INTERNATIONAL STANDARD

ISO 19078

Second edition
2013-01-15

Gas cylinders — Inspection of the cylinder installation, and requalification of high pressure cylinders for the on-board storage of natural gas as a fuel for automotive vehicles

Bouteilles à gaz — Inspection de l'installation des bouteilles, et requalification des bouteilles haute pression pour le stockage du gaz naturel, utilisé comme carburant, à bord des véhicules automobiles

Reference number
ISO 19078:2013(E)

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

Published in Switzerland

Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 19078 was prepared by Technical Committee ISO/TC 58, *Gas cylinders*, Subcommittee SC 4, *Operational requirements for gas cylinders*.

This second edition cancels and replaces the first edition (ISO 19078:2006), with the following main technical revisions:

a) The scope clarifies the rework of some types of rejected cylinders;

b) The periodicity of inspection has been removed from this International Standard. The user is referred to the requirements of ISO 11439 for this information;

c) Damage levels and criteria are more clearly defined and better align with ISO 11439;

d) Clause 7.11 was renamed to better clarify its intent;

e) Table 2 includes acceptance and rejection conditions for gas tight housing;

f) Reference to ISO 25760 for valve removal has been added; and

g) Annex A, Inspector qualifications (informative), and Annex F, Composite matrix (informative), were removed.

Introduction

This International Standard sets out requirements regarding the periodic visual examination and inspection of natural gas fuel cylinders installed in vehicles and the condition of their installation. These cylinders are designed to store natural gas at high pressures.

Where there is any conflict between this International Standard and any applicable regulation, the regulation always takes precedence.

Gas cylinders — Inspection of the cylinder installation, and requalification of high pressure cylinders for the on-board storage of natural gas as a fuel for automotive vehicles

1 Scope

This International Standard specifies the requirements for the inspection, installation and requalification of high pressure cylinders, designed and manufactured in accordance with the requirements of ISO 11439, for the on-board storage of natural gas as a fuel for automotive vehicles.

It provides criteria, in the absence of guidance from the cylinder or vehicle manufacturer, for the acceptance (including any allowed rework) or rejection (including any allowed rework or destruction) of a cylinder and its installation.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 11439, *Gas cylinders — High pressure cylinders for the on-board storage of natural gas as a fuel for automotive vehicles*

ISO 15500-13, *Road vehicles — Compressed natural gas (CNG) fuel system components — Part 13: Pressure relief device (PRD)*

ISO 15500-15, *Road vehicles — Compressed natural gas (CNG) fuel system components — Part 15: Gas-tight housing and ventilation hose*

ISO 15501-1, *Road vehicles — Compressed natural gas (CNG) fuel systems — Part 1: Safety requirements*

ISO 15501-2, *Road vehicles — Compressed natural gas (CNG) fuel systems — Part 2: Test methods*

ISO 25760, *Gas cylinders — Operational procedures for the safe removal of valves from gas cylinders*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
abrasion
damage to an area of the cylinder or its installation equipment caused by scraping, wearing, vibration or rubbing away of the material by friction

Note 1 to entry: Abrasion can be the result of many cycles of something rubbing lightly on the surface of the cylinder or its installation equipment, or due to a few cycles, perhaps only one, of heavy rubbing.

3.2
impact
blow to the surface of the cylinder that can significantly damage and/or indent the surface (e.g. cutting, gouging)

Note 1 to entry: Impact can also induce such damage as delaminations, which are not readily apparent through visual examination.

3.3
component
parts that are used directly in conjunction with the installation of the fuel container to include the cylinder, valve, pressure relief device (PRD), vent and mounting

3.4
condemned
cylinder or piece of its installation equipment no longer fit for service and for which repair is not allowed

3.5
crazing
hairline cracking of the resin, giving it an opaque, frosty appearance

3.6
cut
damage caused by a sharp object coming into contact with the cylinder's surface

3.7
delamination
form of composite damage, in which a separation develops between layers of the composite

3.8
destroyed
cylinder or piece of its installation equipment in a state that makes it physically unusable for its purpose

3.9
dome
curved end portion of the cylinder

3.10
external coating
surface treatment applied to the cylinder for environmental protection and/or improved appearance

3.11
gas tight housing
enclosure fitted at any potential leakage points (e.g. cylinder/valve connection or PRD) to collect and vent any leaked gas to outside the vehicle

3.12
helical
winding in the longitudinal and circumferential direction on both the cylindrical and dome regions of the cylinder

Note 1 to entry: The strands of reinforcing fibres are oriented at an angle to the longitudinal axis of the cylinder.

3.13
hoop direction
hoop pattern
winding along the cylindrical portion of the cylinder

Note 1 to entry: The strands of reinforcing fibres are oriented at an angle of nearly 90 degrees to the longitudinal axis of the cylinder.

3.14
inspection body
organization that performs the visual inspection of compressed natural gas (CNG) cylinders used in natural gas vehicles (NGVs)

3.15
inspector
individual who is authorized by an inspection body to perform the visual inspection

3.16
inspection mark
stamp, label or tag placed by an inspector on the cylinder indicating acceptance of the cylinder

3.17
Level 1 damage/condition
minor damage that can occur during normal use

Note 1 to entry: Such damage normally has no adverse effects on the safety of the cylinder and its continued use. Scratched paint or nicks that have no appreciable depth in metal, or similar damage in the composite cylinder paint or resin where there are no visible frayed fibres, are considered to be of this level of damage.

Note 2 to entry: See Table 1.

3.18
Level 2 damage/condition
damage that is more severe than Level 1, but where after repair the cylinder is authorized to return to service, or based upon the recommendations of the manufacturer may be classified as Level 1 or Level 3

Note 1 to entry: See 7.4.3 and Table 1.

3.19
Level 3 damage/condition
damage that requires a cylinder be condemned

Note 1 to entry: A Level 3 condition is such that the cylinder must be rendered unfit for continued service and cannot be repaired.

Note 2 to entry: See Table 1.

3.20
liner
internal container of the cylinder, which sometimes carries pressure, that prevents leakage of gas through the composite cylinder structure

3.21
manufacturer
cylinder maker, unless otherwise stated

3.22
marking
information permanently applied to an item (e.g. stamping and permanent labelling)

3.23
mounting brackets and/or straps
devices used to secure cylinders in a vehicle

3.24
overpressurization
pressurization of the cylinder, which at 15 °C results in a settled pressure that is higher than the working pressure marked on the cylinder, or pressurization of a cylinder to a pressure that is above 26 MPa independent of temperature conditions (for a 20 MPa working pressure cylinder)

3.25
pressure relief device
PRD
device that releases the contained gas in specific emergency conditions in accordance with ISO 15500-13

3.26
reinforcing fibres
continuous fibrous strands in the composite, such as carbon, aramid, glass or combinations thereof, which withstand loads caused by pressurization

3.27
rejected cylinder or installation equipment
cylinder or its installation equipment that needs to be removed from service, i.e. disassembled from the vehicle

Note 1 to entry: For Level 2 damage, the cylinder is evaluated further before repairing or condemning. For Level 3 damage, the cylinder or equipment is subsequently condemned.

3.28
repair
action, including rework, to return a cylinder to an acceptable Level 1 condition

3.29
resin
material that is used to bind and hold the fibres in place

3.30
working pressure
settled pressure, at a uniform temperature of 15 °C

3.31
stress corrosion cracking
SCC
phenomenon resulting in a split or rift in the materials, caused by a combination of load and aggressive environment

Note 1 to entry: Such cracks in composite materials are typically sharply defined and can appear as a family of cracks or as a single crack.

3.32
valve
device installed in one of the threaded openings of the cylinder used to allow gas flow into or from the cylinder

Note 1 to entry: A manual valve is turned on or off with a handle. A solenoid valve is turned on or off automatically. Some solenoid valves can be operated manually with special tools.

3.33
vent line
high-pressure line used to conduct gas from a PRD to a location outside the vehicle, where gas can be discharged safely

4 Background information

4.1 General

NGV cylinders inspected in accordance with this International Standard are designed and qualified in accordance with ISO 11439. These cylinders have markings that identify the ISO 11439 type of construction.

An inspection body shall perform all inspection work. Trained and qualified personnel shall perform installations or other service required by this International Standard.

4.2 Cylinder types and descriptions

4.2.1 CNG-1 metal

CNG-1 cylinders are all metal and can be made of any alloy of steel or aluminium that meets the qualification requirements outlined in ISO 11439.

