


Natural Gas Familiarization

- Characteristics of natural gas as an alternative fuel.
 - Production
 - Fueling
 - Benefits
 - Safety


EVERY
ALTERNATIVE.



Natural Gas Familiarization

- Why Natural Gas.
 - Nearly perfect fossil fuel.
 - Clean Burning.
 - Less damaging to environment.
 - Good Anti-knock qualities.
 - Not harmful to engine.
 - Efficient
 - Reasonable cost as compared to diesel.
 - Available sources.


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Natural Gas Familiarization

- Fuel Composition
 - Like crude oil and coal, natural gas is a fossil fuel found in the earth's crust.
 - Commonly found trapped between liquid petroleum and impervious rock.
 - It is also found in coal deposits or in reservoirs by itself. Therefore it is a separate class of fossil fuel.


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Natural Gas Familiarization

- Major contents of Natural Gas.
 - Methane or CH₄ (70-90%)
 - Ethane or C₂H₆ (0-20%)
 - Propane or C₃H₈ (1.7%)
 - These gases all burn in the combustion process and vary according to the region where the gas was recovered and sometimes vary according to the time of year it is supplied to the user.


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Natural Gas Familiarization

- Methane.
 - Major content of Natural Gas
 - Octane Rating of 140
 - Burns at higher temperature (1300 F)
 - Resistant to Pre-ignition.
 - To maintain this octane rating the methane content of natural gas must have a 90% concentration or a methane number greater than 80 (65 for wide range fuel).
 - ISL G requires a methane number of 75.


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Natural Gas Familiarization

- Methane
 - When the methane number is below specifications, this will result in poor performance and possible engine damage.
 - The methane content will decrease when other gases increase thus lowering the octane rating of the fuel causing pre-ignition and subsequent engine damage.


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Natural Gas Familiarization

- Methane Number
 - Not to be confused with Methane Mass Percent.
 - The Methane Number is defined as a scale to calculate knock potential of natural gas in a spark ignited engine, relative to the reference fuel.
 - On Cummins Natural Gas engines a minimum Methane Number of 80 is required.
 - The minimum Methane Number for the “Gas Plus” engines, specified as Wide Range Fuel Capable, is 65.
 - The minimum Methane Number for the 07ISL Gas engine is 75


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Natural Gas Familiarization

- Propane
 - Propane is also present in natural gas. Propane is used as a fuel for Cummins engines but only if that engine is designed to run on Propane. Because Propane has different ignition and burn characteristics, it is not a compatible fuel for Cummins natural gas engines.
 - Propane can be changed into a liquid by pressurizing it at 100 psig. This fuel is called liquefied petroleum gas or LPG.


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Natural Gas Familiarization

- Propane
 - Propane has an octane rating of about 110, therefore it will begin to burn at a lower temperature than methane approximately 920 - 1120 degrees F.
 - If the Propane content of the natural gas exceeds 1.7% it will begin to replace the methane in the gas. At that point the octane rating of the fuel will decrease and knock will occur.


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Natural Gas Familiarization

- Ethane
 - Another hydrocarbon found in natural gas is ethane.
 - Maximum concentration is 4% per volume any more and it will reduce the methane concentration thereby reducing the octane rating and pre-ignition (knock) will result.

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Natural Gas Familiarization

- Other contents of natural gas.

– Butane	C4H10
– Hexane	C6H14
– Carbon Dioxide	CO2
– Oxygen	O2
– Nitrogen	N2
– Hydrogen	H2
– Carbon Monoxide	CO

 - These contents and other inert gases are found in trace amounts but should not exceed 4.3% total concentration.
 - Natural Gas is a transparent, odorless fuel. The familiar smell has been added to aid in leak detection.


