



**GUIDANCE FOR THE USE, INSPECTION,  
CARE AND PERIODIC TESTING OF  
WI COMPOSITE CYLINDERS**

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# GUIDELINES

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The information contained in these guidelines was obtained from sources believed to be reliable and is based on technical information, experience and regulations currently available from Worthington Industries (and subsidiaries Structural Composites Industries [SCI], EFI Corporation, EFIC Ltd.), the British Health and Safety Executive, the British Standard Institute (BSI), CEN, ISO and other sources.

The guidelines provided herein are not intended to be comprehensive and are intended to assist suitably trained personnel in the safe operation, inspection, periodic testing and valving of Worthington composite cylinders. The use of these guidelines shall not create or give rise to any liability to Worthington.

There may be situations, however, which may be outside the company's current experience and so are not included in this document. Worthington, the national approval authority or a government approved retest agency should be contacted for guidance and if there is any doubt as to a cylinder's condition. If such consultation is not possible, the cylinder should be condemned.

It should be noted that these guidelines should not be used for inspecting composite cylinders from any other manufacturer.

Worthington can be contacted at the following addresses

## **NORTH AMERICA:**

Worthington Industries  
336 Enterprise Place  
Pomona, CA 91768-3268 USA

Tel: (1) 909 594 7777

Fax: (1) 909 594 3939

[www.worthingtonindustries.com/SCBA](http://www.worthingtonindustries.com/SCBA)

## **EUROPE:**

Worthington Industries  
Email: [sciEUsales@worthingtonindustries.com](mailto:sciEUsales@worthingtonindustries.com)

# AMENDMENT SHEET

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ISSUE	PAGE NUMBERS	DATE
1	Complete Document EFIC	July 1996
2	Complete Document SCI	August 1999
3	Pages 1, 2, 17, 21, 24 & 26	August 2006
4	Cover	May 2010
5	External Damage, §8	July 2010
6	All	June 2016
7	All	March 2017

# SCOPE & INTRODUCTION

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## SCOPE

These guidelines are intended for suitably trained personnel to assist them in carrying out the safe operation, valving, inspection and periodic testing of Worthington composite cylinders, manufactured to approve specifications, standards and national approvals.

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. These fibers include: Glass, Kevlar®, Carbon and also hybrid mixtures of Kevlar®/Glass and Carbon/Glass.

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## INTRODUCTION

The technology for composite cylinders was developed by the aerospace industry for rocket motors and other related pressure vessels in the 1960s. The gas cylinders themselves were first introduced for commercial applications in the USA in the mid-1970s.

The companies have been manufacturing composite pressure vessels since the early seventies and there are currently around 2.0 million SCI and 750,000 EFIC composite cylinders in-service around the world with an exemplary safety record. However EFIC stopped production at the end of 1998, following its acquisition by SCI. Worthington Industries acquired SCI and its subsidiaries in 2009.

Worthington's range of composite cylinders are approved for use in: the United States, Canada, Japan, United Kingdom, Germany, Switzerland, Denmark, Holland, Belgium, Finland, Norway, Sweden, Austria, Czech & Slovak Republics, Poland, Australia and New Zealand and other countries around the world. Each country has its own set of requirements and specifications for cylinders and their testing. Worthington or an official organization should be contacted for questions regarding the specific requirements of a particular country. In 2003 the European Directives became law and Worthington now holds EC Type Approvals under both the Pressure Equipment Directive and Transportable Pressure Equipment Directive.

Worthington's stringent quality assurance procedures, coupled with their expertise in composite cylinder design technology, ensure that the cylinders are of the highest quality when they leave the factory. Thereafter, the maintenance of the cylinder's quality and integrity becomes the responsibility of the user, filler and retest organizations.

These guidelines have been produced to assist trained individuals or organizations that are responsible for the proper examination, repair and hydrostatic testing of Worthington composite cylinders.

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# CYLINDER INSPECTION & DESCRIPTION

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## CYLINDER INSPECTION

The cylinders 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.

