Long Beach City College

Transportation + Energy = ATRE

CNG
Fuel Safety

Technical Resource Guide

Doing what matters for jobs and the economy with funding provided by the California Energy Commission (senate bill AB118) through a partnership with the California Community Colleges, Office of Workforce Development, Advanced Transportation and Renewable Energy sector.

Project Director/Editor
Cal Macy

Development team of Subject Matter Experts
Cal Macy
Bob Vannix
Rich Mensel
Pete Sparks

Photography
Cal Macy
Bob Vannix

Created by:
Long Beach City College
Advanced Transportation Technology Center
1305 E. Pacific Coast Highway
Long Beach, CA 90806
562-938-3067
http://www.lbcc.edu/attc/
Calmacy@lbcc.edu

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COURSE INTRODUCTION

Course Title

CNG Safety Inspector Course

Course Length

8 hours

Description:

This course is designed to teach technicians the unique characteristics of safely working with Compressed Natural Gas (CNG) vehicles and their facilities.

- Fuel characteristics regarding pressure and flammability
- Fueling procedures and requirements
- CNG pressure system design
- Safety-related pressure system components
- Proper depressurization techniques
- Basic cylinder care & damage identification
- CNG maintenance facility basic safety concerns

It is intended to raise the reliability of the industry and the confidence of the general public in understanding the characteristics, safe handling and working around CNG storage systems.

Course Benefits

The benefit of this course is designed to help the students to understand the characteristics and safety aspects in working with CNG fuel systems, along with basic safety and facility concerns. This class is a must for and those who need a basic understanding of CNG Systems and fuel delivery systems. Students will be presented with the proper and safe methods of working with CNG fuel systems associated with CNG vehicles.

Prerequisites

Students should have a basic mechanical knowledge and be familiar with gaseous fuels and fuel systems. A general automotive background is also helpful.

Objectives

- Analyze high pressure storage principles
- Evaluate cylinder definitions and terms
- Compare cylinder types, construction and materials
- Differentiate between General and Detailed Visual Inspection
- Contrast various Pressure Relief Devices, their characteristics and failure modes
- Compare types and levels of cylinder damage

Competence

Competence will be measured by both lab demonstration and pre and post tests.

Course Introduction

Instructional Objectives

By the end of this course the technician will be able to understand:

- Fuel characteristics regarding flammability & pressure
- How the pressure system is designed and operates
- How to safely work on the pressure system
- Basic cylinder care & damage identification
- High pressure fitting servicing & leak detection

Important

The materials presented in this CNG Safety Training are informational in design and not intended to replace ANY manufacturer or fleet-established procedures. All manufacturer or fleet-established procedures, TSB's and recommendations shall be followed as they supersede this material.

Available Programs

CNG Safety Training in concert with the CNG Electronic Engine Management Training Program.

Agenda

- Fuel characteristics regarding flammability
- Fuel characteristics regarding pressure
- Pressure system design
- Safety-related pressure system components
- Cylinder care & damage prevention
- Proper depressurization techniques
- Pressure system component servicing
- High pressure fitting servicing
- Leak detection techniques

Pretest

CNG Fuel Safety

1. What is CNG primarily made of?
   a. Propane b. Acetylene c. Methane d. Isobutylene

2. What is the minimum damage to a cylinder that would require repair?
   a. > .005" b. > .010" c. > .020" d. > .025"

3. Technician A says that CNG is lighter than air. Technician B says that ventilation is needed at the highest point of the shop because CNG goes up.
   Who is correct?
   a. Technician A
   b. Technician B
   c. Both Technicians
   d. Neither Technician

4. How many types of CNG cylinders are there?
   a. One type b. Two types c. Three types d. Four types

5. Can a cylinder be re-certified after it reaches the expiration date?
   a. Yes b. No c. Depends on the cylinder type d. Only with type 1 cylinders

6. Are there different levels of cylinder damage?
   a. Yes b. No c. Depends on the cylinder type d. Only with type 1 cylinders

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- Pressure Regulators
- Electric Shut-Off Valves
- Activity 1

5. Cylinder Care & Damage Prevention

- CNG Cylinders & Installation
- Cylinder Mounting
- CNG Cylinder Handling
- CNG Damage Prevention
- Classification of Damage Levels
- Cylinder Damage Prevention
- Conditions Requiring Inspections
- Inspection Outcomes

6. Depressurization Techniques

- CNG Cylinder Defueling: Four Methods
- CNG Cylinder Defueling
- Defueling Vent Stack

7. System Component Servicing

- System Component Servicing
- Leak Detection Techniques
- Leak Detection Fluid
- Electronic Leak Detectors
- Activity 2

8. High Pressure Fitting Servicing

- High Pressure Fitting Servicing
- Activity 3

Test

References

Module One

CNG / LNG vs. LPG

Compressed Natural Gas, or CNG, is a naturally occurring mixture of combustible non-reactive hydrocarbon gases found in porous formations beneath the earth's surface. Early vehicles utilized CNG as fuel until replaced by gasoline and diesel because of their increased heat factor and range.

Compressed Natural Gas is currently available in two pressures: 3000 and 3600 psi. Two manufacturers have onboard CNG reaching 4800 psi that is created from Liquefied Natural Gas (LNG). CNG is stored in high pressure containers specifically designed to handle these pressures. Natural Gas is lighter than air and a dry gas with an odorant, Ethyl Mercaptan added to detect leaks.

LNG is frozen to -238 °F, and colder, where it becomes a liquid that will pool. It is heavier than air until it warms and evaporates. LNG as a liquid will not burn until it evaporates and reaches the lower flammability limit. The liquid is stored in a stainless steel container under low pressure, 230 psi or less, to allow fuel to pressure transfer. It is warmed to a gaseous state and introduced to the engine at around 120 psi depending upon the system. The engine then reduces the pressure to engine operating pressure. There is no odorant in LNG as it will turn to a solid at those temperatures.

Liquefied Petroleum Gas (LPG) , also referred to as Propane, is often confused with LNG and CNG. It is a liquid at -44 °F and is stored under low pressure to aid in transfer and to raise the boiling point. It is heavier than air as a liquid and is stored in a welded steel container. It has an octane rating of 112, which is lower than CNG and a narrower range of flammability at 2-10%. It was used in place of gasoline as its BTU rating is close to gasoline. It is used on fork lifts, barbecue grills and some houses as well as a motor vehicle fuel.

Characteristics of Natural Gas

Natural gas is 94% pure methane with very little carbon, which makes it non-reactive to photochemical smog. It must be this pure and the other constituents must be limited as they will affect the octane rating and burning characteristics. It is a dry gas that becomes a liquid only when frozen to below -238 °F or lower. This makes it very easy to atomize with air, however, caution must be taken with static buildup of the dry gas. The BTU heat value of natural gas is lower, requiring the engine to be optimized for the best power curve. NG has a high ignition temperature, which makes it stable but more difficult to ignite than gasoline or diesel. This is both an advantage and disadvantage that we have to work with to get the fuel to burn and provide the needed power through valve and ignition timing and design. The optimized engine will take these factors in to effect to adjust the air:fuel ratio to the best stoichiometric (ideal) ratio.

