PDHonline Course K126 (3 PDH)

Use of Compressed Natural Gas and Liquefied Petroleum Gas as an Alternative Motor Fuel

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United States Energy Policy Acts (EPACT) of 1992, 2005 & 2007

The Energy Policy Act (EPACT) of 1992 defines CNG and LPG as alternative fuels. **EPACT and the Alternative Motor Fuels Act of 1988**

EPACT required the federal government to begin purchasing alternative fuel vehicles in 1993 and required state fleets and alternate fuel providers to begin purchasing Alternative Fuel Vehicles (AFVs) in 1997 model year. The Act affects all "persons" operating at least 50 vehicles in the US in cities with a population over 250,000 as of 1980. As a result, EPACT has been a prominent variable in the deployment and use of alternative fuel vehicles in the United States.

EPACT mandated the use AFVs legislation such as the Transportation Equity Act for the 21st century (TEA-21) provided funding which became available to government fleets to make procurement and use of AFVs more affordable. Additionally, Congress provided for tax deductions which made AFV purchases less expensive and tax credits for AFV purchases exceeding EPACT requirements.

Another regulatory influence over AFV fleet penetration was the favorable treatment flex-fuel vehicles (FFVs) received from CAFE as a result of the Alternative Motor Fuels Act (AMFA) of 1988. Flex-fuel vehicles are capable of operating on either gasoline or an alternative fuel, in most cases ethanol (E85), methanol (M85) and biodiesel.

Alternative Fuel Definition

The following fuels are defined as alternative fuels by the Energy Policy Act (EPAct) of 1992: pure methanol, ethanol, and other alcohols; blends of 85% or more of alcohol with gasoline; natural gas and liquid fuels domestically produced from natural gas; liquefied petroleum gas (Autogas or Propane); coal-derived liquid fuels; hydrogen; electricity; pure biodiesel (B100); fuels, other than alcohol, derived from biological materials; and P-Series fuels. In addition, the U.S. Department of Energy (DOE) is authorized to designate other fuels as alternative fuels, provided that the fuel is substantially nonpetroleum, yields substantial energy security benefits, and offers substantial environmental benefits. For more information about the alternative fuels defined by EPAct 1992 as well as DOE's alternative fuel designation authority, visit the EPAct web site http://www.afdc.energy.gov/laws/key_legislation (Reference 42 U.S. Code 13211)

2005 Energy Independence & Security Act –CNG/LPG provisions

- **The Energy Policy Act of 2005 (Pub.L. 109-058) is a statute that was passed by the United States Congress on July 29, 2005, and signed into law by President George W. Bush on August 8, 2005.**
- **Requires federal fleets to use alternative fuels or dual-fuel vehicles.**
- **Provides a tax credit to purchasers of new dedicated AFVs. The tax credit equals 50% of the incremental cost of the vehicle, plus an additional 30% of the incremental cost for vehicles with near-zero emissions. The credit is available on the purchase of light-, medium-, and heavy-duty vehicles and fuel-cell, hybrid, and dedicated natural gas, propane, and hydrogen vehicles. Light-duty lean burn diesel vehicles are also eligible.**
- **Contained in that legislation was the alternative fuel vehicle refueling property credit, otherwise known as the infrastructure credit. CNG & LPG (Propane) is among the alternative fuels whose infrastructure is eligible for the credit. This credit can be applied to infrastructure placed in service after December 31, 2005 and before January 1, 2010. The provision permits taxpayers to claim a 30% credit for the cost of installing the infrastructure to be used in a trade or business of the taxpayer or installed at the principal residence of the taxpayer. In the case of retail property, the credit may not exceed $30,000 for each property placed in service and in the case of residential property the credit may not exceed $1,000. IRS Form 8911 and the instructions thereto explain how to file for the credit and how the credit interacts with the expensing and deductibility of that same property.**

2007 U.S. Energy Independence & Security Act –CNG/LPG provisions

- **Signed December 19, 2007; requires the Department of Transportation (DOT) to develop a new system of rating vehicles that makes it easier for consumers to compare fuel economy and greenhouse gas emissions of vehicles. Requires new labeling for fuel economy information, greenhouse gas emission benefits, and alternative fuel use.**
- **Prohibits federal fleets from acquiring vehicles that are not a low GHG emitting vehicle.**

- **Requires a study of methods of increasing the fuel efficiency of vehicles using biogas by optimizing natural gas vehicle systems that can operate on biogas, including the advancement of vehicle fuel systems and the combination of hybrid-electric and plug-in hybrid electric drive platforms with natural gas vehicle systems using biogas.**
- **Requires the Department of Transportation (DOT) to develop a new system of rating vehicles that makes it easier for consumers to compare fuel economy and greenhouse gas emissions of vehicles. Requires new labeling for fuel economy information, greenhouse gas emission benefits, and alternative fuel use.**

Fuel Properties, Comparisons, Cost per GGE, and Other Data

From: US Department of Energy; Energy Efficiency and Renewable Energy; Alternative Fuels and Advance Vehicle Data Center

This web page features a very useful tool that allows users to create custom charts comparing fuel properties and characteristics for multiple alternative fuels. It provides information on usability, safety, physical properties, emissions, energy security, costs, and other pertinent topics. Gasoline and #2 Diesel are provided for comparison purposes.
http://www.afdc.energy.gov/afdc/fuels/properties.html

CNG AS MOTOR VEHICLE TRANSPORTATION FUEL

Natural gas used in stoves, furnaces & boilers or "pipeline" natural gas should not be used for motor vehicle fuel. The general specifications for natural gas to be used as a motor fuel are described in SAE International Standard J1616. This standard covers requirements for CNG for minimum amounts of Water, Hydrogen Sulfide, Carbon Dioxide, Oxygen, Particulates, Odorant and Lubricating Oil. CNG refueling facilities at a minimum should include: Dryers, Multi-Stage Compressors, CNG Storage Vessels and Priority Panel. The local natural gas utility should informed the CNG Station operator that "Propane/Air Peak Shaving" is in place, a technique to add more propane to the pipeline natural gas during extreme cold weather periods.

Recent media attention and changes in energy policies have made CNG/LPG a valid option for bridging the nation's main transportation fuel from gasoline/diesel to a short term energy source. While the U.S. possesses by far, the largest reserves of natural gas, the production, distribution and processing (infrastructure) of CNG as a transportation fuel is not as common as the major media might lead us to believe.

More than 99 percent of the natural gas used in the United States comes from domestic or other North American sources. However, increasing demand for natural gas in power plants will require new supplies from non-North American countries, increasing our dependence on foreign sources of energy. The Energy Information Administration (EIA) predicts that, by 2025, more than 15 percent of our natural gas supplies will be imported from countries other than Canada and Mexico.

Natural gas has been used as a motor vehicle fuel since the 1930s. In fact, Chrysler, Ford, and General Motors once offered passenger vehicles fueled by CNG, sold primarily to fleets. Today one out of every five new buses uses CNG.

Compressed natural gas, or CNG, is natural gas under pressure which remains clear, odorless, and non-corrosive. Although vehicles can use natural gas as either a liquid or a gas, most vehicles use the gaseous form compressed to minimum pressures above 3,100 pounds per square inch (PSI).

How is CNG used for powering vehicles?
This is accomplished by the following steps:

1. **Natural gas is compressed and enters the vehicle through the natural gas dispenser or fill post The three approaches to filling a vehicle with natural gas:**
   - **A) Time Slow Fill, Vehicles are fueled during periods of down time lasting several hours.**
   - **B) Buffer Fast Fill, When numerous vehicles w/large-capacity fuel cylinders are refueled at peak times.**
   - **C) Cascade Fast Fill, When vehicles are refueled at fewer peak times & mostly throughout the day.**

2. **It flows into high-pressure cylinders that are located on the vehicle.**
3. **When the driver steps on the accelerator, the natural gas leaves the on-board storage cylinder, passes through the high-pressure fuel line and enters the engine compartment.**
4. **Gas then enters the regulator, which reduces pressure from up to 3,600 psi to approximately atmospheric pressure.**
5. **The natural gas solenoid valve allows natural gas to pass from the regulator into the gas mixer or fuel injectors.**
6. **Natural gas mixed with air flows down through the carburetor or fuel injection system and enters the engine's combustion chambers.**

To provide adequate driving range, CNG must be stored onboard a vehicle in tanks at high pressure—up to 3,600 PSI. A CNG-powered vehicle gets about the same fuel economy as a conventional gasoline vehicle on a gasoline gallon equivalent (GGE) basis. A GGE is the amount of alternative fuel that contains the same amount of energy as a gallon of gasoline. A GGE equals about 5.7 lb (2.6 kg) of CNG.

CNG has its advantages and disadvantages over conventional gasoline. Compared to gasoline, CNG has much cleaner emissions while, providing similar fuel economy, performance, and driveability. Its relative energy cost can be about half that of gasoline when using a home-fueling station. And it's mostly a domestically produced energy source; 85 percent of the CNG consumed in the U.S. is also domestically produced. The use of natural gas as a transportation fuel reduces operating cost and emissions. It is very accessible in countries where there are existing distribution infrastructures.

<u>The main factors which stimulates interest in Natural Gas Vehicles (NGV) in U.S.</u>

1. **U.S. energy security encourages use of alternative transportation fuels in order to decrease national dependence on volatile foreign oil markets.**
2. **Environmental pollution in urban areas attracts the use of cleaner-burning fuels.**
3. **Countries with abundant supplies of natural gas find the use of NGVs in order to reduce trade imbalances due to oil imports.**

IS CNG THE ANSWER?

Some have stated that the advantages of using CNG as a motor fuel is outweigh by the economic burden to reinvest in immediate major CNG motor fuel infrastructure rebuilding necessary for CNG. The cost of infrastructure change has to be amortized through fuel purchases or government subsidies/grants.

CNG does have significant existing private/fleet motor fuel infrastructure, in some areas of the U.S. and more so in large urban commercial/governmental fleets. While the raw natural gas distribution pipeline infrastructure from the natural gas wellheads to processing centers lack the capacity to maintain additional demand. Major construction of these delivery/process systems will have to be undertaken.

Existing heavy duty motor vehicle conversion to CNG and manufacture production/retooling would be additional stumbling blocks to wide spread use of CNG. Consider the conversion of diesel-powered heavy duty fleets to CNG requires major vehicle modifications to enable CNG or duel fuel applications. Fleet operations would expend large investments while relying that they are the chicken and the egg would follow.

