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**METHODS FOR EXTERNAL VISUAL
INSPECTION OF NATURAL GAS
VEHICLE (NGV) AND HYDROGEN GAS
VEHICLE (HGV) FUEL CONTAINERS AND
THEIR INSTALLATIONS**

FOURTH EDITION

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NOTE—Appendices A, B, and C (Informative) are for information only.

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1 Introduction

This publication provides information and procedures for the periodic visual examination and inspection of natural gas and hydrogen fuel containers and the condition of the installation. These containers are installed in vehicles qualified by the original equipment manufacturer (OEM) or aftermarket vehicle manufacturer to meet the following U.S. or Canadian standards:

- CSA/ANSI NGV2, *Compressed natural gas vehicle fuel containers* [1];¹
- U.S. Department of Transportation (DOT) National Highway Traffic Safety Administration (NHTSA) FMVSS, Standard No. 304, *Compressed Natural Gas Fuel Container Integrity* [2];
- Canadian Motor Vehicle Safety Regulations, Standard 301.2, *CNG Fuel System Integrity* [3]; and
- Canadian Standards Association (CSA) B51, *Boiler, Pressure Vessel, and Pressure Piping Code* [4].

This publication may be used for the inspection of other natural gas and hydrogen fuel containers that are qualified to meet other specifications and standards (see Section 4). These containers are designed to store natural gas and hydrogen at high pressures. It is critical that this publication be carefully read and completely understood before initiating either the examination or inspection of a container and that all applicable sections of the publication be followed during the examination/inspection process. This publication requires that appropriate information, such as an installation and maintenance manual from the container manufacturer, be reviewed and used during the examination/inspection together with all current container manufacturer's recommendations and guidance documents.

The examinations/inspections covered in this publication are intended to be carried out only by qualified individuals as defined in Section 5. When preparing to conduct an inspection, the inspector should have the equipment described in Section 6 available and within easy access during the inspection. The vehicle to be inspected should be positioned so access to the surface of the container is unimpeded or positioned according to the vehicle manufacturer. If the examination, conducted as described in Section 7, reveals areas that require additional inspection or testing of the container, the container label is not visible, or the container surfaces are not all sufficiently visible to the inspector, the container shall be depressurized (following this publication and the manufacturer's instructions) and removed from the vehicle. See Section 8 for alternative and ancillary inspection methods.

2 Scope and purpose

2.1 Scope

This publication addresses containers manufactured to generally accepted codes and standards for fuel gas vehicle (FGV) service (see Section 4) [1, 2].

2.2 Purpose

The purpose of this publication is to provide guidance for the visual inspection of these containers and to provide criteria for the acceptance or rejection (in the absence of guidance from the manufacturer) with subsequent disposal or repair as necessary. The appropriate documentation to comply with inspection requirements of natural gas vehicle (NGVs) and hydrogen gas vehicle (HGVs) is in the following preferred order:

- a) jurisdictional authority;
- b) standards and specifications;
- c) OEM requirements;
- d) aftermarket vehicle manufacturer requirements;

¹ References are shown by bracketed numbers and are listed in order of appearance in the reference section.

- e) container manufacturer requirements; and
- f) this publication.

For example, if the inspector has OEM requirements and container manufacturer requirements that were different, the inspector shall follow the OEM requirements.

The continued safe use of acceptable containers and the removal from service of unsafe, damaged containers that do not pass the visual inspection criteria are important to the safety and well being of all who come into contact with NGVs and HGVs. This publication is directed to all who perform periodic inspections of compressed natural gas containers.

Without regulatory requirements or in lieu of vehicle manufacturer specifications, the recommended minimum visual inspection frequency is once every 3 years for the life of the container [1]. Manufacturer's recommendations, harsh or abusive conditions (as outlined in Appendix A), or federal, state, provincial/territorial, or local regulations can warrant more frequent inspections. Whatever the frequency of inspection for the fuel gas (FG) container, the inspector needs to know what to look for, how to visually inspect, and how to make the determination whether the container meets the criteria for continued safe service within its specified design life as provided on the label.

3 Definitions

For the purpose of this publication, the following definitions apply.

3.1 Publication terminology

3.1.1 Shall

Indicates that the procedure is mandatory. It is used wherever the criterion for conformance to specific recommendations allows no deviation.

3.1.2 Should

Indicates that a procedure is recommended.

3.1.3 May

Indicates that the procedure is optional.

3.1.4 Will

Is used only to indicate the future, not a degree of requirement.

3.1.5 Can

Indicates a possibility or ability.

3.2 Technical definitions

3.2.1 Abrasion damage

Damage to a container caused by wearing, grinding, or rubbing away of the container material by friction.

3.2.2 Aramid fiber

Type of reinforcement fiber used in composite overwrap.

3.2.3 Carbon fiber

Type of reinforcement fiber used in composite overwrap.

3.2.4 Composite

Structural material composed of load-bearing fibers embedded in a protective resin matrix.

3.2.5 Condemned container

Cylinder no longer fit for service and for which repair is not allowed.

3.2.6 Crazing

Hairline cracking of the resin giving it an opaque “frosty” appearance.

3.2.7 Cut damage

Damage caused by a sharp object coming in contact with a composite surface.

3.2.8 Delamination

Form of composite damage in which a separation develops between layers of the composite.

NOTE—This type of damage usually results from excessive localized loading that is normal to the surface of the laminate.

3.2.9 Destroyed

Alteration of a fuel container to make it physically unusable.

NOTE—Drilling two overlapping holes of 1 in (25.4 mm) diameter or larger completely through the wall is an acceptable means of destroying a container. The overlapping holes generate a “figure 8” or “∞” internal profile that is more difficult to plug using standard round plugs.

3.2.10 External/exterior coating

Clear or colored surface treatment applied to the container for environmental protection and improved appearance.

3.2.11 Fiberglass

Type of reinforcement fiber used in composite overwrap.

3.2.12 Filament winding

Automated process used for orienting strands of high strength fibers and plastic resin to construct composite containers.

3.2.13 Fuel gas (FG)

Compressed natural gas, hydrogen gas, or mixtures thereof, suitable for vehicle fuel.

3.2.14 Fuel gas vehicle (FGV)

Vehicle that uses compressed natural gas, hydrogen gas, or mixtures thereof as fuel.

3.2.15 Helical wrap

Layers in the composite overwrap filament wound to provide primarily longitudinal strength and some hoop strength for the cylindrical region of the container.

NOTE—The strands of reinforcing fibers are oriented at an angle to the longitudinal axis of the container (see Figure 1).

3.2.16 Hoop wrap

Composite reinforcement wound at a nominal angle of 90 degrees to the longitudinal axis that generally carries the major portion of the load in the hoop direction and little load in the longitudinal direction (see Figure 1).

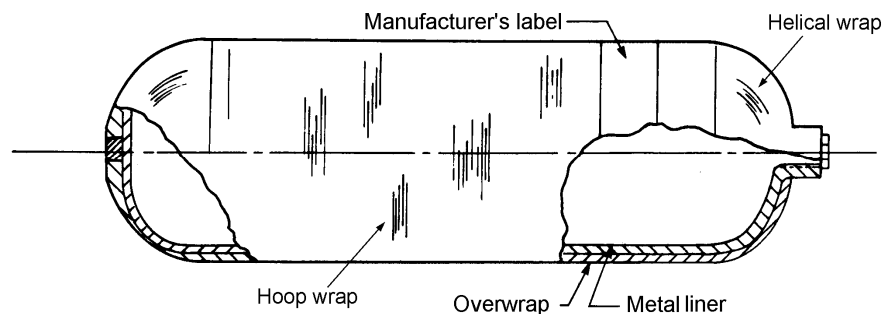


Figure 1—Full-wrapped cylinder with one port

3.2.17 Impact damage

Damage caused by dropping or by a blow from another object.

NOTE—Impact damage can be at the surface, internal to the structure, or both.

3.2.18 Inspection mark

Mark, label, or tag placed by an inspector on the container indicating acceptance of the container.

NOTE—The mark shall at least identify the inspecting agency and the date of inspection (month and year).

3.2.19 Level 1 damage

Minor damage that can occur during normal use.

NOTE—Such damage should have no adverse effects on the safety of the cylinder and its continued use. Such items as scratched paint, nicks, or dings that have no appreciable depth or no significant quantity of frayed fibers are considered to be in this category.

3.2.20 Level 2 damage

More severe damage than Level 1 but keeps open the possibility of repair and the container being returned to service based on the recommendations of the manufacturer or their literature.

NOTE—Level 2 damage can be cuts or gouges that are deeper or longer than those of Level 1. Level 2 damage cannot remain at that level after inspection. It shall be repaired to an acceptable condition or moved to Level 3 and condemned.

