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Gas cylinders — Composite cylinders and tubes — Periodic inspection and testing

Bouteilles à gaz — Bouteilles et tubes composites — Contrôles et essais périodiques

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 58, *Gas cylinders*, Subcommittee SC 4, *Operational requirements for gas cylinders*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 23, *Transportable gas cylinders,* in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This third edition cancels and replaces the second edition (ISO 11623:2015), which has been technically revised.

The main changes are as follows:

— revision of the Scope to include cylinders and tubes with a water capacity up to 3 000 l;

— modification of Table 1 to separate abrasion damage based on water capacity of the cylinder;

— clarification that a transparent sleeve may be left in place during inspection (7.1.3);

— clarification on the use of tare during inspection.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The principal aim of periodic inspection and testing is that at the completion of the test, the cylinders can be reintroduced into service. It is not possible to identify all considerations for periodic inspection and testing of composite cylinders in this document. In such cases or where there is doubt, questions regarding specific cylinders should be directed to the manufacturer or owner.

This document is intended to be used under a variety of national regulatory regimes but has been written so that it is suitable for the application of the UN Model Regulations.[1]

This document also gives other requirements concerning preparation, finishing and maintenance of composite cylinders and tubes as well as the safety precautions for the personnel performing this work. These requirements can be mandatory under other regulations.

Gas cylinders — Composite cylinders and tubes — Periodic inspection and testing

1 Scope

This document specifies the requirements for periodic inspection and testing to verify the integrity for further service of hoop-wrapped and fully-wrapped composite transportable gas cylinders and tubes, with aluminium-alloy, steel or non-metallic liners or of linerless construction (Types 2, 3, 4, and 5), intended for compressed, liquefied or dissolved gases under pressure, of water capacity from 0,5 l up to 3 000 l.

This document addresses the periodic inspection and testing of composite cylinders and tubes constructed according to ISO 11119-1, ISO 11119-2, ISO 11119-3, ISO 11119-4 or ISO 11515. It can be applied to other composite cylinders and tubes designed to comparable standards when authorized by the competent authority.

As far as practicable, this document can also be applied to cylinders of less than 0,5 l water capacity when authorized by the manufacturer.

NOTE Unless noted by exception, the use of the word "cylinder" in this document refers to both cylinders and tubes.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 7225, *Gas cylinders — Precautionary labels*

ISO 10286, *Gas cylinders — Vocabulary*

ISO 10460, *Gas cylinders — Welded aluminium-alloy, carbon and stainless steel gas cylinders — Periodic inspection and testing*

ISO 11114-2, *Gas cylinders — Compatibility of cylinder and valve materials with gas contents — Part 2: Non-metallic materials*

ISO 11119 (all parts), *Gas cylinders — Design, construction and testing of refillable composite gas cylinders and tubes*

ISO 11515, *Gas cylinders — Refillable composite reinforced tubes of water capacity between 450 l and 3000 l — Design, construction and testing*

ISO 11621, *Gas cylinders — Procedures for change of gas service*

ISO 13341, *Gas cylinders — Fitting of valves to gas cylinders*

ISO 13769, *Gas cylinders — Stamp marking*

ISO 18119, *Gas cylinders — Seamless steel and seamless aluminium-alloy gas cylinders and tubes — Periodic inspection and testing*

ISO 22434, *Gas cylinders — Inspection and maintenance of valves*

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 terms and definitions given in ISO 10286 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
composite overwrap
combination of *fibres* (3.3) (including steel wire) and *matrix* (3.15)

3.2
external coating
layer of material applied to the cylinder as a protective coating not intended to be removed or for cosmetic purposes

EXAMPLE Gel coat and paint.

Note 1 to entry: Not all composite cylinders have a special external coating.

3.3
fibre
load-carrying part of the *composite overwrap* (3.1)

EXAMPLE Glass, aramid or carbon.

3.4
Type 5 cylinder
fully wrapped cylinder without a *liner* (3.11) and with composite reinforcement on both the cylindrical portion and dome ends

3.5
Type 4 cylinder
fully wrapped cylinder with a non-load sharing *liner* (3.11) and composite reinforcement on both the cylindrical portion and dome ends

3.6
Type 3 cylinder
fully wrapped cylinder with a load sharing metal *liner* (3.11) and composite reinforcement on both the cylindrical portion and the dome ends

3.7
Type 2 cylinder
hoop-wrapped cylinder with a load-sharing metal *liner* (3.11) and composite reinforcement on the cylindrical portion only

3.8
translucent cylinder
cylinder that permits the passage of light

3.9
identification label
label containing the permanent markings required by the relevant design specification

3.10
design life
maximum life (in number of years) to which a composite cylinder or tube is designed and approved in accordance with the applicable standard

3.11
liner
inner portion of a composite cylinder, comprising a metallic or non-metallic vessel, whose purpose is both to contain the gas and transmit the gas pressure to the *composite overwrap* (3.1)

3.12
non-metallic liner
liner (3.11) made from thermoplastic, thermosetting or elastomeric material

3.13
sleeve
transparent or non-transparent cover fitted to the outside surface of the cylinder

3.14
repair
set of activities performed on defective pressure equipment to restore its compliance with the relevant specification

Note 1 to entry: Repair can include replacing worn or damaged parts meeting the original specification.

3.15
matrix
material that is used to bind and hold the *fibres* (3.3) in place

Note 1 to entry: The matrix is sometimes called resin.

3.16
rejected cylinder
cylinder not fit for service or which needs to be set aside for further evaluation or testing in its present condition

3.17
bulge
visible swelling of the wall

Note 1 to entry: A bulge is away from the centre line (convex) and a dent is towards the centre line (concave).

3.18
crack
split or separation in the material, typically appearing as a line on the surface

3.19
crease
off-colour linear or non-linear feature formed as a result of previous localized over-stressing

3.20
protective attachment
component connected to the cylinder that prevents or resists damage to the composite cylinder

EXAMPLE Casing.

Note 1 to entry: Some protective attachments are designed to be removed at the time of periodic inspection and testing.

3.21
permanent protective attachment
integral part of the cylinder design permanently affixed to composite cylinders (Types 2 to 5) covering part of or the entire surface of the cylinder, providing additional functions during handling, transport and use

3.22
stoving
treat by heating (e.g. in an oven) in order to apply a desired surface coating

4 Due dates for periodic inspection and testing

A cylinder shall be due for periodic inspection and testing on its first receipt by a filler following the expiry of the interval established in accordance with the requirements of national or international regulations or, in the absence of regulations, in accordance with the UN Model Regulations.[1]

NOTE Annex A provides guidance regarding the intervals between periodic inspection and testing.

The expiry date is based on the last test date shown on the cylinder. Other means of indicating the expiry date are permitted.

Provided the cylinder has not been subjected to abusive and abnormal conditions such as being involved in an accident, heat exposure or other severe conditions that would render it unsafe, there is no requirement for the user to return a cylinder before the contents have been used even though the periodic inspection and testing interval has lapsed.

When the design life has expired, the cylinder shall not be refilled and shall be removed from service when presented for the next filling (see Clause 13).

In some jurisdictions, it is the responsibility of the owner or user to submit cylinders used for emergency purposes for periodic inspection and testing within the specified interval.

5 Procedures for periodic inspection and testing

5.1 List of procedures

The inspection, testing and repair of composite cylinders shall be carried out only by competent persons in suitable facilities for cylinders of the size and type being requalified. Care shall be taken to ensure that during the retest procedure, cylinders are handled carefully, particularly with respect to loading. When moving from handling pallets or other transport frames, processes shall be developed to ensure cylinders are not dropped or impacted during movement. Special handling methods and tooling may be required to safely handle cylinders.