LIQUEFIED NATURAL GAS (LNG)

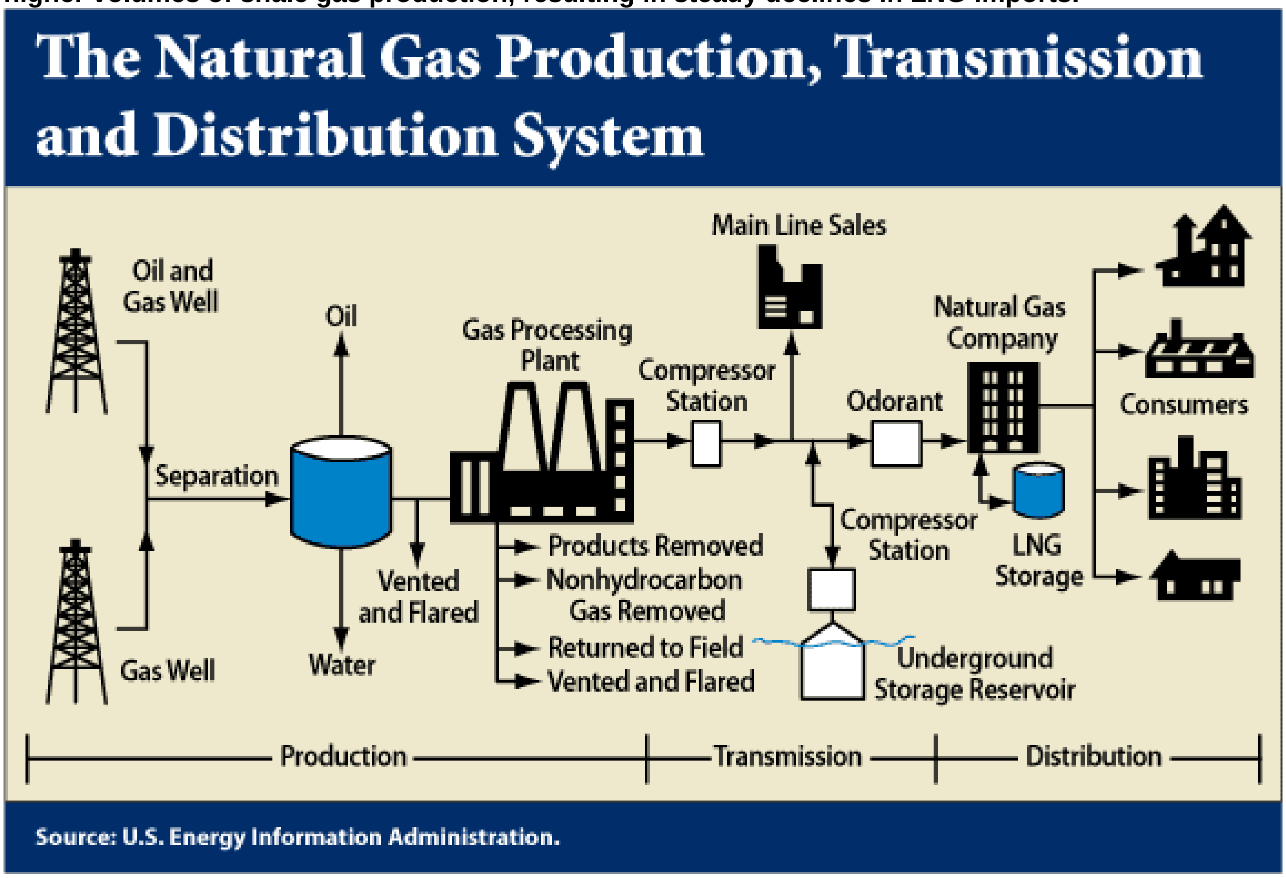
To store more energy onboard a vehicle in a smaller volume, natural gas can be liquefied. To produce LNG, natural gas is purified and condensed into liquid by cooling to -260°F (-162°C). At atmospheric pressure, LNG occupies only 1/600 the volume of natural gas in vapor form. A Gasoline Gallon Equivalent (GGE) equals about 1.5 gallons of LNG. Because it must be kept at such cold temperatures, LNG is stored in double-wall, vacuum-insulated pressure vessels. LNG fuel systems typically are only used with heavy-duty vehicles. While LNG is reasonably costly to produce,

advances in technology are reducing the costs associated with the liquification and regasification of LNG.

Natural gas can be blended with hydrogen to make hydrogen/natural gas blends (HCNG). Vehicles fueled with HCNG are an initial step toward the hydrogen-based transportation of the future. HCNG vehicles offer the potential for immediate emissions benefits, such as a reduction in nitrogen oxides (NO_x) emissions. At the same time, they can pave the way for a transition to fuel cell vehicles by building early demand for hydrogen infrastructure.

LNG is made by compressing natural gas (which is mainly composed of methane (CH_4)), to less than 1% of its volume at standard atmospheric pressure. It is stored and distributed in hard containers, at a normal pressure of 200–220 bar (2900-3200psi), usually in cylindrical or spherical shapes.

According to the EIA, the U.S. imported 0.41 Trillion Cubic Feet (Tcf) of natural gas in the form of LNG in 2010. However, the U.S. Energy Information Administration (EIA), in its Annual Energy Outlook 2013, forecasted that the United States will become a net exporter of LNG by 2016. This projection is supported by growing supplies of domestically produced natural gas, aided partly by higher volumes of shale gas production, resulting in steady declines in LNG imports.



LPG (AUTO GAS PROPANE) AS MOTOR VEHICLE TRANSPORTATION FUEL

Propane is an energy-rich gas, C_3H_8. It is one of the liquefied petroleum gases (LP-Gas or LPGs) that are found mixed with natural gas and oil. Propane and other liquefied gases, including iso-butane, ethane and n-butane, are separated from natural gas at natural gas processing plants, or from crude oil at refineries. The amount of propane produced from natural gas and from oil is roughly equal (50% ratio-this changes with pricing and supply issues).

Propane naturally occurs as a gas. However, at higher then ambient pressure or lower temperatures, it becomes a liquid. Because propane is 270 times more compact as a liquid than as a

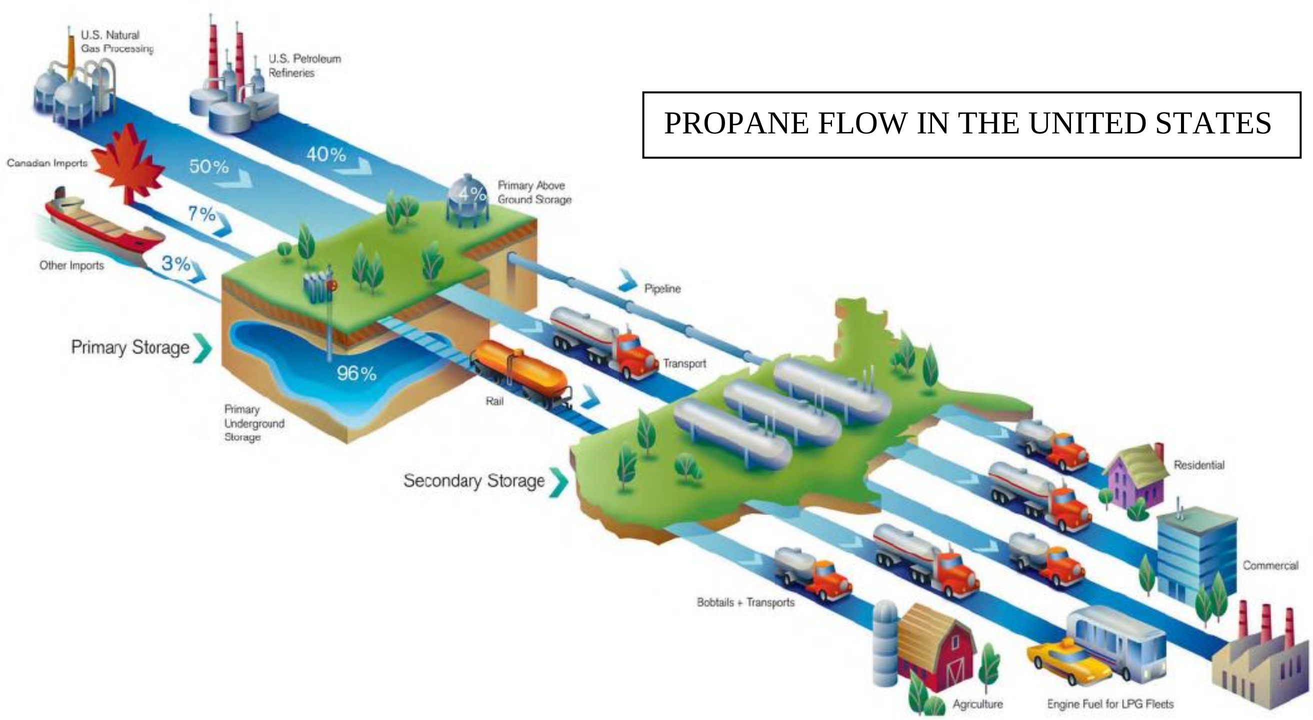
gas, it is transported and stored in its liquid state. Propane becomes a gas again when a valve is opened to release it from its pressurized container. When returned to normal pressure, propane becomes a gas so that we can use it.

Turning LPG in a liquid occurs at a moderate pressure, 160 psi, and is stored in pressure tanks at about 200 psi at 100 degrees Fahrenheit. The LPG is drawn out of the tank in liquid form from a liquid withdrawal opening, and then converted to vapor by a vaporizer (now referred to as a converter) inside the engine compartment, as a gas before it is combusted in the engine. For the vapor Bi-Fuels systems, Liquid Propane Injection (LPI) as the name implies, injects the liquid directly, this is popular with dedicated systems. Propane has been used as a transportation fuel since 1912 and is the third most commonly used fuel in the United States, behind gasoline and diesel.

More than five million vehicles fueled by propane are in use around the world in light, medium, and heavy-duty applications. Propane holds approximately 85 percent of the energy of gasoline and so requires more storage volume to drive a range equivalent to gasoline, but it is price-competitive on a cents-per-mile-driven basis. LPG infrastructure is more entrench in various areas (urban and rural) of the U.S. According to the Department of Energy (DOE), there are 2,600 LPG public fueling stations nationwide, representing the largest fueling infrastructure of any alternative fuel.

