LUXFER
GAS CYLINDERS

Luxfer Composite Inspection Manual

A GUIDE TO THE USE, MAINTENANCE AND PERIODIC INSPECTION OF LUXFER FULLY WRAPPED ARAMID AND GLASS FIBER COMPOSITE CYLINDERS WITH DOT AND TC APPROVAL

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1. Introduction

This guide is intended for use with Luxfer fully wrapped composite cylinder with glass fiber, aramid fiber (Kevlar®) and hybrid mixtures of aramid/glass. Luxfer acquired Structural Composite Industries (SCI) in 2021 and this manual can be used to inspect cylinders marked with SCI labels. These specifications relate to the design and manufacture of composite cylinders, constructed in the form of a seamless aluminum alloy liner, fully overwrapped with high performance fibers in an epoxy resin matrix.

US Department of Transportation (DOT) Special Permits

Aramid (Kevlar®) reinforced cylinders with a design life of 15 years are manufactured to DOT Special Permits SP-8162, SP-7218, SP-8718, and SP-10019. The requalification period is five years.

Glass fiber reinforced cylinders with a design life of 15 years are manufactured to DOT Special Permit SP-7277. The requalification period is three years.

Hybrid Kevlar® and glass fiber reinforced cylinders with a design life of 15 years are manufactured to DOT Special Permit SP-10970. The requalification period is three years.

A copy of the Luxfer DOT permits can be obtained from Luxfer or from the DOT Hazardous Materials website at:

https://www.phmsa.dot.gov/approvals-and-permits/hazmat

Transport Canada (TC) Equivalency Permits

Transport Canada Permit for Equivalent Level of Safety SU 4236 authorizes composite cylinders with aramid and glass fiber reinforcement with a 15-year design life. Cylinder design and testing is conducted in accordance with the standard TC-3FCM in CSA B339-14 and CSA B340-14.

SU 4237 authorizes composite cylinders with aramid fiber reinforcement with a 15-year design life. Cylinder design and testing is conducted in accordance with the standard TC-3FCM in CSA B339-14 and CSA B340-14. The requalification period is five years.

SU 9209 authorizes composite cylinders with aramid fiber reinforcement with a 15-year design life. Cylinder design and testing is conducted in accordance with the standard TC-3FCM in CSA B339-18 and CSA B340-18. The requalification period is five years.

2. Guidelines

High-pressure composite cylinders are durably designed for high pressure gas storage over 15 years. Like all compressed gas equipment, cylinders 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 that you must also follow all applicable local and national regulations concerning filling, use, maintenance and periodic retesting and requalification of your composite cylinder.

If you have questions about the design, development, qualification, manufacturing and testing of your cylinder, visit Luxfer's website at www.luxfercylinders.com or call Luxfer Customer Service in Riverside, California U.S.A. at +1 (800) 764-0366.

Luxfer aramid and glass fiber composite cylinders are designed and manufactured by

Structural Composites Industries LLC (SCI)

336 Enterprise Place

Pomona, CA 91768 USA

Tel: +1 800 764 0366

3. Cylinder Description

Luxfer composite cylinders are manufactured by the application of high strength continuous fibers and epoxy resin over a seamless aluminum alloy liner. This guide is for cylinders where glass fiber or aramid fibers are used as the reinforcing material. These fibers are wrapped in a continuous filament winding pattern which completely covers the liner leaving only the neck thread exposed. The resulting cylinders - known as fully- wrapped composite cylinders - are the lightest currently available. A typical aramid composite cylinder is shown in Figure 1.

Each element of the cylinder has a unique critical function and its integrity must be verified and preserved. The liner serves as a leak tight membrane and is a pressure vessel in its own right. However, it is the fibers that provide the major portion of the cylinder's ultimate structural strength.

The resin protects the fibers from environmental effects and provides the matrix to permit load transfer between the fibers.

During manufacture, Luxfer composite cylinders are subjected to an autofrettage process prior to the standard hydrostatic pressure test. In autofrettage, the cylinder is pressurized such that the liner is strained beyond its yield point, thereby producing permanent plastic deformation of the liner. The resultant residual compressive stresses in the liner and tensile stresses in the fibers at zero internal pressure, make optimum use of the dynamic mechanical properties of the liner and fiber matrix.