Handling procedures shall be available at the authorized inspection site.

Tests and examinations performed to demonstrate compliance shall be conducted using instruments calibrated before being put into service and thereafter according to an established programme.

Each cylinder shall be submitted to periodic inspection and testing. The following procedures form the requirements for this periodic inspection and testing and are explained more fully in this document in the noted clauses:

— identification of cylinder and preparation for periodic inspection and testing (see Clause 6);

— external visual inspection (see Clause 7);

— safe removal of valve (see 8.2);

— internal visual inspection and cleaning (see 8.3);

— pressure test (see Clause 9);

— leak test (see Clause 10);

— inspection of valve (see Clause 11);

— final operations (see Clause 12);

— rejection and rendering cylinders unserviceable (see Clause 13).

The external and internal visual examination (see Clauses 7 and 8) shall be carried out prior to the pressure test (see Clause 9). It is recommended that the other tests are performed in the sequence listed in 5.1; for the safe removal of a valve, the requirements in ISO 25760 shall be met.

Cylinders that fail inspection or testing shall be rejected (see Clause 13). When a cylinder passes the procedures listed in 5.1, but the condition of the cylinder remains in doubt, additional testing shall be performed to confirm its suitability for continued service or the cylinder shall be rendered unserviceable. Depending on the reason for the rejection, cylinders may be recovered and/or repaired (see 7.4).

5.2 Heat exposure

When cylinders are refurbished during periodic inspection, it can be necessary to expose them to heat, for example, during initial cleaning, or as part of a stoving operation when painting or powder coating the cylinder. This heat exposure can affect the mechanical properties of the liners and/or the finished composite cylinder.

It is therefore essential that information on precise heat-effect temperatures from the cylinder manufacturer be available; in the absence of this information, cylinders shall not be exposed to a temperature exceeding 70 °C during refurbishment. If the cylinder manufacturer confirms (i.e. either on a cylinder label or through documentation) that the allowable temperature is greater than 70 °C, then the manufacturer's recommendations shall be followed during refurbishment.

6 Identification of cylinder and preparation for periodic inspection and testing

Before any work is carried out, the relevant cylinder marks (as defined in ISO 13769) and the gas contents (as defined in ISO 7225) shall be identified. The marking shall be checked to ensure that the cylinder in question is within its design life. When composite cylinders have been designed and manufactured for a limited design life, this is indicated on the cylinder marking.

The cylinder shall be depressurized and emptied in a safe, controlled manner before proceeding. For Type 4 and Type 5 cylinders, take necessary precautions and/or consult the cylinder manufacturer for depressurization procedures to avoid damaging the cylinder.

WARNING — The uncontrolled opening and/or removal of valves from cylinders can lead to injury, death and/or property damage.

Prior to valve removal, the user shall follow the procedures described in ISO 25760 to verify that the cylinder is empty of gas. Provided that the requirements in ISO 25760 have been complied with, the cylinder shall be considered safely depressurized, and the valve shall be removed.

Cylinders with unknown gas contents shall be emptied as if the gas is dangerous (i.e. toxic, flammable or oxidizing) as described in ISO 25760.

When the valve is non-functional, cylinders shall be emptied safely as described in ISO 25760.

Access shall be provided to the entire external surface of the cylinder for visual inspection and measurement.

7 External visual inspection

7.1 Preparation

7.1.1 General

The composite material including any external coating applied for protection shall not be removed for the visual inspection.

Composite cylinders differ from their metal counterparts in that a competent person may repair them when only limited damage has taken place (see 7.4). (This repair is not allowed for metal cylinders.) These limits are specified in Table 1. Following this repair, cylinders shall be subjected to a pressure test before being returned to service.

If the cylinder identification label is illegible, the manufacturer shall be contacted, or the cylinder shall be rejected in accordance with Clause 13.

The manufacturer can provide a supplementary identification label to the cylinder if, as a minimum, the original label's serial number is still clearly legible.

When the cylinder manufacturer provides acceptance/rejection criteria for external damage, it takes precedence over the criteria specified in Table 1.

7.1.2 Permanent protective attachments

Permanent protective attachments of the composite cylinder shall not be removed prior to inspection, provided that these attachments are part of the original design. The manufacturer shall provide acceptance/rejection criteria to be applied during the visual inspection for any damage to the permanent protective attachments.

Markings specific to permanent attachments on the cylinder shall indicate if the attachments shall remain in place at the time of the periodic inspection and testing. If such markings are not present, the cylinder manufacturer shall be consulted to establish whether the permanent attachments need to be removed.

7.1.3 Sleeves

When a transparent sleeve is used, it may be left in place as long as the composite wrapping can be inspected effectively without its removal.

When a non-transparent sleeve is used that is not part of the cylinder design, it shall be removed prior to inspection.

When the cylinder is suspected to be damaged, or if there are concerns regarding the operating environment of the cylinder, e.g. saline atmosphere, the transparent sleeve shall be removed, and an inspection of the composite material undertaken.

7.1.4 Cleaning

Care shall be taken not to remove any evidence of in-service damage (e.g. heat and fire damage), which can affect the outcome of this inspection (see Table 1).

Each cylinder shall be cleaned and have all loose foreign matter removed from its external surface by a suitable method (e.g. washing, light brushing, controlled water jet cleaning, plastic bead blasting).

Grit and shot blasting are not suitable. Chemical cleaning agents, paint strippers and solvents shall not be used unless it has been established that they would not have an adverse effect on the cylinder or its materials.

Care shall be taken to ensure the legibility of the identification marks when undertaking a cleaning operation.

7.2 Inspection procedures

The cylinder manufacturer should determine the acceptance/rejection criteria for external damage and make the criteria available to the inspector. The manufacturer's guidance takes precedence over the criteria outlined in Table 1.

The acceptance/rejection criteria given in Table 1 are to be followed in the absence of specific instructions from the manufacturer of the cylinder being examined. The external metallic surface of hoop-wrapped cylinders shall be visually inspected in accordance with the applicable clauses of ISO 18119. Particular attention shall be paid to the interface with the composite overwrap to check for crevice corrosion.

The external surface shall be inspected for damage to the composite overwrap. There are three levels of damage that shall be considered (see 7.3.2); of these, only Level 2 can be repaired (see Table 1).

7.3 Damage

7.3.1 General

Damage to the composite overwrap can appear in many forms, and examples of these are described in 7.3.3. The acceptance/rejection criteria are specified in Table 1, which refers to specified damage levels and the types of damage. Care shall be taken to establish the total extent of damage from impact (see 7.3.3.3) and delamination (see 7.3.3.4) as surface appearance will possibly not indicate the full extent of the damage.

Annex B specifies additional damage criteria for steel wire wound, aluminium-alloy cylinders that shall be taken into account.

When damage is caused by installation (e.g. trailer or bundle), severity or conditions of service, or by improper cylinder use, the inspector should 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. Such actions should be developed with the manufacturer of the cylinder and the original installer.

7.3.2 Damage levels

7.3.2.1 General

The surface of the cylinder shall be inspected for evidence of damage. Damage shall be evaluated in accordance with Table 1. For damage not specified in this document, the manufacturer shall be consulted for guidance.