- **Propane's higher octane burns cleaner and results in more hours and running-time between maintenance stops**
- **No carbon buildup means much less wear and less maintenance on oil, oil filters, spark plugs, carburetors, and engines in general**
- **Using propane instead of gasoline reduces carbon monoxide emissions by as much as 60%, carbon dioxide emissions by around 12%, and nitric oxide emissions by around 20% (source)**
- **Using propane instead of gasoline cuts emissions of toxins such as benzene and toluene by as much as 96% (source)**
- **Drastically reduces particulate emissions, and virtually eliminates black smoke from exhaust of diesel engines**
- **Reduce Dependency On Foreign Oil**
- **90% of propane we use is produced domestically**

Propane-fueled vehicles are already common in many parts of the world. The fuel offers most of the environmental benefits of CNG, including high octane – which means higher compression, more efficient, engines can be used.



NATURAL GAS & LPG SUPPLY/DEMAND

Taking a look at 2013 US data from the Energy Information Administration (EIA)

U.S. Production (Dry Natural gas production)	**24,282 billion cubic feet**
U.S. Natural Gas Consumption	**26,035 billion cubic feet**
U.S. Natural Gas Imports	**2,883 billion cubic feet**
U.S. Natural Gas Exports	**1,572 billion cubic fee**
Dry Natural Gas Proved Reserves (2012)	**308,036 billion cubic feet**

In 2013, EIA estimated that there are 2,203 trillion cubic feet (Tcf) of natural gas that is technically recoverable in the United States. At the rate of U.S. natural gas consumption in 2011 of about 24 Tcf per year, 2,203 Tcf of natural gas is enough to last about 92 years. Technical advances may add an additional 400 to 500 trillion cubic feet by 2030. This has increase (tripled) dramatically with hydraulic fracturing (fracking) drilling coming on line in US shale deposits.

LPG or propane demand in 2010 was roughly 20 billion gallons. Since LPG is made from approximately 50% ratio of natural gas and crude oil, propane supply is tied to the reserves of these products (recently this ratio is about 50% natural gas and 50% crude oil). The use of LPG as a transportation fuel reduces operating cost and emissions. It is very accessible in countries where there are existing distribution infrastructures.

INDUSTRY & GOVERNMENT REGULATIONS:

US EPA 40 CFR PART 112 REGULATIONS (SPCC SPILL PLANS) ON CNG-LPG STORED IN ABOVEGROUND STORAGE TANKS (ASTS).

Currently, CNG, LNG and LPG are not regulated by the Spill Prevention Control and Countermeasure regulations 40 CFR part 112. Natural gas (including liquid natural gas and liquid petroleum gas) is not considered "oil". EPA does not consider highly volatile liquids that volatilize on contact with air or water, such as liquid natural gas or liquid petroleum gas, to be oil. Petroleum distillate or oil that is produced by natural gas wells and stored at atmospheric pressure and temperature (commonly referred to as condensate or drip gas), however, is considered an oil.

§40 CFR 112.2 *Oil* means oil of any kind or in any form, including, but not limited to: fats, oils, the greases of animal, fish, or marine mammal origin; vegetable oils, including oils from seeds, nuts, fruits, or kernels; and, oils and greases, including, but not limited to, petroleum, fuel oil, oil, sludge, synthetic oils, mineral oils, oil refuse, or oil mixed with wastes other than sludge, oil refuse, and oil mixed with wastes other dredged spoil.

US EPA REGULATIONS PERTAINING TO UNDERGROUND STORAGE TANKS

CNG & LPG are exempt from US EPA regulations concerning underground storage tanks (USTs) contained in 40 CFR Part 280, 40 CFR Part 281, and 40 CFR Parts 282.50-282.105. The list of hazardous substances is in 40 CFR Part 302.4.

PETROLEUM EQUIPMENT INSTITUTE (PEI) INDUSTRY STANDARD RP-1500

Recommended Practices for the Design, Installation, Operation and Maintenance of Compressed Natural Gas Vehicle Fueling Facilities: **Contact: PEI, P. O. Box 2380, Tulsa, OK 74101-2380; 6931 S. 66th E. Ave., Suite #200, Tulsa, OK 74133. 918-494-9696 (telephone) 918-491-9895 (fax)**
Web site: http://www.pei.org/ for ordering RP-1500

This document provides basic background information regarding CNG fueling systems. By itself, this recommended practice will NOT provide all of the information required to successfully

design, build, service or inspect a CNG fueling system. These recommended practices present basic information that should allow the careful reader to understand:
- **The hazards presented by natural gas and CNG;**
- **The terminology used to describe CNG fueling systems;**
- **The various types of CNG fueling systems;**
- **The concepts involved in planning and designing CNG fueling systems;**
- **The basic construction techniques used to build a CNG fueling system;**
- **The basic steps required to properly operate and maintain a CNG fueling system.**

Scope. These recommended practices apply to outdoor CNG facilities that typically receive pipeline-quality natural gas from a utility or non-utility distribution system, remove moisture from the gas, compress the gas to several thousand pounds per square inch (psi), store limited quantities of compressed gas, and dispense the CNG into vehicle fuel tanks

INTERNATIONAL FIRE CODES (IFC) ON CNG & LPG FACILITIES

All CNG & LPG storage and dispensing installations at a minimum must comply with:

IFC CHAPTER 22 SERVICE STATIONS AND REPAIR GARAGES:

- **Refers to facilities that dispenser CNG-LNG to motor vehicles.**

IFC CHAPTER 27 HAZARDOUS MATERIALS - GENERAL PROVISIONS:

- **Refers to facilities that store CNG-LNG in bulk for retailing, blending, production or refining.**

IFC CHAPTER 34 FLAMMABLE AND COMBUSTIBLE LIQUIDS:

- **Refers to facilities that store flammable and combustible liquids in bulk for retailing, blending, production or refining.**

IFC CHAPTER 30 COMPRESSED GASES

- **Storage, use and handling of compressed gases in compressed gas containers, cylinders, tanks and systems shall comply with this chapter, including those gases regulated elsewhere in this code.**

IFC CHAPTER 32 CRYOGENIC FLUIDS (LNG)

- **Storage, use and handling of cryogenic fluids shall comply with this chapter.**

Exceptions: Liquefied natural gas (LNG). Liquefied natural gas shall comply with NFPA 59A. Flammable cryogenic fluids, including hydrogen, methane and carbon monoxide, shall comply with NFPA 50B.

IFC CHAPTER 34 FLAMMABLE GASES

- **The storage and use of flammable gases shall be in accordance with this chapter. Compressed gases shall also comply with Chapter 30.**

IFC CHAPTER 38 LIQUEFIED PETROLEUM GASES

- ***This chapter shall apply to the installation and maintenance of all equipment pertinent to systems for the use of liquefied petroleum gas…..***

The National Fire Protection Association (NFPA) has also issued American National Standards related to AFVs:

- **Compressed Natural Gas Vehicular Fuels Systems (NFPA 52) addresses proper installation of aftermarket conversion kits and emphasizes general CNG and equipment qualifications; engine fuel systems; CNG compression, storage, and dispensing systems; and residential fueling facilities. Some states have adopted NFPA 52 as law.**
- **Storage and Handling of Liquefied Petroleum Gases (NFPA 58) covers many propane applications outside engine fuel systems, but Chapter 8 (Engine Fuel Systems) is of particular importance with regard to conversions. It includes provisions for propane containers, container appurtenances, carburetion equipment, piping, hose, fittings, and their installation. It also contains provisions for garaging of vehicles. Most states have adopted NFPA 58 as the basis of safety regulations for propane.**

- **<u>National Fire Protection Association (NFPA) 30, Flammable and Combustible Liquids Code:</u>**
  <u>NFPA 30 & 30A Flammable & Combustible Liquids</u> governs the Fire Codes that uses and dispenses both liquid and gaseous fuels, including liquid hydrogen to motor vehicles. This applies to locations where CNG, LNG, compressed or liquefied hydrogen, LP-Gas, or combinations of these, are dispensed as motor vehicle fuels along with Class I or Class II liquids that are also dispensed as motor vehicle fuels.

  <u>NFPA 30A, Code for Motor Fuel Dispensing Facilities and Repair Garages:</u>

  FROM NFPA 30/30A, 2008 HANDBOOK: "Facilities that dispense only hydrogen, liquefied natural gas (LNG), or compressed natural gas (CNG) are covered directly by <u>NFPA 52, *Vehicular Fuel Systems Code*</u>. Facilities that dispense only LP-Gas are covered directly by <u>NFPA 58, *Liquefied Petroleum Gas Code*.</u> However, the NFPA Standards Council has given the Technical Committee on Automotive and Marine Service Stations responsibility for developing appropriate requirements for refueling vehicles with alternative gaseous fuels where these are dispensed along with liquid fuels. Facilities that dispense both gaseous and liquid fuels are, therefore, covered by NFPA 30A. Most of the requirements for the use of gaseous fuels at mixed fuel facilities are addressed by referencing the primary document for the fuel, such as NFPA 52 for hydrogen, LNG, and CNG."

  <u>NFPA 52 Vehicular Fuel Systems Code:</u>
  Dispensing of gaseous and liquid fuels (CNG, LNG), shall also be in accordance with the requirements of NFPA 52, *Vehicular Fuel Systems Code*, except as modified by NFPA-30.

  <u>NFPA 58 Liquefied Petroleum Code;</u> Dispensing installation and use of LP-Gas (propane) systems shall meet the requirements of NFPA 58, *Liquefied Petroleum Gas Code*, except as modified by NFPA 30 & 30A.

  <u>NFPA-52 defines the following:</u>

- ***<u>Liquefied Natural Gas (LNG),</u> A fluid in the cryogenic liquid state that is composed predominantly of methane.***
- ***<u>Saturated LNG Gas.</u> Preheated LNG held under pressure and released to atmosphere as a gas.***
- ***<u>Natural Gas.</u> Mixtures of hydrocarbon gases and vapors consisting principally of methane in gaseous form.***
- ***<u>Compressed Natural Gas (CNG).</u> Mixtures of hydrocarbon gases and vapors consisting principally of methane in gaseous form that has been compressed for use as a vehicular fuel.***
- ***<u>Gaseous Fuels.</u> All combinations of gaseous natural gas, hydrogen, propane, ethane, and butane commonly used as automotive fuels as they pertain to refueling sites, onboard fuel systems, safety, dispensing, and vehicle onboard use regardless of the fuel combinations.***

<u>NFPA-58 defines LPG:</u>
Any material having a vapor pressure not exceeding that allowed for commercial propane that is composed predominantly of the following hydrocarbons, either by themselves or as mixtures: propane, propylene, butane (normal or isobutene), and butylene's.