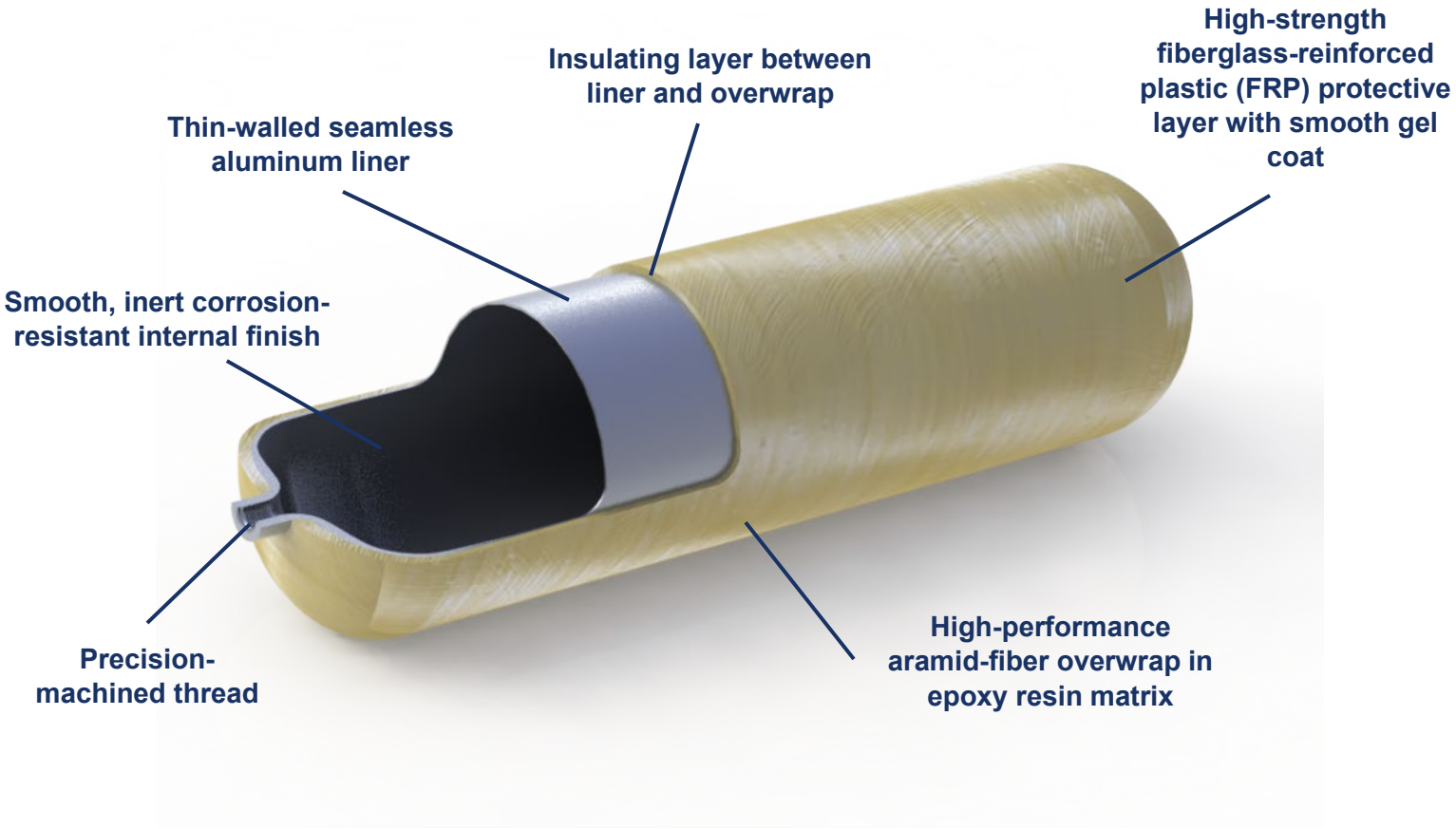

Figure 1: Aramid Composite Cylinder

4. Manufacturer's Cylinder Label

A label displaying regulatory required information is enclosed in the composite material of each Luxfer Gas Cylinders composite cylinder. The specific information displayed on the manufacturer's label is regulated by the government specification to which each cylinder is built.

In general, the manufacturer's labels on Luxfer's cylinders display most, if not all of the following information:

- The government permit number that controls the manufacture, testing and use of the cylinder
- The manufacturer's mark: Luxfer Gas Cylinders
- The charging pressure
- The cylinder serial number
- The mark of the verification body, e.g. Arrowhead Industrial Services Inc., Authorized Testing Inc., or T.H. Cochrane Laboratories Ltd.
- The date (month and year) of the first hydrostatic pressure test at manufacture
- The test pressure
- The water capacity
- Gas contents
- The thread

The cylinder part number, burette size for pressure test, warning notice, the serial number in bar code format, the design life, the weight and aluminum liner material may also be included.

The following figure shows a typical cylinder label for a DOT/TC approved design:

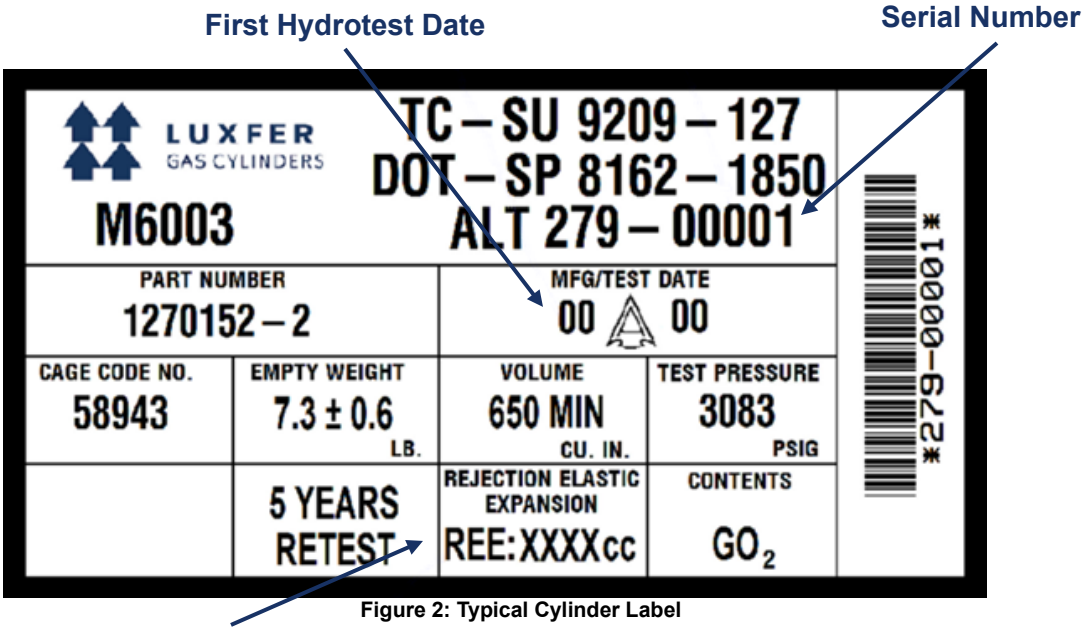

Figure 2: Typical Cylinder Label

IF THE LABEL IS MISSING, THE CYLINDER MUST BE CONDEMNED. IF ANY OF THE REQUIRED MARKINGS ARE ILLEGIBLE, THE MANUFACTURER SHOULD BE CONSULTED.

5. Cylinder Inspection

The cylinder should only be inspected by trained personnel, who are knowledgeable in the care, maintenance and safe handling of gas cylinders.

Cylinders need to be inspected:

- Prior to being filled
- When known to have been abused in-service
- As part of the periodic retest procedures.

The user and/or the retest agency should refer to the applicable government specifications (as marked on the cylinders) for specific requirements pertaining to a given cylinder's use.

