LUXFER
GAS CYLINDERS

Luxfer Composite Inspection Manual

A GUIDE TO THE USE, MAINTENANCE AND PERIODIC INSPECTION OF LUXFER FULLY WRAPPED CARBON COMPOSITE CYLINDERS WITH PED AND TPED APPROVAL

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1. Introduction

This guide is intended for Luxfer fully wrapped carbon composite cylinders that are in use in Europe and the UK. For use in Europe the cylinders are approved and manufactured to the PED (Pressure Equipment Directive) and TPED (Transportable Pressure Equipment Directive) as adopted by the European Standards Council. For use in the UK the cylinders are approved and manufactured to the PESR (Pressure Equipment (Safety) Regulations) and CDG TPED (Transportable Pressure Equipment Directive) as issued by the Health and Safety Executive (HSE).

Luxfer high-pressure carbon composite cylinders are durably designed for the applications and purposes in which they are used; nevertheless, like all compressed gas equipment, they must be treated, maintained and inspected properly. This users' manual will assist suitably trained personnel to operate, valve, inspect and periodically test Luxfer composite cylinders safely and effectively.

Your system supplier or gas company should have provided you with instructions for the safe and proper filling of your composite cylinder. Carefully follow those instructions. Please bear in mind you must also follow all applicable local and national regulations concerning the filling, use, maintenance and periodic retesting and requalification (retest) of your composite cylinder.

This guide is not intended for use with the Luxfer ECLIPSE range of cylinders, which have a separate inspection manual.

If you have questions about your cylinder, visit Luxfer's website at www.luxfercylinders.com or call Luxfer Customer Service in Nottingham at (+44) 0115 980 3000.

2. Our History

Founded in 1898, Luxfer is one of the world's largest manufacturers of high-pressure aluminium and composite cylinders with manufacturing facilities and sales offices around the world. An industry leader in research and development and innovation, Luxfer holds numerous global patents related to cylinder and metallurgical technology.

Luxfer: Setting the Standard Worldwide

As one of the world's leading manufacturers of high-pressure composite cylinders, Luxfer strives continually to improve the quality and performance of its products. The following are some of the improvements and innovations that Luxfer has introduced in the high-pressure cylinder business:

1941	Luxfer produces the world's first hot-extruded seamless aluminium cylinder.
1958	Using its proprietary extrusion technology, Luxfer produces the world's first cold-extruded, seamless, high-pressure aluminium cylinders.
1976	Luxfer begins manufacturing high-pressure hoop-wrapped composite cylinders with fibreglass-reinforced walls.
1997	Luxfer introduces its LCX® line, its lightest-weight composite cylinders, fully wrapped with aerospace-grade carbon composite fibre. Initially used for firefighter life-support, these ultra-lightweight, high-capacity cylinders are soon introduced into other markets, including medical, automotive, aerospace and inflation.
2002	Luxfer introduces its patented L7X® higher-strength aluminium alloy in Europe. The alloy is first used to make ultra-lightweight, higher-pressure (200-bar or 3,000-psi) medical oxygen cylinders that provide up to 50 percent more oxygen in a package no larger than conventional cylinders.
2007	Luxfer introduces its LCX-SL® "Super Light" product line, the world's lightest- weight carbon composite life-support cylinders. In the same year, the company launches two more life- support cylinders: LCX-XD®, "Xtreme Duty" impact- resistant models for especially demanding fire-fighting environments, and LCX-EL® "Extra Life" models with 30-year lifespans.
2016	Luxfer approves a range of large Type 4 cylinders with polymer liners for use in Natural Gas vehicles
2018	Luxfer introduces the ECLIPSE range of carbon SCBA cylinders at the FDIC International show.
2022	Luxfer approves a wide range of Type 3 and Type 4 high pressure cylinders for hydrogen storage and transport

3. Cylinder Design and Specifications

A Luxfer fully wrapped, carbon composite cylinder is composed of these basic components:

- An ultra-lightweight, thin-walled, seamless aluminium liner with no leak paths or joints. Luxfer manufactures its own liners from aluminium alloy 6061 (AA6061). Liners receive an external coating to prevent the possibility of corrosion underneath the composite wrapping.
- Each liner is over-wrapped with carbon fibre in an epoxy matrix using computer controlled winding machines.
- A layer of glass fibre is wound onto the carbon as a sacrificial impact and abrasion layer, and a label is applied under the last layers of glass to protect it from damage.

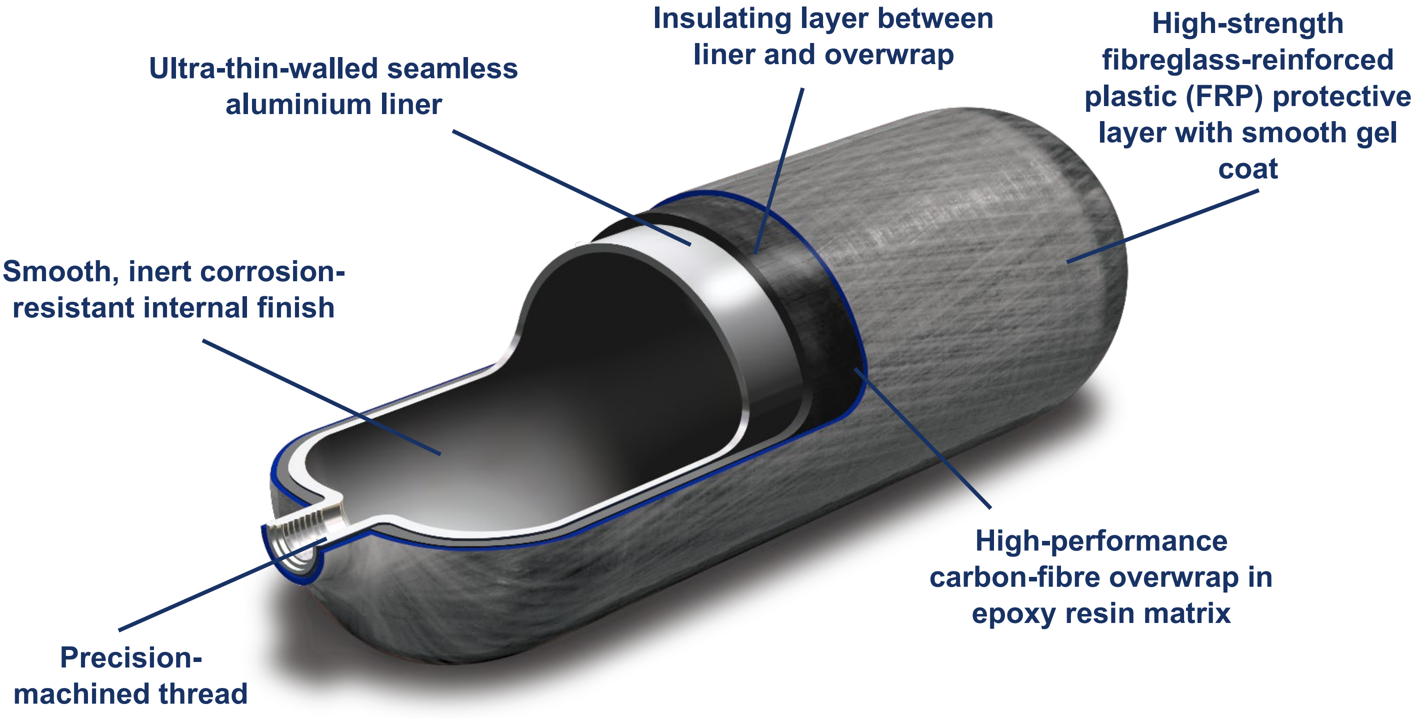


Figure 1: Carbon Composite Cylinder

4. Regulatory Guidelines

Luxfer's full-wrap composite cylinders are designed, manufactured and inspected in accordance with all applicable European and UK standards and regulations as required.

Pressure Equipment Directive (PED)

The Pressure Equipment Directive (PED) (2014/68/EU) applies to the design, manufacture and conformity assessment of stationary pressure equipment for use in Europe with a maximum allowable pressure greater than 0,5 bar. The directive entered into force on 20 July 2016.

The Pressure Equipment Directive aims to guarantee free movement of the products in its scope while ensuring a high level of safety.

Within the context of this guide cylinders approved to the requirements of the PED are cylinders used in self-contained breathing apparatus (SCBA) applications and systems.

Pressure Equipment (Safety) Regulations (PESR)

The Pressure Equipment (Safety) Regulations 2016 for use in the UK, came into force on the 8 December 2016 and have subsequently been amended by Schedule 24 of The Product Safety and Metrology (Amendment) (EU Exit) Regulations 2020.

These Regulations cover pressure equipment and assemblies with a maximum allowable pressure PS above 0.5 bar.

Within the context of this guide cylinders approved to the requirements of the PESR are cylinders used in self-contained breathing apparatus (SCBA) applications and systems.

Transportable Pressure Equipment Directive (TPED)

The Transportable Pressure Equipment Directive (TPED) is a European Directive (2010/35/EU) that applies within the European Economic Area (EEA) to manufacturers, authorised representatives, importers, distributors, operators and owners of certain types of transportable pressure equipment used for the transport of dangerous goods by road, rail and inland waterway.

Within the context of this guide cylinders approved to the requirements of the TPED are all cylinders of 0.5 litres water capacity or more except for those cylinders used in SCBA applications.

Carriage of Dangerous Goods and Use of Transportable Pressure Equipment (CDG TPE)

The Carriage of Dangerous Goods and Use of Transportable Pressure Equipment (Amendment) (EU Exit) Regulations require that from 1 January 2023 Transportable Pressure Equipment may only be placed on the GB market if it has been conformity assessed by a GB appointed body and affixed with the UK "Rho" mark, or if it complies with the Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations (Northern Ireland) 20103 (as amended) and is qualifying Northern Ireland TPE.

These Regulations extend to England, Wales, Northern Ireland and Scotland.

5. Design and Performance Criteria

Design Criteria

The design thickness of the fibre overwrapping cannot be reduced to a simple formula because of varying load-bearing layers and varying orientations and thicknesses of composite layers. Moreover, when these components, with their different strength and stiffness characteristics, are pre-strained in the autofrettage process, a complex distribution of stress results.

This is analysed using finite element analysis computer techniques. All cylinders are manufactured by computer-controlled fibre-winding machines to ensure correct lay-up and high integrity of the overwrap.

Luxfer uses a variety of computer analysis techniques, including finite element analysis, to produce a reliable model of the cylinder and to calculate the maximum stress at any point in the liner and fibres.

Also calculated are load distribution between liner and fibres at zero pressure, service pressure, test pressure and burst pressure. The model used to analyse the cylinder body takes into consideration non-linear material behaviour and non- linear geometric changes, accounting both for circumferential and longitudinal pressure stresses.

NOTE: Maximum stresses in the cylinder ends are always designed to be less than the maximum stresses in the cylinder body to pass burst tests. The maximum calculated tensile stress in any fibres (carbon or glass) must not exceed 30 percent of the fibre stress corresponding to the minimum required burst pressure.