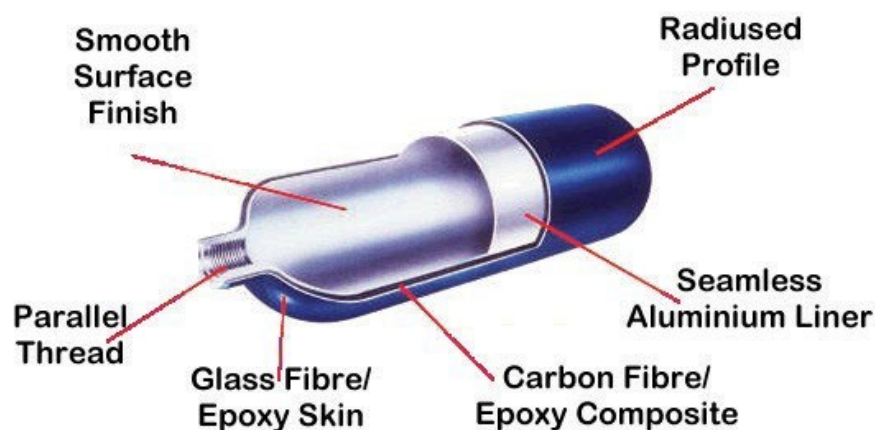
The user and/or the retest agency should refer to the applicable government specifications (as marked on the cylinders) for specific requirements pertaining to a given cylinder's use.

**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 WORTHINGTON'S ATTENTION FOR FURTHER GUIDANCE. THESE GUIDELINES NECESSARILY ONLY ADDRESS THE COMMON, ROUTINE ASPECTS OF COMPOSITE CYLINDER INSPECTION AND TESTING.**

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## CYLINDER DESCRIPTION

Worthington's composite cylinders are produced by the application of high strength continuous fibers and epoxy resin over a seamless aluminum alloy liner. Currently glass, aramid or carbon 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 Carbon Composite cylinder is shown in Figure 1.



**Figure 1: Typical Carbon Composite Cylinder**

# MANUFACTURER'S CYLINDER LABEL

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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, Worthington 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.

**IT SHOULD BE NOTED THAT THE COMPOSITE MATERIAL IS AN INTEGRAL PART OF THE CYLINDER AND SHOULD NOT BE REMOVED.**

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## MANUFACTURER'S CYLINDER LABEL

A label displaying vital information is enclosed in the composite material of each Worthington 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 Worthington's cylinders display most, if not all of the following information:

- The government specification that controls the manufacture, testing and use of the cylinder
- The manufacturer's mark: Worthington Industries
- The charging pressure
- The cylinder serial number
- The mark of the verification body, e.g. CE mark, Pi mark, Arrowhead Industrial Services Inc., Authorized Testing Inc., the German TÜV SÜD, 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 on many cylinder labels.



# PREFILL INSPECTION & CYLINDER USE

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

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## PREFILL INSPECTION

Worthington 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.

*N.B THE GOVERNMENT COMPLIANCE LABEL, EMBEDDED IN THE COMPOSITE MATERIAL, SHOULD 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 cylinder having acceptable levels of damage shall be filled. **Do not fill** where the cylinder has experienced unacceptable damage.

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## CYLINDER USE

Worthington 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.

### Cylinder Filling

The cylinder shall be filled to the design filling pressure indicated on the cylinder label. The

# CYLINDER USE

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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.

Immersing the cylinder in a water bath during filling can aid the removal of this heat build-up, but it is only really helpful with the carbon composite cylinder.

*N.B. In some circumstances small bubbles of air may be expelled from the composite surface. This is normal for this type of cylinder.*

However, it is also possible to optimize 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.

Worthington cylinders can be filled to a higher pressure with a maximum of 10% above normal filling pressure.

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

*N.B. During filling and discharging, some movement of the composite occurs and this can generate some noise, crackling, etc. This is normal.*

## **C.) Fast Filling**

Worthington has no objection to the fast filling of carbon composite cylinders, since the cylinders are designed to take account of: fast filling, exposure to intermittent moderate

# CYLINDER USE

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temperatures and overfilling such that the settled pressure at 15°C does not exceed the rated charging pressure.