3.2.21 Level 3 damage

Damage that renders the cylinder unfit for continued service and cannot be repaired.

NOTE—Containers with Level 3 damage shall be condemned.

3.2.22 Liner

Internal component of the container that prevents leakage of gas through the composite container structure.

3.2.23 Manufacturer

Container manufacturer.

3.2.24 Manufacturer's marks

Required official markings that are stamped on the exposed metal ends or neck, printed on permanent labels, or a combination of stamping and labels.

3.2.25 Manufacturer's recommendations/guidelines

Recommendations or guidelines from the manufacturer to direct and/or advise the inspector on Level 2 damage issues.

3.2.26 Mounting brackets and/or straps

Devices used to secure fuel containers in a vehicle.

3.2.27 Overpressurization

Pressures exceeding those allowed during filling procedures specified in the standards referenced in this document.

3.2.28 Ports

Openings at the ends of the container where valves (manual or solenoid), pressure relief devices (PRDs), and blank plugs are installed.

3.2.29 Pressure relief device (PRD)

Device installed in the container or integrated with a valve that will release the contained gas in specific emergency conditions.

NOTE—PRDs can be activated by excessive temperature, excessive internal pressure, or both.

3.2.30 Reinforcing fibers

Continuous fibrous strands in the composite that withstand loads caused by pressurization.

3.2.31 Rejected container

Container to be removed from service and evaluated further before final disposition.

3.2.32 Resin

Plastic material in the composite overwrap that fills the space between individual reinforcing fibers.

3.2.33 Scuff

Minor abrasion damage to the protective coating, paint, or resin-rich composite surface.

3.2.34 Service pressure

Authorized pressure marking on the cylinder.

3.2.35 Standard

When used and not otherwise qualified, the authoritative document to which a fuel gas (FG) container is qualified for use in fuel gas vehicles (FGVs).

3.2.36 Stress corrosion cracking (SCC)

Cracks in composite materials that typically are sharply defined and perpendicular to the fiber direction.

NOTE—They can appear as a family of cracks or as a single crack. Stress corrosion cracking can be caused by exposure to harsh liquid chemicals.

3.2.37 Valve, manual

Device installed in one of the ports of the container used to regulate gas flow into and out of the container, which is turned on and off manually with a handle.

3.2.38 Valve, solenoid

Device installed in one of the ports of the container used to regulate gas flow into and out of the container, which is turned on and off electronically.

NOTE—The valve can be operated manually, if necessary, with special tools.

3.2.39 Vent line

High pressure line used to conduct gas from a PRD to a location outside the vehicle.

NOTE—Vent lines are required where pressure-carrying components are installed in a closed compartment.

4 General design information

Fuel gas vehicle (FGV) fuel containers can be designed and qualified to one of a number of appropriate specifications or standards. These include but are not limited to:

- ANSI NGV2 [1];
- FMVSS 304 [2];
- CSA B51 [3];
- Standards approved by Transport Canada (TC); and
- ISO 11439, *Gas cylinders—High pressure cylinders for the on-board storage of natural gas as a fuel for automotive vehicles* [5].

These containers have labels that identify the standards to which they are built and identify the type of construction used.

4.1 Design types and descriptions

FGV fuel container types are designated as follows:

4.1.1 Type 1—metal

Type 1 containers are all metallic and can be of any steel or aluminum alloy that meets qualification requirements outlined in the appropriate standard.

4.1.2 Type 2—resin impregnated continuous filament with metal liner of prescribed strength

Type 2 containers have a metallic liner with sufficient strength and thickness to carry the entire longitudinal load at the required burst pressure and to withstand the standard-specified factor of the nominal service pressure (e.g., 1.25 in ANSI NGV2) without rupture. Metal liner materials are those identified under Type 1 containers (see 4.1.1). They are reinforced with fibers normally wound only in the hoop (circumferential) direction. Reinforcing fibers are carbon, aramid, fiberglass, or combinations thereof.

4.1.3 Type 3—resin impregnated continuous filament with metal liner

Type 3 containers have a metallic liner that is generally load carrying but does not have sufficient strength and thickness to carry the longitudinal load at the burst pressure. They are reinforced with fibers normally wound in both a helical (polar) pattern to provide longitudinal reinforcement and in a hoop direction. Reinforcing fibers are carbon, aramid, fiberglass, or combinations thereof. Metal liner materials are those identified under Type 1 containers (see 4.1.1).

4.1.4 Type 4—resin impregnated continuous filament with a nonmetallic liner

Type 4 containers have a nonmetallic liner that does not carry load. The liner is typically a thermoplastic material. Reinforcing fibers are carbon, aramid, fiberglass, or combinations thereof. They are reinforced with fibers wound in both a helical (polar) pattern to provide longitudinal reinforcement and in a hoop direction. Metallic bosses are used to accept valves or pressure relief devices (PRDs). Boss materials are typically aluminum or stainless steel.

4.2 Installation and mounting of NGV fuel containers

Periodic inspection is an integral element of the maintenance requirements for safe operation of an FGV fuel container.

Safe operation of a fuel container is also dependent on proper installation and use of PRDs, container valves, ancillary and connected equipment, and other components of the fuel system.

The container shall be mounted in a manner that adequately restrains it but does not induce damage. Only brackets, straps, and mounting systems recommended by the OEM vehicle or container manufacturer should be used. The container expands and contracts as the pressure in the container increases and decreases. This causes the container's diameter and length to vary depending on pressure. The container mounting system shall be able to accommodate this expansion without inducing excessive loads in the container or causing abrasion of the container. Brackets should be designed and used in accordance with:

- NFPA 52; *Vehicular Natural Gas Fuel Systems Code* [6];
- CSA B109, *Natural gas for vehicles installation code* [7]; and
- CSA ANSI/AGA NGV3.1/CGA 12.3, *Fuel System Components for Natural Gas Powered Vehicles* [8].

4.3 Labeling information

Information on labels typically required in ANSI NGV2 and FMVSS 304 and regulations includes [1, 2]:

- the statement: "If there is a question about the proper use, installation, or maintenance of this container, contact _____." (inserting the FGV fuel container manufacturer's name, address, and telephone number);

- “CNG ONLY” or “H2 ONLY” depending on container service;
- the statement: “Manufactured in _____.” (inserting the month and year of manufacture of the FGV fuel container);
- “DO NOT USE AFTER (MONTH/YEAR)”;
- the service pressure (in kPa or psig)²;
- the standard to which the cylinder is qualified and the type of cylinder;
- the PRDs and valves that are qualified for use with the cylinder or the means for obtaining this information;
- the symbol “DOT,” constituting a verification by the FGV fuel container manufacturer that the container complies with all requirements of the FMVSS 304 standard [2];
- the serial number; and
- the part number.

Review the appropriate standard for exact wording required and the requirements for letter sizes. If working with containers made to another standard, check the specific design specification or standard for exact wording required, size of lettering, format, etc. (see Section 4).

Other information that can be included:

- operating temperature range;
- nominal water capacity;
- initial pressure test date; and
- inspector’s mark.

A typical label reads:

If there is a question about the proper use, installation, or maintenance of this container, or for information on qualified valves and relief devices, contact XYZ Corp. at 1-800-555-XXXX.

CNG ONLY
 Manufactured in 01/96
 DO NOT USE AFTER 01/2011
 XYZ Corporation - P/N 12345/00123
 S/N 88897968484
 3600 PSIG
 NGV2-4
 DOT

5 Qualifications of inspector

The inspector of the container, valves, and PRDs shall have at least one of the following qualifications:

- two years of experience conducting container inspections on the type of cylinder being inspected;
- supervision by a person with two years of experience relevant to the type of cylinder being inspected;
- approval by the manufacturer of the container being inspected;

² kPa shall indicate gauge pressure unless otherwise noted as (kPa, abs) for absolute pressure or (kPa, differential) for differential pressure. All kPa values are rounded off per [CGA P-11](#), *Metric Practice Guide for the Compressed Gas Industry* [9].

- certification as an inspector by one of the organizations with specific OEM-approved training centers with the FG cylinder standards' recommended inspection guidelines;
- certification as an inspector by a state or nationally recognized organization that tests for specific knowledge of applicable FG cylinder standards' recommended inspection guidelines; or
- certification as an inspector by the authority having jurisdiction (AHJ).

5.1 Container and installation knowledge

The inspector shall have a complete understanding of the types of containers used in FG vehicle systems and the specific allowances for damage to each type.

5.2 Resources

The inspector shall have all of the container manufacturer's guidelines and recommendations pertinent to the inspection readily available and be able to verify that they are the most current set of guidelines and recommendations available from the container manufacturer.

