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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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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).

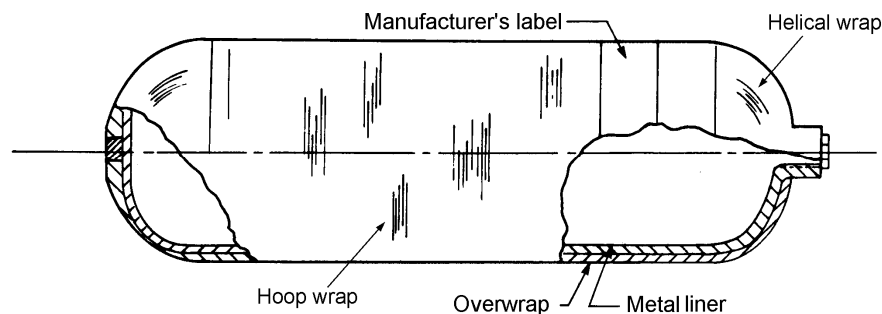


Figure 1—Full-wrapped cylinder with one port

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].