CYLINDER OPENINGS:

- Openings are permitted on heads only. The centreline of the openings must coincide with the centreline of the cylinder.
- Threads must be clean-cut, even, without checks, and must be designed in compliance with the requirements of the Federal Standard FED-STDH28.
- Tapered threads are not permitted in CFFC cylinders.
- Straight threads having at least six threads must have a calculated factor of safety in shear of at least 10 at the test pressure for the cylinder.

Qualification Testing

It is not possible to use finite-element modelling techniques accurately for all different environments to which a gas cylinder might be exposed. To ensure the safe application of the cylinder design, a testing program is necessary to prove performance in the anticipated service environment.

The following tests are conducted on the cylinder materials and composite overwrap:

- Strength of the carbon fibres
- Strength of the glass fibres
- Interlaminar shear strength of the composite
- Flexural strength of the composite

The following tests are conducted on finished cylinders:

- Extreme temperature fluctuation: -40ºC to +60ºC
- Impact resistance (drop test)

- High-velocity impact resistance (gunfire test)
- Environmental exposure at high temperatures and high humidity
- Exposure to fire
- Cylinder ultimate strength (burst test)
- Cyclic fatigue performance
- Thread resistance

6. Manufacture

Aluminium-alloy procedures

Luxfer manufactures liners from 6061-alloy (AA6061) aluminium plate. Each liner is cold-drawn to thickness and hot-spun closed on the open end. The liner is then subjected to a solution heat treatment and artificial aging process to develop strength and toughness required for “T6” mechanical properties.

The liner neck is then machined for threads and port seal surfaces.

Inspection procedures

Raw materials are checked and identified on receipt. Liners are checked for wall thickness, straightness, out-of-roundness, eccentricity and surface finish. The effectiveness of the heat treatment is verified by conducting tensile tests on a sample liner from a heat-treatment lot. The thread for every liner is verified.

Liners are inspected by lot according to EN 1975, ISO 7866 or ISO 11119-2. Additional visual checks are conducted on liners prior to wrapping to ensure they are clean, free from surface defects and manufactured to the design drawing.

Composite overwrapping

Liner manufacture, composite overwrapping, pressure testing and finishing operations are carried out at Luxfer Gas Cylinders in Riverside, California USA. and Luxfer Pomona in Pomona, California, USA.

Reinforcing carbon fibre in an epoxy matrix contributes most of the strength of full-wrap carbon composite cylinders. Fibres are impregnated with epoxy resin and applied to the liner by computer-controlled filament-winding machines that ensure correct placement of each fibre.

The cylinder is then over-wrapped with layers of fibreglass, and an identification label is applied under the last layer of glass. The purpose of the outer layer of glass fibre is to protect the cylinder from damage. The net load-sharing capability or this layer is not considered part of the total pressure load in the cylinder at minimum required burst pressure.

Composite resin is cured using appropriate controlled-temperature profiles to ensure intimate contact between the fibre filaments and the resin system, as well as complete curing of the resin matrix.

After the resin is cured, cylinders undergo autofrettage to redistribute the stresses within the aluminium and composite overwrap. Autofrettage is a pressurization process at a designated pressure in excess of test pressure, and at this stress level the yield point of aluminium is exceeded—that is, the aluminium deforms plastically. When the pressure returns to zero, the aluminium is in compression and the carbon and glass fibre composite is in tension.

Therefore, at normal working pressure, the developed stresses in the aluminium liner are reduced compared to those found in a standard aluminium cylinder.

Luxfer applies a UV gel-coat finish on top of the glass fibre layers, creating an easy- to-clean, smooth surface that is extremely resilient. The gel-coat resists abrasion, impact and UV degradation.

Cylinder Lot Inspection and testing

The maximum composite cylinder lot (or batch) size is 200 units, plus the number of cylinders required for destructive testing, in accordance with EN 12245 or ISO 11119-2.

Each lot of composite cylinders is examined to ensure compliance with design specifications. The following final inspections are carried out in accordance with Luxfer's Quality Assurance procedures:

Visual inspection	100% (all cylinders)
Dimensional check	10% or to customer requirements
Weight check	100%
Water-capacity check	100%
Compliance or marking	100%

For the Dimensional check, if one unacceptable cylinder is found, then all cylinders in the lot are inspected. The following performance tests are conducted:

HYDROSTATIC TEST - Performed on each cylinder after the auto-frettage process, this test requires that the hydraulic pressure in the cylinder be increased gradually and regularly until the test pressure is reached. The cylinder test pressure shall be held for a sufficiently long period (at least 30 seconds) in order to determine there are no leaks and no failure.

HYDRAULIC BURST TEST - This test is conducted on one cylinder per batch. The cylinder is pressurized at a uniform rate until cylinder failure. The achieved pressure at time of the failure and the rupture mode are recorded.

PRESSURE CYCLING TEST - This test is conducted on one cylinder per batch. The cylinder must withstand a corresponding number of cycles at test pressure or maximum developed pressure as required by EN 12245 or ISO 11119-2. This is cycling for 250 times the number of years of design service life at test pressure (e.g., a 15-year cylinder must withstand a minimum of 3,750 cycles at test pressure). Alternatively, the cylinder can be cycled for 500 times the number of years of design service life at maximum developed pressure (e.g., a 15-year cylinder must withstand a minimum of 7,500 cycles at maximum developed pressure).

Independent Inspection Authorities

The independent inspection authority used by Luxfer for cylinders sold for use in Europe and the UK is:

Arrowhead Industrial Service Ltd.

Orion House

14 Barn Hill Stamford

Lincolnshire PE9 2AE UK

Notified body identification number - 1266.

Marking and Labelling

Each finished composite cylinder has a label applied under the fibreglass overwrap. The label contains the following information:

PED cylinders and PESR cylinders (SCBA & life support)

- Thread reference
- Design standard
- Country of manufacture
- Manufacturer name
- Cylinder serial number
- Mass of the empty cylinder
- Water capacity (L)
- Working pressure (BAR) at 15°C
- Test pressure (BAR)
- Developed pressure at maximum temperature (BAR)
- Date of manufacture
- Liner material
- Temperature range (°C)
- End of service life date
- For PED cylinders a CE mark followed by the number of the notified body
- For PESR cylinders a UKCA mark followed by the number of the notified body number.
- Luxfer part / model number.

TPED cylinder (medical & paintball)

- Thread reference
- Design standard
- Country of manufacture
- Manufacturer name
- Cylinder serial number
- Mass of the empty cylinder
- Water capacity (L)
- Working pressure (BAR) at 15°C
- Testing pressure (BAR)
- Date of manufacture
- Liner material

- End of service life date
- For TPED cylinders a pi mark followed by the number of the notified body
- For CDG TPE cylinders a rho mark followed by the number of the notified body number.
- Luxfer part / model number.

A Luxfer composite cylinder that still has a legible serial number can be returned to service only after all other product information is made legible. For instance, an illegible part of a composite SCBA cylinder label that still has a legible serial number can be corrected by putting required information back on the cylinder, but only Luxfer can perform this process.

Contact Luxfer for further information, if needed. Sample labels are included as

Appendix 1.

7. Cylinder Use

General

Follow these general guidelines to ensure safe, proper use.

MAINTENANCE OF CARBON COMPOSITE CYLINDERS

No regularly scheduled maintenance is required apart from periodic requalification (retest). Visually inspect each cylinder before filling for signs of damage (see Cylinder Damage Criteria).

If desired, clean the cylinder using fresh tap water alone or water and a mild detergent, if necessary. If a detergent is used, rinse the cylinder thoroughly with clean water. Thoroughly dry all components before reassembly.

Do not apply heat.

SHORT-TERM STORAGE (LESS THAN 6 MONTHS)

Tightly close the cylinder valve. Leave pressure between 2 and 3 bar in the cylinder.

Secure the cylinder and assembly to prevent the cylinder from rolling loose, tipping over or falling.

Store at room temperature in a dry place, away from chemicals, artificial heat sources and corrosive environments.

LONG-TERM STORAGE

If it becomes necessary to store a cylinder for a prolonged period, the following procedure is recommended:

Empty the cylinder and remove the valve. Wash the cylinder internally and externally with fresh tap water, rinse with distilled or de-ionized water and then thoroughly dry the cylinder inside and out.

Visually inspect the internal surfaces. Install the valve and O-ring according to the SCBA manufacturer's recommendations. The valved cylinder should have between 2 and 3 bar of positive pressure inside the cylinder valve assembly. Protect the valve from possible damage.

Store the cylinder either upright or horizontally at room temperature in dry conditions away from chemicals, artificial heat sources and corrosive environments.

HANDLING

Do not drag, drop or roughly handle cylinders. When transporting cylinders, ensure that the valve is protected from damage and that the cylinder is well secured. Cylinders should not be allowed to roll around loose, tip or fall during transport. Secure cylinders in a protected position, and do not allow other cargo to strike or damage cylinders.

PAINTING

Never use corrosive, caustic or acid paint strippers, burning techniques or solvents to remove paint from composite cylinder surfaces or to prepare those surfaces for painting. Retouch damaged paint areas with air-drying paint.

Never heat a cylinder to dry or cure paint. If cylinder composite materials or metal are damaged, do not paint over the damage. Have the cylinder inspected by an authorized technician.

It should not be necessary to paint an entire composite cylinder. In the unlikely event that overall painting is required, contact Luxfer for recommendations.

Approved Gases

Luxfer carbon composite cylinders are manufactured for and used within several gas services and applications. Please refer to ISO 11114-1 or Part 4 [Packing and tank provisions] of The European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR) or contact Luxfer Gas Cylinders for more information on gases safe for storage within Luxfer composite cylinders.

Luxfer carbon composite cylinders for SCBA and life support applications are approved for use with air and oxygen to the Pressure Equipment Directive (PED) in Europe and the Pressure Equipment (Safety) Regulations (PESR) in the UK. The cylinders are marked on the cylinder label with the gas name and must only be filled with the indicated gas.

Cylinder Filling

The pressure of a filled cylinder must not exceed the design filling pressure indicated on the cylinder label.

Composite material used in the manufacture of the cylinder is a good insulator, and so heat generated by the filling process takes longer to dissipate than with traditional metal cylinders.

Consequently, a cylinder charged to normal filling pressure will reach temperatures in excess of 49°C during filling, particularly if filled quickly.

(Note: This temperature is well below any temperature that might degrade the aluminium or the composite material.)

Then, on returning to ambient temperature, the pressure inside the cylinder will drop slightly, and the cylinder will not have a full charge. Topping up will be necessary to achieve a full charge. However, it is also possible to optimize filling procedures (e.g., by varying the speed of filling) to achieve a full charge.

SLOW FILLING

Filling a cylinder slowly will significantly reduce the heat generated in the filling process. A maximum charging rate of 30 bar/min or less is recommended.

FAST FILLING

A Luxfer composite cylinder can be fast-filled and reused if the cylinder is properly handled, well maintained and undamaged. However, the filler should take care not to exceed the maximum service pressure.

COMPRESSED AIR

When filling composite cylinders with compressed air, always ensure that the compressor has been properly maintained so that the air quality complies with the appropriate standard.

In uncontrolled conditions during which moisture may have entered the cylinder, internally inspect the cylinder at least every six months. Do not apply heat. If contaminants are found inside the cylinder, the cylinder interior must be cleaned and dried following procedures found in the Drying and Cleaning section of this manual.