5.3 Inspection knowledge

The inspector shall have a thorough understanding of all required inspections, tests, test apparatus, inspection procedures, and inspection techniques and equipment applicable to the types of vessels to be inspected. The inspection requirements are covered in Sections 6 and 7.

5.4 Gas and technical knowledge

The inspector shall have basic knowledge of the:

- concepts of containment of compressed gases in containers;
- container material types and properties;
- effects of thermal exposure upon each type of FG pressure vessel and relief device;
- concepts of pressure fittings and pressure tight connections; and
- concepts of safe work methods and hazards of flammable gases.

5.5 Literacy

The inspector shall have an understanding of inspection requirements and associated documents before conducting the inspection. The inspector shall be capable of reading and writing in the language of the associated documents used in the inspection.

5.6 Supervisory ability

The inspector shall be capable of directing subordinate persons so the results of inspections are coordinated into an accurate and reliable report for each container inspected. ASNT Recommended Practice No. SNT-TC-1A should be used as a guideline for certification and qualification of inspectors [10].

Inspectors in facilities approved by DOT's Pipeline and Hazardous Materials Safety Administration (PHMSA) Approvals Branch under the provisions of Title 49 of the U.S. *Code of Federal Regulations* (49 CFR) 107.805, cylinder requailifiers registered by TC under the provisions of CSA B339, *Cylinders, spheres, and tubes for the transportation of dangerous goods* and the *Transportation of Dangerous Goods Regulations*, as well as inspectors licensed by the National Board of Boiler and Pressure Vessel Inspectors³, should be capable of meeting the requirements listed in Section 5 to inspect the fuel container, but will need additional training and knowledge to inspect installations [11, 12, 13].

³ National Board of Boiler and Pressure Vessel Inspectors, 1055 Crupper Avenue, Columbus, Ohio 43229. www.national-board.org

6 Inspection equipment

6.1 Inspection of mounting

6.1.1 Adequate light

To properly examine the external surfaces of containers, mounting brackets, valves, vent lines, etc., a light source capable of illuminating all surfaces should be used.

6.1.2 Inspection mirrors

Angled inspection mirrors should be used to aid in the examination of cylinder surfaces that are partially concealed by the installation.

6.1.3 Hand tools

Various hand tools may be necessary to remove covers or shields so the external cylinder surfaces, brackets, valves, PRDs, and other components can be viewed.

6.1.4 Torque wrench

A torque wrench may be necessary to verify that the mounting bracket bolts are tightened properly.

6.2 Inspection of container

6.2.1 Depth gauge

Depth gauges are required to determine the depth of cuts, pits, and abrasions. It is recommended that a commercial-type pit or depth gauge be used for this purpose. Alternatively, equipment to estimate imperfection depths is acceptable.

6.2.2 Rule and straight edge

A rule is necessary to determine the length of noted cuts and the general area of abrasion. A rule and straight edge in combination are necessary to evaluate indentations or bulges.

6.2.3 Inspection of valves and relief devices with leak test fluid

A commercial-type leak test fluid that does not contain ammonia or harsh corrosives is necessary to verify that leakage is not present at the container/valve interface, the PRD, and the fuel line connections.

7 Inspection and examination

7.1 Inspection interval

FGV fuel containers should be inspected by a qualified inspector at intervals of 36 months or less (see Section 5 and Appendix A). Failure to perform examinations on a regular basis or promptly (in the case of a potentially damaging incident or unusual behavior) can result in a serious incident causing severe damage, injury, or both. Table 1 provides container inspection criteria limits (see 7.5). Table 2 provides installation equipment criteria (see 7.4).

Table 1—Container inspection criteria limits

Condition	Level 1	Level 2	Level 3	C-6.4 ref.
Composite and metal containers (All container types)				
Labeling	Legible and clean. Required information all legible. Information correlates with vehicle service	Only manufacturer and serial number is clear. Other required information is illegible. ¹⁾	Serial number illegible or traceable, or unidentified manufacturer or model/part number. Beyond service life	7.9
Cuts/scratches/gouges	<0.01 in (0.25 mm) deep	²⁾	≥0.01 in (0.25 mm) deep ²⁾	7.5.2
Charring/sooting	None	Washes off ²⁾	Permanent marking	7.5.3
Gas leakage	None	Bubble test negative	Bubble test confirms leak	7.5.4
Chemical attack	Cleans off. No residue or affect. Chemical is known not to affect container type	Discoloration is minor after cleaning; no material loss ²⁾	Permanent discoloration, loss/disruption of material ¹⁾	7.5.5
Weathering (UV effects)	None	Coating disruption and/or loss ²⁾	Excessive. Look for other condition effects	7.5.6
Involved in a collision, accident, or fire. Container subjected to high or unknown heat.	No indications and vehicle owner knows of no accident, fire, or heat exposure	Owner reports vehicle was in a fire, accident, or exposed to heat ¹⁾	Indications of vehicle and/or container impact or heat damage ¹⁾	7 7.2 7.5.3
Overpressurization	No indication or knowledge by inspector		Cylinder reported to have been pressurized above the applicable design standard	7.5
Composite containers (Types 2, 3 and 4)				
Impact	None	Dents, fiber breaking, cuts, etc. ¹⁾	Permanent deformation of container ¹⁾	7.7.2
Stress corrosion cracking (SCC)	None	Questionable or unsure ¹⁾	Any identified SCC	7.5
Abrasion	<0.01 in (0.25 mm) deep	^{2), 3)}	≥0.01 in (0.25 mm) deep	7.7.1
Metal containers (Type 1 and the exposed metallic portions of Type 2)				
Bulging/bowing	None, or shape can be identified as “banana” or bowed (Type 1 containers only)	All visible bulges are Level 3 damage. See ¹⁾ for questionable bow	Visible bulge, or bowed shape interferes with proper mounting	7.6.2
Corrosion, pits	<0.035 in (0.889 mm) deep	¹⁾	≥0.035 in (0.889 mm) deep	7.6.1.1
Corrosion, line pits	<0.03 in (0.76 mm) deep	¹⁾	≥0.03 in (0.76 mm) deep. Any depth, over 6 in (15.2 cm) long	7.6.1.2
Corrosion, general	<0.03 in (0.76 mm) deep	¹⁾	≥0.03 in (0.76 mm) deep	7.6.1.4
Dents	None	Minor dent(s) ¹⁾	≤2 in (51 mm) diameter or ≥0.0625 in (1.588 mm) deep	7.6.3
Abrasions	None	Minor ¹⁾	Depths that reduce wall thickness below minimum allowable ¹⁾	7.6.4
¹⁾ Contact container manufacturer for criteria and procedure(s), or get the needed information from product literature, instruction manual(s), written recommendations, advisements, etc. ²⁾ Specified by manufacturer. Repair may be possible if directed by container manufacturer. ³⁾ Exposed fibers may be coated. Contact manufacturer.				

Table 2—Installation equipment criteria

Equipment/ condition	Level 1	Level 2	Level 3	C-6.4 ref
All equipment	Clean, no damage, in good condition	Evidence of chemical attack or minor corrosion. Unclear Level 1 condition ¹⁾	Damaged, leaking. Cannot make proper connection. Heavy corrosion	7
Mounting system	Container manufacturer approved and in good condition	Loose, wear showing, or in questionable condition. Inspect for other fuel system damage ²⁾	Broken, excessive wear, damaged, or not approved. Inspect for other fuel system damage	7 7.4.1 7.4.1.2
PRD vent lines and assemblies (except PRDs and hex nut)	Clean, no damage, and container manufacturer approved	Possible seal damage ¹⁾	Damaged or deformed. Allows leakage	7.8
PRD dents, gouges, and/or scratches	None evident or minimal	≥ 0.02 in (0.51 mm) deep, or unclear Level 1 condition ¹⁾	Determined by or from equipment manufacturer guidance	7.8.3
PRD hexagonal-torque nut	No damage, or scratches, dents, or gouges	Worn ¹⁾	Rounded edges, distorted, nonfunctional, or leaking	7.8
PRD	Clean, no damage. Both container manufacturer approved and appropriate for container type	Evidence of wear ¹⁾	Rusted, plugged, corroded, bulged, deformed, defective, leaking, or fusible metal has extruded	7.8
Valving	Clean, no damage, and container manufacturer approved	Dirty. Gaps or loose container port connections ¹⁾ and O-ring inspection	Deformed, leaking, damaged, not container manufacturer approved	7.8
¹⁾ Contact equipment manufacturer or review equipment manufacturer literature, recommendations, and guidelines for criteria, procedure for repairs (if permitted), and specific advice. From this point, the inspector will obtain and read information (or effect repairs) and then set the condition as either Level 1 or Level 3 damage.				
²⁾ Specified by manufacturer. Repair may be possible if directed by container manufacturer.				