NOT ALL ASPECTS OF RETESTING COMPOSITE CYLINDERS ARE ADDRESSED IN THESE GUIDELINES IT IS ESSENTIAL THAT ANY UNFORESEEN RESULTS OF UNUSUAL CIRCUMSTANCES SHOULD BE BROUGHT TO LUXFER's ATTENTION FOR FURTHER GUIDANCE THESE GUIDELINES NECESSARILY ONLY ADDRESS THE COMMON, ROUTINE ASPECTS OF COMPOSITE CYLINDER INSPECTION AND TESTING

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6. Prefill Inspection

Luxfer composite cylinders shall be given an external inspection by the filler, prior to filling to ensure that they are within their retest period and that they have not suffered any significant damage since their previous filling.

Preparation for Prefill Inspection

Remove any objects which may interfere with the visual inspection, such as foreign matter, dirt, loose paint, etc.

THE GOVERNMENT COMPLIANCE LABEL, EMBEDDED IN THE COMPOSITE MATERIAL, MUST NOT BE REMOVED.

In normal use, any integral protective sleeve or cover may remain on the cylinder and should be inspected visually prior to filling. Where the protective sleeve or cover has been badly damaged, it should be removed to permit inspection of the cylinder.

External Inspection

Each cylinder label should be checked to ensure that the cylinder is within test and not due for periodic testing, and that the design service life has not been exceeded. **Do not fill** if the cylinder is out of test date.

Each cylinder shall be inspected externally for damage as described in Section 8 and only those cylinders having acceptable levels of damage shall be filled. **Do not fill** where the cylinder has experienced unacceptable damage.

7. Cylinder Use

Approved Gases

Luxfer composite cylinders shall only be filled with gases that are compatible with the aluminum liner and that are approved for use as listed in the appropriate DOT Special Permit or TC Equivalency Certificate as appropriate.

The cylinders shall be marked with the gas name, either on the cylinder label or by another label affixed to the cylinder and shall 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 120°F (49°C) during filling, particularly if filled quickly.

(Note: This temperature is well below any temperature that might degrade the aluminum 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 435 psi/min (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.

Compresses 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.

Maximum moisture content should conform to recommendations in Compressed Gas Association (CGA) G-7. 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 section 8.1 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. 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 fiber windings and valve.

Do not use a chain vise. Consult manufacturer’s recommendations before carrying out this procedure; also see CGA V-11.

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.

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9. Periodic Testing

Every Luxfer aramid or glass fibre reinforced composite cylinder with DOT and TC approval is required to undergo a periodic examination as defined by the appropriate Special Permit.

The periodic test 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.

Only authorized, or government approved retest organizations can be used to carry out the periodic testing of Luxfer composite cylinders.

Preparation for Periodic Testing Inspection

Remove any foreign matter, loose coatings and secondary labels from the external cylinder surface by a suitable method (e.g. washing, brushing, controlled water jet cleaning, plastic bead blasting or other suitable method).

Grit and shot blasting are not considered suitable.

All covers and protective sleeves should be removed.

Paint removal is not necessary and so is not recommended.

Chemical cleaning agents, paint strippers and solvents which are harmful to the composite material shall not be used.

External Inspection

Each cylinder shall be inspected externally for damage as described in the following section and only those cylinders having acceptable levels of damage or which have been repaired shall be subjected to the hydrostatic pressure test.

10. External Damage

Damage Levels

The surface appearance of Luxfer composite cylinders are similar to traditional all-metal cylinders, as the resin outer skin covers the fiber strands. They have a general ‘smooth’ surface but are not necessarily as flat as the all metal cylinder.

Damage levels are divided into three categories:

Allowable - Level 1

Damage is less than 0.25mm (0.01”) deep and has no effect on cylinder safety or performance. Examples of Allowable damage are damage to the paint coating; scratches, abrasions or cuts less than 0.25mm deep; or small groups of frayed fibres.

Repairable - Additional Inspection and Repairs Required - Level 2

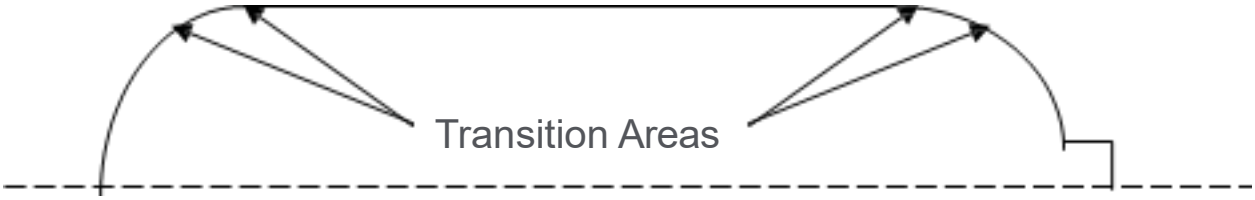
Damage may be cuts, abrasions or gouges which are deeper or longer than those of the allowable damage and which may include a group of broken fibers. This degree of damage may be repairable.

Unacceptable - Condemned - Must not be Repaired – Level 3

The cylinder has become so damaged it is no longer safe for continuing use and cannot be repaired. Cylinders with **Unacceptable** damage must be condemned.

OUTSIDE DIAMETER (mm)	CHARGE PRESSURE (psi)	TEST PRESSURE (psi)	MAXIMUM DEFECT LENGTH (in)	ALLOWABLE DIMENSION DEPTH (in)
61-90	3000	5000	0.79	0.02
91-110	3000	5000	1.00	0.024
111-140	3000	5000	1.18	0.028
141-170	3000	5000	1.18	0.031
171-190	3000	5000	1.38	0.035
191-210	3000	5000	1.38	0.039
61-90	4500	7500	0.79	0.026
91-110	4500	7500	0.98	0.031
111-140	4500	7500	1.18	0.035
141-150	4500	7500	1.18	0.039
151-170	4500	7500	1.38	0.043
171-190	4500	7500	1.57	0.047
191-210	4500	7500	1.57	0.051
211 - 500	4500	7500	1.57	0.051

Table 1: Maximum Allowable Repairable Defect



Note: The maximum allowable defect depth shall be reduced by 1/3 for the wall/ base transition and wall/shoulder transition areas

11. Cylinder Damage Criteria

Abrasion Damage

The cylinder rubbing against a harder object or surface or in extreme cases by grinding causes this type of damage. This is typified by removal of material from the surface.