OXYGEN

Use only cylinders, valves and other components specifically cleaned for oxygen or oxygen-enriched applications. (Breathing air that contains more than 23.5 percent oxygen is generally referred to as “oxygen-enriched air”). Use only lubricants approved for oxygen and oxygen-enriched applications. Non-approved lubricants, especially those containing hydrocarbons, could react with oxygen and cause a fire.

The cylinder interior, valve threads, O-ring and any equipment coming into contact with oxygen must be cleaned for oxygen and oxygen-enriched use and be free of any contaminants that might react with oxygen.

For additional information about the use of oxygen and oxygen-enriched gas mixtures, contact Luxfer or the oxygen equipment manufacturer.

8. Periodic Inspection and Requalification

General

The principal aim of periodic inspection and testing is that at the completion of the test, the cylinders can be reintroduced into service for a further period of time.

For TPED cylinders, the re-test companies are approved by the competent authority of the relevant country. This could be directly or under the control of a Notified Body. The specific details may be different in different countries, in some countries the Notified Body themselves are re-testers. In all cases the ADR applies.

For PED cylinders, the national regulations apply. Retest companies are approved by the competent authority of the relevant country. They can be the same third party than the TPED, but they need to be register in the country.

For ISO 11623 gas cylinders — composite construction — periodic inspection and testing is the standard that provides guidance on for composite cylinders and should be used in conjunction with this retest manual for the periodic inspection of carbon composite cylinders. It is not possible to identify all considerations for periodic inspection and testing of composite cylinders in the International Standard or this retest manual. In such cases or where there is doubt, questions regarding specific cylinders should be directed to the manufacturer or owner.

ISO 11623 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. Requirements in the relevant national regulations of the country (countries) where the cylinders are intended to be used that might override the requirements given in ISO 11623 and this manual. Where there is any conflict between these and any applicable regulation, the regulation always takes precedence.

In general, Luxfer carbon composite cylinders are expected to be subjected to a thorough periodic inspection and requalification every five years unless national regulations require a different period.

During periodic requalification, each cylinder must be examined internally and externally for damage and degradation and then subjected to a hydrostatic pressure test to the design test pressure. Only after completing these procedures satisfactorily can the cylinder be returned to service.

Procedures for external and internal inspection are specified in this section, including the appropriate damage identification criteria for the acceptance or rejection of cylinders for further use.

Cylinders with only superficial damage - i.e., damage that does not affect safety and integrity - are described as having Level 1 damage. Such cylinders may continue in service.

Cylinders with minor damage below the rejection level (see Cylinder Damage Criteria), including repairable damage to the reinforcement, can be sent to an authorized cylinder requalification facility for examination and repair. A repaired cylinder must pass a hydrostatic pressure test before being returned to service.

Cylinders must be **rejected** if they do not meet the volumetric expansion criteria or if any damage has grown or worsened following repair and testing.

Rejected cylinders must be rendered unable to hold gas under pressure (usually by drilling a hole in the cylinder).

Exterior Inspection

Fibre-wrapped cylinders must be periodically inspected for exterior damage to the wrap. Prompt identification of damage and proper repair will keep cylinders in service.

The cylinder should be clean, and all attachments that might interfere with visual inspection must be removed. Protective boots, caps or sleeves must be removed prior to inspection (the procedure for removing Luxfer protective boots and caps is shown in Appendix 2).

When removing a boot or sleeve, ensure that the surface fibres of the cylinder have not been cut or damaged.

Since the exterior surface of a composite cylinder does not look or feel the same as that of an all-metal cylinder, be prepared for differences in appearance and acceptance criteria.

Clean the cylinder exterior surface, removing all loose coatings, tar, oil or other foreign matter by a suitable method (e.g., washing and soft brushing). Blasting with grit or shot is not suitable.

Do not use chemical cleaning agents, paint strippers or solvents that may harm the composite material (see Chemical Attack).

Paint removal is neither necessary nor recommended prior to inspection. (If paint touch-up or repainting is required, see the Repainting section for guidance.)

CHEMICAL EXPOSURE

Composite materials can be attacked by chemicals and, in some cases, by treated water. If a cylinder has been exposed to chemicals or aggressive fluids, check the external composite surfaces for any visible signs of damage.

If cylinders are known to have been covered, splashed or left standing or soaking in unknown chemical(s), call Luxfer for further instructions; such chemical(s) may have damaged the composite material.

Reject composite cylinders if the composite surface is blotchy or if paint or resin shows any signs of chemical attack (e.g., paint or resin has softened, smeared, bubbled, etc.).

CAUTION

Some chemicals are known to cause damage to composite materials. The types of chemicals listed below are known to damage, attack or harm composite surfaces. Any cylinder composite material coming into prolonged contact (e.g., soaking) with these types of chemicals and materials must be rejected:

- **Solvents:** Paint thinners, kerosene, turpentine, paint solvents, paint cleaners, epoxy solvents, resin removers, organic solvents and other aggressive solvents.
- **Vehicle fluids:** Materials that contain benzene, battery acids/alkalis, oils containing solvents, flammable materials, gasoline and oil additives and fuels.

- **Strong bases:** Materials that contain medium-to-high concentrations of sodium hydroxide, potassium and/or other hydroxides.
- **Acids:** Materials that are or contain any concentration of acids, including hydrochloric, sulfuric, nitric and phosphoric acids.
- **Corrosives:** Corrosive materials or those containing corrosive components, including chemicals mentioned above, as well as harsh all-purpose cleaners, glass cleaners, metal cleaners, resin cleaners/removers, drain openers/cleaners, glues, rubber cement and other chemical cements; also, atmospheres containing corrosive gases.

HIGH-TEMPERATURE EXPOSURE

In general, a carbon composite cylinder that reaches a temperature of 71°C or more should be sent to an authorized cylinder requalification facility for evaluation before being returned to service. Cylinders that show obvious signs of prolonged exposure to fire or high temperatures must be rejected (see the Heat or Fire Damage section). It is important not to confuse environmental temperature with the actual cylinder temperature.

It is also important to take into consideration not only temperature, but also exposure time - both of which are critical factors. Brief exposure to elevated temperatures may not damage a cylinder. This is particularly relevant in the case of self-contained breathing apparatus (SCBA) cylinders used by firefighters.

Firefighters can wear composite SCBA cylinders with complete confidence even though they are frequently exposed to high temperatures, because a firefighter is never exposed long enough to excessive heat to affect cylinder properties. Even when wearing protective equipment, a firefighter will feel sufficient discomfort from life-threatening heat to pull back before the heat exposure could damage a cylinder.

The exceptional safety record of carbon composite cylinders in fire service over more than a decade clearly proves the durability and reliability of these products. The main concern is with SCBA cylinders left in a fire or high heat environment for a prolonged period; such cylinders must be rejected.

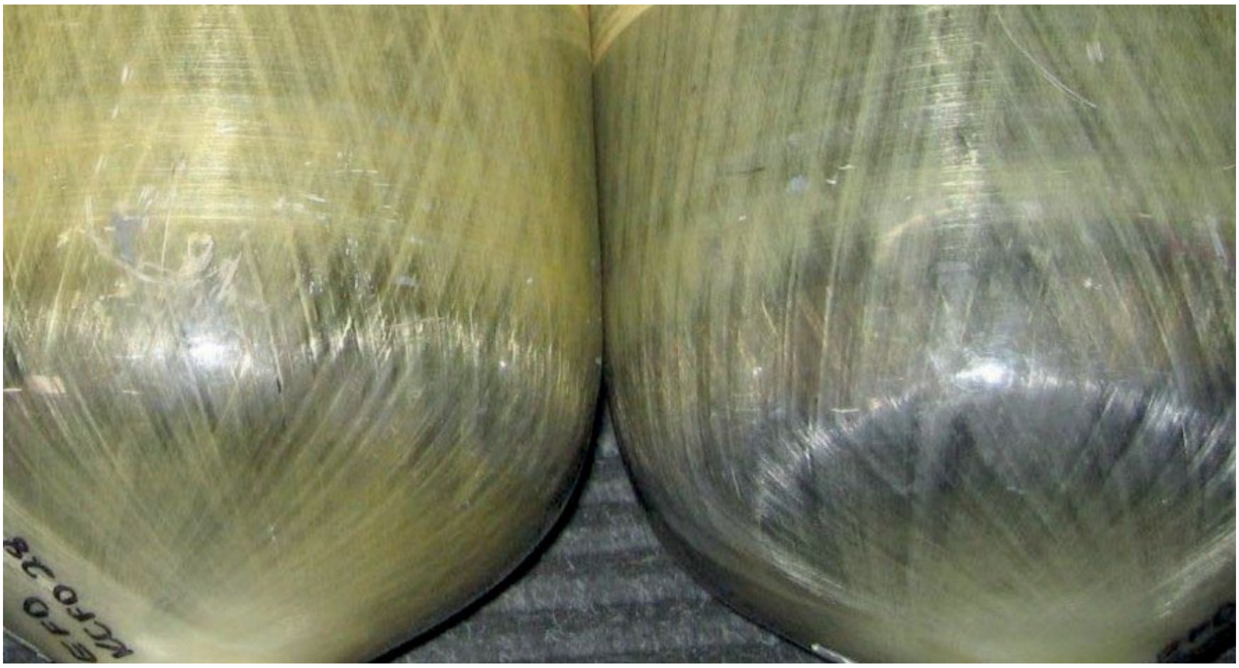
Note: some SCBA manufacturers specify a maximum temperature that necessitates retesting or rejecting an exposed cylinder. SCBA users should always follow the original equipment manufacturer's recommendations.

DISCOLORATION OF COATING

The cosmetic resin coating of carbon composite cylinders can discolour over time. This is a normal occurrence and discoloration will occur more quickly if the cylinders are subjected to a UV light source, such as sunlight. This has no effect on the cylinder integrity or performance and does not require repair.

CRACKS IN THE COSMETIC RESIN COATING

Superficial cracks occasionally appear in the cosmetic resin coating of carbon composite cylinders. Such minor resin cracks do not affect cylinder integrity or performance and do not require repair.