4.2.2 CNG-2 metal liner partially reinforced with resin-impregnated continuous filament (hoop-wrapped)

CNG-2 cylinders have a metallic liner with sufficient strength and thickness to carry the entire longitudinal load at the required burst pressure, and to withstand the working pressure without rupture. Metal liner materials are those identified under CNG-1 cylinders (see 4.2.1). These cylinders are reinforced with fibres wound only in the hoop (circumferential) direction.

4.2.3 CNG-3 metal liner totally reinforced with resin-impregnated continuous filament (fully wrapped)

CNG-3 cylinders have a metallic liner that is generally load carrying, but they do not have sufficient strength and thickness to carry the longitudinal load at the burst pressure. They are reinforced with fibres wound in both a helical and hoop pattern. Metal liner materials are those identified under CNG-1 cylinders (see 4.2.1).

4.2.4 CNG-4 non-metallic liner totally reinforced with resin-impregnated continuous filament (all composite)

CNG-4 cylinders have a non-metallic liner that does not carry load. The liner is typically a thermoplastic material. These cylinders are reinforced with fibres wound in both a helical pattern and hoop direction. Metallic bosses are used to accept accessories such as valves and PRDs. Boss materials are typically aluminium alloy or stainless steel.

4.3 Required marking information

The marking requirements of ISO 11439 shall be reviewed to verify the exact wording, lettering size and required content as follows:

a) “CNG ONLY”;

b) “DO NOT USE AFTER MM/YYYY” (providing the month and year of expiry);

c) the manufacturer’s identification;

d) the cylinder identification (a unique serial number for each cylinder);

e) the working pressure;

f) the ISO standard, along with cylinder type and certification registration number (if applicable);

g) the words “Use only a manufacturer-approved PRD”;

h) the date of manufacture (month and year);

i) any additional markings, as required by the regulations of the country (or countries) of use.

When labels are used, all cylinders shall have a unique identification number and the manufacturer’s identification stamped on an exposed metallic surface, to permit tracing in the event of the label being destroyed.

5 Inspection body and inspectors

The inspection body shall be recognized in accordance with the regulations in the country of use.

In order to ensure that the cylinders are fit for continued safe use, the inspection shall be carried out exclusively by persons competent to do so. The inspector shall have available and within easy access during the inspection the equipment described in Clause 6 and the documentation referenced in 7.3.2. The vehicle to be inspected shall be positioned in such a way that the inspector has unimpeded access to the surface of the cylinder, or else in accordance with the vehicle manufacturer’s recommendations (see

7.3.5). If the inspector finds areas, such as those described in Clause 7, that require additional inspection or testing, the cylinder shall be depressurized in accordance with the recommendations in Annex A and with the manufacturer's instructions, and then removed from the vehicle. If the inspector determines that the cylinder needs to be permanently removed from service, this shall be done in accordance with Clause 9.

6 Inspection equipment

6.1 Adequate light, sufficient to illuminate all surfaces clearly, in order to examine properly the external surfaces of cylinders, mounting brackets, valves, vent lines, etc.

CAUTION — To avoid combustion or fire, either use explosion-proof lights or ensure that the area is well ventilated.

6.2 Angled inspection mirrors, or other suitable devices, to aid in the examination of cylinder surfaces that are partially concealed by the installation.

6.3 Various hand tools, to remove covers, shields or other installed equipment, such that the external cylinder surfaces, brackets, valves, PRDs and other components can be viewed.

6.4 Torque wrench, to verify that the mounting bracket bolts are properly tightened.

6.5 Depth gauge, to determine the depth of cuts, pits and abrasions. A commercial-type pit or depth gauge should be used for this purpose; alternatively, the use of other equipment to estimate imperfection depths is acceptable.

6.6 Rule and straightedge, in combination, to evaluate indentations and bulges.

6.7 Rule or tape measure, to determine the length of noted cuts and the general area of abrasion.

6.8 Commercial-type leak test fluid, which does NOT contain ammonia, harsh corrosives or chemicals incompatible with the system materials (the fluid is usually a mild soap solution that meets these criteria). A methane gas detector may also be used to test for leakage. Additional information is provided in 7.6.4.

6.9 Ultrasonic thickness gauge, to determine the remaining wall thickness on cylinders with exposed metal regions (excluding boss).

7 Cylinder, valve and pressure relief device inspection

7.1 Inspection interval

CAUTION — Failure to perform diligent and accurate inspections on a regular basis, or promptly (in the case of a potentially damaging incident or unusual behaviour), can result in a serious accident causing severe damage or injury, or both.

NGV fuel storage systems shall be visually inspected by a recognized inspector (see Clause 5), at intervals as stated in ISO 11439. Annex B specifies typical conditions and usage that may warrant more frequent inspections, while Annex D outlines specific considerations relating to internal inspections.

7.2 Conditions requiring immediate inspection

Inspections usually are carried out as stated in 7.1 on pressurized cylinders; however, due to the high risk presented by cylinders described in this clause, it is essential to depressurize the cylinder and consider the following list prior to the normal inspection procedure in 7.4.

An inspection shall be performed immediately on a depressurized CNG cylinder, prior to filling or returning it to service, if for example

a) the cylinder or vehicle in which it is installed is involved in a fire,

b) the cylinder is exposed to excessive heat,

c) the cylinder is dropped during installation or subjected to impact,

d) the NGV has been involved in a collision,

e) the cylinder is suspected to have been damaged,

f) any odour is detected (e.g. a compound added to natural gas to enable it to be detected),

g) there is unusual behaviour including, but not limited to:

   1) unexpected loss of gas pressure;

   2) rattling or other indications of looseness;

   3) unusual snapping or hissing sounds,

   NOTE Some minor noise is not unusual for composite materials when cylinders are being pressurized or depressurized.

h) the cylinder is reinstalled after removal from the vehicle,

i) the cylinder installation is changed significantly,

j) the cylinder is transferred to another vehicle, or

k) the cylinder has been overpressurized, not in accordance with the limits of its design.

7.3 Preparation for inspection

7.3.1 Background vehicle information

CAUTION — A cylinder shall not be pressurized with air or an oxidizing gas mixture prior to use or inspection. This can create a reactive mixture with the gas that the cylinder was previously filled with and can be very dangerous.

The cylinder owner/vehicle operator should be questioned regarding any known conditions or incidents that could have caused damage to the cylinder. The inspector shall review service and previous cylinder inspection records (if available) prior to the inspection. Knowledge of the service history and interviews of the cylinder owner/vehicle operator concerning known repairs and accidents can provide insight, which can aid in the inspection process.

Known conditions or incidents that could have caused damage to the cylinder include, but are not limited to

a) overpressurization,

b) dropping of the cylinder (during installation),

c) impacts to the cylinder,

d) exposure to excessive heat or fire,

e) vehicle accidents, and

f) exposure to harsh chemicals.

7.3.2 Background information

Before starting the inspection, pertinent information shall be reviewed from the following sources:

— the cylinder manufacturer;

— the vehicle manufacturer (when the CNG fuel system is factory-installed);

— the after-market installers (when the CNG fuel system is installed after the vehicle is manufactured, and installed by someone other than the vehicle manufacturer).

As a minimum, this shall include a survey of ISO 11439, including inspection criteria for the specific cylinder and vehicle model. This review should include a study of the maintenance manual and recommendations and guidance documents for the cylinder and its installation.

7.3.3 Cylinder external surface

The external surface of the cylinder shall be clean and free from dirt or other debris that impedes the ability to clearly determine the condition of the external surface of the cylinder (see 7.3.5). Shields or covers that inhibit the inspection shall be removed or opened, to gain access to the cylinder surface area for inspection.

If a sleeve, which can conceal damage, is fitted to a cylinder, it should be removed to enable a thorough inspection to be performed.

7.3.4 Cylinder depressurization

Cylinders do not require depressurizing prior to inspection.

Cylinders that require immediate inspection (see 7.2) shall be depressurized prior to examination. Cylinders with known or suspected Level 2 damage shall be depressurized prior to inspection. Cylinders with Level 3 damage and cylinders to be condemned shall be depressurized (see 9.2). Compliance with all authorities having jurisdiction in the depressurization process and release of CNG to the atmosphere is mandatory. Depressurization guidelines are given in Annex A.

7.3.5 Cylinder access

Resin, paint or coatings of installed cylinders shall not be removed for the visual inspection. The cylinder shall not be disassembled from the vehicle for inspection unless visual damage or deterioration is noted on the exposed cylinder surface, or if damage is believed to have occurred on an unexposed surface. If the cylinder surface is not accessible, the cylinder shall be disassembled from the vehicle for visual inspection or tested by a method appropriate for its installation.