Scuffs, removing paint from the surface of the cylinder, would be considered minor abrasion damage. Abrasions would involve greater wearing away of the surface of the cylinders and typically numerous fibers would be visible. A flat spot on the surface of the cylinder could indicate excessive loss of the composite layer.

The three categories of abrasion damage are defined as follows:

Allowable - Level 1

Abrasions and scuffs less than 0.01” (0.25mm) deep are acceptable.

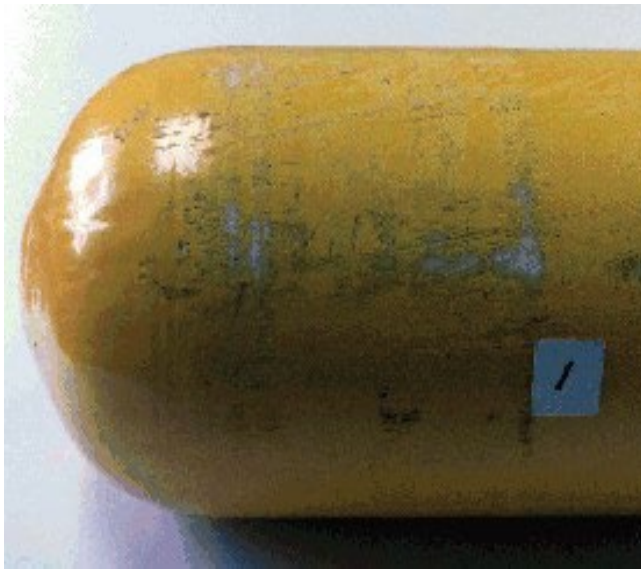
Repairable - Level 2

Abrasions with some fibers exposed or flat spots with a depth between 0.01” (0.25mm) and 0.03” (0.76 mm) but less than 50% of the allowable defect size shown in Table 1. The damaged area should be repaired with epoxy resin to protect against further damage.

Unacceptable - Level 3

Cylinders with abrasions exceeding Repairable damage (level 2) must be condemned.

Abrasion Damage Images



Allowable – Normal Wear

Unacceptable – Must Condemn

12. Cut Damage

Cuts or gouges are caused by contact with sharp objects, surface edges or corners in such a way as to cut into composite, effectively reducing its thickness at that point.

The three categories of cut damage are defined as follows:

Allowable - Level 1

Any superficial cuts less than 0.01” (0.25mm) deep are acceptable.

Repairable - Level 2

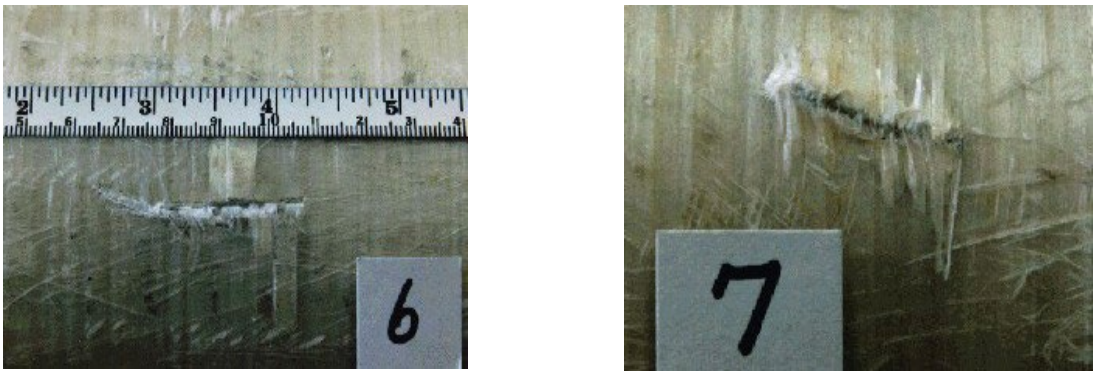
Cuts greater than 0.01” (0.25mm) deep and up to the maximum allowable defect size shown in Table 1, with a maximum 1” (25mm) length perpendicular to the fibers. The damage area is repairable.

Unacceptable - Level 3

Cylinders with cuts or gouges exceeding Repairable damage (Level 2) must be condemned.

Cut Damage Images

Level 2 - Repairable



Level 2- Repairable

13. Impact Damage

Impact damage is caused by the cylinder coming into contact with edges or corners of objects. This can come about from dropping the cylinder or the cylinder being involved in some kind of collision. Impact damage can be observed in the form of dents, as small hairline cracks in the epoxy resin, or by delamination of the composite overwrap.

The categories of impact damage are defined as follows:

Allowable - Level 1

Light damage, such as a small area where the fiberglass is frosted, does not require repair. Damage which is relatively slight, such as bruising, or which appears as areas of small fine cracks at the surface of the impact area are acceptable.

The cylinder may be returned to service.

Repairable - Level 2

Damage from heavy impact is not reparable

Unacceptable - Level 3

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

Cylinders with heavy impact that has caused cuts or gouges or cylinders with dents, delamination or other structural damage must be condemned.

Impact Damage Images

Allowable - Level 1

14. Delamination

Delamination is a separation of the fiber strands from the body of the composite, the fibers coming away from the fiber layer underneath. A delamination may appear as a whitish patch beneath the first layer(s). Delamination can result in fibers peeling away from a cut or gouge.

The three categories of delamination damage are defined as follows:

Allowable - Level 1

No definable limits.