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Natural Gas Familiarization

- The Composition of Gaseous Fuels.
 - Critical to proper engine performance
 - Engine power.
 - Engine durability.
 - Changes in different areas.
 - Climate
 - Gas company
 - Filling facility

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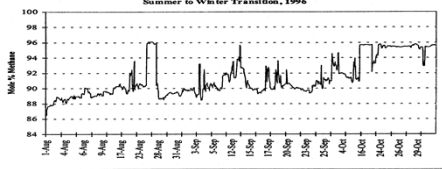


Natural Gas Familiarization

Key Question: How much can the composition of the natural gas coming into the Tech Center change over a three month period (summer to winter)?

Hypothesis/Topic: Specifically, how much did the methane content of the gas vary in the fall of 1996?

**% Methane in Columbus Natural Gas
Summer to Winter Transition, 1996**



Overview:

- The natural gas supplied to the Tech Center is sampled every hour and a gas composition analysis is done by the Fuel, Labor, and Chemistry Department.
- Monthly summaries of gas composition are published in tech reports by Neal Currier.
- CTR 0789-96038 details the testing operation and the equipment.
- The plot is the mole percent methane sampled over a three month period in 1996.


Conclusions:

- There is a variation in the percentage of methane with time. The methane content increased from the end of summer to the beginning of winter. According to Neal Currier, this is a trend that is seen annually.
- In addition to the seasonal change, large changes can also be seen in smaller time periods. For instance, toward the end of August, there were several large changes in methane content.

Recommendations:

- Plot the remaining gas constituents.
- Determine how much this composition change affects performance parameters such as LHV, stoichiometric A/F, etc.
- Determine the maximum change over a short period of time (~ 1 day).

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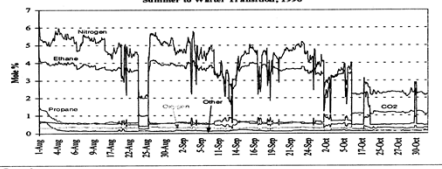


Natural Gas Familiarization

Key Question: How much can the composition of the natural gas coming into the Tech Center change over a three month period (summer to winter)?

Hypothesis/Topic: Specifically, how much did the non-methane constituents of the gas vary in the fall of 1996?

**% of Other Constituents in Columbus Natural Gas
Summer to Winter Transition, 1996**



Overview:

- The natural gas supplied to the tech center is sampled every hour and a gas composition analysis is done by the Fuel, Labor, and Chemistry Department.
- Monthly summaries of gas composition are published in tech reports by Neal Currier.
- CTR 0789-96038 details the testing operation and the equipment.
- Fact sheet PS-002 shows the methane content over the same time period as the above plot.
- The curve labeled 'other' in the plot is made up of Ethane, n-Butane, i-Butane, n-Pentane, n-Hexane, Heptane, and Octane.


Conclusions:

- The main constituents in the natural gas supplied to the Tech Center besides methane are nitrogen and ethane. These vary as the methane content varies.
- The nitrogen and ethane content decrease from the end of summer to the beginning of winter with significant day to day changes along the way.

Recommendations:

- Determine how much this composition change affects performance parameters such as LHV, stoichiometric A/F, etc.
- Determine the maximum change over a short period of time (~ 1 day).

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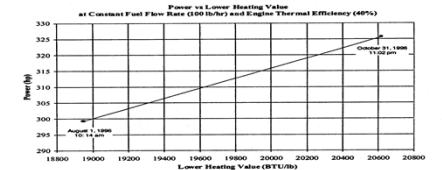


Natural Gas Familiarization

Key Question: How much difference in power could be expected due to the variation in fuel properties of natural gas supplied to the Tech Center over the Fall of 1996, if all other things are held constant?

Hypothesis/Topic: Fuel supplied to the Tech Center in the Fall of 1996 experienced a 9% variation in lower heating value. This will result in a similar variation in engine power, at constant fuel rate and thermal efficiency.

