



HSE-LL-FW4

**SPECIFICATION FOR FULLY-WRAPPED
LINERLESS TRANSPORTABLE PRESSURE
RECEPTACLES.**

Issue 3.

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1. SCOPE

This standard specifies minimum requirements for the materials, design, construction, approval tests and routine manufacturing inspections of composite gas cylinders without liners with a water capacity up to and including 30 litres for liquefied petroleum gas (LPG). Application for approval from HSE is required for other gases.

This standard is applicable to cylinders manufactured without a liner with filament reinforced plastic to provide longitudinal and circumferential reinforcement to achieve a required level of stress distribution.

2. REFERENCES

This document is referring to the following European/ International Standards.

ISO 75-1/3	Determination of temperature of deflection under load - Part 1. General test method. Part 3. High strength thermosetting laminates and long-fibre-reinforced plastic.
ISO 527-1	Plastics - Determination of tensile properties - Part 1. General principles.
ISO 2884	Determination of the viscosity of paint at high rate of shear.
EN 1089 -1 and 2	Gas cylinder identification
EN 629-2	Transportable gas cylinders - 25E taper thread for connection of valves to gas cylinders - Part 2. Gauge inspection
EN/ISO 13341	Gas Cylinders - Procedures for fitting valves to gas cylinders.
ISO/DIS 11439	High pressure cylinders for the on-board storage of natural gas as a fuel for automotive cylinders.
ASTM 2196 D -86	Test Methods for Rheological Properties of Non-Newtonian Materials by Rotational (Brookfield) Viscometer.
CGA. C14. 1992	Procedures for Testing of DOT Cylinder Pressure Relief Device Systems.

3. SYMBOLS AND DEFINITIONS

For the purpose of this standard, the following definitions and symbols apply:

3.1 Symbols

Pb Burst pressure of finished cylinder, in bar¹ above atmospheric pressure.

Pbmin Minimum burst pressure obtained during design variant approval testing, in bar¹ above atmospheric pressure

Ph Hydraulic test pressure, in bar¹ above atmospheric pressure

¹ 1 bar = 10⁵Pa = 0,1 Mpa

3.2 Definitions

3.2.1 Batch:

Set of homogeneous items or material. The number of items/ quantity in a batch varies according to the context in which the term is used, i.e. a batch of resin normally has a quantity of approximately 20 tons which is the quantity produced in one reactor at one time.

3.2.2 Batch of finished cylinders:

Production quantity of up to 200 finished cylinders, plus cylinders for destructive testing, of the same nominal diameter, thickness, length and design.

3.2.3 Burst pressure:

Maximum pressure obtained during a pressure bursting test.

3.2.4 Fibre or strand:

Load-carrying part of the composite overwrap, i.e. glass.

3.2.5 Fully wrapped cylinder:

Cylinder reinforced by wrapping to take both circumferential and longitudinal stress.

3.2.6 Matrix:

Material which is used to bind and hold the fibres in place.

3.2.7 Rejected cylinder:

A cylinder which in its present condition has not passed the test requirements.

3.2.8 Thermoset:

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

3.2.9 Ambient temperature:

Temperature of surroundings varying between 10°C and 35°C.

4. DESIGN AND MANUFACTURE**4.1 General**

A fully wrapped composite cylinder shall be manufactured without a liner and shall be manufactured from two parts joined together.

Cylinders may be designed with one or two openings along the central axis only.

Additional parts such as rings, bases, are also permitted.

4.2 Fully wrapped cylinder**4.2.1 Materials**

The cylinder manufacturer shall specify the material requirements for both the fibre matrix and adhesive in accordance with Test No. 1 Clause 5.2.1.

4.2.2 Manufacturing (two step process)**4.2.2.1 Dry winding (first step)**

Appropriate procedures shall be defined for the dry winding process to ensure good repeatability and traceability.