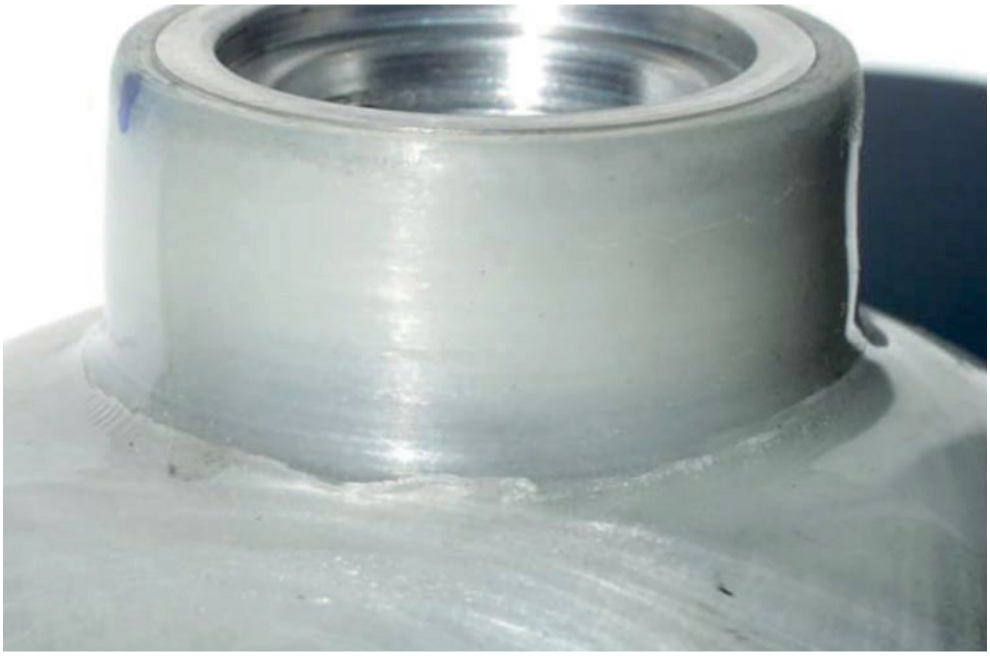


The cylinder on the left is an example of UV discoloured resin.

CRACKS IN THE VICINITY OF THE NECK WRAP

Luxfer carbon composite cylinders are often manufactured with glass fibre composite wrapping on the neck to protect exposed aluminium or to provide extra security to the threaded joint. Since this neck wrapping is not joined to the wrapping of the cylinder body, minor resin cracking sometimes occurs at the transition point due to different expansion rates of the fibres, resin and paint (if applicable).

The neck-to-shoulder transition point is a low-stress area. A crack in this area is merely cosmetic and does not affect cylinder integrity or performance. No repair is necessary. If desired, such cracking can be filled according to the Repair Procedure. Since this is a cosmetic repair, no hydrostatic pressure test is necessary.



Cracks in the vicinity of the neck wrap

CRACKS IN THE VICINITY OF THE BASE PLUG

As part of the manufacturing process, a plug is inserted into the centre of the cylinder base, and composite material is wrapped around the plug. Sometimes superficial cracks develop in the cosmetic resin coating in the vicinity of this plug.

If the area around the plug is painted, small cracks may appear in the paint, and minor porosity can also develop. These phenomena, which occur due to

different expansion rates of the plug, fibres, resin and paint, do not affect cylinder integrity or performance. The base of a composite cylinder is a low-stress area, and the base plug does not contribute to cylinder strength. Superficial cracks and porosity in this area do not affect cylinders performance, and no repair is necessary.

If desired, any crack or porosity can be filled and the cylinder painted, according to the repair procedure outlined in the Repair Procedure section. Repainting: this is a cosmetic repair that does not necessitate a hydrostatic pressure test.

CRACKS IN THE LABEL AREA

Circumferential hairline cracks may appear in the cosmetic resin coating in the area of the label. Since the label is under the final layer of glass fibre, a slightly raised area results. Occasionally superficial resin cracking occurs at the label edge. This does not affect the integrity of the cylinder, and no repair is needed.

VARIATIONS IN SHAPE OF CYLINDER BASES

Luxfer composite cylinders are manufactured by fibre reinforcement of a metal liner. The fibre reinforcement is built up by filament winding and as such the shape of the cylinder base can vary depending on the winding pattern or design characteristics.

The picture below shows examples of the typical variation that is possible. The cylinder on the left has not been deformed by pressure but is exhibiting a more pointed shape due to the winding process.

Valve Removal

Before an internal inspection can be performed, the cylinder must be emptied of pressurized gas and the valve must be removed.

Slowly release the pressure from the valved cylinder in a safe manner. Do not de-pressurize a cylinder where the contents are not known. Flammable or hazardous gases must be vented using proper equipment. When the cylinder is empty, remove the valve using proper tools, including a holding fixture that prevents damage to the cylinder fibre windings and valve.

Do not use a chain vise. Consult manufacturer's recommendations before carrying out this procedure; also see EN ISO 11623.

Luxfer recommends a thorough inspection of the valve at this time. Contact the original equipment manufacturer for the proper valve-inspection procedure.

Inspect the threads of the valve and cylinder for damage. Clean the O-ring groove, being careful not to remove metal or damage the groove.

CAUTION

If the valve is hard to remove, **STOP!** If the valve is damaged or not functioning properly, the inspector/operator may think that the cylinder is empty after opening the valve and not hearing gas released. All valved cylinders thought to be empty should still be handled as if they were under pressure. Luxfer is not responsible for malfunctioning or incorrectly installed valves used with Luxfer cylinders. If the valve is not working properly, contact the original equipment manufacturer for guidance before proceeding.

Internal inspection

Internal inspection is normally required only during the periodic inspection and requalification. Each cylinder must be inspected internally in accordance with requirements in this Inspection Guide. More frequent internal inspection is required in cases where cylinders are charged with breathing air that has not been dried and cleaned to the recommended levels (see Drying and Cleaning) or when water may have been drawn into the cylinder during service.

The internal surface of each cylinder should be inspected using sufficient illumination to detect any damage. The cylinder interior should be free of dirt and other foreign material prior to inspection. If internal surfaces are not clean, it will be necessary to clean them so that a proper inspection can occur (see Drying and Cleaning).

RECOMMENDED INSPECTION EQUIPMENT

Use a magnifying dental-type mirror and a high-intensity light that will adequately illuminate the threads and internal diameter below the threads. Optical Plus™ and similar magnification devices with built-in lights are also helpful inspection tools—however, bear in mind that magnification devices can make harmless cosmetic features appear worse than they really are. If you are uncertain about a feature you see under magnification, contact Luxfer for guidance before rejecting a cylinder.

REJECT all cylinders with internal isolated corrosion pit(s) estimated to be more than 0.75 mm deep.

REJECT all cylinders with sidewall line or broad-spread corrosion when one or more interior pit(s) in the line corrosion is deeper than 0.50 mm and/or if the interior broad-spread corrosion is deeper than 0.51 mm.

REJECT all cylinders that have bulges or dents on the inside of the liner. This indicates severe impact or another form of serious damage.

THREADS

Inspect clean cylinder threads for cracks, broken threads and other forms of damage with a magnifying dental mirror and high-intensity light or with an Optical Plus™ or similar device. Check for corrosion on cylinder threads and valve threads (if the valve is available). If you cannot determine the thread form, contact Luxfer for advice. Remove the O-ring. Inspect the O-ring gland and cylinder face for cracking. Follow the original equipment manufacturers recommendation about when to replace the O-ring.

REJECT all cylinders with corroded or damaged threads.

REJECT all cylinders that show evidence of cracking in more than one continuous full thread. Contact Luxfer with this information and findings. If you are unsure whether you are detecting a harmless tool-stop mark or a crack, contact Luxfer for guidance before rejecting a cylinder.

REJECT all cylinders with O-ring gland cracks, face cracks or other damage that may prevent an effective and safe seal.

Return to service all cylinders with acceptable glands, faces and threads (including those with harmless tool-stop marks; see Recommended inspection equipment, above.).

CAUTION

Do not replace components without following the valve manufacturers or OEM's instructions. Replace components only with parts that are authorized by the OEM and/or valve manufacturer.

Pressure Testing

Each cylinder must be subjected to a pressure test in accordance with EN ISO 11623. This may be a proof pressure test of volumetric expansion test, as appropriate to the design of the cylinder. The test pressure shall be established from the markings on the cylinder.

Thoroughly dry cylinders after pressure testing. Do not use heated air above 23°C or place the cylinder in an oven to dry. Inspect each tested cylinder for residual moisture before reinstalling the valve.

9. Cylinder Damage Criteria

General

The acceptance/rejection criteria given in this Luxfer manual are the manufacturer's recommendations and do not replace or supersede any criteria required by local regulation (if it exists).

First check the marking to ensure that the cylinder is within its working life. Working life is within 15 to 30 years from the date of manufacture as indicated on the cylinder label.

Luxfer carbon composite cylinders have an outer glass fibre layer that is additional to the structural strength of the carbon wrapping. As a rule, any damage to the glass layer is either acceptable or can be repaired. However, any damage that exposes the structural carbon fibre layers is sufficient to cause rejection of the cylinder.

Damage to composite overwrapping can take multiple forms, examples of which are described in the following sections.

Luxfer recommends the use of three categories of damage in accordance with EN ISO 11623 (note that in some of the cases specified below, only Levels 1 and 3 are used).

Level 1 damage is minor damage considered normal wear-and-tear and that has no adverse effects on the integrity or safety of a cylinder. Cylinders with Level 1 damage can continue in service.

Level 2 damage is greater than Level 1, but less than Level 3. Level 2 damage can be repaired.

Level 3 damage is sufficiently severe that the cylinder must be rejected. Level 3 damage cannot be repaired.

Abrasion Damage

Abrasion damage is caused by the wearing, grinding or rubbing away of material by friction.

Level 1 damage, which consists of small abrasions to the outer gel coating or glass-fibre layer, will not require repair unless the area is large enough to cause unravelling of fibres.

Level 2 damage is abrasion that may be repaired. This is where the outer glass fibre layer has been abraded but the underlying carbon fibre has not been abraded. Pressure test a cylinder after the repair and reinspect the cylinder before filling.

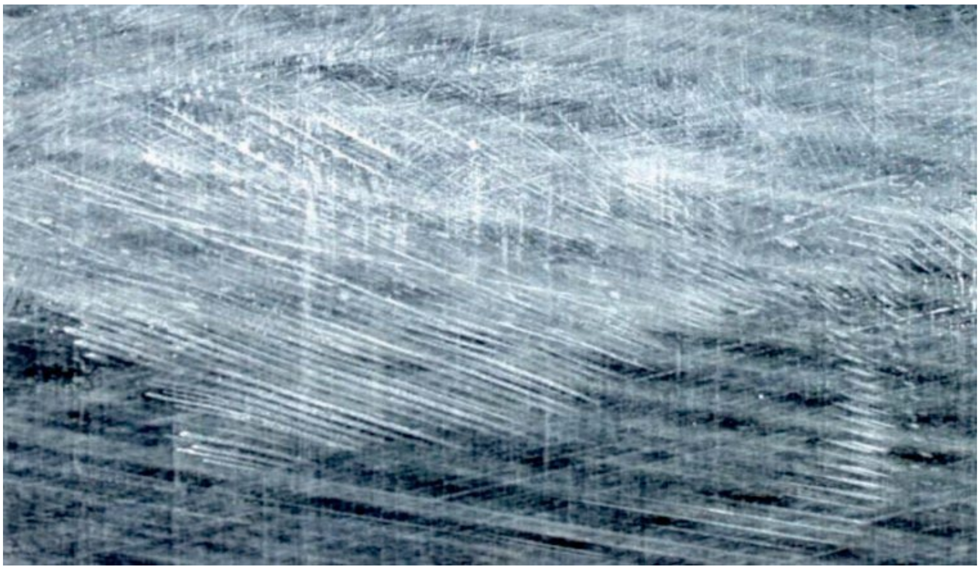
Level 3 damage is sufficiently severe that abrasion has passed through the outer glass layer and into the underlying carbon fibre layers.