**Power vs Lower Heating Value
at Constant Fuel Flow Rate (100 lb/hr) and Engine Thermal Efficiency (40%)**



Overview:

- Natural gas supplied to the Tech Center does not have constant properties. This will result in variations in engine performance at the test cell.
- From August 1 to October 31, the lower heating value of the natural gas supplied to the tech center increased by 9%.
- If an engine had been run on these two days at the same fuel flow rate and same thermal efficiency, there would be a 9% change in power produced by the engine.


Conclusions:

- On August 1, the lower heating value of the fuel was less than on October 31, this means that more fuel (by mass) is needed on August 1 to supply the engine with the same fuel energy. In other words, by just by keeping the mass flow rate of fuel constant, the fuel energy delivered to the fuel is not constant.

Recommendations:

- It is noted that the lower heating value of the natural gas supplied to the Tech Center is not constant and it can have a large impact on engine data.
- Implement the gas sampling equipment on line so that the real-time lower heating value can be saved with each data point.

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Natural Gas Familiarization

Effects of Gas Products on an Engine

Element	Problem	Effect
Methane	Below 90%	Pre-ignition (Loss of Ignition control) Burned Pistons and Valves
Ethane	Above 4%	Replaces Methane Pre-ignition-Burned Pistons and Valves
Propane	Above 1.7%	Replaces Methane Pre-ignition-Burned Pistons and Valves
C4	Above 0.7	If methane is high, no effect If methane is low, pre-ignition
C6	Above 0.2	If methane is high, no effect If methane is low, pre-ignition
CO ₂ & N ₂	Above 3%	Inert gas, replaces combustible gases
Hydrogen	Above 0.1 %	Pre-ignition (Loss of Ignition control) Burned Pistons and Valves
Carbon Monoxide	Above 0.1 %	Inert gas, low power
Oxygen	Above 0.5%	Upsets air/fuel ratio Enhances corrosion
Sulfur	Above 10 ppm	Increased particulate emissions Corrodes tanks, fittings and Regulators
Moisture		Freeze during cranking Difficult cold starting
Oil contamination	By-product of compressor	Gums up regulators Causes Gas Mass Flow Sensor to fail

Note: Gaseous engine fuel usage is still in a developmental stage. Other effects may result.


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Natural Gas Familiarization

- Compressed Natural Gas (CNG).
 - Natural gas is commonly used as a fuel for stationary applications. Fuel supply for stationary applications is taken right off the line from the public utility. However, natural gas in a automotive application requires a transportable fuel storage system with sufficient supply to travel the required range.


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Natural Gas Familiarization

- Compressed Natural Gas (CNG).
 - It will take 140 SCF's of natural gas to equal the heating value of 1 gallon of diesel fuel (129,575 BTU's)
 - Typically natural gas gets approximately 20% fewer miles per gallon than diesel.
 - In order to have enough fuel on board an automotive application to have a comparable range to a diesel, we must compress the gas into several CNG storage tanks on the vehicle.

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Natural Gas Familiarization



- The CNG fueling station takes natural gas supplied at 30-50 psig from the pipeline, or stationary CNG storage vessels, and compresses it into storage vessels on the vehicle at operating pressures of 3,000 to 3,600 psig.


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Natural Gas Familiarization

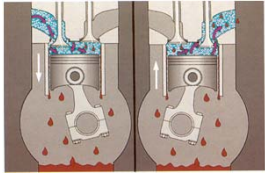
- Fueling
 - Special safety precautions concerning refueling are required to prevent accidents.
 - Accidental ignition.
 - Fuel tank rupture.
 - Only trained personnel should perform refueling procedures.
 - Individuals should be trained on each particular fueling station they will be required to use.

