Long Beach City College

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Compressed Natural Gas Cylinder Inspection

Guidelines & Procedures

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.

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This material is based upon work supported by the California Energy Commission under Grant No. 12-041-008

COURSE INTRODUCTION

Course Title

CNG Cylinder Safety Inspection/Fuel Systems Inspector

Course Length

16 hours

Description

This course is designed to teach technicians the safe and proper procedures to do visual inspection of high-pressure CNG Cylinders/Fuel Storage Systems. This course includes discussion of:

- Fuel characteristics regarding pressure and flammability
- Safety related pressure system components
- Proper fueling and defueling techniques
- Tank care & damage prevention
- CNG delivery system diagnostics
- CNG leak detection techniques
- CNG container and plumbing diagnosis and repair

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

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 those who need a basic understanding of CNG 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 fuel systems. A general automotive background is also helpful.

Objectives

Upon completion of the course, students will be able to:

- Examine high-pressure storage principles
- Examine cylinder definitions and terms
- Examine cylinder types, construction and materials
- Differentiate relative sensitivities to operating conditions and failure modes
- Inspect applicable cylinder standards
- Contrast proper installation and handling of high-pressure cylinders
- Differentiate between General and Detailed Visual Inspection
- Appraise inspection requirements
- Contrast various Pressure Relief Devices, their characteristics and failure modes
- Compare types and levels of cylinder damage
- Manage Scheduled and Emergency Defueling procedures
- Assess proper disposition procedures
- Prepare Cylinder Inspection Forms and documentation

Resources:

The primary text for the course is:

- CNG System Owners manuals on testing and repair from the Manufacturer (OEM)

Additional References Include:

- NFPA 52
- CGA 6.4

Competence

Competence will be measured by both lab demonstrations and class participation.

Instructional Objectives

By the end of this course ,the student will be able to:

- Identify the equipment and procedures to perform a visual and detailed CNG Cylinder Inspection.
- Define CNG cylinder types and type of damages associated with each cylinder.
- Identify cylinder damage levels and disposition.
- Properly document CNG inspections.

Agenda

- Intro to CNG Systems
- CNG Cylinder Types
- Resources and Inspection Guidelines
- Cylinder Damage Appraisal
- Theory of Operation
- Inspection Techniques
- Inspection Equipment
- Cylinder Inspection
- Disposition of Damaged Cylinders
- Defueling

Important

This material is intended as an aid in performing cylinder inspections and maintenance. Any other applicable manufacturer's reference material and/or industry standards are the ultimate authority for these procedures.

Authority Having Jurisdiction

Information presented in this class is not meant to replace cylinder and/or manufacturer guidelines, and is not intended to supersede other manufacturer, fire safety officials, or other applicable standards and recommended practices

Pretest

CNG Fuel Systems Inspector

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. Is it OK to mix different cylinders types and in the same system?
   a. Yes b. No c. Depends on the cylinder type d. Only for 3000 psi cylinders

6. Is it OK to mix different cylinder pressures within the same system?
   a. Yes b. No c. Depends on the cylinder type d. Only with type 1 cylinders

7. What is the depth of damage needed to condemn a cylinder?
   a. > .020" deep b. > .040" deep c. > .050" deep d. > .080" deep

8. Can a cylinder be recertified after it reaches the expiration date?
   a. Yes b. No c. depends on the cylinder type d. Only with type 1 cylinders

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

10. Can a PRD be reused on another cylinder?
    a. Yes b. No c. depends on the cylinder type d. Only with type 1 cylinders

Course Introduction

Compressed Natural Gas, or CNG, has emerged as the fuel of choice to meet growing requirements to reduce dependency on foreign oil, along with addressing environmental and health concerns. Natural gas has been in use for many decades and was actually one of the first fuels used in internal combustion engines. In the effort to increase use of natural gas, vehicle range has been increased through the use of pressure storage cylinders. When originally introduced, use and inspection of these cylinders were the sole responsibility of government agencies, like the Department of Transportation (DOT). DOT standards required that these cylinders be hydrostatically tested, which usually required removal every 5 years. To help reduce this expense while maintaining the safety factor, the NGV2 standards were developed by a group of industry experts. These standards for construction and inspection of CNG cylinders became acceptable when the cylinders were used as a fuel storage receptacle to power a vehicle over a limited life span of 15 years. Later, standards in the Federal Motor Vehicle Safety Standard 304 were developed that closely paralleled the NGV2 standard. In most cases, both standards eliminated the requirement to hydrostatically test the cylinders, provided that a detailed visual inspection was completed by a qualified technician at a specific interval and properly documented. Since the hydrostatic test has been eliminated, the process of inspecting CNG cylinders on a periodic schedule is one that needs to be taken very seriously.

The relatively new CNG fuel storage technology is very different from that of gasoline, diesel, or even propane (LPG). The extremely high pressure associated with CNG cylinders create a unique hazard if the cylinders are not properly maintained.

CNG cylinders are available in a number of different types and sizes. Recent developments in cylinder technology mean that conformable cylinders may become available in the near future. Conformable cylinders allow more flexibility in shape and positioning of the cylinder in the vehicle.

CNG cylinders have to be structurally strong in order to contain the high-pressure gas. Prior to gaining approval, the cylinders are subject to a wide range of tests. Although great care is taken in the design and construction of high-pressure cylinders, care must be taken in their installation and maintenance.

CNG cylinders are required to be inspected on a regular basis. The procedures required to ensure that CNG cylinders are properly inspected are outlined in this book. The information gathered for this book is the most up-to-date information available at the time of printing.

Table of Contents

- Hydrostatic Testing
- Acoustic Emission Testing
- CNG Installation Safety Standards Worksheet

6. Inspection Equipment

- High Intensity Light
- Inspection Mirrors
- Hand Tools
- Torque Wrenches
- Depth Gauge
- Rule and Straightedge
- Leak Testing
- Inspection Form

7. Cylinder Inspection

- Intervals
- Cylinder Manufacturer's Requirements
- Conditions Requiring Inspection
- Preparation
- Documentation of Cylinder Inspections
- Inspection Techniques
- Sample CNG Cylinder Inspection Form

8. Disposition of Damaged Cylinders and Installations

- Repair Requirements
- Disposal Requirements
- Documentation of Failed Cylinders and Installations
- Determining Disposition

9. Cylinder Defueling

- Cylinder Defueling
- Methods of Defueling

References

Glossary of Terms

Test

1 Module One

CNG Cylinder Types and Installation

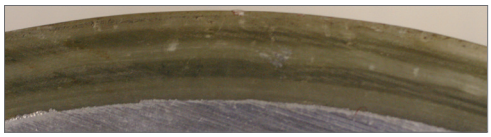
Cylinder Types

CNG cylinders are manufactured to contain compressed natural gas at high pressure. To withstand these forces, 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. 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 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 and need to be protected from fatigue cracking and excessive heat. The chart on page 1-10 will break down the four types of cylinders to help you understand.

Type	Material	Burst Test Strength	Vulnerability
NGV 2-1	All Steel or Aluminum	100% of strength is from the metal	Rust & corrosion
NGV 2-2	Hoop-Wrapped Aluminum	55% from metal 45% fiber wrap	Corrosion, acids, cuts & abrasions to wrap
NGV 2-3	Fully-Wrapped Aluminum	80% from fiber wrap 20% metal	Damage to wrap & crush
NGV 2-4	Fully Composite with Poly Liner	100% from composite	Impact & abrasion allowing liner to dislodge Rapid depressurization

Cylinder Cross-Sections

Metal *Type 1*



Type 3

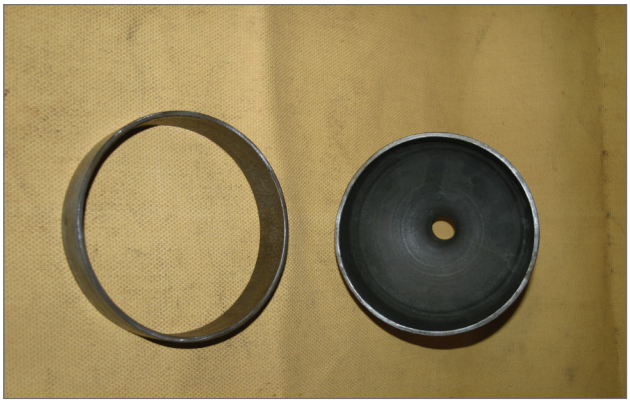
Type 2

Liner

Composite *Type 4*

Type 1 (All Metal) Cylinder

Type 1 cylinders are made of either steel or aluminum and are the oldest type of CNG cylinders. As noted in the chart on page 1-10, the metal holds 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. Their major vulnerability is rust, corrosion damage and oxidation.



Type 1 (All Metal) Cylinder

A Cascade of Type 1 Cylinders

Type 2 (Hoop-Wrapped) Cylinders

Type 2 cylinder consists of a metal liner and a composite wrap. The cylinder is called hoop-wrapped because the composite wrap is wound only around the cylinder sidewall. As noted in the chart on page 1-8, 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 a safety factor. These cylinders weigh considerably less than the Type 1 cylinders. Their major vulnerability is corrosion to the exposed metal and cuts or abrasions to the wrap material.

Type 2 Cut-Away

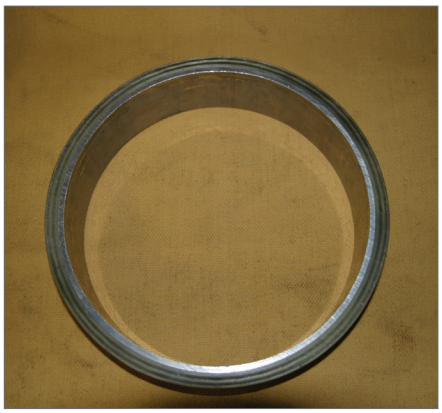
Type 2 Cylinder

Type 3 (Full-Wrapped) Cylinders

Type 3 cylinders consist of a metal liner wrapped with composite over the entire sidewall and dome portions of the cylinder. As noted in the chart on page 1-8, 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, their major vulnerability is 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 4 (All-Composite) Cylinders

Type 4 cylinders consist of a plastic liner wrapped with composite over the entire sidewall and domes of the cylinder. As noted in the chart on page 1-8, 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 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 vulnerability is from impact, cuts and abrasions, and rapid depressurization, causing the liner to separate from the composite and leak or trap gas.