Cylinders with Level 3 damage must be rejected.

- **REJECT** cylinders where the carbon fibre has been exposed.
- **REJECT** cylinders that show abrasion into the carbon fibre.

LEVEL 1 ABRASION

LEVEL 2 ABRASION



LEVEL 3 ABRASION

Cuts

This type of damage consists of cuts caused by contact with sharp objects that penetrate into the composite material, effectively reducing its thickness at the point of contact. This damage is similar in some ways to abrasion damage.

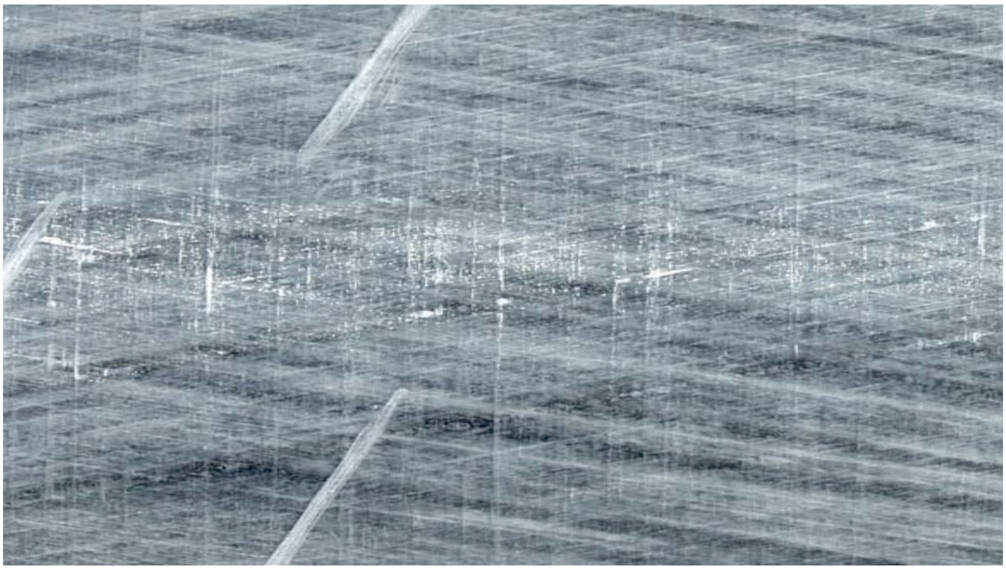
Level 1 damage: Consists of cuts to the outer gel coating or light cuts in the outer glass fibre layer.

Level 2 damage: Heavier cuts in the glass fibre layer that have not cut into the underlying carbon fibre layers. Level 2 cuts can cause delamination and/or unravelling of the glass fibres (see Delamination). Pressure test cylinders after the repair and re-inspect before filling.

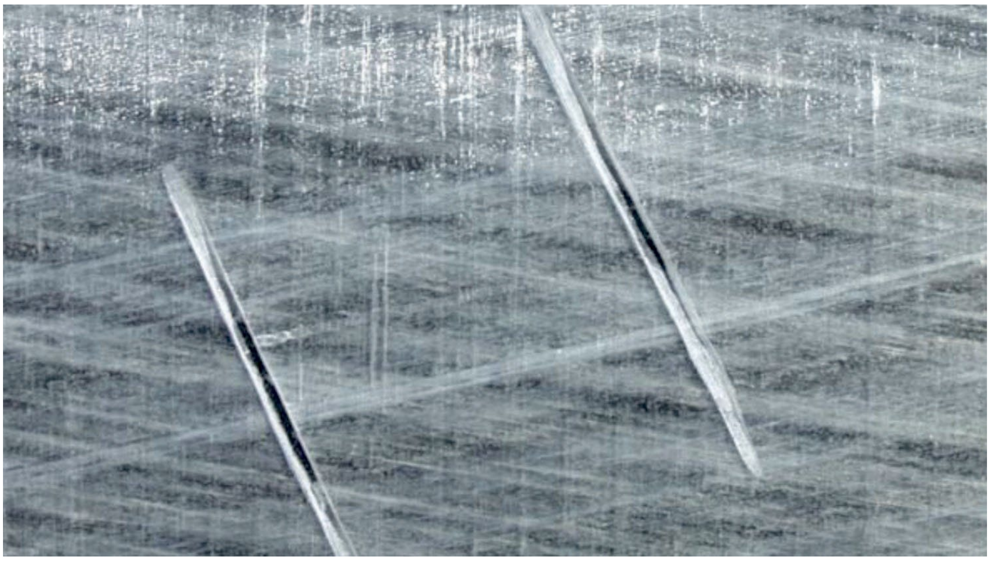
Level 3 damage: Reject composite cylinders with cuts through the glass fibre layer and into the underlying carbon fibre layers.

LEVEL 1 CUT

LEVEL 2 CUT



LEVEL 3 CUT



Reject all cylinders that show cuts into the carbon fibre.

Impact Damage

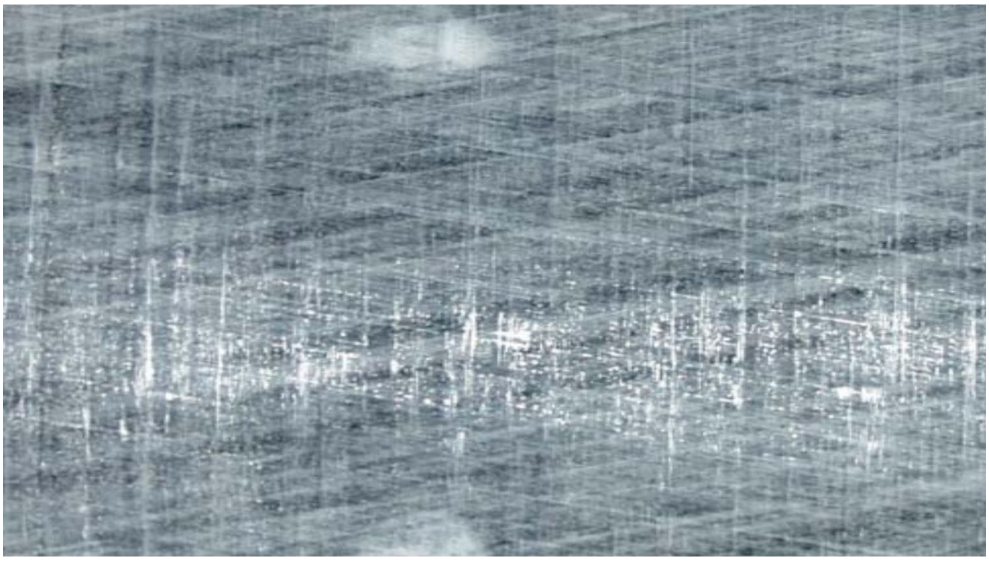
Impact damage may appear as cracks in the resin, as delamination or as cuts in the overwrap. All cylinders that show evidence of impact damage must be visually inspected for evidence of indentation of the internal surface of the metal liner. Two levels of impact damage are recognized: Level 1 and Level 3 (there is no Level 2).

Level 1 damage: Light damage, such as a small area where the fibreglass is frosted, does not require repair. The cylinder may be returned to service.

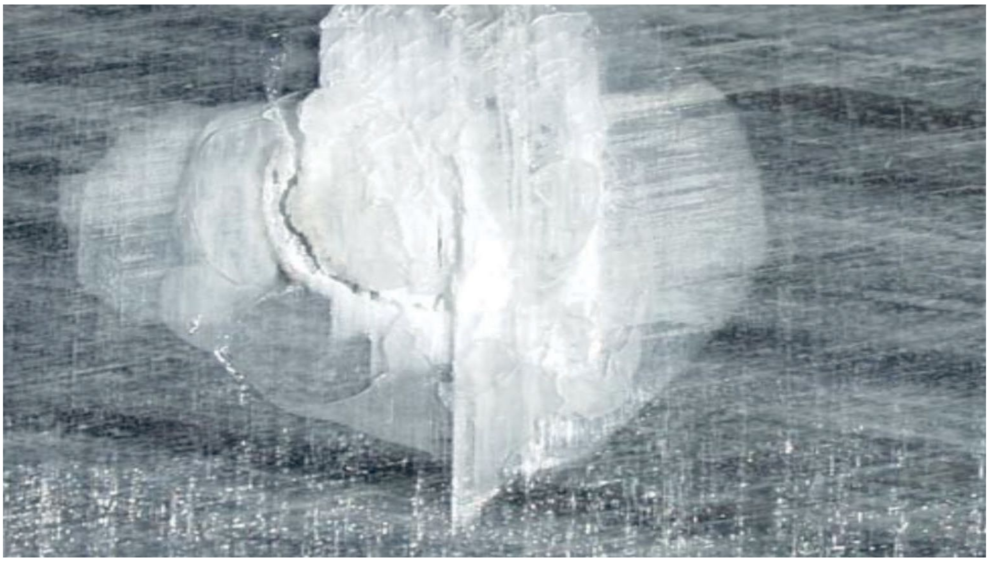
Level 3 damage: The cylinder must be rejected if impact damage causes a large area of frosting, delamination of fibres or other such readily noticeable structural damage.

Reject composite cylinders with any visual evidence of indentation on the internal surface of the metal liner.

LEVEL 1 IMPACT



LEVEL 3 IMPACT



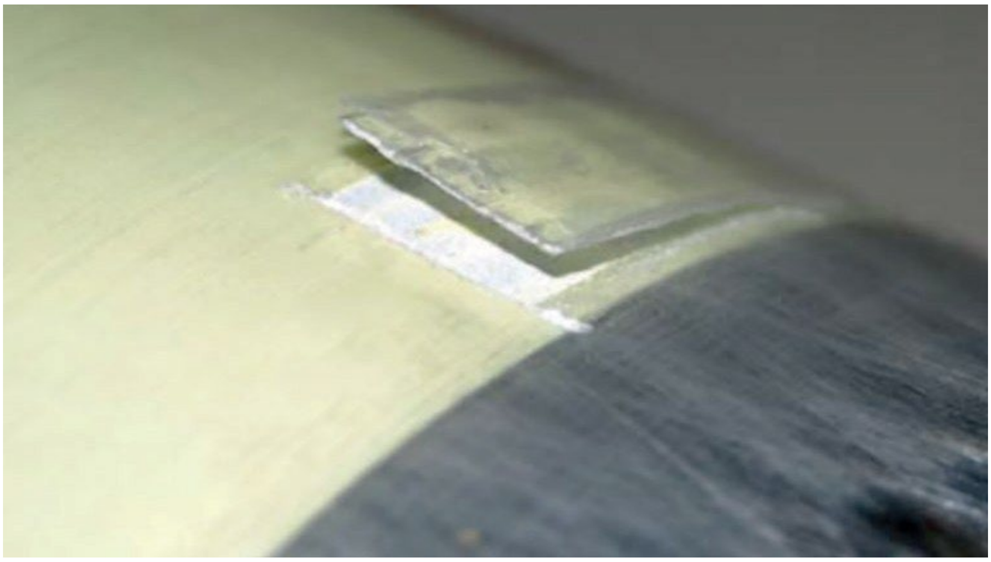
Delamination

Luxfer has issued a more comprehensive report on assessing and repairing delamination on carbon composite cylinders and this is available on our website. That is GUIDANCE FOR THE REPAIR OF DELAMINATED COMPOSITE CYLINDERS MANUFACTURED IN THE UNITED STATES

Delamination is a separation of composite overwrap layers or strands. It may also appear as a whitish patch, such as a blister or an air space beneath the surface. Delamination is usually a result of an impact, cut or exposure to temperatures of more than 95°C.