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Natural Gas Familiarization

Fueling

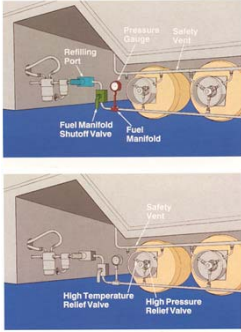


- The natural gas compressors must be well maintained to minimize the migration of oil around the piston and ring pack, which contaminates the fuel. When oil contamination is excessive, pressure regulators, laminar flow devices and other engine components may become restricted decreasing engine performance and damaging engine components. Multiple filters and traps must be used to minimize compressor oil in the fuel.

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Natural Gas Familiarization

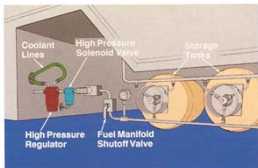


- Cylinder Installation.
 - The cylinders are connected to a fuel manifold and a safety vent system.
 - The fuel manifold has a refilling port and a manual shutoff valve.
 - The safety vent system consists of relief valves in each cylinder connected to a manifold. In the event of high pressure, the cylinder relief valve vents gas to the atmosphere above the vehicle
 - Natural gas is 3 times lighter than air so it will rise and dissipate.

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Natural Gas Familiarization

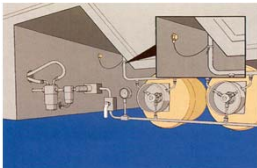


- Supply Components.
 - From the manifold the gas flows to an O.E.M. supplied normally closed high pressure fuel solenoid valve controlled by the vehicle key switch.
 - When the solenoid is energized, gas flows to the high pressure regulator (O.E.M. supplied) which drops the supply pressure down to approximately 100 psig. Engine coolant is circulated through the regulator valve to prevent icing of the valve due to the rapid expansion of the fuel.

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Natural Gas Familiarization



- Static Electricity
 - Static electricity can be an ignition source.
 - Ground the fuel system to prevent problems with static electricity
- Follow Cummins Recommended Installation Guidelines on CNG Fuel Systems.
 - AEB 21.25


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Natural Gas Familiarization

- Liquefied Natural Gas (LNG) System.
 - Compressing natural gas allows us to carry enough fuel necessary to drive a predetermined distance. To be capable of driving farther without refueling the customer could add more CNG tanks or install a LNG storage system.
 - LNG is produced through a cryogenic process in which the gas is cooled to -258 degrees F. At that temperature which point it becomes a liquid.
 - In the liquid state, the vehicle can carry more fuel in a smaller area.


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Natural Gas Familiarization

- LNG.
 - Many of the gases contain in natural gas solidify at temperatures above -258 F.
 - The odorant normally added to natural gas will solidify above these temperatures. Thus LNG used in vehicles will not have the familiar gas odor.

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Natural Gas Familiarization

Factors use in determining capacity requirements when converting Diesel to LNG

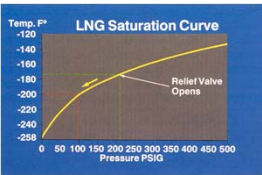
<ul style="list-style-type: none"> • LNG <ul style="list-style-type: none"> – 1 U.S. gallon weighs 3.4 lbs. – Heating value is 21,500 Btu per lb, and 73,000 Btu per gallon. 	<ul style="list-style-type: none"> • Diesel <ul style="list-style-type: none"> – 1 U.S. gallon weighs 7.1 lbs. – Heating value is 18,250 Btu per lb and 129,575 Btu per gallon.
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Using mileage data and the above information, plus keeping in mind that the thermal efficiency of a natural gas engine is 20% less than diesel, you will need about twice the fuel volume to match the range produced by the diesel engine. 6.026 LBS of LNG is equal to the BTU's of 1 gallon of Diesel

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Natural Gas Familiarization

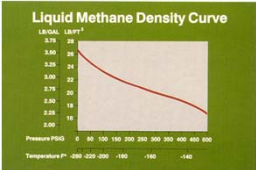


- LNG Saturation Curve.
 - LNG is said to be saturated when it is at its boiling point. The relationship between temperature and pressure follows the saturation curve. As saturation occurs, pressure increases and the temperature at which the liquid boils off into gas also increases. Controlling the pressure at which saturation occurs is important to many LNG fuel systems because pressure is the driving force for delivering fuel to the engine.