7.3.2.2 Level 1 damage

Cylinders with minor or superficial damage are categorized as having Level 1 damage. Such damage has no adverse effects on the safety of the cylinder and its continued use. These cylinders may be returned to service with no repair.

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.

7.3.2.3 Level 2 damage

Level 2 damage is rejectable damage that requires repair, testing or rendering the cylinder unserviceable. 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.

7.3.2.4 Level 3 damage

Level 3 damage is sufficiently severe that the cylinder shall not be repaired but shall be rejected and subsequently rendered unserviceable. See Tables 1 and 2.

7.3.3 Types of external damage

7.3.3.1 Abrasion damage

Abrasion damage is caused by wearing, grinding or rubbing away by friction of the overwrap material. Minor abrasion damage to the protective coating or paint is shown in Figure 1 a) and b). "Flat spots" evident on the surface can indicate excessive loss of composite overwrap thickness [see Figure 1 c)].

7.3.3.2 Damage from cuts

Cuts or gouges are caused by contact with sharp objects in such a way as to cut into the composite overwrap, reducing its thickness at that point, see Figure 2 a), b) and c).

7.3.3.3 Impact damage

Impact damage can appear as hairline cracks in the resin, or delamination or cuts of the composite overwrap, see Figure 3 a) and b). The resin can have a frosted, crazed or opaque appearance.

7.3.3.4 Delamination

Delamination is a separation of layers of strands, or of the strands themselves, of the composite overwrap, see Figure 4 a) and b). It also can appear as a whitish patch, like a blister, or an air space beneath the surface.

7.3.3.5 Heat or fire damage [see Figure 5 a) and b)]

7.3.3.6 Structural damage

Structural damage is any evidence of:

— external bulges, distorted neck thread connections or depressions not originally designed;

— bulging of the liner of Type 2 or Type 3 cylinders;

— internal bulging of Type 4 or Type 5 cylinders.

7.3.3.7 Chemical attack

Chemical attack would appear as the dissolution of the matrix surrounding the fibres, see Figure 6 a) and b). The resulting cylinder surface can be pitted, feel soft/sticky, discoloured, etc.

7.3.3.8 Loose permanent attachments

For example, signs of a collar, neck ring or permanent protective attachment that is part of the design becoming loose are causes for rejecting the cylinder.

7.3.3.9 Damaged permanent attachments

Damage to permanent attachments, e.g. cage, outer casing, permanent protective attachment, etc., excluding transparent sleeves (see 7.1.3), that are part of the original cylinder design is Level 3 damage unless the manufacturer provides an inspection manual of damage criteria based on experimental data.

7.3.3.10 Improper repairs

Signs of damage in the repaired area in excess of Level 1 are causes for rejecting the cylinder.

Table 1 — Acceptance/rejection criteria for external damage

Type of damage	Level of damage		
	Level 1 **Acceptable damage**	**Level 2** **Rejectable damage (requiring additional inspections or repairs)**	**Level 3** **Condemned damage (not repairable)**
Abrasion damage for cylinders with a water capacity of less than 80 l	Damage to the following depth is acceptable: Less than or equal to 10 % of the thickness of the composite overwrap with a maximum length in any direction of 25 % of the cylinder diameter.	Damage greater than Level 1 but less than Level 3 shall be referred to the manufacturer for repair procedures. Otherwise, the damage shall be considered Level 3. If the manufacturer does not provide repair instructions, the damage shall be considered Level 3.	Without further reference to manufacturer's instructions, damage greater than 10 % of the thickness of the composite overwrap or with a maximum length in any direction more than 25 % of the cylinder diameter shall be considered Level 3.
Abrasion damage for cylinders with a water capacity of 80 l or more	Damage to the following depth is acceptable: Less than or equal to 15 % of the thickness of the composite overwrap with a maximum length in any direction of 15 % of the cylinder diameter.	Damage greater than Level 1 but less than Level 3 shall be referred to the manufacturer for repair procedures. Otherwise, the damage shall be considered Level 3. If the manufacturer does not provide repair instructions, the damage shall be considered Level 3.	Without further reference to manufacturer's instructions, damage greater than 15 % of the thickness of the composite overwrap or with a maximum length in any direction more than 15 % of the cylinder diameter shall be considered Level 3.
Damage from cuts for cylinders with a water capacity of less than 80 l	Damage to the following depth is acceptable: Less than or equal to 20 % of the thickness of the composite overwrap to a maximum of 2 mm.	Damage greater than Level 1 but less than Level 3 shall be referred to the manufacturer for repair procedures. Otherwise, the damage shall be considered Level 3. If the manufacturer does not provide repair instructions, the damage shall be considered Level 3.	Without further reference to manufacturer's instructions, damage greater than 20 % of the thickness of the composite overwrap to a maximum of 2 mm shall be considered Level 3.
Damage from cuts for cylinders with a water capacity of 80 l or more	Damage to the following depth is acceptable: Less than or equal to 20 % of the thickness of the composite overwrap to a maximum of 2 mm	Damage greater than Level 1 but less than Level 3 shall be referred to the manufacturer for repair procedures. Otherwise, the damage shall be considered Level 3. If the manufacturer does not provide repair instructions, the damage shall be considered Level 3.	Without further reference to manufacturer's instructions, damage greater than 20 % of the thickness of the composite overwrap to a maximum of 2 mm shall be considered Level 3.

Table 1 *(continued)*

Type of damage	Level of damage		
	Level 1 **Acceptable damage**	**Level 2** **Rejectable damage (requiring additional inspections or repairs)**	**Level 3** **Condemned damage (not repairable)**
Impact damage	Damage from impact, which causes a frosted appearance or hairline cracking in the impact area that is less than 25 mm in diameter without permanent deformation, is acceptable.	Damage greater than Level 1 shall be referred to the manufacturer for evaluation. Otherwise, the damage shall be considered Level 3.	Without further reference to manufacturer's instructions, damage greater than Level 1 shall be considered Level 3.
Delamination	No visible delamination	Loose fibre ends from the termination of the wrapping process shall be repaired.	Delaminating fibres not included in Level 2
Heat or fire damage	When the composite overwrap is only soiled from smoke or other debris and is found to be suitable for further service. Additional attention shall be given to cylinders with an aluminium-alloy liner/boss or a non-load sharing liner.	Damage greater than Level 1 no repair allowed – consider as Level 3.	Cylinders with evidence of heat or fire damage greater than Level 1 shall be rendered unserviceable.
Composite matrix shows deterioration and/or loose fibres	Yellowing of the external surface, or superficial deterioration of the matrix No fibre ends exposed	Minor deterioration of the matrix, exposing the outermost layer of reinforcing fibres. Repair in accordance with 7.4	Extensive deterioration, fibres have become exposed and loose
Structural damage	Not acceptable	No repair allowed	Cylinders with structural damage shall be rendered unserviceable.
Chemical attack	When the cylinder has only superficial discoloration	If the chemical's nature is known, the cylinder manufacturer shall provide documentation confirming Level 1 or 2. If Level 2, the manufacturer shall suggest a suitable repair procedure.	All cylinders if chemical unknown Any attack of the fibre
Missing/illegible identification label or markings	Not applicable	When the manufacturer can unmistakably identify the cylinder, by at least the serial number, a new label shall be supplied by the manufacturer and affixed or the marks applied either by the inspector or the manufacturer (see ISO 13769).	All cylinders that cannot be identified and relabelled/ remarked
Loose permanent attachments	Not applicable	Repair possible provided manufacturer gives written consent.	All cylinders other than those in Level 2
Improper repair	Not applicable	Following a repair (see 7.4), all defects can be repaired a second and final time; the cylinder shall be retested.	All cylinders with defects after the second repair

Table 1 *(continued)*

Type of damage	Level of damage		
	Level 1 **Acceptable damage**	**Level 2** **Rejectable damage (requiring additional inspections or repairs)**	**Level 3** **Condemned damage (not repairable)**
Damaged permanent attachment	No damage or minor damage such as nicks, scratches consistent with normal wear	When dented, cracked, broken, showing other signs of damage (e.g. discolouration from impact) or as advised by the manufacturer. Permanent attachment to be removed and composite cylinder to be assessed for damage. New attachment may be fitted provided cylinder suitable for further service.	If Level 2 damage exists and replacement of the damaged attachment is not possible Or If the composite cylinder shows damage adjacent to a damaged area on the attachment

7.4 Repairs

Any repairs shall be made by a person competent in repair procedures.