Note: During hydrostatic testing cylinders are pressurised to test pressure and depressurised within 2-4 seconds. 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.

## Approved Gases

Worthington cylinders shall only be filled with gases that are compatible with the aluminium liner and that are approved for use either by reference to standards or by a government authority.

The cylinders shall be marked either on the cylinder label or by another label affixed to the cylinder with the gas name and shall only be filled with the indicated gas.

## Compressed Air

When filling Worthington 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:

MAXIMUM MOISTURE CONTENT		
Filling Pressure bar	Moisture Content	
	mg/m <sup>3</sup>	Dew Point
200	35	-51°C
300	27	-53°C

*N.B. 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 15.1.*

## Oxygen

The cylinder interior, valve threads and 'O' ring of cylinders to be filled with oxygen must be clean and free of any contaminant which may react with the oxygen.

# CYLINDER USE

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## Valve Removal and Insertion

### Valve Removal

Secure cylinder firmly. The holding fixture should be designed to prevent any damage to the composite cylinder.

ENSURE THAT THE CYLINDER IS COMPLETELY EMPTY, BY CAREFULLY OPENING THE HANDWHEEL WITH THE OUTLET POINTING AWAY FROM THE OPERATOR, BEFORE ATTEMPTING TO REMOVE THE VALVE.

In the event that the valve cannot be easily removed, apply penetrating fluid to the joint and the valve and then carefully rotate the valve forwards and backwards. A liberal application of the penetrating fluid is recommended and it should be given sufficient time for penetration of the threads before the valve is loosened. The cylinder and valve threads and the cylinder interior should be thoroughly cleaned afterwards to remove all traces of the penetrating fluid, contamination, dirt, etc. (see Section 10a)).

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

*N.B. 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 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: Silicone grease must not be used on cylinders filled with oxygen.**

# CYLINDER USE & EXTERNAL DAMAGE

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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.

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## EXTERNAL DAMAGE

### Damage Levels

The surface appearance of Worthington 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:

#### A) 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.

#### B) Repairable - Additional Inspection and Repairs Required - Level 2

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

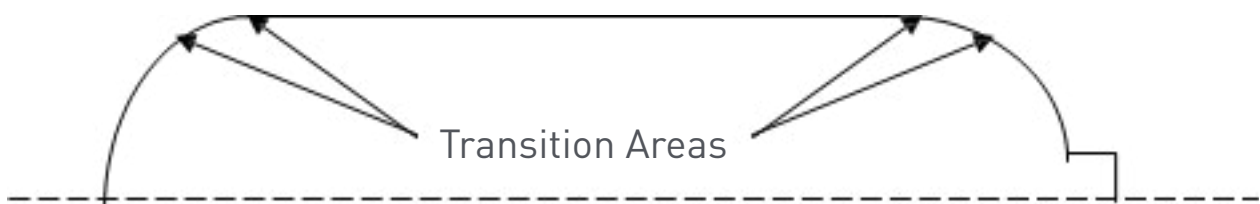
# EXTERNAL DAMAGE

## C) 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.

OUTSIDEDIAMETER (mm)	CHARGE PRESSURE (bar)	TEST PRESSURE (bar)	MAXIMUM DEFECT LENGTH (mm)	ALLOWABLE DIMENSION DEPTH (mm)
61-90	200	300	20	0.5
91-110	200	300	25	0.6
111-140	200	300	30	0.7
141-170	200	300	30	0.8
171-190	200	300	35	0.9
191-210	200	300	35	1.0
61-90	300	450	20	0.7
91-110	300	450	25	0.8
111-140	300	450	30	0.9
141-150	300	450	30	1.0
151-170	300	450	35	1.1
171-190	300	450	40	1.2
191-210	300	450	40	1.3
211 - 500	300	450	40	1.3

**Table 1: Maximum Allowable Repairable Defect with Repair**



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

# EXTERNAL DAMAGE

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## Types of Damage and Acceptance Criteria