7.2 Preparation for inspection—all types

The container owner/vehicle operator should be questioned regarding any known conditions or incidents that can have caused damage to the container. These include but are not limited to:

- overpressurization of the container;
- dropping of the container;
- impacts to the container;
- exposure of the container to excessive heat or fire;
- exposure of the container to harsh chemicals or conditions (see Appendix A); or
- vehicle accidents (including collisions of 5 mph [8 km/h] or more).

The container owner/vehicle operator should also be questioned regarding any unusual observations regarding the container, service history of the container, and any container repairs that may have been made since its last inspection.

7.2.1 Background information

Before starting the inspection, pertinent information from the container manufacturer, vehicle manufacturer (when a FG fuel system is factory installed), and after-market installers (when a FG fuel system is installed after the vehicle is manufactured and by someone other than the vehicle manufacturer) should be reviewed. At a minimum, this should include a survey of the original specifications for the specific container and vehicle model. This

review should include a study of the maintenance manual and recommendations and guidance documents for the container and its installation.

7.2.2 Surface of the container

The surface of the container should be clean and free of dirt or other debris that can impede the inspection of the external surface of the container. Shields or covers should be removed, where possible, to provide access to the container surface area for inspection.

7.2.3 Depressurizing containers

Containers with known or suspected Level 2 or Level 3 damage or containers that require inspection from a condition noted in 7.2 shall be depressurized before inspection operations continue. Containers shall be depressurized in accordance with established safe procedures. See Appendix C for an example procedure.

7.3 Examination of installation—all container types

Table 2 outlines acceptance, rejection, and condemning conditions for installation equipment. Table 2 should not be used without a thorough understanding and knowledge of 7.4 and 7.5 as well as the equipment manufacturer's recommendations, manual, advisements, etc.

Examination of the installation by the inspector should:

- Determine if the installation is in compliance with applicable regulations;
- Verify that the fuel container is being used only for the storage of the FG specified on the label;
- Determine the potential for damage due to location in the vehicle and whether the container could be damaged by tools, shifts of cargo, cargo leaks, road debris, or proximity to the exhaust system;
- Verify that the container is not in contact or close proximity to objects that could cut, gouge, or abrade its surface. This includes cables, tubing, vehicle components, or mounting bracket components;
- Verify that installations in which containers are enclosed in a vehicle are vented external to the vehicle. The vent line from the PRD should be in compliance with applicable regulations and adequately secured to the vehicle to prevent whipping in the event of PRD activation. The vent line and exit should be free of debris, insects, fluid, etc., and should be oriented so as not to trap fluids. A lightweight cap that can easily be expelled by pressure in the vent line may be used to prevent accumulation of debris in the vent line;
- Verify that all non-original equipment manufacturer (non-OEM) installations are installed to prevent damage to the plumbing when the vehicle flexes or when the container expands under pressurization; and
- Verify that the free drainage of water and other fluids is away from the container.

7.3.1 Fuel system general inspection

Check for any signs of looseness in the mounting system and fuel and vent lines by grasping them firmly and attempting to displace them. Also, look for signs of abrasion between components, which can be indicated by shiny or burnished spots on either the components or the vehicle.

7.3.1.1 Fuel or vent lines

Any points of looseness or abrasion shall be closely inspected to determine if damage has occurred. If fuel or vent lines have been abraded so the material is below safe operating/use standards, hose lines shall be replaced. Fuel and vent lines shall also be tightly secured to the vehicle. Check all fuel and vent line fittings at their attachment points for appropriate tightness, and tighten if needed. Remove any collection of debris and water from the vent system. Any comments regarding damaged and/or replaced fuel and vent lines or loose fittings shall be recorded on an appropriate inspection form.

7.3.1.2 Mounting bracket and/or strap

The brackets or straps, or both, are specially designed to restrain containers without causing damage and to accommodate container expansion caused by changes in internal pressure. Any indication of looseness in the mounting system requires service by a qualified technician of the bracket and/or strap assembly. Isolate the source of looseness, which can be between the bracket and/or strap and container, or between the bracket and/or strap and vehicle mounting locations. Also, carefully examine the brackets and rubber isolator straps for signs of wear. Replace badly worn components.

7.3.1.3 Examination of brackets, straps, and mounting—all container types

The mounting system shall allow the container to expand and contract as the internal pressure fluctuates without causing the container to be loosened or abraded. The interface between the container and mounting brackets or straps shall be lined with a rubber pad to allow little or no movement of the container in the mounting system. The inspector should verify that the mounting system is complete and meets all of the container manufacturer's approvals. Extensively damaged sheet metal should be referred to a qualified technician for repair or replacement.

The person inspecting the mounting brackets or straps should verify that:

- The mounting system used is the container manufacturer's approved system;
- The container is firmly restrained. The container and mounting system should be firmly attached to the vehicle and permit no rocking or other evidence of container looseness. Since looseness of the bracket and/or strap assemblies may have permitted the container to abrade against the vehicle structure, a check of this area is important;
- The bolts that secure the mounting brackets or straps to the vehicle are present and tight. Deformation of the vehicle's sheet metal indicates a need for more support;
- The bolts that secure the container to the mounting system are present and tight. Signs of damage to the valve and relief devices such as flat spots, abrasions, or a bent appearance can indicate a need for further inspection or replacement of these components;
- The rubber bracket/strap pads are in place, have not been worn through, and are in good condition. Refer to a qualified service technician for replacement of worn pads; and
- The mounting system is free of severe corrosion or cracking. Refer to a qualified service technician for any necessary repair or replacement.

7.3.2 Stone shield or cylinder protection

Inspect the installation of any stone shield or cylinder protection on the vehicle. Verify that there is clearance between the container and the shield and that all drains are open and free. When debris is found in the clearance gap or drains are obstructed or otherwise not functioning properly, the matter shall be referred to a qualified service technician for repair or replacement of the shield and a review of the shield and installation design.

7.3.3 Further attention/correction

Follow the container manufacturer's recommendations if any observed condition warrants further attention or correction.

7.3.4 Inspection form

Use an appropriate inspection form to record any damage observed and recommendation for corrective action (see Appendix B).

7.4 Container examination—all container types

Table 1 outlines acceptance, rejection, and condemning conditions for containers. Table 1 should not be used without a thorough understanding and knowledge of this section as well as the container manufacturer's recommendations, manual, advisements, etc.

Since the examination depends primarily on visual observation, the surface of the container shall be accessible, clean, and well illuminated. The cylinder shall not be uninstalled for inspection unless visual damage or deterioration is noted on the exposed container surface. Removal of paint or coating for the visual inspection is not permitted. See Section 8 for alternative methods of inspection.

The inspector should review examination/service records for the container before the inspection. Knowledge of the service history and interviews (as described in 7.3) of the vehicle owner/operator can provide insight that will aid the examination process.

Visual examination of the container surface is the primary means of detecting container damage. Evidence of potential damage includes corrosion, cuts, scratches, gouges, fractures, material loss/removal, discoloration of the container surface (soot, charring, chemical attack, etc.), evidence of impact or accidents, and deterioration of the surface.

If the inspector is aware the cylinder has been pressurized above its design standard, then the cylinder shall be condemned (see Section 9).

7.4.1 Damage level defined

No damage or Level 1 damage is acceptable and repair is not required. Level 2 damage is rejectable damage that requires repair, more thorough evaluation, testing, or destruction of the container as advised by the container manufacturer depending on severity. Level 2 damage is also reserved for conditions specified by the manufacturer that can differ from Level 1 or Level 3 damage outlined in Table 1. Level 3 damage is sufficiently severe that the container shall not be repaired and shall be condemned (see Section 9).

The damage levels identified in this document are given as general guidelines. If differences exist between a manufacturer's recommendation for damage assessment and the recommendations of this document, the manufacturer's recommendations should be followed.

The surface of the container shall be inspected for evidence of damage. Damage observed shall be evaluated and categorized.

7.4.2 Cuts, scratches, and gouges

Cuts or scratches less than 0.01 in (0.25 mm) deep are defined as Level 1 damage and are acceptable regardless of length, number, or direction. Cuts or scratches greater than or equal to 0.01 in (0.25 mm) deep are defined as Level 2 or Level 3 damage and can require the use of manufacturer's guidelines.

Level 2 damage includes cuts or gouges having a depth greater than 0.01 in (0.25 mm), but less than the Level 3 depth specified by the manufacturer, and they may be repaired. Repair instructions shall be obtained from the manufacturer.