Operating Pressures and Safety

Natural gas is one of the safest fuels being used today. It is not toxic to humans although it does displace oxygen so it is an asphyxiate. It is lighter than air so if it leaks in an enclosed environment, it will collect from the ceiling down. It must be contained and mixed with air to burn, which can be accomplished on the peripheral edges of a escaping cloud. If a leak occurs, evacuate the building and ventilate the ceiling similar to if the room became filled with smoke. The ventilation must be non-sparking roof vents or fans designed for NG. Crawl on the floor to the nearest exit and seek fresh air to revive. The flammability window for natural gas is between 5-15% concentration, which is narrower than gasoline or diesel. The shop must be customized for natural gas usage with proper ventilation, detectors and flameproof space heaters and lights. The most critical element of CNG is the pressure in the system. It can exceed 3600 psi and must be respected as this can create hazardous situations.

Energy Content of Alternative Fuels

Replacing Diesel and Gasoline is a challenge due to the energy content (BTUs) of those fuels. It is the reason they were developed and continue to be popular. With the application of emerging technologies, alternative fuels can be an effective option when these differences are addressed. The BTU content of Natural gas is lower than that of other fuels so the engines must be optimized to run on this fuel for best efficiency. Both CNG and LNG must be converted to a low pressure gaseous state to be burned in most systems. Once it is returned to a gaseous state, LNG is utilized in the same engine families as CNG. The use of CNG or LNG is for storage purposes and range as the engine burns low pressure gaseous methane.

Composition of Natural Gas

CNG is made of up of 94% pure methane with an actual percentage of constituents that can vary by region. Many of the impurities contained in natural gas will affect the operation and power of the vehicle as they work to lower the octane rating. Stabilizing and limiting the other components of natural gas was a challenge to making an engine run properly until computerized systems that can adapt became available. Methane is at a stable high octane rating of 130, which simplifies designing electronic fuel systems to work on this fuel. The high octane rating produces less detonation (knock) issues and emissions when operating properly.

System and Ignition Temperature

Natural gas has a higher ignition temperature than gasoline or diesel, which is an advantage as well as a challenge. This higher ignition temperature makes the fuel safer to use as it takes a hotter source to ignite initially. Gasoline and Diesel will ignite at relatively low temperatures where natural gas requires over 500 °F. This is also a challenge to the ignition system as it takes a hotter spark to ignite in the combustion chamber. Ignition systems are specially designed and their proper operation is critical.

Temperature vs. Pressure

Natural gas expands and contracts when heated and cooled. Compressing a gas will create heat as the gas is squeezed into the cylinder. The increase is affected by the rate of compression, which is why a slow fill compressor does not create as much heat during fueling as a fast fill and more BTU's will be stored in the cylinder.

The fuel temperature is critical when filling a vehicle so we don't over or under fill a vehicle. When the fuel is warm, it increases pressure and when it cools, it contracts, reducing pressure. The amount of fuel obtained, the fuel temperature, and the end pressure in the tank are directly related so some fueling stations are temperature compensated to obtain the largest possible range for their fleet. Fueling stations compensate for this temperature/pressure change by increasing the final pressure at the pump when it is hot or decreasing it when it is cold. When the temperature of the gas is above or below 70 °F, the final pressure is adjusted so its Settled Pressure will remain below the Maximum Allowable Working Pressure (MAWP). This is called Temperature Compensation and may result in a slightly higher final pressure than the cylinder is rated for. In hot climates, this pressure can be up to 125% of the rating in the tank but must never exceed the MAWP or the cylinder is level 3 damaged and must be condemned. The fuel in cold climates will expand as it warms, so the pressure must be kept lower to allow this expansion without exceeding the MAWP.

Review Questions

CNG temperature changes with pressure? T/F

CNG is heavier than air? T/F

Natural Gas Safety Considerations

TOXICITY: Nontoxic. It is not a poison like carbon monoxide but it does displace oxygen.

FLAMMABILITY: Flammability range is narrow 5-15% -- below 5 is too lean to burn, above 15 too rich. Edges of a cloud could be right mixture. Heaters and other spark producing items must be relocated.

VENTILATION: Must be trapped vertically to be dangerous -- look up for traps at ceiling/false ceilings, etc. Lighter than air so most shops are equipped with auto vents on the methane detection circuit.

LEAK DETECTION: Mercaptin NOT present in LNG unless infused so it will have no odor. Methane detectors and hand held combustible gas detectors available along with commercial bubble style leak detectors. CG detectors will go off on many substances such as glycol, silicone, diesel, hyd. fluid so it is just a gross indicator.

COLLISION: Cylinders must have a Detailed visual inspection and hardware should be carefully inspected for damage. Cylinders should be closed and ¼ turn valve closed if vehicle is involved in an accident.

STORAGE: LNG vehicles should be stored outside due to venting of tank. CNG system is sealed and will not leak to atmosphere

SHOP SAFETY/EQUIPMENT: Methane detectors and ceiling ventilation should be reviewed by engineering. Special tools kit being provided to perform defueling, etc.

2 Module Two

CNG Facility Considerations

- Ventilation
- Leak Detection
- Collision
- Storage
- Shop Equipment
- Personal Protective Equipment
- Eyewash Stations
- Hearing Protection
- Defueling

There are many new considerations when introducing CNG vehicles to your facility. Every maintenance facility will have its own facility considerations regarding the servicing of CNG vehicles. Local regulations may vary with the design and layout of each facility. Location of offices, lighting, heaters, ventilation requirements, safety equipment and methane detection should be evaluated by engineering professionals trained in these types of installations.

CNG cylinders will not vent pressure when stored like LNG, however, there can be other sources of release so vehicles should not be stored inside for extended periods. Escaping gas under pressure is very dangerous and should be respected at all times so detection systems should be installed. Natural Gas can cause physical injury, eye and hearing damage from the pressure and noise requiring personal protection equipment. A defueling station should be established as defueling a cylinder is required whenever level 2 or 3 damage is suspected to ensure the system is depressurized and safe when servicing the fuel system components. Level 2 damage is as little as a .010” scratch or a damaged line.

Review Questions

With CNG, extra ventilation is not required because CNG is odorless? T/F

3 Module Three

Operational Theory of Naturally Aspirated Carbureted CNG Systems

The vehicle stores natural gas at high pressure to extend the range of the vehicle. The engine will operate at a much lower pressure. There are several engine operating pressures being utilized with naturally aspirated, "or carbureted" and electronically injected vehicles. The naturally aspirated system relies on engine vacuum or suction to draw in a low pressure fuel and the injected system relies on positive fuel pressure to inject the fuel into the intake. While the engine operating pressure is much lower on naturally aspirated systems, both designs can utilize turbo charged air intakes for additional power. They can be adjusted using a closed-loop O_2 sensor-driven calibration along with computer inputs to monitor engine operating modes.