The following parameters shall be defined and monitored:

- A the batch numbers of the fibres used
- B the number of strands used
- C the winding tension for all strands
- D the winding speed(s)
- E the winding angle and pitch for each layer
- F the number and order of layers

D, E and F shall be monitored by the winding programme given to the winding robot

4.2.2.2 Injection moulding (second step)

Appropriate procedures shall be defined for the injection moulding process to ensure good repeatability and traceability.

The following parameters shall be defined and monitored:

- A the batch numbers of the matrix and the current agent used
- B the percentage of the components of the matrix and the current agent
- C the matrix temperature
- D the curing process approximate temperatures and minimum duration

4.3 Finished cylinder

4.3.1 Design drawings

A fully dimensioned definition drawing of all parts that constitute the finished cylinder shall be supplied. The design drawing shall also include tolerances on all dimensions, including out-of-roundness and straightness.

The drawing shall include the specification of the material(s), the material properties and the reinforcement pattern. The specification and the reinforcement patterns may be given in a Technical Specification enclosed with the drawing.

The manufacturer shall specify the minimum burst pressure for the design which shall be at least 2 x test pressure (Ph).

4.3.2 Matrix materials

The properties of the matrix materials and adhesives shall be specified as follows:

Property	Standard*	
Tensile strength	ISO 527-1	Determination of tensile properties - Part 1. General principles
Tensile modulus	ISO 527-1	"
Elongation	ISO 527-1	"
Heat distortion temperature	ISO 75-1/3	Determination of temperature of deflection under load - Part 1. Determination of temperature of deflection under load. Part 3. High strength thermosetting laminates and long-fibre-reinforced plastic.
Viscosity	ASTM D 2196	Test method for rheological properties of non-newtonian materials by rotational (Brookfield) viscometer. Calculations of dynamic viscosity.

*Equivalent tests in accordance with recognised standards or test specifications may be applied

4.3.3. Adhesive.

The following parameters shall be defined and monitored:-

- percentage of the components of the adhesive system and their batch numbers, (all batches shall undergo acceptance tests).
- the polymerisation cycle.
- the polymerisation process (e.g. thermal cycling, ultrasound, ultraviolet or radiation).

4.3.4. Visual Inspection, internal and external, for the finished cylinder

The internal and external surfaces of the finished cylinder shall be free of defects which could adversely affect the safe working of the cylinder. In addition there shall be no visible foreign matter (e.g. resin, swarf or other debris) present inside the cylinder.

5. CYLINDER AND MATERIAL TESTS

5.1 General

This section specifies the tests to be conducted on composite cylinders and the materials used in manufacture for type approval of new cylinder designs, design variant approvals and batch acceptance tests.

5.2 Test procedures and test requirements

5.2.1 Test No. 1 Composite material tests

5.2.1.1 Procedure:

Mechanical properties of the composite materials (matrix) shall be determined in accordance with the Standards in the following Table:

Property	Standard *	
Tensile strength	ISO 527-1	Determination of tensile properties - Part 1. General principles.
Tensile modulus	ISO 527-1	"
Elongation	ISO 527-1	"
Heat distortion temperature	ISO 75-1/3	Determination of temperature of deflection under load - Part 1. Determination of temperature of deflection under load. Part 3. High strength thermosetting laminates and long-fibre-reinforced plastic.
	ISO 1218	Determination of the melting point of synthetic resins.
Viscosity	ASTM D 2196	Test method for rheological properties of non-newtonian materials by rotational (Brookfield) viscometer calculations of dynamic viscosity.
	ISO 2884.	Determination of the viscosity of paint at a high rate of shear.
Shear Strength	ASTM 2733 - 70	

* Equivalent tests in accordance with recognised standards or test specifications may be applied

5.2.1.2 Jointing Adhesive

The component parts of the jointing adhesive, by percentage, shall be specified and recorded against the batch numbers.

The polymerisation cycle and production process shall be specified and recorded against batch numbers.

5.2.1.3 Criteria:

The mechanical properties shall meet the minimum requirements for the design as specified by the manufacturer. Certificated records to be maintained.

