HSE - TP - FW3

SPECIFICATION FOR FULLY WRAPPED CARBON/ GLASS FIBRE COMPOSITE GAS CYLINDERS WITH THERMOPLASTIC LINER.

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SPECIFICATION FOR FULLY-WRAPPED CARBON/GLASS FIBRE COMPOSITE GAS CYLINDERS WITH THERMOPLASTIC LINERS.

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1.SCOPE

This specification applies to composite gas cylinders up to 10 litre water capacity for the storage and transport of compressed air constructed in the form of a thermoplastic liner over-wrapped with filament reinforced plastic to provide longitudinal and circumferential reinforcement to achieve a required level of stress distribution.

The composite cylinders shall be used for containing air, in a compressed state, for breathing apparatus, for the purpose of rescue, fire fighting and similar operations or related training.

The composite cylinder shall be certified by a Verification Body approved by the Health and Safety Executive. The verification body shall certify that the design, manufacture, inspection and testing were carried out in accordance with this specification. A suitable form of certificate is shown in Appendix II.

2.SYMBOLS AND DEFINITIONS

For the purpose of this standard the following definitions and symbols apply.

2.1**Symbols**

D Nominal outside diameter of cylinder in mm
LNominal length of cylinder in mm
PbBurst pressure of finished cylinder, in bar
PoCharging or filling pressure at 15°C, in bar
Ph Test pressure in bar
PmaxService pressure at maximum operating or reference temperature in bar

2.2**Definitions**

2.2.1 **Maximum Service Pressure** Pmax: The pressure developed in the container at the reference temperature, tp.

2.2.2 **Filling Pressure**, Po: The filling pressure at the reference filling temperature of 15^{o}C shall be obtained by reference to British Standard BS 5355.

2.2.3 **Batch**:Collective term for a set of homogeneous items or material. The number of items in a batch may vary according to the context in which the term is used.

2.2.4 **Batch of liners**: Quantity of liners of the same nominal diameter, thickness and design, made successively from the same batch of materials and subjected to the same manufacturing process. The length of the liners in the batch may vary by up to 2%.

2.2.5 **Batch of finished cylinders with liners:** Production quantity of up to 200 finished cylinders plus finished cylinders required for destructive testing, of the same nominal diameter, thickness and design having liners made from the same batch.

2.2.6 **Batch of raw material**: A quantity of raw material, of homogeneous composition, manufactured as a single batch by the raw material manufacturer.

2.2.7 **Qualification batch**: Pre-production quantity of not less than 30 finished cylinders from which those required for type approval or type-variant testing are taken at random by the verification or approval body.

2.2.8 **Burst pressure**: Pressure at which a cylinder fails by rupture of the winding and liner, when subjected to a steadily rising pressure.

2.2.9 **Circumferential wrap**: Fibres wound around the circumference of the cylinder.

2.2.10 **Composite overwrap**: The combination of fibres and matrix.

2.2.11 **Exterior coating**: Layer of material applied to cylinders as a protective coating or for cosmetic purposes.

2.2.12 **Fibre**: Load carrying part of the overwrap consisting of continuous filaments.

2.2.13 **Glass fibre**: General term referring to the glass fibres used for reinforcement.

2.2.14 **Carbon fibre**: Continuous filaments of carbon laid up in either strand or ribbon form (tow) used for reinforcement.

2.2.15 **Fully wrapped cylinder**: Cylinder reinforced to take both circumferential and longitudinal stress.

2.2.16 **Identification label**: Label containing the official permanent markings.

2.2.17 **Liner**: Inner portion of the composite cylinder made from thermoplastic, or elastomer material whose prime purpose is both to contain the gas and transmit the gas pressure to the fibres.

2.2.18 **Longitudinal wrap**: Fibres running in the general direction of the long axis of the cylinder.

2.2.19 **Matrix**: Material which is used to bind and hold the fibres in place.

2.2.20 **Thermoplastic**: Plastic which is capable of being repeatedly softened by increase of temperature and hardened by decrease of temperature.

2.2.20 **Thermoset:** Plastic which, when cured by the application of heat, or chemical means, changes into a substantially infusible and insoluble product.

3. DESIGN

3.1 Design Criteria

3.1.1 The metallic end fittings shall be designed to be compatible with the liner material, the overwrap material and the intended gas service.

3.1.2 The minimum burst pressure of the cylinder shall be not less than 2 times the test pressure.

3.1.3 The test pressure for the composite cylinder, Ph, shall not be less than the greater of:

a) 1.5 times the specified filling pressure, Po, or
b) 1.18 times the intended maximum service pressure, Pmax.

3.1.4 The maximum service pressure, P_{max} is the pressure developed by the contents of a container at the reference temperature, T_p

For design purposes the reference temperature for UK use shall be :

for permanent gases 60^0C
for high pressure liquifiable gases 52.5^0C
for carbon dioxide in containers
fitted with safety valves 50^0C

3.1.5 Only parallel threads shall be used to accommodate valve fittings.

3.2 Liner Materials

3.2.1 The material composition of the thermoplastic liner shall be compatible with the proposed contents of the finished cylinder as determined by prEN ISO 1114-2 : 1997

3.2.2 A material suppliers conformance certificate supplied by the manufacturer of the liner material shall be kept at the cylinder manufacturers premises.