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Natural Gas Familiarization



Liquid Methane Density Curve


ENRHO (LB/FT³)

Pressure PSIG

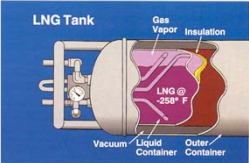
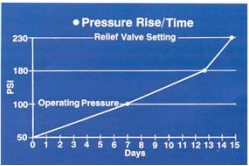
Temperature F

- **LNG Density Curve.**
 - The LNG density curve shows the relationship between pressure and density. As the fuel temperature increases, pressure in the LNG tank increases and it becomes less dense because it is changing from liquid to vapor. Also as the fuel vaporizes and tank pressure increases, the weight of the fuel is less.

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Natural Gas Familiarization


• **Pressure Rise/Time Relief Valve Setting**

PSI

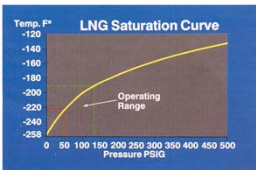
Days

- **Vehicle Storage Tanks.**
 - Vehicle storage tank are insulated containers that maintain the fuel in a liquid form.
 - The insulation technology used in LNG tanks maintains the temperature of LNG for a period of time without excess pressure build-up. The insulation in many LNG tanks have an R value of 8,500.
 - The fuel tank operate at a specified pressure for saturation, which is maintained by a series of relief valves. These relief valves also protect the tank from over pressurization.

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Natural Gas Familiarization



LNG Saturation Curve


Temp. F

Pressure PSIG

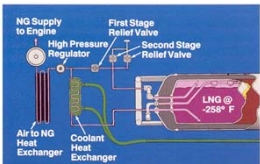
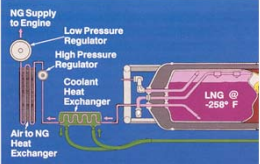
Operating Range

- Though LNG tanks are well insulated, over time the LNG naturally takes on heat from the atmosphere and vaporizes. Some systems depend on this normal pressure rise in the tank to supply fuel to the engine.
- During refueling, a sufficient head pressure must be maintained to run the engine. Fuel that is pumped into a top fill tank usually is colder than the liquid that is already in the tank. Care must be taken that the cold fuel entering the tank does not reduce the pressure of the tank to the point that there is not enough head pressure to supply fuel to the engine.

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Natural Gas Familiarization

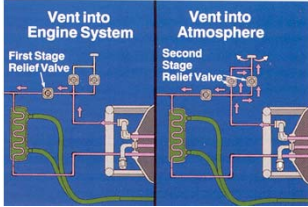



- To use LNG
 - The cold liquid must be vaporized and brought up to operating temperature.
 - Tank pressure must be regulated and maintained in order to supply adequate pressure to the engine.
- Vaporization.
 - Fuel leaving the tank goes through a heat exchanger that uses engine coolant to vaporize the fuel. A high pressure regulator is used to maintain a specified gas pressure to the engine.

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Natural Gas Familiarization



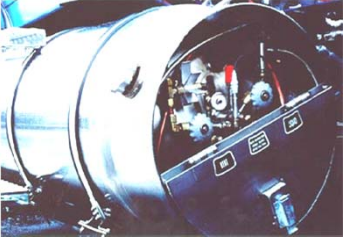

- Tank Venting
 - The storage tank is designed to operate at a specific pressure. If the pressure in the tank rises above the intended level, the gas is first vented to the engine for consumption. This gas is pure methane because methane tends to vaporize first and rise to the top of the tank.
 - If the first stage vent does not control tank pressure, the second stage relief valve vents the gas into the atmosphere.