A resin system compatible with that used in the construction of the cylinder may be used to repair composite cylinders. Reference shall be made to the manufacturer for the repair procedure.

All repaired cylinders shall be subjected to a pressure test before being returned to service. After the pressure test, the repairs shall be examined for lifting, peeling or delamination of the composite overwrap. The damage criteria identified in 7.3 shall be used. In the event of a failure, if it can be established that the repair procedure was inadequate or not followed, then a second and final repair may be performed.

Any cylinder showing signs of a repair from a previous inspection shall not be repaired in the same area.

Figure 7 a) through e) illustrates the sequence of a typical repair procedure.

8 Internal visual inspection

8.1 Translucent cylinders

Annex C specifies additional internal visual inspection requirements for translucent cylinders that shall be followed and supersede the requirements of Clause 8.

8.2 Safe removal of valve

The valve shall not be removed until it is verified that there is no pressure inside the cylinder. A valve in the open position does not guarantee that the cylinder is not pressurized. The procedures in ISO 25760 shall be followed for the safe removal of a valve.

8.3 Internal visual inspection and cleaning

8.3.1 General

The whole of the internal surface of each cylinder shall be inspected, using an adequate technique and illumination to identify any imperfections present.

8.3.2 Metallic liners

A cylinder that shows the presence of foreign matter, or signs of more than light surface corrosion, shall be cleaned internally under closely controlled conditions. Care shall be taken to avoid damaging the liner and composite materials.

8.3.2.1 Steel liners

Suitable cleaning methods such as shot blasting, water jet abrasive cleaning, steam jet, hot water jet, rumbling, chemical cleaning or others may be used. The method used to clean the cylinder shall be a validated, controlled process.

If the cylinder has been cleaned by one of the methods in 8.3.2.1, the internal surface shall be visually inspected after the cleaning operation in accordance with the applicable clauses of the relevant standard (e.g. ISO 18119 or ISO 10460) or manufacturer's guidelines.

Ensure that the cylinder is thoroughly dried after cleaning.

See Annex D, Table D.1 for a list of gases that are corrosive to steel liners and steel bosses.

8.3.2.2 Aluminium-alloy liners

Suitable cleaning methods such as water jet abrasive cleaning, steam jet, hot water jet, chemical cleaning, blasting with glass beads or others may be used. The method used to clean the cylinder shall be a validated, controlled process.

Cleaning with material other than aluminium beads, glass beads or other abrasive materials shall be avoided. Hard media can embed itself in the aluminium, which can cause galvanic corrosion. Alkaline solutions and paint strippers that are harmful to aluminium and its alloys shall not be used.

If the cylinder has been cleaned by one of the methods in 8.3.2.2, it shall be dried immediately after being cleaned and the internal surface shall be visually inspected in accordance with the applicable clauses of the relevant standard (e.g. ISO 18119 or ISO 10460) or manufacturer's guidelines.

Ensure that any aqueous liquid does not stay in the cylinder for more than two hours.

See Annex E for more information on cleaning seamless aluminium-alloy liners.

8.3.3 Linerless and non-metallic liners

For cylinders without liners or with non-metallic liners, the following criteria shall be used.

A cylinder showing the presence of foreign matter shall be cleaned internally under closely controlled conditions by controlled water jet abrasive cleaning or a method recommended by the manufacturer. Any cleaning methods and/or chemical solutions used for cleaning shall be in accordance with the cylinder manufacturer's procedures.

After cleaning and drying, the cylinders shall be inspected again and any cylinder showing discolouration or other surface defect (i.e. heat damage, chemical attack, cracks, bulges) shall be leak tested (see Clause 10).

8.4 Types of internal damage

8.4.1 Type 2 and Type 3 cylinders

8.4.1.1 Cracking

Cracking of the liner can occur as a result of stress corrosion or fatigue.

8.4.1.2 Dented liner

For Type 2 and 3 cylinders with metallic liners, deflection of the liner toward the centre line of the cylinder can be caused by a severe impact on the external surface.

8.4.1.3 Discoloured interior

A discoloured interior can be caused by chemical attack or contamination and can be identified as either local or widespread discolouring.

8.4.1.4 Corrosion pitting of the interior

Corrosion of the liner is indicated by corrosion pitting of aluminium or by rust on steel. Each case demonstrates the loss of structural metal to corrosion, and this may lead to failure by leakage. See Figure 8.

8.4.1.5 Bulge outward

Outward bulges or deflection of the internal surface away from the centre line can occur as a result of damage to the composite overwrap.

8.4.2 Type 4 cylinders

8.4.2.1 Inward bulging liner

For Type 4 cylinders with non-metallic liners, bulging of the liner caused by an improper depressurization is not considered structural damage.

8.4.2.2 Blistered liners

For cylinders with non-metallic liners, blistering of the liner can occur, for example, due to rapid depressurisation, and can result in leakage.

8.4.2.3 Indications of chemical attack

Chemical attack can be identified through loss of material or discoloration due to internal contamination or from the gas product.

8.4.2.4 Indications of melting

Exposure to external heat or rapid compression can be identified as, for example, flow or lack of material and deformation of the liner surface.

8.4.2.5 Discoloured interior

A discoloured interior can be caused by chemical attack or contamination and can be identified as either local or widespread discolouring.

8.4.2.6 Crease

Creases are seen as sharp folds/overlaps in the liner caused by, for example, yielding of the liner through bulging.

8.4.3 Type 5 cylinders

Deterioration or loose fibres can be caused by, for example, chemical attack or ageing of the composite matrix.

8.4.4 Excess resin droplets

Excess resin can be a result of improper repair or, in the case of 2-part cylinders, from the process of joining the two parts in the manufacturing process.

8.5 Inspection of cylinder neck

The internal neck threads (valve connections) and the area of the cylinder below the neck threads shall be inspected in accordance with ISO 18119.

External neck threads or mounting fastener threads shall be inspected using the manufacturer's recommendations.

All collars shall be inspected if fitted.

8.6 Inspection criteria

For Type 2 and Type 3 cylinders, denting of the liner is irreparable and the cylinder shall be condemned in accordance with Clause 13. Any Type 2 or Type 3 cylinder with a bulge that is visible internally shall be cause for rejection.

The cylinder manufacturer shall determine the acceptance/rejection criteria for internal damage, which takes precedence over the criteria outlined in Table 2 and 8.3.