7.4.3 Fire and excessive heat damage

FGV fuel containers have a maximum service temperature of 180 °F (82.2 °C) unless otherwise identified on the label. Excessive heating, which can occur if the container is not properly located relative to an exhaust system or involved in a fire, can cause significant damage.

Containers showing evidence of fire or excessive heat exposure are defined as having Level 3 damage and shall be removed from service and condemned (see Section 9).

Fire damage can be evident by discoloration, darkening, charring, or sooting of the surface in the area of exposure of container surfaces. Severe exposure can result in resin removal and loose fibers of composite containers. Other indications of heat or fire exposure can include burning; charring; discoloration of the coating, label, or

container; or connection distortion such as melted plastic. PRD activation can be evidence that the cylinder has been exposed to fire or excessive heat.

7.4.4 Gas leakage

Containers that exhibit apparent gas leakage shall be removed from service. Begin by following the recommended procedure for depressurizing and purging the fuel container (see Appendix C). Contact the manufacturer to report the condition and obtain information regarding container depressurization or additional testing and disposition. Containers with irreparable gas leakage shall be condemned.

Gas leakage can be confirmed by use of a commercial-type leak test fluid or a flammable gas detector. If a commercial-type leak test fluid is used, leakage is indicated by persistent bubbling. For composite containers, some bubbling can be observed that is caused by air trapped between the composite shell and the liner. The trapped air is forced out through the composite by the internal pressure. This condition will persist for one-half hour to several hours, depending on the pressure in the cylinder. Contact the manufacturer for information on distinguishing natural gas leakage from the normal air bubbles for composite containers.

It is important to calibrate flammable gas detectors before using them to confirm natural gas leaks since the detectors can be sensitive to normal out-gassing from composite or plastic materials, oils, other hydrocarbons, normal indoor air, or even commercial-type leak test fluids. Contact the container manufacturer for information on leak detection using the gas detectors.

7.4.5 Chemical attack

The container should be examined for evidence of chemical attack. The materials used in the container are resistant to chemical agents encountered in the normal fuel container environment. The container, however, should be maintained in a clean state and should not be allowed to have prolonged exposure to moisture, automotive fluids, or corrosive agents.

Chemical damage appears as an alteration of the surface. This can include corrosion, discoloration, etching, pitting, blistering, swelling, and, in addition for composites, softening, stress corrosion cracks, and resin removal. In extreme cases, the composite can exhibit fractures and broken or loose fibers.

Minor discoloration and no material loss are defined as Level 2 damage and are considered acceptable provided that:

- the chemical is known;
- the chemical is totally removed;
- the container surface is cleaned; and
- the container manufacturer's recommendations are followed.

Any evidence of blistering, swelling, softening, resin removal, broken or loose fibers not attributable to mechanical damage or weathering, stress corrosion cracks, or fractures is Level 3 damage for composites. Metal containers exhibiting pitting, corrosion, and/or oxidation defined as Level 3 (see 7.6 and Table 1), and Level 3 damaged composites shall be condemned.

7.4.6 Weathering

The container can exhibit degradation of the external coating after prolonged exposure to sunlight and weathering. This can result in discoloration and/or potential deterioration of the coating on exposed surfaces. This condition is Level 1 or Level 2 damage provided there is no evidence of surface metal corrosion or loose or broken fibers. After completion of the inspection process, the affected surface with Level 2 damage should be repaired by applying a coating in accordance with the manufacturer's procedures. The surface may be prepared for painting according to the manufacturer's procedures. Use of a powered brush, sand or grit blasting, peening, power sanding, grinding, or chemical strippers is prohibited on composite materials. Hand sanding with a fine grit paper is permissible provided it is used only to remove loose, deteriorated coating or to deglaze the surface.

7.5 Additional inspection of metal containers—Type 1 and metallic portions of Type 2

All metal containers and the exposed metallic portions of Type 2 containers should be inspected for metal damage.

7.5.1 Corrosion

Corrosion of a metal surface involves the loss of wall thickness. The following describes the different types of corrosion.

7.5.1.1 Isolated pitting

Isolated pitting is the loss of wall thickness in small, remote areas. Isolated shallow pits of small diameter do not effectively weaken the container.

Isolated pits with a depth less than 0.035 in (0.889 mm) can be considered acceptable Level 1 damage. Pitting 0.035 in (0.889 mm) or greater in depth is Level 3 damage.

7.5.1.2 Line corrosion

Where corrosion results in a continuous pattern or when pits are connected to others in a narrow band or line, it is called line corrosion. This condition is more serious than isolated pitting and can be found anywhere on the container. If the deepest pit in the line corrosion is less than 0.03 in (0.76 mm), the container has Level 1 damage and may be returned to service. If the deepest pit in the line corrosion is greater than or equal to 0.03 in (0.76 mm), the container has Level 3 damage.

Line corrosion greater than 6 in (15.2 cm) long with any pit depth is considered Level 2 damage. The container manufacturer shall indicate in guidelines or recommendations the proper disposition of containers when line corrosion in the metal is over 6 in (15.2 cm) long.

7.5.1.3 Corrosion at junction of overwrap and liner on Type 2 cylinders

Any corrosion at the junction of the liner and overwrap in excess of 0.010 in (0.25 mm) should be considered Level 2 damage.

7.5.1.4 General corrosion

General corrosion covers considerable surface areas of the container. It is also sometimes known as broad spread corrosion and it reduces structural strength. General corrosion is often accompanied by pitting. The level of damage should be determined by using line corrosion pit depth criteria (see 7.6.1.2). General corrosion covering more than 25% of the total external surface of the container is Level 3 damage. General corrosion that reduces wall thickness by 0.03 in (0.76 mm) or more is Level 3 damage.

7.5.2 Bulges/bows

Bulges are considered to be severe structural damage when the container is deformed in an outward manner. All containers showing bulging have Level 3 damage.

Type 1 containers with a bow or “banana” shape are acceptable and may be returned to service provided their shape does not interfere with proper mounting.

7.5.3 Dents

Dents with a depth greater than 0.0625 in (1.588 mm) or a major diameter of 2 in (51 mm) or less, or both, are considered Level 3 damage and shall be condemned. A dent that is deformed excessively or abruptly (such as a small, shallow dent) is also considered Level 3 damage because stresses are high in these defects. The container shall be condemned. Minor dents shall comply with manufacturer's recommendations (see Figure 2).

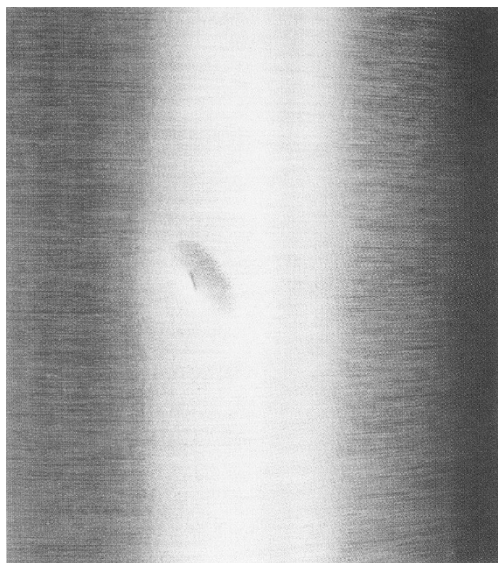


Figure 2—Dent to all metal cylinder

7.5.4 Abrasions

An abrasion can be the result of many cycles of something rubbing lightly (light loading) on the surface of the container or due to a few cycles (or perhaps only one) of heavy rubbing (high loading). Metal containers exhibiting evidence of abrasion shall be examined closely to verify that the amount of metal removed by the abrasion is less than 0.01 in (0.25 mm).

If an abrasion has reduced metal thickness below minimum acceptable limits, the container shall be removed from service and condemned. Use guidelines set by the manufacturer to make this determination.

7.6 Additional inspection composite containers (Types 2, 3, and 4)

Containers of Type 2 should be inspected for both composite and metal criteria (see 7.6).

7.6.1 Abrasions

An abrasion can be the result of many cycles of light loading on the surface of the container or due to a few cycles (or perhaps only one) under high loading. Surfaces subjected to abrasion under light loading tend to be smooth and somewhat polished in appearance. Surfaces abraded under high loading tend to appear as a group of parallel gouges or cuts (see Figure 3).

Containers exhibiting evidence of abrasion under high loading should also be examined as though the surface were subjected to impact (see 7.7.2).

Abrasions or scuffs less than 0.01 in (0.25 mm) deep are Level 1 damage and are acceptable regardless of size, number, or direction. Exposed fibers should be coated with a filler material in accordance with the manufacturer's instructions. Abrasions greater than 0.01 in (0.25 mm) deep are Level 2 or Level 3 damage and require guidance from the container manufacturer.