### Abrasion Damage

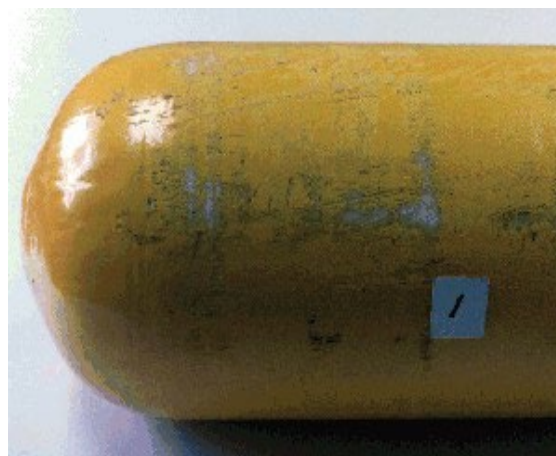
The cylinder rubbing against a harder object or surface or in extreme cases by grinding causes this type of damage. This is typified by removal of material from the surface.

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 0.25mm (0.01") deep are acceptable.
- **Repairable - Level 2**  
Abrasions with some fibers exposed or flat spots with a depth between 0.25mm (0.01") and 0.76 mm (0.03") 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.



**Allowable - Normal wear**

# EXTERNAL DAMAGE

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**Borderline - Repairable**



**Unacceptable**

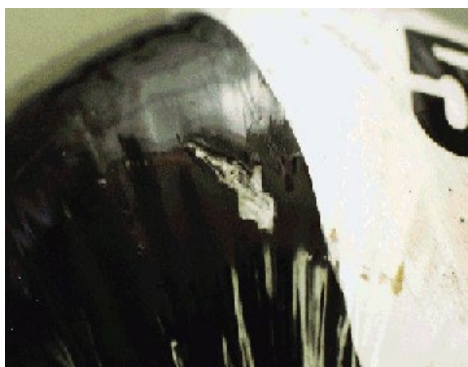
**Figure 2: Abrasion Damage**

## 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 0.25mm (0.01") deep are acceptable.
- **Repairable - Level 2**  
Cuts greater than 0.25mm (0.01") deep and up to the maximum allowable defect size shown in Table 1, with a maximum 25mm (1") 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.



**Level 2 Repairable**

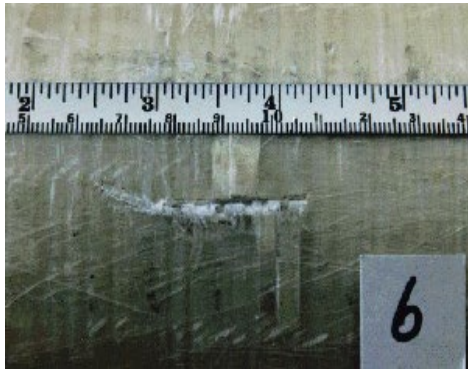


**Level 2 Repairable**



# EXTERNAL DAMAGE

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**Level 2 Repairable**



**Level 2 Repairable**

**Figure 3: Cut Damage**

## 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 three categories of impact damage are defined as follows:

- **Allowable - Level 1**  
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.
- **Repairable - Level 2**  
Cuts or gouges resulting from the impact no greater than 0.25mm (0.01”) deep and up to the maximum 25mm (1”) length transverse to the fibers. The damage area is repairable.
- **Unacceptable - Level 3**  
Cylinders with cuts or gouges exceeding Repairable damage (Level 2), or cylinders with dents, delamination or other structural damage must be condemned.



**Allowable Level 1**

**Figure 4: Impact Damage**

# EXTERNAL DAMAGE

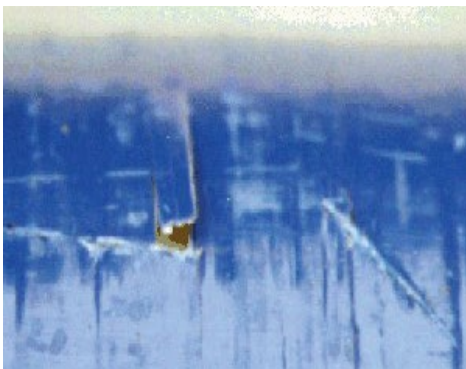
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## Delamination

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.