7.4 Cylinder inspection

7.4.1 Cylinder acceptance and rejection criteria

In the absence of any recommendation from the cylinder manufacturer, Table 1 shall be used for the acceptance and rejection criteria for cylinders. Table 1 shall not be used without a thorough understanding and knowledge of Clause 7, as well as of the manufacturer's instructions.

7.4.2 Damage evidence

Visual inspection of the cylinder external surface is the primary means of detecting cylinder damage. Evidence of potential damage includes

— corrosion,

— cuts,

— scratches,

— gouges,

— cracks,

— exposed fibres,

— dents,

— bulges,

— fractures,

— material loss/removal,

— discolouration of the cylinder surface (soot, charring, chemical attack, etc.),

— evidence of heat exposure,

— impact or accidents, and

— deterioration of surface materials.

7.4.3 Damage levels

The extent of the damage is categorized as Level 1, Level 2 or Level 3.

The cylinder damage levels identified in this International Standard are given as general guidelines. The inspection body shall accept manufacturer-specified acceptance criteria where noted in Table 1, if such criteria are based upon cylinder test results. Where not noted, or where the manufacturer does not provide acceptance criteria based upon testing, the inspection body shall apply the acceptance criteria in this International Standard. In the absence of acceptance criteria based upon testing, all Level 2 conditions shall be identified as Level 3 conditions. The surface of the cylinder shall be inspected for evidence of damage. Damage observed shall be evaluated in accordance with Table 1.

Whenever cylinder damage is discovered, the likely cause of the damage shall be investigated. When cylinder damage is caused by installation, severity or conditions of service (see Annex B), or by improper cylinder use, the inspector shall advise the cylinder owner of the need to take corrective action to prevent or reduce further cylinder damage, or to prevent damage to a replacement cylinder. The original cylinder installer shall develop such actions and if necessary will involve the cylinder manufacturer.

7.4.3.1 Level 1

Cylinders with no external visual damage or minor damage are categorized as Level 1 damage and are acceptable; hence, no repair is required.

7.4.3.2 Level 2

Cylinders with damage that requires repair, testing or condemnation as advised by the cylinder manufacturer are categorized as Level 2 damage. Level 2 damage is also reserved for conditions specified by the manufacturer, which can differ from Level 1 or Level 3 damage outlined in Table 1. Level 2 conditions are either shown to be acceptable (Level 1) by the manufacturer's test and investigation results, or else evaluated to be Level 3.

7.4.3.3 Level 3

Cylinders with damage that is sufficiently severe that it shall not be repaired, but shall be rejected and subsequently condemned are categorized as Level 3 damage.

7.4.4 Cuts, scratches, gouges and abrasion

The rejection criteria for these types of damage may be provided by the manufacturer (e.g. abrasion in accordance with 7.5.5). Full details of acceptance and rejection conditions can be found in Table 1. Damage between Level 1 and Level 3 is determined to be acceptable or rejectable by the cylinder manufacturer's guidance, based upon the manufacturer's test data (see 7.4.3).

Repair instructions shall be obtained from the manufacturer.

Table 1 — Acceptance and rejection conditions for cylinders

Type of damage	Description	Decision			Remarks
		Level 1 accept	Level 2	Level 3 reject	
All cylinder types					
Marking	Stamping, labelling and attached information	Required information is present and legible	Some required information is not legible; manufacturer may supply information for repair If this information is unavailable this becomes Level 3.	Required information is not legible or any traceability; repair not allowed	Manufacturer may supply new labelling if serial number is legible.
Cuts/ scratches/ gouges	A sharp impression where material has been removed or redistributed. Also includes line corrosion pitting where distance between the pits is less than one pit width	When depth is less than 0,25 mm and (for composites only) no fibres were exposed, cut or separated	Greater than Level 1 damage that is accepted and can be repaired in accordance with the manufacturer's specifications (composite cylinders only). For types CNG-2, −3 and −4, a depth included between 0,25 mm and 1,25 mm when other parameters are critical (length, width, number), in accordance with the manufacturer's recommendations. For type CNG-1 cylinders when depth is ≥ 0,25 mm and < 0,5 mm, repair (e.g. grinding for steel) in accordance with the manufacturer's recommendations provided the minimum design wall thickness is maintained.	For CNG-1 when depth is ≥ 0,5 mm or the remaining wall thickness is less than the minimum design wall thickness. For CNG-2, −3, −4 type cylinders, when the depth is greater than 1,25 mm.	Composite cylinders may be repaired if fibres are not cut or separated.
Abrasion	Damage to an area of the cylinder or its installation equipment caused by scraping, wearing, vibration and rubbing of the material away by friction (see 3.1)	When the depth is less than 0,25 mm and (for composites only) no fibres were exposed, cut or separated	Greater than Level 1 damage that is accepted and can be repaired in accordance with the manufacturer's specifications (composite cylinders only). For type CNG-1 cylinders when depth is ≥ 0,25 mm and < 0,5 mm, repair (e.g. grinding for steel) in accordance with the manufacturer's recommendations provided the minimum design wall thickness is maintained.	For CNG-1 when depth is ≥ 0, 5 mm or the remaining wall thickness is less than the minimum design wall thickness. For CNG-2, −3, −4 type cylinders, when the depth is greater than 1,25 mm.	Composite cylinders may be repaired if fibres are not exposed, cut or separated.

Table 1 *(continued)*

Type of damage	Description	Decision			Remarks
		Level 1 accept	Level 2	Level 3 reject	
All cylinder types					
Charring/ soot	Blackening or browning of an area	None or washes off	Follow the manufacturer's test guidelines for Level 2 damage (see 7.4.5)	Permanent charring; discolouration	
Gas leakage	Loss of contents through a defect (not intended to include loss by permeation)	None detected	If the cylinder leaks it shall not be repaired. If through composite material (if permeation suspected), see 7.6.4 and seek the manufacturer's advice.	Leak detected	
Chemical attack	Cylinder is subjected to a chemical that corrodes, dissolves or has any adverse effect on the material	Cleans off; no residue or effect, and chemical is known not to affect cylinder materials	Chemical unknown; effects on cylinder materials unknown; moves to Level 3 if these cannot be resolved	Permanent discolouration, loss/disruption of material, chemical is known to affect cylinder materials; cannot determine if materials have been affected	Manufacturer shall provide guidance on exposure to chemicals; (see under "Stress corrosion cracking").
Weathering	Effects of the sun's ultraviolet radiation	Minor gloss loss or chalking	Only coating or non-structural material is affected; may be repainted (see 7.4.7)	Structural materials affected	Repainting with the manufacturer's guidance might change Level 2 to Level 1.
Cylinder types CNG-2, –3 and –4					
Impact, e.g. caused by collision or accident	Cylinder material was struck or hit. The resin may have a frosted or smashed appearance	Damaged area is less than 1 cm^2 and no other damage is apparent	Damage is uncertain, requiring the manufacturer's advice	Permanent deformation of cylinder or liner, or frosted/damaged area is greater than 1 cm^2 (does not pass the "coin-tap" test; see 7.6.3)	Contact manufacturer if additional advice is needed.
Stress corrosion cracking	Fibres may crack or split as a result of a chemical attack, favoured by stresses in the material	Materials in contact with chemical(s) (not prone to cause stress corrosion cracking but nothing visible is detected)	Possibility that cracking or splitting has occurred, because cylinder was known to have had chemical contact	Identified stress corrosion cracking	Contact manufacturer if questionable condition exists.

Table 1 *(continued)*

Type of damage	Description	Decision			Remarks
		Level 1 accept	Level 2	Level 3 reject	
Cylinder types CNG-1 and metal portions of other designs					
Bulge	Visible swelling of cylinder	None	Could be bow shape rather than bulge (see 7.5.3)	Visible or detectable bulge	
Corrosion, pits	An isolated hole caused by a chemical, oxidation or rusting of material	When depth is less than 0,25 mm	Repair (e.g. grinding for steel) in accordance with the manufacturer's recommendations provided the minimum design wall thickness is maintained	When depth is ≥ 0,25 mm and the remaining wall thickness is less than the minimum design wall thickness.	If Level 1 corrosion is found, the manufacturer's recommended procedure to prevent further corrosion should be followed.
Corrosion, line	Corrosion pits in a narrow band, such that the distance between pits is greater than one pit width. If pits are closer, see under "Cuts/ scratches/ gouges"	When depth is less than 0,25 mm and the length is less than 50 mm	Repair (e.g. grinding for steel) in accordance with the manufacturer's recommendations provided the minimum design wall thickness is maintained	When depth is ≥ 0,25 mm and the length is greater than 100 mm. The remaining wall thickness is less than the minimum design wall thickness.	
General corrosion	An area of material loss due to chemical oxidation or rusting	Area corrosion is less than 25 % of the outside surface area, provided that the remaining thickness is at least minimum design wall thickness	Repair (e.g. grinding for steel) in accordance with the manufacturer's recommendations provided the minimum design wall thickness is maintained	Corrosion depth is below minimum wall thickness or the area is 25 % or more of the outside surface area.	
Dents	A depression in the cylinder that has neither penetrated nor removed material	Dents less than 1,6 mm deep and which are larger than 50 mm in diameter or length	N/A cylinder cannot be repaired.	Dents 1,6 mm or more deep and the largest diameter or length is less than 50 mm	A large shallow dent is less of a concern than a small shallow dent. A dent with sharp angles creates material stresses, which reduce cylinder safety.
Corrosion of metals under composite	Metal corrosion as evidenced on the composite surface or on the liner surface adjacent to the edge of the composite material	None visible	Corrosion deposits or stains originating from unknown chemical, beneath or at the edge of the composite. Cylinder shall be referred to manufacturer. If effects on cylinder materials unknown; moves to Level 3 and these cannot be resolved.	Corrosion at the edge of the composite, which has Level 3 characteristics of line corrosion	Corrosion deposits or stains originating from corroded vehicle components other than the cylinder are not to be confused with this phenomenon.