Type 3 Cut-Away

Type 4 Cut-Away

Type 3 Cylinder

Type 4 Cylinder

Cylinder Standards

Currently, there are two sets of standards for CNG cylinders in the U.S. They are:

- ANSI/AGA, NGV2
- DOT NHTSA Standard FMVSS304

Manufacturers Can Meet Both Standards

Cylinders manufactured prior to these two standards were produced under DOT guidelines and may have different inspection requirements. They are listed as DOT E on the label and were generally constructed prior to 1996. Consult the manufacturer for inspection requirements for these cylinders.

1-ANSI/AGA, NGV2

Establishes standards for construction and certification of CNG cylinders. Requires extensive testing for durability before certification and a detailed visual inspection every 3 years. Maximum cylinder life is 15 or 20 years.

2-DOT NHTSA Standard, FMVSS304

Requires similar testing for certification as NGV 2 standard with same cylinder life and a detailed visual inspection every 3 years/36,000 miles, whichever come first. Maximum cylinder life is 15 or 20 years, depending on certification.

Installation of Cylinders

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

Cylinder Mounting

A correctly mounted CNG cylinder should:

1. Have the label visible.
2. 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.
3. Be capable of restraining the cylinder when subjected to a force of 8 times the weight of the cylinder in 6 principal directions.
4. Incorporate manufacturer's recommended brackets with rubber gaskets and torqued to specification.
5. Be shielded properly from excessive sunlight, vehicle cargo, road debris, or vehicle exhaust.
6. Be protected from excessive heat or pressure by a relief device.
7. Be properly vented to the outside using tubing or a vapor barrier.

Cylinder Handling

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

1. The vehicle has been in a fire.
2. The vehicle has been in an accident and the cylinder or brackets have been damaged.
3. Vehicle maintenance or repair requires the cylinders be removed to access the area in question.
4. 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.

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

Review Questions

Which cylinder type is all metal?

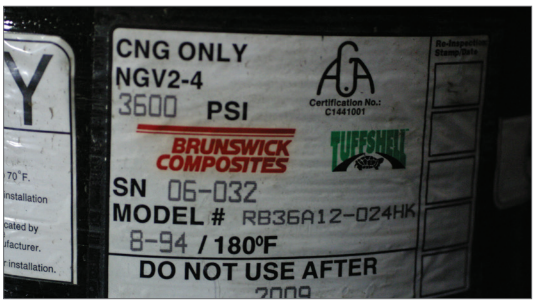
Which cylinder type has exposed metal ends?

Which cylinder type has no metal liner?

NGV2 Cylinder Label

Cylinders are aging out regularly on older vehicles and these cylinders must be scrapped. Watch for "do not use after" to quickly identify they are NGV or FMVSS certified.

- NGV2 cylinders were available prior to 1995.
- Requires visual inspection every 3 years.
- Industry moving from 15 year to 20 year life cycle.
- Longer life cycle is greater than expected life of vehicle.



15 Year NGV2-4 Label

20 Year NGV2-4 label

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Read the label on the cylinders supplied and determine the following:

First Cylinder

- Manufacturer _____
- Cylinder Type _____
- Type Description _____
- Working Pressure _____
- Date Built _____
- Part # _____
- Serial # _____
- Expiration Date _____
- Certification Type _____
- Inspection Interval/Procedure _____

Second Cylinder

- Manufacturer _____
- Cylinder Type _____
- Type Description _____
- Working Pressure _____
- Date Built _____
- Part # _____
- Serial # _____
- Expiration Date _____
- Certification Type _____
- Inspection Interval/Procedure _____

2 Module Two

Resources and Inspection Guidelines

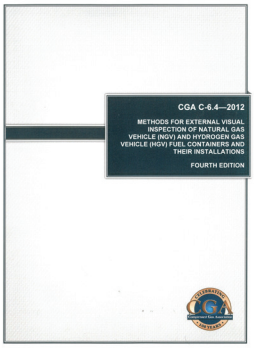
Inspection Guidelines

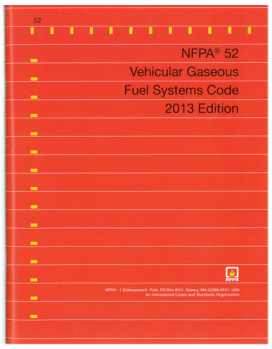
In order to be properly prepared, your technical library should include current issues of the following guidelines:

- NFPA 52
- CGA 6.4
- FMSS 304
- CHP Title 13
- ANSI/NGV-2
- Manufacturer's Guidelines for Inspection and Repair

Copies of these manuals can be obtained using the information sheets on page R-2.

It will be necessary to identify the cylinder manufacturers on your equipment and contact them for their inspection and repair guidelines. Although it is not necessary to obtain this information prior to inspection, you will need it immediately if any damage was observed.





Review Questions

What does CGA 6.4 cover?

What version do you need when doing inspections?

What standard covers installations?

What version do you need when doing inspections?

Who is the ultimate authority on cylinder damage?

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Activity 1
CGA Worksheet

Start at page one of the 2012 CGA manual and answer the following questions:

1. This document provides information and procedures for _____ and _____ cylinders.

2. It is critical that this document must be read and carefully understood before either examination or _____ of a cylinder.

3. If the examination reveals areas requiring _____ _____ the container _____ or _____ are not visible, the container shall be _____ and _____ from the vehicle.

4. The purpose of this document is to provide criteria for the acceptance or rejection in absence of guidance from _____. Which instructions have priority in the event of a difference? _____.

5. By definition, a Destroyed cylinder has a _____ as an acceptable means to make it physically unusable. Page 30 says they can be rendered unusable by drilling _____ holes.

6. Level 1 damage is considered _____ damage and the cylinder can / cannot be returned to use.

7. Level 2 damage shall be repaired to _____ or moved to level 3 and condemned.

8. The _____ recommendations must be used to direct or advise the inspector on level 2 damage.

9. FGV fuel containers can be designed and qualified to one of two specifications or standards for the U.S. They are _____, _____ _____.

10. Pressure Relief Devices can be activated by _____ or _____or both.

11. Type 1 cylinders are all _____.

12. Type 2 cylinders are reinforced with fibers wound in the _____ direction.

13. Type 3 cylinders are reinforced with fibers wound in both _____ and _____ direction.

14. Type 4 cylinders have a _____ that does not carry a load.

15. Only _____ and _____ _____ recommended by the container manufacturer should be used.

16. There is a statement on the label stating the manufacturer's _____, _____, _____, _____, and _____

17. The frequency of inspection is once every _____ years for the life of the container.

18. You are being trained as an inspector by providing you which qualification? _____

19. Why are hand tools required to do an inspection? To inspect _____

20. Is minor noise when composite cylinders are being pressurized or depressurized a condition requiring _____ inspection? Yes / No?

21. Containers with known or suspected _____ or _____ damage shall be _____ before inspection operations continue.

22. If the cylinder has been pressurized above its design standard, then the cylinder shall be _____.

23. Cuts, abrasions or scratches less than _____ are level 1 but evidence of fire or excessive heat is level _____.

24. Bubbling caused by _____ may persist for up to several hours after pressurizing a Type _____ cylinder.

25. Weathering cannot be repaired and the cylinder must be condemned? True / False

26. Isolated pits with a depth less than _____thousandths may be considered acceptable level 1 damage but line corrosion pitting cannot be over _____ deep or _____ long.

27. All outward bulging and dents to the exposed metal surface _____ than 2 inches are Level _____.

28. More than one PRDs may be required on cylinders longer than _____ inches and they are in direct communication with the contents of the container which means they are _____ regardless of whether the valve is open or closed.

29. PRDs, once removed shall not be installed _____ and may / may not be re-installed on the same container.

30. The container shall be _____ if the identity cannot be clearly established due to an illegible label. Contact the container manufacturer for a _____ label if mandatory information is missing or damaged.

31. What information must the inspector put on the container before returning it to service after an inspection?

_____

32. Containers with level 2 damage shall _____ until the condition is resolved and in the absence of manufacturer's recommendations, it shall be considered _____.

33. Purging a cylinder can be accomplished with the use of _____, or by _____.

3 Module Three

Damage Levels

These guidelines of damage are defined in specific detail in the CGA 6.4 document.

CNG cylinder damage is divided into 3 levels. The levels are as follows:

1. **Level 1**— any scratch, gouge, or abrasion with a damage depth of less than or equal to .010 inch. Level 1 damage is acceptable and does not need to be repaired.*
2. **Level 2** — any scratch, gouge, or abrasion with a damage depth of .011 to .050 inch. Level 2 damage requires rework (either in the field or by the manufacturer), a more thorough evaluation, or destruction of the cylinder, depending on severity.**
3. **Level 3** — any scratch, gouge, or abrasion with a damage depth greater than .050 inch. Level 3 damage is severe enough that the cylinder cannot be repaired and must be destroyed. All fire, chemical, and weather damage is Level 3, if it does not wash off.

***NOTE: Although Level 1 damage does not require rework, all damage must be recorded.**

****NOTE: Consult the cylinder manufacturer on any Level 2 damage.**

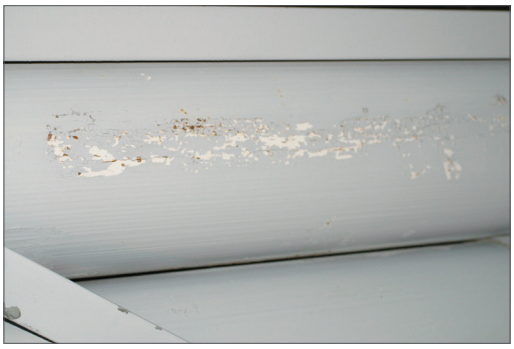
Damage Types

This section provides the user with a description of some types of damage that can occur with CNG cylinders. As it is not possible to address every possible damage scenario, these are the most prominent types of damage.

NOTE: The publication CGA 6.4 lists these general guidelines; however, you should consult the cylinder manufacturer for specific allowable damage and repair procedures, if any of the following damage is observed, as their specifications may vary.