3.3 Overwrap Materials

3.3.1 The overwrap materials shall be carbon fibre with an outer layer of glass

3.3.2 The carbon fibres shall be fabricated from a precursor material of polyacrylonitrile (PAN). It shall be coated with an epoxy compatible sizing and shall be in a continuous tow form.

3.3.3 The resin system shall be a thermoset eg; polyester or vinylester or epoxy or modified epoxy with amine or anhydride curing agent.

3.3.4 The supplier of the filament material and of the resin system component materials shall provide sufficient documentation for the composite cylinder manufacturer to be able to identify fully the batch of materials used in the manufacture of each cylinder.

3.3.5 The materials used shall be of uniform and consistent quality. The composite cylinder manufacturer shall verify that each new batch of materials has the correct properties and is of satisfactory quality, and maintain records from which the batch of materials used for the manufacture of each cylinder can be identified.

3.3.6 Batches of material shall be identified and documented to the satisfaction of the approved Inspection Body.

3.4 Cylinder Classification

No alteration shall be made to the design or the method of manufacture after approval unless such alteration has received prior agreement of the approved Inspection Body.

3.4.1 A cylinder shall be considered to be of a new design, if:

a)It is manufactured in a different factory, using different equipment.
b)It is manufactured by a significantly different process
c)The liner design has changed:

(i)It is manufactured in a different factory, using different equipment.
(ii)It is manufactured by a different process
(iii)It is manufactured from a material of different composition or composition limits from the original design
d)It is manufactured using different fibre materials.
e)It is manufactured using different matrix materials ie. resin, curing agent or
accelerator.
f)The nominal outside diameter has changed by more than 50%.
g)The design test pressure has increased by more than 60%.

3.4.2 For cylinders similar to an approved design, a reduced qualification testing
programme may only be necessary, see table I. A cylinder shall be considered to be of a similar
design if :
a) The nominal outside diameter has changed by more than 2% and less than 20%.
b) The nominal length of the cylinder has changed to below 2 x diameter or has increased by more than 50%.
c) The base profile and/or the base thickness of the liner has changed relative to the cylinder diameter and minimum wall thickness.
d) The wall thickness of the liner has changed.

e) The thickness of the fibres or the wrap pattern have changed.f) There is a small increase in design test pressure (œ 10 bar), that can be accomodated by an existing approved design.

NB. Where a cylinder is to be used for a lower pressure than that for which design
approval has been given, it shall not be deemed to be of a new design.

The different testing requirements are prescibed in Table I. The approved Inspection
Body will determine the level of reduced inspection required if not defined in Table I.

TEST NO	TEST	NEW DESIGN	DESIGN CHANGES									
			DESIGN TEST PRESSURE CHANGED BY LESS THAN OR EQUAL TO 60%	DIMENSIONAL CHANGES				MINOR CHANGES				
				NOMINAL LENGTH L		NOMINAL OUTSIDE DIAMETER D		DESIGN TEST PRESSURE	BASE PROFILE OR THICKNESS	LINER WALL THICKNESS	FIBRE THICKNESS OR WRAP PATTERN CHANGE	THREAD CHANGE
				2 x D	>1.5 L	≤20%	>20% <50%					
4.3	Hydro Test	X	X	X	X	X	X	X	X	X	X	
4.4	Burst Test	X	X	X	X	X	X		X	X	X	
4.5	Ambient Cycle	X	X	X	X	X	X	X	X	X	X	
4.6	Environ mental Cycle	X									X	
4.7	Saltwater Immersion	X					X					
4.8	High Temp-erature	X										
4.9	Drop Test	X	X		X		X			X	X	
4.10.	Flaw Test	X	X				X				X	
4.11	Bonfire	X										
4.12	Perme-ability	X					X			X		
4.13	Torque Test	X					X					X

Table I - Qualification Testing Requirements

3.5 **Design Submission**

Three copies of detailed drawings shall be prepared for design approval and submitted to theapproved Inspection Body showing each new design of composite cylinder including dimensional details of valve threads and any other permanent features, together with the method of manufacture of both the liner and the composite cylinder. The design and other particulars listed under 3.1, 3.2, 3.3, 3.4, 3.5.1, 3.5.2, 3.5.3, 3.5.4 and 3.5.5. below shall be shown on or attached to the drawings.

3.5.1 Each design submission shall contain the following details:

a)water capacity in litres (to three significant figures)
b)list of intended contents ie: compressed air
c) filling pressure, Po, at 15°C
d)composite cylinder maximum service pressure, Pmax
e)composite cylinder design test pressure, Ph
f)minimum wall thickness of the liner
g)calculated fibre stress in the filament at test pressure
h)design cycle life in years (non-limited).