**Level 2 Repairable**



**Level 3 Unacceptable**



**Level 3 Unacceptable**

**Figure 5: Delamination**

# EXTERNAL DAMAGE

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## Heat or Fire Damage

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

*N.B. 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**

NA

- **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.

N.B. WORTHINGTON SHOULD BE CONTACTED FOR GUIDANCE, OR THE CYLINDER CONDEMNED, IF THERE IS ANY DOUBT AS TO THE SAFE CONDITION OF THE CYLINDER.



**Figure 6: Heat and Fire Damage**

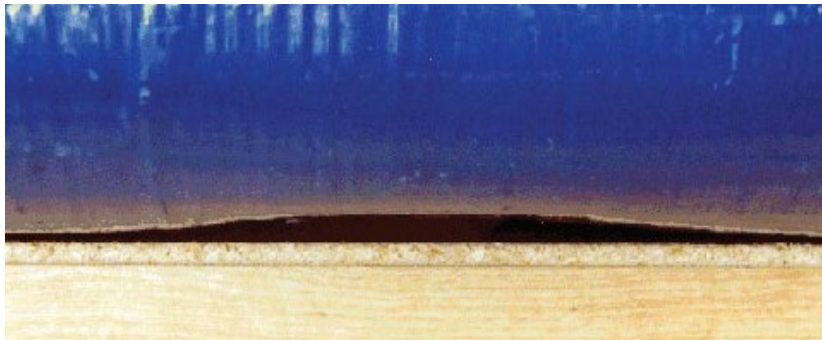
# EXTERNAL DAMAGE

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## 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.



**Figure 7: Structural Damage**

## 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. sulphuric 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 Worthington 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. The cylinder should be de-pressurized and Worthington contacted for guidance.
- **Unacceptable - Level 3**  
Any dissolution of the epoxy resin shall be cause for condemnation.

# EXTERNAL DAMAGE

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**Figure 8: Chemical Attack**

## **Illegible Label**

Illegibility of the label may be cause for the cylinder to be condemned. In this circumstance, Worthington 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.

## **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 filled condition.



**Figure 9: Neck Defect**

### **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

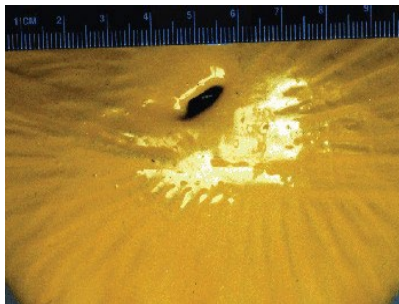
# EXTERNAL DAMAGE

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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.



**Figure 10: Base Defect**

## 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.



**Figure 11: Resin Discoloration**

# PERIODIC TESTING

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## PERIODIC TESTING

Every Worthington composite cylinder is required to undergo a periodic examination and test every so many years from the date of its first hydrostatic pressure test. There is a growing acceptance that this type of cylinder has proved itself in service and so the time between periodic inspections is now generally accepted to be 5 years. This is now the norm throughout most of Europe and the USA.

The EN ISO Standard EN ISO 11623:2002 Transportable Gas Cylinders – Periodic Inspection and testing of composite gas cylinders, is recommending 5 years.

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

Note: All records relating to the service life of the cylinders are required to be held by the manufacturer in some countries, as a means of monitoring the performance of the cylinders in the field.

### 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).

*N.B. 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. See Section 13.2 for guidance on repainting, if required.

*N.B. 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 Section 8 and only those cylinders having acceptable levels of damage or which have been repaired shall be subjected to the hydrostatic pressure test.

# INTERNAL INSPECTION

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## INTERNAL INSPECTION

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

More frequent internal inspection is required in the case where cylinders are charged with breathing air that is not dried and cleaned. See Approved Gases Section for more information on this subject.

Guidelines for internal inspection are presented below:

a) Each cylinder shall be inspected with an inspection lamp of sufficient intensity to identify any defects such as corrosion, dents or cracks. Any cylinder with internal dents or cracks should be condemned.

Any cylinder showing signs of internal contamination or corrosion should be cleaned internally by water jet abrasive cleaning, flailing, steam jet, hot water jet, rumbling with ceramic chips or other suitable method recommended by Worthington. Care should be taken to avoid damaging the cylinder.