For either system, the storage pressure is usually regulated to a first-stage of approximately 100-150 psi using a pressure regulator. On naturally aspirated systems, this first stage pressure is introduced to a second-stage pressure regulator, which decreases the pressure to about 0.18 psi above atmospheric pressure. The gas is then drawn into the engine using the suction of the pistons. Gas flow rate is controlled by the secondary regulator utilizing the pressure differential between the air intake and the CNG system pressure with a vacuum port to increase the gas flow under load.

Operational Theory of Fumigated Pilot Ignition LNG/CNG Systems (Westport)

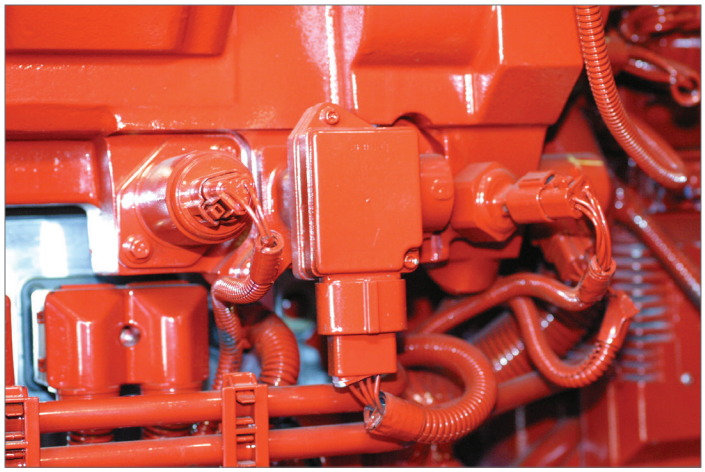
The Westport HPDI is a current example of a pilot ignition system in which diesel fuel is used to ignite a natural gas charge. This is an alternative to spark-ignited engines that inject 1700 psi– 4300 psi CNG and Diesel directly into the combustion chamber. It utilizes a Fuel Conditioner to control both pressures separately into a computer-controlled Dual Injector. The Dual Injector provides 5% diesel initially followed by high pressure CNG that is produced onboard from LNG.

Operational Theory of CNG Injection Systems ISL-G

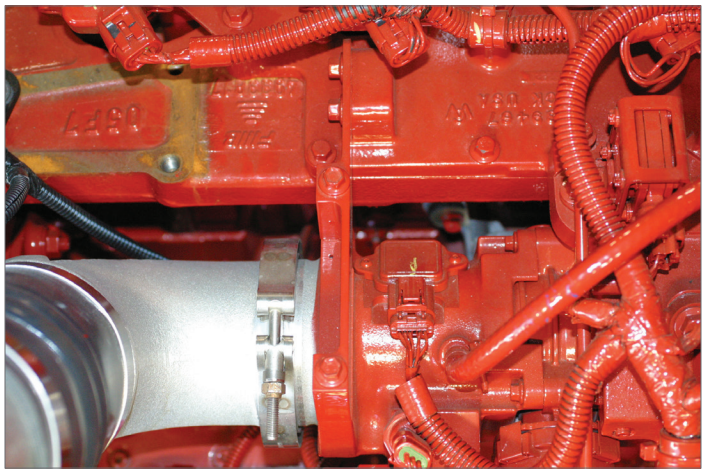
Injected systems are Spark Ignited and usually have the same primary pressure of 100 -150 psi with varying secondary pressures by manufacturer design. Cummins requires 120 psi primary pressure and delivers 65 -73 psi secondary pressure to a computer-driven Fuel Control Valve.

Cummins Mass Gas/Airflow System

This system monitors gas volume with a Mass Gas Sensor and the volume of air going into the mixer with the Mass Air flow sensor. This system computer adjusts the Fuel delivery, monitoring other sensors and the O_2 sensor in closed loop.



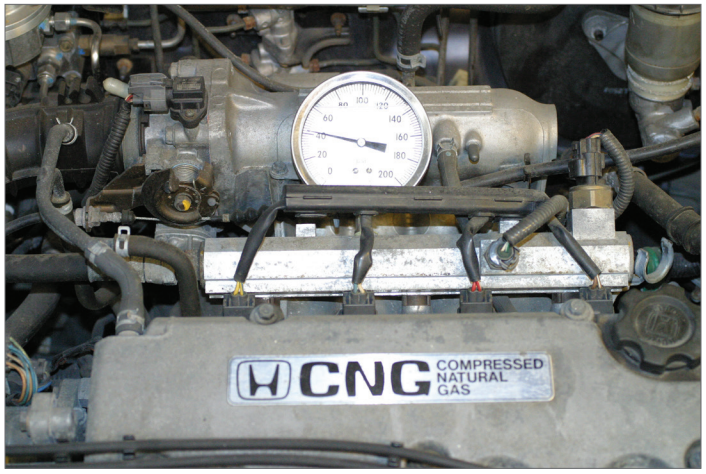
Mass Gas Sensor



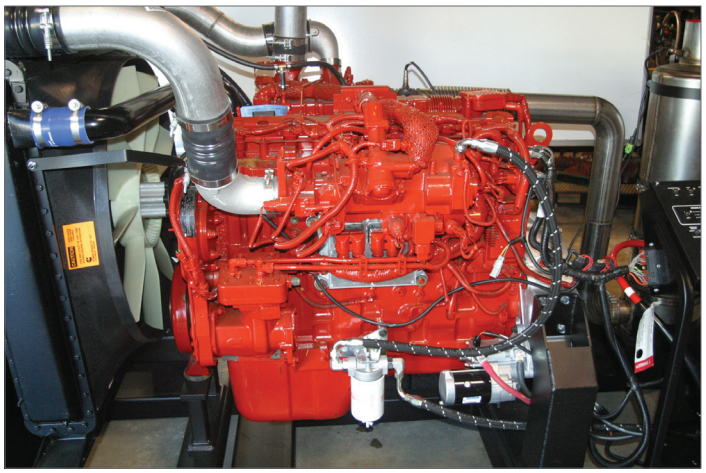
Mass Air Flow Sensor

Operational Theory of CNG Injection Systems

Other manufacturers use batch and multi-port injector or solenoid systems that are also computerized to meet performance and emission standards. In most cases they use the same primary pressure of 100 -150 psi with varying secondary pressures. Some heavy duty like John Deere inject at higher pressures and others like Honda uses a dual stage regulator to keep the pressures lower. Some systems use a second computer that interfaces with the OEM computer to control the injector drivers.



