Your guide to the use, maintenance and periodic testing of Luxfer Composite Cylinders
Luxfer carbon fully wrapped composite cylinders are among the lightest gas cylinders available for general high pressure applications. The products will meet the needs of many end users in breathing apparatus, escape sets, medical support and anywhere portability is important.

High-pressure carbon composite cylinders are designed to be durable for the hard service they receive. Nevertheless, like all self-contained breathing apparatus (SCBA) and compressed gas equipment components, cylinders must be treated with respect and be well maintained. This guide is intended for suitably trained personnel to assist them in carrying out the safe operation, valving, inspection and periodic testing of Luxfer composite cylinders.

Your SCBA manufacturer or gas company will have provided you with instructions for the safe and proper filling of the composite cylinder. Carefully follow those instructions and the advice that follows.

In addition to your equipment manufacturer’s instructions on how to properly and safely fill your Luxfer composite cylinder, you must also be aware of and familiar with any, and all, filling guidelines, regulations, requirements and laws of all the appropriate local and/or national authorities and industry organisations.

Luxfer carbon composite cylinder design, development, qualification, manufacturing and testing are conducted by Luxfer’s Composite Cylinder Division in Riverside, California, USA.
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Cylinder Design and Specifications

The seamless liners are made at Hydrospin, a division of Luxfer Gas Cylinders, in aluminium alloy that complies with the specification AA6061. The standard thread is M18 x 1.5 but other thread sizes can be accommodated if required.

The liners are given a proprietary external coating to prevent the possibility of corrosion underneath the composite wrapping. The liners are then overwrapped by 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. A label is applied under the last layer of glass to protect it from damage.

1. Ultra thin-walled aluminium liner
2. Smooth, inert internal finish
3. Insulating layer
4. High performance carbon fibre overwrap in epoxy resin matrix
5. High strength fibreglass reinforced plastic (FRP) protective layer
6. Radius base
7. Parallel thread
At this time Luxfer produces the following sizes of carbon cylinders for Europe:

<table>
<thead>
<tr>
<th>Luxfer Part</th>
<th>Service Pressure</th>
<th>Gas Capacity</th>
<th>Diameter</th>
<th>Length</th>
<th>Weight</th>
<th>Water Capacity</th>
<th>Type</th>
<th>Thread</th>
</tr>
</thead>
<tbody>
<tr>
<td>M06C</td>
<td>300</td>
<td>170</td>
<td>85</td>
<td>196</td>
<td>0.5</td>
<td>0.6</td>
<td>FW Carbon</td>
<td>M18 x 1.5</td>
</tr>
<tr>
<td>M09A</td>
<td>207</td>
<td>255</td>
<td>101</td>
<td>233</td>
<td>0.8</td>
<td>1.1</td>
<td>FW Carbon</td>
<td>0.625 - 18</td>
</tr>
<tr>
<td>M10C</td>
<td>300</td>
<td>283</td>
<td>85</td>
<td>294</td>
<td>0.8</td>
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<td>FW Carbon</td>
<td>M18 x 1.5</td>
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<td>M10T</td>
<td>300</td>
<td>283</td>
<td>85</td>
<td>294</td>
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<td>1.0</td>
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<td>17E tapered</td>
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<tr>
<td>L14C</td>
<td>200</td>
<td>396</td>
<td>101</td>
<td>386</td>
<td>1.4</td>
<td>2.0</td>
<td>FW Carbon</td>
<td>M18 x 1.5</td>
</tr>
<tr>
<td>M15A</td>
<td>207</td>
<td>425</td>
<td>100</td>
<td>373</td>
<td>1.2</td>
<td>2.0</td>
<td>FW Carbon</td>
<td>0.750 - 16</td>
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<td>300</td>
<td>538</td>
<td>101</td>
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<td>FW Carbon</td>
<td>M18 x 1.5</td>
</tr>
<tr>
<td>M19T</td>
<td>300</td>
<td>538</td>
<td>101</td>
<td>384</td>
<td>1.4</td>
<td>2.0</td>
<td>FW Carbon</td>
<td>17E tapered</td>
</tr>
<tr>
<td>M24B</td>
<td>200</td>
<td>679</td>
<td>137</td>
<td>490</td>
<td>3.4</td>
<td>4.7</td>
<td>FW Carbon</td>
<td>M18 x 1.5</td>
</tr>
<tr>
<td>L29C</td>
<td>300</td>
<td>821</td>
<td>114</td>
<td>442</td>
<td>1.9</td>
<td>3.0</td>
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<td>M18 x 1.5</td>
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<tr>
<td>L43C</td>
<td>300</td>
<td>1217</td>
<td>117</td>
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<td>M18 x 1.5</td>
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<tr>
<td>L45D</td>
<td>300</td>
<td>1274</td>
<td>137</td>
<td>490</td>
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<td>M18 x 1.5</td>
</tr>
<tr>
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<td>300</td>
<td>1274</td>
<td>138</td>
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<td>M18 x 1.5</td>
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<tr>
<td>L58C</td>
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<td>1641</td>
<td>156</td>
<td>470</td>
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<td>FW Carbon</td>
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<tr>
<td>L62C</td>
<td>207</td>
<td>1755</td>
<td>171</td>
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<td>9.0</td>
<td>FW Carbon</td>
<td>M18 x 1.5</td>
</tr>
<tr>
<td>L65C</td>
<td>300</td>
<td>1840</td>
<td>157</td>
<td>525</td>
<td>4.0</td>
<td>6.8</td>
<td>FW Carbon</td>
<td>M18 x 1.5</td>
</tr>
<tr>
<td>L65N</td>
<td>300</td>
<td>1840</td>
<td>157</td>
<td>530</td>
<td>4.0</td>
<td>6.8</td>
<td>FW Carbon</td>
<td>M18 x 1.5</td>
</tr>
<tr>
<td>L65X</td>
<td>300</td>
<td>1840</td>
<td>156</td>
<td>522</td>
<td>3.5</td>
<td>6.9</td>
<td>FW Carbon</td>
<td>M18 x 1.5</td>
</tr>
<tr>
<td>L87A</td>
<td>300</td>
<td>2462</td>
<td>174</td>
<td>556</td>
<td>4.8</td>
<td>9.0</td>
<td>FW Carbon</td>
<td>M18 x 1.5</td>
</tr>
<tr>
<td>P15C</td>
<td>345</td>
<td>396</td>
<td>117</td>
<td>249</td>
<td>1.3</td>
<td>1.5</td>
<td>FW Carbon</td>
<td>0.625 - 18</td>
</tr>
<tr>
<td>P12A</td>
<td>345</td>
<td>340</td>
<td>103</td>
<td>234</td>
<td>1.2</td>
<td>1.1</td>
<td>FW Carbon</td>
<td>0.625 - 18</td>
</tr>
<tr>
<td>P09C</td>
<td>345</td>
<td>198</td>
<td>94</td>
<td>206</td>
<td>0.8</td>
<td>0.7</td>
<td>FW Carbon</td>
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<td>P08E</td>
<td>207</td>
<td>227</td>
<td>101</td>
<td>233</td>
<td>0.8</td>
<td>1.1</td>
<td>FW Carbon</td>
<td>0.625 - 18</td>
</tr>
</tbody>
</table>
National Approvals

Cylinders from the composite range have been approved in the following countries:

- United Kingdom
- Netherlands
- Denmark
- Germany
- Switzerland
- Czech Republic
- Hungary
- Poland
- Belgium
- Eire
- Austria
- Portugal
- Iceland
- Luxembourg
- Spain
- Sweden
- Norway
- Slovakia
- Russian Federation
- China
- Hong Kong
- Australia
- (USA and Canada for the M09A)

CE Approval

EC Type Approval to the Directive 97/23/EC (Pressure Equipment) 0044 RWTÜV Anlagentechnik GmbH.