*N.B. Alkaline solutions which are harmful to aluminum, such as caustic soda, must not be used for internal cleaning.*

After cleaning and drying, the cylinders should be inspected again. Any cylinders showing excessive corrosion should be condemned.

b) The internal neck threads of each cylinder should be inspected and gauged to ensure that they are full of form, clean and free from burrs and other imperfections.

c) The 'O' ring gland in the cylinder neck shall be clean and free from damage.

*Note: The internal surface of cylinders, which have been treated with Alumashield, will have a darker, almost brownish appearance. This is normal and should not be removed.*



# REPAIRS

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## REPAIRS

Any repairs to the composite must only be conducted by an organization approved by Worthington 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 12.

**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.

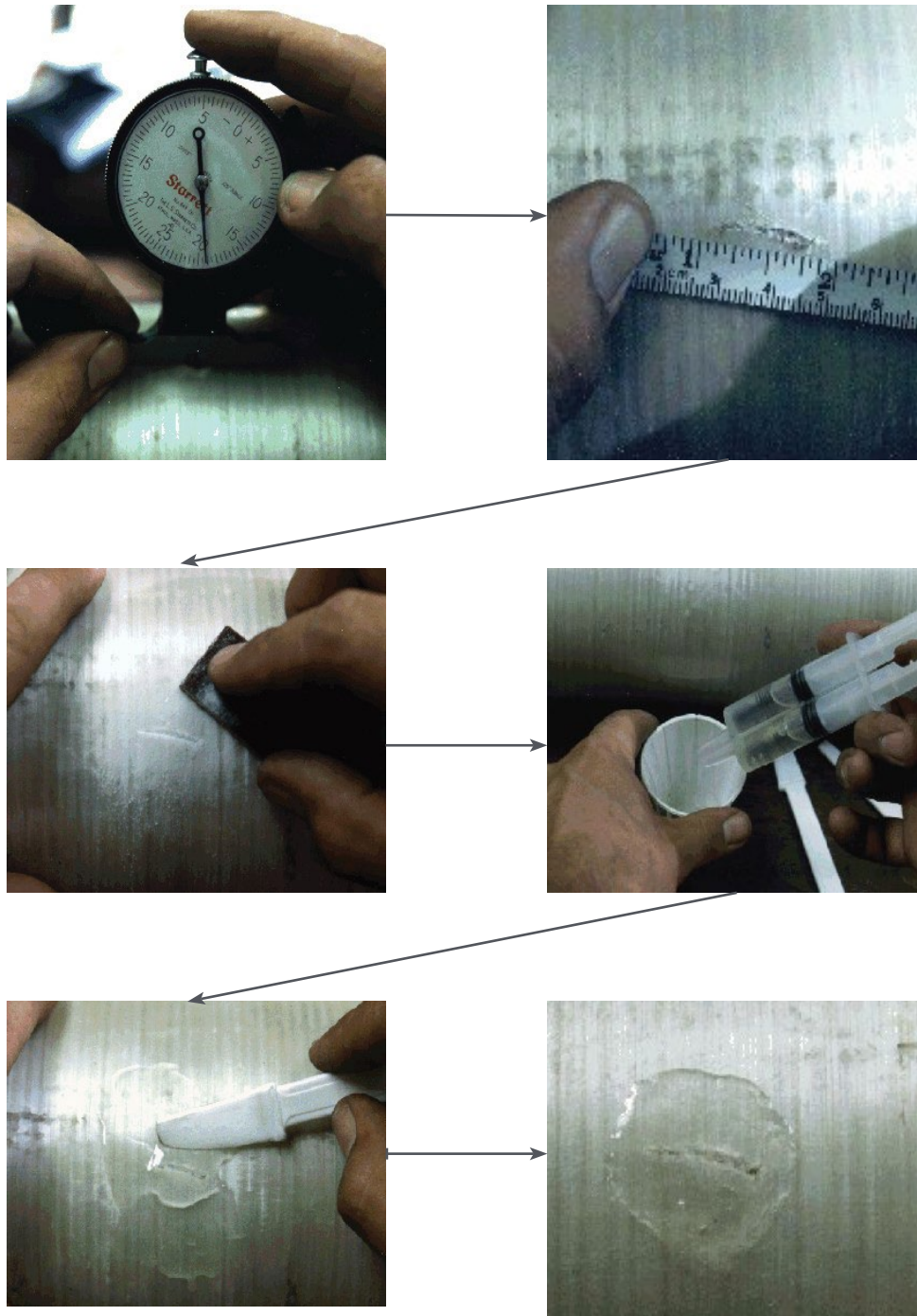
Apply a thin layer of resin over the veil, where used, making sure that it is completely covered.