For coating chipping and/or abrasion, contact the container manufacturer and follow the manufacturer's instructions.



Figure 3—Abrasion level 2

7.6.2 Impact damage

For Type 3 and Type 4 composites, impact damage differs from other forms of container damage because the container wall can suffer more severe damage within the wall of the container than at the surface of the container. This is particularly true if the surface of the container returns to its original shape after an impact and, therefore, does not dent like a Type 1 or Type 2 container (see Figure 4).

Impact damage can cause delaminations between, and fractures of, the composite layers used to construct the container. Surface damage associated with impact loading can include denting, cutting, gouging, scraping, scuffing, chipping, puncturing, fiber breakage, loose fibers, resin cracking, or a change in coloration or appearance. The surface shall be carefully examined for these types of indications. Known areas of impact should be marked to aid the inspection process (see Figure 5).

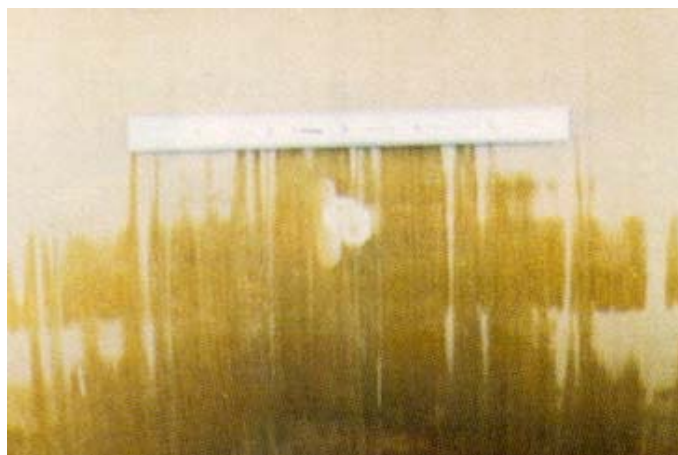


Figure 4—Impact damage

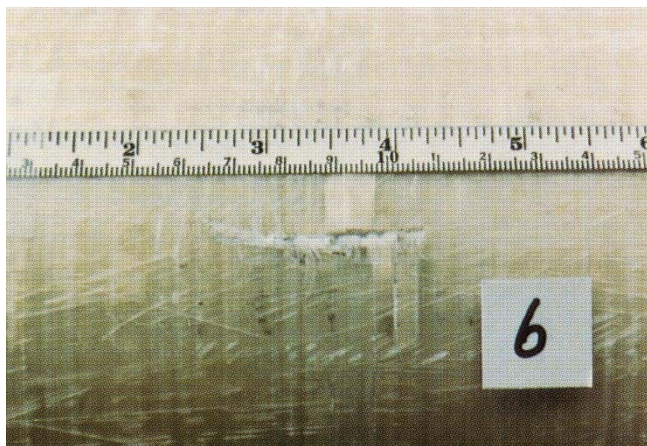


Figure 5—Cut with delamination

Known areas of impact and zones of detectable surface damage shall be inspected for evidence of damage within the wall. Evidence of damage within the wall includes:

- permanent deformation of the container surfaces. Denting is evidence of severe internal damage. Containers exhibiting this type of damage shall be closely inspected for possible Level 2 or Level 3 damage;

NOTE—This condition does not include highly localized pitting at the surface such as might result, for example, from impact by a small stone.

- bulging of the container wall. The container wall should be uniform and not exhibit localized bulging. Containers exhibiting this condition shall be condemned;
- localized differences in container coloration. Containers that incur impact damage often exhibit differences in surface appearance. These differences can produce a change in coloration due to delamination, crazing, or cracking of the composite material or scuffing of the external coating. Each area exhibiting these indications shall be closely inspected for possible Level 2 or Level 3 damage (see Figure 6); and
- localized areas of surface cracking. Containers that incur impact damage can exhibit circular, oval, or linear zones of cracking of the composite surface. The cracking can also be accompanied by a change in coloration as mentioned previously. Each area exhibiting these types of indications shall be closely inspected for possible Level 2 or Level 3 damage (see Figure 7).



Figure 6—Crazing

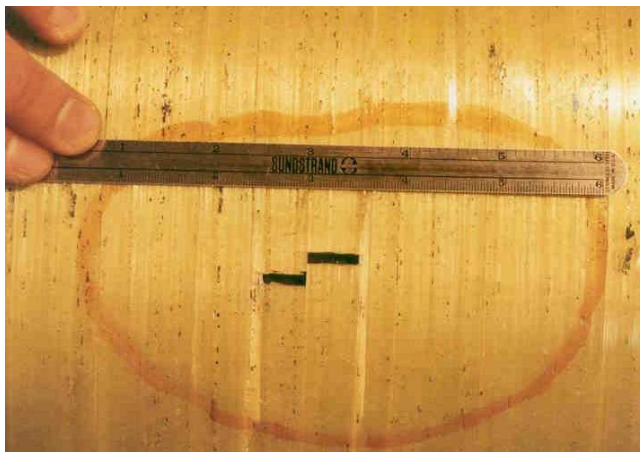


Figure 7—Stress corrosion cracking

7.7 Examination of valves and relief devices—all container types

The fuel container is equipped with a container valve with a PRD(s). Containers longer than 65 in (1.65 m) and other installations may require more than one PRD to meet the appropriate design standard. All PRDs shall be in direct communication with the contents of the container regardless of whether the container valve is open or closed.

The vent line bag material may need to be removed from the hardware at the ends of the container for this inspection. Inspection of the valve and plug/PRD should include the following:

- Examination of the valve and PRD assemblies, including the hexagonal torque nut, for damage. The valve and PRD assemblies should not be deformed or show other signs of damage. Damaged valves and PRD assemblies shall be replaced by a qualified service technician in accordance with equipment manufacturer's instructions;
- Examination of the interface between the valve and container port, the PRD and container port, and any other plug and container port. These interfaces should be tightly seated with no gaps or looseness. There should also be no rubber shavings or other evidence of seal damage at these interfaces. If there is evidence of looseness or seal damage, the container should be depressurized, the suspicious area disassembled, and the O-ring should be replaced as necessary. Damaged PRD assemblies shall be replaced by a qualified service technician in accordance with equipment manufacturer's instructions;
- Leak testing the interfaces between the valve and container port and the plug/PRD and container port. The fuel line and PRD connections to the container valve should also be checked for leakage. These interfaces should be serviced if any leakage is observed; and
- External inspection of PRDs for corrosion; damage; rust; bulging; plugging of external PRD channels; and mechanical defects such as leakage, extrusion of fusible metal, or looseness of fusible metal triggers. This shall occur each time a FG container is inspected.

7.7.1 Cleaning PRD and tubing for inspection

The PRD and tubing should be cleaned as necessary with a rag and mild detergent solution to allow inspection of their external surface and any orifices.

7.7.2 Verification of PRD suitability with container

The inspector shall verify that the PRD in use with the container is a suitable PRD for the container type and that the container manufacturer has approved the PRD. PRDs not approved by the manufacturer that do not conform to the container type shall be replaced by a PRD suitable to the container and manufacturer.

7.7.3 Dents, gouges, and scratches

Dents, gouges and scratches equal to or greater than 0.02 in (0.51 mm) deep in locations other than the hexagonal torque nut are Level 2 damages. The inspector will review the PRD manufacturer's recommendations to determine what, if any, action should be taken with regard to the PRD, and then determine the condition as either Level 1 or Level 3 damage.

7.7.4 Reinstallation of the PRD

Once removed, PRDs shall not be installed on any other container but may, if they are appropriate and pass inspection, be reinstalled on the exact same container from which they were removed, as recommended by the container manufacturer.

7.8 Labeling—all container types

Containers without labels displaying mandatory information or with labels having illegible mandatory information shall be removed from service. If the container can be positively identified by manufacturer and serial number, a replacement label may be applied to the container in accordance with container manufacturer's directions, and it may remain in service.

Labeling inspection should include at least all of the following:

- Verification that the label is attached and clearly legible. The container shall be condemned if the identity (i.e., manufacturer, model/part number, and serial number) cannot be clearly established. Contact the manufacturer for a replacement label if mandatory information is missing, if the label is damaged, or if it is not firmly attached;
- Verification that the container service life has not expired. The label identifies the service life as DO NOT USE AFTER MONTH/YEAR. The container shall be removed from service and condemned when the service life expires; and
- Verification that the service pressure rating listed on the container label is greater than or equal to the vehicle refueling markings for service pressure.

7.9 Inspection record/check list—all container types

See Appendix B for a sample inspection form.