1. Surface Corrosion or Pitting.

Most prominent on Type 1 and 2 cylinders due to exposed metals. Many newer cylinders have epoxy-painted coatings to help prevent this damage. More prominent on cylinders exposed to road salts and snow. Corrosion should be cleaned off, evaluated, and resealed to prevent further damage. Over .030 inch can be Level 3 damage.



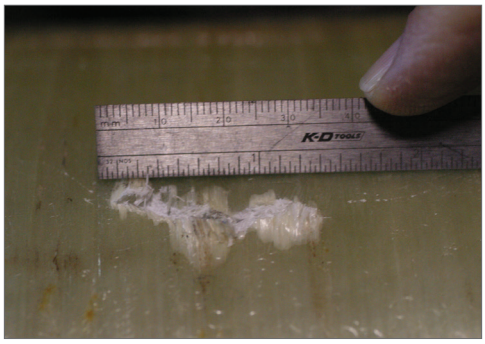
Corrosion and Peeling Paint on Type 1 Cylinder

2. Fatigue or Stress Corrosion Cracking.
This occurs when the cylinder is cycled repeatedly causing expansion and contraction of the cylinder, which is usually a sign of age or over pressurization. The fiber wrap cracks longitudinally causing loss of the cylinder pressure safety factor. Any identified stress or fatigue cracking is Level 3 damage.

3. Scuffing or Abrasion Damage.
Very common on cylinders that are mounted underneath the vehicle, if shielding is inadequate or the cylinder is exposed. Type 2, 3, and 4 cylinders allow .010 inch damage, while Type 1 cylinders must be evaluated for loss of wall thickness.

Scuffing Damage on Type 2 Cylinder

4. Surface Cuts and Scratches
This is caused by a foreign object coming in contact with the cylinder. Brackets and other items rubbing against the cylinder can also cause this damage. Any cuts or scratches over .010 inch deep must be evaluated and repaired or condemned. Cuts over 1 inch long are Level 3 cuts, even if less than .010 inch deep. They will damage an entire band of the wrap causing it to unravel.



Surface Cut Under 1 Inch

5. Blunt or Sharp Object Impact Damage
Minor dents up to .020 inch on Type 1 cylinders can be tolerated. However, blunt impact damage on Type 2, 3 and 4 cylinders is very hard to evaluate and can be dangerous, especially on Type 4 cylinders. Extreme care must be taken to determine if any deformation of the cylinder is present indicting fiber damage. This is a sign that the cylinder may not be structurally sound and is considered Level 2 or 3 damage.

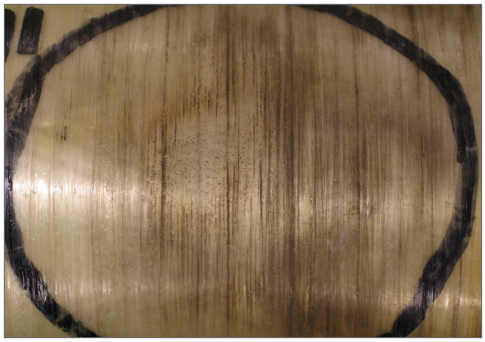
Impact Damage

6. Collision, Fire or Heat Damage
Any indication that the vehicle has been involved in an accident or fire requires careful examination of the cylinders. Follow the manufacturer's guidelines for such damage. Generally, if Type 2, 3, or 4 cylinders are exposed to excessive heat, or any discoloration occurs that does not wash off, it is considered Level 3 damage.

Fire Damage

7. Chemical Attack

Acids and other chemicals can severely damage the cylinder wrap and possibly the metal itself. Extreme care should be taken to identify and neutralize any chemicals spilled on the cylinder. Only minor discoloration is allowed after neutralization and a very careful inspection should be performed to make sure the chemical did not get between the wrap and the cylinder where unseen damage could progress.



Chemical Attack

8. Bulging, Bowing of Cylinder Wall

All visible bulges indicate a problem with the cylinder material and should be considered Level 3 damage. Most prominent on Type 1 and the exposed surfaces of Type 2 cylinders.

9. Weathering/UV Damage

Ultra Violet light causes damage to the wrap which must be addressed. In most cases the manufacturers have coatings on the cylinder to prevent this damage. Excessive weathering results in Level 3 damage, as the fibers are damaged.

UV Damage

10. Over-Pressurization, Leaks, Labeling

Any cylinder that leaks or has been exposed to over 1.25 times its service pressure is to be considered Level 3 damage. Bubbles on the surface of Type 4 cylinders are indications of leaking of the liner and would be Level 3 damage. A label that cannot be seen requires repair and, if it is missing, illegible, or the serial number is not present, it becomes Level 3 damage.

Manufacturer's Allowable Damage

Refer to CGA 6.4 as a guideline for each type of damage and the allowable limits. Some manufacturers allow different limits over .010 inch for newer tanks. Always consult the manufacturer of the cylinder if damage exceeds .010 inch for their exact procedure.

All the following are to be considered Level 3 damage:

- A missing cylinder label
- All fire damage, if it leaves discoloration
- All chemical damage, if it leaves discoloration
- Any noticeable discoloration that cannot be washed off
- Stress cracking
- Corrosion
- Weathering
- Any signs of skin leakage
- Impact damage on Type 4 cylinders

Special concern should be given on inspections of vehicles involved in collisions or fires.

Level 1 cut or abrasion damage is generally .010 inch or less according to CGA 6.4. However, the manufacturer is the final authority having jurisdiction over damage level. Some Level 2 damage may be repaired at the field level depending upon manufacturer's guidelines and procedures. Between Level 2 and Level 3, there are acceptable field repairs available to resolve some conditions to a level where they can be returned to service. There is even Level 2 damage criteria where the manufacturer has to complete the repair, but the cylinder can be re-certified and returned to service. Depending upon the type of cylinder and the manufacturer, the point at which damage becomes Level 3 varies. The general rule is that after .040 inch the cylinder is Level 3 on most Type 2 and 3 cylinders. Some, like Dynetek Type 3 cylinders, allow rework by the manufacturer for cuts from .030 to .050 inch damage. Some Type 4 cylinders, such as the Tuffshell by General Dynamics, allow rework by the factory for scratch, gouge, or abrasion damage from .036 to .050 inch and condemn the cylinder after .050 inch.

Measuring Damage

Measuring damage is very difficult with the normal differences in the cylinder wrap thickness. Cuts tend to have a flared edge to them, which makes them also stick up on the edges. A depth gauge or dial caliper that has been sharpened to a point is needed to accurately measure the damage while bridging the gap accurately.

Measuring Depth with Dial Gauge

Sometimes, it is necessary to use a straightedge across a gouge to seek a level from which to measure. With this method you must subtract the thickness of the straightedge from your reading.

Measuring Depth with Veneer Calipers

NOTE: There is generally an 800 number on the cylinder near the manufacturer's name to contact them regarding disposition and repair procedures. They are usually very cooperative, but you should be prepared with the description of the cylinder (including serial number) so they can get you accurate information. Additional contact information is in the module entitled "References."

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Cylinder Damage Inspection

Inspect this cylinder and determine the following for each area:

	Description of Damage	Damage Level	Cylinder Manufacturer	Manufacturer's Specified Corrective Action
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				
11.				
12.				

4 Module Four

Theory of Operation

CNG is "Compressed Natural Gas." Natural gas is a naturally occurring mixture of combustible non-reactive hydrocarbon gases found in porous formations beneath the earth's surface. Natural gas is created by the decomposition of plant and animal remains, under great pressure and heat, and over very long periods of time. The exact composition of natural gas varies from different parts of the country and different refineries. For the most part, natural gas is composed of mostly methane (CH_4). This very simple chemical formula allows a complete combustion with relatively low emissions.

Natural gas in its natural chemical formula is non-toxic, lighter than air, and only combustible in correct concentrations. With a vapor density of 0.6 (lighter than air), CH_4 tends to rise in the air. Flammability ranges are safe in the 5 to 15% (by volume) range. For safety reasons, natural gas is required to be odorized to indicate positively, by distinct odor, the presence of gas in levels over .5%. This is achieved by adding ethyl mercaptan, thiophane, or amyl mercaptan to the natural gas.

Natural gas is in a gaseous state at ambient temperatures (70 °F) and has a relatively low-density level (compared to gasoline). The natural gas has to be compressed and stored in the vehicle to achieve the desired vehicle range. Early compressed natural gas (CNG) vehicles had fuel storage pressures of 2000 psi. As cylinder technology developed, the fuel storage pressures have increased to a storage pressure of 3600 psi. The standard for compressed natural gas vehicles is now 3600 psi. This pressure can be very dangerous if not handled correctly. The gas is reduced from its storage pressure to the operating pressure at the engine, which can range from as low as 14.8 psi to as high as 150 psi.

Operating Pressures and Safety

There are many safety regulations that should be followed when operating or repairing any part of the CNG system. It is imperative that you understand component operation and service procedures before you attempt any repairs.

SAFETY NOTE: Before working on any CNG fuel system, study the National Fire Protection Agency (NFPA) 52 standards manual.

The storage pressure of the compressed natural gas (CNG) fuel system can be as high as 3600 psi. While the operating pressure of the CNG system is much lower, usually 125 psi or less, a CNG fuel system component failure can have the potential to seriously harm someone. With this in mind, CNG fuel systems have a variety of safety features, which are mandated by the National Fire Protection Agency. These recommendations and guidelines include pressure relief devices, vent tubes, safety shut-off valves, pressure sensors, construction of annealed fuel lines, connector fittings, and storage tank installation.

Remember, natural gas is lighter than air and will rise to the highest point possible. In case of a leak, the gas will naturally vent away from the vehicle, but can be trapped in overhead compartments. Avoid working on a CNG vehicle in areas where overhead heaters, non-sealed lights, or other combustion creating devices are being used.