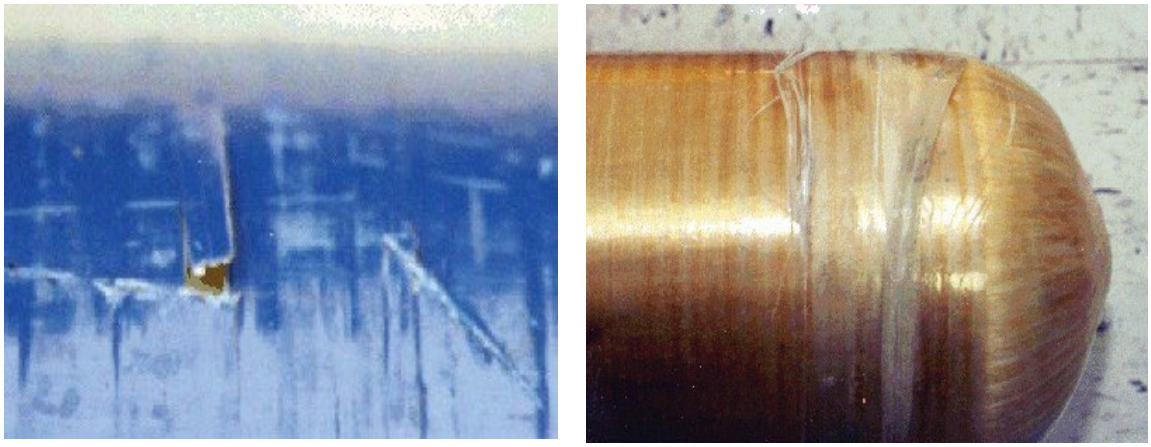
Repairable - Level 2

Cuts or gouges less than 25mm (1”) wide with depth limited to the outer layer of fiber only and which causes the fibers to peel away. This can be repaired, but the hydrostatic pressure test should be used to determine cylinder’s ultimate acceptability.

Unacceptable - Level 3

Cuts or gouges and fiber peeling exceeding Repairable damage (Level 2) must be condemned.

Delamination Images



Level 2- Repairable

Level 3- Unacceptable

15. Heat or Fire Damage

Heat or fire damage is shown by discoloration, charring, burning or melting of the cylinder, paint labels or valve materials.

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 also be inspected.

The three categories of damage are defined as follows:

Allowable - Level 1

The cylinder surface is soiled from smoke and dirt but is found to be intact after cleaning.

However, it is recommended that if there is any concern as to the extent of exposure to fire, the cylinder should be pressure tested.

Repairable - Level 2

Heat or fire damage is not repairable.

Unacceptable - Level 3

Charring or burning of the composite material, labels or paint has occurred, or there is evidence that the epoxy resin has melted. Cylinders with Unacceptable damage must be condemned.

LUXFER GAS CYLINDERS SHOULD BE CONTACTED FOR GUIDANCE, OR THE CYLINDER CONDEMNED, IF THERE IS ANY DOUBT AS TO THE SAFE CONDITION OF THE CYLINDER.

Heat and Fire Damage Image

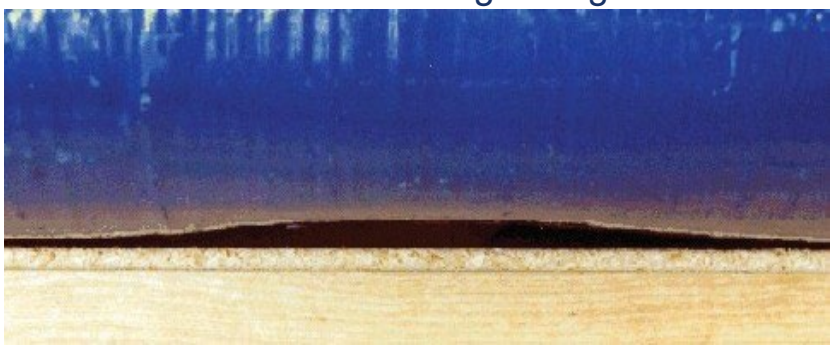
Level 3 Unacceptable

16. Structural Damage

Structural damage is evidenced by the alteration to original external configuration of the cylinder. Bulges, where there is visible swelling of the cylinder, dents, where there is a visible depression in the cylinder and crooked necks are all indications of structural damage.

This type of damage is considered to be Unacceptable damage.

Structural Damage Image



Level 3 Unacceptable

17. Chemical Attack

Chemical attack would appear as deterioration of the paint coating or dissolution of the epoxy resin surrounding the fibers. In other instances where solvents are involved the cylinder surface may become sticky when touched.

Some acids e.g. sulfuric and hydrofluoric acid are known to attack glass fiber and so where contact with acids is known, the cylinder(s) should be de-pressurized and Luxfer Gas Cylinders contacted for guidance.

There are only two categories of chemical damage and these are defined as follows:

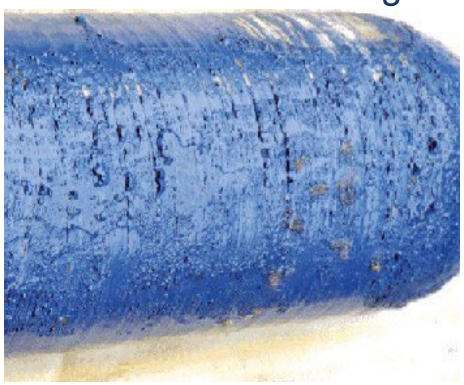
Repairable - Level 1

Damage to the paint coating only and where no damage to the composite material may be repairable by repainting.

Unacceptable - Level 3

Any dissolution of the epoxy resin shall be cause for condemnation.

Chemical Attack Image



Level 3 Unacceptable

18. Illegible Label

Illegibility of the label may be cause for the cylinder to be condemned. In this circumstance, Luxfer Gas Cylinders may be contacted and if it is possible for the cylinder to be accurately identified, a supplementary label may be affixed to the cylinder by the manufacturer.

19. Other Damage

Neck Defect

A small circumferential crack may appear in the composite material between the cylinder body and the neck, which in some circumstances can be seen to open up during filling. This crack is the boundary between the neck wrap and the cylinder overwrap and is not structurally critical.