3.5.2 **Liner**

a)material, including manufacturers reference details
b)minimum thickness and tolerances
c)process and specification of manufacture
d) inspection procedures (minimum requirements)
e)materials properties (material specifications and minimum mechanical properties)

3.5.3 **Overwrap**

a)filament material, specification and strength test requirements
b)filament construction, strand geometry and treatment
c)resin system - main components, materials and specifications
d)resin system - curing agent, materials and specifications where applicable
e)resin system - accelerator, materials and specification where applicable
f)overwrap construction
g)curing process, approximate temperatures and minimum duration

3.5.4 **Composite Cylinder**

a)identity and mark of theapproved Inspection Body
b)proposed marking and labelling
c)proposed periodic inspection and test procedure and rejection criteria for the type of composite cylinder (Appendix I)

3.5.5 **Qualification Test Particulars**

The results of the finished cylinder qualification tests section 4, demonstrating that the cylinder design performs satisfactorily.

4. QUALIFICATION TESTS

4.1 Prototype

4.1.1 For each new prototype cylinder design a production batch of at least 30 cylinders shall be produced, from which cylinders will be chosen at random by theapproved Inspection body for qualification testing.

4.1.2 All the cylinders in the batch produced for prototype approval shall be subjected to the following checks:

a)Visual inspection for surface defects and blemishes
b)Dimensional conformity check
c)Weight conformity check
d)Water capacity check
e)Marking compliance
f)Hydraulic proof test in accordance with Clause 4.3

4.2 Prototype Tests

From the completed prototype production, 30 cylinders shall be chosen at random by theapproved Inspection Body to the new design and subjected to:

a)hydraulic proof test in accordance with Clause 4.3
b)burst test in accordance with Clause 4.4
c)ambient temperature cycling test, in accordance with Clause 4.5
d)environmental cycling test, in accordance with Clause 4.6
e)immersion in salt water in accordance with Clause 4.7
f)high temperature test in accordance with Clause 4.8
g)drop test in accordance with Clause 4.9
h)flaw test in accordance with Clause 4.10
i)fire resistance test in accordance with Clause 4.11
j)permeability test in accordance with Clause 4.12
k)torque test on cylinder neck thread in accordance with Clause 4.13

4.3 Hydraulic Proof Test

4.3.1 Procedure

The test shall be carried out at ambient temperature 20 ± 5°C. The hydraulic pressure in the cylinder shall be increased at a controlled rate until the test pressure (Ph) is reached. The cylinder shall remain under the pressure (Ph) for at least 30 seconds.

4.3.2 Criteria

Pressure shall remain steady and there shall be no leaks. Pressure and, if applicable, increase in volume shall be monitored. After the test the cylinder shall show no visible deformation.

4.4 Burst Test

Three cylinders shall be tested hydraulically to destruction, by pressurising, at a uniform rate up to the bursting pressure (Pb), excessive heating of the container during pressurisation shall be avoided.The burst pressure shall be noted.

4.4.1 Criteria

Burst pressure shall be at least 2 times the test pressure, Ph, of the composite cylinder design.

Failure shall initiate in the cylinder side wall and the container shall not fail into more than 3 major pieces.

4.5 Ambient Pressure Cycle Tests(See Appendix III)

Four cylinders shall be subjected to hydrostatic pressure cycle test to test pressure, Ph, for 12 000 cycles at ambient temperature without leakage or failure.

If there are no signs of leakage or failure, the outcome is satisfactory, and the cylinder shall be hydrostatically pressurised to failure and the burst pressure recorded.

4.6 Environmental cycle test.

One cylinder, free of any protective coating, shall be tested in accordance with the following sequence without deterioration, leakage or failure:

4.6.1 **Procedure**

The procedure shall be in accordance with Appendix III. One cylinder shall undergo this test.

The cylinder shall be:

a)conditioned for 48 hours at atmospheric pressure at the cylinder's maximum operating temperature, which shall not be less than 60°C, and at a relative humidity greater than or equal to 95%.

b)hydraulically cycled 5,000 times from a pressure approximately equal to atmospheric pressure (pa) to 2/3 of the test pressure (Ph), under the same conditions.

c)stabilised at ambient conditions

d)conditioned at -50°C

e)cycled 5,000 times from pa to 2/3 Ph at -50°C, pressure rise speed in accordance with Appendix III.

f)stabilised at ambient conditions

g)cycled 30 times from Po to Ph at 20 ± -5°C

h)hydrostatically pressurised at a uniform rate to failure.

4.6.2 **Criteria**

The burst pressure, Pb, shall be greater than 5/3 x test pressure Ph..

4.7 **Salt Water Immersion Test**

Two cylinders shall undergo this test.

4.7.1 **Procedure**

The cylinders shall be unpainted but otherwise finished for the intended application

Two closed cylinders shall be immersed in an aqueous solution containing 35g of sodium chloride per litre at a temperature of 20 ! 5°C for 90 days as follows:

- for 45 days at operating pressure
- for 45 days without pressure

Then

- one of the two cylinders shall be submitted to a burst test (see 4.4)

- the other cylinder shall be submitted to an ambient cycle test (see 4.5) following which the cylinder shall be sectioned longitudinally and examined for any signs of corrosion.

4.7.2 **Criteria**

In accordance with 4.4 for the first cylinder and in accordance with 4.5 for the second cylinder.