Major Components

The major system components of a compressed natural gas fuel system consist of the following components:

- Fill Connector (NGV-1)
- One-Way Check Valve
- Fuel Storage Cylinder (Tank)
- Cylinder Shut-Off Valve
- Pressure Relief Device (PRD)
- Manual (Quarter-Turn) Shut-Off Valve
- Annealed Seamless Stainless Steel Fuel Tubing (306, 316)
- Shut-Off Valves (Lock-Offs)
- Pressure Regulator(s)
- Dry Gas Injectors (Injector Block)
- Mixer Assembly

Gauges, pressure sensors and switches, and other electronic components on computerized systems are also present. Some of these devices are under cylinder or operating pressure.

MAJOR COMPONENTS OF A COMPRESSED NATURAL GAS SYSTEM

Fill Connector

One-Way Check Valve

Fuel Storage Cylinder

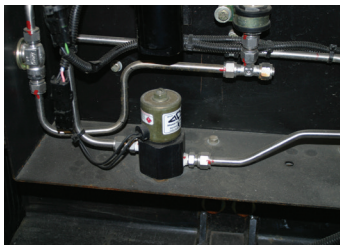
Pressure Regulator

Dry Gas Injectors (Injector Block)

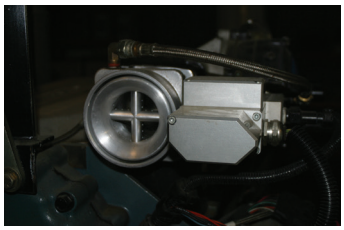
Cylinder Shut-Off Valve

or

Shut-Off Valve (Lock-Offs)

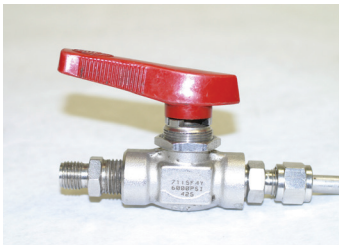


Mixer Assembly

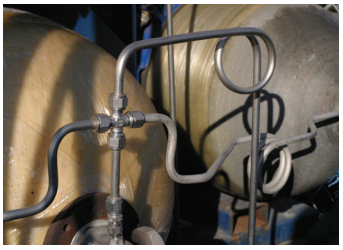


Pressure Relief Device (PRD)

Manual Shut-Off Valve (Quarter-Turn)



Annealed Stainless Fuel Lines



NOTE: Gas goes from regulator to injector or mixer.

Major Components

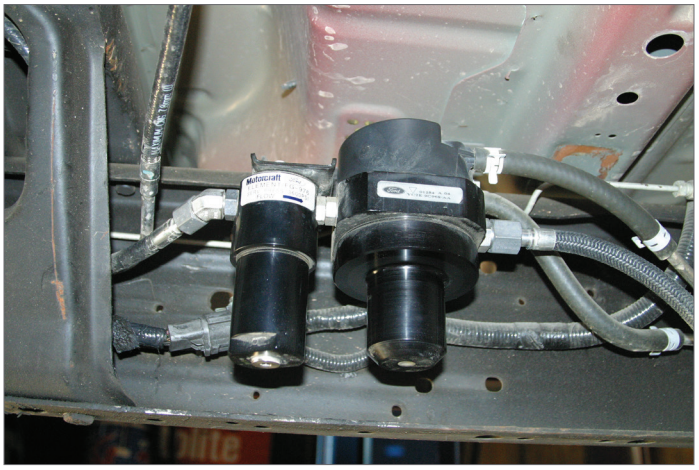
CNG delivery systems are specifically designed for the high-pressure dry gas they transport. The components are designed to safely store and dispense this gas without leaks. Caution should be taken when working with these components as they are all under pressure. There are many safety devices designed 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 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.

Fill Connector/Receptacle

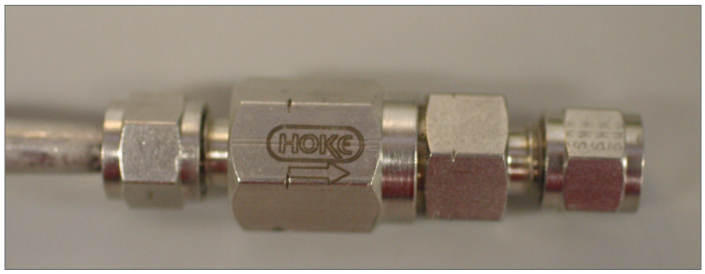
A coalescing filter can be in line with the nozzle to prevent compressor oil or contamination from entering the system; however, it may impede a fast fill. Low pressure filters are installed to capture any contaminants before they reach the engine fuel system.



Coalescing Filter and Regulator

Low Pressure Filter with Drain

One Way Check Valve



One Way Check Valve Flow Direction

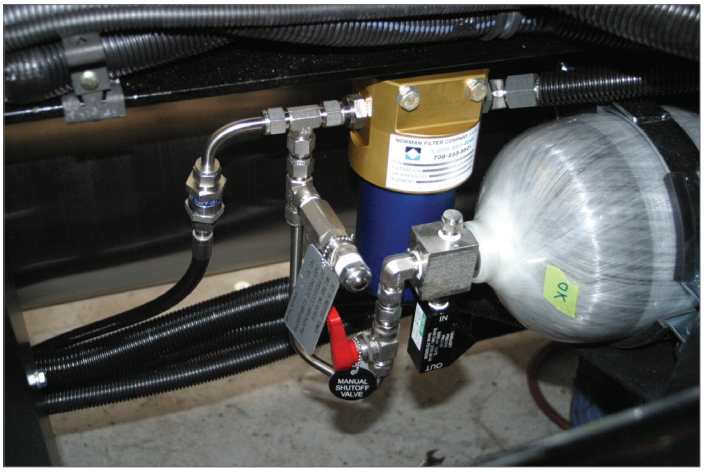
A one-way check valve is installed in the system fill line to prevent fuel leakage should the receptacle or plumbing become damaged in an accident. It must be installed correctly to allow fuel flow only in the direction of the arrow. The valve is usually installed beyond the "crush zone" of the vehicle.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

CNG High-Pressure Cylinders

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.

Cylinders should be Matching Pressure

Cylinders must meet stringent testing which 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 Pressure, which is 137.5% of the cylinder pressure. Exceeding this amount requires that the cylinder be condemned.



Cylinders and Safety Devices 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, 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.

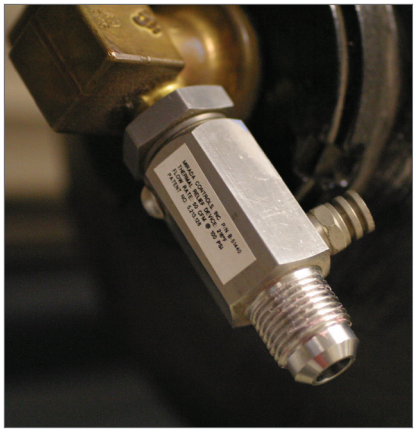
Manual and Electronic Valves

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.

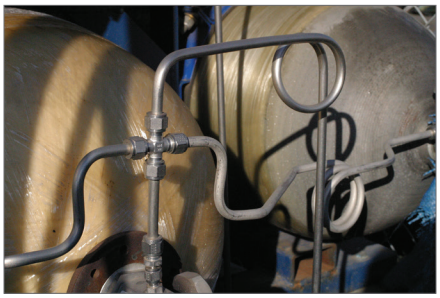
Pressure Relief Device (PRD)

Pressure Relief Devices (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 PRD's 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

The fittings and lines on the system are made of stainless steel and able to withstand 4 times the pressure 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.

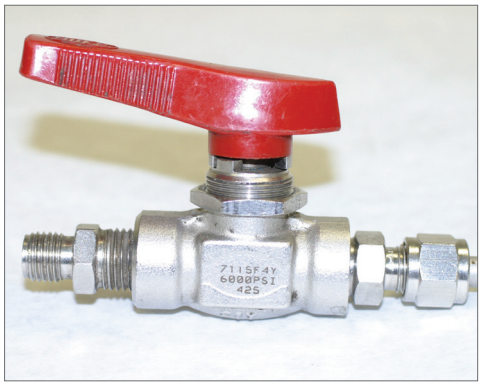


Seamless Stainless Steel

Braided Stainless

Manual Shut-Off Valve (quarter turn)

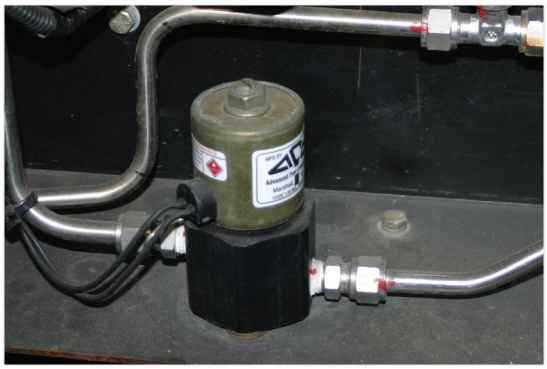
A manual valve that shuts off with a quarter turn is installed to isolate the cylinders from the engine compartment for servicing or emergencies. This valve is supposed to be accessible and marked from the outside saying ***Manual Shut-Off Valve*** but it may be hard to find or nonexistent, as electronic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



Quarter Turn Valve

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

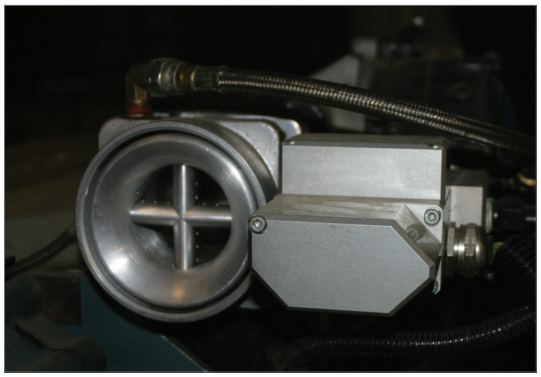
Pressure Regulators

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 wit h the fittings on the ITT regulator as they are O-ring style not compression.

ITT Conoflow Regulator

Injectors / Mixer Assembly

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

Safety Devices

Due to the extreme pressures that are present in the filling of a modern CNG system, there are numerous safety devices incorporated into a CNG system. The Natural Gas Vehicle coalition established guidelines for receptacles, storage cylinders, and installation of conversion components. These regulations were established in 1992 and are updated in three-year intervals. Many of the standards are covered in Module Three, which provides more details on associated regulations.