Repair is not necessary, but the crack may be repaired by filling with a commercial room temperature cure two-component epoxy resin system. This can be carried out more easily when the cylinder is in the pressurized condition.

Neck Defect Image

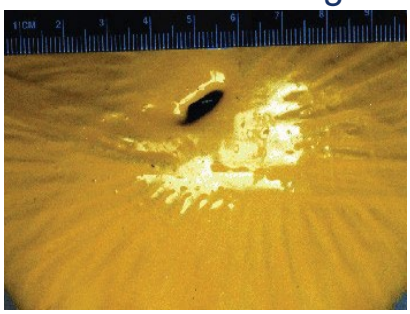
Base Defect

A small hole may appear in the center of the cylinder base. In the wrapping process, the center of the base is not actually wound and afterwards the resulting cavity has to be filled with resin. In some circumstances an air pocket prevents the proper resin penetration, which can later appear as a hole.

This is not a structurally critical area and the cylinder's performance will not be affected. The hole can be easily repaired by filling with a commercial room temperature cure two-component epoxy resin system.

It is not necessary to carry out a pressure test after repairing the hole.

Base Defect Image



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 fiber and as a result there is a localized area, which is slightly raised from the rest of the cylinder. Sometimes a circumferential hairline crack can be observed at the actual edge of the label, which is typically 5-10mm into the painted region above or below the cylinder label.

This has no impact on the integrity of the cylinder and repair is not necessary.

Resin Discoloration

Sometimes the gel-coat on the outside of the cylinder can become discolored over time. This is not serious and does not impact on the integrity of the resin or the cylinder.

Resin Discoloration Image

20. 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 and CGA C-6.1 and CGA C-6.2. 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 section 4.3) 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.

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 TM 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 0.03 inches (0.76 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 0.020 inches (0.51 mm), and/or if the interior broad-spread corrosion is deeper than 0.020 inches (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 TM 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.

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.

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21. Repair

Any repairs to the composite must only be conducted by an organization approved by Luxfer Gas Cylinders or by a person who has had adequate training. A commercial room temperature cure two-component epoxy resin system shall be used. A typical repair sequence is shown in Figure 14.

All cylinders that have been repaired must be subjected to a hydrostatic 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 condemned.

Repair Procedure

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 fibers 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 in line with 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. There is no benefit in preparing a large batch of the quick drying resin as it cures and hardens off more quickly than small amounts.

Apply a sufficient amount of the epoxy resin to the damaged area on the cylinder, replacing loose fibers where appropriate. Push down with applicator damaged area is filled with resin.

Where additional protection is required, apply piece of glass fiber 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

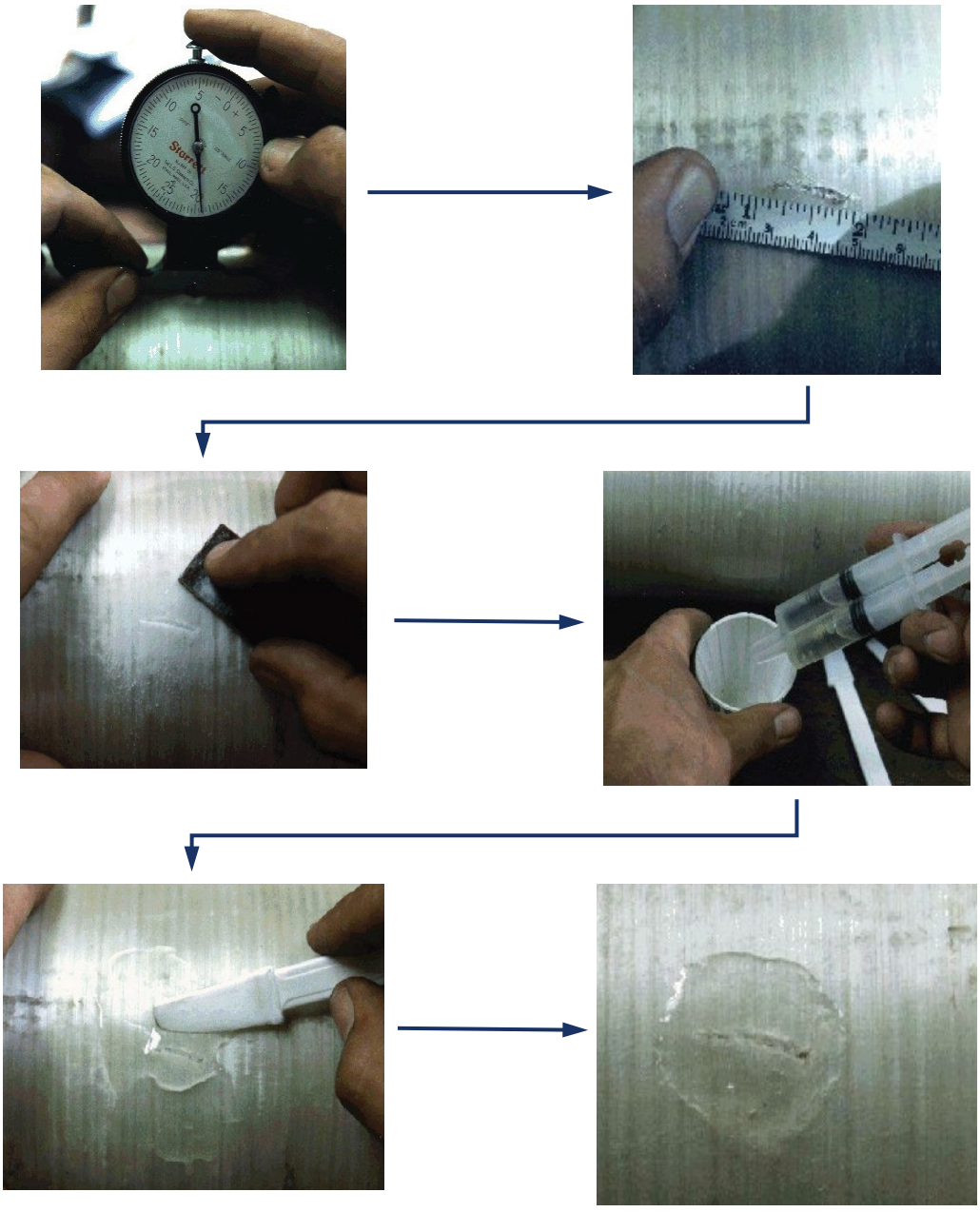
with ordinary adhesive tape. Apply heat to tape with hot air dryer to bring about shrinkage. Peel off tape after epoxy resin has fully cured.