- ✓ **It is made of hydrocarbons. The main component is methane which is a very non-reactive component.**
- ✓ **It has narrow combustion limits. It will ignite only when there is an air and gas mixture of between 5 and 15 percent natural gas.**
- ✓ **Ignition point : 593 degree C**
- ✓ **Relative density : 0.3 m/s +**
- ✓ **It has a flammability range of 4.5% to 14.5%**
- ✓ **It undergoes uninhibited chain reaction.**
- ✓ **When gas is burned completely carbon dioxide and water vapor are produced.**

CNG & LPG CHEMICAL CHARACTERISTICS

Natural gas and liquefied petroleum gas are complex mixtures that can consist of between 300 and 400 organic and inorganic components, many of which are present at relatively low or trace concentrations. Most of these materials are naturally occurring, while some are intentionally added during processing, such as odorants and anti-corrosives. The properties of many of these trace constituents are important since they can strongly affect the overall behavior of the natural gas.

Property	CNG	LPG
Octane Rating (varies with pressure) (1)	120-130 (2900 psi)	105-115 (145 psi)
Specific Gravity of Vapor @ 60ºF, Air = 1.0	0.55 to 0.64	1.50 (Heavier than Air)
Specific Gravity of Liquid @ 60ºF, Water = 1.0	0.42 to 0.46	0.504 to 0.509
Specific Heat of Liquid Btu/lb @ 60ºF (cp)	0.56	0.630
Reid Vapor Pressure psi @ 100ºF	2400	208
Energy Content Btus/gallon	±19,800	±92,500 (average)
Initial Boiling Point ºF @ 14.7 psia	-259	-44
Weight lb/gal @ 60ºF Liquid	3.66 LNG	4.2
Flash Point -ºF	-306	-100 to -150
Auto ignition Temperature in Air -ºF	900-1,170	842-1,010
Maximum Flame Temperature in Air -ºF	3,562	3,595
Limits of Flammability in Air, percent of vapor in air gas mixture		
Lower-LEL	4.0%	2.15%
Upper-UEL	15.0%	9.60%

Table Notes:

1. **The high octane number of CNG & LPG allows high compression ratio in optimized gaseous engines which means an increase in power and efficiency. However, antiknock rating higher than that required for knock-free operation does not improve performance.**
2. **Flammability limit of a fuel is a range of percentages within which the fuel would burn in air; outside the range, the fuel would not burn. The percentage is the ratio between the volumes of the fuel (in gaseous state) to the volume of air in a given area. A fuel with a wide flammability limit burns more readily than a fuel with narrow limit.**
3. **Natural gas is gaseous at any temperature over -259 Fº (-161 ºC) at atmospheric pressure. Since that is a very cold temperature, we normally consider natural gas as a gas. Natural gas boils at atmospheric pressure and a temperature of -259 Fº, exactly like water turns into a vapor (steam) at 212ºF (+100 ºC). Because of this property, natural gas is normally transmitted and stored as a gas, even when compressed at high pressures.**

VAPOR PRESSURE

Vapor Pressure of a fuel is a prime importance of drivability of vehicles under all conditions. One of the most common methods to measure fuel volatility is Reid Method. In this method, the vapor pressure of liquid fuel is measured at 100 F in a chamber having 4:1 air to liquid ratio. There is no need to vaporize CNG or Vapor Auto Gas; contrarily liquid fuels (except LPI) have to be vaporized before they are introduced into the engine. This characteristics of CNG makes the cold start problems and low temperature emissions due to the cold enrichment, minimum.

SPECIFIC ENERGY

It defines the fuel energy delivered to the combustion chamber per unit mass of air inducted. In other words the lower A/F ratio means that chemical energy released per kg of stoichiometric mixture burnt during combustion is greater. It is calculated by dividing the lower heating value of the fuel by the air/fuel ratio. This explains why gasoline has a greater heat release although it has a lower heat of combustion.

HEAT OF VAPORIZATION

The heat of vaporization of a fuel affects the volumetric efficiency positively by decreasing the temperature of the fuel-air mixture which means makes the mixture dense. Although natural gas has a higher heat of vaporization, it is already in gaseous state when it is inducted into engine and it does not provide this cooling effect. On the other hand cold starting problems would occur with higher heat of vaporization in IC engines.

FLAME TEMPERATURE

Thermal efficiency increases with lower flame temperature due to the reduced heat losses from an engine. The lower flame visibility (luminosity) also decreases heat loss by radiation. Flame temperature is also a parameter in NOx. Lower flame temperature reduces NOx emission.

FLAME SPEED

Flame speed defines the relative motion of the flame front towards the unburned mixture. Stoichiometric A/F ratio strongly determines the flame speed. The fast combustion rates provide more efficient torque development. On the other hand, the increasing thermal and mechanical burdens along with increased combustion temperatures cause higher thermal losses, combustion noise and NOx emissions.

FLAMMABILITY LIMITS

Wide **flammability limit** allow intense lean operation with extremely reduced NOx emissions. Also high **diffusion coefficient** affects lean operation positively by providing homogeneous charges. Wide flammability limits also may be useful because rich air / fuel ratios can be used when needed to maximize power by delivering more fuel per charge. However operating at higher levels in this way reduces efficiency. Gaseous fueled engines which operate in lean side suffer from low fuel conversion rates. Low **quenching distance** offers some improvement in this manner. It characterizes the penetration of a flame into smallest crevices. Flame of a fuel with lower quenching distance reaches to difficult chamber zones like quenching areas with high surface to volume ratios.

CLOUD POINT

The temperature at which the precipitation occurs is called cloud point. At this point wax settles out and blocks the fuel system lines. The cloud point of a fuel indicates the temperature at which it may clog filter systems and restrict flow. More paraffinic fuel means the higher precipitation temperature and the less suitable the fuel for low temperature operation. Cloud point is especially important for fuels used in high speed diesel engines due to the trend towards finer filters. The finer filters more easily become clogged due to the small quantities of precipitated wax.

FLASH POINT

Flash point defines the temperature to which the fuel must be heated to produce an ignitable vapor-air mixture above the liquid fuel when exposed to an open flame. The flash point of a fuel does not affect the performance in an engine. Auto-ignition temperature, fuel injection and combustion performance are not influenced by the flash point. Flash point especially has an importance in point of safety. A low-flash point may be the reason of fire hazard subject to flashing, and possible continued ignition and explosion.

WOBBE NUMBER

The Wobbe number, or Wobbe index, of a fuel gas is found by dividing the high heating value of the gas in BTU per standard cubic foot (scf) by the square root of its specific gravity with respect to air. The higher a gases' Wobbe number, the greater the heating value of the quantity of gas that will flow through a hole of a given size in a given amount of time. In almost all gas appliances, the flow of gas is regulated by making it pass through a hole or orifice. The usefulness of the Wobbe number is that for any given orifice, all gas mixtures that have the same Wobbe number will deliver the same amount of heat. Pure methane has a Wobbe number of 1363; natural gas as piped to homes in the United States typically has a Wobbe number between 1310 and 1390.

Properties of Fuels (a)

Property	Gasoline	#2 Diesel Fuel	Methanol	Ethanol	Propane (LPG)	CNG	Hydrogen	Biodiesel
Chemical Formula	C4 to C12	C8 to C25	CH3OH	C2H5OH	C3H8	CH4 (83-99%), C2H6 (1-13%)	H2	C12-C22 FAME
Molecular Weight	100–105	~200	32.04	46.07	44.1	16.04	2.02	~292(q)
Composition, Weight %								
>Carbon	85–88(b)	87(g)	37.5	52.2	82	75	0	77(g)
>Hydrogen	12–15(b)	13(g)	12.6	13.1	18	25	100	12(g)
>Oxygen	0	0(g)	49.9	34.7	–	–	0	11(g)
Specific gravity, 60° F/60° F	0.72–0.78(b)	0.85(g)	0.796(h)	0.794(h)	0.508(m)	0.424	0.07(o)	0.88(g)
Density, lb/gal @ 60° F	6.0–6.5(b)	7.079(g)	6.63(b)	6.61(b)	4.22	1.07(n)	–	7.328(g)
Boiling temperature, °F	80–437(b)	356-644(g)	149(h)	172(h)	-44(m)	63.2 to -126.4(m)	-423(m)	599-662(g)
Reid vapor pressure (100° F),								
psi	8–15(c)	<0.2	4.6(i)	2.3(i)	208	2400	–	<0.04(r)
Heating value (2)								
>Lower (liquid fuel-water vapor) Btu/lb	18,676(d)	18,394(d)	8637(d)	11,585(d)	19,900(d)	20,263(d)	52,217(d)	16,131(d)
>Lower (liquid fuel-water vapor) Btu/gal @ 60° F	116,090(d)	~129,050(g)	57,250(d)	76,330(d)	84500	19,800(6)	–	~118,170(g)
Octane no.(1)								
>Research octane no.	88–98(c)	–	–	–	112	–	130+	–
>Motor octane no.	80–88(c)	–	–	–	97	–	–	–
Cetane no.(1)	–	40-55(g)	–	0-54(f)	–	–	–	48-65(g)
Freezing point, °F	-40(e)	-40–30(4)	-143.5	-173.2	-305.8(m)	-296	-435(p)	26-66(g)(7)
Viscosity, mm/s								
>@104 °F	–	1.3-4.1(g)	–	–	–	–	–	4.0-6.0(g)
>@68 °F	0.5-0.6(f)	2.8-5.0(f)	0.74(f)	1.50(f)	–	–	–	–
>@-4 °F	0.8-1.0(f)	9.0-24.0(f)	1.345(f)	3.435(f)	–	–	–	–
Flash point, closed cup, °F	-45(b)	140-176(g)	52(i)	55(i)	-156(m)	-300	–	212-338(g)
Auto ignition temperature, °F	495(b)	~600	867(b)	793(b)	842(m)	900-1170(m)	932(m)	–
Water solubility, @ 70° F								
>Fuel in water, volume %	Negligible	Negligible	100(h)	100(h)	–	–	–	–
>Water in fuel, volume %	Negligible	Negligible	100(h)	100(h)	–	–	–	–
Flammability limits, volume%								
>Lower	1.4(b)	1.0	7.3(i)	4.3(i)	2.2	5.3	4.1(o)	–
>Higher	7.6(b)	6.0	36.0(i)	19.0(i)	9.5	15	74(o)	–
Latent heat of vaporization								
>Btu/gal @ 60° F	~900(b)	~710	3,340(b)	2,378(b)	775	–	–	–
>Btu/lb @ 60° F	~150	~100	506(b)	396(b)	193.1	219	192.1(p)	–