7.4.5 Fire and excessive heat damage

Excessive heating (e.g. resulting from the cylinder not being properly located in relation to a vehicle exhaust system or being involved in a fire) can cause significant damage to the cylinder.

Cylinders showing evidence of fire or excessive heat exposure (not necessarily sooting) are defined as having Level 3 damage and are to be rejected, condemned and destroyed.

Fire damage can be evident on exposed cylinder surfaces (e.g. burning, discolouration, darkening, charring or sooting of the surface, melted or deformed attachments or materials). Sooting might only be dirt or settled debris in which case it shall be wiped off the cylinder and be considered as Level 1.

For composite cylinders, severe exposure can result in resin removal and loose fibres. Other indications of heat or fire exposure include burning; charring; discolouration of the coating, label or cylinder; and evidence of connection distortion, such as melted or deformed attachments or installation materials.

7.4.6 Chemical attack

The cylinder shall be examined for evidence of chemical attack. Chemical damage can appear in the form of an alteration to the cylinder surface (e.g. corrosion, discolouration, etching, pitting, blistering and swelling). For composites, chemical damage can also include softening, stress corrosion cracks and resin loss. In extreme cases, the composite can exhibit fractures and broken or loose fibres.

Minor discolouration and no material loss are defined as Level 1 damage and are considered acceptable, provided that

a) the chemical to which the cylinder has been exposed is known,

b) the chemical has been totally removed from the cylinder surface,

c) the cylinder surface has been cleaned, and

d) the cylinder manufacturer's recommendations have been followed.

Any evidence of blistering, swelling, softening, resin removal and broken or loose fibres in the composite attributable to chemical attack is defined as Level 3 damage.

CNG-1 cylinders and the metallic areas of other cylinder types exhibiting signs of chemical attack (e.g. pitting, corrosion and/or oxidation) shall be evaluated in accordance with the requirements of Table 1.

The materials used in the cylinder are resistant to chemical agents encountered in the normal fuel cylinder environment. The cylinder, however, shall be maintained in a clean state and shall not be allowed to have prolonged exposure to moisture, automotive fluids, cargo chemicals or corrosive agents.

7.4.7 Weathering

The cylinder can exhibit degradation of the external surface/coating after prolonged exposure to sunlight and weather. This can result in discolouration and/or potential deterioration of the coating on exposed surfaces. This condition is defined as Level 1 damage or Level 2 damage, provided that there is no evidence of surface metal corrosion or loose or broken fibres. After completion of the inspection process, the affected surface with Level 2 damage should be repaired by application of a coating in accordance with the manufacturer's procedures. The surface may be prepared for painting in accordance with 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 that it is used only to remove loose, deteriorated coating or to deglaze the surface. Level 3 damage is evidence of structural materials being affected (e.g. evidence of surface metal corrosion or loose or broken fibres, but not discoloration).

7.4.8 Overpressurization

Cylinders subjected to overpressurization shall be rejected, condemned and destroyed. Overpressurization information can usually only be determined through the preliminary inquiry, unless the cylinder shows signs of bulging (see 7.5.3).

7.5 Additional inspection of metal cylinders — CNG-1 and metallic areas of CNG-2, CNG-3 and the metal bosses of CNG-4

7.5.1 General

All-metal cylinders and the exposed metallic areas of other types of cylinder shall be inspected for metal damage.

7.5.2 Corrosion

7.5.2.1 Introduction

Corrosion of a metal surface involves a loss of wall thickness due to strongly acid or caustic chemicals. The following describes the different types of corrosion.

7.5.2.2 Pitting corrosion

Pitting corrosion consists of the loss of wall thickness in small, isolated areas. Isolated shallow pits of small diameter (see Table 1) do not effectively weaken the cylinder.

7.5.2.3 Line corrosion

Line corrosion refers to corrosion resulting in a narrow band pattern or line, where the space between pits is more than one pit width.

7.5.2.4 General corrosion

General corrosion, sometimes known as broad spread corrosion, refers to corrosion which covers large surface areas of the cylinder, reducing wall thickness and thus structural strength. Some types of general corrosion are acceptable (see Table 1).

7.5.2.5 Corrosion of metal under composite

When there is corrosion at the join between composite materials and metallic materials, a type of line corrosion can occur that, if advanced enough, qualifies as Level 3. Criteria given for Level 3 line corrosion can be applied to this damage. Any visual signs of corrosion under the composite material shall warrant contacting the manufacturer for guidance. Without guidance or a determination on the damage level of corrosion under the composite material, the damage is declared to be Level 3.

7.5.2.6 Galvanic corrosion

When in contact with other electrically conductive materials, cylinder and boss materials can be susceptible to a specialized form of corrosion known as galvanic corrosion, e.g. when aluminium comes into contact with stainless steel, or carbon fibre comes into contact with steel. The guidelines for corrosion in Table 1 apply to this type of corrosion, as well as to corrosion from oxidation.

7.5.3 Bulges

Bulges are considered to be severe structural damage where the cylinder is deformed by swelling. All cylinders showing bulging shall be condemned.

CNG-1 cylinders with a bow or in the shape of a banana are acceptable and may be returned to service, provided that their shape does not interfere with proper mounting and installation.

7.5.4 Dents

Level 3 dents refers to dents with a depth greater than or equal to 1,6 mm, or where the largest diameter or length is less than 50 mm regardless of dent depth, or where both conditions exist.

7.5.5 Abrasion

Metal exhibiting evidence of abrasion shall be examined closely to verify that the amount of metal removed by the abrasion has not exceeded the manufacturer's recommendations. See Table 1 for rejection limits.

7.6 Additional inspection requirements for composite cylinders (CNG-2, CNG-3 and CNG-4)

7.6.1 General

Cylinders of type CNG-2 and CNG-3 shall be inspected for metal criteria and composite criteria (see 7.5). The metal connections of the CNG-4 (boss) shall be inspected for metal criteria (see 7.5).

7.6.2 Abrasion

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.

Cylinders exhibiting evidence of abrasion under high loading shall also be examined as though the surface were subjected to impact (see 7.6.3).

Level 3 damage refers to abrasion with a depth greater than 1,25 mm. Level 2 damage may be repaired by coating with a filler material, in accordance with the manufacturer's instructions.

For coating, chipping and/or abrasion without effects on the cylinder material, contact the cylinder manufacturer and follow the manufacturer's instructions.

7.6.3 Impact damage

For CNG-3 and CNG-4 type cylinders, impact damage differs from other forms of cylinder damage because the cylinder wall can suffer more severe internal damage than at the surface. This is particularly true if the surface of the cylinder returns to its original shape after impact, and therefore does not display a dent, like a CNG-1 or CNG-2 type cylinder.

Impact damage can cause fractures and delaminations between composite layers, which are used to construct the cylinder. Surface damage associated with impact loading can include denting, cutting, gouging, scraping, scuffing, chipping, puncturing, fibre breakage, loose fibres, resin cracking or a change in colouration or appearance. The surface shall be carefully examined for these types of indications. Known areas of impact shall be marked to aid in the inspection process.

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 cylinder surfaces. Denting is evidence of severe internal damage. Cylinders exhibiting this type of damage shall be closely inspected for possible Level 2 or Level 3 damage.

This condition does not include highly localized pitting at the surface, such as might result from impact by a small stone, as in the following examples.

— Bulging of the cylinder wall: the cylinder wall shall be uniform and not exhibit localized bulging. Any bulging is Level 3 damage.