Honda CNG uses Dual / Stage Regulator



Cummins uses 2 Separate Regulators

Review Questions

What is the CNG primary pressure on most applications?

_____

_____

What is the difference between a high and low pressure shut-off?

_____

_____

4 Module Four

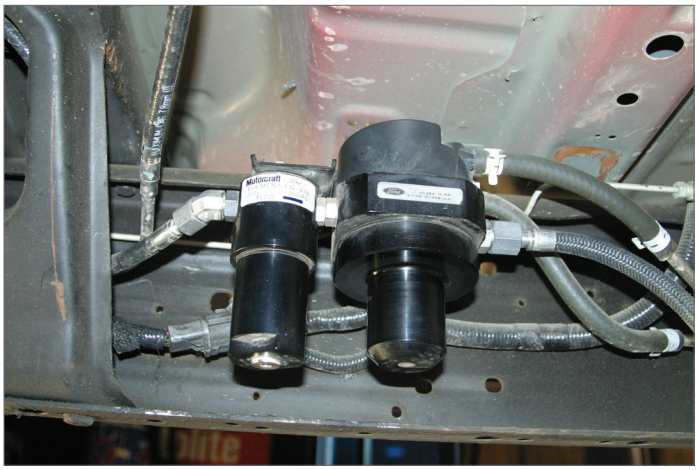
Major Components

CNG delivery systems are specifically designed for the high pressure dry gas they transport. The components are designed to safely store and dispense this gas without leaks. Caution should be taken when working with these components as they are all under pressure. There are many Safety devices designed to protect the system and operators from this pressure and they should be maintained and functional. Always assume these items are under pressure until proven otherwise. Proper isolation and depressurization must be accomplished by a technician knowledgeable in the system before any disassembly. Care must be taken when disassembling systems as pressure can even be trapped between components. Place a rag over the flare wrench as a fitting is loosened as a precaution.

Fill Valve and Coalescent Filter

The fill receptacle is where the pump nozzle attaches to fill the cylinders and it must have a dust cap installed when not filling. The design has been standardized by the Natural Gas Vehicle Coalition for safety and promotion of public stations. The NGV1 standard allows all of the same pressure fueling nozzles to fit to all receptacles without any adapters. It will not allow a 3600 psi pressure nozzle to connect to a vehicle with a 3000 psi receptacle where over-pressurization would occur due to the higher pump pressure. It is important that the receptacles installed match the pressure of the cylinders.

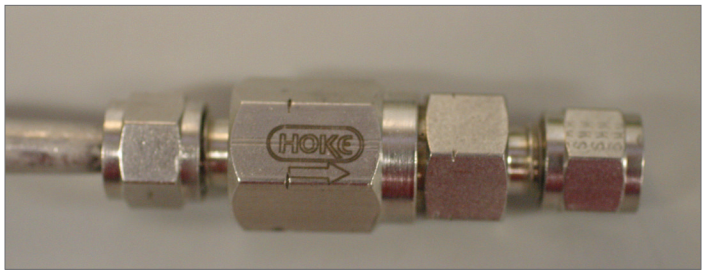
A coalescing filter can be in line with the nozzle to prevent compressor oil or contamination from entering the system, however, it may impede a fast fill. Low pressure filters are installed to capture any contaminants before they reach the engine fuel system.



Coalescing Filter and Regulator

Low Pressure Filter with Drain

One-Way Check Valve



One-Way Check Valve Flow Direction

A one-way check valve is installed in the system fill line to prevent fuel leakage should the receptacle or plumbing become damaged in an accident. It must be installed correctly to allow fuel flow only in the direction of the arrow. The valve is usually installed beyond the "crush zone" of the vehicle, or with Fords, it is in the filler receptacle assembly.

Fuel Storage Cylinders

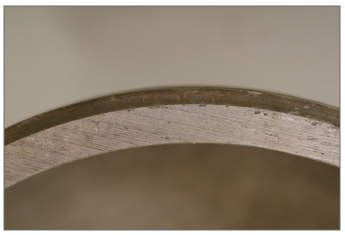
Cylinders should be Matching Pressure

The high pressure Fuel Storage Cylinders are used to provide range to the vehicle by storing larger quantities of fuel under pressure. They come in various sizes and can be neck or strap mounted in any configuration on top or under the vehicle within installation regulations. They should be all matching pressures or the system would be limited by the lower pressure receptacle. There are two pressures currently available with development of higher pressure cylinders for hydrogen and natural gas in the future. The Westport HDPI currently creates 4800 psi CNG that is stored in a Luxfer on board type 3 cylinder. There are 4 different construction types currently available with a 5th type emerging.

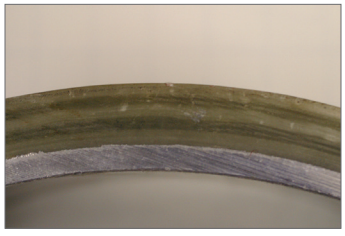
Cylinder Types

To withstand the pressure, cylinders are constructed from thick-walled, high-strength materials, such as steel, aluminum, or composites. According to construction type, these high-pressure cylinders are labeled Type 1, Type 2, Type 3, or Type 4 in compliance with NGV2 standards. Each cylinder type is made of different materials and has a specific usage.

Type 1



Type 2



Type 3

Type 4

For example, a Type 1 cylinder is made of all metal (steel or aluminum). These cylinders are very heavy and are ideal for stationary applications. The Type 4 cylinders, which consist of a plastic liner and a fully composite or fiber wrap, are very lightweight. This makes them ideal for small vehicle and roof-mount applications. Each type is built to stringent standards that include fire damage tests, cycling tests, and burst testing of the cylinder to 2.25 times its working pressure. This is necessary as the cylinders do expand slightly under pressure when cycling and need to be protected from fatigue cracking and excessive heat.

Cylinder Type 1

Type 1 cylinders are made of either steel or aluminum and are the oldest type of CNG cylinders. The metal must hold 100% of the cylinder burst test pressure, or 2.25 times the storage pressure. They are less expensive than the others to produce, but are heavier and very rugged. Their major vulnerabilities are rust, corrosion damage and oxidation. They are widely used in Europe and other countries.

Cascade of Type 1 all Steel Cylinders

Cylinder Type 2

Type 2 cylinder consists of a metal liner and a composite or fiber wrap. The cylinder is called hoop wrapped because the wrap is wound only around the cylinder sidewall. The metal portion of the cylinder and the composite wrap share the internal forces almost evenly. This means that the cylinder itself will hold the full storage pressure of the cylinder and the wrap gives the burst test safety factor. These cylinders weigh considerably less than the Type 1 cylinders. Their major vulnerabilities are corrosion to the exposed metal and cuts or abrasions to the wrap material.