Table 2 describes certain criteria for Type 4 and Type 5 cylinders to be followed in the absence of specific instructions from the manufacturer of the cylinder being examined. A substantial variety of liner materials and their associated designs exist, making a comprehensive and uniform description difficult to formulate within this document. The inspector shall contact the manufacturer and obtain specific instructions for the cylinder design. The criteria in Table 2 can be used when manufacturer's instructions cannot be obtained.

Table 2 — Acceptance/rejection criteria for internal damage of Type 4 and Type 5 cylinders

Type of damage	Level of damage		
	Level 1 Acceptable damage	Level 2 Rejectable damage (requiring additional inspections or repairs)	Level 3 Condemned damage (not repairable)
Bulge outward	None	Not allowed	Any
Inward bulging liner (Type 4 cylinders with non-metallic liners)	Inward bulging but with no visible fold/crease	If no manufacturer guidance is available, it shall be considered Level 3.	Any bulging in excess of Level 2
Blistering of non-metallic liner	Blisters covering less than 10 % of the surface area and no single blister larger than 5 % of the cylinder's external diameter.	In the absence of manufacturer's guidance, blistering in excess of Level 1 shall be considered Level 3.	Blisters torn open Any blistering in excess of Level 2
Cracking	None	Not allowed	Any

Table 2 *(continued)*

Type of damage	Level of damage		
	Level 1 **Acceptable damage**	**Level 2** **Rejectable damage (requiring additional inspections or repairs)**	**Level 3** **Condemned damage (not repairable)**
Indications of chemical attack	None Or If liquid/chemical is detected and identified and does not adversely affect internal materials, e.g. oil in liquefied petroleum gas cylinders, can be cleaned out and dried.	If liquid/chemical is present and not identified, it shall be classified as Level 3 damage.	Not leak tested or failed leak test (see Clause 10) or liquid/chemical is unidentified Or Liquid/chemical is detected and identified and is not compatible with the internal materials
Indications of melting	None	Not allowed	Any
Discoloured interior	None or known to be inconsequential	If discoloration is from a known source that does not affect cylinder safety or performance, then can be removed if possible or Level 1. Can be leak tested if discoloration is from unknown source (see Clause 10).	Any reason for discolouration that adversely affects cylinder safety and/or performance. Not leak tested or failed leak test (see Clause 10)
Composite matrix (no liner) shows deterioration and/or loose fibres	None or minor confirmed to pass leak test (see Clause 10)	A few strands noted or doubtful, then shall pass leak test (see Clause 10)	Not leak tested or failed leak test (see Clause 10) OR When deterioration is extensive
Crease	None	Not allowed	Any
Excess resin droplets (no liner only)	None or identified as excess resin	Not applicable (no need to repair)	Not applicable

9 Pressure test

Each cylinder shall be subjected to a pressure test using a suitable fluid, normally water, as the test medium. When a cylinder is pressure tested with water, the internal surface shall be dried as soon as possible after the test. Leaving water in Type 2 or Type 3 cylinders for a prolonged period can cause corrosion. Either the proof pressure test or the hydraulic volumetric expansion test may be replaced by a pneumatic proof pressure test.

All types of composite cylinders covered by this document shall be pressure tested in accordance with the relevant design standards such as ISO 11119-1, ISO 11119-2, ISO 11119-4, ISO 11515 or the proof pressure test in ISO 11119-3, as appropriate. The test pressure shall be established from the marking on the cylinder.

In the case when a pneumatic pressure test is carried out, appropriate measures should be taken to ensure safe operation and to contain any energy that can be released.

WARNING — Appropriate measures shall be taken to ensure safe operation and to contain any energy that can be released. Pneumatic proof pressure tests require more precautions than hydraulic volumetric expansion tests, regardless of the size of the cylinder or tube. Errors in carrying out this test can lead to a rupture under gas pressure. Therefore, these tests shall be carried out only after ensuring that the safety measures adopted satisfy the safety requirements.

Special care shall be taken using air as the medium for the pneumatic pressure test due to the oxidizing potential of high-pressure air. At 300 bar[1)], the partial pressure of oxygen is approximately 60 bar.

Any cylinder failing to conform to the requirements of this test shall be rejected.

The pressure test may be replaced by a suitable non-destructive examination (NDE) technique (e.g. ISO 23876, ISO/TS 19016) with agreement between the manufacturer and the competent authority.

When a cylinder is used in an assembly in a protective frame, a pneumatic proof pressure test of the entire assembly may be conducted, where allowed by the competent authority of the country of use.

10 Leak test

WARNING — Appropriate measures shall be taken to ensure safe operation and to contain any energy that can be released. Pneumatic pressure tests require more precautions than hydraulic tests, regardless of the size of the cylinder or tube. Errors in carrying out this test can lead to a rupture under gas pressure. Therefore, these tests shall be carried out only after ensuring that the safety measures adopted satisfy the safety requirements.

Leak testing of the cylinder surface, i.e. excluding the valve and fittings, shall be performed on Type 4 and Type 5 cylinders when indicated by the nature of the imperfections found during the internal inspection as noted in Table 2. This leak test shall be conducted after completion of the pressure test. The following method is an example for leak testing and is recommended, but alternatives which achieve the same result are permitted.

— Pressurize the cylinder to 2/3 of the test pressure with a gas compatible with the previous contents and liner. In most cases, this can be air or nitrogen.

— Maintain this pressure in the cylinder for not less than 2 h.

— Conduct a bubble leak test for at least 10 min. The cylinder shall be visually checked for leaks using a suitable technique (e.g. cylinder immersion or with soapy water).

A failure of the leak test occurs if:

— for cylinders with a water capacity up to and including 450 l: leakage greater than 1 bubble/min, i.e. 6 ml/h in the bubble leak test; or

— for tubes with a water capacity greater than 450 l up to 3 000 l: leakage greater than 2 bubble/min, i.e. 12 ml/h in the bubble leak test.

Adequate safety precautions should be taken to contain any energy that can be released.

This test may be augmented or replaced with a compatible trace gas detection system with an accuracy comparable to or better than the bubble leak test.

The difference between leakage and the expulsion of trapped gas between the liner and composite overwrap in Type 4 cylinders shall be considered.

Liners in Type 4 cylinders can absorb gas when the cylinder is pressurized. Absorbed gas will be released from the liner when the cylinder is depressurized for inspection. Gas will be released from the liner both into the cylinder, as well as trapped between the liner and the composite overwrap. The amount of gas trapped will be less than the absorbed amount of gas in the liner. When pressurizing the cylinder after inspection, trapped gas can be expelled through the composite overwrap and/or at the boss/liner interface.

Initially, the rate of gas that is expelled can be greater than the acceptance criteria for a leak but will gradually decrease until the trapped gas is expelled.

1) 1 bar = 0,1 MPa = 10^5 Pa; 1 MPa = 1 N/mm^2.

11 Inspection of valve

If a used valve is to be reintroduced into service, it shall be ensured that only valves inspected and maintained in accordance with ISO 22434 are fitted.

12 Final operations

12.1 Drying and cleaning

The interior of each cylinder shall be thoroughly dried by a suitable method immediately after the pressure test to remove all traces of free water. The interior of the cylinder shall be inspected to ensure that it is dry and free from other contaminants. If heat is used for drying, care shall be taken to ensure that the maximum time and temperature as indicated in 5.2 are not exceeded.