Test Pressure

1.5 x Specified Filling Pressure.

Re-Test Period

Between two and five years depending on country. A five year re-test period is permitted for Luxfer carbon cylinders manufactured and approved to:

- HSE-AL-FW2 standard
- VdTÜV-Merkblatt Druckgase 505 - Prüfen von Druckgasbehältern in Verbundbauweise aus faserverstärktem Kunststoff
- European Pressure Equipment Directive (CE mark) and Transportable Pressure Equipment Directive (π mark)
- DOT Exemption E10945

If you are uncertain as to the correct re-test period for your cylinders please contact your SCBA supplier or your local Luxfer representative.

Cylinder Life

Between 15 and 45 years depending on specification and cylinders design. The cylinder label will show the date of manufacture and the date of the end of the cylinder design life. See Section 2.6
2.1 Aluminium Alloy Liners

The liners are manufactured by Luxfer Gas Cylinders, Hydrospin Division from either cold rolled 6061 aluminium plate or cold impact extruded 6061 bar. The liner is cold drawn to thickness and hot spun closed on the open end. The liners are then subjected to a solution heat treatment and artificial ageing process to obtain the strength and toughness required for the “T6” mechanical properties. Material tests are conducted in accordance with the relevant standards but are generally as follows:

**UTS:** Not less than 310N/mm² (45.0 ksi)

**0.2% Proof stress:** Not less than 286N/mm² (41.5 ksi)

**Bend test:** No cracks when bent over former not more than 6 times the actual thickness of the test strip

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

**Valve thread:** M18 x 1.5 or to customer requirements

Prior to overwrapping, the liners are coated with a proprietary insulating layer to prevent the potential for corrosion between the liner and wrapping.

2.2 Inspection Procedures

Raw materials are checked and identified on receipt. Liners tested 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 cylinder from a heat treatment batch. Threads are verified as to gauge.

The liners are given the batch inspections according to EN 12245 draft standard. Additional visual and dimensional checks are conducted on liners prior to wrapping to ensure they are clean, free from surface defects and manufactured to the design drawing.
2.3 Composite Overwrapping

The composite overwrapping, pressure testing and finishing operations are carried out at Luxfer Gas Cylinders Composite Cylinder Division in Riverside, California.

The main contribution to the strength of carbon composite cylinders is the fibre reinforcement of the Toray T-700® carbon fibre in an epoxy matrix. The fibres are impregnated with epoxy resin and applied to the liner using one of Luxfer’s computer controlled filament winding machines, to ensure correct placement of each fibre. The cylinder is then over-wrapped with layers of S2® fibreglass and an identification label is fixed under the last layer of glass. The fibreglass is added to provide additional impact and damage resistance to the product.

Luxfer applies a Gel Coat finish to the cylinder on top of the glass fibre layers. This provides a smooth surface to the product that makes the surface much more resilient in service and easier to clean. The gel coat is resistant to abrasion, impact and UV degradation.

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

After curing the resin, the cylinders undergo auto-frettage to redistribute the stresses within the aluminium and composite overwrap. Auto-frettage is a pressurisation process, at a designated pressure in excess of test pressure, and at this stress level the yield point of aluminium is exceeded, i.e. the aluminium deforms plastically.

When the pressure is returned 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.
2.4 **Cylinder Batch Inspection and Testing**

The maximum composite cylinder batch size is 200 units, plus the number of cylinders required for destructive testing, in accordance with EN 12245 specification.

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

- **a) visual inspection** 10 % minimum
- **b) dimensional check** 10 % minimum
- **c) weight check** 10 % minimum
- **d) water capacity check** 10 % minimum
- **e) compliance of marking** 100%

For a), b), c) and d), if one unacceptable cylinder is found then 100% of the cylinders in the batch is inspected.

The following performance tests are conducted:

- **Hydraulic test** on all cylinders at 1.5 times service pressure;
- **Hydraulic burst test** on one cylinder per batch. The cylinder is pressurised at a controlled rate until failure. The maximum pressure achieved during the test is recorded as the burst pressure. The burst pressure has to be greater than or equal to the minimum specified design burst pressure and 2 x test pressure. Burst initiation has to occur in the cylindrical part, and the liner can fail in not more than three pieces.
- **Pressure cycling test** normally on one cylinder per batch, but on no less than one cylinder per five batches (i.e. a maximum of 1000 cylinders produced sequentially). The cylinder has to withstand N cycles up to test pressure without failure by burst or leakage, where:

  \[ N = y \times 250 \text{ cycles} \]

  where: \( y \) = the number of years of design service life.
The test continues for a further N cycles, or until failure by leakage whichever is the sooner. In either case the cylinder shall be deemed to have passed the test. However should failure during this second half of the test be by burst, then the cylinder will have failed the test.

For a cylinder with a 15 year design life, the product has to reach 3,750 cycles to test pressure without leaking or bursting. Then a further 3,750 cycles to test pressure are applied. The cylinder can leak during this section of the test but must not burst.

### 2.5 Independent Inspection Authorities

The independent inspection authorities* used by Luxfer in the manufacture of composite cylinders at the present time are:

**RWTÜV Systems GmbH**  
Kurfurstenstr. 58  
D-45138 Essen  
Germany

**TÜV Rhineland of North America**  
1279 Quarry Lane  
Suite A  
Pleasanton, CA 94566  
USA

**Arrowhead Industrial Services**  
3537A S NC 119  
PO Box 1000  
Graham, NC 27253  
USA

*Note: Independent inspection authorities are referred to as “Notified Bodies” under the Pressure Equipment Directive (PED) 97/23/EC.
2.6 Marking and Labelling

Each finished composite cylinder has a label incorporated in the reinforcing wrapping.

The label will contain the following information:

- The CE mark to show compliance with the Pressure Equipment Directive including the number of the notified body: e.g. 0044 for RWTÜV
- The specification that controls the manufacture, testing and use of the cylinder: e.g. EN 12245
- Aluminium alloy of the liner: e.g. AA 6061
- The test pressure: e.g. PH 450 Bar
- Thread identity: e.g. M18
- The cylinder serial number
- The manufacturer’s mark: Luxfer
- The charging pressure: e.g. 300 Bar
- Empty cylinder weight in kilograms: e.g. 4.0 KG
- Date (year and month) of the first hydrostatic pressure test: e.g. 2001/01
- The water capacity in litres: e.g. 6.8 L
- Design Life (month and year): e.g. FIN 2016/01
- Gas Contents
- Essential minimum and maximum operating limits
Additional information may also be included on cylinder labels:

- **EN 1089-2 precautionary labels**

- **Hazard diamond background coloured for risk of gas/gas mixture:**
  - Oxidising
  - Gas under pressure

- **Labels (diamond and panel) shall be firmly attached to the cylinder and maintained in a legible condition**

- **Preferred location is below the cylinder shoulder; cylinder sidewall is however acceptable**

- **Specific diamond sizes are required**
  (function of cylinder diameter; » 10 to 25 mm)

- **Current diamond “label”**
  (UN dangerous goods number “2”; gas under pressure symbol)

*A sample label is included on section 10. APPENDIX 1.*

Label damage or illegibility can be cause for rejecting a cylinder. If the serial number is no longer legible, the cylinder must be rejected or Luxfer contacted for advice. A composite cylinder that is known to be a Luxfer cylinder, which still has a legible serial number, can be returned to service only after all the other product information is made legible. For instance, an illegible part of a composite SCBA cylinder label which has the part identification on it can be corrected by putting that information back on the cylinder, only if the serial number is still legible on the label.