— Localized differences in cylinder colouration: cylinders that incur impact damage often exhibit differences in surface appearance. These differences can produce a change in colouration 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.

— Localized areas of surface cracking: cylinders 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 colouration, as mentioned previously. Each area exhibiting these types of indications shall be closely inspected for possible Level 2 or Level 3 damage.

— Localized differences in sound from a "coin-tap" test: the area of potential impact damage may be evaluated using a common coin. The coin should be approximately 25 mm in diameter and approximately 5,5 g in weight. Using your hand and a loose grip of the coin, impact the composite surface with the edge of the coin and note the resulting sound. Areas of impact damage will produce a distinctly different (hollow) sound, as opposed to the sound produced by undamaged composite.

7.6.4 Gas leakage

Cylinders that exhibit apparent gas leakage in excess of the prescribed limits shall be rejected, condemned and destroyed. ISO 11439 prescribes a maximum permissible permeation rate of 0,25 $cm^3/h/l$ water capacity. This is not to be confused with a leak. When leakage is suspected or discovered, steps shall be taken to avoid possible combustion, then the vehicle shall be moved to a large open area and the cylinder depressurized as described in Annex A. Contact the manufacturer to report the condition and obtain information regarding additional testing and disposition.

Gas leakage can be confirmed by a leak test fluid or a methane gas detector (see 6.8). If a leak test fluid is used, persistent bubbling indicates leakage. Contact the manufacturer for information on distinguishing natural gas leakage from the normal air bubbles for composite cylinders.

It is important to calibrate methane gas detectors prior to using them, in order to confirm natural gas leaks, since the detectors might be sensitive to normal out-gassing from composite or plastic materials, oils, other hydrocarbons, normal indoor air, or even leak test fluids. Contact the type CNG-2, –3 and –4 cylinder manufacturer for information on leak detection using the gas detectors.

7.6.5 Stress corrosion cracking

SCC is an important consideration for glass reinforced polymers and can occur where acid has access to the fibres in the matrix. In the case of composite gas cylinders, SCC can be caused by attack from environmental causes such as carbonic acid or from leakage of acids from a vehicle's components. An example is shown in Figure 1.

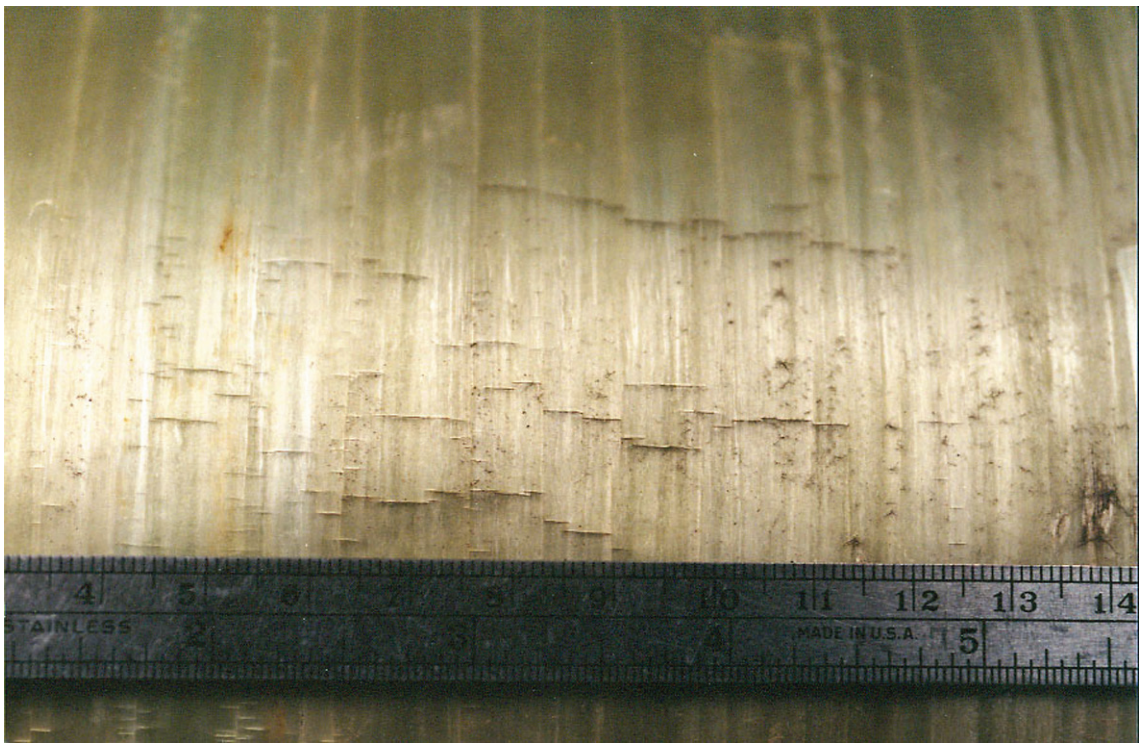

Figure 1 — Example of stress corrosion cracks in a glass fibre composite cylinder

7.7 Valve and pressure relief device inspection

7.7.1 General

The installation shall meet the requirements of ISO 15501-1 and ISO 15501-2. If at any time the equipment needs to be disassembled, replaced or serviced, the fuel system shall be depressurized prior to such work being undertaken (see Annex A).

7.7.2 Requirements

The vent line bag material might need to be removed from the hardware at the ends of the cylinder for this inspection. The PRD and tubing shall be cleaned as necessary with a rag and mild detergent solution to allow inspection of their external surfaces and any orifices. The choice of detergent shall be compatible and non-reactive with the materials with which it comes into contact, e.g. the use of ammonium containing compounds on brass can cause stress corrosion; hence, detergents containing ammonia shall not be used on brass components. Inspection of the valve and plug/PRD shall include the following aspects.

a) Examination of the valve and PRD assemblies for damage: the valve and PRD assemblies shall not be deformed or show other signs of damage. Damaged valves and PRD assemblies shall be replaced.

b) Examination of the interface between the valve and cylinder port, the PRD and cylinder port and any other plug and cylinder port: these interfaces shall be tightly seated with no gaps or looseness. If there is evidence of looseness or seal damage, the cylinder shall be depressurized, the suspicious area disassembled and the seal shall be replaced, as necessary (see Annex A). In all cases the components shall be reassembled/reinstalled by a trained technician in accordance with the torque limits recommended by the cylinder manufacturer.

c) Leak testing of all the connections between the valve and cylinder port, and the plug/PRD(s) and cylinder port (see 7.6.4): the fuel line connection to the valve, all plug/PRD connections and the valve connection shall be checked for leakage. These connections shall be serviced by a trained technician if any leakage from these areas is detected.

d) External inspection of PRDs for corrosion, damage, rust, bulging, and mechanical defects, such as leakage, extrusion of fusible metal or looseness of attachments: these shall be checked each time a CNG cylinder is inspected. If any of the above are observed, the cylinder shall be depressurized and the PRD shall be replaced by a trained technician (see 7.7.3).

e) Plugging of the PRD vent system: If present the system then shall be cleaned and returned to normal operating condition.

7.7.3 Approved equipment

The inspector shall verify that the PRD(s) in use with the cylinder, in accordance with ISO 15500-13, is approved and specified by the manufacturer for the cylinder type.

7.7.4 Damaged equipment

Dents, gouges and scratches with depths greater than or equal to 0,5 mm in locations other than the hexagonal torque nut constitute Level 2 damage. The inspector shall review the PRD manufacturer's recommendations or contact the valve/cylinder manufacturer, as appropriate, to determine the condition as either Level 1 or Level 3.

7.8 Cylinder marking

Marking inspection shall include at least all of the following aspects.

— Verification that the marking is legible, permanent and complete: If not, this is Level 2 damage (see Table 1).

— Verification that the cylinder service life has not expired: the marking shall identify the service life as "DO NOT USE AFTER MM/YYYY" (providing month and year of expiry). If expired, this is Level 3 damage.

— Verification that the service pressure rating listed on the cylinder label is greater than or equal to the vehicle refuelling markings for service pressure.

7.9 Cylinder inspection record/checklist

Annex C shows an example of a cylinder inspection checklist that may be used.

7.10 Cylinder final acceptance/rejection

7.10.1 General

As a result of the inspection, the fuel cylinder can be attributed one of the three outcomes outlined in 7.10.2 to 7.10.4. After all the inspection preliminaries have been performed (see 7.3), if any single, confirmed Level 3 condition is identified in the inspection process, the inspection may stop, and the inspector proceeds to 7.10.5.