Sources:

(a) The basis of this table and associated references was taken from: American Petroleum Institute (API), Alcohols and Ethers, Publication No. 4261, 3rd ed. (Washington, DC, June 2001), Table B-1.
(b) "Alcohols: A Technical Assessment of Their Application as Motor Fuels," API Publication No. 4261, July 1976.
(c) Petroleum Product Surveys, Motor Gasoline, Summer 1986, Winter 1986/1987, National Institute for Petroleum and Energy Research.
(d) Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) Model, Argonne National Laboratory, accessed 11-20-06
(e) "Status of Alcohol Fuels Utilization Technology for Highway Transportation: A 1981 Perspective," Vol. 1, Spark-Ignition Engine, May 1982, DOE/CE-56051-7.
(f) American Petroleum Institute (API), Alcohols and Ethers, Publication No. 4261, 3rd ed. (Washington, DC, June 2001), Table 2
(g) J. Tuttle and T. von Kuegelgen, Biodiesel Handling and Use Guidelines--Third Edition, National Renewable Energy Laboratory, 2004.
(h) Handbook of Chemistry and Physics, 62nd Edition, 1981, The Chemical Rubber Company Press, Inc.
(i) API Technical Data Book – Petroleum Refining, Volume I, Chapter I. Revised Chapter 1 to First, Second, Third and Fourth Editions, 1988.
(j) "Data Compilation Tables of Properties of Pure Compounds," Design Institute for Physical Property Data, American Institute of Chemical Engineers, New York, 1984.

(k) API Monograph Series, Publication 723, "Teri-Butyl Methyl Ether," 1984.
(l) ARCO Chemical Company, 1987.
(m) Praxair, Inc. Material Safety Data Sheets for Propane, CNG, and Hydrogen. September 2004. Danbury, CT USA.
(n) Value at 80 degrees F with respect to the water at 60 degrees F (Mueller & Associates).
(o) C. Borusbay and T. Nejat Veziroglu, "Hydrogen as a Fuel for Spark Ignition Engines," Alternative Energy Sources VIII, Volume 2, Research and Development (New York: Hemisphere Publishing Corporation, 1989), pp. 559-560.
(p) Technical Data Book, Prepared by Gulf Research and Development Company, Pittsburgh, PA, 1962.
(q) National Biodiesel Board, "Soybean Methyl Ester Formula and Molecular Weight". Accessed at www.biodiesel.org/pdf_files/fuelfactsheets/Weight&Formula.PDF on 11-20-06
(r) National Biodiesel Board, "Biodiesel Fact Sheet", accessed at www.biodiesel.org.au/biodieselfacts.htm on 11-20-06.

NOTES

(1) Octane values are for pure components. Laboratory engine Research and Motor octane rating procedures are not suitable for use with neat oxygenates. Octane values obtained by these methods are not useful in determining knock-limited compression ratios for vehicles operating on neat oxygenates and do not represent octane performance of oxygenates when blended with hydrocarbons. Similar problems exist for cetane rating procedures.
(2) Since no vehicles in use, or currently being developed for future use, have power plants capable of condensing the moisture of combustion, the lower heating value should be used for practical comparisons between fuels.
(4) Pour Point, ASTM D 97 from Reference (c).
(5) Based on cetane.
(6) For compressed gas at 2,400 psi.
(7) Cloud Point

CNG-LPG ENERGY CONTENT, FUEL ECONOMY

RE: UNITED STATES ENVIRONMENTAL PROTECTION AGENCY NATIONAL VEHICLE AND FUEL EMISSIONS LABORATORY 2565 PLYMOUTH ROAD ANN ARBOR, MICHIGAN 48105-2498

ENERGY CONTENT OF CNG/LPG VS. CONVENTIONAL PETROLEUM

Gasoline gallon equivalent (GGE) or gasoline-equivalent gallon (GEG) is the amount of alternative fuel it takes to equal the energy content of one liquid gallon of gasoline. In 1994, the U.S. National Institute of Standards and Technology or NIST defined "Gasoline gallon equivalent (GGE) means 5.660 pounds of natural gas."

GGE allows consumers to compare the cost of competing fuels against a commonly known fuel -- gasoline. CNG for example is a gas rather than a liquid. It can be measured by its volume in cubic feet (CF), by its weight in pounds (LB) or by its energy content (BTU).

Electricity's energy is measured in Kilowatt-Hours (kWh). It is difficult to compare the cost of gasoline with other fuels if they are sold in different units. GGE solves this. A GGE of CNG and a GGE of electricity all have the same energy content as one gallon of gasoline. CNG sold at filling stations is priced in dollars per GGE

Fuel	Net Heating Value (LHV) Btu/gal.	Gallons of Diesel Equivalent (1 gal)
No. 2 Petroleum Diesels	129,500 LHV to 138, 690 HHV	
CNG-(LHV)	19,800 BTUs/gal.	6.54 diesel gals.
LPG-(LHV)	84,300 BTUs/gallon	1.54 diesel gals.
Fuel	**Net Heating Value LHV-HHV Btu/gal.**	**Gallons of Gasoline Equivalent (GGE--LHV)**
Petroleum Gasoline's	115,000 LHV to 125,072 HHV	
CNG-(LHV-19,800 BTUs/gal.)	900 BTUs/cu. Ft	126.67 cu. ft
LNG-(LHV)	75,000 BTUs/gallon	1.52 gallons
LPG-(LHV)	84,300 BTUs/gallon	1.35 gallons

TABLE NOTES

- **The above table shows both the low heating value (LHV-the amount of heat released by the fuel, ignoring the latent heat of vaporization of water) and the high heating value (HHV the amount of heat released by the fuel, including the latent heat of vaporization of water).**
  For example, it takes 6.54 gallons of CNG to equal 1 gallon of diesel fuel and 1.35 gallons of LPG to equal 1 gallon of gasoline (energy comparison).
- **One GGE of natural gas is 126.67 cubic feet. This volume of natural gas has the same energy content as one US gallon of gasoline (based on lower heating values: 900 BTUs/CF of natural gas and 115,000 BTUs/gallon of gasoline.**
- **One GGE of CNG pressurized at 2,400 psi is 0.77 cubic feet. This volume of CNG at 2,400 psi has the same energy content as one US gallon of gasoline (based on lower heating values: 148,144 BTU/CF of CNG and 115,000 BTU/gallon of gasoline.) Using Boyle's Law, the equivalent GGE at 3,600 psi is 0.51 cubic feet which corresponds to 14.5 liters or 3.82 actual US gallons.**
- **The National Conference of Weights & Measurements (NCWM) has developed a standard unit of measurement for compressed natural gas, defined in the NIST Handbook 44 Appendix D as follows: "1 Gasoline [US] gallon equivalent (GGE) means 2.567 kg (5.660 lb) of natural gas."[12]**
- **In order to allow for thermal expansion of the contained liquid, motor fuel LPG storage tanks are not filled completely; typically, they are filled to between 80% and 85% of their capacity. The ratio between the volumes of the vaporized gas and the liquefied gas varies depending on composition, pressure and temperature, but is typically around 250:1.**

  - **Natural Gas Therm 100,000 BTUs or ±1,000 BTUs/cubic foot**
  - **Propane Gallon 92,000 BTUs**
  - **Liquefied Natural Gas Gallon 85,800 BTUs**
  - **Electricity Kilowatt 3,413 BTUs**
  - **Diesel (Light #2, same as Heating Oil) Gallon 129,500 BTUs**
  - **Gasoline 87 octane Gallon ±115,500 BTUS**

HEATING VALUE

The **heating value** in another word, (heat of combustion, calorific value,) of a fuel is the amount of heat produced when the fuel is burned completely. There are two values for the heating value. They are higher heating value and lower heating value. The difference between them is that higher heating value exceeds the lower heating value by the energy supplied by the water vapor in condensing.
A fuel with low heating value provides less heat on combustion which means less power than the same amount of fuel with high heating value. In order to maintain power output with low-heating value fuel, more consumption of it would be necessary. If natural gas is used in optimized engine, better fuel consumption will be obtained

Energy content based on volume, determines the vehicle range. To increase the range, a high **density** fuel is preferred because heating value per unit volume of fuel is greater. This explains why the liquid state is of primary interest for storage problem. According to published data vehicles using CNG can travel only 26% as far as it could on gasoline.