Level 1 damage: Light damage, such as a small area where the fibreglass is frosted, does not require repair (see "Level 1 impact," above). The cylinder may be returned to service.

Level 2 damage: If delamination is restricted to the glass-fibre layer only and any defect does not exceed a width of 50 mm, the cylinder may be repaired and returned to service.



Level 2 Delamination

Level 3 damage: Delamination damage greater than Level 2 requires the cylinder to be rejected.

Heat or Fire Damage

Elevated heat exposure—a different condition than obvious heat or fire damage— may or may not result in permanent heat damage to a cylinder. Elevated heat exposure occurs when the cylinder itself, absent any outer protection, has been subjected to a temperature environment in excess of 80°C.

A composite cylinder is not intended for prolonged use in any environment that would result in composite overwrap temperatures in excess of 71°C. However, temporary short-term exposure to air temperatures in excess of 71°C in a fire-fighting environment is not cause for cylinder condemnation. As extensive field experience has shown, a composite cylinder used within a self-contained breathing apparatus (SCBA) carried by a firefighter can withstand limited exposure to elevated temperatures without damage (see High Temperature Exposure in the Exterior Inspection section).

CAUTION

Other components used with the cylinder may not be suitable for use at temperatures of 71°C. Please refer to the OEM's guidelines for further information.

Developed composite material temperatures in excess of the original cure temperature of the composite will cause discoloration of the resin. This discoloration can range from a very light golden or caramel colour to a deep, brownish-black appearance. Light discoloration will occur naturally over time with continued direct exposure to sunlight and may not necessarily be a result of elevated temperature exposure. The discoloration may also be caused from soot or smoke from a fire-fighting environment. Normally, the degree and depth of discoloration is dependent on either the temperature or duration of exposure. The higher the temperature, or the longer the duration of exposure, the darker the resin system will become.

Pay close attention to the condition of any attachments such as valves, decals, stickers, stencils, exposed metal (e.g., aluminium liner ends or necks) and the outer protective paint;

these can indicate prolonged exposure to heat or fire. If the valve is available, the condition of the pressure relief device (PRD) should be evaluated to assess the extent of any heat effects. Fire damage to cylinders or equipment is also shown by melted plastics, burned or frayed straps and discoloured components.

Clean the cylinder and remove smoke residue and dirt from the surface before conducting a thorough inspection. Any cylinder used in equipment that has experienced fire damage should be rejected. Fire damage is shown by charring or burning of the composite, paint, labels, valve materials, melted resin, absence of some or all of the resin and/or by paint damage (e.g., bubbling or melting).

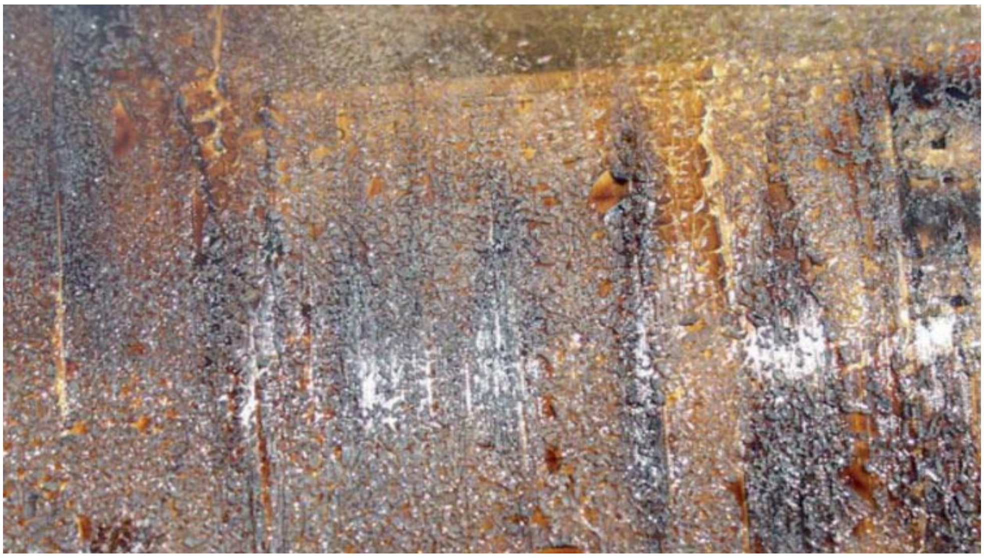
Two levels of heat or fire damage are recognized: Level 1 and Level 3 (there is no Level 2).

Level 1 damage occurs when the surface of the clear gel coat, paint or composite is soiled from smoke or other contaminants but is intact underneath with no evidence that the resin has been burned. In this case, a cylinder can be returned to service after cleaning.

This smoke-darkened cylinder only has Level 1 damage. After cleaning, it can be returned to service.

Over time, resin can become tinted due to exposure to heat and smoke. This is not unusual, and the cylinder can be returned to service. Light discoloration of the resin gelcoat or painted surface may be evaluated by cleaning the surface with a fine-grit Scotchbrite® scrubbing pad, fine steel wool or 320-grit sandpaper, as well as liquid dishwashing detergent mixed with warm water. An immediate colour change back to an off-white colour indicates that the cause of the discoloration has no significant depth. This method may also be used to evaluate the condition of a painted surface that shows no evidence of blistering or charring. After this evaluation, the cylinder must pass a pressure test.

Level 3 damage: Cylinders showing excessive heat damage must be rejected. Cylinders known to have been left unattended in a fire and exhibiting any evidence of heat damage must be rejected. Evidence of heat damage includes charring or melting of the composite or any attachments, valve components, protective layers, stickers or paint. Evidence can also include blistering of a protective layer. The composite would appear dark brown or black in colour and would remain unchanged when cleaned and evaluated, as noted above. The original manufacturer's label may be totally illegible due to the darkness of the resin. If the valve is available, the condition of the pressure relief device (PRD) should be evaluated to assess the extent of any temperature exposure.

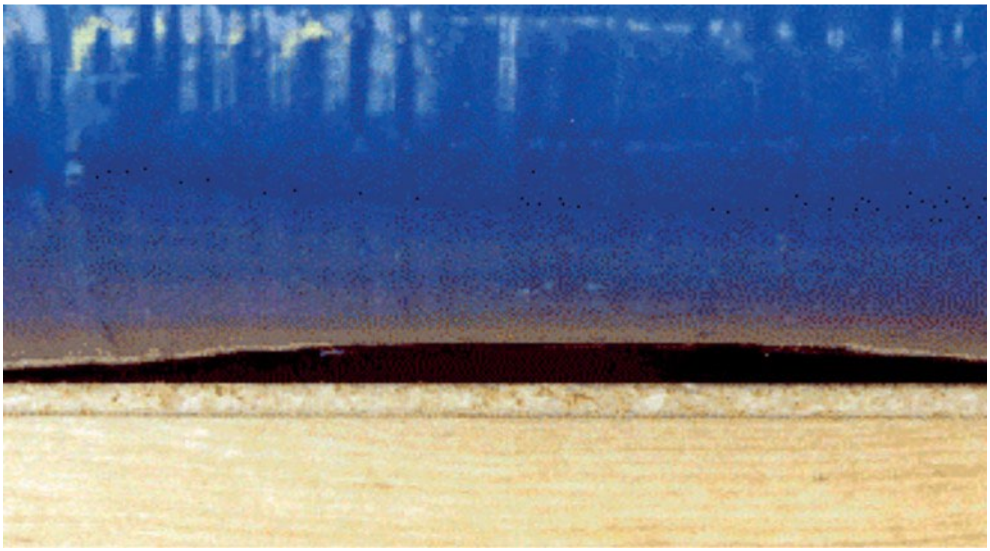


Level 3 damage like this required the cylinder to be rejected.

Cylinders known to have been subjected to the direct action of fire (i.e., prolonged impingement by flame) must be rejected. Evidence of fire damage might include signs of actual burning. Fire damage could occur either in an isolated area of the cylinder surface or over a wider area.

Structural Damage

A cylinder is rendered unserviceable if there is any evidence of surface bulges or depressions, distorted valve connections or deformation of the aluminium liner revealed by visual examination of the cylinder interior. In some cases, there may be irregularities in the fibreglass overwrap or gel-coat finish; these are normal and are not cause for rejection. Contact Luxfer if you are uncertain about how to distinguish such normal conditions from actual damage.



Chemical Attack

Chemicals can dissolve, corrode, soften, remove or ruin cylinder composite materials. They can also cause bubbling, pitting or extreme dulling of the resin; cause deterioration of the resin or protective paint layer; or create multiple fractures transverse to the direction of the fibre. Sometimes solvents can cause the cylinder to become sticky to the touch. Cylinders with evidence of such damage must be rejected.

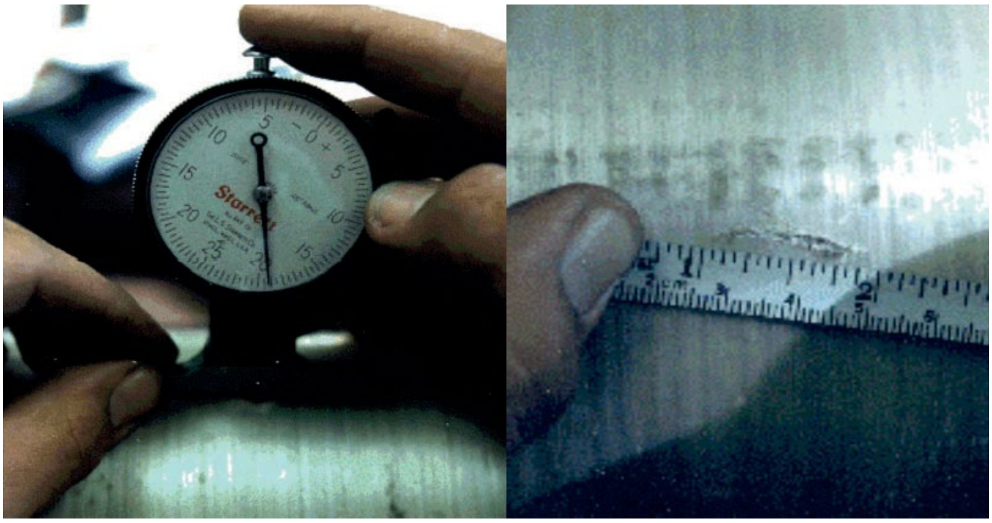
Carbon fibres are far less susceptible to chemical attack than glass fibres—but if a carbon composite cylinder has been clearly damaged by chemicals, it must be rejected.