NGV Coalition Industry Safety Standards

NGV1 — established standardized fill receptacles to allow fueling from public stations. Due to the changing system pressures and many variations of fill receptacles in use, it discouraged the use of adapters used to adapt to different styles of nozzles. It prevented use of higher-pressure (3600 psi) nozzles on lower-pressure (3000 psi) systems, while permitting lower-pressure nozzles to be used in higher-pressure systems to allow a partial fill.

3600 psi Fill Nozzle

NGV2 — established construction standards for cylinders and visual inspection requirements. Cylinders must meet minimum testing requirements for safety. A detailed visual inspection is required every 3 years. The term, "detailed visual inspection," means removing guards and shields for inspection with high-intensity lights and full surface inspection. Under NGV2 standards, hydrostatic testing of cylinders is no longer required.

NGV2 Type 2 Cylinder

NGV3 — relates to vehicle conversions to CNG. NFPA 52 guidelines also cover these installations.

NFPA 52 is the source for all system installations, while CGA 6.4 is the source for inspection of cylinders.

NFPA 52 covers all areas of CNG system installation guidelines. The guidelines are based on recommendations from experts in the industry and should be adhered to or exceeded. Older vehicles may have installations regulated from earlier versions of NFPA 52, and as these industry standards have changed, may not currently comply. They only need to be retrofitted where safety is a concern.

Review the worksheet (shown on pages 1-8) using NFPA 52 as a reference to become familiar with the guidelines of NFPA 52. The Cylinder Inspection Form in CGA 6.4 refers to these guidelines.

Inspection of Cylinders

Some areas of NFPA include:

- Cylinder installation to secure the cylinder from movement and damage with proper shields and location.
- Installation and location of valves.
- Venting procedures required to shut off cylinder and vent to outside of passenger compartments.
- Fuel line installation with lines supported every 24 inches.
- Hoses, tubing, valves, and fittings rated to four times their working pressure.
- Gauges reading 1.2 times the working pressure.
- One-way check valves to prevent leakage in case of damage to system fill lines.
- Pressure relief devices designed to prevent accident due to excessive heat or pressure.
- Fuel shut off devices to shut off fuel with key on and engine not running.

CAUTION: PRDs are under direct pressure of the cylinder and not controlled by the valve. As a result, they cannot be removed without defueling that cylinder. Sometimes several cylinders are on the same vent system. Before servicing any fuel system, always consult the manufacturer's safe handling procedure to defuel cylinder.

5 Module Five

Cylinder Inspection Techniques

Inspection Methods

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.

There are three potential types of inspections that are performed during the life span of the pressure cylinder. They are:

- Visual Inspection (required)
- Hydrostatic Testing
- Acoustic Emission Testing

Visual inspections are required at the 3-year date of cylinder manufacture. Hydrostatic and acoustic emission inspections are not usually required with the newer standards.

Visual Inspections

Visual inspections are the preferred method of cylinder inspections as they do not require disassembly of the CNG system or removal of the cylinder. This is an external inspection of the cylinder for damage.

Visual inspection consists of two main areas:

1. General visual inspection
2. Detailed visual inspection

General Visual Inspections

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 wear inspection. The frequency of these inspections would be up to the fleet manager or as specified in the safety plan.

Detailed Visual Inspections

Detailed Visual inspection is an inspection that is required for NGV cylinders under new standards. 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.

Hydrostatic Testing

This is the method used on cylinders prior to 1992 when the DOT required cylinders to be tested. Hydrostatic testing involves filling the cylinder with liquid and then pressurizing it to 1.5 times its service pressure while watching its expansion. If it expands more than 10%, it fails. This method generally requires removal of the cylinder from the vehicle, making the procedure costly.

NOTE: Hydrostatic testing has, in recent years, fallen out of favor as an appropriate inspection technique.

Acoustic Emission Testing

Acoustic emission testing is similar to a sonogram in that waves are sent through the cylinder looking for hairline cracks. It is only used to verify damage in conjunction with the detailed visual inspection and has limited usage.

LONG BEACH CITY COLLEGE

CNG INSTALLATION SAFETY STANDARDS

Answer these questions based upon the 2013 edition of NFPA 52

Section #

_____ 1. Retroactivity only applies to any situation presenting an _____ .

_____ 2. Such deviations or improvements can provide equivalent _____ and compatible operation that meet the intent of this code.

_____ 3. Who is the authority having jurisdiction? _____ .

_____ 4. The fueling _____ is on the pump and the fueling _____is mounted on the vehicle.

_____ 5. The "point of transfer" is where _____ .

_____ 6. The MAWP formula is _____ x the service pressure.

_____ 7. Service pressure and settled pressure would be the same once the system has stabilized at _____ °F (21 °C).

_____ 8. The varying pressure in the containers is called _____ .

_____ 9. Multiple pressure vessels are called a _____ storage system.

_____ 10. Cylinders must comply with _____ or _____ or _____ regulations.

_____ 11. Cylinders that have reached the labeled expiration date shall be _____ .

_____ 12. Pressure relief devices are in _____ and vented to the _____ .

_____ 13. Pressure gauges have to read _____ times the system design pressure.

_____ 14. Pipe, tubing and fittings and other components must be designed with a minimum safety factor of _____ .

_____ 15. Which Fuel Line components shall NOT be used? _____ .

_____ 16. CNG Fueling connections must comply with _____ standard.

_____ 17. The use of _____ shall be prohibited.

_____ 18. NFPA 52 includes final stage integrator/manufacturer (FSVIM) instructions. The FSVIM is responsible for integration of engine, fuel system, and gaseous detection systems, where required, onto the vehicle _____ .

_____ 19. Cylinders cannot be mounted ahead of the _____behind the _____.

_____ 20. Cylinders shall not protrude beyond the_____ or _____ of a vehicle where it is installed.

_____ 21. Each rack or container must be able to withstand _____times its weight in _____ directions without moving more than _____ inch (fully pressurized container).

_____ 22. There must be a protective shield against direct heat if a cylinder closer than _____ of the exhaust.

_____ 23. Minimum clearance of a vehicle shall be measured from the road to the container, its housing, or fittings, whichever is lowest, and shall not with vehicle loaded to its _____ allow any _____ to touch the _____ in the event of a _____.

_____ 24. No portion of a fuel supply container mounted on the undercarriage of the vehicle shall be located _____ of the front axle or _____ the point of attachment of the _____ of the vehicle.

_____ 25. The PRD for Cylinders mounted in the passenger compartment shall be _____.

_____ 26. The vent line must not terminate in the _____.

_____ 27. At the end of the vent line, a means shall be provided to _____.

_____ 28. Pressure relief devices must be installed in _____ and its tubing must have a burst pressure of _____ .

_____ 29. Piping and fittings shall be clear and free from cutting or threading _____.

_____ 30. All joints or connections must be located in an _____ .

_____ 31. Every cylinder must have a _____ valve or a _____ remotely activated shutoff valve.

_____ 32. In addition, a _____ or _____ valve to isolate the containers is required.

_____ 33. It must have a label that says _____.

_____ 34. A valve is required to shut off flow to the _____ with the engine _____ and the key _____ .

_____ 35. Multiple fuel systems must be able to _____ the unused fuel system.

_____ 36. A backflow check valve must be installed to prevent _____.

_____ 37. Gauges installed inside must not _____ if it fails.

_____ 38. The fueling receptacle must withstand the Fueling connection's breakaway of _____ lbs.

_____ 39. A label is required in the engine compartment stating

a. _____ b. _____ c. _____

d. _____ e. _____ f. _____.

_____ 40. A label is required near the fueling connection to state

a. _____ b. _____ c. _____

d. _____ e. _____

_____ 41. Before use, the entire system must be _____.

_____ 42. If a vehicle is involved in an accident or fire causing damage to a cylinder, or if the container is subjected to a pressure greater than 125% of the service pressure, the container shall be _____ or _____.

_____ 43. Damaged fuel lines must be _____ NOT repaired.

_____ 44. No pressure relief device that has been in service shall be _____ on another cylinder.

_____ 45. What must be done during vehicle maintenance? **Use reverse side of paper to list.**

_____ 46. The point of transfer must be _____ feet from any building, doors or readily ignitable material.

_____ 47. Point of transfer must be at least _____ feet from any railroad tracks.

BONUS - Not in NFPA 52

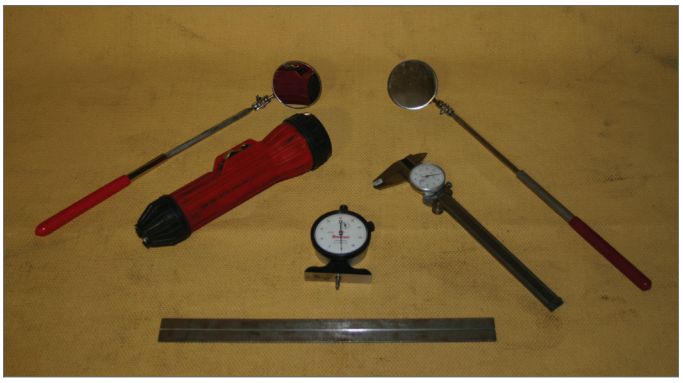
**38. Ethyl Mercaptan is added because natural gas has no _____ .

**39. CNG is mostly made up of a type of hydrocarbons called _____ .

**40. Fill pressure varies due to _____ .

6 Module Six

The following tools should be available in order to properly perform the Detailed Visual Cylinder inspection.



Inspection tools

High Intensity Light

CNG cylinders are typically mounted in well-protected locations. With this in mind, the ability of the certified inspector to properly see the tank surface, pressure relief device, lines, and fittings of the CNG cylinder is not always optimum. CNG cylinder inspection requires the inspector to have sufficient light to perform the job properly.

Inspection Mirrors

CNG cylinder inspection requires the inspector to inspect 360° and every inch of the cylinder surface. Due to the location of these cylinders, mirrors are often used with high intensity light to visually ensure that there are no hidden safety concerns regarding the cylinder. Inspection mirrors come in many sizes. An inspector should have a variety of mirrors in many shapes and sizes. A Boroscope may also assist inspecting cylinders in hard-to-access areas.