Leave the cylinder until the epoxy resin is set, typically 5-10 minutes. Then move the cylinder to another location and leave for an hour or so to ensure that the epoxy resin is fully hard before pressure testing or finishing as appropriate.

Surface Veil (Optional) Thin fiber glass mat.

Shrink Tape (Optional) 1.5 in. Polyester Tape, which shrinks on exposure to heat

Typical Repair Sequence



22. Hydrostatic Pressure Test

Each cylinder must be subjected to a pressure test in accordance with 49 CFR 180.205 and as defined in the marked DOT Special Permit (SP-8162, SP-7218, SP-7277, SP-8718, SP-10970 or SP-10019) or Transport Canada Permit (SU 4236, SU 4237 or SU 9209).

The test pressure is marked on the cylinder label.

A cylinder not marked with a REE number must be condemned if the permanent volumetric expansion exceeds 5 percent of the total volumetric expansion at test pressure.

A cylinder marked with a REE number must be condemned if the elastic expansion exceeds the marked rejection elastic expansion.

Any cylinder failing to hold pressure shall be cause for rejection.

Cylinders must be condemned if either the permanent expansion exceeds 5% of the total expansion, if they fail to hold pressure or if they demonstrate visible structural damage brought about by the pressurization.

On satisfactory completion of the periodic inspection and hydrostatic pressure test, it is necessary to mark or affix a label in an area close to the original date of manufacture, indicating the date of hydrostatic pressure test and identifying the approved retest organization.

Paper, plastic or metal foil are appropriate materials for the labels and these shall be securely affixed to the cylinder, using a clear epoxy resin, the label being coated on both sides. A rubber stamp using an indelible ink, which is then over coated with a clear epoxy resin, can also be used.

See repair procedure for guidance on application of the resin.

CYLINDER DESIGN LIFE

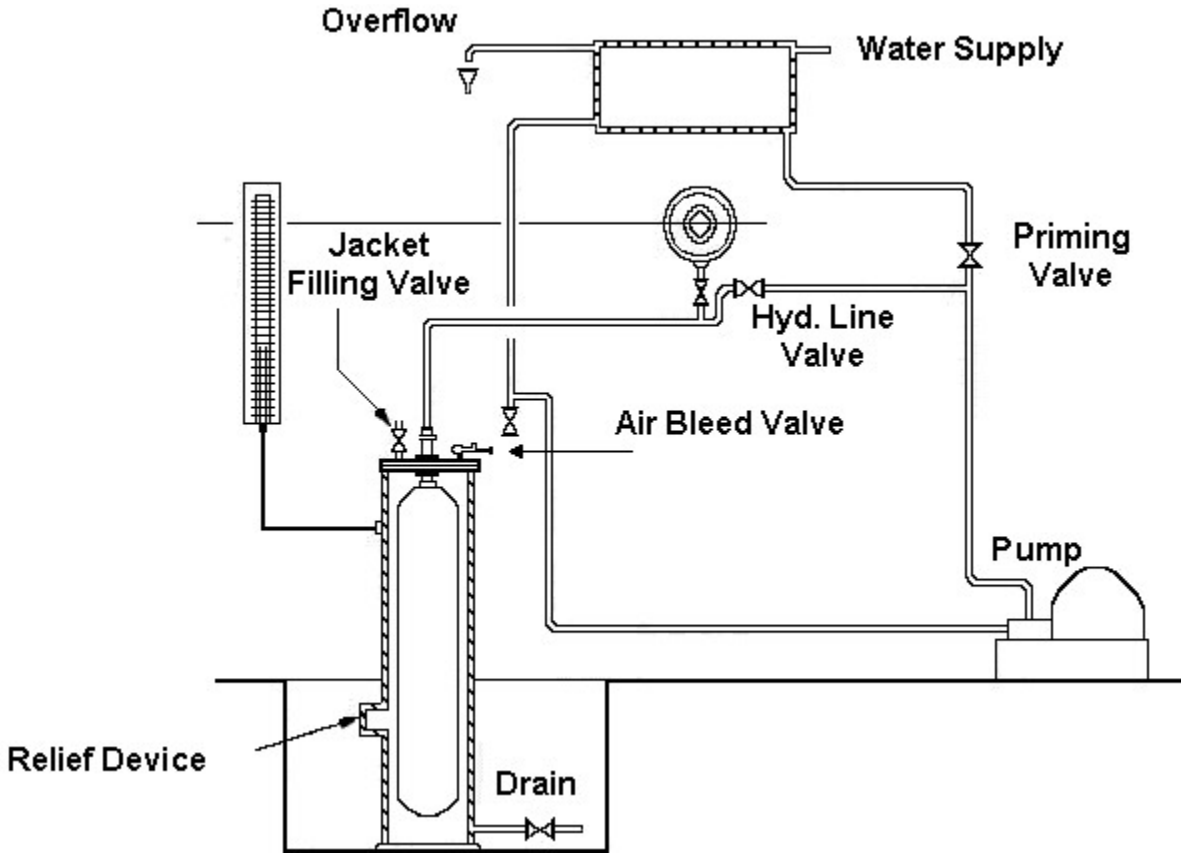
Luxfer aramid and glass fiber composite cylinders approved to DOT and TC permits are all approved with a design life of 15 years from date of manufacture. All cylinders reaching 15 years can no longer be used and shall be condemned and destroyed so that they can no longer be used.

Volumetric Expansion Test Procedure

The following procedure for testing the cylinders refers to the test equipment, illustrated below.

Fill the cylinder with water and attach to the water jacket cover.