5.2.2 Test No. 2 Hydraulic (proof) test of finished cylinders at ambient temperature**5.2.2.1 Procedure:**

The cylinder shall be completely full of water at ambient temperature. The water pressure in the cylinder shall be increased at a controlled rate until the test pressure (P_h) is reached. The cylinder shall remain under the pressure (P_h) for at least 30 seconds.

5.2.2.2 Criteria:

- pressure shall remain steady
- there shall be no leaks
- after the test the cylinder shall show no visible permanent deformation.

5.2.2.3 Parameters to monitor during the test:

- pressure.

5.2.3 Test No. 3 Burst test under hydraulic pressure at ambient temperature**5.2.3.1 Procedure:**

The hydraulic pressure burst test shall be carried out using a test rig, which allows pressure to be increased at a controlled rate. The conditions apply to finished composite cylinder.

The test shall be carried out in ambient conditions and the temperature on the outside of the cylinder shall be maintained at less than 50°C. The rate of pressurisation shall not exceed 10 bar per second.

The cylinder shall be completely full of water and pressurised at a controlled rate until failure. The pressure against time curve or pressure against volume curve shall be plotted.

The maximum pressure achieved during the test shall be recorded as the burst pressure.

5.2.3.2 Criteria:

- burst pressure shall be greater than or equal to the manufacturers minimum specified design burst pressure and 2 x test pressure ($P_b \geq 2,0 P_h$)
- burst initiation shall be in the cylindrical part
- the burst shall not result in separation at the joint.

5.2.3.4 Parameters to monitor during the test:

- burst pressure
- number of pieces
- pressure/time curve or pressure/volume curve

5.2.4 Test No. 4 Resistance to pressure cycles up to internal test pressure (Ph), at ambient temperature**5.2.4.1 For non-limited life:****5.2.4.1.1 Procedure:**

The cycle test shall be carried out using a test rig, which allows pressure to be increased and decreased at a controlled rate and automatically suspend the test when the cylinder has failed, either by leakage or rupture.

The test shall be carried out with non-corrosive liquid subjecting the cylinders to successive reversals at an upper cyclic pressure equal to the hydraulic test pressure (Ph). The value of the lower cyclic pressure shall not exceed 10% of the upper cyclic pressure and shall have an absolute maximum of 30 bar.

The cylinder shall actually experience the maximum and minimum cyclic pressures during this test.

The ambient cycle test shall be carried out in ambient conditions and the temperature on the outside surface of the cylinder not exceed 50°C during the test. The frequency of reversals of pressure shall not exceed 0.25 Hz (15 cycles per minute).

The number of cycles achieving the upper cyclic pressure during the test shall be recorded.

After completion of this test the cylinders shall then be destroyed, (e.g. by bursting), or made incapable of holding pressure.

5.2.4.1.2 Criteria:

- the cylinder shall withstand 12,000 cycles up to test pressure (Ph) without failure by burst or leakage.

5.2.4.1.3 Parameters to monitor during the test:

- the temperature of the cylinder is monitored at least twice a day
- number of cycles.

5.2.4.2 For limited life

5.2.4.2.1 Procedure:

This test is conducted in accordance with the procedure as described in 5.2.4.1 above and consists of two halves run sequentially and continuously. Different criteria apply to the halves as shown in Figure 1.

After completion of this test the cylinders shall then be destroyed, (e.g. by bursting), or made incapable of holding pressure.

5.2.4.2.2 Criteria:

The cylinder shall first withstand N cycles up to test pressure Ph without failure by burst or leakage, where:

- $N = y \times (250 \text{ cycles})$
- $y =$ the number of years of design service life
- $y \geq 10$ years and is a whole number

The test shall continue for further N cycles, or until failure by leakage whichever is the sooner. In either case the cylinder shall be deemed to have passed the test. However should failure during this second half of the test be by burst, then the cylinder shall have failed Test No. 4.