CNG-LPG ENERGY CONTENT, FUEL ECONOMY

RE: UNITED STATES ENVIRONMENTAL PROTECTION AGENCY NATIONAL VEHICLE AND FUEL EMISSIONS LABORATORY 2565 PLYMOUTH ROAD ANN ARBOR, MICHIGAN 48105-2498

How fuel economy is calculated from gasoline, diesel, CNG, or LPG fueled vehicles? **Gasoline fuel economy is calculated based on the equation in 40 CFR 600.113-93(e) (1). Diesel fuel economy is calculated based on the equation in 40 CFR 600.113-93(f) (1). CNG fuel economy is calculated based on the equation in 40 CFR 600.113-93(h).**

(h) For automobiles fueled with natural gas, the fuel economy in miles per gallon of natural gas is to be calculated using the following equation:

$$Mpge = \frac{(CWF_{HC/NG} \times D_{NG} \times 121.5)}{[(0.749 \times CH_4) + (CWF_{NMHC} \times NMHC) + (0.429 \times CO) + (0.273 \times (CO_2 - CO_{2NG}))]}$$

$$mpg_e = \frac{CWF_{HC/NG} D_{NG}\ 121.5}{(0.749)CH_4 + (CWF_{NMHC})NMHC + (0.429)CO + (0.273)(CO_2 - CO_{2NG})}$$

Where:

- **Mpge=miles per equivalent gallon of natural gas.**
- **$CWF_{HC/NG}$=carbon weight fraction based on the hydrocarbon constituents in the natural gas fuel as obtained in paragraph (d) of this section.**
- **D_{NG}=density of the natural gas fuel [grams/ft^3 at 68 °F (20 °C) and 760 mm Hg (101.3 kPa)] pressure as obtained in paragraph (d) of this section.**
- **CH_4, NMHC, CO, and CO_2=weighted mass exhaust emissions [grams/mile] for methane, non-methane HC, carbon monoxide, and carbon dioxide as calculated in §600.113.**
- **CWF_{NMHC}=carbon weight fraction of the non-methane HC constituents in the fuel as determined from the speciated fuel composition per paragraph (c) (2) of regulation.**
- **CO_{2NG}=grams of carbon dioxide in the natural gas fuel consumed per mile of travel.**
- **$CO_{2NG}=FC_{NG} \times D_{NG} \times WF_{CO2}$**

Where:

$$FC_{NG} = \frac{[(0.749 \times CH_4) + (CWF_{NMHC} \times NMHC) + (0.429 \times CO) + (0.273 \times CO_2)]}{(CWF_{NG} \times D_{NG})}$$

FC_{NG} = cubic feet of natural gas fuel consumed per mile

$$= \frac{(0.749)CH_4 + (CWF_{NMHC})NMHC + (0.429)CO + (0.273)(CO_2)}{CWF_{NG} D_{NG}}$$

Where:

CWF_{NG}=the carbon weight fraction of the natural gas fuel as calculated in paragraph (d) of this section.

(d) Calculate the city fuel economy and highway fuel economy from the grams/mile values for total HC, CO, CO2 and, where applicable, CH3, OH, HCHO, NMHC and CH4 and, the test fuel's specific gravity, carbon weight fraction, net heating value, and additionally for natural gas, the test fuel's composition. The emission values (obtained per paragraph (a) or (b) of this section, as applicable) used in each calculation of this section shall be rounded in accordance with 40 CFR 86.084–26(a) (6) (iii) or 40 CFR 86.1837–01 as applicable. The CO2 values (obtained per paragraph (a) or (b) of this section, as applicable) used in each calculation of this section shall be rounded to the nearest gram/mile. The specific gravity and the carbon weight fraction (obtained per paragraph (c) of this section) shall be recorded using three places to the right of the decimal point. The net heating value (obtained per paragraph (c) of this section) shall be recorded to the nearest whole Btu/lb.

WF_{CO2}=weight fraction carbon dioxide of the natural gas fuel calculated using the mole fractions and molecular weights of the natural gas fuel constituents per ASTM D 1945.

Per Attachment 1-B to CISD-06-02 LPG Fuel Economy Equation:
The following fuel economy equation will be used by EPA to calculate fuel economy for vehicles tested on Liquefied Petroleum Gas (LPG) until an equation is added by EPA regulations:

$$\text{MPG Equivalent} = \frac{[CWF\ fuel \times SG\ fuel \times 3781.8]}{[(CWFHC \times HC) + (0.429 \times CO) + (0.273 \times CO_2)]}$$

Where:

MPG Equivalent = Miles per equivalent gallon of liquefied petroleum gas

- **SG fuel = Specific gravity of the fuel**

- **CWF fuel = Carbon weight fraction of the fuel**
- **CW FHC = Carbon weight fraction of hydrocarbons in the exhaust gas, which is assumed to be equivalent to CWF fuel**
- **HC = Hydrocarbons in grams per mile**
- **CO = Carbon monoxide in grams per mile**
- **CO_2 = Carbon dioxide in grams per mile**
- **3781.8 = Grams of H2O per gallon conversion factor**

MPG Equivalent-gasoline = (1.377 x MPG Equivalent)

Where:

1.377 = 1 gallon LPG /0.726 gallons gasoline, (ref. 49 CFR Part 538.8)

Vehicle Range of Fuels

- **The CNG cylinders that typically power light-duty vehicles have a range of 80-100 miles, about 70-80% less than that of a gasoline vehicle. In most converted bi-fuel CNG vehicles, the original gasoline tank is retained to provide additional range. If more cylinders are added to improve range, however, the increased weight and reduced trunk space will decrease the vehicle's efficiency and capacity. Operators of large fleets would be required as well to accommodate range and power reduction as a result of the lower BTU yields per unit of fuel.**
- **The range of LPG vehicles is 15-20% less than that of gasoline vehicles with comparable tank size. This difference is compensated by propane tanks that are slightly larger than conventional gasoline tanks.**

	PROS	***CONS***
CNG-NATURAL GAS (METHANE)	***Very low emissions of ozone-forming hydrocarbons, toxics, and carbon monoxide*** ***Can be made from a variety of feedstocks, including renewables*** ***Excellent fuel, especially for fleet vehicles***	***Higher vehicle cost*** ***Lower vehicle range*** ***Less convenient refueling***
LPG-PROPANE	***Cheaper than gasoline today*** ***Most widely available clean fuel today*** ***Somewhat lower emissions of ozone-forming hydrocarbons and toxics*** ***Excellent fuel, especially for fleet vehicles***	***Cost will rise with demand*** ***Supply is becoming a non-issue.*** ***Possible energy security or trade balance benefits***

AIR EMISSIONS FROM CNG-LPG

CNG-NATURAL GAS (METHANE)

Compressed natural gas (CNG) vehicles emit low levels of toxics and ozone-forming hydrocarbons. But CNG fuel must be stored under pressure in heavy tanks, and the cost of accommodating these tanks must be considered. There are significant tradeoffs for CNG vehicles among emissions, vehicle power, efficiency, and range; however, natural gas is already used in some fleet vehicles and appears to have a bright future as a motor vehicle fuel.

While CNG creates only 89% as much CO2 as gasoline (2.750/3.087), when compared by energy density CNG creates only about 71.5% as much CO2. In addition to producing less CO2, CNG also creates less particulate matter and other types of emissions, such as NOx.

Actual emissions will vary with engine design; these numbers reflect the potential reductions offered by compressed natural gas, relative to conventional gasoline.

- **Reductions in carbon monoxide emissions of 90 to 97 percent, and reductions in carbon dioxide emissions of 25 percent.**
- **Reductions in nitrogen oxide emissions of 35 to 60 percent.**
- **Potential reductions in nonmethane hydrocarbon emissions of 50 to 75 percent.**
- **Fewer toxic and carcinogenic pollutants and little to no particulate matter produced.**
- **No evaporative emissions in dedicated engines (such as those associated with gasoline or diesel).**
- **Estimates based on CNG's inherently "cleaner" chemical properties with an engine that takes full advantage of these properties.**

LPG-AUTO GAS-PROPANE

Compared with emissions from vehicles on Gasoline/Diesel, emissions from LPG-driven vehicles contain lower levels of hydrocarbon compounds, nitrogen oxides, sulfur oxides, air toxics, and particulates. Propane is a by-product of petroleum refining and natural gas production. It burns more cleanly than gasoline.

- **With LPG, PM10 and ultrafine particle emissions are a tiny fraction of those emitted from diesel vehicles.**
- **NOx emissions from an LPG vehicle were up to one tenth of those for diesel – even greater reductions can be experienced in urban use.**
- **LPG engines emit 60% less ozone precursors (VOC) than gasoline.**
- **CO_2 reductions are typically between 11% and 12% lower than lower sulfur gasoline.**
- **Compared to gasoline, LPG reduces CO by 20%, total hydrocarbons by 40%, and NOx by 30%**

CNG/LPG MATERIALS COMPATIBLY

Must be used with extreme caution. No raw data such as this can cover all conditions of concentration, temperature, humidity, impurities and aeration. It is therefore recommended that this table is used to choose possible materials and then more extensive investigation and testing is carried out under the specific conditions of use. The collected data mainly concern high pressure applications at ambient temperature and the safety aspect of material compatibility rather than the quality aspect.

Methane Material Compatibility

Water, sulfur compounds, carbon dioxide, oxygen and other impurities in natural gas cause storage tank and fuel system corrosion and corrosion-fatigue cracking of the materials. The limitations of these impurities are important in terms of minimizing of corrosion and acceptable service life of the storage tank. Ice occurrence in regulators and lines due to condensation of water content in natural gas should be considered. Besides this, clogging in fuel injectors and fuel filters cause rough engine operation.

The dew point indicates the point at which gas to become saturated with water vapor. At dew point, the mixture contains maximum amount of water. Relative humidity is 100 % at this temperature. When the natural gas is compressed from pipeline pressure of approximately 50 psi to tank pressure of 3600 psi, this increase causes higher dew point which is the function of pressure. Liquid water would precipitate out of the gas with the consequence of this increase. Dryers or desiccants are used to remove the water. Another method is the methanol injection in order to decrease the freezing point of the gas. Pipeline quality natural gas has a dew point of -28ºF at 50 psi which corresponds 52ºF at 3600 psi. In order to prevent occurrence of corrosion problems in vehicles, natural gas must be dried to a dew point under the minimum ambient temperature in which the vehicle run. Regarding this matter the dew point of the gas at the maximum operating pressure to be at least 10 F below the winter design dry bulb temperature will be required.

Fuel stratification in the cylinder should be considered when the natural gas contains heavy hydrocarbons. At low ambient temperatures, as fuel draws from the storage tank, the pressure decreases. This decrease changes the composition of liquid and vapor states. For instance,

propane/air peak shaving gas is not suitable for natural gas vehicles due to the variation of propane concentration more than 10 percent during the operation. Obviously, the variation of the fuel composition has a primary impact on engine performance, knock tendency, emissions and fuel economy.