12.2 Painting

Composite cylinders are not required to have their original paint renewed. When repainting is undertaken, it shall be carried out with great care to ensure that no damage is caused to any of the composite surfaces for pre-paint surface conditioning. When the original paint has to be removed or the surface pre-conditioned, it shall be done using the manufacturer's specifications. Cylinders are sometimes repainted using paints that require stoving. In these circumstances, care shall be taken to ensure that the maximum time and temperature as indicated in 5.2 are not exceeded so that the cylinder is not degraded in any way. It is recommended that manufacturers be contacted for appropriate paint specifications and painting procedures for their cylinders.

Care shall be taken that the identification label is masked out prior to painting to maintain its legibility.

12.3 Cylinder re-valving

If re-valving is required after the pressure test, the neck thread shall be reinspected in accordance with 8.4 before the cylinder is re-valved to verify absence of damage.

The valve shall be fitted to the cylinder using a suitable method of sealing. The optimum torque necessary to ensure both the seal between the valve and the cylinder and prevent any possibility of over stressing of the neck shall be used in accordance with ISO 13341 for the most common ISO thread sizes unless contrary information is shown on the label. For other threads, see ISO/TR 11364.

When the use of lubricants/sealing material is permitted, only those compatible with the gas service shall be used, taking particular care for oxygen service, in accordance with ISO 11114-2 or ISO 13341.

12.4 Check of cylinder tare

These requirements only apply when permanent attachments are replaced (e.g. valves, protective attachments) on cylinders for liquefied gases. The cylinder tare shall be obtained using a weighing machine that is regularly calibrated and checked for accuracy. The capacity of the weighing machine shall be suitable for the weight of the appropriate cylinders.

The tare shall include the mass of the cylinder, valve(s) and all permanent attachments. If the tare of the cylinder differs from the marked tare, the original tare shall be cancelled, and the correct tare marked in a permanent and legible fashion in accordance with ISO 13769. Table 3 gives examples of acceptable deviation of the tare weight between scale and stamped marks.

Stamp marking of the composite overwrap is not permitted.

Table 3 — Maximum differences between scale weight reading to marked tare

Cylinder water capacity V l	Maximum permissible deviation in tare g
$0,5 \leq V < 1,0$[a]	±25
$1,0 \leq V < 5,0$	±50
$5,0 \leq V \leq 20$	±200
$20 < V \leq 80$	±400
NOTE For cylinders of water capacity greater than 80 l, a different maximum permissible deviation in their tare can be necessary. [a] For cylinders with less than 0,5 l of water capacity, the maximum weight deviation should be reduced to a value less than 25 g.	

12.5 Retest marking

After satisfactory completion of the periodic inspection and test, each cylinder shall be permanently marked by stamping or affixing a label in accordance with the relevant national regulation or relevant standard, e.g. ISO 13769. The marking should include:

a) the character(s) identifying the country that authorizes the body performing the periodic inspection and testing as indicated by the distinguishing signs of motor vehicles in international traffic specified in the UN Model Regulations[1];

b) the mark or symbol of the authorized testing facility;

c) the present test date (as either YY/MM or YYYY/MM).

The mark may be engraved on a ring made of a material compatible with the gas service and affixed to the cylinder when the valve is installed. The ring can only be removed by disconnecting the valve from the cylinder.

12.6 Reference to next periodic inspection and test date

The next periodic inspection and test date may be shown by an appropriate method such as by a plastic-coloured ring/disc fitted between the valve and the cylinder indicating the year (and the month, when required) of the next periodic inspection and/or tests.

Annex F provides one example of an existing system for indicating retest dates; other systems are in use, and the same systems are used but with different colours for the same year.

12.7 Identification of contents

If the identification of the cylinder's contents is required, then ISO 7225 and ISO 32 can be used as examples for labelling and colour coding, respectively.

If painting is required, care shall be exercised in accordance with 12.2.

If a change of gas service is involved, follow the requirements of ISO 11621.

12.8 Records

The inspector shall record details of the present test and the following information shall be available:

— owner's name;

— owner's and/or manufacturer's serial number;

— cylinder tare where applicable;

— test pressure;

— present test date;

— year of manufacture;

— identification symbol of the authorized body carrying out the inspection;

— identification of inspector;

— details of any modifications made to the cylinder by the inspector.

Additionally, it shall be possible to obtain the following items of information from records which need not necessarily be kept in a single file but will enable a particular cylinder to be traced. These items are:

— cylinder manufacturer;

— manufacturing specification;

— nominal water capacity.

All information regarding the test shall be retained by the testing facility and shall be available for a minimum of two periodic inspection and testing intervals.

13 Rejection and rendering cylinders unserviceable

The decision to reject a cylinder may be taken at any stage during the periodic inspection and testing procedure.

If a rejected cylinder cannot be recovered, the owner shall be notified, and the cylinder shall be condemned. The cylinder shall be rendered unserviceable for holding gas under pressure by one or more of the methods listed in Clause 13 so that it is impossible for the cylinder to be reintroduced into service.

In some cases, it can be necessary to transport condemned cylinders to a place where they can be scrapped. If there are no specific regulations, the condemned cylinder shall be identified.

The following methods may be used for rendering cylinders unserviceable:

— crushing or shredding the entire cylinder by mechanical means;

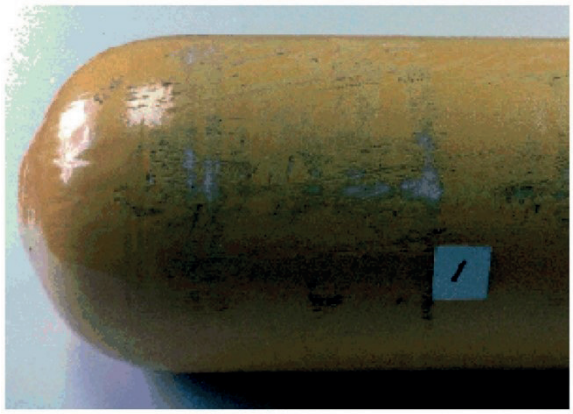
— burning an irregular hole in the top dome equivalent in area to approximately 10 % of the area of the top dome or, in the case of a thin-walled cylinder, piercing in at least three adjacent places;

— jagged cutting of the neck and shoulder;

— irregular cutting of the cylinder in two or more pieces including the shoulder;

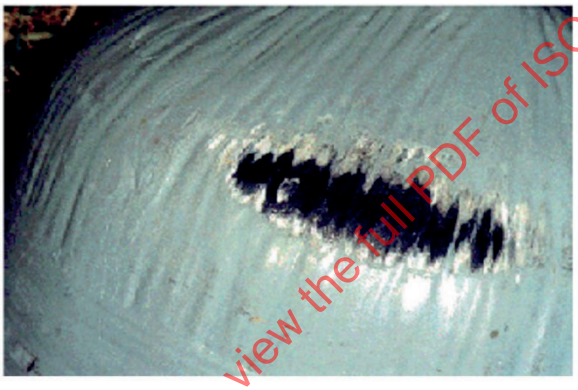
— bursting using a safe method.

Care shall be taken to ensure that the method used does not create an environmental hazard. Furthermore, care shall be taken to ensure that the method used is carried out in a safe manner.