Type 2 with Exposed Metal Ends

Cylinder Type 3

Type 3 cylinders consist of a metal liner wrapped with composite over the entire sidewall and dome portions of the cylinder. The metal portion of the cylinder is much thinner than the Type 2 cylinders. The metal portion of the Type 3 cylinder holds 20%, while the fiber over-wrap holds the remaining 80% of the load. This means that the metal liner cannot withstand the storage pressure alone without the help of the overwrap. Again, due to the reduction of metal usage, these cylinders weigh less than the

Type 2 cylinders. In addition to damage from over-pressurization or impact, their major vulnerabilities are cuts or abrasions to the wrap material and corrosion coming from any exposed metal at the fittings on the domed end of the cylinder.

Type 3 Fully Wrapped Aluminum

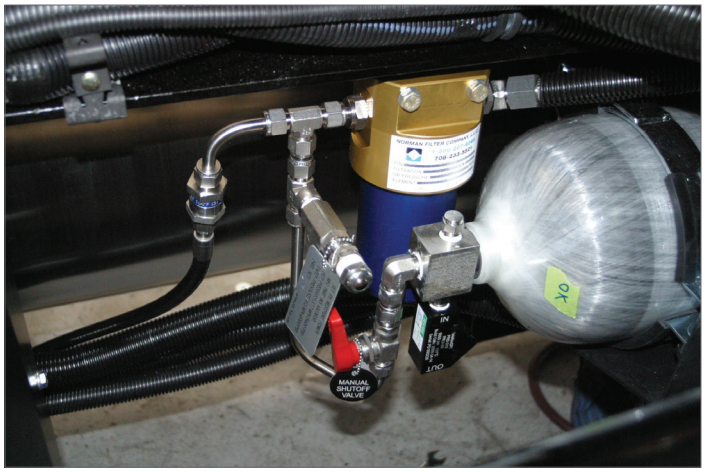
Cylinder Type 4

All Composite with Liner

Type 4 cylinders consist of a plastic liner wrapped with composite over the entire sidewall and domes of the cylinder. These cylinders are fully composite and have no metal portion. The plastic liner is used only as a gas barrier. The composite material is designed to handle 100% of the burst test pressure. These cylinders are the lightest due to their lack of metal content and are ideal for light vehicles or on the roof of busses where weight is very important. They do not transfer heat as well as the others and, as a result, are required to have a metal heat transfer strap in some applications to allow the special pressure and heat relief device to work properly. In addition to damage from over-pressurization, their major vulnerabilities are from impact, cuts and abrasions, and depressurization allowing the liner to separate from the composite and leak or trap gas.

CNG High Pressure Cylinders

Cylinders must meet stringent testing that includes the intentional bursting of a cylinder. To prove it fulfills its designs, a cylinder must be able to withstand 225% of its rated pressure before it ruptures. This is to ensure that it will perform safely during its cycle life expectancy. During operation, cylinders must not be overfilled beyond their Maximum Allowable Working, which is 137.5% of the cylinder pressure. Exceeding this amount requires that the cylinder be condemned.



Cylinders and Safety Devises are Designed for the Pressure

CNG Temperature Compensation

Some fueling stations compensate for temperature changes by overfilling the cylinder so it "settles" to the cylinder pressure when it warms or cools providing maximum range. It is very important to under pressurize in cold climates as the fuel expands when it warms. Over pressurizing due to hot fuel is permissible up to 125% of the rated cylinder pressure without damage.

Physical Properties of Cylinder

There are many manufacturers of CNG cylinders both foreign and domestic. Each cylinder is required to have a label providing valuable information including the type of certification obtained, the date of manufacture and the date the cylinder is removed from service. This information is required along with serial and model numbers. Contact information on the manufacturer is included and inspection recording is included. This label must be visible to do the inspections and may be vulnerable to cleaning solvents.

Fuel Door and Cylinder Labels

Cylinder Shut-Off Valve

Each cylinder is equipped with a shut-off valve of either manual or automatic design. The Valves contain a manifold connection to link cylinders together so caution should be taken as pressure may be present from other cylinders. It is possible for a trained technician to isolate a cylinder and empty it for servicing without emptying the entire vehicle, providing proper steps are taken to eliminate any pressures present.

The electronic solenoid valves are normally closed valves that must be activated to open. There is a special procedure to open them if they fail closed. This special tool will destroy the valve during the process.

Manual and Electronic Valves

CNG Excessive Flow Valve

Excessive Flow valves are used on vehicles mainly in Europe to prevent flow should a fuel line break open. It is installed in the supply line from the cylinders to shut off fuel flow if it exceeds a preset amount. The valve flows normally until it gets locked in the closed position due to the volume.

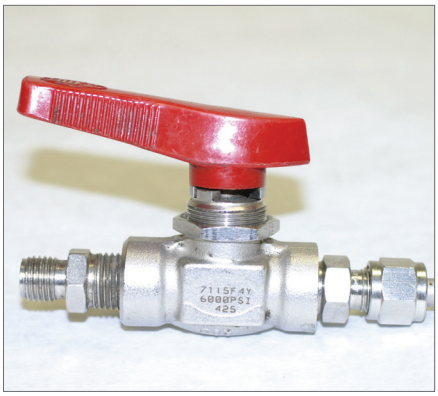
Pressure Relief Device (PRD)

Pressure Relief Device (PRD) is installed on the valve or is a part of the electronic valve itself. It is to protect the system from over pressurization or high temperature causing pressure. It releases in case of excessive heat or pressure in the cylinder and vents to the atmosphere quickly. The PRD is mounted on the valve IN DIRECT PRESSURE AT ALL TIMES. The cylinder MUST be vented fully to remove the PRD and it is a one-time failure. There are examples of resettable PRDs on stationary engines. They cannot be reused on another cylinder but can be removed and reinstalled on the same cylinder if needed. There is a special design for Type 4 - all composite cylinders because the plastic does not transmit heat effectively.

Type 4 PRD

Manual Shut-Off Valve (quarter turn)

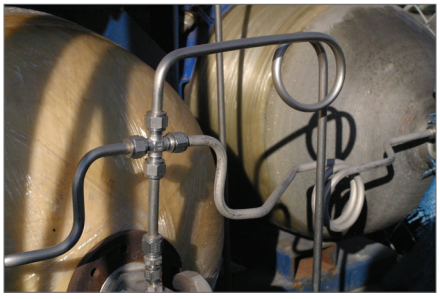
A manual valve that shuts off with a quarter turn is installed to isolate the cylinders from the engine compartment for servicing or emergencies. This valve is supposed to be accessible and marked from the outside saying Manual Shut-Off Valve but it may be hard to find or nonexistent as electronic valves on the cylinders are used.



Quarter Turn Valve

Stainless Steel Fuel Lines

The fittings and lines on the system are made of stainless steel and able to withstand four times as much pressure as they are subjected to. To allow for flexing, the tubing must have relief loops or utilize flexible weave tubing. Recent changes allow for 3 times redundancy as outlined in the industry standard NFPA.