There shall be no sign of any corrosion of the liner or composite material. However superficial corrosion of the metalic components is permitted.

4.8 **High temperature test**

Two cylinders shall undergo this test.

4.8.1 **Procedure**

The test shall be conducted at a temperature of 70 ± 5°C and at a relative humidity of less than 50%.

The two cylinders shall be hydrostatically pressurised to test pressure (Ph) and maintained at this pressure for 2,000 hours.

Measurement of the water capacity shall be taken before and after test.

Temperature shall be continuously monitored.

After the test, the cylinders shall then be pressurised hydraulically until they burst.

4.8.2 **Criteria**

Burst pressure, Pb shall not be less than 2 x test pressure, Ph.

4.9 **Drop Test**

Two cylinders shall each be filled with water to 50% capacity and fitted with a plug flush with the end of the cylinder.

Each cylinder shall then be dropped twice, in each of the five positions, shown in figure 1, from a height of 1,2m on to a 1m x 1m x 0.1m thick concrete block, cast in one operation and made of mixed cement, sand and gravel, protected by a 0.6m square, 25mm thick cotton fabric plate, comprising equal to 30 threads per cm, impregnated with phenolic resin, with a Brinell hardness of 45 HB (10mm ball and a 500 kg load).

The protective plate shall be sufficiently flat that the difference in level between any two points on its surface is no more than 2mm. It shall be replaced regularly and, in any event if damaged.

Figure 1 Drop test

Visual appearance shall be checked after each drop and positions and dimensions of any impact damage measured and recorded.

After the full sequence of drops, the cylinders shall be tested as follows:

- one of the two cylinders shall be subjected to Clause 4.4

- the other cylinder shall be subjected to Clause 4.5

4.9.1 **Criteria**

First cylinder, as specified in Clause 4.4
Second cylinder, as specified in Clause 4.5

4.10 **Flaw test**

Two cylinders shall be subjected to the flaw test.

4.10.1 **Procedure**

Two flaws, one longitudinal and the other transverse, shall be made on each of two cylinders, in the central part approximately 120° apart.

Both flaws shall be made with a 1mm thick cutter whose diameter is approximately 20mm, to a depth equal to, or greater than, 40% of the wound composite thickness and to an effective length, in the bottom of the gouge, equal to five times the composite thickness.

One of the two cylinders shall then be pressurised hydraulically until it bursts. Procedure in accordance with Clause no 4.4.

The other cylinder shall then be subjected to pressure cycling at Po until leakage or burst occursor until 5000 cycles have elapsed. Procedure in accordance with clause 4.5.

4.10.2 **Criteria**

First cylinder, Pb shall be no less than 2 x the filling pressure, Po.

Second cylinder, shall withstand at least 1,000 pressure cycles to pressure Po, without failure. If the cylinder fails by leakage after 1000 cycles it shall be deemed to have passed the test. However if the cylinder fails by bursting before the 5000 cycles are complete, the cylinder shall have failed the test.

4.11 **Fire resistance test**

4.11.1 **Procedure**

Two cylinders shall undergo this test as follows:

- one in a horizontal position

- the other in a vertical position

A suitable method for creating a fire is shown in Appendix IV, alternatively, the equivalent hydrocarbon based fire may be used.

Cylinders shall be:

- fitted with the valve intended for use (if fitted with a relief device) or with a valve fitted with a pressure relief device set to operate between Ph and 1.15 Ph

- filled with air at filling pressure (Po) at 15°C

- exposed to the fire until completely empty or until the pressure relief device ceases to function, the pressure shall be recorded every second.

The pressure within the cylinder shall be monitored throughout the test.

4.11.2 **Criteria**

The cylinders may leak but shall not burst during the fire test.

4.12 **Permeability Test**

Two cylinders shall be tested for permeability.

4.12.1 **Procedure**

The following procedure should be used but alternative procedures, which will achieve the same result, may be used.

The cylinder shall be pressurised to filling pressure (Po) and the valve and the junctions of, the thermoplastic liner with, the metallic bosses or rings, shall be visually checked for leaks eg with soapy water (bubble test). Any leaks shall be rectified before proceeding with the test. The cylinder shall be depressurized.

The cylinder shall then be:

- hydraulically cycled 1,000 times from zero to service pressure (Po)
  - weighed, while empty, and the weight recorded. The cylinder shall then be charged, with a test gas (see criteria), to operating pressure (Po) at a temperature of 15°

- weighed again and the weight of the gas contained, determined and recorded

- weighed after:
- 1 day
- 7 days
- 14 days
- 21 days
- 28 days

The graph of weight loss, per number of days, shall be plotted.

4.12.2 **Criteria**

The weight loss of contained gas for each type of thermoplastic shall be determined. The rate of weight loss shall not be greater than x ml/hr/1 volume, where x is as follows:

- for general applications, where the permeability rate of the intended gas is greater than that of air, the test gas shall be the gas for which the cylinder is intended, or alternatively one with a higher permeability rate, and x = 0.25

- for general applications where the permeability rate of the intended gas is less than that of air or nitrogen, the test gas shall be either the intended gas, air, or nitrogen and x = 0.25

- for specialised applications the rate of weight loss per container shall not be greater than 10 ml/hr/L vol.