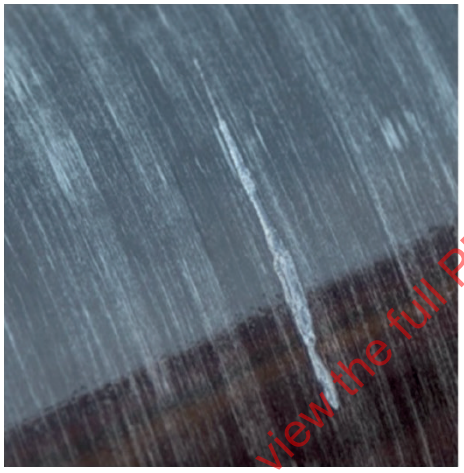
a) Examples of Level 1 abrasion damage — Superficial abrasion

b) Example of Level 2 abrasion damage

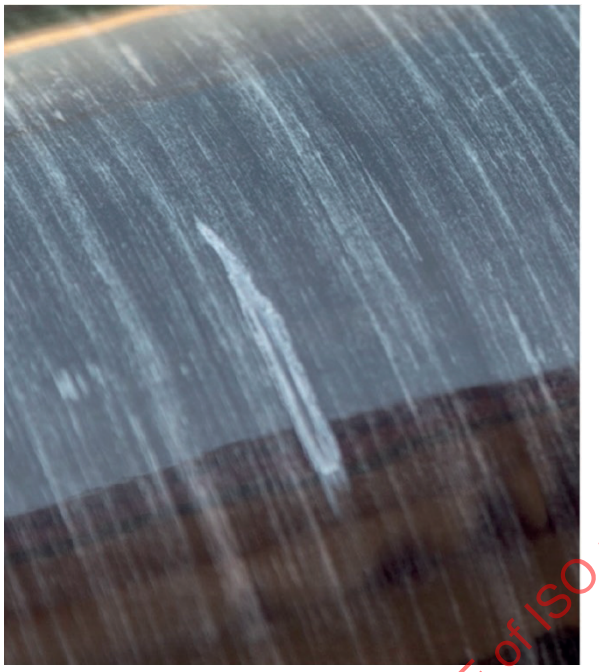


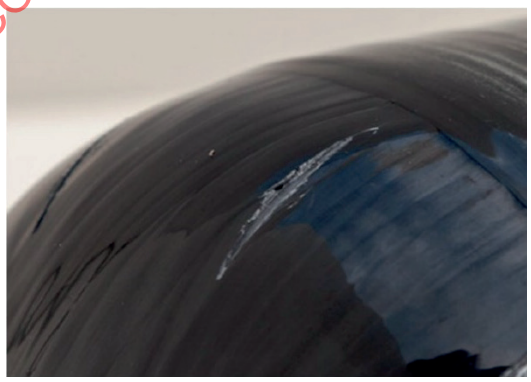
c) Examples of Level 3 abrasion damage

Figure 1 — Abrasion damage — see Table 1 for criteria



a) Example of Level 1 damage from cuts — Superficial cut and showing device for cut depth measurement

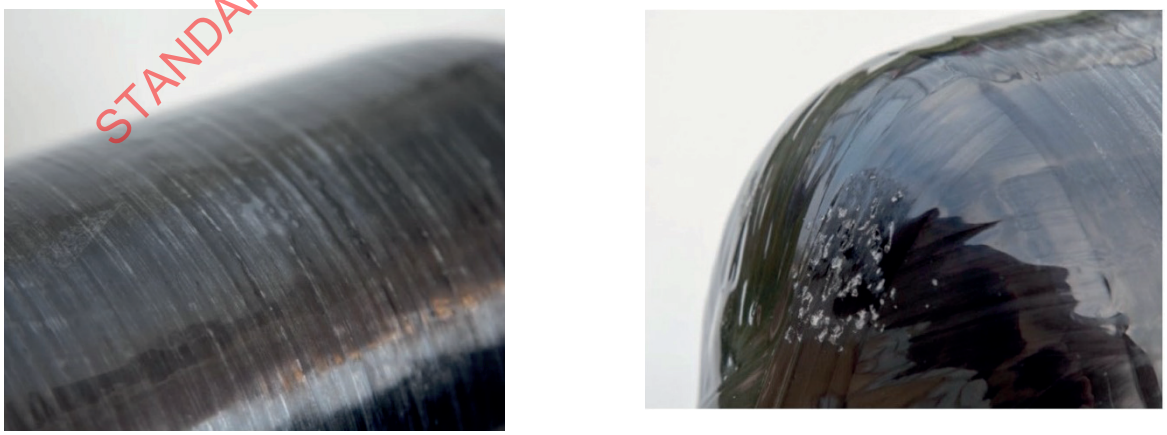




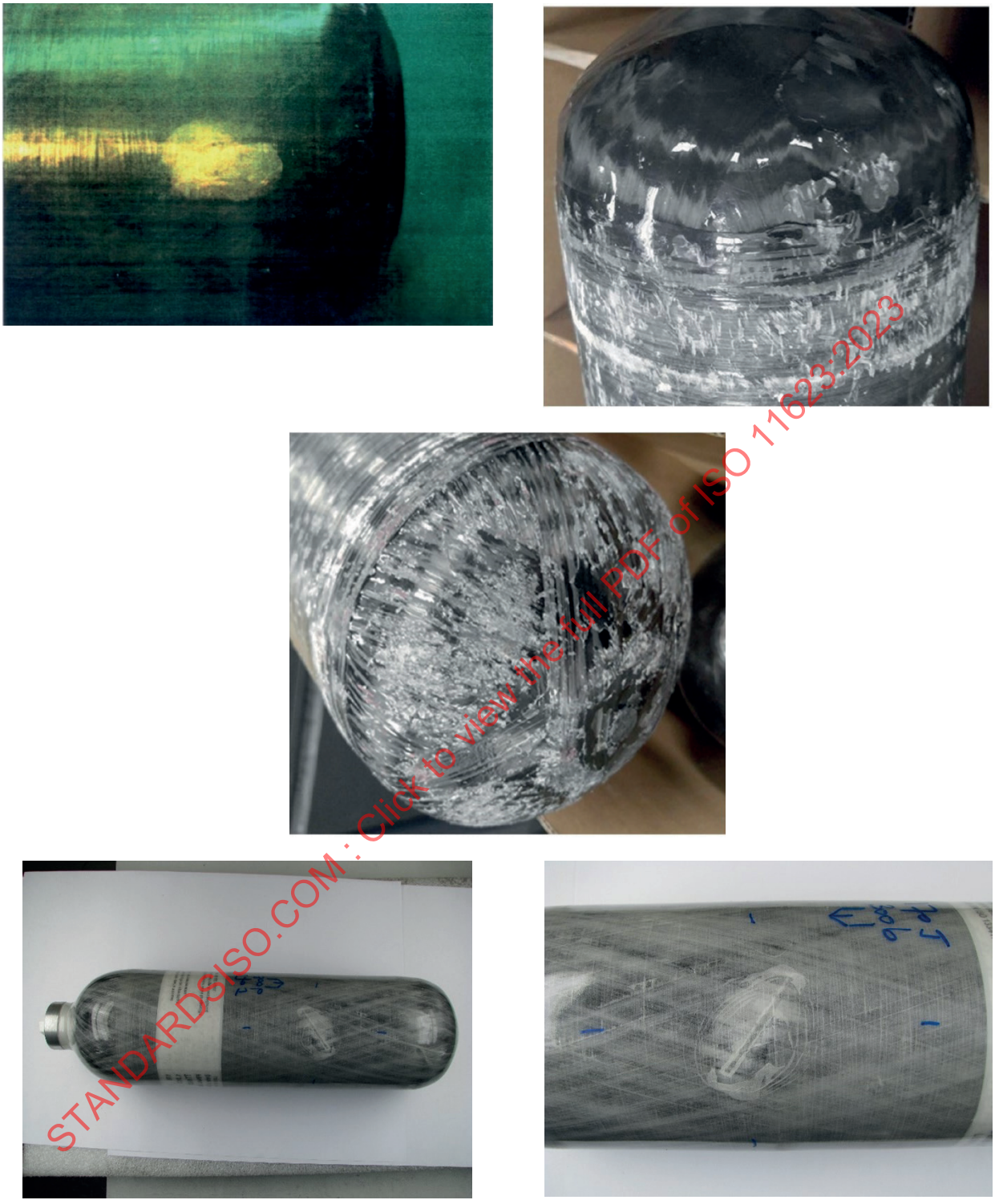
b) Examples of Level 2 damage from cuts

c) Examples of Level 3 damage from cuts and showing device for cut depth measurement