Seamless Stainless Steel

Braided Stainless

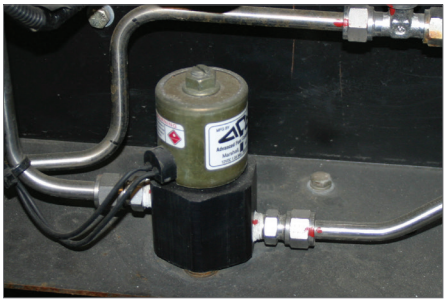
Pressure Regulators

The pressure regulator is used to reduce the cylinder pressure to engine operating pressure. This may take two stages or two regulators to achieve the pressure of under 120 psi. They are warmed by the coolant to reduce the refrigeration effect of dropping pressure. Care must be taken with the fittings on the ITT regulator as they are O-ring style not compression.

ITT Conoflow Regulator

Shut-Off Valves (Lock-Offs)

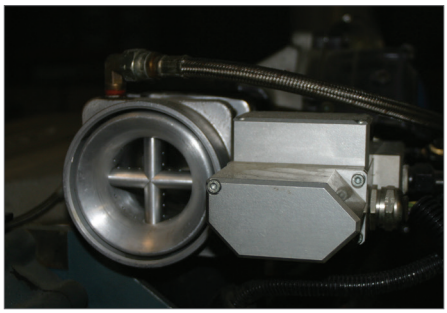
The fuel Lock-Off Valve prevents fuel flow unless engine RPM is present. If the engine stalls with the key on, the system must shut down the fuel. It can be in the low or high pressure side of the circuit. They are rated and the pressure must match the solenoid. It is usually ground side controlled by PCM. Early types were vacuum operated. Both require a minimum cranking RPM to initiate the solenoid and provide the fuel.



Solenoid Lock-Off

Fuel Introduced into Intake Air Stream

The fuel is introduced to the engine through the mixer or injectors through the intake air stream. The mixer is like a gas stove, lightly expelling gas that is then drawn into the engine. On injected systems, the fuel is electronically released into the intake at pressure.



Mixer Assembly

Review Questions

How many cylinder types are there?

_____

_____

Which cylinder type is the lightest?

_____

_____

LONG BEACH CITY COLLEGE

CNG Fuel Safety Class
Activity 1
Component Identification

Tools and equipment:

1. Classroom materials
2. Flashlight
3. Clipboard

Step 1: Truck Overview

Locate the following components and note their location in the space provided. If the bus does not include an item write N/A in the space provided.

Cylinders_____

How many are there? _____ What is the pressure rating? _____

Who made them? _____

Is there a way to contact the manufacturer? _____

What kind of shielding is present? _____

What is the Do not Use After date? _____

Is there an inspection interval labeled? _____

Cylinder valve _____

Are they manual or electric? _____

HPR _____

Who is the manufacturer? _____

Are there hoses on it and why? _____

Coalescing filter _____

Is it High or Low Pressure? _____

¼ turn valve _____

How is it labeled? _____

What is down stream of the valve? _____

PRD _____

Where does it vent? _____

Secondary filter _____

Is it a spin on or in-line? _____

Does it have a drain? _____

Fill receptacle _____

What is its pressure rating? _____

What, if any, labeling is present? _____

High pressure gauge _____

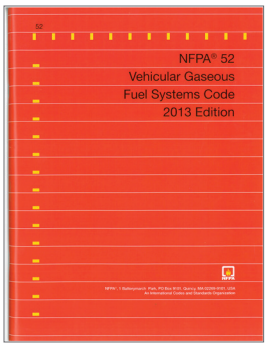
What is its maximum reading? _____

Notes:

5 Module Five

Cylinder Care & Damage Prevention

CNG Cylinders & Installation



The National Fire Protection Association (NFPA) regulates CNG cylinder installation. NFPA 52, "Standard for Compressed Natural Gas Vehicular Fuel Systems," establishes the industry standards for all CNG system installations. An industry standard is a guideline established by a team of experts and is accepted as the proper procedure in most cases including the courts. Some states like California adopt it as law while others paraphrase it into law. The standard that was in effect when the vehicle was built or converted should be complied with.

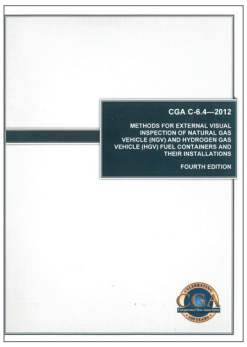
Cylinder Mounting

Listed below is a summary of NFPA 52 cylinder installation requirements:

A correctly mounted CNG cylinder should:

- Have the label visible.
- Be mounted 7 inches above the ground for short wheelbase or 9 inches for long wheelbase vehicles (over 9 feet), and not behind the rear bumper or in front of the front axle. (The 2013 version now states "adequate" clearance).
- Be capable of restraining the cylinder when subjected to a force of 8 times the weight of the cylinder in 6 principal directions.
- Incorporate manufacturer's recommended brackets with rubber gaskets and torqued to specification.
- Be shielded properly from excessive sunlight, vehicle cargo, road debris, or vehicle exhaust.
- Be protected from excessive heat or pressure by a relief device.
- Be properly vented to the outside using tubing or a vapor barrier.

CNG Cylinder Handling



Compressed Gas Association pamphlet CGA 6.4 is the industry standard for handling, removal, defueling and inspection of cylinders. It is the instruction manual on damage inspection procedures and should be followed using the version in effect when the inspection is being made. It will refer to the manufacturer for final disposition on any level 2 damage. Inspections can be accomplished with a little creativity as removal of the cylinder for inspection is not required or recommended.

In general, cylinders should not be removed from the vehicle except for the following reasons:

- The vehicle has been in a fire.
- The vehicle has been in an accident and the cylinder or brackets have been damaged.
- Vehicle maintenance or repair requires the cylinders be removed to access the area in question.
- The cylinder is condemned due to age of the cylinder or level 3 damage.

If the cylinders are to be removed, the following guidelines should be followed:

- Cylinders should be handled with extreme care and depressurized when possible.
- Cylinders should not be picked up or handled using the shut-off valve or the pressure relief device.
- Cylinders should never be dropped.
- Cylinders should never be dragged along the ground.
- Cylinders should be strapped to a pallet and stored outside. This eliminates the risk of the cylinder rolling off and striking any object.
- Pressure relief devices can be removed and reinstalled on the same cylinder, but cannot be reused on another cylinder or vehicle.

Cylinder Damage Prevention

Compressed natural gas cylinders are manufactured with safe operation in the construction and operating design. These CNG cylinders, although designed and tested prior to installation in the vehicles, must be inspected and certified for continued use.

A General visual inspection is an inspection that is performed during normal preventative maintenance (PM). The PM technician or the driver of the vehicle would complete these inspections. This inspection would be similar to a tire or brake wear inspection. The frequency of these inspections would be up to the fleet manager or as specified in the safety plan.