Metals

General Behavior: Risk of corrosion by gas contained impurities in presence of moisture; see compatibility with CO, CO_2, and H2S.
Aluminum, Brass, Copper, and Ferritic Steels (e.g. Carbon steels) Stainless Steel all performed satisfactory

Plastics

- **Polytetrafluoroethylene (PTFE)** — **Satisfactory**
- **Polychlorotrifluoroethylene (PCTFE)** — **Satisfactory**
- **Vinylidene polyfluoride (PVDF) (KYNAR™)** — **Satisfactory**
- **Polyamide (PA) (NYLON™)** — **Satisfactory**
- **Polypropylene (PP)** — **Satisfactory**

Elastomers

- **Butyl (isobutene - isoprene) rubber (IIR)** — **Non recommended, significant swelling.**
- **Nitrile rubber (NBR)** — **Satisfactory**
- **Chloroprene (CR)** — **Satisfactory**
- **Chlorofluorocarbons (FKM) (VITON™)** — **Satisfactory**
- **Silicon (Q)** — **Non recommended**
- **Ethylene - Propylene (EPDM)** — **Non recommended, significant swelling.**

Lubricants

Hydrocarbon based lubricant & Fluorocarbon based lubricant performed satisfactory

Propane Material Compatibility

Metals

General Behavior: Risk of corrosion by gas contained impurities in presence of moisture.
Aluminum, Brass, Copper, Ferritic Steels (e.g. Carbon steels) & Stainless Steel all performed Satisfactory

Plastics

- **Polytetrafluoroethylene (PTFE)** — **Satisfactory**
- **Polychlorotrifluoroethylene (PCTFE)** — **Satisfactory**
- **Vinylidene polyfluoride (PVDF) (KYNAR™)** — **Satisfactory**
- **Polyamide (PA) (NYLON™)** — **Satisfactory**
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Elastomers

- **Butyl (isobutene - isoprene) rubber (IIR)** — **Non recommended, significant swelling.**
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- **Chloroprene (CR)** — **Non recommended, significant swelling.**
- **Chlorofluorocarbons (FKM) (VITON™)** — **Satisfactory**
- **Silicon (Q)** — **Non recommended, significant swelling and modification of the mechanical properties.**
- **Ethylene - Propylene (EPDM)** — **Non recommended, significant swelling and modification of the mechanical properties.**

Lubricants

- **Hydrocarbon based lubricant** **Non recommended, significant loss of mass by extraction or chemical reaction.**
- **Fluorocarbon based lubricant** **Satisfactory**

Tanks

DO NOT USE LPG TANKS FOR STORAGE OF CNG/LNG. LPG TANKS ARE NOT CONSTRUCTED/DESIGNED TO HOLD THE PRESSURES REQUIRED BY CNG/LNG.

Both CNG-LPG cylinders are manufactured according to rigorous safety standards. CNG cylinders are tested according to ANSI codes. The tests can be conducted at any ANSI-certified laboratory. They may include repeatedly over pressurizing and depressurizing the tank thousands of times; placing the tank in a fire to be sure the pressure relief device works and the tank does not burst; and dropping the tank from a height of 6 feet. CNG cylinders must exceed a safety factor of at least 2.25-3.5 times the pressure of the tank.

CNG cylinders manufactured to DOT standards may need to be recertified periodically: every 5 years for steel cylinders and every 3 years for steel composite and aluminum composite cylinders. CNG conversions may also use cylinders manufactured according to NGV2 standards; these have a 15-year useful life. Check with your cylinder manufacturer for specific recertification requirements.

Because propane is not stored at such high pressures, the testing for propane cylinders is not as rigorous as that for CNG cylinders. Every propane cylinder must be exposed to twice its service pressure, and one out of every 500 is exposed to four times its pressure, or about 960 psi.

Two types of containers are authorized for Autogas Propane per NFPA 58 2011 Chapter 11: DOT cylinders and American Society of Mechanical Engineers (ASME) tanks. See http://www.allianceautogas.com/, NGV Community Library (Non-Commercial Distribution Only) http://www.ngvcommunity.com, http://www.ngv.com.my

- **DOT cylinders are manufactured under the provisions of DOT Hazardous Materials Regulations. They must be requalified for continued use 12 years from the date of manufacture. If the DOT authorized visual inspection procedure is used, the cylinders must be requalified every 5 years thereafter. They must be checked for physical wear or damage every time they are refilled, and the paint must be kept in good condition. DOT engine fuel cylinders are usually removed from the vehicle and refilled elsewhere, though they may be refilled in place if they are properly installed and equipped for that purpose.**
- **ASME engine fuel tanks are always refilled on the vehicle. These containers are manufactured under the provisions of the ASME Pressure Vessel Code. Periodic requalification is not required, but the tanks should be inspected for unusual wear or physical damage, and the paint must be kept in good condition.**

How to Convert Existing Gasoline Engines

Gasoline-powered vehicles are easily converted by adding CNG-LPG components that make CNG-LPG the primary fuel. Storage cylinders are installed either in the trunk of a car or underneath vans or pick-up trucks. Stainless steel lines are run from the tanks to a regulator that will reduce the pressure of the gas stored on-board. The CNG-LPG then passes through a fuel-air mixer and then into the air intake manifold where it is introduced for combustion. A fuel selection switch is installed on the dash to allow the driver to switch between CNG-LPG and gasoline/diesel

***Industry Safety Standards*: Although no government safety standards exist for CNG and propane conversion kits, voluntary industry standards are in place. Companies are not required to follow industry standards, but they help reduce uncertainty and ensure reliability and safety.**

The American National Standards Institute (ANSI) is a private nonprofit organization that coordinates voluntary consensus standards systems and approves American National Standards. ANSI accredited developers ensure that a single set of non-conflicting standards is formulated, and all interests concerned have the opportunity to participate in the development process.

ANSI has accredited standards developed by the Natural Gas Vehicle Coalition (NGV):

- **Compressed Natural Gas Vehicle Fueling Connection Devices (NGV1) establishes standards for construction, performance testing, and safe operation of NGV fueling nozzles and receptacles.**
- **Basic Requirements for Compressed Natural Gas Vehicle Fuel Containers (NGV2) contains standards for construction, performance testing, and safe operation of onboard CNG storage containers for vehicles.**
- **Fuel System Components for Natural Gas Powered Vehicles (NGV3) sets standards for construction, operation, and testing of components for NGV fuel systems.**

Another standard, CNG Fueling Station Components (NGV4), is currently in draft form and awaiting accreditation.

Vehicle Tanks for CNG:

Four Cylinder Types:–Type 1: all metal (steel or aluminum)–Type 2: hoop wrapped steel or aluminum–Type 3: fully wrapped steel or aluminum–Type 4: all-composite (non-metallic)

Dispensers Refueling

There are far few public refueling stations exist for CNG, but more for LPG. Although the infrastructure is expanding, CNG-LPG vehicles often must return to their home bases for refueling, and CNG vehicle range limitations can require more frequent refueling.

CNG vehicles have two basic types of refueling systems: slow-fill and fast-fill:

- **The slow-fill method uses a compressor that directly compresses natural gas from a pipeline and dispenses it to the on-board storage tank. Because it can take up to 14 hours to fill the tank, this method is more suitable for fleets. Smaller slow-fill compressors are also available for refueling one vehicle at a time at a home garage. Check with local building and fire authorities before installing such a system.**

- **The fast-fill method involves filling the vehicle's on-board storage tank from high-pressure storage tanks that are filled from a natural gas pipeline by a compressor. The fast-fill method takes the same time as conventional gasoline pumping (2-5 minutes). This method is suitable for both public and fleet refueling stations.**

Refueling a propane vehicle involves filling the on-board storage cylinder from a dispenser connected to a bulk storage tank. This method takes the same amount of time as refueling a gasoline or diesel vehicle. Just as propane is stored in the engine fuel tank as a liquid, it is stored and handled as a liquid at the fuel dispenser. The propane is pumped from the dispenser storage tank into the vehicle tank.

NOTE ON FIRE FIGHTING WITH CNG/LPG

CFR 49, Part 571–Standards
571.303 Standard No. 303; Fuel system integrity of compressed natural gas vehicles.
571.304 Standard No. 304; Compressed Natural Gas Fuel Container Integrity.

304 Compressed Natural Gas Fuel Container Integrity ***Flame Test Standard: Flame impingement generating 1550-1650°F. at the surface for the length of the cylinder for 20 minutes or until fuel is completely vented through PRD-PRV.***

Design Note: The PRD (pressure relief device) activates similar to a fusible link (it fails versus resealing like a spring-assisted pressure reducing valve –PRV). The gas is vented out the vent tube until the tank is empty. Discharge time depends on fuel level.

Note:
BTU per lb. = 22,800 (gasoline = 18,900)

- ***Not*** **a liquid when compressed (it becomes a very close dense gas)**
- ***Not*** **the same as Liquefied Natural Gas –LNG (cryogenic: -260°to become liquefied)**
- **Lighter than air when released (0.6 air)**
- **Compressed to 3,600 psi fuel cylinder**

- **CNG rated at 117 octane fuel**
- **BTU per lb = 22,800 (gasoline = 18,900)**
- ***Not* a liquid when compressed (it becomes a very close dense gas)**
- ***Not* the same as Liquefied Natural Gas –LNG (cryogenic: -260°to become liquefied)**
- **1 cubic foot of CNG = 245 cu.ft. of natural gas at sea level (uncompressed)**
- **1 cubic foot of CNG weighs 13 lb**
- **5.66lb = 1 Gasoline Gallon Equivalent (GGE)**
- **Honda Civic tank = 8 GGE**
- ***Note: 1 gallon of gasoline properly vaporized has the explosive equivalency of 83 pounds of dynamite (CDC).***

Best Practices Lessons Learned for CNG-LPG Motor Vehicle Fires:

- **Approach from 45°angle to vehicle ends•**
- **Be aware of CNG-LPG vehicles–Cabs, city vehicles, shuttles•**
- **Look for CNG-LPG placards**
- **Watch for other hazards, i.e. bumper struts; hood and tailgate struts; airbags; burning fuel runoff; hazardous vehicle contents; exploding tires; other traffic**
- **Consider cooling streams from a distance**

DO NOT EXTINGUISH A LEAKING CNG-LPG FIRE UNLESS LEAK CAN FIRST BE STOPPED.
SMALL FIRES: Dry chemical or CO2.
LARGE FIRES: Water spray or fog. Move containers from fire area if you can do it without risk.

FIRE INVOLVING TANKS: Fight fire from maximum distance or use unmanned hose holders or monitor nozzles. Cool containers with flooding quantities of water until well after fire is out. Do not direct water at source of leak or safety devices; icing may occur. Withdraw immediately in case of rising sound from venting safety devices or discoloration of tank. ALWAYS stay away from tanks engulfed in fire. For massive fire, use unmanned hose holders or monitor nozzles; if this is impossible, withdraw from area and let fire burn.