7.10 Final disposition—all container types

As a result of the inspection, the fuel container can have one of the dispositions outlined in 7.11.1 and 7.11.2. After all inspection preliminaries have been performed (see 7.1), if any single, confirmed Level 3 damage condition is identified in the inspection process, the inspection may stop. The inspector proceeds to 7.11.3.

7.10.1 Fit for service—Level 1 damage (or no damage)

For no damage or Level 1 damage, the container is approved for returning to service. Level 1 damage includes:

- no damage found during inspection;
- minor damage as defined by this publication and outlined in Table 1; or
- Level 2 damage repaired according to container manufacturer's procedures and directions.

Before returning the container to service, the inspector shall put an inspection mark on the container showing that it has passed inspection and is suitable for service. The inspector shall mark the container (a tag, label, or

other permanent marking that does not obscure container manufacturer's label[s] or manufacturing marks and does not obscure previous inspection marks) with at least:

- the date the container was inspected (month and year); and
- the inspection agency.

The inspection mark shall conform to acceptable markings allowed by the container manufacturer.

7.10.2 Needs container manufacturer's advice—Level 2 damage

Containers that have suspected Level 2 damage should be handled according to container manufacturer recommendations and guidelines. Classify all unclear Level 1 and Level 3 damage as Level 2 damage. Containers identified as having Level 2 damage shall not be returned to service until the condition is resolved. Level 2 damage is also reserved for conditions specified by the manufacturer that differ from Level 1 or Level 3 damages outlined in Table 1.

Level 2 damage can, in some cases, be repaired according to container manufacturer's approved procedures and direction. After approved repairs, Level 2 damage becomes acceptable for use.

Level 2 damage can, in some cases, be determined by container manufacturer's guidelines to be Level 3 damage. In such cases follow the procedures in 7.11.3.

7.10.3 Remove from service and condemn—Level 3 damage

Containers that have confirmed Level 3 damage shall be condemned according to Section 9. Also, containers that have Level 2 damage determined by the container manufacturer to be severe enough to remove it from service shall be considered Level 3 damage.

Containers exhibiting Level 3 damage shall not be repaired and shall not be returned to service. Follow Section 9 procedures.

7.11 Final disposition—all equipment

As a result of the examination, the equipment can have one of three dispositions:

7.11.1 Fit for service—Level 1 damage (or no damage)

In this case the equipment can be approved for continued operation. It should be remounted, if removed, and connected to the FGV fuel system according to the equipment manufacturer's and container manufacturer's recommendations and guidelines. The container is marked with inspection markings (see 7.11.1).

7.11.2 Needs equipment manufacturer's advice—Level 2

In this case, the equipment is allowed to be repaired and returned to service or the equipment manufacturer can recommend condemning the equipment. The container manufacturer determines how to repair each container or if specific components should be condemned. Each recommendation shall be made in writing. In the absence of manufacturer's recommendations, Level 2 damage shall be considered Level 3 damage.

Equipment manufacturers (valves, PRDs, mounting systems, etc.), or their accompanying literature may need to be consulted when equipment conditions are classified as Level 2 damage, or when Level 1 damage is unclear. Level 2 damage is also reserved for conditions specified by the manufacturer that can differ from Level 1 or Level 3 damages outlined in Table 2.

Once repaired and ready to be returned to service, the equipment is classified as having Level 1 damage.

7.11.3 Remove from service—Level 3 damage

In this case the equipment shows obvious Level 3 damage that requires it to be removed from service. A second inspector should review the equipment to verify Level 3 damage(s) and then condemn it.

8 Alternatives to visual inspection (nondestructive inspection)

The objective of visual inspection is to determine the extent of degradation from any source of damage and to define the container's suitability for service.

This goal can be met by alternative methods that do not rely on visual examination. Alternative methods can be used in lieu of visual examination, to augment visual examinations, or in situations where visual examination is inconclusive. Use only nondestructive inspection (NDI) methods recommended by the manufacturer. Certain NDI methods require that the container be depressurized.

8.1 In situ acoustic emission testing

For some containers, where it is undesirable to remove the container from its mounting fixture to perform visual examination, the in situ acoustic emission testing (AET) method may be an alternative. See [CGA C-18, *Methods for Acoustic Emission Requalification of Seamless Steel Compressed Gas Tubes*](#), for AET terminology and general methodology [14].

Permanently installed on-board monitors (OBM) using the same AET technique or other methods as recommended, validated, and adapted by the container manufacturer can be used to provide continuous surveillance of the container. An OBM can provide in-service inspection each time the FGV container is filled, which may preclude the need for additional inspection.

8.2 Traditional nondestructive testing methods

For all-metal FGV containers, traditional nondestructive testing techniques can be used to supplement visual inspection. In some instances, it may be necessary to remove exterior paint and labels to have a clean surface to perform this test. Verify with the container manufacturer that this is acceptable. Valve removal is not generally necessary.

8.2.1 Ultrasonic examination (UE)

Ultrasonic examination (UE) is particularly sensitive to crack-like flaws. It can be applied in an automated scanning mode to map the wall thickness and locate internal defects. Information on UE is found in [ASTM E213, *Standard Practice for Ultrasonic Testing of Metal Pipe and Tubing*](#); [ASTM E797, *Standard Practice for Measuring Thickness by Manual Ultrasonic Pulse-Echo Contact Method*](#); and [CGA C-20, *Requalification Standard for Metallic, DOT and TC 3-Series Gas Cylinders and Tubes Using Ultrasonic Examination*](#) [15, 16, 17].

8.2.2 Eddy current testing

Eddy current testing (ET) is for aluminum containers only, is particularly sensitive to surface defects, and can be automated to map their location and size. ET probes can be permanently mounted on the container wall to provide an OBM system. Use of an OBM can preclude the need for additional inspection. Some details relating to ET inspection are found in [ASTM E215, *Standard Practice for Standardizing Equipment and Electromagnetic Examination of Seamless Aluminum-Alloy Tube*](#) [18].

8.2.3 Radiographic testing

Radiographic testing (RT) can be used to make a full-size film image of the container indicating any flaws in the wall or automated to produce a digital image. RT is always carried out following strict safety precautions. General details relating to RT are found in [ASTM E94, *Standard Guide for Radiographic Examination Using Industrial Radiographic Film*](#) [19].

9 Disposition of condemned containers

Fuel containers can be condemned for a number of reasons that render them unfit for continued service such as:

- The container has reached or exceeded the marked service life. The service life expiration date is indicated by markings on the label that read DO NOT USE AFTER (MONTH/YEAR);

- The container label is missing or obliterated so positive identification is not possible, and an alternate means of determining the identification is not available;
- The container exhibits Level 3 damage. Level 3 damage shall not be repaired; or
- The container has Level 2 damage, but no manufacturer's recommendations exist on how to repair it or classify the condition as Level 1 damage.

Condemned containers shall not be refilled or reused for any purpose and shall be properly depressurized, purged, and disposed of to prevent further service (see Appendix C).

The owner of the container(s) shall be advised by the inspection agency in writing of containers that have been condemned. With the expressed consent of the owner, the container shall be rendered incapable of further service by appropriate methods.

The proper and safe disposition of condemned fuel containers is important since substantial potential hazards exist that shall be recognized and evaluated by those who attempt to dispose of them. Containers can hold a significant quantity of flammable gas under pressure, and containers that appear to be empty can still retain enough residual gas to create an explosive mixture.

Individuals or organizations that have reason to dispose of condemned containers shall be properly trained to perform the necessary procedures. Disposal recommendations are intended for use only by qualified individuals or organizations and are not intended for use by container owners or the general public.

These recommendations were primarily developed from a safety perspective for disposing of condemned containers and are not intended to ensure compliance with applicable federal, state, or local laws and regulations including environmental standards and other standards, which can vary from place to place and over time. Full responsibility for determining the applicable regulatory requirements and ensuring compliance with them rests with the individual or organization that disposes of condemned containers.

10 References

Unless otherwise specified, the latest edition shall apply.

- [1] CSA/ANSI NGV2, *Compressed natural gas vehicle containers*, American National Standards Institute. www.ansi.org
- [2] *Code of Federal Regulations*, Title 49 (Transportation), Part 571 (FMVSS), Standard No. 304, *Compressed Natural Gas Fuel Container Integrity*, U.S. Government Printing Office. www.gpo.gov
- [3] Canadian Motor Vehicle Safety Regulations, Standard 301.2, *CNG Fuel System Integrity*, (Transport Canada), Canadian Government Publishing. www.tc.gc.ca
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Appendix A—Frequency of inspection (Informative)

FGV fuel storage systems can warrant more frequent inspections when their design or installation does not match specific risks. Consult the equipment manufacturer (including the cylinder manufacturer) when conditions or usage can warrant more frequent inspections. Such conditions or usage include the following:

A.1 High usage

FGVs that use gaseous fuel in excess of 750 cylinder fills per year are in high usage. The regulatory authority or the equipment manufacturer may require or recommend more frequent requalification of high usage vehicle fuel storage systems.