Note that some Luxfer full-wrap SCBA cylinders have the serial number stamped on the neck in addition to the serial number marking on the manufacturer’s cylinder label. *CONTACT LUXFER for further advice, if needed.*
3.1 Design Criteria

The design thickness of the fibre overwrapping cannot be reduced to a simple formula due to the combined load carrying requirements of an aluminium liner, and a combined carbon fibre and glass fibre composite structure. When these components, with their different strength and stiffness characteristics, are pre-strained in the auto-frettage process, a complex distribution of stress results. These are analysed using finite element computer techniques and all the cylinders are manufactured by computer-controlled fibre winding machines to ensure the correct lay-up and high integrity of the overwrap.

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

The following tests were 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**
- **Volume fraction of fibre in the composite**
- **Intercrystalline corrosion susceptibility of the aluminium liner**
The following tests were conducted on finished cylinders:

- **Extreme temperature fluctuation**: -50°C to +60°C
- **High temperature creep at design test pressure**
- **Cyclic fatigue at design test pressure**
- **Impact resistance**
- **High velocity impact resistance**
- **Flaw tolerance**
- **Environmental exposure at high temperatures and high humidity**
- **Exposure to fire**
- **Extreme low temperature burst performance**
- **Extreme high temperature burst performance**

The test procedure and criteria of EN 12245 was used for all tests, except the last two tests, where RWTÜV defined the test parameters.
### 3.2 Qualification Testing

A test programme was agreed with the notified body RWTÜV to address the performance requirements for the cylinder design according to the essential safety requirements of the European Pressure Equipment directive.

A prototype batch of carbon composite cylinders was manufactured and duly witnessed by RWTÜV. Cylinders were then selected and tested in accordance with the qualification test programme prescribed by RWTÜV, which encompassed the requirements of EN 12245 - Transportable Gas Cylinders - Fully Wrapped Composite Cylinders.

The results of testing on the 6.8 litre 300 bar design are summarised here for information.

**Table 1. Qualification Testing Summary for CE Approval**

<table>
<thead>
<tr>
<th>Description</th>
<th>Minimum requirement for 300 bar cylinder</th>
<th>Example results 6.8 litre 300 bar design</th>
</tr>
</thead>
<tbody>
<tr>
<td>EN 60 Determination of loss on ignition</td>
<td>Match or exceed fibre volume fraction used in the design calculations</td>
<td>Passed</td>
</tr>
<tr>
<td>EN 63 Determination of flexural properties</td>
<td>Match or exceed the flexural modulus and flexural strength used in the design calculations</td>
<td>Passed</td>
</tr>
<tr>
<td>ASTM D 4018-93 Tensile properties of carbon and graphite fibre tows</td>
<td>Match or exceed the tensile strength used in the design calculations</td>
<td>Passed</td>
</tr>
</tbody>
</table>

CONT'D.
### Design and Performance Criteria

<table>
<thead>
<tr>
<th>Description</th>
<th>Minimum requirement for 300 bar cylinder</th>
<th>Example results 6.8 litre 300 bar design</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTM D 2343-95 Tensile properties of glass fibre strands used in reinforced plastics</td>
<td>Match or exceed the tensile strength used in the design calculations</td>
<td>Passed</td>
</tr>
<tr>
<td>Tensile test to EN 10002-1</td>
<td>0.2% Proof Stress 286 N/mm² Ultimate Tensile Strength 310 N/mm² Elongation 5.65%A 12%</td>
<td>All tests satisfactory</td>
</tr>
<tr>
<td>Bend Test to EN 1975:1999</td>
<td>No cracking</td>
<td>All tests satisfactory</td>
</tr>
<tr>
<td>Intercrystalline Corrosion Test - EN 1975:1999 Annex A</td>
<td>Average of 200 µm and maximum 300 µm permitted from 9 specimens</td>
<td>Average corrosion depth 158 µm. Maximum depth 210 µm.</td>
</tr>
<tr>
<td>Stress Corrosion Test - EN 1975:1999 Annex A</td>
<td>None of the rings to exhibit cracks after the 30 days in solution</td>
<td>Passed</td>
</tr>
<tr>
<td>Liner Burst Test</td>
<td>Burst pressure 140 bar. One piece burst</td>
<td>155 bar. One piece burst</td>
</tr>
<tr>
<td>Burst Test (3 cylinders)</td>
<td>Burst pressure 900 bar. Three pieces maximum</td>
<td>1086 bar 1121 bar 1138 bar</td>
</tr>
</tbody>
</table>
### Design and Performance Criteria

<table>
<thead>
<tr>
<th>Description</th>
<th>Minimum requirement for 300 bar cylinder</th>
<th>Example results 6.8 litre 300 bar design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambient Cycle Test (2 cylinders)</td>
<td>3750 cycles at test pressure (450 bar)</td>
<td>7500 cycles without failure</td>
</tr>
<tr>
<td>Maximum Temperature Test. (2 cylinders) 70°C for 1,000 hours</td>
<td>Burst pressure 900 bar</td>
<td>1062 bar 1082 bar</td>
</tr>
<tr>
<td>Drop Test (2 cylinders) Half fill with water. Drop 5 times from 1.2m onto steel plate</td>
<td>Burst pressure 900 bar 3750 cycles to test pressure (450 bar)</td>
<td>1067 bar 7500 cycles without failure</td>
</tr>
<tr>
<td>Flawed Cylinder Test (2 cylinders). Two flaws 50% of composite thickness</td>
<td>Burst pressure 600 bar 1000 cycles to service pressure</td>
<td>792 bar 1000 cycles without failure</td>
</tr>
<tr>
<td>Extreme Temperature Cycle Test (1 cylinder)</td>
<td>No leakage in test. Post test burst pressure 751.5 bar</td>
<td>Passed 1050 bar</td>
</tr>
<tr>
<td>Fire Resistance Test (2 cylinders). Vertical/Horizontal</td>
<td>Pressurised cylinders must withstand 2 minutes in fire without burst</td>
<td>Passed. Vented safely through pressure relief device</td>
</tr>
</tbody>
</table>
# Design and Performance Criteria

## Minimum Example results 6.8 litre 300 bar design

<table>
<thead>
<tr>
<th>Description</th>
<th>Minimum requirement for 300 bar cylinder</th>
<th>Example results 6.8 litre 300 bar design</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Velocity Impact Test (1 cylinder)</td>
<td>Pressurised cylinder to withstand bullet impact without fragmenting</td>
<td>Passed</td>
</tr>
<tr>
<td>Torque Test</td>
<td>No deformation of thread after 110% or maximum torque</td>
<td>Passed</td>
</tr>
<tr>
<td>Neck Strength Test</td>
<td>No deformation of cylinder neck after 150% or maximum torque</td>
<td>Passed</td>
</tr>
<tr>
<td>Extreme low temperature burst test: -50°C</td>
<td>Burst pressure 900 bar</td>
<td>1145 bar</td>
</tr>
<tr>
<td>Extreme high temperature burst test: +60°C</td>
<td>Burst pressure 900 bar</td>
<td>983 bar</td>
</tr>
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</table>
Cylinder Use

4.1 General

Luxfer cylinders are intended to be used in the same manner as other high pressure gas cylinders. There are certain differences, however, which are addressed in the following sections.