Classification of Damage Levels

There are 3 classifications of damage that the qualified inspector will evaluate. Level 1 requires no action other than to document the location and severity of the damage for future reference. Digital Photos and the inspection report are used to document any findings. Level 2 must be resolved to either level 1 or condemnation of the cylinder in level 3. Level 2 can include installation and plumbing issues.

Level 3 damage is not repairable and the cylinder must be removed from service.

Here are some examples of each level and the limits from CGA. Manufacturer's standards determine the final disposition of any findings.

Level 1

- Any scratch, gouge, or abrasion with a damage depth of .010" or less.
- Can be documented and returned to service & considered minor.

Level 2

- Any scratch, gouge or abrasion with a damage depth of .011 to .050" depending upon type of cylinder and manufacturer.
- Must be repaired according to OEM method.

Level 3

- Any scratch, gouge or abrasion greater than .050".
- Pitting over .035" or Line Corrosion over .030" or over 6".
- Level 2 damage that is not resolvable to level 1.
- All fire, chemical and weather damage that does not wash off.

Cylinder Damage Prevention

Any evidence of damage noticed during a general visual inspection would require review by a qualified inspector using the required resources.

When a general inspection reveals any damage to the cylinder or its delivery systems, a Detailed Visual Inspection by a qualified inspector should be performed. This would include the mounting brackets, fuel lines and components as well as the cylinders themselves. Damage to the cylinder is very critical as a scratch or gouge on a cylinder can lead to a failure. A scratch that can be felt with your fingernail is all that is required to condemn a cylinder. Damaged fuel lines or brackets must be replaced and regular inspections are needed to discover any hidden damage. Each manufacturer establishes its own criteria for damage and repairs allowed. Any known or suspected level 2 damage requires depressurization of the system before continuing.

Detailed Visual Inspection

Detailed Visual Inspection is an inspection that is required for NGV cylinders.

A trained cylinder inspector utilizing CGA or the cylinder manufacturer standards is required to perform the detailed visual inspection. These inspections are required by NGV2, FMVSS304, and the manufacturer's recommendation. The standard frequency for detailed cylinder inspection is every 3 years or 36,000 miles (whichever comes first). Detailed inspection reports are required and the CHP has the authority to audit compliance.

Conditions Requiring Inspections

The cylinders should also be inspected if:

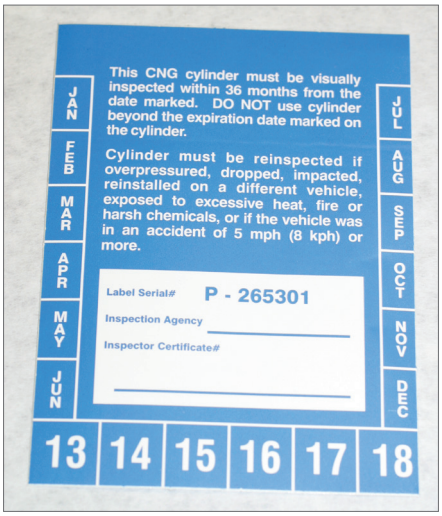
- The vehicle was involved in a fire or accident.
- The cylinder was subjected to an impact or excessive heat.
- The cylinder was exposed to any foreign chemical or substance.
- Natural gas odor is apparent or you see bubbles on type 4 cylinders.
- The fuel tank is removed and replaced for any reason.
- The cylinder requires periodic inspection.

NOTE: Failure to perform inspections on a regular basis or during any situation above may result in serious damage and injury.

Inspection Outcomes

Each fleet inspector must establish a comprehensive procedure to label inspected cylinders and ensure proper disposition in case of noted damage. Some cylinder manufacturers have a location on the label to stamp inspections. Some facilities have pass/fail labels or red tag procedures. Your safety committee should develop the internal procedure to ensure compliance that is consistent with other vehicle safety procedures.

Level 2 or 3 Failure



Pass Label

Review Questions

How many levels of damage are there?

_____

_____

Describe each level of damage.

_____

_____

6 Module Six

CNG Cylinder Defueling: Four Methods

Defueling is required for all level 2 and 3 repairs. There are 4 methods to defuel a cylinder with scheduled defueling the preferred method.

The four methods are:

1. Run cylinder out of fuel by driving or allow to idle

a. Preferred for scheduled maintenance

2. Transfer fuel to another vehicle or cylinder

a. Requires special plumbing

3. Return fuel to compressor inlet

a. Least desirable as it may introduce contaminants to compressor

4. Vent to atmosphere

a. Requires vent stack carefully grounded and bonded to eliminate static

CNG Cylinder Defueling

A portable vent stack can be used to defuel a vehicle in a open space. It needs to electrically bond the components together and ground them to eliminate static caused by the escaping dry gas. Check local regulations regarding the release of methane.
A permanent vent stack located within pushing distance of the repair facility is preferred providing high voltage and other hazards described in CGA 6.4 are considered. Look down wind for ignition sources and nuisance hazards caused by the smell of the escaping gas.

Defueling Vent Stack

Preparation for defueling should be made before there is an emergency need. CGA 6.4 outlines the procedure for defueling and gives a diagram of a defueling device. They are easily assembled and should be available before they are needed.

Review Questions

Why is it so important to have a defueling station?

7 Module Seven

System Component Servicing

Care should be taken when handling cylinders to prevent damage to the valve, which could result in the cylinder becoming airborne. Escaping gas will make a cylinder fly like a released balloon. Leave the cylinder attached to the vehicle when defueling or secure it to a pallet on a forklift or other solid object to keep it safe and in place.

Cylinder pressure can be trapped behind any closed solenoid or even the regulators as they do not vent when shut off. The valves provide a manifold to connect all the cylinders together and the PRD is in constant pressure from the tank. Extreme care must be taken to eliminate this pressure safely before continuing with repairs or removing these components. Depressurizing the cylinder(s) requires special equipment / procedures and should be done before working on any system with known or suspected level 2 damage. When working on the fuel system components, closing the tank valves or the quarter turn valve (if so equipped) and then running the engine out of fuel is the preferred method to ensure all pressure is dropped from the system before removing any fittings. Wear a face shield and place a rag over the fitting as a safety measure when disconnecting a de-pressurized line to ensure any residual pressure does not spray contaminants in your face. Only trained and qualified personnel should attempt these procedures.

Leak Detection Fluid

After completing assembly all fittings should be leak tested to ensure no leaks are present. This should be done with a commercial leak test fluid that meets the requirements for Natural Gas. Make sure it is designed for natural gas as other detectors such as Air Conditioning leak test fluid may not work properly. Making your own fluid is not recommended as the mixture will vary and the pH balance is critical to prevent damage. Checking for leaks in stages at lower pressures is preferred before subjecting the fittings to full pressure.