Figure 1

	1st half	2nd half
Criteria	No leakage/ burst = PASS	
	No leakage or burst	Leakage = Pass Burst = Fail
Number of cycles	0 <-----> N	N <-----> 2N

5.2.4.2.3 Parameters to monitor during test

- The temperature of the cylinder shall be monitored at least twice a day.
- Number of cycles.

5.2.5 Test No. 5 Exposure to elevated temperature at test pressure

5.2.5.1 Procedure:

For a claimed life of up to 20 years, two cylinders shall be hydraulically pressurised to test pressure Ph, and shall be maintained at this pressure for 1000 hours.

For a claimed life greater than 20 years, including non-limited life, two cylinders shall be hydraulically pressurised to test pressure Ph, and shall be maintained at this pressure for 2000 hours.

The test shall be conducted at $(70\pm 5)^{\circ}\text{C}$ and a relative humidity of less than 50%. After this test, the cylinders shall be subjected to Test No. 3 (see 5.2.3).

5.2.5.2 Criteria:

- burst pressure: $P_b \geq 2,0 P_h$.

5.2.5.3 Parameters to monitor during the test:

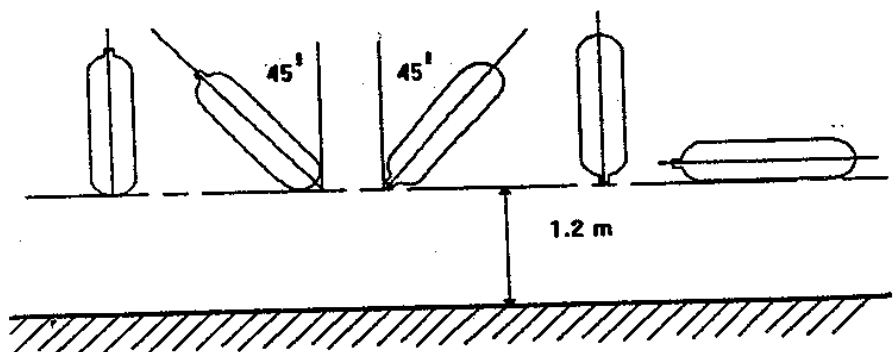
- measurements of the water capacity before and after test
- burst pressure
- number of cycles

5.2.6 Test No. 6 Drop test

5.2.6.1 Procedure:

Two cylinders, each filled with water to 50% capacity shall be 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 2, from a height of 1,2 m on to a steel plate. The protective plate shall be sufficiently flat so that the difference in level between any two points on the surface is no more than 2 mm. It shall be replaced regularly and in any event, if damaged.

Figure 2 Impact test



After full sequence of drops:

- one of the two cylinders shall be subjected to Test No. 3 (see 5.2.3)
- the other cylinder shall be subjected to Test No. 4 (see 5.2.4).

5.2.6.2 Criteria:

- burst pressure shall be greater than or equal to 2 x test pressure ($P_b \geq 2,0 P_h$)
- as Test No. 4 for the second cylinder.

5.2.6.3 Parameters to monitor during the test:

- check visual appearance after each drop - record position and dimensions of impact damage
- burst pressure
- number of cycles.

5.2.7 Test No. 7 Flawed cylinder test**5.2.7.1 Procedure:**

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

Two flaws shall be made with a 1 mm thick cutter to a depth equal to at least 40% of the wound composite thickness and to a length in the bottom of the flaw equal to five times the composite thickness.

After introducing the flaws one of the two cylinders shall be subjected to Test No. 3 (see 5.2.3)

- the other cylinder shall be subjected to Test No. 4 (see 5.2.4) except that the upper cyclic pressure shall be $2/3 P_h$ and the number of cycles shall be a maximum of 5000.

5.2.7.2 Criteria:

- first cylinder: burst pressure shall be greater than or equal to $4/3$ x test pressure ($P_b \geq 4/3 P_h$)
- second cylinder: shall withstand at least 1,000 pressure cycles to $2/3 P_h$, without leakage. If the cylinder fails by leakage after 1,000 cycles it shall be deemed to have passed the test. However should failure occur during this second half of the test by burst, then the cylinder shall have failed Test No. 7.