Aramid /Glass cylinders require special care when retesting to avoid anomalous readings. Differences in the temperature between the cylinder and the water have been found to cause problems. Therefore, it is important that the cylinder, the water inside it, and the water in the water jacket are the same temperature as is practicably possible. The difference between the temperature of the water in the water jacket and inside the cylinder should be no more than 4°F (2°C).



Water Jacket Volumetric Expansion Test (Fixed Burette)

Seal the cylinder in the jacket and fill the jacket with water, allowing air to bleed off through the air bleed valve.

Connect the cylinder to the pressure line. Adjust the burette so that its zero mark coincides with the zero mark on the burette support. Adjust the water level to the zero marks by manipulation of the jacket filling valve and drain valve. Raise the pressure in the cylinder to 85% of the test pressure, close the hydraulic pressure line valve and stop pumping. Hold until the burette reading stabilizes and remains constant.

A continuing rise in water level indicates either a leaking joint between the cylinder and the jacket or a faulty cylinder connection. For some designs of composites and particularly Aramid/Glass cylinders, air can also be expelled during the pre-pressurization.

Open the hydraulic line drain valve to release the pressure from the cylinder. Hold until the burette reading stabilizes. Reset the water level to the zero mark by manipulation of the jacket filling valve and drain valve, ensuring all air has been expelled.

Restart the pump, open the hydraulic pressure line valve and raise the pressure in the cylinder to the working pressure and, if the water level is stable, then pressurize to the test pressure. Close the hydraulic pressure line valve and stop pumping. Check that the burette reading has stabilized and remains constant.

Lower the burette until the water level is at zero mark on the burette support. Note the water level reading on the burette scale. This is a measure of the total elastic expansion and shall be recorded. If the elastic expansion measurement exceeds the REE number on the cylinder label then the cylinder has to be condemned.

Open the hydraulic line drain valve to release the pressure from the cylinder. Hold until the burette reading stabilizes and remains constant. Raise the burette until the water level is at the zero mark on the burette support. Check that the pressure is at zero and that the water level is constant.

In some circumstances and particularly with the Aramid/Glass cylinders it may take a few minutes for the water level in the burette to stabilize.

Note the water level reading on the burette scale. This is a measure of the permanent expansion, if any, and shall be recorded.

If the cylinder does not have a marked REE number on the label then the cylinder has to be condemned if the permanent expansion exceeds 5% of the total expansion as determined by the following equation:

$$\frac{\text{Permanent Expansion} \times 100}{\text{Total Expansion}}$$

Cylinders with permanent expansions >5% shall be cause for rejection.

Volumetric Expansion Test Procedure - Non-water jacket

Fill the cylinder with water and connect it to the pressure test rig, noting the temperature.

Connect the cylinder to the pressure line and fill the system with water, ensuring no air is trapped in the system. Adjust the burette so that the water coincides with the zero mark by manipulation of the filling valve and the drain valve.

Raise the pressure in the cylinder to maximum service pressure (85% test pressure). Close the hydraulic pressure line valve and stop pumping. Hold this pressure until the burette reading stabilizes and remains constant.

Note: A continuing rise in water level indicates a leaking joint somewhere in the system.

Open the hydraulic line drain valve to release the pressure from the cylinder. Hold until the burette reading stabilizes. Reset the water level to the zero mark by manipulation of the filling valve and the drain valve, ensuring all air has been expelled from the system.

Raise the pressure in the cylinder to the working pressure (2/3 test pressure) and if the water level is stable, then continue to pressurize the cylinder to test pressure. Close the hydraulic pressure line valve and stop pumping. Hold this pressure until the burette reading stabilizes and

remains constant. Note the water level reading on the burette scale. This is the initial measure of the total expansion and shall be recorded.

Open the hydraulic line drain valve to release the pressure from the cylinder. Hold until the burette reading stabilizes and remains constant; this may take some minutes. Note the water level reading on the burette scale. This is a measure of the permanent expansion and shall be recorded.

Carry out the necessary calculations to account for the compressibility of water at the indicated temperature.

Check that the permanent expansion does not exceed 5% of the total expansion. Cylinders with permanent expansions >5% shall be cause for rejection.

23. Final Operations

Drying and Cleaning

The interior of each cylinder shall be thoroughly dried after the pressure test, such that all traces of water are removed.

The interior of the cylinder shall be inspected to ensure that it is dry and free from any other contamination.

Should heat be used, care should be taken to ensure temperatures above 160°F (71°C) are not exceeded.

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 if possible.

Do not heat a cylinder beyond 104º F (40º C) 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.

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

Valve Insertion

Before the valve is inserted into the cylinder, it should be carefully inspected and repaired as necessary, in line with the valve manufacturers or breathing apparatus manufacturers' recommendations, to ensure satisfactory performance in-service.

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

Note: 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 hydrocarbon-free, oxygen-compatible grease may be applied to the ‘O ring 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 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.

Valves should be tightened to the following recommended torque levels:

THREAD	TORQUE RANGE
M18x1.5	80 - 100 NM (60 - 75 ft.lbs)
M25 x 2	120 - 140 NM (90 - 105 ft.lbs)
0.625 -18 UNF	55 – 75NM (40 - 55 ft.lbs)
0.750 - 16 UNF	80 - 100 NM (60 - 75 ft.lbs)
0.875 - 14 UNF	120 - 140 NM (90 - 105 ft.lbs)
1.125 - 12 UNF	165 - 175 Nm(125 - 130 ft.lbs)

Caution: The valve manufacturer should be contacted to ensure that these torque levels are appropriate.

24. Destruction of Cylinders

Condemned or expired cylinders can be destroyed by:

- Sawing the neck off the cylinder or
- Cutting the cylinder in half or
- Drilling a hole greater than 0.5 in. in the cylinder sidewall near the label.

Some companies are now recycling carbon composite cylinders and are able to reclaim both the carbon fiber and the aluminum. For more information contact Luxfer Gas Cylinders.

Caution: Even if completely vented, the cylinder can contain a significant amount of residual gas.