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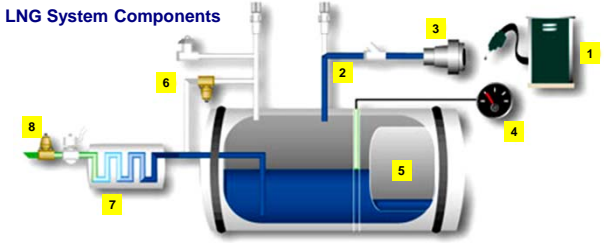
Natural Gas Familiarization

LNG Components

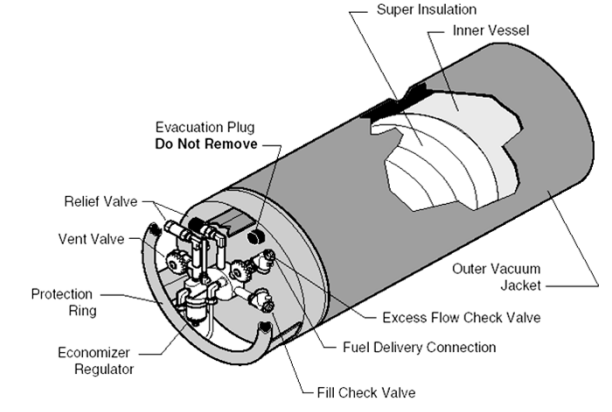
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LNG System Components




- 1 - **LNG Dispenser.** With a locking fueling nozzle provides fuel to the tank.
- 2 - **Top Fill.** Enables single hose fueling— spray of liquid collapses vapor for faster fills.
- 3 - **Fuel Receptacle.** A poppet valve on the receptacle is automatically opened by engagement of the fueling nozzle onto the receptacle. Receptacle has matching locking mechanism to the fueling nozzle to ensure a tight seal during fueling.
- 4 - **Fuel Gauge.** Can be mounted in the cab or in a protected area by the fuel receptacle.
- 5 - **Vapor Space.** Has a small hole near the top of the tank to absorb excess vapor pressure. Extends tank hold time when a vehicle is not in use for several days.
- 6 - **Economizer Regulator.** Determine tanks operating pressure.
- 7 - **Heat Exchanger.** Uses the coolant fluid from the engine to warm the LNG to a gaseous phase.
- 8 - **Over Pressure Regulation.** Ensures that the vaporized fuel pressure does not exceed the pressure specified by the engine manufacturer.

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Super Insulation
 Inner Vessel
 Evacuation Plug
 Do Not Remove
 Relief Valve
 Vent Valve
 Protection Ring
 Economizer Regulator
 Fuel Delivery Connection
 Fill Check Valve
 Excess Flow Check Valve
 Outer Vacuum Jacket


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Natural Gas Familiarization




Cryogenic Super insulation






Fuel Tank Cut Away


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Natural Gas Familiarization




Economizer Regulator



Excess Flow Valve




Fill Check Valve




LNG Fill Fitting


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Natural Gas Familiarization

Fuel Contents Gauge






In-line Check Valve




Product Isolation Valve




Overpressure Regulator (optional)


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Natural Gas Familiarization




Tank Pressure Gauge



Dual Relief Valves


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Natural Gas Familiarization

- LNG Weathering.
 - Due to the various processes for maintaining pressure in the LNG fuel tank system, it is possible for the engine to receive pure methane for a period of time. As pure methane is removed from the fuel tank, the percentages of the other natural gas components can increase beyond the Cummins natural gas specification.
 - To prevent the possibility of the engine operating on a fuel with a methane content of less than the 90% specification, Cummins recommends that LNG contain a minimum of 98% methane.


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Natural Gas Familiarization

- Fueling
 - Special safety precautions concerning refueling are required to prevent accidents.
 - Accidental ignition.
 - Fuel tank rupture.
 - **Only trained personnel should perform refueling procedures.**
 - Individuals should be trained on each particular fueling station they will be required to use.