4.13 **Torque Test on Cylinder Neck Threads**

The cylinder threads shall show no permanent expansion or deformation and shall remain within the tolerances shown on the approved drawing when mated with a corresponding valve and tightened to 110% of the manufactures recommended torque of 50Nm.

NB: It is important that the metal neck boss is securely held during this test.

4.13.1 **Criteria**

A test for leaks (bubble test) in the cylinder neck area shall be carried out following the tightening test and pressurisation. Any leakage will constitute a failure.

5. **MANUFACTURING AND MATERIAL BATCH TESTS**

5.1 **Liner**

5.1.1 The liner shall be manufactured in accordance with the approved drawing This process may be centrifugal casting, blow moulding or injection moulding.

The liner manufacturer shall supply a certificate of conformity for the material.

5.2 **Inspection checks on the liner**

5.2.1 For every batch of liners, a selected number of specimens shall be checked with respect to dimensions as detailed on the approved drawing.

5.2.2 Each liner shall be tested for leakage after the assembly of the metallic fittings.

Equipment : Air manometer with suitable scale.

Procedure : Connect the manometer to the liner valve pressurise the cylinder to 1.0 ! 0.1 bar at 20°C.

After 1 minute read off the value on the manometer

Criteria: The pressure shall be 1.0 ± 0.1 bar at 20°C.

5.2.3 The liner shall be clean and smooth internally and shall show no flaws or defects that would affect the safety of the cylinder.

5.2.4 If the test results are not satisfactory, then a 100% inspection of the batch will be carried out. Those liners found to be unsatisfactory shall be rendered unserviceable.

5.3 **Overwrap**

5.3.1 Fibre reinforced plastic shall be applied to the entire surface of the liner by winding resin impregnated continuous filament in accordance with the approved drawing.

5.3.2 After winding is completed the composite shall be cured using a controlled temperature profile as specified for the system used. The maximum temperature shall be such that the properties of the liner material are not adversely affected.

6. PRODUCTION BATCH TESTS

6.1 Hydraulic Pressure Test

6.1.1 Each completed cylinder shall be subjected to a proof pressure test at the pressure specified with reference to clause 3.1.4.

6.1.2 The test shall be carried out at ambient temperature 20 ± 5°C. The hydraulic pressure in the cylinder shall be increased at a controlled rate until the test pressure (Ph) is reached. The cylinder shall remain under pressure (Ph) for at least 30 seconds.

6.1.3 **Criteria**
Pressure shall remain steady and there shall be no leaks.
The pressure shall be monitored during the test and, if applicable the increase in volume.
After the test the cylinder shall show no visible permanent deformation.

6.2 Pressure Cycle Test

6.2.1 One completed cylinder per batch 202 shall be subjected to a pressure cycle test (see Appendix III) of 12,000 cycles from less than, 0.10 test pressure to test pressure, Ph.

There shall be no failures by burst or leakage.

6.2.2 If there are no signs of leakage or failure, the outcome is satisfactory and the cylinder shall be hydraulically tested to destruction in accordance with 6.3.1.

6.3 Burst Test

6.3.1 One complete cylinder per batch 202 (or less) shall be tested hydraulically to destruction, by pressurising at a uniform rate up to the failure pressure (Pb), the failure pressure shall be noted.

6.3.2 Burst pressure shall be at least 2 times the test pressure (see Clause 3.1.4). Failure shall initiate in the cylinder side wall. The liner shall fail in not more than 3 pieces. The cylinder subjected to the pressure cycling test of Clause 6.2.1 shall be used for the burst test.

6.3.3 If the results of the pressure cycle and burst test (Clause 6.2.1 to 6.3.1) are not satisfactory, the cylinders in the batch shall be rendered unserviceable for holding gas under pressure.

6.3.4 If a cylinder fails the hydraulic pressure test clause 6.1.1 or the pressure cycle and burst test Clause 6.2.1 and 6.3.1 the cause shall be investigated to the satisfaction of the approved Inspection Body. If failure is not due to an error in the manufacturing or test procedure a specimen from the overwrap material shall be prepared and tested. If the shear strength is less than required, a further specimen also fails to pass the test the batch of material shall be rejected and any cylinders overwrapped using this batch of material shall be rendered unserviceable.

6.4 **Visual and Dimensional Inspection**

Each batch of composite cylinders shall be and dimensionally checked to confirm compliance with this specification. The following checks shall be carried out in accordance with the manufacturers quality assurance procedures:-

a) Visual inspection of surface finish.
b) Full dimensional conformity check.
c) Weight conformity check.
d) Marking compliance.
e) Minimum thickness
f) Water capacity
g) Cleanliness.