5.2.7.3 Parameters to monitor during the test:

- burst pressure
- number of cycles.

5.2.8 Test No. 8 Extreme temperature cycle test**5.2.8.1 Procedure:**

The cylinder and the contained pressurising medium shall be conditioned for 48 hours at atmospheric pressure at between 60°C and 70°C at a relative humidity greater than or equal to 95%.

The hydraulic pressurising medium external to the cylinder under test shall commence the cycle testing at ambient temperature. 5,000 cycles shall be

applied from a pressure approximately equal to atmospheric pressure to two-thirds of the test pressure (P_h), under the same conditions. For details of the cycle testing procedure see 5.2.4 (Test No. 4) but with the exception that the extreme temperature cycle test has temperature and humidity conditions as specified in this clause. The rate of pressure cycles for this test shall not exceed 0.08 Hz (5 cycles per minute) to enable the temperature conditions to be maintained.

On completion of these cycles the pressure shall be released and the cylinder stabilised at ambient conditions.

The temperature shall then be reduced and the cylinder and the contained pressurising medium stabilised at a temperature between minus 50°C and minus 60°C. The environmental chamber shall be maintained at the specified conditions by regulating temperature. The cylinder skin temperature shall be measured and recorded.

The hydraulic pressurising medium external to the cylinder under test shall commence the second stage of cycle testing at ambient temperature. 5,000 cycles shall be applied from a pressure approximately equal to atmospheric pressure to two-thirds of the test pressure (P_h), The rate of pressure cycles for this test shall not exceed 0.08 Hz (5 cycles per minute) to enable the temperature conditions to be maintained.

On completion of these cycles the pressure shall be released and the cylinder stabilised at ambient conditions. 30 cycles shall be applied from a pressure approximately equal to atmospheric pressure to test pressure (P_h) under the same conditions.

5.2.8.2 Parameters to monitor during the test:

- temperature
- cycle pressure

5.2.8.3 Burst test

The test cylinder from test No 8 shall then be burst tested in accordance with Test No. 3 (see 5.2.3).

5.2.8.4 Criteria:

- burst pressure shall be greater than or equal to 1.67 x test pressure ($P_b \geq 1.67 P_h$).

5.2.8.5 Parameters to monitor during the test:

- burst pressure.

5.2.9 Test No. 9 Fire resistance test

5.2.9.1 Procedure:

Two cylinders shall undergo this test:

- one in a horizontal position
- one in a vertical position.

The cylinder shall be fitted:

- a) with a valve with the type of pressure relief device intended for service (e.g. fusible or burst disc); or
- b) with a valve fitted with bursting disc set to operate at between test pressure (P_h) and $1.15 P_h$.

If the valve in a) is fitted with a fusible plug this shall operate at a minimum temperature of 100°C .

The cylinder shall be charged with either air or nitrogen to $2/3 P_h$.

A suitable fire can be created with either wood, or kerosene or petrol. Standards that contain directions to produce a suitable fire test are ISO/DIS 11439, CGA C14 1992.

One cylinder shall be placed in the horizontal position with the lowest part of the cylinder approx. 0.1 m from the top of the firewood or 0.1 m from the surface of the liquid. The fire shall be capable of enveloping the entire length of the cylinder and valve, but in no case shall the flames be allowed to impinge directly on to the pressure relief device.

One cylinder shall be placed in the upright position (valve uppermost) with the lowest part of the cylinder approximately 0.1 m from the top of the firewood, (in the case of a wood fire), or at the surface of the liquid, in an oil based fire. The cylinder shall be exposed to a total fire engulfment, but in no case shall the flames be allowed to impinge directly on to the relief device.

If the cylinder is too long to enable the fire to envelop its entire length when in the vertical position, and the cylinder does not have relief devices at both ends, the vertical bonfire test may be replaced by a second test in the horizontal position.

After completion of this test the cylinders shall then be destroyed, (e.g. by bursting).