EVERY ALTERNATIVE.



Natural Gas Familiarization

- Static Electricity
 - Static electricity can be an ignition source.
 - Ground the fuel system to prevent problems with static electricity
- Follow Cummins Recommended Installation Guidelines on CNG Fuel Systems.
 - AEB 21.53


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Natural Gas Familiarization

- Remember the basic properties of natural gas.
 - It is lighter than air, so it rises when released.
 - It can be trapped under a roof.
 - It is ignitable when mixed with oxygen.
 - CNG has a detectable odor.
 - LNG is odorless.
 - LNG can pool before vaporization occurs.
 - It is non-toxic however when natural gas is present at a ratio of 7 parts or more of natural gas to 1 part oxygen, suffocation will occur. This is the standard for any gas.
- Natural gas is flammable when mixed with oxygen, but only at a certain level. Natural gas must make up 4 to 16% of the volume of air.


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Natural Gas Familiarization

- Remember
 - Liquefied Natural Gas is cooled to -258 degrees F.
 - LNG will splash and pool before evaporating.
 - Wear protective clothing while working around LNG to prevent cryogenic burns.
 - Impermeable Protective Apron.
 - Long Sleeve Shirt.
 - Face Shield.
 - Gloves.
 - Boots suitable for intended exposure.

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Natural Gas Familiarization

- If frostbite should occur:
 - Remove any clothing that may restrict circulation to the frozen area. Do not rub frozen parts, as tissue damage may result. Obtain medical assistance as soon as possible.
 - When practical, place the affected part of the body in a warm bath (105 - 115 F). The temperature of the air in the room should also be kept warm.
 - Frozen areas are painless and appear waxy with a possible yellow color. These areas will become swollen, painful, and prone to infection. Area must be thawed gradually.
 - If frozen tissue has been thawed before medical attention has been administered, cover the area with dry sterile dressings and a large, bulky protective covering.


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Natural Gas Familiarization

- The vehicle repair and storage facility must accommodate natural gas fuel.
 - Must be well ventilated with a roof exhaust fan.
 - The heating system must not be an open flame type.
 - Methane detectors are recommended.
 - Strictly follow local fire and safety codes.
 - Before performing any repair procedure that could cause ignition, refer to the manufacturer's operation and maintenance manual for safety recommendations.

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Natural Gas Familiarization

**Bringing the vehicle into the shop for minor work
(4 hour maximum)**

- Check tank and under hood for gas leaks. Contact foreman or leadman if there are leaks
- Bring the vehicle into the bay.
- Install the vent hose over the vehicle vent stack.
- Turn the vehicle off.
- Inform shop Foreman or Leadman of the time the vehicle entered the bay.
- The tank pressure must be recoded every hour. This log should be kept on record.
- The vehicle must not be left unattended, if work stops on the vehicle it must be removed from the bay.
- Remove the vehicle after 4 hours

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Natural Gas Familiarization


Bringing the vehicle into the shop for major work

- Carefully check tank with the hand held methane detector.
Drive the truck into the bay.
- Install the vent hose over the vent stack.
- Turn the vehicle off.
- Vent the fuel system plumbing with the high pressure vent valve, gas will be captured by the vent hose.

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Natural Gas Familiarization



HP Gas + Carelessness = Safety Risk

- The CNG System contains high pressure Gas (up to 3400 psig). High pressure gas is present in plumbing and components even when truck is not running.


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Natural Gas Familiarization

- Always:
 - Use caution when working on HP components.
 - Know where HP gas is located in system, and how to isolate it, and drain it before working on it.
 - Follow installation and assembly procedures.

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Natural Gas Familiarization

- Never:
 - Work on something if you're not positive of it's contents.
 - Fix a leak while the system is pressurized.
 - Work on a component while under pressure.
 - Take short-cuts to save time.

EVERY ALTERNATIVE.