7. **MARKING**

7.1 Each finished composite cylinder which satisfies the requirement of this specification shall be permanently and legibly marked with a label incorporated in the reinforcing wrap of the cylinder, showing the following:

a)the mark of this specification HSE-TP-FW3

b)filling pressure in bar units at 15°C (permanent gases)

c)test pressure in bar units prefixed with "PH”

d)manufacturer's mark

e)mark of the approved Inspection Body

f)date (month and year) of the first hydraulic pressure test

g)the mass in kg of the composite cylinder

h)the minimum water capacity in litres prefixed by "L"

i)design cycle life in years. NLL for non-limited life.

j)thread identity eg M17 = (M17 x 1.5)

k)cylinder serial number

l)country of origin

m)special provisions.

7.2 The cylinder serial number may be marked in a permanent manner on the top dome (outlet end) as agreed with the approved Inspection Body, in a manner that will not create distortions of the cylinder profile or harmful stress concentrations.

7.3 Additional markings, eg re-test dates, may be contained on label securely affixed to the cylinder side wall and overcoated with epoxy resin.

7.4 The marking shall not be less than 3mm in height.

7.5 The layout of the label and marking shall be part of the registered design.

8. DESIGN LIFE VERIFICATION

8.1 Fifteen years from the date of the first hydrostatic pressure test all composite cylinders shall be returned to the manufacturer or competent organisation(s) authorised to test composite cylinders on behalf of the manufacturer, for re-assessment. The manufacturer, in conjunction with the competent organisation(s) where appropriate, and the approved Inspection Body shall establish suitability for further service. Where this is found to be appropriate, the Health and Safety Executive shall be advised.

8.2 Thirty years from the date of the first hydrostatic pressure test any composite cylinders still in-service shall be returned to the manufacturer or competent organisation(s)

authorised to test composite cylinders on behalf of the manufacturer, for re-assessment. Thereafter they may continue in service to the end of their design life only with written consent of the manufacturer and the approved Inspection Body.

APPENDIX 1

PERIODIC EXAMINATION AND TESTING

1. Composite cylinders to this specification shall be examined for defects externally by visual inspection at each cylinder fill, by a person having appropriate training, experience and facilities.

2. Within the period of 3 years from the date of the last hydraulic pressure test every composite cylinder to this specification shall be examined for defects externally and internally, and before continuing in service, be subjected to a hydrostatic pressure test in accordance with an appropriate standard and the manufacturers recommended procedure, by the manufacturer or an organisation authorised to test composite cylinders on behalf of the manufacturer.

3. The procedure for external and internal inspection shall be specified by the manufacturer, including the appropriate damage identification criteria for the acceptance or rejection of cylinders for further service. This procedure may refer to the draft guidance in the appropriate CEN document.

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

5. Cylinders with minor damage below the rejection level in accordance with the criteria specified under paragraph 3 of this appendix including manor flaws in the reinforcement that may be repaired, shall be returned to the manufacturer of his authorised tester/repairer for examination or repair and subject to hydrostatic pressure test in accordance with the manufacturers recommended procedure.

6. Cylinders shall be rejected if they do not meet hydraulic proof pressure criteria or if any flaw has grown following repair and testing.

7. Rejected cylinders shall be rendered unserviceable from holding gas-under pressure.

8. In the event of doubt or dispute in connection with paragraphs 4 to 7 of this appendix, the manufacturer and, if necessary, the approved Inspection Body shall be consulted.

9. Records of all periodic examinations and testing shall be held by the manufacturer together and test certificates and inspection reports relating to the manufacture of the cylinder, for the lifetime of the cylinder.

NB: After the first re-test performance data will be reviewed by the manufacturer, the competent organisation(s) where appropriate, and the approved Inspection Body.

Satisfactory performance will result in the extension of the re-test period from 3 to 5 years. The Health and Safety Executive will have to be notified of the change.

APPENDIX II

SPECIMEN REPORT

APPROVED INSPECTION BODIES REPORT ON:

THE MANUFACTURER OF FULLY WRAPPED CARBON/GLASS FIBRE COMPOSITE GAS CYLINDERS WITH THERMOPLASTIC LINER

HSE - TP - FW3

Approved Inspection body: _____

Approved Inspection Body's Mark
Certificate No.: _____

Place : _____ Date: _____

Cylinder Manufactured by: _____

Manufactured for: _____

Consigned to: _____

Quantity _____ Overall Size _____ Outside diameter by _____

Serial Number _____ to _____ inclusive

SPECIFICATION HSE - TP - FW3

Drawing Number :

Date of Hydrostatic Pressure Test : _____

Test Pressure: _____

Water Capacity: _____

Gas : _____

Filling Pressure (Permanent): _____

Mass of container (in kg)

Minimum _____ Maximum _____ Without valve

Minimum _____ Maximum _____ With valve

Each cylinder was made by over-wrapping a thermoplastic liner with resin impregnated filament reinforcement.

Liner material designated as _____ was supplied by _____

Metal end fittings designated as _____ was supplied by _____

Overwrap was applied by winding under controlled tension filament.

designatedGlass _____ Carbon _____

supplied byGlass _____ Carbon _____

Impregnated with resin

designated _____ manufactured by _____

Identified by package number and cured after wrapping to the manufacturer's specification.

Each cylinder was subjected to a hydrostatic pressure test at the pressure stated above and was found to be satisfactory.

The results of the batch pressure cycle and burst tests were satisfactory.