7.10.2 Fit for service — Level 1 damage

The cylinder is approved for a return to service in conditions of Level 1 damage, such as when

— no damage is found during inspection,

— the damage is acceptable or minor, as defined by this International Standard and outlined in Table 1, and

— there is Level 2 damage that is authorized for repair, and has been successfully repaired in accordance with the cylinder manufacturer's procedures and directions (see 7.10.4).

7.10.3 Inspection mark

Before returning the cylinder to service, the inspector shall put an inspection mark on the cylinder showing that it has passed inspection and is suitable for service. The inspector shall mark the cylinder (by means of a tag, label or other permanent marking that does not obscure the cylinder manufacturer's label(s) or manufacturing marks, and does not obscure previous inspection marks) with at least the date on which the cylinder was inspected and the identification of the inspection body.

7.10.4 Need for the cylinder manufacturer's advice — Level 2 damage

Cylinders that have suspected Level 2 damage and for which, as indicated in Table 1, the cylinder manufacturer must be contacted, shall be handled in accordance with the cylinder manufacturer's recommendations and guidelines. Classify all unclear damage as Level 2 damage. Cylinders identified as having Level 2 damage shall not be returned to service until the condition is resolved. Level 2 damage also is reserved for conditions specified by the manufacturer that can differ from Level 1 or Level 3 conditions, as outlined in Table 1.

Level 2 damage may, as indicated in Table 1, be repaired in accordance with the cylinder manufacturer's specified procedures and direction. After the specified repair has been completed, the cylinder becomes acceptable for use (see 7.10.2).

Level 2 damage may, as indicated in Table 1, be determined by the cylinder manufacturer's guidelines to be Level 3 damage. In such cases, follow the procedures in 7.10.5.

7.10.5 Reject, condemn and destroy — Level 3 damage

Cylinders that have confirmed Level 3 damage shall be rejected, condemned and destroyed. In addition, when the manufacturer does not supply information which confirms that a cylinder with Level 2 damage can be classified as Level 1, then these are also classified as Level 3.

7.11 Component final acceptance/rejection

7.11.1 General

As a result of the inspection (see 7.8), the components (excluding the cylinder) can be attributed one of the three outcomes outlined in 7.11.2 to 7.11.4.

7.11.2 Fit for service — Level 1 damage

In the case of Level 1 damage, the component can be approved for continued operation. It shall be remounted/attached (if it was removed) and connected to the NGV fuel system, in accordance with the component manufacturer's and the cylinder manufacturer's recommendations and guidelines.

7.11.3 Need for the manufacturer's advice — Level 2 damage

In the case of Level 2 damage, either the component may be repaired and returned to service, or the component manufacturer may recommend condemning the component. The component manufacturer shall determine how to repair the component or whether specific components should be condemned. Each recommendation shall be made in writing.

Component manufacturers may need to be consulted directly, or their current accompanying literature may need to be referred to, when component conditions are classified as Level 2 damage or when Level 1 damage is unclear. Level 2 damage also is reserved for conditions specified by the manufacturer that can identify from Level 1 or Level 3 damage as outlined in Table 2.

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

7.11.4 Remove from service — Level 3 damage

In this case, the component shows obvious Level 3 damage that would require it to be rejected and condemned. If the component manufacturer is not able to determine if a cylinder with Level 2 damage can be classified as Level 1 or Level 3, the component shall be considered to be Level 3 and shall be rejected and condemned.

Table 2 — Acceptance and rejection conditions for components

Component/ condition	Level 1 accept	Level 2	Level 3 reject	Remarks
All components	Clean, no damage, working, good condition	Evidence of minor chemical attack, oxidation, rust or corrosion; unclear Level 1 condition; need component manufacturer's advice; may be reparable	Damaged, cracked, leaking, cannot make proper connection	
Mounting system	Mounting system complies with cylinder manufacturer instructions	Loose, wear showing or in questionable condition; inspect for other potential damage that may have been caused by mounting failure; follow component and cylinder manufacturer's advice	Broken, excessive wear, damaged, cracked, corroded, abrasion noted or not in compliance with cylinder manufacturer's instructions	
Fuel system	Fuel and vent line connections to the cylinder components are secure and dry and there are no leaks or damage	Lines are loose but can be properly tightened	Broken, excessive wear, damaged, cracked, corroded, or abrasion noted	

Table 2 *(continued)*

Component/ condition	Level 1 accept	Level 2	Level 3 reject	Remarks
PRD and valve vent lines and assemblies (excluding valves, PRDs and hexagon nut)	Clean, no damage, no leaks	Possible seal damage; possible leaking; vent lines dirty or partially obstructed; component manufacturer's instructions not followed; advice needed on repairs or acceptance criteria	Damaged, cracked, deformed, leaking, obstructed or non-working parts	
Gas tight housing	Clean, no damage, no leaks and complies with the requirements of ISO 15500-15	Possible seal damage; possible leaking; vent lines dirty or partially obstructed; component manufacturer's instructions not followed; advice needed on repairs or acceptance criteria	Damaged, cracked, deformed, leaking, obstructed or non-working parts	
PRD	Clean, no damage; cylinder manufacturer approved and appropriate for cylinder type/model and properly marked (see 7.8.1)	Evidence of minor wear, or corrosion; leakage evident; component manufacturer's advice needed on repairs or acceptance criteria	Corroded, obstructed, rusted, bulged, deformed, cracked, defective, leaking or fusible metal has extruded or partially extruded	
PRD dents, gouges and/or scratches	No damage evident	Less than 0,5 mm deep; contact component manufacturer for advice	0,5 mm deep or greater, or unclear Level 2 condition	
PRD torque nut (mainly hexagonal)	No damage and clean	Some minor wear noted; obtain advice of component manufacturer	Rounded edges; distorted, non-functional or leaking	
Valves	Clean, no damage, no leaks, no connection leaks	Dirty, gaps or loose connections; needs valve-cylinder port further inspection	Damaged, deformed, leaking	

8 Installation and mounting inspection

8.1 Installation and mounting of Natural Gas Vehicle fuel cylinders

The cylinder shall have been mounted in a manner that adequately restrains the cylinder but does not induce damage. Only brackets, straps and mounting systems that follow the instructions from the cylinder manufacturer shall be used.

The cylinder expands and contracts as the pressure in the cylinder increases and decreases. This causes the cylinder's diameter and length to vary, depending on pressure. The cylinder mounting system shall be able to accommodate this expansion without inducing excessive loads in the cylinder or causing abrasion of the cylinder.

8.2 Cylinder installation inspection

8.2.1 General

Table 2 outlines acceptance and rejection conditions for installation components. Table 2 should not be used without a thorough understanding and knowledge of 8.2 and 7.8, as well as of the component manufacturer's recommendations, manual, advice, etc.

Examination of the installation by the inspector shall

— determine if the installation is in compliance with applicable regulations,

— verify that the fuel cylinder is being used only for the storage of compressed natural gas,

— determine potential for damage due to location in or on the vehicle, and whether the cylinder could be damaged by tools, shifts of cargo, cargo leaks, road debris or proximity to and the condition of the exhaust system,

— verify that the surface of the cylinder is not in contact with or in close proximity to objects that could cut, gouge or abrade the surface of the cylinder, including cables, tubing or vehicle components: a minimum of 12,5 mm clearance completely around the cylinder is recommended, but additional clearance can be required in areas where the vehicle may flex during operation,

— verify that installations in which cylinders are enclosed in a vehicle are vented external to the vehicle: the vent line from the PRD should be a high pressure line that is adequately secured to the vehicle to prevent whipping in the event of PRD activation, with the vent line exit being free of debris, insects, etc. and designed so as not to trap fluids,

— verify that the installation of gas tight housings and ventilation hose comply with ISO 15500-15,

— verify that lines connected to the cylinder are installed in a manner that prevents damage to the plumbing when the vehicle flexes or when the cylinder expands under pressurization, and

— reveal evidence of damage by chemicals or prolonged exposure to moisture: the installation should allow free drainage of water or other fluids and not allow fluids to have prolonged contact with the cylinder or mounting brackets; if shields are used, a clearance distance of 9,5 mm or more is recommended.

8.2.2 Fuel system inspection

The fuel system shall be inspected for at least

a) signs of looseness in the mounting system, fuel and vent lines,

b) signs of abrasion between components (e.g. shiny or burnished spots on either the component or the vehicle). If fuel or vent lines have been abraded such that their material is below safe operating/use standards, they shall be replaced,

c) areas of looseness or abrasion (e.g. to determine whether damage has occurred), and

d) the vent system shall be examined for evidence of water accumulation.

Any observations regarding damaged and/or replaced fuel and vent lines or loose fittings shall be recorded.