Commercial Leak Detection Fluid for CNG

Electronic Leak Detectors

Electronic Detection

When searching for suspected leaks, electronic leak testers can be used to trace a leak. Caution must be taken as the tester will react to other combustible materials such as curing silicone. Leaking fittings should be depressurized before any repairs are attempted. Just readjusting a fitting and re-torquing it will resolve many leaks. There is a specific procedure that must be followed for initial and reassembly torquing of fittings.

Review Questions

Why is leak detection important?

_____

_____

Name various methods of leak detection.

_____

_____

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Activity 2:
System Depressurization

Tools and equipment:

1. Classroom materials 2. Tool set 3. Filters & Seals 4. Leak Detector

Step 1: Locate the Quarter Turn Valve, Lock-Off Solenoid and Cylinder Valves
What is "downstream" of each component?

_____

_____

Step 2: Does the vehicle have a coalescing or inline filters?

- Coalescing filter _____
- Inline filter _____

Step 3: What is the best way to depressurize the filters? _____

Step 4: Isolate the system by shutting down the ¼ turn valve, Lock-Off Solenoid and/or Cylinder Valves and run the bus out of fuel to depressurize the filters.

Step 5: (Optional) Drain & Remove the coalescing filter cup and clean the reservoir and filter element & replace the seal.

Was there any signs of oil contamination? _____

Step 6: (Optional) Drain & Remove the inline filter and replace it with a new one including the seals.

Was there any signs of oil contamination? _____

Step 7: Turn the tank valves "on" and re-start the engine

Step 6: When the engine has started check the coalescing and inline filter with SNOOP leak detection soap and an Electronic Methane Leak Detector.

Notes:

_____

_____

_____

8 Module Eight

High Pressure Fitting Servicing

High pressure fittings must be assembled correctly to prevent leaks and damage to other systems. Most manufacturers recommend use of liquid sealer such as Swak to seal tapered or straight pipe fittings. Teflon tape is not recommended as it can flake off and plug internal components.

Special instructions must be followed for double farrule fittings as they must be de-burred and assembled very carefully to ensure they will withstand the high pressure. Additional training in class or from the manufacturer is needed as initial angle torque is used to make the ferrules. Reassembly of components requires ¼ turn after hand snugging.

Liquid anaerobic sealers must be assembled for up to 8 hours before pressurizing according to instructions. If Teflon tape is used it should be designated for CNG as it is thicker. Many times it is a different color indicating CNG use. Regardless of the method, the sealant should be installed with 2 threads not covered to ensure traces of tape or liquid do not travel to upstream components creating a safety or operational problem.

A commercial liquid leak check fluid should be used to ensure no leaks are present after assembly. Many fleets make this a regular PM duty, finding leaks before they become an issue. Be sure to use a fluid that is commercially designed for CNG leak checking. Many air conditioning leak detective fluids do not react to natural gas leaks. What works to blow bubbles for your children may not react properly causing a poor response.

High Pressure Fittings must be Carefully Sealed and Assembled

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Activity 3:
Instructor-Led Fitting Demonstration

Tools and equipment:

1. Swagelok Fitting manuals/booklets
2. Fittings & Tubing
3. Wrenches, Swagelok, & Vice Grips
4. Tube Benders and Tubing
5. Templates

Note: This exercise can be a demonstration or full class participation depending upon time and materials available to instructor. In order to have each tech assemble a fitting, you will need one wrench and one Swagelok vice grip along with a fitting and tubing for each tech. This can be expanded to a full tube bending and deburring demo if time/materials permit.

Step 1: Demonstrate the proper fitting assembly showing techs the ferrules

Step 2: Demonstrate the proper preparation of tubing for assembly into the fitting

Step 3: Demonstrate the proper Angle Torque method to swage new ferrules (11/4 turns)

Step 4: Disassemble the fitting and show techs the result

Step 5: Reassemble the fitting demonstrating the proper Angle Torque for reassembly

Step 6: Time/Materials permitting have techs practice steps 2-5

Step 7: Time/Materials permitting have techs practice tube bending using templates/formulas

Notes.

Post Test
CNG Fuel Safety

1. When does a cylinder lifecycle begin?
   a. At time or being placed in service
   b. At time of manufacture
   c. At time of first fueling
   d. No such thing

2. What is CNG primarily made of?
   a. Propane b. Acetylene c. Methane d. Isobutylene

3. What is the minimum damage to a cylinder that would require repair?
   a. > .005" b. > .010" c. > .020" d. > .025"

4. Technician A says that CNG is lighter than air. Technician B says that ventilation is needed at the highest point of the shop because CNG goes up.
   Who is correct?
   a. Technician A
   b. Technician B
   c. Both technicians
   d. Neither technician

5. How many types of CNG cylinders are there?
   a. One type b. Two types c. Three types d. Four types

6. What is the depth of cut damage needed to condemn a cylinder?
   a. > .010" deep b. >.020" deep c. >.050" deep d. >.080" deep

7. How many levels of cylinder damage are there?
   a. one b. two c. three d. four

8. What agency monitors Commercial CNG vehicle inspections?
a. EDD b. National Park Service c. CHP d. NFPA

9. What is the inspection interval for CNG Vehicles?
a. 1 yr/1200mi b. 2yr/2400mi c. 3yr/3600 d. 4yr/4800mi

10. Can a cylinder be re-certified after it reaches the expiration date?
a. Yes b. No c. Depends on the cylinder type d. Only with type 1 cylinders

References

Sources:

Compressed Gas Association
1725 Jefferson Davis Highway,
#1004 Arlington, VA 22202-4102
Telephone: 703-412-0900

Gas Research Institute
8600 W. Bryn Mawr Avenue
Chicago, IL 60631-3652
Telephone: 773-399-8352

American National Standards Institute
11 W. 42nd Street
New York, NY 10036
Telephone: 212-642-4900

National Fire Protection Association
11 Tracy Drive
Avon, MA 02322
Telephone: 800-593-6372

Natural Gas Vehicle Coalition
1515 Wilson Blvd. Suite 1030
Arlington, VA 22209
Telephone: 703-527-3022

Department of Transportation
400 Seventh Street, SW
Washington, DC 20590
Telephone: 202-366-4000

Publications:

CGA C-6.4, “Methods for External Visual Inspection of Natural Gas Vehicle Fuel Containers and Their Installations,” 1st Edition (1997)

NFPA 52, “Standards for Compressed Natural Gas Vehicular Fuel Systems” National Fire Protection Association, 1 Batterymarch Park, Box 9101, Quincy, MA 02269-9101

ANSI/AGA-NGV2, “ Basic Requirements for Compressed Natural Gas Vehicle Fuel Containers,” American Gas Association Laboratories, 8501 East Pleasant Valley Road, Cleveland, OH 44131

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Gas Research Institute, “ Natural Gas Vehicle Cylinder Care and Maintenance Handbook” (1997)

CHP Title 13

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