10. Repair Procedure

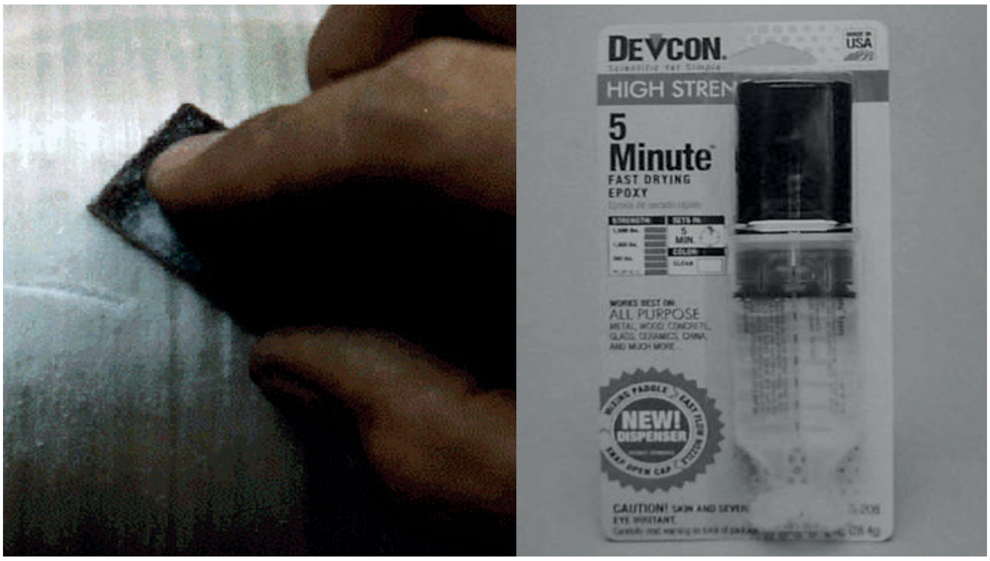
All cylinders that have been repaired must be subjected to a pressure test before being returned to service. After pressure test, the repair sites must be carefully examined for any lifting, peeling or delamination of the composite material.

Any cylinders showing signs of lifting, peeling or delamination must be rejected.

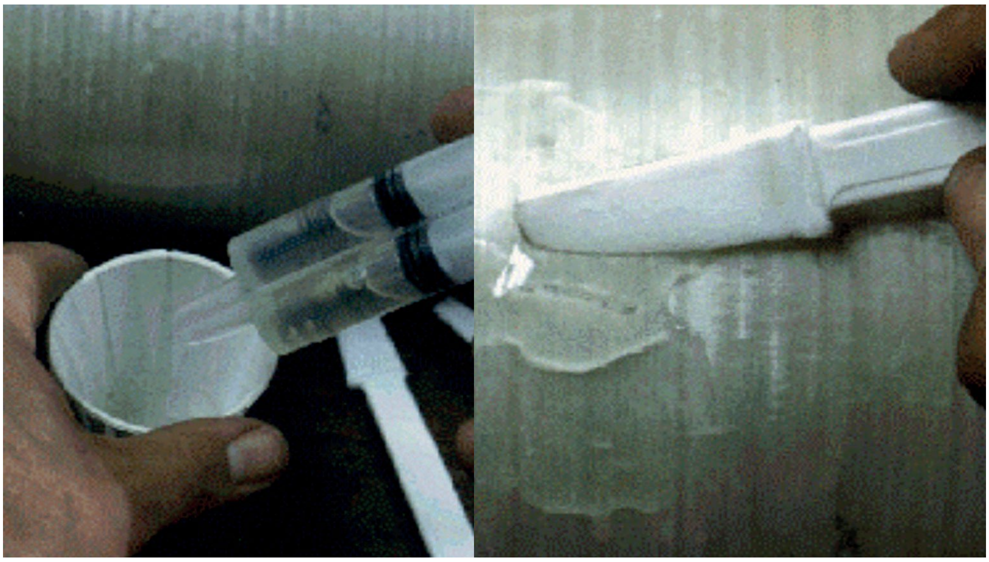
Place the cylinder on a table or bench with the damaged area uppermost and easy to reach. Check the damage site carefully in accordance with allowable defect limits.



Ensure the surface is clean and dry. Cut away any loose glass fibres. Slightly roughen the damaged area with either fine sandpaper or a Scotchbrite® scrubbing pad to prepare an acceptable surface for proper resin adhesion.



Mix a sufficient amount of two-part epoxy resin according to the resin manufacturer's instructions. Epoxy resin sets up quickly, so it is important to apply it without delay after it has been mixed. Apply a sufficient amount of epoxy resin to the damaged area, using the applicator to thoroughly coat and burnish down any loose fibres. Completely fill the damaged area with resin.



Wear additional protection is required, apply a slightly oversized piece of fibreglass surface veil over the damaged area. Apply a thin layer of resin over the veil, making sure that the veil and damaged area are completely covered.

Where a superior surface finish is required, use shrink tape. Affix a piece of unidirectional shrink tape, approximately 150mm longer than the damaged area, with outer surface of tape facing downwards, over the damage with ordinary adhesive tape. Apply heat to the tape with a hot air dryer to cause shrinkage. Peel off the tape after the epoxy resin has fully cured.

Allow the epoxy resin to set, typically 5 to 10 minutes. Then move the cylinder to a protected location and leave it undisturbed until the epoxy resin is fully cured in accordance with the resin manufacturer's guidelines. Apply a desired finish to the repair. Pressure test the cylinder before returning it to service.

LUXFER GAS CYLINDERS

11. Final Operations

Drying and Cleaning

EXTERNAL CLEANING

Problem	Cleaning Method
Moisture and light soil	Wipe with a soft cloth.
Oil and grease	Degrease with mild soap and water, wipe or blow dry.
Dirt and soot	Clean with mild soap and water, wipe or blow dry.

INTERNAL CLEANING

Problem	Cleaning Method
White deposits or staining	Tumble with walnut shells, plastic chips or other non-aggressive media. Then wash with hot water and thoroughly dry. Do not use heated air above 160°F or place in an oven to dry.
Odor	Wash with hot water and thoroughly dry. Do not use heated air above 160°F or place in an oven to dry.

For any problems other than the above, please contact Luxfer Gas Cylinders for assistance.

Repainting

Luxfer does not recommend the removal of the existing paint from cylinders, since this can only be carried out effectively by using specialized equipment.

Never use paint strippers, burning techniques or solvents to remove paints from aluminium or composite surfaces. If the cylinder is dirty, clean the exterior surface with a mild water-based detergent, rinse and dry the cylinder thoroughly. Do not use heat to dry the cylinder. If any damage to the cylinder composite materials is evident, have the cylinder visually inspected by an authorized technician before painting.

If the composite materials are undamaged, lightly rub down the cylinder exterior with 320-grit or finer sandpaper to prepare the surface for good paint adhesion. Retouch damaged paint areas with air-drying paint. Do not heat a cylinder beyond 40º C to dry or cure paint.

The type of air-drying paint is not critical, but flame-retardant epoxy or polyurethane paint is recommended. Do not thin solvent-based paint with toluene, xylene or other aggressive solvents.

Water-based polyurethane paint has been found to have good flame-resistant properties.

Spray painting normally gives a better finish.

If the entire cylinder is to be painted, contact Luxfer for recommendations.

Do not paint over the cylinder label. If painting near the label, mask off the label to protect it and ensure future legibility (a regulatory requirement).

Take care not to spray paint onto the top face of the cylinder neck since paint in this area can impair proper valve sealing.

Contact Luxfer if you have questions or require additional information.

Valve insertion

Before inserting the valve into the cylinder, carefully inspect it and, if necessary, repair it in accordance with the recommendations of the valve manufacturer and or SCBA manufacturer. Do not install any valve that has not passed an inspection. Failure to follow these guidelines can lead to unsatisfactory in-service performance.

The valve threads should be free from damage. Use an appropriate gauge to ensure that the valve complies with the correct thread specification. The mating surface on the valve should be smooth and free from damage.

Damaged or distorted valve threads can damage cylinder threads. Damage to the mating surface can prevent sealing and damage the top sealing face of the cylinder.

Check to make sure that the O-ring groove and threads in the cylinder are clean and free from damage.

Install a new O-ring on the valve in accordance with the valve manufacturer’s or SCBA manufacturer’s recommendations.

A thin smear of hydrocarbon-free, oxygen-compatible grease may be applied to the bottom three or four threads to provide lubrication—but take care not to apply grease to the bottom face of the valve stem. Only a small amount of grease is necessary. Too much grease can cause sealing problems.

CAUTION

Hydrocarbon-based lubricants must not be used on cylinders containing oxygen or oxygen-enriched gas.

Insert the valve into the cylinder neck and tighten first by hand to make sure the threads are properly aligned. Then finish tightening the valve in accordance with the OEM or system manufacturer's recommendations. If no manufacturer's data are available, please refer to torque values specified in EN ISO 13341.

Recommended torque values:

Parallel Thread	Torque Values					
	Nm min	Nm max	Nm set point	lb ft min	lb ft max	lb ft set point
M18 x 1.5	85	100	90	62	75	66
M25 x 1.5	95	130	110	70	95	80

Tapered threads – Check to ensure the cylinder's threads are clean and free of damage.

In accordance with the guidelines of EN ISO 13341 cover the valve threads with oxygen-compatible PTFE tape and insert valve into the cylinder neck and hand tighten ensuring proper alignment and full engagement of the threads. Further tighten the valve to torque values in accordance with the OEM or system manufacturer's recommendations. If no manufacturer's data are available, please refer to torque values specified in EN ISO 13341.

Tapered Thread	Torque Values					
	Nm min	Nm max	Nm set point	lb ft min	lb ft max	lb ft set point
17 E (19.8 DIN 477)	75	95	85	55	70	62
25 E (28.8 DIN 477)	95	110	100	70	80	75

Destruction of condemned or expired cylinders

To destroy condemned or expired cylinders, drill a minimum 13mm hole all the way through the cylinder wrapping and liner so that the cylinder cannot hold gas.

WARNING

If a cylinder contains the valve it can appear to have been completely vented but the cylinder may contain a significant amount of residual gas. Always remove the vale before drilling or cutting the cylinder.

12. Summary

Care and maintenance of a Luxfer carbon composite cylinder

ALWAYS:

- **ALWAYS** be alert for air leaks with each fill.
- **ALWAYS** keep the threads and cylinder interior dry and free from oil, dirt and other contaminants.
- **ALWAYS** fill cylinders with proper gas recommended by the original equipment manufacturer.
- **ALWAYS** follow appropriate inspection recommendations.
- **ALWAYS** follow the valve manufacturer's or SCBA manufacturer's installation procedures and recommendations.
- **ALWAYS** maintain accessory equipment used with your cylinder in strict accordance with the manufacturer's recommendations.