BLEVE EFFECT

Boiling Liquid Expanding Vapor Explosion (BLEVE) is the most dangerous case of fire for CNG-LPG installation. The pressure in tank exerted by boiling liquid -heated from fire in tank's surrounding -cause rupture of tank and explosion of huge cloud of gas. Only cooling of the tank during fire and proper condition of Safety Relief valve can help to avoid this disaster.

LPG is dangerous when it is allowed to accumulate in enclosed areas such as garages. LPG is denser than air and tends to sink and accumulate. It evaporates quickly and expands 270 times its volume in liquid state. Sufficient quantity of LPG can cause asphyxiation due to the quick displacement of oxygen. Since LPG is colorless and odorless, a pungent smell is often added to it so that it can be easily detected in case of leakage.

When released, compressed natural gas will mix with air and become flammable only when the mixture is within 4 to 15 percent natural gas. When the mixture is less than 4 percent natural gas, it doesn't burn. When the mixture is more than 15 percent natural gas, there is not enough oxygen to allow it to burn. Because natural gas is lighter than air, it quickly dissipates when released from tanks.

US DOT PLACARDING/SHIPPING REGULATIONS for CNG-LPG

ALTERNATIVE FUELS SHIPPING PAPER:

The federal HAZMAT regulations requires a person who offers hazardous materials for transportation to describe the material on a shipping paper (bill of lading, product transfer documents) pursuant to 49 CFR 172.

Product	CAS #	UN #	DOT Class	NFPA 704
CNG- (Natural Gas Compressed)	74-82-8	1971 (Gas)	2.1 (Flammable Gas)	Health-1 Flammability-4 Reactivity-0
LNG- (Natural Gas Refrigerated Liquid)	74-82-8	1972 (liquid LNG-refrigerated)	2.1 (Flammable Gas)	Health-1 Flammability-4 Reactivity-0
LPG- Propane C_3H_8	74-98-6	1978 Propane 1075 LPG	2.1 (Flammable Gas)	Health-1 Flammability-4 Reactivity-0

Safety Regulations

Government Safety Standards: **The National Highway Traffic Safety Administration (NHTSA), an agency of the U.S. Department of Transportation (DOT), is authorized to ensure the safe performance of AFVs, including conversions. The NTHSA has issued safety standards related to alternative fuel:**

• Fuel Integrity Systems (Standard No. 303) became effective on September 1, 1995. This safety standard applies to OEM natural gas and propane vehicles. It requires AFVs to meet a 30-mph barrier crash test (without exceeding specified leakage limits) with limited damage.

• Compressed Natural Gas Fuel Containers (Standard No. 304) became effective on March 27, 1995. This safety standard outlines performance and labeling requirements for CNG containers. To prevent fires caused by CNG leakage, the containers must undergo a pressure cycling test to evaluate durability, a burst test to evaluate initial strength, and a bonfire test to evaluate pressure relief characteristics.

State Safety Standards: **Because of the hazards of high-pressure fuel systems, some states place restrictions on CNG and propane vehicles driving over bridges and through tunnels and parking in underground lots. Although no uniform restrictions exist, many regulations are geared toward transporting gaseous fuel as cargo rather than as an engine fuel. To find out what restrictions apply in your area, contact your local fire protection agency.**

Hazardous Materials Transportation Act

The Hazardous Materials Transportation Act of 1975 (HMTA), is the major transportation-related statute affecting transportation of hazardous cargoes. The objective of the HMTA according to the policy stated by Congress is "…to improve the regulatory and enforcement authority of the Secretary of Transportation to protect the Nation adequately against risks to life and property which are inherent in the transportation of hazardous materials in commerce."

Regulations apply to "…any person who transports, or causes to be transported or shipped, a hazardous material; or who manufactures, fabricates, marks, maintains, reconditions, repairs, or tests a package or container which is represented, marked, certified, or sold by such person for use in the transportation in commerce of certain hazardous materials."

Enforcement of the HMTA is shared by each of the following administrations under delegations from the Secretary of the Department of Transportation (DOT):

- **Research and Special Programs Administration (RSPA) - Responsible for container manufacturers, reconditioners, and retesters and shares authority over shippers of hazardous materials.**
- **Federal Highway Administration (FHA) - Enforces all regulations pertaining to motor carriers.**
- **Federal Railroad Administration (FRA) - Enforces all regulations pertaining to rail carriers.**
- **Federal Aviation Administration (FAA) - Enforces all regulations pertaining to air carriers.**
- **Coast Guard - Enforces all regulations pertaining to shipments by water.**

Material Designation and Hazard Communication

The Hazardous Materials Table (49 CFR Part 172.101) designates specific materials as hazardous for the purpose of transportation. It also classifies each material and specifies requirements pertaining to its packaging, labeling, and transportation. Hazard communication consists of documentation and identification of packaging and vehicles. This information is communicated in the following formats:

- **Shipping papers**
- **Package marking**
- **Package labeling**
- **Vehicle placarding**

Upon determining the proper shipping name (i.e., the name of the hazardous material shown in Hazardous Materials Table), the Hazardous Materials Table will specify the correct packaging. Packaging authorized for the transportation of hazardous materials is either manufactured to DOT standards or does not meet DOT standards, but is approved for shipments of less hazardous materials and limited quantities. The shipper is responsible for determining the shipping name. The shipper must also ascertain the hazard class, United Nations Identification number (if required), labels, packaging requirements, and quantity limitations.

The Hazardous Materials Transportation Act (HMTA) preempts state and local governmental requirements, unless that requirement affords an equal or greater level of protection to the public than the HMTA requirement.

HIGH-PRESSURE TANK TRUCK (MC-331):

- Typically carries **gases liquefied by pressure, such as anhydrous ammonia, LPG, propane, butane**
- Tank can carry up to 11,500 gallons; tank pressure is generally above 100 psi.
- Shorter "bobtail" version of MC-311 tank can carry up to 3,500 gallons.
- High BLEVE potential.

CRYOGENIC LIQUID TANK TRUCK (MC-338):

- Typically carries **gases liquefied by refrigeration, such as liquid oxygen, nitrogen, argon, carbon dioxide, and hydrogen. Product likely to be corrosive or flammable gas, or poisonous or oxidizing liquid.** Temperature of product -150 degrees F or below.
- Outer shell surrounds insulated inner tank, with vacuum space between. Large compartment mounted at rear of tank. Capacity of inner tank up to 7,000 gallons.
- Very high BLEVE potential.

FEDERAL TRADE COMMISSION CNG/LPG DISPENSER LABELS REGULATIONS

Motor fuels of CNG, LPG & LNG must comply with "16 CFR PART 306. AUTOMOTIVE FUEL RATINGS, CERTIFICATION, AND POSTING" Labeling Alternative Fuels

The Federal Trade Commission (FTC) prepared guides to help comply with two FTC Rules that require businesses to provide certain information to help potential purchasers of vehicle fuels compare products.

The guides explain the provisions of the Fuel Rating Rule (the Automotive Fuel Ratings, Certification and Posting Rule) and the new Alternative Fuels and Vehicles Rule (the Labeling Requirements for Alternative Fuels and Alternative Fueled Vehicles Rule). It includes answers to commonly asked questions about the Rules. Also, the Fuel Rating Rule and Subparts A (definitions) and B of the Alternative Fuels and Vehicles Rule are now available.

The Alternative Fuels and Vehicles Rule has separate requirements for the labeling of alternative fueled vehicles (Subpart C). For information about the requirements for these vehicles, see- http://www.business.ftc.gov/documents/bus12-how-comply-ftc-fuel-rating-rule

Who Must Comply

Importers, producers, refiners, distributors, and retailers of vehicle fuels and manufacturers of electric vehicle fuel dispensing systems must comply with the Rules.

Vehicle Fuels Covered By the Rules

1. **Gasoline, including gasohol, reformulated, and oxygenated gasoline.**
2. **Liquid alternative automotive fuels, including:**
3. **Methanol, denatured ethanol, and other alcohols**
4. **Mixtures containing 85 percent or more by volume of methanol, denatured ethanol, and/or other alcohols (or such other percentage, but not less than 70 percent, as determined by the Secretary of the U.S. Department of Energy to provide for requirements relating to cold start, safety, or vehicle functions), with gasoline or other fuels**
5. **Liquefied natural gas**
6. **Liquefied petroleum gas**
7. **Coal-derived liquid fuels**
8. **Non-liquid alternative vehicle fuels, including compressed natural gas, hydrogen, and electricity.**

Labels

The standard gasoline and alternative liquid automotive fuel labels are 3 inches wide by 2 1/2 inches long. The size, typestyle, and dimensions of the labels are specified in the Rule. Gasoline labels are to be printed in black ink on a yellow background.

Alternative liquid automotive fuel labels must be printed in black ink on an orange background. All labels must be capable of withstanding extremes of weather conditions for a period of at least one year.

They must be resistant to automotive fuel, oil, grease, solvents, detergents, and water. The label specifications are included in section 306.12 of the Rule.

If you are covered by the Fuel Rating Rule and wish to change the dimensions of the label to accommodate a longer fuel descriptor, or to accommodate additional fuel components, you must file a petition with the FTC for an exemption from the Rule and state the size and contents of the label you wish to use, and the reasons you want to use it.

Excise Road Taxes

Recent legislation passed by the U.S. Congress and signed by President Obama that adjusts the federal excise tax on liquefied natural gas (LNG) and propane used in vehicles. These changes are effective January 1, 2016. The following summary highlights the key aspects of the legislation that relate to alternative fuel excise tax changes.

NOTABLE CHANGES:

Adjusts the federal excise tax rates for propane and LNG used in vehicles so that, similar to compressed natural gas (CNG), the fuels are now taxed on an *energy equivalent* basis rather than a *volumetric basis*.

Establishes clear energy equivalencies for each fuel, as follows:

- **One diesel gallon equivalent (DGE) is equal to 6.06 pounds of LNG**
- **One gasoline gallon equivalent (GGE) is equal to 5.75 pounds of propane and 5.66 pounds of CNG**
- **Propane is taxed on an energy content basis that is equal to gasoline, rather than a volumetric gallon.**
- **LNG is taxed on an energy content basis that is equal to diesel, rather than a volumetric gallon.**
- **CNG- No change from current tax rates**

Effective date: January 1, 2016 (i.e., the amendments apply to any sale or use of these fuel types after December 31, 2015). New Federal Tax Rate effective January 1, 2016.

UPDATED: January-2016