8.2.3 Mounting bracket and/or strap inspection

8.2.3.1 General

Any indication of looseness in the mounting system requires careful inspection of the bracket and/or strap assembly.

Brackets and isolator straps shall be inspected for signs of wear and/or looseness.

A trained technician shall replace worn components and tighten loose straps.

8.2.3.2 Examination of brackets, straps and mounting

The cylinder shall be mounted in a system that holds it securely in place, but which does not cause damage to the cylinder or vehicle. The mounting system shall allow the cylinder to expand and contract as the internal pressure fluctuates, without causing the cylinder to be loosened or abraded. The interface between the cylinder and the mounting brackets or straps shall be lined with an isolator pad, to allow little or no movement of the cylinder in the mounting system. Check the mounting points where the cylinder brackets meet the vehicle frame or any mounting component. If the frame or mounting component show signs of distortion, repair or replacement shall be completed.

8.2.3.3 Inspection criteria

Mounting brackets and straps shall be inspected in order to verify that the

a) mounting system is in accordance with the cylinder manufacturer's instructions,

b) cylinder is firmly mounted,

c) mounting bracket or strap fixing bolts are tightened to the correct torque,

d) bracket/strap mounting pads are in place, have not been worn through and are in good condition,

e) mounting system is in good condition and suitable for continued service, and

f) if fitted, any stone shield or cylinder protection device is not damaged and is fit for purpose.

Any damage found and the corrective action taken shall be recorded (see Annex C).

9 Condemned cylinders

9.1 General

Fuel cylinders may be condemned for a number of reasons that render them unfit for continued service, e.g.

— the cylinder has reached or exceeded the marked service life: the service life expiration date is indicated by markings on the label, which reads "DO NOT USE AFTER MM/YYYY " (providing the month and year of expiry),

— the cylinder marking is missing or obliterated, such that positive identification is not possible, and an alternate means of determining the identification is not available,

— the cylinder exhibits Level 3 damage, and

— the cylinder exhibits Level 2 damage, for which the manufacturer recommends the cylinder be condemned.

9.2 Condemned cylinders

Condemned cylinders shall not be refilled or reused for any purpose. All condemned cylinders should be properly destroyed to prevent further service. It is the responsibility of the owner to ensure that condemned cylinders enter the destruction process.

9.3 Destruction process

9.3.1 General

Individuals or organizations that have a reason to destroy condemned cylinders shall be properly trained and authorized by the owner to perform the necessary procedures. Destruction recommendations are intended for use by qualified individuals or organizations only, and are not intended for use by cylinder owners or by the general public.

These procedures were primarily developed from a safety perspective with a view to destroying condemned cylinders, and are not intended to ensure compliance with applicable national or local laws and regulations, including environmental standards and other standards that can vary from place to place and over time. Full responsibility for determining the applicable regulatory requirements and for ensuring compliance with them rests with the individual or organization that destroys condemned cylinders.

Generally speaking, the destruction process of all condemned cylinders requires adherence to the procedures outlined in 9.3.2 to 9.3.4.

9.3.2 Depressurization and purging

The cylinder shall be depressurized and subsequently purged before any attempt is made to destroy it (see Annex A).

NOTE Cylinders hold a significant quantity of flammable gas under pressure; hence, cylinders that appear to be empty can still retain enough residual gas to create an explosive mixture.

9.3.3 Valve and PRD removal

Remove the manual valve in accordance with ISO 25760. In case of automated operated valves, the valve manufacturer's instructions shall be followed.

PRD(s) that are removed from condemned cylinders and those from cylinder valves from condemned cylinders shall not be returned into service.

9.3.4 Destruction of the cylinder

The condemned cylinder shall be rendered, by destructive methods, incapable of further service. The condemned cylinder shall be destroyed by a method that makes repair impossible.

Prior to taking any of the following actions, ensure that the cylinder is empty. One of the following methods may be used depending on whether the cylinder is type 1, 2, 3 or 4 respectively.

a) crushing the cylinder by mechanical means,

b) making an irregular hole in the top dome equivalent in area to approximately 10 % of the area of the top dome or, in the case of a thin-walled cylinder, by piercing in at least three places,

c) irregular cutting of the neck,

d) irregular cutting of the cylinder in two or more pieces including the shoulder, and

e) bursting the cylinder using a safe method.

Annex A
(informative)

Depressurization and purging of CNG fuel cylinders

A.1 Vehicle location

In the absence of a dedicated facility with approved procedures and access, the vehicle having the cylinder to be depressurized shall

a) be parked outside (e.g. not enclosed within a building or structure), and

b) have a defined a safety perimeter taking into account the direction and strength of the prevailing wind and any climatic conditions that might affect the safety of the operation.

In addition

c) suitable fire extinguishers should be available for instant use,

d) access through the safety perimeter should be prevented for any person not involved in the operation,

e) people around the safety perimeter should be warned that a depressurization of a cylinder containing flammable gas is to be performed,

f) it should be verified that there is no risk of ignition from sources within or close to the safety perimeter [e.g. the removal of all communication devices (radios, cellular phones, pagers, telephones, computers)], and

g) no more than one vehicle should be situated within the safety perimeter.

A.2 Cylinder depressurization

In the absence of a specific depressurization procedure

a) at least two operators should be present for the depressurization and maintain safe distance from the vehicle whenever possible,

b) operators within the perimeter shall wear noise protection, safety helmet, gloves and safety shoes,

c) the cylinder/valve manufacturer should be consulted prior to depressurization so as to obtain guidance regarding the proper venting of their equipment (e.g. if any special precautions or procedures are necessary),

d) prior to depressurization, it should be ensured that the vent line is clear, clean and free of any caps or devices and verified that the pipe can handle the venting pressure and that it does not choke the flow,

e) all personnel present should stand up-wind and at a safe distance from the vehicle during venting, and

f) once venting is complete, the cylinder may be disconnected and removed from the vehicle but it will still contain a small amount of residual gas. The cylinder should then be purged to cause it to be inert.

A.3 Inerting (purging)

WARNING — The introduction of air or an oxidizing gas or mixture to a cylinder containing even the smallest quantity of CNG is dangerous.

This operation should be performed using an inert gas (e.g. nitrogen), injected at a pressure of 1 bar or 2 bar, preferably when the cylinder is on a suitable support.

It can be verified that the cylinder does not contain an explosive gas mixture by using a suitable measuring instrument (e.g. a cathetometer or an explosimeter).

A.4 Storage

If the cylinder is to be stored, it shall be cleaned and dried internally.

Once it has been cleaned and dried, all openings of the cylinder should be sealed (e.g. using a secure plug).

Annex B
(informative)

Conditions and usage that may warrant more frequent inspections

B.1 General

NGV fuel storage systems may warrant more frequent inspections when their design or installation does not match specific risks. Consult the component manufacturer (including the cylinder manufacturer) when conditions or usage may warrant more frequent inspections. Examples of such conditions or usage are outlined in this Annex.

B.2 High usage

NGVs that utilize natural gas fuel in excess of 400 cylinder fills per year are considered to be in high usage. The regulations of the country of use, or the component/cylinder manufacturer, could require or recommend more frequent inspections of high usage vehicle fuel storage systems than would usually be necessary.

B.3 Terrain

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

B.4 Mounting/installation

NGVs for which all or part of the fuel storage system is exposed to elements such as bad weather, the sun, cargo, etc., and which have no designed protection of the system, are more likely to incur physical damage than those with a protected system. The inspection frequency should not exceed 48 months, which is appropriate for fuel storage systems located in the trunk of NGVs, enclosed in protective shields or mounted within the vehicle frame with no external exposure. The equipment manufacturer may recommend more frequent inspections of NGV fuel systems that are mounted with external or unprotected exposure.

B.5 Weather conditions

NGVs in extreme weather conditions (very hot, cold or wet) or in abnormal chemical atmospheres could require their fuel storage systems to be requalified more frequently than every 48 months. The effects of these extremes are dependent on type and cylinder design. Follow the recommended equipment manufacturer's advice regarding more frequent inspections under these conditions.

B.6 Natural gas composition

NGVs operating with an actual filled natural gas quality that does not match the gas composition specified in ISO 11439 could require internal inspection (see Annex D) or cylinder testing, which identifies wall loss due to corrosion or chemical interaction. Guidance can be obtained from the cylinder manufacturer and the natural gas provider.

Annex C
(informative)

Inspection checklist example

Vehicle Inspector Name:

Vehicle Inspector Organization:

Date:

Vehicle Mileage:

Vehicle Make and Model:

Vehicle Identification Number (VIN):

Manufacturer:

Part Number:

Serial Number:

Location:

An examination form shall be filled out for each fuel cylinder in an installation.