Hand Tools

A quality set of hand tools is a requirement of any CNG cylinder inspector and should include the following:

- Torque Wrench
- Socket Driver
- Measuring Device, i.e., 6-inch Scale/Depth Gauge
- Liquid Leak Detector
- Electronic Methane Detector
- Socket Set
- Crow's Feet Wrenches
- Open-End Wrench Set
- Coin (quarter)
- Grounding Straps/Cable
- Drill with 1/2-inch bit
- Cloth Rags
- High-Intensity Lamp (flashlight)

To fully inspect the CNG cylinders on a vehicle, it may be necessary to remove obstructions that will not allow the inspector to fully perform a detailed visual inspection of the cylinders. Cylinder shields are one example of an item that needs to be removed prior to any cylinder inspection, if they obstruct the inspection of the cylinders.

Torque Wrenches

CNG cylinders are mounted using manufacturer's specifications. Some manufacturers use specially designed brackets that are designed for certain CNG cylinder locations. These brackets could have spring-loaded compression retainers for expansion, and all require specific torque requirements. These brackets are designed to be tightened to a specific torque value to ensure they do not come loose with the expansion and contraction that occurs due to pressure cycling of the cylinder. A good quality torque wrench will ensure that the brackets and tank are mounted properly.

Depth Gauge

Although CNG cylinders are designed to provide high safety and can handle pressures beyond their working pressures, the slightest nick or scratch should be identified, measured, documented, and repaired, if needed. Using a high quality depth gauge to accurately measure the depth of a scratch or gouge becomes a critical part of the CNG cylinder inspector's responsibility.

Rule and Straightedge

Using a rule or straightedge sometimes becomes necessary when using a depth gauge. The surface of the CNG cylinders may not be smooth, making it difficult to find a flat surface from which to work. The rule or straightedge can be used to create a flat surface, which allows the inspector the ability to make accurate measurements. A 12-inch rule or straightedge made of machined metal is ideal.

The list of inspection equipment should also include:

- Cloth rags and approved cleaner solution to completely clean the tank surfaces prior to the inspection process.
- Creeper or drop cloths to navigate under the vehicle in the event the CNG cylinders are mounted underneath the vehicle chassis.
- A ladder and appropriate safety harness in the event the CNG cylinders are mounted on the roof of a vehicle.

Leak Testing

Inspecting CNG cylinders, lines, and fittings for leaks is a crucial part of the CNG inspector's responsibilities. Since natural gas in the fuel system is under high pressure, leaks are an inherent part of these fuel system operations. There are several tools to help locate and diagnose fuel system leaks. The more common one is a soapy solution sprayed directly on the suspected leak. If a leak is present, a small amount of bubbles will occur. The larger the leak, the more noticeable the bubbles will appear. The second tool is an electronic methane detector. This tool can be calibrated and is good to detect large volumes of methane, but is less effective on isolating the leak to a specific connector. The soap will work better for this. Commercial leak detectors are recommended, as they ensure the proper dilution without damaging chemicals.

CAUTION: Never use a soap spray or window cleaner with ammonia. This combination will attack the surfaces of the CNG fittings and could result in component failure.

Leak checking

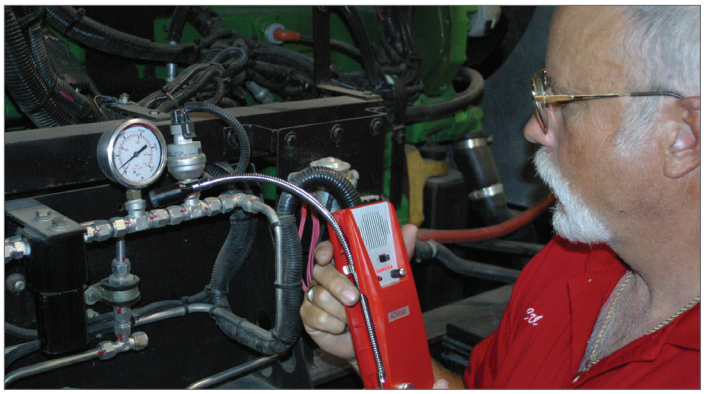
Leak Detection Fluid

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.

Electronic Leak Detectors

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-torqueing it will resolve many leaks. There is a specific procedure that must be followed for initial and reassembly torqueing of fittings.



Electronic Leak Detectors

Inspection Form

An approved CNG Cylinder Inspection Form can be found in the back of this textbook, as outlined in CGA 6.4. A Cylinder Inspection Form needs to be filled out completely for each cylinder. A good practice is to make three copies of any inspection form.

- Inspector's copy for his own records
- Office file copy
- Vehicle copy

NOTE: If a Level 3 fault is detected, the vehicle should be taken out of service immediately. A Level 3 failure presents unimaginable danger if returned to service before repair.

The form covers the inspection of the vehicle according to NFPA 52 guidelines for proper installation and possible damage or loose components. It then includes sections on identifying the cylinder and inspecting it for damage. A separate procedure needs to be developed when damage is noted to ensure that the vehicle is not driven until the cylinder or hardware is repaired to Level 1 or removed as Level 3 damage. One copy stays in the vehicle file, while another copy stays with the inspector. The CNG Cylinder Inspection Form is to be signed and dated by the certified cylinder inspector.

7 Module Seven

Intervals

Although CNG cylinders are designed with the highest safety factors and undergo many tests to ensure safety, they should also undergo periodic safety visual inspections. The minimum requirement for conducting these inspections is as follows:

General Visual Inspection: During preventative maintenance service, when fueling the vehicle, or any other time the cylinders are visible.

Detailed Visual Inspection: 3 years in NGV-2; 3 years or 36,000 miles (whichever comes first) in FMVSS304. Individual manufacturers may set more frequent schedules.*

***NOTE: Detailed inspections should be performed by a trained cylinder inspector following CGA inspection procedures and manufacturer's guidelines.**

Cylinder Manufacturer's Requirements

The specifications and inspection requirements from the manufacturer are necessary if cylinders are earlier versions, DOT E (exemption), and not FMVSS 304 or NGV 2 cylinders, or if any damage is noted.

The steps necessary to determine inspection requirements are as follows:

- Determine applicable cylinder standards.
- Are they NGV-2?
- Are they FMVSS304?
- Are they earlier cylinders?
    - Is there a current Exemption Certificate?

NGV-2 standard requires a detailed visual inspection every 3 years.

FMVSS304 standard requires a detailed visual inspection every 3 years or 36,000 miles (whichever comes first).*

***NOTE: These are minimum requirements. Consult the cylinder manufacturer's guidelines on your specific cylinder prior to performing any cylinder inspection.**

Conditions Requiring Inspections

The cylinders should also be inspected if:

1. The vehicle was involved in a fire or accident.
2. The cylinder was subjected to an impact or excessive heat.
3. The cylinder was exposed to any foreign chemical or substance.
4. Natural gas odor is apparent or you see bubbles on type 4 cylinders.
5. The fuel tank is removed and replaced for any reason.
6. 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.

Preparation

A trained and qualified CNG cylinder inspector knows the value of proper preparation before beginning any inspection procedure. The following items should be addressed:

1. If the cylinders are mounted underneath the vehicle, place the vehicle on a lift. Crawling under a vehicle for visual inspection is highly discouraged and should be avoided.
2. If cylinders are roof-mounted, special procedures are needed after opening these self-contained modules. Consult the builder's guide for roof-mount service.
3. If cylinders are mounted in a truck bed or the trunk of a passenger car, remove all shields to ensure the inspection of all surface areas.
4. If stone shields obstruct the view of any portion of the cylinder that cannot be seen with a mirror, remove them.
5. Clean the cylinder, if needed, with an approved cleaning solution.*

***NOTE: Consult the cylinder manufacturer for guidelines or restrictions regarding cleaning solution.**

Any discoloration that cannot be wiped off or has penetrated the composite material is considered Level 3 damage, as would a missing or illegible label. If any damage is noted, complete a measurement of the damage to determine what level of damage is present. Module Three discusses levels of damage according to CGA 6.4 and the manufacturer of the cylinder, who is the ultimate authority on damage classification.

When service requires a detailed visual inspection, removal or defueling of the cylinder is not required; however, shields may have to be removed if an unrestricted view of the cylinder is not possible without their removal. CGA 6.4 details the visual inspection and classification of damage. It contains a sample inspection form.

Documentation of Cylinder Inspections

The necessary documentation needed for detailed visual inspection is as follows:

1. An inspection report for each CNG cylinder being inspected. (See sample form at end of this module.)
2. A copy of the finished report must be kept with the vehicle records.

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.

Inspection Techniques

Inspecting the vehicle and cylinders by a qualified inspector is a thorough process. Using the inspection form, document the information from the label and vehicle, then proceed step-by-step to complete the inspection.

Use the Inspection Form to Document Each Step

Look for signs of movement, wear, loose brackets, or poor installation of the cylinders and components using NFPA 52 as a source.

Check for Signs of Cylinder Movement

Check the torque of the brackets to make sure they are tight.

The Gasket Can Slip with Frame Flexing

If the brackets are not properly installed, the rubber gasket will move and slip out of the bracket, allowing cylinder-to-bracket contact and a loose cylinder.

Check Torque on Mounting Brackets

Using a mirror and light, carefully inspect all 360° of the cylinder surface for any discoloration, nicks, cuts, or abrasions that would require further study.

You Must Be Able to Inspect All 360° of the Cylinder Surface

The pressure relief device (PRD) should be inspected for signs of extrusion. This may be difficult without disassembling the venting system on some vehicles, as the PRD is not visible.