5.2.9.2 Criteria:

The cylinders shall not burst during a period of two minutes from the start of the fire test. They may vent through the pressure relief device or leak through the cylinder wall or other surfaces.

5.2.10 Test No. 10 High velocity impact (bullet) test

5.2.10.1 Procedure:

For cylinders with diameter above 120 mm a representative cylinder charged with air or nitrogen to 2/3 test pressure shall be impacted by a 7,62 mm (0.3 calibre) armour-piercing projectile (of nominal length 51 mm) and having a velocity of approximately 850 m/s. The cylinder shall be positioned in such way that the point of impact of the projectile shall be in the bottom (the area with no circumferential winding) and shot at an angle of around 45° to the centre line of the cylinder, so that it will exit through the cylinder wall. Distance from firing location to test cylinder shall not exceed 45 m.

5.2.10.2 Criteria:

- the test cylinder shall reveal no evidence of a fragmentation failure, whether or not the bullet penetrates the cylinder.

5.2.10.3 Parameters to monitor during the test:

- approximate size of the entrance and exit openings shall be recorded.

5.2.11 Test No. 11 Permeability test

The following procedure is recommended but alternatives may be used which achieve the same result.

5.2.11.1 Procedure:

The cylinder shall be 90% full of water, pre-pressurised to 2/3 test pressure (Ph) and the valve shall be visually checked for leaks, e.g. with soapy water (bubble test). Any leaks shall be eliminated before proceeding with the test. The test cylinder shall be weighed empty, before the test.

The cylinder shall be completely filled with water and hydraulically cycled 1,000 times from zero to 2/3 test pressure before being weighed while empty, and the weight recorded.

The cylinder shall then be filled to 2/3 test pressure with air or nitrogen at a temperature of 15°C.

The cylinder shall be weighed and the weight of the gas stored determined and recorded. The cylinder shall then be re-weighed after 1 day, 7 days, 14 days, 21 days and 28 days. For the duration of the test the cylinder shall be stored in an environment with stable temperature and humidity. The graph of weight change per number of days shall be determined.

After the test the cylinder shall be re-weighed empty. Any difference in weight between this measurement and the weights obtained during the test shall be modified accordingly.

5.2.11.2 Criteria:

The maximum rate of weight loss shall be less than 0.25 ml/h/l water capacity.

5.2.11.3 Parameters to monitor during the test :

- cylinder weight empty
- cylinder weight after 1, 7, 14, 21 and 28 days
- temperature and humidity to be recorded daily

5.2.12 Test No. 12 Torque test

The cylinder threads shall show no permanent expansion or deformation when mated with a corresponding valve or plug and tightened to 110% of the maximum torque specified in ISO 13341 or as recommended by the manufacturer where this standard does not apply. The thread shall be verified with the relevant thread gauge, (e.g. EN 629-2) to ensure no deformation has occurred.

5.2.13 Test No. 13 Neck strength

The neck of the cylinder shall show no significant deformation and shall remain within the drawing tolerance when mated with a corresponding valve and tightened to 150% of the torque specified in ISO 13341 or as recommended by the manufacturer where this standard does not apply. If the neck contains a threaded insert a permeability test as in 5.2.11 (Test No. 11) shall be carried out after this test.

5.2.14 Test No. 14 Cylinder stability

For a cylinder designed to stand on its base, the variation from vertical shall be less than 1% of its height, and the outer diameter of the surface in contact with the ground shall be greater than 75% of the nominal outside diameter.

5.2.15 Test No. 15 Neck ring

The manufacturer shall ensure that the axial load required to remove the neck ring is greater than 10 x the weight of the empty cylinder and not less than 1000 N. The minimum torque to turn the neck ring is greater than 100 Nm.