Each cylinder has been marked as required by the specification.

We hereby certify that each of the above cylinders meet in full the requirements of the specification.

For and on behalf of the manufacturer _____

For and on behalf of the Approved Inspection Body_____

Date: _____

APPENDIX III
(See clause 4.5 and 6.2)
PRESSURE CYCLING TEST

Repeated pressurisation test of cylinders containing compressed or liquefied gases.

1.**Scope**

To describe a test method for the repeated pressurisation testing of cylinders containing compressed or liquefied gases.

2. **Field of Application**

It principally concerns the qualification testing of prototype cylinders during type and type-variant tests for approval purposes and the production batch testing of finished cylinders.

3. **Test Principles**

This test consists of subjecting the gas cylinder to increasing and decreasing hydraulic pressure between two pressure extremes in accordance with a cycle defined beforehand.

4. **Terms, Definitions and Symbols**

The terms, definitions and symbols are as given in Clause 2, with the addition of the following:

4.1 Lower cyclic pressure (Pi)

The "lower cyclic pressure" is the minimum pressure of the cycle, ie: the value of the residual pressure after relaxation. It is expressed in bar*. See figure 1.

5. **Procedure**

5.1 Test Equipment

The repeated pressurisation test is carried out using equipment which is designed to permit steady, regular, successive pressurisation and to ensure the verification of pressures and recording of the number of cycles the cylinder is subjected to under satisfactory conditions.

An example of test equipment is given in figure 2.
* 1 bar = 10^5 Pa

5.2 **Test Conditions**

5.2.1 Cylinders which are manufactured with a ring around the neck are tested equipped with this ring.

5.2.2 The manometer, recording manometer, or any sensor used to read the extreme pressure values of the gas cylinder test cycles shall measure to an accuracy of at least 2% it shall be periodically inspected and calibrated in relation to a standard measure.

5.2.3 For the fatigue test, the gas cylinder shall be filled with a liquid which does not act as a corrosive agent in relation to the material of the cylinder.

5.2.4 During the fatigue test, the temperature on the outside wall of the cylinder shall not exceed 50°C.

5.3 **Performance of the test**

5.3.1 Prior to the pressurisation, once the gas cylinder and equipment are filled with liquid, it shall be ensured that no air is enclosed in any part of the circuit by discharging the hydraulic pump by means of drain cock.

5.3.2 The fatigue test is performed by subjecting the cylinder to successive hydraulic pressure cycles of which the amplitude shall be at least equal to the difference between the hydraulic test pressure Ph and the lower cyclic pressure Pi.

5.3.3 The lower cyclic pressure Pi shall not be greater than the following values:

- 5 bar for a test pressure which is less than or equal to 100 bar.

- 5% of the maximum pressure of the test cycle for a test pressure greater than 100 bar.

5.3.4 As an example, the frequency of the recommended cycle for repeated pressurisation is in inverse relation to the test pressure Ph and the volume of the gas cylinder subjected to the test.

It shall be chosen such that the maximum pressure is reached in the region of the container walls for each of the cycles and that the lower cyclic pressure complies with the requirements of 5.3.3.

The minimum test pressure shall be maintained for a sufficient length of time to ensure relaxation of stress.

5.3.5 The test is continued until the cylinder has been subjected a previously arranged number of pressure cycles without presenting any leakage or until the failure of the container either by leakage or burst. All the cylinders tested shall be rendered unfit for use as pressure vessels.

6. Results

6.1 After the tests have been performed a test report is drawn up with the following information included:

6.1.1 The characteristics of the cylinder subjected to the test, in particular:

- the nominal outside diameter D, expressed in millimetres
- the nominal volume, expressed in litres
- the minimum guaranteed mechanical characteristics, where applicable

6.1.2 The main difference between the hydraulic test pressure Ph and the lower cyclic pressure Pi over the duration of the test.

6.1.3 The number of cycles undergone and the frequency of the pressurisation.

6.1.4 The reasons for interrupting the test.

6.2 The following is attached to the test report.

6.2.1 A recording of the pressure cycle taken at the beginning of the test.

6.2.2 Where failure occurs, a sketch to scale or photograph showing the location of the leak or the shape of the rupture.

6.3 The test-report is dated and signed by the person responsible for the tests.

7. Interpretation of the test

7.1 The criteria for the interpretation of the repeated pressurisation fatigue test shall be given.

APPENDIX IV

BONFIRE TEST

Test Fire

1. Scope

To describe a test method for the building of a bonfire of standard proportions. To carry out these tests the operator shall wear suitable working clothes, which may include helmet and face visor.

Note: Attention is drawn to the necessity for taking precautions to safeguard the health of personnel conducting the tests against the risk of fire and inhalation of smoke and any toxic products of combustion.

2. Apparatus

2.1 Metal frame support, 250 ± 10mm high 900 ± 100m and of a length equal to that of the test fire (within the tolerance limits). The steel frame (see figure 1) is constructed of 50mm x 50mm angle sections.