Maintenance

After the use of an SCBA cylinder in an emergency or rescue operation, remove the harness assembly (backpack) and check for cylinder damage. Clean the cylinder and components. If water is used to clean, make sure all components are allowed to dry. Don’t reassemble until all components are thoroughly dried. Do not apply heat over the temperature of steam (212°F/100°C) in order to dry a wet cylinder.

See section 8 FINAL OPERATIONS for recommendations on internal cleaning of the cylinder.

Storage

Short term (Less than six months)

Tightly close the cylinder valve. Leave some pressure in the cylinder (between 2 and 3 bar). Secure the cylinder and assembly 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

Prior to prolonged storage, the valve should be removed from the empty cylinder. Wash the cylinder internally and externally with fresh tap water, rinse with distilled or de-ionised water, then thoroughly dry (inside and out). Visually inspect the internal surfaces. Install the valve and O-ring according to the SCBA manufacturer’s recommendations. Store the valved cylinder at room temperature in dry conditions either upright or horizontal and properly protect the valve which could otherwise be damaged. Always store with some positive pressure inside the cylinder valve assembly (between 2 and 3 bar). Store at room temperature in a dry place, away from chemicals, artificial heat sources and corrosive environments.
Handling
Cylinders should never be dragged, dropped, or roughly handled. When transporting cylinders, take steps to insure that the valve is protected and that the cylinder is well secured. SCBA cylinders should never 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 cylinder.

Painting
Retouch damaged paint areas with air drying paint, but if damage has been done to the cylinder metal or composite materials, have it visually inspected first by an authorised technician. Never allow the cylinder to be heated in order to dry or cure paint. Never use corrosive, caustic, or acid paint strippers, burning techniques, or solvents, in order to remove paints from aluminium or composite surfaces.

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

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

REJECT composite cylinders known to have been covered, splashed or left standing (soaked) in unknown chemical(s) such that the composite material came in contact with the chemical(s).

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

HOLD composite cylinders if the composite portion has come into contact with a type of chemical that isn’t listed below and if you are unsure of its affects on the composite material. Contact Luxfer for advice.
CAUTION!

Some chemicals are known to cause damage to composite materials. The following lists examples of the types of chemicals that are known to cause damage, attack, or harm composite surfaces.

Any cylinder composite material coming into prolonged (e.g. soaking) contact 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, etc.)

**Vehicle Fluids:**
(materials that contain benzene, glycol (anti-freeze), battery acids/alkalis, window washer fluids, oils containing solvents, flammable materials, organic volatile materials, gasoline and oil additives, fuels (gasoline, gasohol, methanol, etc.)

**Strong Bases:**
(materials that contain medium to high concentrations of: sodium hydroxide, potassium (and/or other) hydroxides, materials that contain strong soap solutions, cleaning (soap) solutions, etc.)

**Acids:**
(materials that are or contain any concentration of acids like hydrochloric, sulphuric, nitric, phosphoric, etc.)

**Corrosives:**
(materials that contain corrosive components or that are corrosive themselves, such as the chemicals mentioned above and: cleaners, glass cleaners, metal cleaners, resin cleaners/removers, drain openers/cleaners, glues, rubber and other chemical cements, and atmospheres containing corrosive gases).
High Temperature Exposure

As a general rule, all-aluminium cylinders that reach temperatures in excess of 175°C (350°F) must be rejected. This is because the properties of the aluminium metal are reduced when temperatures exceed 175°C (350°F) over a period of time, and the longer the exposure the greater the degradation of the metal. The higher the temperature above 350°C (175°C), and the longer the exposure the faster and greater the degradation. It is a combination of temperature and time that is critical.

However, fire-fighters can wear aluminium and composite SCBA cylinders with complete confidence even though they are frequently exposed to temperatures in excess of 175°C (350°F). A fire-fighter is never exposed long enough to excessive temperatures to cause damage to the cylinder’s metal properties. Even wearing the typical fire fighting protective equipment, a fire-fighter will feel sufficient discomfort from life-threatening heat and pull back before his or her cylinder could be affected by the exposure to that excessive temperature.

The exceptional safety record of aluminium and composite cylinders in fire service over 25 years is a clear proof of the durability of the products. Luxfer’s concern, and yours too, is the SCBA cylinder left in a fire unattended. Such cylinders must be rejected. For further information about heat effects, read Luxfer’s Technical Bulletin on the subject. CONTACT LUXFER for a copy.

4.2 Cylinder Filling

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

The composite material used in the manufacture of the cylinders is a good insulator and so the heat generated in the filling process takes longer to dissipate than with traditional metal cylinders. Consequently, a cylinder charged to normal filling pressure, particularly if filled quickly, will reach temperatures in excess of 30°C during filling. Then on returning to ambient temperature, the pressure inside the cylinder will reduce and the cylinder will not have a full charge. Further topping up will be necessary.
However, it is also possible to optimise the filling procedures to achieve a full charge.

**a. Slow Filling**

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

**b. Higher Filling Pressure**

It is possible to compensate for the higher temperatures occurring during the filling process by filling to a higher pressure.

A cylinder filled to 300 bar at 15°C will develop a pressure of 324 bar at 30°C or alternatively, if a cylinder were filled under ambient condition of 30°C, it would be necessary to fill the cylinder to 324 bar to achieve a full charge.

Luxfer carbon cylinders can be filled to a higher pressure up to a maximum of 10% above settled filling pressure (service pressure) as long as the settled pressure is at the correct, marked service pressure.

In the event that cylinders are still not fully charged, when they return to ambient conditions, they can be topped up.

During filling and discharging, some movement of the composite overwrapping occurs and this can generate some noise, often described as snapping or popping. This is normal.

**Fast Filling**

Luxfer composite cylinders can be fast filled and re-used if the cylinder is properly cared for, well maintained and undamaged. However, the filler should ensure that the settled pressure at 15°C does not exceed the rated charging pressure.

Note: During hydrostatic testing cylinders are pressurised to test pressure typically within 15 seconds. Luxfer fast fill experiments on glass composite cylinders have shown that the aluminium liner achieves temperatures of about 50°C when the cylinders are filled with air within 30-60 seconds. This temperature is well below any temperature that might degrade the aluminium or the matrix.
4.3 Approved Gases

Carbon composite cylinders are approved to the Pressure Equipment Directive for use in Europe with air and oxygen. The cylinders are marked on the cylinder label with the gas name and shall only be filled with the indicated gas.

Oxygen

Do not mix gases. This practice can cause catastrophic failure and loss of life or serious injury. Air cylinders, valves and other components are not specifically cleaned for oxygen, or oxygen enriched, use.

Also, some lubricants used in the industry are not compatible with pure oxygen, or oxygen enriched air. This could result in a fire or rupture. Breathing air that contains more than 23.5 percent oxygen is generally referred to as "oxygen-enriched air."

The cylinder interior, valve threads, 'O' ring of cylinders to be filled with oxygen, and any equipment coming into contact with the oxygen, must be clean and free of any contaminant which may react with the oxygen. For additional information, or for guidance on the use of other gasses, oxygen, and various air combinations, contact the SCBA equipment manufacturer.

Compressed Air

When filling composite cylinders with compressed air, care should be taken to ensure that the compressor is properly maintained so that the air quality complies with the appropriate standard.

