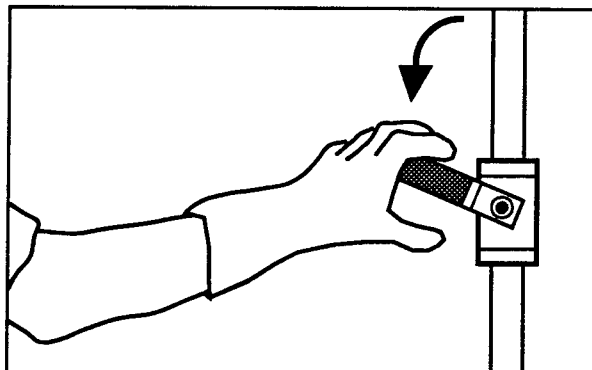
■ Extinguishing a CNG fire.

- If the fire is small and can be fought without personal danger, use a fire extinguisher.
- Be aware that fire extinguishers may be less effective on natural gas fires than on other types of fires.
- Extinguishing the fire may be undesirable because of the possibility of re-ignition.
- If the fire is severe, **CALL PROFESSIONAL FIREFIGHTERS**.

Accidents

Accident procedures - Facilities

Shut off the flow of gas.



Safety Precautions and Procedures

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Accident procedures-Facilities
•**Accident procedures-Vehicle**

Inhalation
•**Avoiding exposure**
•**Treatment**

Accidents (con't)

Accident procedures - Vehicle

Normal vehicle accident response procedures should be undertaken, with the following considerations for CNG...

accident procedures

Be aware that using CNG as a fuel requires special consideration.

- ① Shut off the engine.
- ② Listen for a hissing sound indicating a leak.
- ③ Check for the odor of a leak.

If a leak is found...

- ④ Turn off the shut-off valve. If that is not possible, or if the leak continues
- ⑤ Move everyone upwind in a calm and orderly fashion.

Inhalation

Avoiding exposure

Inhaling small quantities of natural gas is not considered harmful. Inhaling large quantities of natural gas in a confined area could lead to suffocation.

Treatment

Treatment for excessive inhalation exposure to natural gas includes providing the victim with fresh air and artificial respiration and/or oxygen, if necessary.

Safety Precautions and Procedures

Operating Vehicles with CNG

Operating Vehicles with CNG

Vehicle Operations

- Operating characteristics
- Venting
- Condensation
- Overheating
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- Questions from passengers

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- Safety Rules
- Checking for leaks
- Tanks
- Parts
- Heat shielding

Fueling

- Safety Rules
- Toxicity
- Hoses/fittings

Common Questions and Answers

Vehicle Operations

Operating characteristics

CNG as an engine fuel exhibits the following characteristics...

- ✓ high octane
- ✓ reduced exhaust emissions
- ✓ no cold start problems
- ✓ no hot start problems

Venting

In the unlikely event of excessive pressure in the CNG tanks due to extreme heat, a thermal/pressure relief valve will vent the contents of the tanks through the upper portion of the coach and release it into the atmosphere.

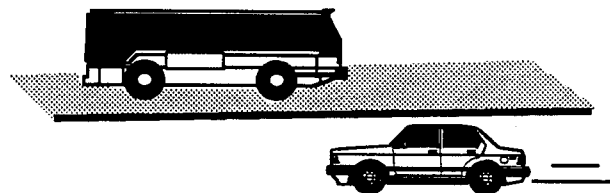
Condensation

During cold start-ups of the vehicle, some condensation and water dripping from the exhaust pipe may occur. This is considered normal.

Overheating

The same precautions and procedures regarding engine overheating should be taken for CNG fueled vehicles as for any conventionally fueled vehicle. The vehicle should be pulled to the side of the road, shut down, and the Dispatcher contacted.

Note: CNG engine exhaust is hotter than diesel exhaust. Nearby components are hot! Ensure that all the manufacturer's heat shielding is in place.



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Vehicle Operations (con't)

Accident procedures

In the event of an accident, appropriate vehicle accident response procedures should be undertaken, with the following considerations for CNG...

accident procedures

Be aware that using CNG as a fuel requires special consideration.

- ① Shut off the engine.
- ② Listen for a hissing sound indicating a leak.
- ③ Check for the odor of a leak.