Figure 2 — Damage from cuts — see Table 1 for criteria

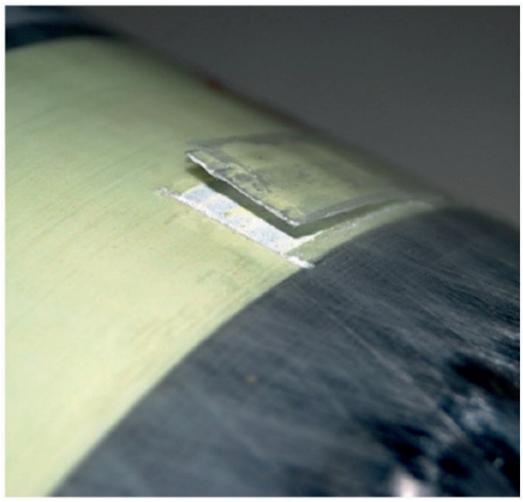


a) Examples of Level 1 impact damage — Superficial impact damage



b) Examples of Level 3 impact damage

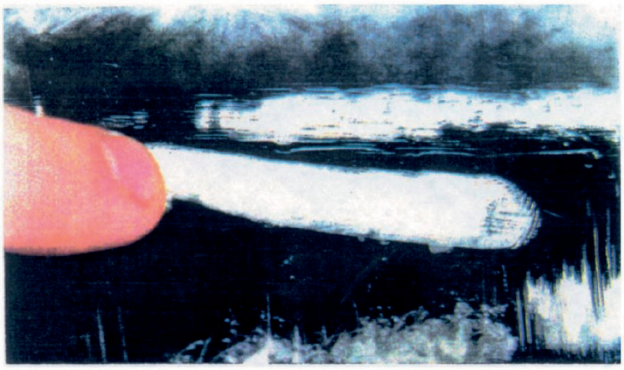
Figure 3 — Impact damage — see Table 1 for criteria



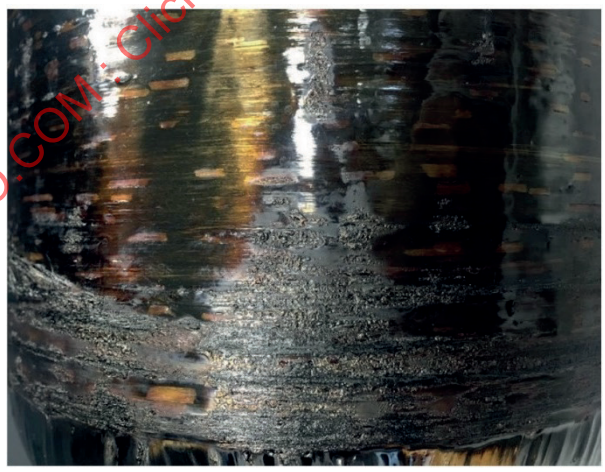
a) Example of Level 2 delamination damage

b) Example of Level 3 delamination damage

Figure 4 — Delamination damage



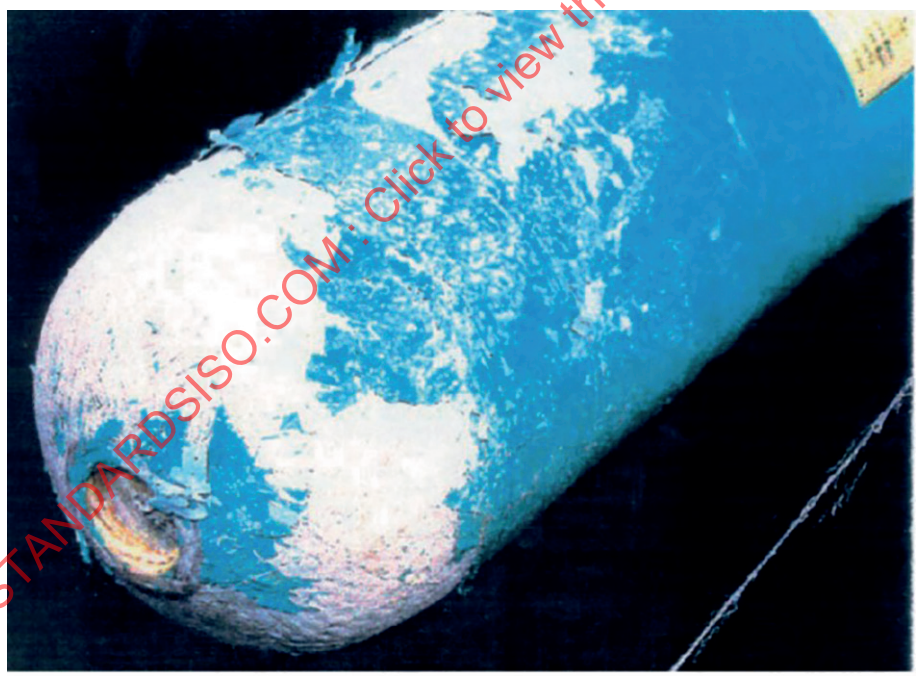
a) Example of Level 1 fire damage — Surface charring only



b) Example of Level 3 fire damage

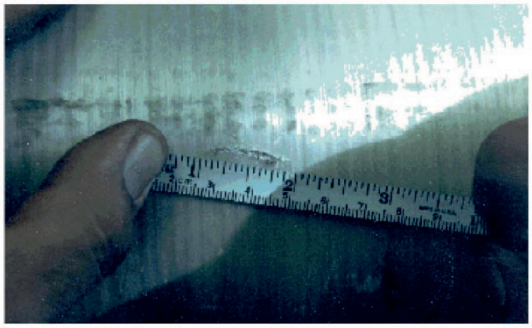
Figure 5 — Heat or fire damage

a) Level 3 — Example of chemical damage



b) Level 3 — Example of chemical damage

Figure 6 — Chemical attack damage

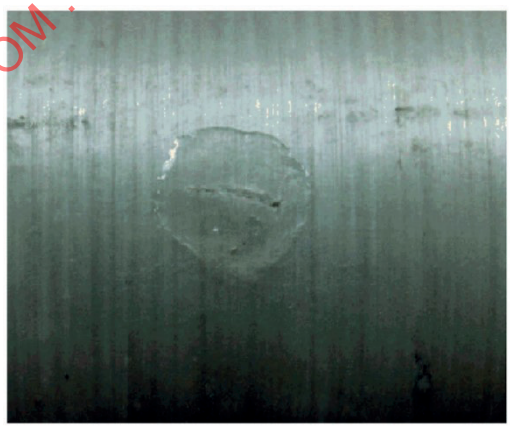


a) Length measurement

b) Depth measurement

c) Resin mixing

d) Resin application



e) After cure

Figure 7 — Level 2 repair by competent person

Figure 8 — Internal corrosion damage