The maximum moisture contents indicated in the following table are recommended:

<table>
<thead>
<tr>
<th>FILLING PRESSURE</th>
<th>MOISURE CONTENT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mg/m³</td>
</tr>
<tr>
<td>bar</td>
<td></td>
</tr>
<tr>
<td>200</td>
<td>35</td>
</tr>
<tr>
<td>300</td>
<td>27</td>
</tr>
</tbody>
</table>
NOTE

Where the quality of air is not controlled and moisture is suspected to have entered the cylinder, it is recommended that the cylinder is subjected to an internal examination every 6 months. Following this inspection, the cylinder shall be washed with a mild detergent, thoroughly rinsed with fresh water and then dried, before the valve is refitted. If contaminants are found inside the cylinder, the cylinder interior must be cleaned and dried using the procedures defined in section 8.1.
5.1 General

Cylinders must be subjected to a thorough periodic inspection within the time specified by the national regulations. This period is between three and five years depending on country.

In May 2001 Luxfer carbon cylinders were the first composite cylinders to be granted a five year re-test period in the USA. This was based on the exceptional performance and reliability of the products.

In 2003 the quality and performance of Luxfer carbon cylinders has enabled the cylinder range to be granted a five year re-test period for cylinders manufactured and approved to:

- HSE-AL-FW2 standard
- VdTÜV-Merkblatt Druckgase 505 - Prüfen von Druckgasbehältern in Verbundbauweise aus faserverstärktem Kunststoff
- European Pressure Equipment Directive (CE mark) and Transportable Pressure Equipment Directive (π mark)

Note that for Luxfer carbon cylinders manufactured before 2003 to the above standards the re-test period has also been extended to five years.

The periodic requalification requires each cylinder to be examined internally and externally for defects, then subjected to a hydrostatic pressure test to the design test pressure. Only on completing these procedures satisfactorily can the cylinder be returned to service.

The cylinder should be examined for defects externally and internally, and before continuing in service, subjected to a hydrostatic pressure test in accordance with the relevant regulations and the manufacturer’s recommended procedure, by the manufacturer or a station authorised to test composite cylinders on behalf of the manufacturer.

The procedure 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 service. This procedure refers to relevant
guidance published by the Compressed Gas Association in the USA (CGA Pamphlet C-6.2 1988) and the draft International standard for re-testing of composite cylinders (EN/ISO 11623). We also refer to the relevant sections of BS 5430: Part 3 1990 or ISO10461 in respect of non-wrapped and internal surfaces, excluding any method of cleaning or surface preparation that might damage the composite.

The inspector must follow regulatory authority requirements and criteria in the country the periodic inspection and testing takes place. If the following guidelines are less stringent than the regulatory requirements, apply the regulatory authority criteria.

A cylinder with superficial damage only that has no adverse effect on its safety and integrity, may continue in service.

Cylinders with minor damage below the rejection level in accordance with the criteria specified in sections 6.2 to 6.5, including minor flaws in the reinforcement that may be repaired, shall be returned to Luxfer or a competent tester/repairer for examination or repair and subject to hydrostatic pressure test in accordance with the recommended procedure.

Cylinders shall be rejected if they do not meet the volumetric expansion criteria or if any flaw has grown following repair and testing.

Rejected cylinders shall be rendered unable to hold gas under pressure.

In the event of doubt or dispute in connection with re-testing, Luxfer and, if necessary, the approved Inspection Body shall be consulted.

**IMPORTANT!**

Records of all periodic examinations and testing should be sent to Luxfer on completion of the examinations for storage together with materials and test certificates and inspection reports relating to the manufacture of the cylinder, for the lifetime of the cylinder.
5.2 Exterior Inspection

Fibre wrapped cylinders should be periodically inspected for exterior damage to the fibre wrap. Prompt identification of damage and repair will maintain cylinders in a serviceable condition.

The cylinder should be clean and all attachments that will interfere with visual inspection should be removed. The exterior surface of a composite cylinder does not look or feel the same as that of an all metal cylinder. Therefore one should be prepared for differences in appearance and acceptance criteria.

Each cylinder shall be cleaned and have all loose coatings, tar, oil or other foreign matter removed from the external cylinder surface by a suitable method (e.g. washing, soft brushing, controlled water jet cleaning, plastic bead blasting or other suitable method). Grit and shot blasting are not considered suitable. Chemical cleaning agents, paint strippers and solvents which are harmful to the composite material shall not be used (see figure in 6.8 and the CAUTION BOX in section 4.1). Paint removal is not necessary and so is not recommended. See section 8.2 REPAINTING for guidance, if required.

A protective sleeve is not an integral part of the cylinder and should be removed from the cylinder prior to inspection. Removal should be accomplished with no damage to the overwrap.

Resin Cracking

There are occasions when cracks can appear in the composite surface of carbon composite cylinders. The following instances are seen occasionally and are not a concern.

Base Plug

As part of the manufacturing process a plug is inserted into the centre of the cylinder base and the composite material is wrapped around the plug. In some circumstances, particularly when the cylinder is painted, a crack in the resin and/or no paint, can be seen associated with this plug. This is due to differences in expansion rates of the plug, fibres, resin and paint.
The base of the cylinder is a low stress area and the plug has no contribution
to the strength of the cylinder. Any cracks or porosity in this area does not
affect the cylinder’s 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 section 8.2 REPAINTING.
This is a cosmetic repair and as such it is not necessary to carry out a
pressure test afterwards.

**Label Hairline Crack**

A circumferential hairline crack may appear in the area of the label.
The label is situated under the final layer of glass fibre and as a result there is
a localised area, which is slightly raised from the rest of the cylinder.
Occasionally a circumferential hairline crack can be observed at the actual
edge of the label.
This has no impact on the integrity of the cylinder and repair is not necessary.

**Neck Wrap**

Luxfer carbon composite cylinders
are generally manufactured with
glass fibre composite wrapping on
the neck. This is intended to prevent
exposed aluminium and to provide
extra security to the threaded joint.
The neck wrapping is not joined to the wrapping of the cylinder body and in
some cases a crack can be seen at the transition. This is due to differences in
expansion rates of the fibres, resin and paint (if applicable).
The neck-to-shoulder transition of the cylinder is a low stress area. A crack in
this area is cosmetic, does not affect the cylinder’s performance, and no repair
is necessary. If required any crack can be filled and the cylinder painted,
according to the repair procedure outlined in section 7 REPAIR PROCEDURE.
This is a cosmetic repair and as such it is not necessary to carry out a
pressure test afterwards.
5.3 Valve Removal

The cylinder must be empty of pressurised gas for an internal visual inspection. Slowly release the pressure from the valved cylinder according to recommendations by the SCBA or respirator manufacturer.

When the cylinder is empty, remove the valve using proper tools and holding fixture so that the cylinder fibre windings and valve are not damaged. See the SCBA or respirator manufacturer’s recommendations. British Standard BS5430 Part 3 “Periodic Inspection Testing and Maintenance to Transportable Gas Containers” also provides major requirements.

If, for any reason, the valve is hard to remove, stop. If for any reason the operator suspects a defective valve, do not remove valve.

Check to see that the valve is functioning properly by adding a small amount of air to the cylinder to prove that air goes in and out of the valve. Depressurise and then proceed to remove the hard-to-remove, or suspected damaged valve, only after this valve check shows that the valve is working properly and that the cylinder has been depressurised. For further instructions, contact the respirator manufacturer if the valve isn’t working according to the SCBA manufacturer.

Luxfer recommends the inspection of the valve at this time. Contact the respirator manufacturer for the proper inspection procedure of the valve.

Inspect the threads of the valve and cylinder for damage. Clean O-Ring groove.