If a leak is found...

- ④ Turn off the shut-off valve. If that is not possible, or if the leak continues
- ⑤ Move everyone upwind in a calm and orderly fashion.

Questions from passengers

Many passengers will be curious about CNG fuel. Some will likely be concerned about the safety of the vehicle.

A common concern is that the pressurized gas could blow up like a bomb. This is impossible because there is no air in the tank to burn the fuel.



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Common Questions
and Answers**Repairing - general****Safety Rules**Keep all ignition sources away from natural gas fuel systems

- Do not strike matches or smoke cigarettes.
- Do not operate welding or cutting tools in the immediate area.
- Do not use tools that generate sparks, like grinding wheels.
- Do not operate electrical equipment which is not approved for use near flammable gases.

Ensure that fueling connections are secure and fittings are properly locked.Know the location of all shut-off valves.

- ▶ At the dispenser.
- ▶ At the compressor.
- ▶ At the control panel.
- ▶ On the vehicle.

NOTE: Never use CNG to pressure test any component.

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Common Questions

and Answers

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Checking for leaks

- Leaks are generally detected by
 - hearing a hissing sound,
 - smelling the sulfur odorant, or by
 - visual observation of icing around the leak.

Tanks, because of their thickness and strength, **WILL NOT RUPTURE.**

Troubleshooting for leaks should involve soaping suspected locations or handheld gas detectors, but should **never** involve the use of flame.



DO NOT try to fix leaks under pressure. Remove the pressure first.

Tanks

Generally, tanks would only be removed for inspection and recertification. Only trained and certified mechanics following approved procedures may remove and/or repair tanks. Approved procedures must be followed for purging tanks.

Parts

Replacement parts **MUST BE** designed for use with CNG and carry an adequate pressure rating. For example, fittings are required to have adequate threads for the operating pressure. In particular, brass fittings must be avoided before the first stage regulator. All non-routine repairs to the fuel system should be verified by engineering staff.

Heat shielding

One major difference between the CNG engine and the diesel engine is the higher combustion temperature of the CNG engine. This may require more attention to heat shielding.

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Common Questions and Answers**Fueling****Toxicity**

No toxic effects are expected from inhalation or skin exposure to CNG. However, because of the high pressures involved, it is possible that a direct exposure to a fuel leak could cause physical injury.

The risk of toxicity from CNG leaks is generally less than from diesel.

Hoses/fittings

Fueling hoses are equipped with break-away fittings. Some fuel doors have starter lock-outs. A static groundwire is built into the system.

Fueling hoses are rated at four times the pressure of the fuel. The risk of a hose breaking is minimal, unless the hose has been damaged.

However, in the unlikely event of a break, the hose would whip around wildly and could cause injury.

EMERGENCY SHUT-OFFS SHOULD BE ACTIVATED IMMEDIATELY.



To avoid damage to the fueling hose...

- » DO NOT lay the hose on the ground
- » DO NOT run over the hose
- » AVOID kinking the hose
- » DO NOT use a frayed hose - report it
- » BE CAUTIOUS not to drop the hose
- » If you suspect a hose is bad, do not use it - get it inspected

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Common Questions and Answers

What are the major advantages of natural gas as a vehicle fuel?

- 1) Natural gas is cheaper per gallon equivalent than gasoline or diesel.
- 2) Natural gas produces fewer pollutants than most fuels.
- 3) Natural gas supplies are abundant and available domestically.
- 4) Based on physical properties, natural gas vehicles are safer than gasoline powered vehicles.

How does the compressed natural gas vehicle system work?

Natural gas is compressed to approximately 3000 to 3600 psi and stored in reinforced tanks under or over the vehicle. When the gas is needed, it passes through manual shut-off valves to a high pressure reducer or regulator located in the engine compartment.

The natural gas enters the carburetor at atmospheric pressure through a specially designed natural gas mixer where it is mixed with air in the proper proportions and fed to the engine for combustion. Special solenoid valves prevent the gas from entering the engine when it is shut off.

Are the high pressure CNG tanks dangerous?

These cylinders are manufactured and tested in compliance with strict Department of Transportation regulations. The metal tank walls are approximately 3/4 inch thick. Stringent and severe tests have proven these tanks durable and safe.