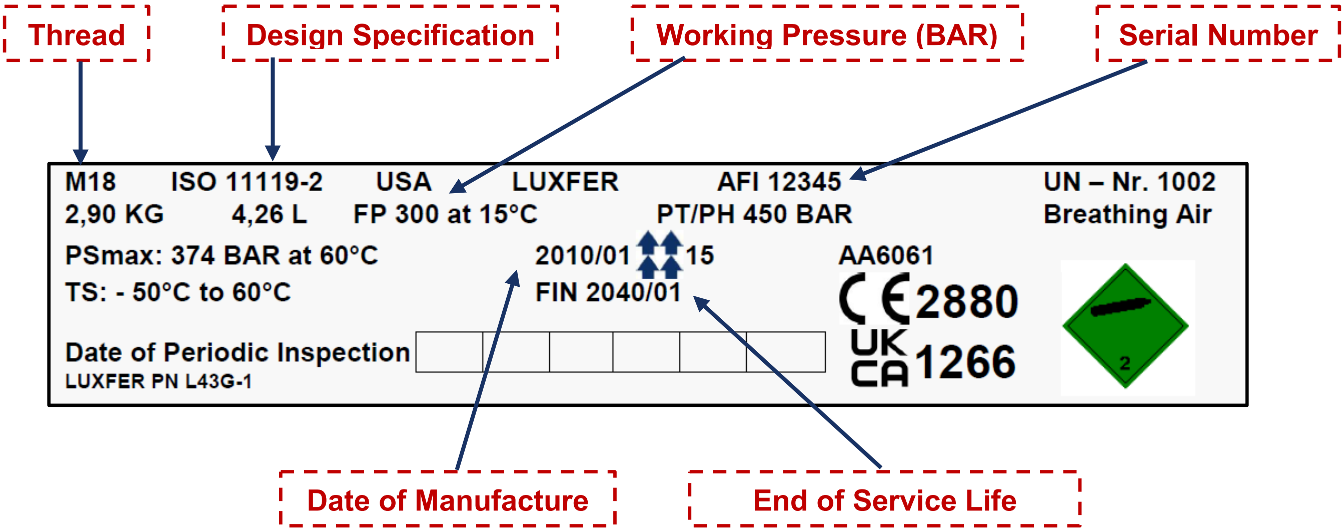
NEVER:

- **NEVER** fill a cylinder if it leaks.
- **NEVER** fill a damaged cylinder.
- **NEVER** fill a cylinder if it is past its required requalification date.
- **NEVER** fill a composite cylinder past its allowable life.
- **NEVER** completely discharge a cylinder (except when you are planning to remove the valve) since it can lead to moisture entering into the cylinder.
- **NEVER** use hydrocarbon-based lubricants with oxygen.
- **NEVER** use non-oxygen-compatible components with oxygen or oxygen-enriched gases.
- **NEVER** over-torque a valve.
- **NEVER** remove, obscure or alter the manufacturer's labels.
- **NEVER** use a cylinder that has been exposed to an extremely corrosive atmosphere or environment without having it properly inspected and tested.
- **NEVER** use a cylinder that has been exposed to extreme heat or fire for a prolonged period without having it properly tested.

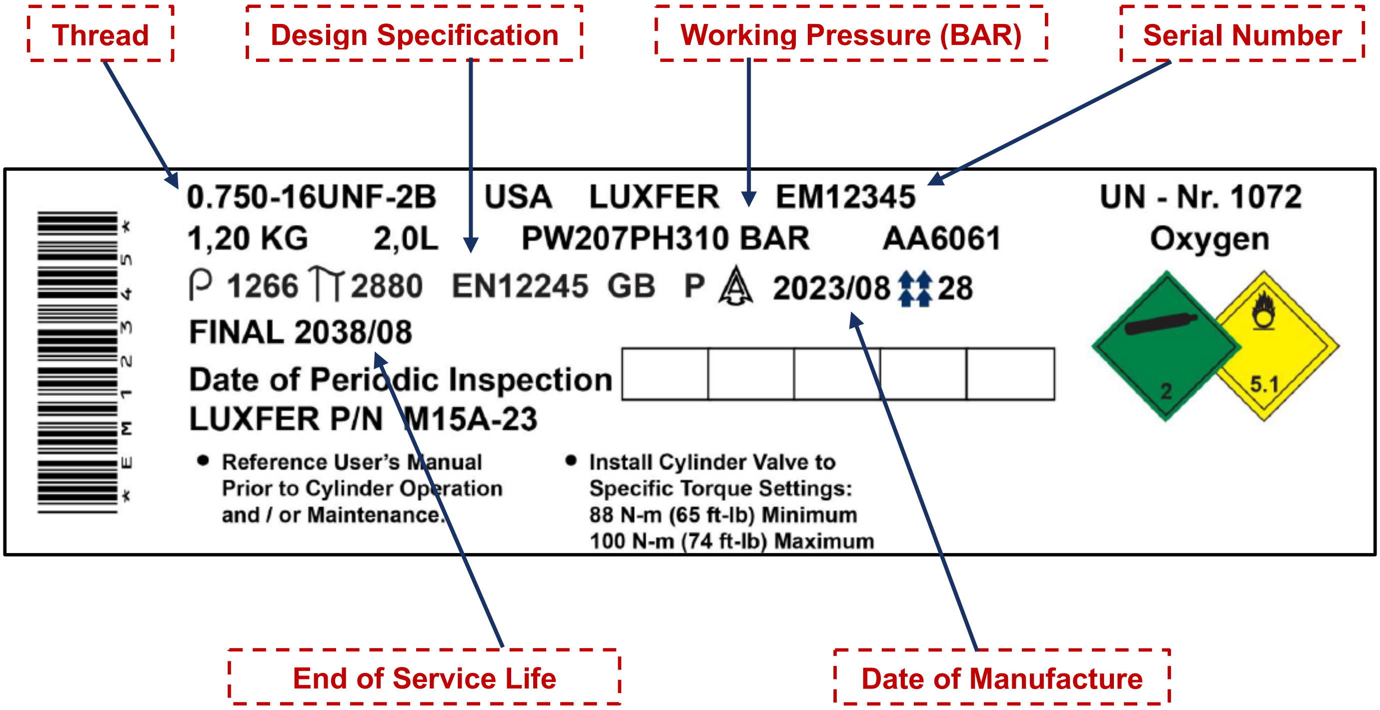
13. Appendix

Appendix 1: Sample Labels

PED/PESR Label



TPED/CDG Label



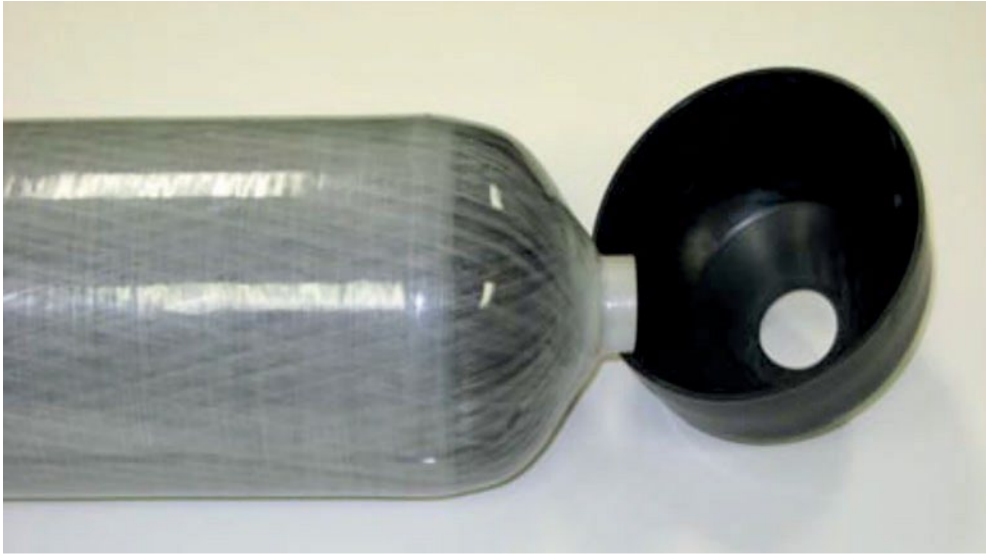
Appendix 2: Removal and refitting of protective caps and boots

Luxfer composite cylinders used in SCBA applications may be fitted with high- impact polymer caps and boots that are bonded to the cylinder with an adhesive. This procedure describes how to remove these caps and boots so that the entire composite surface may be examined during requalification.

Tools required: Thin, flexible metal strip and a Loctite® adhesive kit.

Procedure: Carefully slip the metal strip between the cap or boot and cylinder as shown in Photo 1 to a depth of 40-50mm. Continue to insert the metal strip in this manner every 20mm around the circumference of the cylinder.

Note the depth of the blade under the cap. The adhesive head is 20-30mm from the edge.

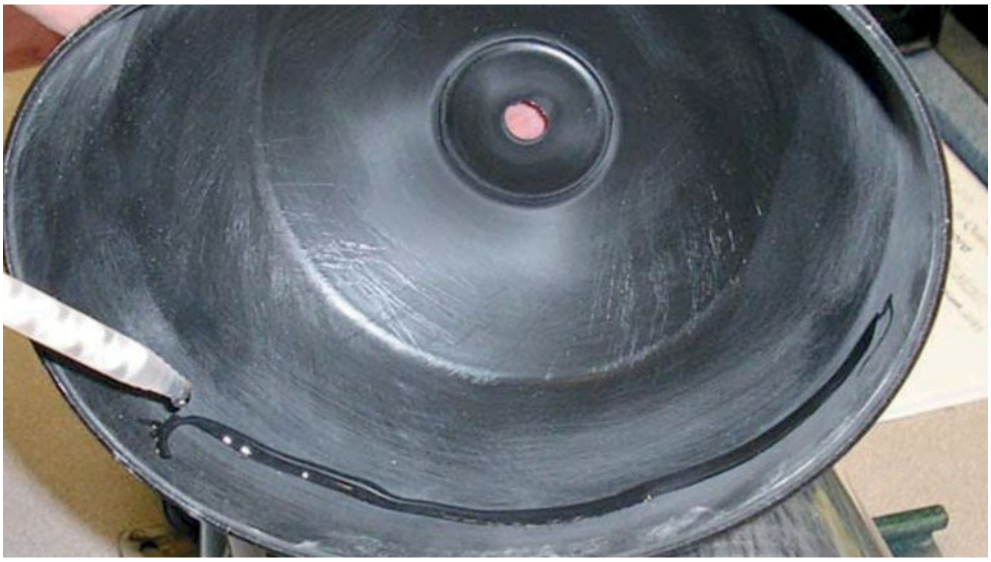


Cylinder surface after the cap has been removed.

Once the metal strip has been passed between the cylinder and cap all the way around, the cap may be removed by lifting the cap by the edge while working around the cylinder.

Perform the same procedure to remove the boot from the base-end of the cylinder.

Any remaining adhesive on the cylinder or cap/boot may be removed by rubbing the surface with a finger or cloth, if necessary, by using isopropyl alcohol.



Applying adhesive.

Installation of new caps and boots

Caps and boots are normally reusable. (New caps and boots may be purchased by contacting Luxfer Customer Service.)

Luxfer recommends using Loctite adhesive for bonding caps and boots. This adhesive is available for purchase from Luxfer. Contact Luxfer Customer Service for information.

Apply a small bead of adhesive to the inside surface of the cap approximately 20 to 30mm from the outside edge (see photo above ‘Applying adhesive’).

Immediately after applying the resin, place the cap firmly over the cylinder dome and press in place.

Do not use heat to cure the adhesive! Heat may have an adverse effect on the cylinder’s performance.