If a rejecting feature is found at any time during the external inspection, the inspection should stop.

**CAUTION!**

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 any gas released. All valved cylinders thought to be empty should still be handled as if they are under pressure, and the valve should be removed carefully, according to the valve manufacturer’s guidelines.
5.4 Interior Inspection

Internal inspection is normally required only during the periodic inspection procedure. Each cylinder must be inspected internally in accordance with national standard requirements or, if none available, should be inspected in accordance with the British Standard BS5430: Pt 3, ‘Periodic Inspection, Testing and Maintenance of Transportable Gas Cylinders - Seamless Aluminium Alloy Cylinders’ or ISO 10461.

More frequent internal inspection is required in the case where cylinders are charged with breathing air that is not dried and cleaned to the recommended levels (see section 4.3) or when water may have been drawn into the cylinder during service.

The internal surface of each cylinder shall be inspected using adequate illumination to identify any defects present. The cylinder interior should be free of dirt and other foreign material prior to inspection. If this is not the case it will be necessary to clean the internal surfaces (see section 8.1 DRYING AND CLEANING.)

Recommended Inspection Equipment: A dental type mirror having magnification of 2X and a high intensity light source which will adequately illuminate the threads and internal diameter below the threads should be used.

REJECT all full-wrapped cylinders with internal isolated corrosion pit(s) estimated to be over 0.76 mm (0.03 inches) deep.

REJECT all full-wrapped cylinders with sidewall line or broad spread corrosion when one or more interior pit in the line corrosion is deeper than 0.51 mm (0.020 inch), and/or if the interior broad spread corrosion is deeper than 0.51 mm (0.020 inch).

REJECT all full-wrapped cylinders that exhibit bulges or dents on the inside of the liner. This indicates severe impact damage or another form of serious defect.
Threads

Inspect clean cylinder threads with and without a dental mirror and light. Inspect cylinder threads for any imperfections. Check for corrosion on cylinder thread as well as valve thread, if valve is available.

Count the number of continuous full threads, starting at the top, that do not have imperfections. Cylinders must have a specified minimum number of continuous full threads as required in applicable thread standards. The overriding requirement is to have no less than the minimum number of threads so that a gas-tight seal can be obtained by reasonable valving methods.

The thread form is listed on the cylinder label. If you cannot determine the thread type, contact Luxfer for advice.

Inspect all cylinder threads for cracking with and without a dental mirror and light.

Remove the O-ring. Inspect the O-ring gland and cylinder face for cracking. Follow the SCBA or respirator manufacturer’s recommendation on when to replace the O-ring.

**REJECT** all cylinders that do not have the required minimum number of continuous full threads without imperfection, counting from the top according to *table 2* criteria.

**REJECT** all cylinders with corrosion in a thread that is a thread required and defined above.

**REJECT** all cylinders that show evidence of cracking in more than one continuous full thread. Contact Luxfer with this information and findings.

**REJECT** all cylinders with O-ring gland or face cracks or damage that prevents an effective and safe seal of gas pressure.

**RETURN TO SERVICE** all cylinders with tool stop marks on otherwise acceptable threads, with acceptable glands and faces.
Table 2. Minimum Thread Forms

The following thread forms are fitted to Luxfer Carbon Composite cylinders. The minimum number of full threads, counted from the O-ring groove down, is noted for each form.

<table>
<thead>
<tr>
<th>THREAD FORM</th>
<th>MINIMUM NUMBER OF FULL THREADS</th>
</tr>
</thead>
<tbody>
<tr>
<td>M18 x 1.5</td>
<td>12</td>
</tr>
<tr>
<td>17E tapered</td>
<td>Per ISO 11116-1</td>
</tr>
<tr>
<td>0.750 - 16 UNF-2B</td>
<td>8</td>
</tr>
<tr>
<td>0.625 - 18 UNF-2B</td>
<td>10</td>
</tr>
</tbody>
</table>

**CAUTION!**

DO NOT replace components without following the SCBA or valve manufacturer’s instructions. Replace components with parts that are authorised by the SCBA and/or valve manufacturer.
5.5 Pressure Testing

Each cylinder must be subjected to a pressure test in accordance with the applicable national standard requirements. If relevant national standards do not cover composite cylinders, Luxfer carbon composite cylinders may be tested using methods in standards for high pressure aluminium cylinders, for example, the British Standard BS5430: Pt 3, ‘Periodic Inspection, Testing and Maintenance of Transportable Gas Cylinders - Seamless Aluminium Alloy Cylinders’ or EN/ISO 11623.

When performing a volumetric expansion test, the cylinder should be subjected to a pre-test pressurisation not in excess of 90% of the official test pressure. This pressure should be held for a few seconds, then released. Zero the measuring equipment and then conduct the official test. This procedure helps to stabilise the cylinder and test equipment, as a closed system, prior to testing.

Volumetric Expansion Test

Where permitted by national legislation it is possible to conduct a volumetric expansion test at periodic inspection. There are various methods for measuring the volumetric expansion of the cylinder during hydrostatic test. The water jacket volumetric expansion test necessitates enclosing the water-filled cylinder in a jacket also filled with water. The total and any permanent volumetric expansion of the cylinder are measured in relation to the amount of water displaced by the expansion of the cylinder when under pressure and after the pressure is released. A cylinder failing to hold pressure, or failing to meet the applicable expansion criteria will be rejected.

The volumetric expansion test - non-water jacket method can also be used. The procedures can be found in a variety of documents such as British Standard BS5430: Pt 3, and Compressed Gas Association Bulletin CGA 1.
Proof Pressure Test

Where permitted by national legislation it is possible to conduct a proof pressure test at periodic inspection. Here the pressure in the cylinder is brought to test pressure using a suitable fluid, such as water.

The water pressure in the cylinder shall be increased at a controlled rate until the test pressure (ph) is reached. The cylinder shall remain at the test pressure for at least 30 seconds.

The tolerance on attaining test pressure shall be -0% +3% of test pressure (ph).

Where cylinders are subjected to autofrettage the hydraulic proof pressure test may immediately follow or be part of the autofrettage operation.

The water pressure in the cylinder shall be increased at a controlled rate until the test pressure (ph) is reached. The cylinder shall remain at the test pressure (ph) for at least 30 seconds.

The tolerance on attaining test pressure shall be -0% +3% of test pressure (ph).

To pass the test the pressure shall remain steady; there shall be no leaks and after the test the cylinder shall show no visible permanent deformation.

A cylinder failing a proof pressure test will be rejected.
6.1 General

The acceptance/rejection criteria given in this document are the manufacturers recommendations and do not replace any regulatory authority required criteria in existence or to be published.

Composite cylinders may be designed and manufactured for a limited design life, and this is indicated on the cylinder marking. Therefore, the marking shall first be checked to ensure that the cylinder is within its working life.

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. Any damage that exposes the structural carbon fibre layers is sufficient to cause rejection of the cylinder.

Damage to composite overwrapping can take a number of forms and examples of these are described in the following sections.

We recommend the use of three categories of damage in accordance with both the Compressed Gas Association guidelines CGA 6.2 and the European proposed standard EN/ISO 11623.

**LEVEL 1 DAMAGE**

is minor damage that would be considered normal and that would have no adverse effects on the safety of the cylinder and its continued use.

These cylinders can continue in service.

**LEVEL 2 DAMAGE**

is damage of a level greater than level 1 but less than level 3. This is damage that can be repaired.