2.2 Wooden sticks, made of Pinus silvestris containing 12.5% to 17.5% of moisture by mass, and of square section of side 39 ± 2mm. The moisture content of the sticks shall be determined using commercially available instruments which measure electrical conductivity between two needle probes pushed into the sticks.

Note: Some variation of reading may be obtained due to structural variation of the timer and the direction of the grain. This type of instrument should therefore be calibrated in case of doubt by drying samples of the sticks at 103 ± 2°C cut to convenient length and to constant mass, and by weighing them at 24 hr intervals.

The moisture content expressed as a percentage is given by the following equation:

$$\text{Percentage moisture} = \frac{\text{Initial mass - Dry mass}}{\text{Dry mass}} \times 100$$

The wooden sticks shall be stacked in 8 layers of the metal frame(s) as shown in figure 1 and 2.

The sticks in each layer shall be spaced at nominal 100mm centres with nominal 61mm gaps between the sticks.

The sticks laid transversely (layers 2, 4, 6, 8) shall have lengths equal to the test fire length again with a permissible deviation of ± 10mm.

For vertical test positions the fire size shall be 500mm x 500mm with tolerance of ± 10mm.
For horizontal test positions the test fires length shall exceed that of the cylinder (including valve) by a minimum of 200mm.

2.3 Lightening fuel, consisting of an aliphatic hydrocarbon having an initial boiling point of not more than 105°C.

Note: Typical fuels meeting this requirement are heptane and certain solvent tractions sometimes referred to as commercial heptane.

2.4 Lighting tray being 100 ± mm longer than the nominal length of the test fire of width of 600 ± 10mm and depth of 100 ± 10mm. Long lighting trays are difficult to handle and it is convenient to use any number of smaller trays to give the required length. Arrange with no appreciable gap between the trays.

3. Test fire location

Locate the test fire outdoors and sheltered from draughts.

4. Procedure

The procedure is as follows:

a)Pour water into the lighting tray(s) to form a layer at least 3mm deep over the whole base of the tray then add 2 litres of lighting fuel to give an additional approximate depth of 5mm.

b)Ignite the fuel.

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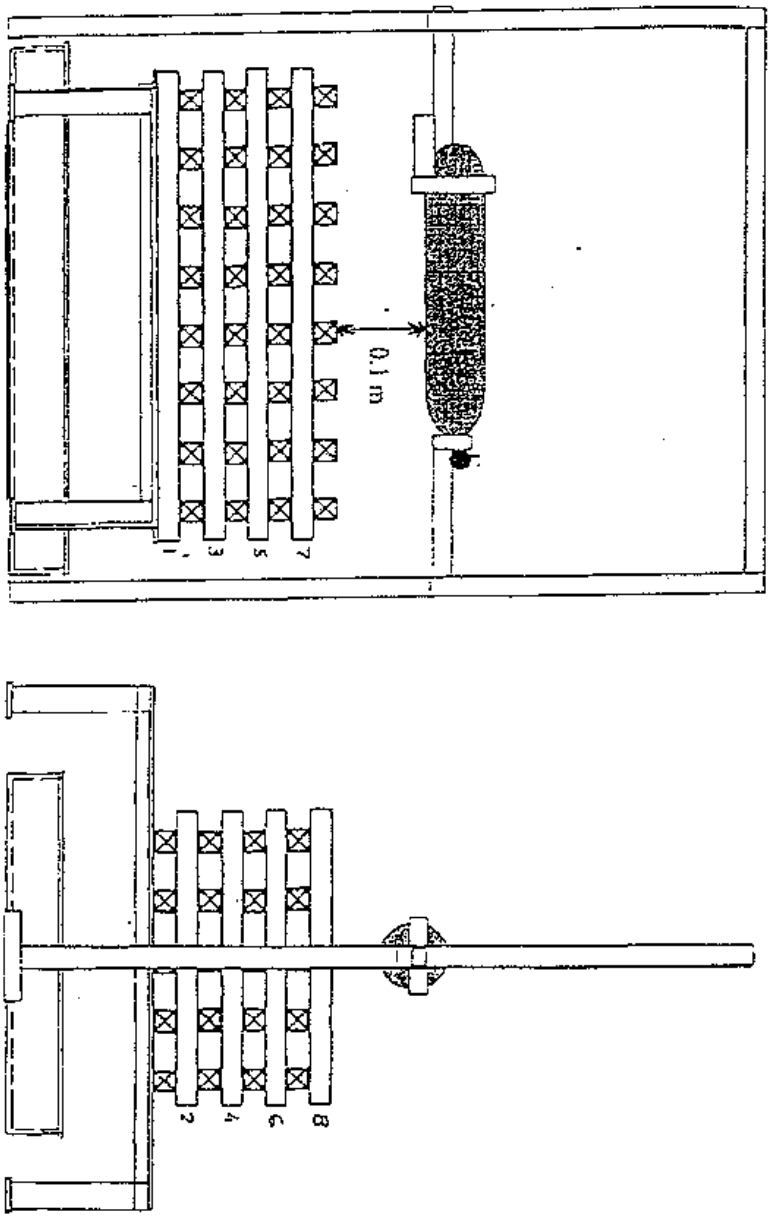

Figure 1

Figure 2