A.2 Terrain

FGVs used in off-road terrain; dirt, gravel, or stone roads; or uneven terrain can incur physical damage to fuel storage systems that are not designed for such terrain. The equipment manufacturer may recommend more frequent requalification of the fuel storage system for FGVs used in such terrains depending upon the type of installation.

A.3 Mounting/installation

FGVs that mount all or part of the fuel storage system exposed to weather, cargo, sun, etc., without designed protection of the system, will likely incur physical and/or chemical damage more than a protected system. The requalification frequency is not to exceed 36 months, which is appropriate for fuel storage systems located in the trunk of FGVs, enclosed in protective shields, or mounted within the vehicle frame with no external exposure. The equipment manufacturer may recommend more frequent requalification of FGV fuel systems mounted with external or unprotected exposure.

A.4 Weather conditions

FGVs in extreme weather conditions (very hot, cold, wet, or chemical atmospheres) may require their fuel storage systems to be requalified more frequently than every 36 months. The effects of these extremes are type and cylinder design dependent. Follow recommended equipment manufacturer's advice regarding more frequent inspections under these conditions.

Appendix B—Sample inspection form (Informative)

Vehicle Inspector Name: _____

Vehicle Inspector Organization: _____

Date: _____ Vehicle Mileage: _____

Vehicle Make and Model: _____ Vehicle Identification Number (VIN): _____

NGV Container: _____ Manufacturer: _____

Part Number: _____ Serial Number: _____

Location: _____

NOTE—An examination form shall be filled out for each fuel container in an installation.

Y	N	Examination
		1 Is the container and mounting bracket area clean, free of dirt, and ready for examination?
		2 Is the container free from evidence of fire or exposure to extreme temperatures?
		3 Is the container free from indications that the container has been involved in an accident?
		4 Has the owner been questioned about any conditions or incidents that may have caused damage to the container? (Report adverse findings below.)
		5 Is the installation in compliance with applicable regulations (e.g., NFPA 52 or CSA B109)?
		6 Is this inspection being conducted before the expiration of the container service life?
		7 Are the container service pressure markings greater than or equal to the vehicle service pressure markings?
		8 Is there a minimum of 0.5 in (12.7 mm) clearance around the container when mounted? (A minimum standoff of 0.375 in [9.52 mm] is recommended for shields.)
		9 If containers are enclosed in the vehicle, are they properly vented externally to the vehicle?
		10 Are fuel and vent lines properly and securely attached to the vehicle?
		11 Is the rubber pad between the mounting bracket and fuel container in place and in good condition?
		12 Is the container firmly restrained by the brackets (i.e., no rocking or looseness)?
		13 Are the bolts that secure the brackets to the vehicle present and tight?
		14 Is the mounting bracket in good condition and not bent or deformed?
		15 Is the vehicle free of damage where the mounting brackets are attached?
		16 Are bolts on brackets or straps torqued to proper levels?
		17 Are the valve and/or relief device assemblies free of damage?
		18 Are the valves and relief devices tightly seated? (Caution: Do not loosen valves or relief devices while the tank is pressurized.)
		19 Are the interfaces between the valves or relief devices and the container free of leaks?
		20 If there are cuts, gouges, or abrasions present, are they less than 0.01 in (0.25 mm) deep?
		21 Is the container free of impact damage (e.g. surface discoloration, cracked resin, chipping, loose fibers)?
		22 Is the container free of surface dents?
		23 Is the container free of rust, corrosion, or etching of the outer surface?
		24 Is the container surface free of discoloration?
		25 Is the external paint, composite layer, or metal surface free of bubbles or bulges?
		26 Is the pressure relief device (PRD) in good condition with no visible extrusion of fusible metal?
		27 Are all relief devices in place?
		28 Are brackets or straps free of corrosion?
		29 Has the area under the straps been examined?
		30 Has a new examination sticker or stamp/mark been applied?
		31 Has the cylinder been pressurized above the applicable design standard?

(continued on next page)

Summary of examination and description of any damage or adverse findings:

Repair or replace brackets or other components as follows:

Recommended disposition for fuel container:

	1	Repair fuel container as follows:
	2	Send fuel container to manufacturer for further inspection as follows:
	3	Remove fuel container from service and condemn
	4	Return fuel container to service

Signature of inspector: _____

Appendix C—Depressurizing containers, an example procedure (Informative)

Containers involved in an accident that may have damaged the container shall be depressurized before examination. Also, containers with known or suspected Level 2 and/or Level 3 damage shall be depressurized before inspection. Containers to be disposed of should be depressurized (see Section 9). Compliance with all authorities having jurisdiction in this area is mandatory. The following guidelines should be considered minimums and exceeding these guidelines is recommended. All depressurizing should be in accordance with the following procedure:

- a) Consult the container manufacturer's manual, recommendations, and guidance documents to determine if special precautions are required for cylinder depressurization. If there is any doubt, consult the container manufacturer for instructions;
- b) Before venting the container, the vehicle shall be moved to an open and well-ventilated area (outside, not inside a building) to prevent the accumulation of natural gas, which could result in the formation of an explosive atmosphere. As an added precaution, an area or safety perimeter greater than 150 ft (46 m) in radius from the vehicle should also be free of ignition and heat sources. The area, or safety perimeter size, should be determined by taking into account the direction and strength of the wind and any climatic conditions that might affect the operation. Have fire extinguishers ready. Notify all employees and persons on the premises about the safety perimeter, and that the depressurization of a flammable gas operation will occur. Forbid access to the safety perimeter by any person not involved in the operation unless it is an emergency response. Clear safety perimeter and nearby area of all ignition sources including communications devices (walkie-talkies, radios, speakers, cell phones, pagers, telephones, etc.), computers, other vehicles, etc. Only one vehicle should be in the safety perimeter at any one time;
- c) The container shall be grounded before venting the contents. Rapid discharge can generate a static electrical charge, which can be sufficient to ignite the escaping gas. A 3-gauge copper wire (e.g., a battery cable) should be used to connect the valve to an appropriate ground source such as a water pipe that extends at least 8 ft (2.4 m) underground;

NOTE—Some consideration should be given to personal exposure issues and to recovering released natural gas fuels, preventing its release into the environment. At least two operators should be present and maintain safe distances when possible. Operators within the perimeter should wear a noise-protection safety helmet, gloves, and safety shoes;

- d) Manually close all isolation valves of the other cylinders and close the cylinder from the fuel system. When opening the valve, the outlet should be pointed away from anyone in the vicinity. Manually open the valve slowly and slightly to determine by sound, soap bubbles, or pressure gauge whether any gas is present; then, close the valve immediately. The absence of escaping gas does not necessarily mean that the container is empty as the valve may have become inoperative or the container may hold low pressure liquid. If this is suspected, refer the matter to a supervisor;
- e) After following the precautions stated previously and following the rules of the local AHJ over the operation (such as a local fire marshal or environmental protection agency), open the valve and begin depressurizing the cylinder. After venting, the cylinder can contain a little of the residual gas. The cylinder should then be purged; and
- f) The purge operation can be performed on the roof of a large vehicle (e.g., a bus or truck) or preferably when the cylinder is put on a fitted support. Inject nitrogen under low pressure (less than 100 psi [690 kPa]) into the cylinder. Be sure that the cylinder does not contain gas with a katharometer or an explosimeter. The cylinder can be filled with water as an alternative to injecting with nitrogen.

In general, the disposal of all condemned containers requires adherence to the following procedures:

- a) safely purge the contents;
- b) remove the valve and other fittings;
- c) obliterate all markings;

- d) destroy the container; and
- e) properly discard the container.

The container should be purged before any attempt is made to destroy it. Before purging the container, depressurize it according to the procedure given in this appendix. Purging can be accomplished with the use of inert gases, steam, or by filling the container with water.

Any markings on the container should be obliterated to discourage further use of the container. Stamped markings can be removed by grinding them out. Adhesive labels or labels wound in under glass fiber composite can be obliterated by covering with paint or a suitable alternate method.

The containers should be destroyed by a method that makes repair difficult or impossible. Metal containers can be cut in half with a cutting torch. Any type of container can be rendered unusable by perforation of the sidewall with two or more holes 0.50 in (12.7 mm) or greater in diameter.

Scrap containers shall be disposed of in a manner that will help prevent repair or reuse by uninformed persons. Container recycling programs may be offered by some manufacturers. Dispose of scrap containers in accordance with applicable federal, state, or local laws and regulations.



Compressed Gas Association

The Standard For Safety Since 1913

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