PRD

Checking the PRD

LONG BEACH CITY COLLEGE

Transportation + Energy = ATRE

Date: _____

CNG CYLINDER INSPECTION FORM

Vehicle Make	Model	Mileage	Year	VIN#

Cylinder No.	1	2	3	4
Manufacturer				
Serial #				
Location				
Label Serial # (Applied)				P = Pass F = Fail

NFPA 52 Sect.	CGA sect.	CNG Cylinder Examination	1	2	3	4
3-3	7.4.2.4	Cylinder and mounting bracket are clean				
3-3	7.4.1	Cylinder installation compliant with NFPA-52				
3-3	7.4.1	Minimum ___ inch clearance around cylinder and 3/8 inch from shields				
3-3	7.4.2.4	Rubber mounting pads in place and in good condition				
3-3	7.4.2.4	Cylinder firmly restrained by the brackets (no rocking, looseness or cracks)				
3-3	7.4.2.4	ALL the bracket securing bolts present and tight				
3-3	7.4.2.4	Bracket and strap bolts torqued to proper specifications				
3-3	7.4.2.4	Mounting brackets in good condition (not bent, no deformation)				
3-3	7.4.2.4	Mounting bracket area free of damage				
3-3	7.4.2.4	Check bracket-to-vehicle mounting for signs of stress				
3-3	7.4.2.4	Brackets and straps corrosion free				
	7.5.3	Cuts, gouges and abrasions on the cylinder are less than 0.010 inch in depth				
	7.5.4.1	No signs of cylinder exposure to fire or extreme heat				
	7.3	No signs of cylinder involvement in an accident				
	7.5.1.3	Cylinder is free of impact damage (surface discoloration, cracked resin, chipping, loose fibers)				
3-3	7.9	Cylinder service pressure markings not less than vehicle service pressure.				
2-5	7.9	Cylinder has not exceeded the marked service life.				
3-4	7.4.1	Cylinder is properly externally vented (cylinders enclosed in vehicles only)				
	7.5.1.3	Cylinder is free of rust, corrosion or etching of outer surface				
	7.6.2	External paint, composite layer or metal surface is free of bubbles or bulges				
2-8	7.8	Valves, lines and/or Pressure Relief Device (PRD) assemblies are damage free				
2-5	7.8	PRD is in good condition (with no visible extrusion of eutectic material)				
3-5	7.4.2.1	Fuel and vent lines are properly attached to the vehicle				
	7.3	Vehicle history (no incidents possibly damaging the cylinder)				
	7.11.2	Installation of new inspection sticker				

Cylinder Inspection Results (check one)

_____ Return Cylinder(s) to service.

_____ Repair Cylinder(s) as follows: _____
_____
_____
_____

_____ Send Cylinder(s) to Mfr. for further inspection as follows: _____
_____
_____
_____

_____REMOVE CYLINDER(S) FROM SERVICE AND DESTROY

Certificate No. _____ Inspector Signature: _____

8 Module Eight

Disposition of Damaged Cylinders & Installations

Repair Requirements

Level 1 damage need not be repaired; just prevent further damage and return to service after making a detailed note of the damage. Some Level 2 damage may be able to be repaired in-service and returned to service, if the repair is performed to manufacturer's recommended procedures. It is necessary to contact the manufacturer or have their Service Bulletin regarding the procedure in order to properly repair the cylinder. Only approved materials should be used in this process and much care must be taken to ensure the damage is within the acceptable limits. The manufacturers have specific epoxy and solvents or cleaning agents that they approve for use with their cylinders. Some deeper Level 2 damage may require reworking by the manufacturer and recertification before it can be returned to service. In this instance, defueling and shipping of the cylinder to the manufacturer may be necessary. Upon re-working, the damage becomes Level 1 and the cylinder can be returned to service. Level 2 damage that is deemed unrepairable becomes Level 3 damage requiring disposal of the cylinder.

Disposal Requirements

Cylinders that are condemned, or if their service life of 15 or 20 years has expired, need to be destroyed in a safe and thorough manner. Only trained personnel must perform the destruction of cylinders. The following guidelines for disposal of CNG cylinders, as recommended in CGA 6.4, are as follows:

1. Remove all gas by purging cylinder with an inert gas, such as nitrogen.

NOTE: Pay close attention to Type 4 cylinders as the cylinder lining may have trapped gas between the liner and the composite fibers of the cylinder.

2. Remove all valves and fittings.
3. After recording serial number, remove or grind off all labels or markings on the cylinder.
4. Destroy the cylinder by cutting the cylinder in half or drilling a one half-inch hole into the cylinder. If it is not your cylinder, inform the owner of the vehicle how to dispose of the cylinder.
5. Dispose of the cylinder in the trash or appropriate scrap bin, adhering to local regulations. The aluminum and steel can be recycled once the fiber wrap is properly removed.

NOTE: The CGA document and all relevant cylinder manufacturer guidelines should be followed when a cylinder is destroyed.

Documentation of Failed Cylinders and Installations

When finished with a detailed visual inspection, cylinders that have failed inspection, either for cylinder failure or installation failure, need to be marked as such. The Cylinder Inspection Form will have an area for the inspector to log the following information:

1. A summary of damage found. (documented with pictures)
2. A recommendation of repairs that are needed to return the cylinder to service.

NOTE: As a qualified cylinder inspector, it is necessary to fully describe any findings in writing on the Cylinder Inspection Form.

Determining Disposition

Each cylinder manufacturer should have developed procedures for determining the levels of damage and the acceptable repair methods. This may vary with the type and age of the cylinder, especially if they are not FMVSS 304 or NGV 2 certified cylinders. DOT E exemption and earlier cylinders may not qualify for detailed visual inspections. Before performing an inspection, or after seeing any damage that would be beyond Level 1, it is recommended that the manufacturer of the cylinder be contacted to obtain any bulletins or special procedures that they recommend. For instance, the cleaner used to clean the cylinder and label should be an approved fluid which may be thinner, or soap and water, depending upon the construction materials.

Sometimes, it is necessary to use a straightedge across a gouge to seek a level from which to measure. With this method, you must subtract the thickness of the straightedge from your reading.

Measuring Depth with Dial Gauge

9 Module Nine

Cylinder Defueling

Cylinder defueling is only required when it is necessary to remove the cylinder from service or to replace components in the system. There are two types of defueling: scheduled and emergency. Scheduled defueling is when you plan on doing maintenance to the system and remove the fuel from one or more cylinders. This is the preferred method of removing a cylinder from service. Emergency defueling is when a major problem exists that requires immediate removal of pressure from the cylinders for safety reasons.

Methods of Defueling

There are four basic methods to defueling a vehicle. Each has its advantages and disadvantages.

1. Run the cylinder or vehicle out of fuel.

This is the preferred method for all scheduled defueling as it does not emit methane into the atmosphere. Scheduling the vehicle for service when it will already be low on fuel allows the easiest method to defuel a cylinder. Isolating a cylinder by turning off all other cylinders and running the engine until the cylinder to be serviced is empty will complete the defueling process. It is not always possible to run the cylinder completely out of pressure and care must be taken to make sure the other cylinders do not share PRDs or other pressure. Electric cylinder valves must be closed manually and prevented from opening during this process.

2. Transfer the fuel to another vehicle or cylinder.

This method requires some plumbing considerations to accommodate the transfer. Total pressure cannot be removed without stages of transfer, as two cylinders will equalize based upon size and pressure, but never drop total pressure.

Contamination transfer to another cylinder is also possible.

3. Return fuel to compressor inlet.

This method also requires some plumbing considerations and the possible contamination of the compressor station.

4. Vent to the atmosphere.

This is the least desirable method as it involves release of methane to the air, which although not illegal in most areas, can be dangerous. Methane is a dry gas and will create static electricity when released. Care should be taken to properly ground all components and bond them together using ground straps and CNG approved hose containing carbon black to eliminate any possible static discharge. Cylinders should be connected to a vent stack which is a 2 inch or larger cast-iron pipe, securely fastened to a wall or building, and extending 10 feet into the air beyond any combustion sources. A CNG approved hook-up hose is connected to this pipe through a control valve and attached to the cylinder being de-pressurized. The cylinder, properly restrained, is then vented as slow as possible to prevent static and temperature/condensation problems. Defueling Type 4 cylinders in this manner can cause separation of the liner from the composite if not done slowly.

Post Test

CNG Fuel Systems Inspector

1. In an inspection, you notice that one cylinder is rated @ 3600 psi and the other two are rated @ 3000 psi. In addition, the fuel receptacle is rated @ 3000 psi. What should you do?
   a. Remove and replace the 3000 psi cylinders and nozzle with a 3600 psi replacement.
   b. Remove and replace the 3600 psi cylinder with 3000 psi cylinder.
   c. This is not a problem.
   d. Replace the 3000 psi fuel receptacle with a 3600 psi receptacle.

2. A 3600 psi System is overfilled @ station to 5500 psi. What do you do?
   a. Have all system components replaced, including cylinders and plumbing, which are level 2 damage.
   b. Replace all cylinders because they are level 3 damage and their pressure exceeded MAWP.
   c. This is not a problem because cylinders have not exceeded MAWP.
   d. Replace the secondary regulator and coalescence filter.

3. During an inspection, you find an unused bracket near one of the CNG cylinders. What should you do?
   a. Determine the purpose of the bracket and if there are missing shields and have shields reinstalled.
   b. Remove the brackets before completing inspection.
   c. This is not a problem.
   d. Add more brackets next to the other cylinders.

4. If you notice that a cylinder has moved inside of its brackets, what should you check for?
   a. Re-torque cylinder brackets.
   b. Replace cylinder brackets.
   c. Replace bracket nuts with Ny-lock nuts.
   d. Determine if cylinder was damaged from movement and what caused the movement. Replace damaged components and cylinders.

5. The Owner reports possible cylinder leakage after 5:00 pm filling because pressure at 7:00am the next morning is down to 3300 psi. Is this OK?
   a. No, immediately condemn the cylinder and defuel.
   b. Yes, explain, that due to temperature compensation, pressure drops as temperature drops after filling.
   c. No, the pressure gauge is defective and needs to be replaced.
   d. Yes, someone took fuel from the vehicle and put it in their vehicle or let it into the atmosphere.

6. If a Cylinder is known to have fire damage, what is the first thing to do?
   a. Call the fire department and put out the fire.
   b. Level 1 damage only. Document and put back in service.
   c. Check to see if it washes off. If it washes off this is not a problem. Otherwise, it is Level 2 damage.
   d. Check to see if it washes off. If it washes off this is not a problem. Otherwise, it is Level 3 damage.