**LEVEL 3 DAMAGE**

is sufficiently severe that the cylinder has to be **REJECTED**. Level 3 damage cannot be repaired.
6.2 Abrasion Damage

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

LEVEL 1

Small abrasions (less than 0.25mm or 0.010” deep) to the glass fibre layer will not require repair unless the area is large enough to cause unravelling of the fibres.

LEVEL 2

Abrasion damage may be repaired if it is deeper than 0.25mm (0.010”), but less than the depth listed in table 3.

Pressure test cylinders after the repair and reinspect before filling.

LEVEL 3

REJECT composite cylinders with abrasion in the composite material (transverse to the fibre direction) which exceed the limits for Level 2 damage as listed in table 3.

REJECT cylinders where the carbon fibre has been exposed.

REJECT cylinders that show abrasion into the carbon fibre.
6.3 Damage from cuts

Cuts or gouges caused by contact with sharp objects in such a way as to cut into the composite, effectively reducing its thickness at that point. Cut damage may be treated in a similar way as abrasion damage.

**LEVEL 1**

Cuts of less than 0.25 mm (0.01”) deep to the glass fibre layer will not require repair unless the area is large enough to cause unravelling of the glass fibres. However a thin coat of adhesive or paint will seal the surface and hold any loose glass fibres.

**LEVEL 2**

Repair composite cylinders with cuts, digs, scratches, abrasion or gouges in the composite material greater than 0.25 mm (0.010”) in depth but less than the depths or lengths given in table 3. Pressure test cylinders after the repair and reinspect before filling.

**LEVEL 3**

**REJECT** composite cylinders with cuts or gouges in the composite material (transverse to the fibre direction) that exceed the limits for Level 2 damage listed in table 3. Cuts of this depth will normally expose the carbon fibres underneath the glass fibre layer.

**REJECT** cylinders that show cuts or damage into the carbon fibre.
6.4 Impact Damage

Impact damage may appear as hairline cracks in the resin or delamination or cuts in the overwrap. All cylinders that show evidence of impact damage shall be visually inspected for evidence of indentation of the internal surface of the metal liner.

**LEVEL 1**

Light damage such as a small area where the fibre glass is frosted will not require repair and may be returned to service.

**LEVEL 2**

Repair is allowed of impact damage that has caused cuts or exposed glass fibres in the composite material that meet the Level 2 criteria as listed in table 3. Pressure test cylinders after the repair and reinspect before filling.

**LEVEL 3**

The cylinder must be rejected if impact damage has caused a large area of frosting, delamination of fibres or structural damage.

**REJECT** composite cylinders with cuts, gouges or flat spots in the composite material (transverse to the fibre direction) that exceed the limits for Level 2 damage as listed in table 3.

**REJECT** composite cylinders with any visual evidence of indentation of the internal surface of the metal liner.
6.5 Delamination

Delamination is a separation of layers of strands, or of the strands themselves, of the overwrap of the composite. It may also appear as a whitish patch, like a blister or an air space beneath the surface.

**LEVEL 1**

If delamination is restricted to the glass fibre layer only and of a size no more than 50mm² the cylinder may be returned to service.

**LEVEL 2**

Repair the cylinder if delamination is of a depth and length that does not exceed the limits of Level 2 damage as listed in *table 3*. Pressure test cylinders after the repair and reinspect before filling.

**LEVEL 3**

Delamination damage greater than Level 2 will require the cylinder to be **REJECTED**.
6.6 Heat or Fire Damage

Elevated heat exposure is a different condition than obvious heat or fire damage. It may or may not result in permanent heat damage to the cylinder. Elevated heat exposure is when the cylinder itself, absent of any outer protection, has been subjected to a temperature environment in excess of the original cure temperature of the composite material.

A composite cylinder is not intended for normal use in any environment that would result in prolonged composite overwrap temperatures in excess of 177°C (350°F). However, temporary, short term exposures to air temperatures in excess of 177°C (350°F) in a fire fighting environment is not cause for cylinder condemnation. A composite cylinder used within a self contained breathing apparatus (SCBA), as personally carried by a fire-fighter, may experience elevated temperature exposure without significant damage.

Developed composite material temperatures in excess of the original cure temperature of the composite will cause discoloration of the resin system. This discoloration can range from a very light golden caramel colour to a deep, brownish black burnt appearance. The light discoloration will occur naturally over time and with continued direct exposure to sunlight, and not necessarily be a result of temperature exposure. The discoloration may also be caused from the 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.

Careful attention needs to be paid to the condition of any attachments such as valves, decals, stickers, stencils, any exposed metal of the liner (ends or necks), and the outer protective paint coat. If the valve is available, the condition of the pressure relief device (PRD) should be evaluated in order to properly assess the extent of any heat effects. Fire damage to cylinders or equipment is shown by melted plastics, burnt or frayed straps, discoloured components etc.
It is important to clean the cylinder and remove smoke and dirt from the surface to allow a proper inspection. Any cylinder which has been used in equipment which has experienced fire damage should be REJECTED. Fire damage is shown by charring or burning of the composite, paint, labels, valve materials, melted resin, the absence of some or all of the resin, or evidenced by paint effects (bubbling, melting, etc.).

The two levels of heat or fire damage are defined as follows:

**LEVEL 1**

Where the surface of the paint or composite is only soiled from smoke or other debris, and is found to be intact underneath, e.g. no burning of the resin, the cylinder can be returned to service after cleaning.

Over time the resin can also 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 clear coat or painted surface may be evaluated by using a fine grit (Scotchbrite™) scrubbing pad and liquid dish detergent mixed with warm water to clean the surface. An immediate colour change back to an off-white colour indicates that the cause of discoloration has no significant depth and is acceptable. This would also apply to a painted surface that has no evidence of blistering or charring.

Subsequent to this evaluation, the cylinder must pass the pressure test.

**LEVEL 3**

Cylinders subjected to excessive heat damage shall be REJECTED. Cylinders known to have been left unattended in a fire with any evidence of heat damage shall be rejected. Evidence of heat damage would be the charring or melting of the composite or any attachments, valve components, protective layers, stickers, or paint. Evidence
might include blistering of a protective layer. The composite would appear to be a dark brown or black and would remain unchanged when 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 properly assess the extent of any temperature exposure.

Cylinders known to have been subjected to the direct action of fire (prolonged impingement by flame), shall be REJECTED. Evidence of fire damage might include evidence of actual burning. Fire damage could occur in an isolated area of the cylinder surface.

6.7 Structural Damage

A cylinder shall be rendered unserviceable if there is any evidence of surface bulges or depressions, distorted valve connections, or, if by visual examination of the cylinder interior, there is evidence of damage involving deformation of the liner.

6.8 Chemical Attack

Chemicals may dissolve, corrode, soften, remove or ruin cylinder materials. They may also cause bubbling, pitting or extreme dulling of the resin, deterioration of the resin or protective layer (paint), or create multiple fractures transverse to the direction of the fibre. Cylinders with evidence of such damage shall be REJECTED. In other instances where solvents are involved the cylinder surface may become sticky when touched.

Carbon fibres do not suffer anything like the same degree of chemical attack as glass fibres but if a carbon cylinder has been damaged by chemicals it must be REJECTED.
Table 3. Acceptance/Rejection Criteria

The acceptance and rejection criteria in TABLE 3 is based on the European Standard EN/ISO11623, with exceptions as noted.