Yes	No		**Examination**IF “x_+3” “<Tbl_large_span_->” “”<Tbl_large_span_->IF “x_-3” “</Tbl_large_span_->” “”</Tbl_large_span_->
		1	Is the cylinder and mounting bracket area clean, free of dirt and ready for examination?
		2	Is the cylinder free from evidence of fire or exposure to extreme temperatures?
		3	Is the cylinder free from indications that the cylinder has been involved in an accident?
		4	Has the owner been questioned about any conditions or incidents that may have caused damage to the cylinder? (Report adverse findings below.)
		5	Is the installation in compliance with applicable regulations?
		6	Is this inspection being conducted prior to the expiration of the cylinder service life?
		7	Are the cylinder service pressure markings greater than or equal to the vehicle service pressure markings?
		8	Is there a minimum of 12,5 mm clearance around the cylinder when mounted? (A minimum standoff of 9,5 mm is recommended for shields.)
		9	If cylinders are enclosed in the vehicle, are they properly vented external 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 cylinder in place and in good condition?
		12	Is the cylinder firmly held in place by the brackets? (i.e. no rocking or looseness)
		13	Are the bolts that secure the brackets to the vehicle fully tightened?
		14	Are the mounting brackets in good condition and not bent, cracked or deformed?
		15	Is the vehicle free from damage where the mounting brackets are attached?
		16	Are bolts on brackets or straps torqued to proper levels?
		17	Are the valve and/or PRD assemblies free of damage?

Yes	No		**Examination**IF “x_+3” “<Tbl_large_span_->” “”<Tbl_large_span_->IF “x_-3” “</Tbl_large_span_->” “”</Tbl_large_span_->
		18	Are the valves and PRDs tightly seated? **(CAUTION — Do not loosen valves or PRDs while the tank is pressurized.)**
		19	Are the interfaces between the valves or PRDs and the cylinder free of leaks?
		20	If there are cuts, gouges or abrasions present, are they less than 0,25 mm deep?
		21	Is the cylinder free of impact damage? (e.g. surface discolouration, cracked resin, chipping, loose fibres)
		22	Is the cylinder free of surface dents?
		23	Is the cylinder free of rust, corrosion or etching of the outer surface?
		24	Is the cylinder surface free of discolouration?
		25	Is the external paint, composite layer or metal surface free of bubbles or bulges?
		26	Is the PRD in good condition, with no visible extrusion of fusible material?
		27	Are all PRDs 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?

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

Repair or replace brackets or other components, as follows:

Recommended disposition for fuel cylinderIF “x_+3” “<Tbl_large_->” “”<Tbl_large_->IF “x_-3” “</Tbl_large_->” “”</Tbl_large_->		
	1	Repair fuel cylinder, as follows:
	2	Send fuel cylinder to manufacturer for further inspection, as follows:
	3	Remove fuel cylinder from service and destroy.
	4	Return fuel cylinder to service.

Signature of inspector: _____.

Annex D
(informative)

Considerations for hydrostatic test and internal inspection

D.1 General

Hydrostatic testing and internal inspection are often conducted on cylinders used to transport compressed gases. However, there are issues relating to safety, reliability and system performance when using cylinders in CNG service as fuel cylinders on automotive vehicles that favour the use of external visual inspection. Conducting a hydrostatic test and/or internal inspection might create problems. The following list outlines issues that relate to the inspection of gaseous fuel cylinders for vehicles.

a) There could be difficulties in effectively cleaning fuel cylinder interiors prior to conducting an internal inspection. There could also be problems relating to the disposal of contaminants that adhere to the interior walls of the cylinder and are removed by cleaning, but which are not harmful, e.g. compressor oil or mercaptan. Internal inspection requires the release and purging of contents. This often results in the release of gas to the atmosphere.

b) If internal corrosion is a concern, introducing water through a hydrostatic test is not advisable because any water retained after the test could cause corrosion or affect engine performance. The implementing of a hydrostatic test requirement increases the chance of internal corrosion.

c) A hydrostatic test requires disconnection of fuel lines, removal of the cylinder from its mounting and removal of the valve. This process has to be reversed upon installation, and this introduces a risk associated with not reinstalling the valve properly, which could cause a reduction in thread strength or leakage. In such cases, the O-ring often needs to be replaced, and there is risk of fitting the wrong one. There is a risk associated with possible improper reinstallation of the cylinder in its mountings, of the cylinder dropping from its brackets if not properly installed, or of the brackets breaking. The brackets have rubber pads between the bracket and the tank, which are likely to be permanently deformed over time (i.e. take a permanent set), thus affecting the torque levels of bolts used on the straps. If the torque used is too low, the tank can slip. If the torque used is too high, the straps can break. To avoid problems related to reinstallation when pads have a permanent set, the pads should be replaced. Pad replacement incurs the risk that the new pads might not be reinstalled correctly, or even that the wrong pads might be used. There is some risk of improper reinstallation of fuel lines, which could lead to leaks or require the fittings to be replaced. In addition, there is a risk of someone dropping the cylinder while it is being removed, reinstalled or transported to and from the visual inspection location and/or the hydrostatic test location, as well as of damage to the threads when a test fitting is installed. Taking into account all these factors, it would appear that requiring an internal visual inspection or hydrostatic testing introduces much risk (and cost) with little, if any, gain.

d) Anecdotal evidence indicates that no hydrostatic test has revealed damage to a composite cylinder (burst tests are often performed on rejected cylinders) that was not obvious from visual inspection, and that some cylinders which have passed the hydrostatic test have been found to be faulty (e.g. in one or two cases, a repressurized cylinder ruptured at the retest facility within one week of testing, while awaiting shipment back to the owner). The most common cause for cylinder rejection in a hydrostatic test is some kind of problem with the test equipment itself (including false readings caused when the composite retains some of the water during a water jacket test). Similar anecdotal evidence exists for steel cylinders.

e) The hydrostatic test only identifies a significant change in elastic expansion or permanent set if all (or at least most) of the composite or liner are affected. Given that tanks are autofrettaged to a pressure of at least 150 % of service pressure, there needs to be a significant loss in modulus of the

composite to get strains high enough to allow permanent set of the liner. If defects are due to cracks, gouges or similar local damage, the test results are likely to be the same as for a good tank.

f) Generally speaking, composite materials are self-screening for UV, so only the outer layers are likely to be affected, which would be visually apparent by chalking or decomposition of the resin or protective paint. Exposure to acid or other harsh chemicals is likely to cause surface cracking of the composite; hence, it is unlikely that there could be universal damage to the composite without it being visually apparent.

g) ISO 11439 and similar national or regional standards have an extensive array of material, qualification and batch tests to ensure that the materials are acceptable, the designs are sound and the manufacturing process is repeatable. These standards have more test requirements than for conventional cylinders. The drop test, gunfire test, flaw tolerance test and environmental test provide considerable assurance that the cylinders can sustain damage or environmental exposure and still be safe.

h) When the original equipment manufacturers (OEMs) were consulted, one OEM representative indicated that they would not implement a requirement for disassembly for the purpose(s) of an internal inspection and/or a hydrostatic test. He cited their experience that the risk of improper installation was higher than any risk of missed defects. The OEMs currently neither require nor recommend that NGV cylinders be disassembled from their vehicles for the sake of a total external visual inspection, nor do they require any internal visual inspection or requalification test. The experience to date of the OEMs has proven this to be a safe and reliable practice.

i) Results of tests and data gathered have verified that unseen corrosion under strapping (where there is no outward visual evidence that such corrosion occurs under strapping) is very rarely missed, and that when it is, the risk of an incident resulting from such corrosion is far less than the risk involved in a poor reinstallation. Reports show that fuel cylinders have adequate strength even in the event that damage does occur under the strap region.

D.2 Conclusions

On the basis of worldwide experience over more than 40 years with hundreds of thousands of natural gas vehicles, it seems appropriate that NGV cylinders should be requalified by an external visual inspection, without disassembly of the cylinder, unless evidence at the time of inspection warrants its removal.

Bibliography

[1] ISO 9712, *Non-destructive testing — Qualification and certification of NDT personnel*

[2] EN 473, *Non-destructive testing — Qualification and certification of NDT personnel — General principles*

[3] Webster C.T., Wong J.Y. *Tolerance of NGV Containers to Damage Induced Under Mounting Bracket Straps*, GRI Report 97/0208, Gas Technology Institute, 1700 South Mount Prospect Road, Des Plaines, IL 60018, U.S.A. (Powertech Report 9221-36)

ICS 43.060.40, 23.020.30

Price based on 31 pages