7. What is the approx. depth that you can catch with your nail?
   a. .010" b. .020" c. .030" d. .040"

8. A CNG cylinder has a .020 cut and is 1" long. What do you do?
   a. Level 3 damage. Replace cylinder.
   b. Level 2 damage. Contact manufacturer and determine repair procures, complete repair, document and place back in service as Level 1 damage.
   c. Document and place back in service as Level 1 damage.
   d. No further work necessary.

9. A type 4 cylinder has bubbling on the surface. What should you do?
   a. This is not a problem - type 4 cylinders always bubble.
   b. Condemn cylinder and replace.
   c. Defuel and drain water from cylinder.
   d. Determine if cylinder was recently refueled. Type 4 cylinders can bubble for several hours after refueling from air trapped between cylinder and liner.

10. There are cracks around the shoulder where a valve is screwed into the cylinder. What is the most probable cause?
   a. Cylinder shifted during refueling.
   b. Valve was over-tightened when installed.
   c. This is not a problem - this is normal from heat expansion.
   d. Cylinder was exposed to excessive temperatures.

11. What are the primary concerns when defueling a cylinder using a defueling station?
   a. Ozone layer.
   b. Weather and which way the wind is blowing.
   c. What is downwind, a ground and bonding between defueling stack and cylinder being defueled.
   d. Birds that may fly over while defueling.

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

13. Is it OK to mix different cylinders types and pressures in the same system?
    a. Yes b. No c. Depends on cylinder pressures d. Depends on Cylinder Types

14. Can a PRD be reused on another cylinder?
    a. Yes b. No c. Depends on the cylinder type d. Only with type 4 cylinders

15. You notice in an inspection that the ¼ turn valve is in a lock box with the fuel receptacle. What should you do?
    a. Remove the fuel door.
    b. Condemn the vehicle.
    c. This is not a problem
    d. Level 2 damage if ¼ turn valve is in a lock box. Have lock removed and changed so valve cannot be locked.

References

Cylinder Manufacturers:

1. Hexagon Plastics
"Tuffshell Composites"
4300 Industrial Avenue Lincoln, NE 68504
Telephone: 800-279-8265

2. Dynetek
5915 36th Street SE
Calgary, Alberta, Canada
Telephone: 403-720-0262

3. Structural Composites Industries (SCI)
325 Enterprise Place Pomona, CA 91768
Telephone 909-594-7777

4. Luxfer Cylinders
3016 Kansas Ave.
Riverside, CA 92507
Telephone: 800-764-0366

NOTE: There is generally an 800 number on the cylinder near the manufacturer's name to contact them regarding disposition and repair procedures. They are usually very cooperative, but you should be prepared with the description of the cylinder, including serial number, so they can provide accurate information.

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

FMVSS304, “Compressed Natural Gas Fuel Container Integrity,” Federal Motor Vehicle Safety Standards, US DOT, NHTSA

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

CHP Title 13

Glossary of Terms

Abrasion Damage: Damage to composite materials caused by wearing or grinding of the composite material.

Acoustic Emission: A form of non-destructive cylinder inspection.

AGA: American Gas Association.

All Composite Cylinder: A cylinder made primarily from non-metallic materials, such as plastics and composites.

All Metal Cylinder: A cylinder that is made from metal only (steel or aluminum).

Aluminum: A material used in making cylinders.

Anneal: Temper process by heating and cooling material, then tubing is drawn or pilgered into shape.

ANSI: American National Standards Institute.

Aramid: One of the types of fibers used in composite over wraps.

Blunt Impact: A forceful blow to a cylinder that does not cut, gouge, or significantly indent the surface of the cylinder.

Carbon Fiber: One of the types of fibers used in composite cylinders.

CGA: Compressed Gas Association.

Coin Tap Test: An inspection technique where the surface of the composite wrapped cylinder is tapped with a small coin. A damaged area will sound different than an undamaged area.

Composite: A material formed by combining two or more materials.

CNG: Compressed Natural Gas.

Condemned Cylinder: A cylinder that must be removed from service. The cylinder has been damaged beyond repair.

Corrosion: Process that refers to the oxidation of materials primarily in wet environments.

Crazing: Hairline cracking of the composite resin giving an opaque or frosty appearance.

CSA: Canadian Standards Association

Cut Damage: Damage caused by a sharp object in contact with the composite surface.

Cylinder: The thick-walled pressure vessel used to store the compressed natural gas. Often referred to as a fuel storage tank.

Cylinder Region: The cylindrical portion of the tank.

Defueling: The removal of the CNG from the cylinders.

De-lamination: Damage in which separation occurs between composite material layers.

Destroyed: Alteration of a cylinder to make it unusable.

Drilling a hole completely through the cylinder wall is an acceptable destruction method.

Domes: The curved end portion of a cylinder.

DOT: Department of Transportation.

External Coating: A clear or colored coating on a cylinder for environmental protection and appearance.

Epoxy: A type of resin used in the composite wrap to protect the fibers and hold them together.

Factory Inspection: Inspection of the cylinder by the tank manufacturer.

Fatigue: Damage that occurs by repeated pressure cycles.

Fibers: The continuous fiber strands in a composite that will withstand the pressure forces. Fibers used in CNG cylinders are typically carbon or fiberglass.

Fiberglass: One of the types of fibers used in composite over wraps.

Filament Winding: A process whereby fibers, wetted

in a resin, are wound around a liner.

FMVSS: Federal Motor Vehicle Safety Standard.

Fuel Storage System: One or more cylinders used to store CNG for NGVs.

Fuel Delivery System: The system that delivers fuel to the engine. Includes tubing, valves, regulators, and filters.

Full Wrap: The wrapping in a filament-wound cylinder over both the cylinder sidewall and domes regions.

Full Wrap Cylinder: A cylinder that contains composite material over the cylinder sidewalls and domes.

Galvanic Corrosion: Corrosion that occurs when different materials are in contact with each other.

Glass Fibers: Fiberglass. One of the types of fibers used in the composite over wrap.

Hoop Wrap: Layers of composite over-wrap, filament-wound to provide additional circumferential strength in the cylindrical section of the tank.

Hoop Wrap Cylinder: A cylinder that uses hoop wrap for reinforcement.

Hydrostatic Test: A test performed on a cylinder where the cylinder is pressurized hydraulically to at least 1.5 times the service pressure. The cylinder volume expansion is used to determine its condition.

IAS: International Approval Services. An organization involved in standards development and product certification.

Impact Damage: Damage caused by dropping the cylinder or by a blow from another object.

Level 1 Damage: Minor damage, which is considered normal and should have no adverse effects on the safety of the cylinder and its continued use.

Level 2 Damage: Moderate damage which requires the cylinder to be repaired and equalized before returning to service.

Level 3 Damage: Severe damage which is not repairable.

The cylinder is unfit for service and must be condemned. Liner: An internal component of a fully composite tank which prevents gas leakage.

Manufacturer's Label: The label on the cylinder containing the official markings.

Mounting Brackets: The devices used to secure fuel tanks in vehicles. The brackets are specially designed to restrain tanks without causing damage and to accommodate tank growth caused by changes in external pressure.

NFPA: National Fire Protection Association.

NFPA 52: Natural gas vehicle standard written by the NFPA.

NGV2: Cylinder standard approved by the American National Standards Institute.

NHTSA: National Highway Traffic Safety Administration. A division of the D.O.T.

Non-Load Bearing: Part of the cylinder which does not support a load. An example is the plastic liner in an all-composite cylinder.

Natural Gas Vehicle: Vehicles that use natural gas as a motor fuel.

Nylon: A type of plastic material used in liners of all composite cylinders.

Operating Pressure: The pressure of the fuel system.

Permeation: Process by which gas diffuses through a plastic liner.

Pitting: Type of localized corrosion that occurs in metals.

Polyethylene: A type of plastic material used in liners in all composite cylinders.

Glossary of Terms

Ports: The openings at the ends of the cylinder in which valves, pressure relief devices, and plugs are installed.

PRD: Pressure relief device. A device installed in the tank or integrated with a valve that will release the contained gas in specific emergency conditions. The device may be activated by excessive temperature, excessive pressure, or both.

Protective Wrap: The external protective wrap consists of multiple layers of fiberglass-reinforced composite, which minimizes the sensitivity of the fuel tank to surface damage.

Rejected Cylinder: A cylinder that must be removed from service and evaluated further before final disposition.

Resin: The plastic binding material in the composite over wrap which acts as the glue between layers of fiber.

Road Debris: Material such as small rocks, stones, or gravel that have the potential to damage cylinders.

Seamless Tubing: Cold-worked seamless tubing is produced from billets by either trepanning or extrusion, followed by pilgering and/or drawing.

Service Pressure: The service pressure is the settled pressure at a uniform gas temperature of 70° F. and full gas content. It is the pressure for which the equipment has been constructed, under normal conditions. Also referred to as nominal pressure.

Shielding: Structure constructed to protect a cylinder from road debris or other forms that may damage the cylinder.

Sidewall: The cylindrical portion of the cylinder that does not include the domes.

Solid Plug: A threaded plug used to block cylinder ports not occupied by a valve or a PRD.

Steel: A material used to construct cylinders.

Storage Pressure: Cylinder Pressure.

Stress Corrosion: A form of cracking that occurs as a result of a combination of stress and a corrosive environment.

Type 1: Classification for a cylinder that is constructed of all metal.

Type 2: Classification for a cylinder that is constructed using a metal liner and a composite hoop wrap. Also known as hoop wrapped.

Type 3: Classification for a cylinder that is constructed using a metal liner and a composite full wrap. Also known as full wrapped.

Type 4: Classification for a cylinder that is constructed from a plastic liner and a composite full wrap. Also known as all composite.

Thermal Trigger: The portion of a thermally activated pres-sure relief device which is activated by excessive heat input.

Valve, Manual: A device installed in one of the cylinder ports to control flow of gas to or from the cylinder. The device is turned manually.

Valve, Solenoid: A device installed in one of the cylinder ports to control flow of gas to or from the cylinder. The device is turned on electronically.

Visual Inspection: A form of inspection where a trained inspector looks at the cylinder for signs of damage.

Vent Lines: A high-pressure line from a PRD to a location outside the vehicle.

Working Pressure: The pressure for which the equipment has been constructed to operate under normal conditions.

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