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.

# REPAIRS

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) Fiber Glass mat, 0.25mm thick roving in random format. Shrink Tape (Optional) 32mm Polyester Tape, which shrinks on exposure to heat



**Figure 12: Typical Repair Sequence**

# DESTRUCTION

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## DESTRUCTION

All cylinders that have been established as being no longer safe for continued service shall be destroyed by:

- Sawing the neck off the cylinder or
- Cutting the cylinder in half.

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

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## HYDROSTATIC PRESSURE TEST

Each cylinder must be submitted to a hydrostatic pressure test using a suitable fluid, usually water, as the test medium.

The first periodic inspection shall be as designated by the national authority (see Periodic Testing section).

Worthington recommends that cylinders shall be pressure tested using the volumetric expansion test - levelling burette method described in BS5430: Pt 3. This method is used to avoid errors due to parallax or the effect of the hydrostatic head.

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.

The proof pressure test method is also being used more extensively as this is the more common method used in Europe and is also described in the EN ISO 11623: 2002 Periodic Inspection Standard.

### CAUTION:

- Use only correctly threaded pressure test adapters
- Test adapters should be clean and free from dirt, grit or burred threads
- Ensure that the cylinder and test jacket are filled slowly to exclude air bubbles
- Before testing, verify that the test equipment is functioning correctly and that there are no leaks, either by using a calibrated cylinder or other suitable method.
- Do not leave water inside cylinders for more than 30 minutes and dry thoroughly