<table>
<thead>
<tr>
<th></th>
<th>Level 1 (acceptable)</th>
<th>Level 2 (repairable)</th>
<th>Level 3 (rejectable)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abrasion</td>
<td>&lt;0.25mm depth</td>
<td>&gt;0.25mm depth up to carbon exposure</td>
<td>carbon exposure</td>
</tr>
<tr>
<td>Cut/gouge</td>
<td>&lt;0.25mm depth</td>
<td>&gt;0.25mm depth up to carbon exposure</td>
<td>carbon exposure</td>
</tr>
<tr>
<td>Impact:</td>
<td></td>
<td></td>
<td>carbon exposure and/or liner damage</td>
</tr>
<tr>
<td>disbond</td>
<td>&lt;50mm$^2$ area</td>
<td></td>
<td></td>
</tr>
<tr>
<td>delamination</td>
<td>see abrasion/cut/gouge/disbond criteria</td>
<td></td>
<td></td>
</tr>
<tr>
<td>fire/heat</td>
<td>outer surface “soiled”</td>
<td></td>
<td>evidence of burnt/ charred resin</td>
</tr>
</tbody>
</table>
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 examined for lifting, peeling or delamination of the composite which may have occurred.

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

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

Ensure the surface is clean and dry. Any loose fibres may be cut away before coating with resin. Roughen damage area slightly with either fine sandpaper or 3M Scotchbrite™ to provide a key for the resin.

Mix an appropriate amount of the two part epoxy resin according to the resin manufacturer’s instructions, sufficient to repair damage. The epoxy resin is quick drying and so it is important that there are no delays after it has been mixed. Therefore preparation is important.
Repair Procedure

Apply a sufficient amount of the epoxy resin to the damaged area on the cylinder, replacing loose fibres where appropriate. Push down with applicator and fill damaged area with resin.

Where additional protection is required, apply piece of glass fibre surface veil over the damaged area. This should be slightly larger than the damage. Apply a thin layer of resin over the veil, where used, making sure that it is completely covered.

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

Leave the cylinder until the epoxy resin is set, typically 5-10 minutes. Then move the cylinder to another location and leave undisturbed until the epoxy resin is fully cured (according to the manufacturer’s guidelines) before pressure testing or finishing as appropriate.
8.1 Drying and Cleaning

The following procedures are recommended for ID cleaning of aluminium cylinders:

<table>
<thead>
<tr>
<th>PROBLEM</th>
<th>CLEANING METHOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture &amp; light soil</td>
<td>Steam clean and blow dry</td>
</tr>
<tr>
<td>Oil and grease</td>
<td>Degrease with soap and water, steam clean and blow dry</td>
</tr>
<tr>
<td>Odour</td>
<td>Rinse with a solution of baking soda (sodium bicarbonate), then rinse with a solution of vinegar (acetic acid), steam clean and blow dry</td>
</tr>
<tr>
<td>Corrosion</td>
<td>Tumble with a water slurry of aluminium oxide chips or pellets, steam clean and blow dry</td>
</tr>
</tbody>
</table>

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

8.2 Repainting

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

Under normal circumstances, the cylinders should be lightly rubbed down to provide a key for the paint. Should the cylinders be dirty, the surface should be cleaned with a water-based detergent, rinsed and dried thoroughly.

Retouch damaged paint areas with air drying paint, but if damage has been done to the cylinder composite materials, have it visually inspected first by an authorised technician. Never allow the cylinder to be heated in order to dry or cure paint. Never use corrosive, caustic, or acid paint strippers, burning techniques, or solvents, in order to remove paints from aluminium or composite surfaces.

The type of paint is not critical although either epoxy or polyurethane paint of the flame retardant type is recommended. Water-based polyurethane paint has been found to have good flame resistant properties.
Spray painting is preferred as it gives a better finish.

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

If painting near the cylinder label, it is important to ensure that the label is masked off and protected to ensure future legibility.

Care should also be taken to ensure that paint is not sprayed onto the top face of the cylinder neck as this can affect the ability of the valve to be sealed to the cylinder.

Luxfer should be contacted if there are any questions or if additional information is required.

### 8.3 Valve Insertion

Before the valve is inserted into the cylinder, it should be carefully inspected and repaired as necessary, in accordance with the valve manufacturers or breathing apparatus manufacturers’ recommendations, to ensure satisfactory performance in-service. Do not install any valve that has not passed an inspection.

The valve threads should be free from damage and also checked for compliance to the thread specification by using the appropriate gauges. The mating surface on the valve should also be smooth and free from damage.

Damaged or distorted valve threads can damage the 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 breathing apparatus manufacturer’s recommendations.

A thin smear of silicone, hydrocarbon-free grease may be applied to the bottom three or four threads to provide lubrication, taking care that no grease is applied 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 with 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.

Valves should be tightened to the following recommended torque levels:

<table>
<thead>
<tr>
<th>THREAD</th>
<th>TORQUE RANGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>M18 x 1.5</td>
<td>80 - 100 NM (60 - 75 ft.lbs)</td>
</tr>
<tr>
<td>17E</td>
<td>61 - 68 NM (45 - 50 ft.lbs)</td>
</tr>
<tr>
<td>0.750 - 16 UNF-2B</td>
<td>100 NM (74 ft.lbs) (maximum)</td>
</tr>
<tr>
<td>0.625 - 18 UNF-2B</td>
<td>61 - 68 NM (45 - 50 ft.lbs)</td>
</tr>
</tbody>
</table>

CAUTION!
The valve manufacturer should be contacted to ensure that these torque levels are appropriate.
CARE AND MAINTENANCE OF A COMPOSITE CYLINDER

ALWAYS:

be alert for air leaks with each fill
keep the threads and cylinder interior dry and free from oil, dirt and other contaminants
fill cylinders with proper breathable air
follow the inspection recommendations (see section 5)
follow valve manufacturer’s installation procedures and recommendations
maintain all accessory equipment to your cylinder according to manufacturer’s recommendations.

NEVER:

fill a cylinder if it leaks
fill a cylinder with a defect
ever completely discharge cylinder (except when you’re planning to remove the valve) as it can lead to moist air seeping into the cylinder
fill a cylinder with oxygen unless the label identifies the contents as oxygen
fill or partially fill a cylinder with any gas not identified on the label
artificially heat your cylinder
fill a cylinder if it is past its required retest date
fill a composite cylinder past its allowable life
over-torque the valve
remove, obscure or alter manufacturer’s labels or stamped markings
use a cylinder after it has been exposed to an extremely corrosive atmosphere or environment, without having it pass the periodic inspection and test process.
## Appendix

### LUXFER GAS CYLINDERS
Composite Cylinder Division

**Label Drawing**

<table>
<thead>
<tr>
<th>Revision</th>
<th>Change</th>
<th>By</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Original</td>
<td>CSG</td>
<td>04-03-01</td>
</tr>
<tr>
<td>A</td>
<td>Revised as per DCN</td>
<td>CSG</td>
<td>09-21-01</td>
</tr>
</tbody>
</table>

**Label A**

M18   prEN 12245 USA       LUXFER   IC 127003       UN – Nr. 1002
4,20KG 6,8L       FP 300 at 15°C   PT/PH 450 BAR
AA6061 PSmx: 374 BAR at 60°C   2001/09 04
TS: -50°C to 60°C   FIN 2016/09

Reference User’s Manual Prior to Cylinder Operation and/or Maintenance
- Install Cylinder Valve to Specified Torque Settings in Accordance With EN ISO 13341
- Fill with Breathing Air ONLY in Accordance with EN 12021

Stamp/Date of Periodic Inspection

LUXFER PH L65C-45
11 Contact Luxfer

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Or visit our website (click below)  
[www.luxfer-cylinders.com](http://www.luxfer-cylinders.com)