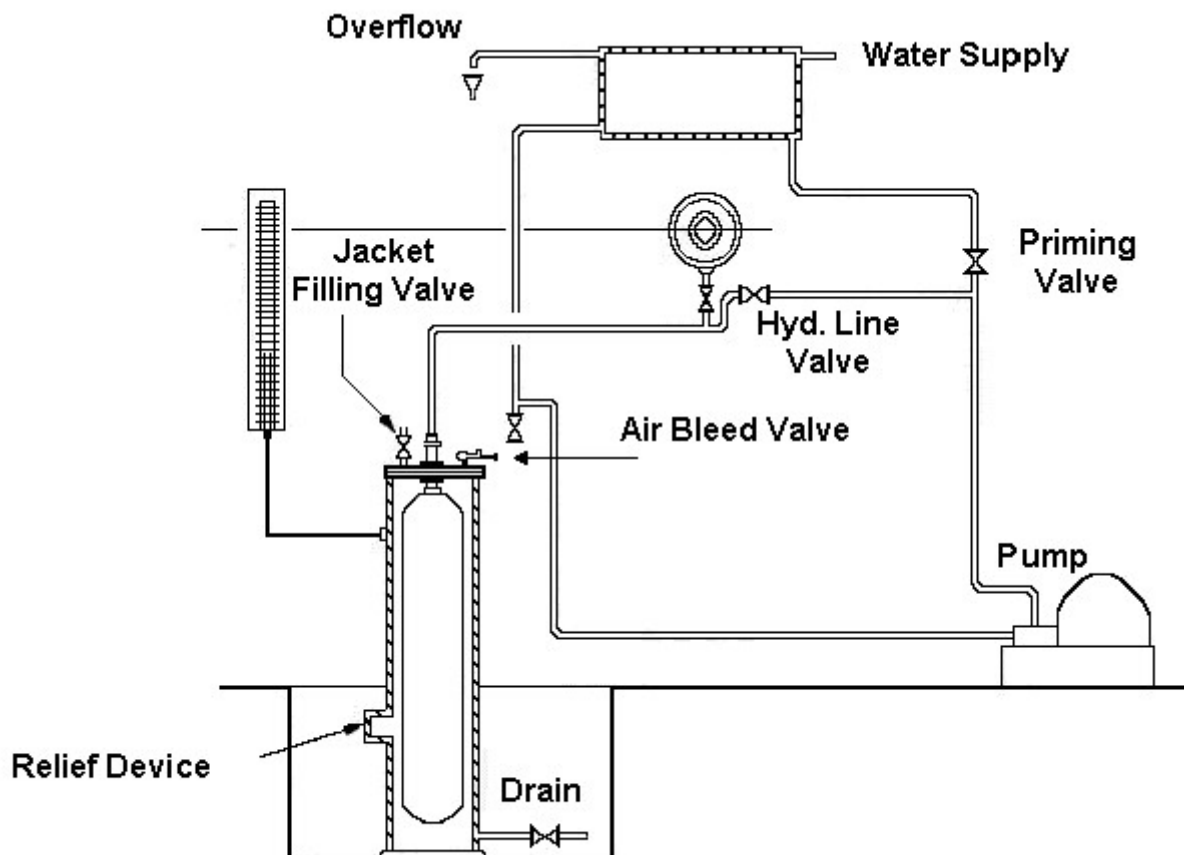
# HYDROSTATIC PRESSURE TEST

## Volumetric Expansion Test Procedure

The following procedure for testing the cylinders refers to the test equipment, illustrated in Figure 13:

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

*N.B. EFIC Kevlar®/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 2°C.*



**Figure 13: 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

# HYDROSTATIC PRESSURE TEST

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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 the maximum service pressure (85% of the test pressure), close the hydraulic pressure line valve and stop pumping. Hold until the burette reading stabilizes and remains constant.

*N.B. 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 EFIC's Kevlar®/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 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. 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.

*N.B. In some circumstances and particularly with the Kevlar/Glass cylinder 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.

Check that the permanent expansion does not exceed 5% of the total expansion as determined by the following equation:

$$\frac{\text{Permanent Expansion} \times 100}{\text{Total Expansion}} < 5\%$$

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.

# HYDROSTATIC PRESSURE TEST

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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.

## **Proof Pressure Test Procedure**

Fill the cylinder with water and attach it to the pressure test rig.

Pressurize the cylinder gradually to the working pressure (2/3 test pressure) and hold for a few seconds to ensure there are no leaks in the system.

Continue to pressurize the cylinder gradually to the test pressure. The cylinder shall be held at test pressure for at least 30 seconds to ascertain that there is no tendency for the pressure to decrease and that tightness is guaranteed.

# CYLINDER DESIGN LIFE & MARKING

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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.

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## CYLINDER DESIGN LIFE

The first cylinders in use were 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.

However Worthington has also developed cylinders with design lives of 20 year, 30 year and Non Limited. These shall also need to be removed from service after the design life has expired.

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## MARKING OF CYLINDERS

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.

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## 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 100°C are not exceeded.

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# FINAL OPERATIONS

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## Repainting

### Surface Preparation

Worthington 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 and dried thoroughly.

### Painting

The type of paint is not critical and Worthington recommends either epoxy or polyurethane paint, and of the flame retardant type. Water-based polyurethane paint has been found to have good flame resistant properties.

Spray painting is preferred as it gives a better finish.

### Paint Curing

The paint should be air cured at around 60°C/70°C for 15/20 minutes. However, for the paint to become fully hard, the cylinder may need to be left for a further 24/48 hours.

### Other

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.

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



# REFERENCES

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## REFERENCES

1. Sections 13 and 14 of these Guidelines are based on BS 5430: Part 3: 1990 and are reproduced with the permission of the British Standards Institute (BSI).
2. EN ISO 11623: 2002 Transportable Gas Cylinders- Periodic inspection and testing of composite gas cylinders, has been published.
3. EN 12245:2009+A1:2011 Transportable Gas Cylinders – Fully Wrapped Composite Cylinders, has been published