5.3 Failure to meet test requirements

In the event of failure to meet test requirements, re-testing is carried out, as follows:

- if there is evidence of a fault in carrying out a test, or an error of measurement a second test may be performed on the same cylinder if

possible. If the results of this test is satisfactory, the first test is ignored;

- if the test has been carried out in a satisfactory manner, the cause of test failure shall be identified or the batch(es) shall be rendered unserviceable for the intended purpose. If the cause of failure is identified the defective cylinders may be reclaimed by an approved method or shall be rendered unserviceable for the intended purpose. If reclaimed, these cylinders, along with the original satisfactory cylinders, shall be considered a new batch and the type approval and/or batch tests shall be carried out again. If any test or part of a test is unsatisfactory, all the cylinders of the batch or batches covered by the test shall be rendered unserviceable for the intended purpose.

6. CONFORMITY EVALUATION

Type testing, design variant testing and production testing are carried out in accordance with Annex A.

7. MARKING

Each finished Composite Cylinder shall be marked in accordance with ISO 1089-1 and 2. The identification label shall show the following information: -

- this specification number.
- serial number
- max contents in kg
- test pressure in bar
- manufacturers mark
- mark of the approved inspection body
- date (year and month) of acceptance
- the tare weight in kg of the composite cylinder
- the minimum water capacity in litres
- date (year and month) of revision

APPENDIX A

TYPE TESTING AND PRODUCTION TESTING ON COMPOSITE CYLINDER WITHOUT LINER

A.1 GENERAL

This annex describes the schedules of tests to be carried out on the cylinders, as required to approve new cylinder designs (type approvals), to extend type approvals to permitted variants (design variant approvals) and also to ensure compliance of a production batch of cylinders with the design specification of the approved cylinder design (production tests).

Approval shall be issued for each new design or design-variant of cylinder (see A.2 and A.3).

A.2 TYPE TESTING

A.2.1 General

This approval applies to cylinders of identical design (materials, manufacturing process) from the same factory, equipment and the same sub-contractor, if applicable. The approval/qualification test shall be performed on cylinders having the same dimensions (see diameter and length).

Type approval shall be issued for each new design of cylinder.

The type approval is valid for cylinders having the same diameter but whose length may vary from twice the diameter of the approved cylinder to 1.5 times the length of the approved cylinder.

Shorter cylinders, i.e. those cylinders whose length is less than twice the diameter of the nominated approved design shall not be considered part of the family and shall be approved individually as a design variant.

A.2.2 Definition of new design

A previously approved cylinder shall be considered to be of a new design when any of the following conditions apply:

- a) It is manufactured in a different factory (see Note 1).
- b) It is manufactured by a significantly different process. A significant change is regarded as a change that would have a measurable change in the performance of the finished cylinder. The Approved Inspection Body shall determine when a change in process or design or manufacture is significantly different from the original qualified design.

- c) It is manufactured with a new fibre.
A fibre shall be considered of a new fibre type when any of following conditions apply:
- 1) The fibre is of a different classification, e.g. glass, aramid, carbon etc.
 - 2) The fibre is produced from a different precursor (starting material), e.g. PAN.
 - 3) The nominal fibre modulus is more than $\pm 5\%$ of that defined in the approved design.
 - 4) The nominal fibre strength is more than $\pm 5\%$ of that defined in the approved design.
- d) It is manufactured using different matrix materials, e.g. resin, curing agent, accelerator (see Note 2).
- e) The hydraulic test pressure has changed by more than 60% (see Note 3).
- f) The cylinder diameter has changed by more than 50%.

Note 1: Where a factory moves to a different location with the same equipment, a reduced testing programme may be agreed with the Approved Inspection Body.

Note 2: Where a new matrix material has been approved for an existing design, then all the manufacturers existing approved designs are approved with the new matrix system without the need for any additional qualification tests.

Note 3: A cylinder may be used and marked for a lower test pressure than stated in the original type approval without additional testing.

A.2.3 Type approval test requirements

The applicant for type approval shall, for each new design of cylinder, submit the documentation necessary for the checks specified below. The applicant shall make available to the Approved Inspection Body a batch of at least 50 cylinders from which the number of cylinders required for the test referred to below will be taken.

If the total production is less than 50 cylinders, enough cylinders shall be made to complete the type approval tests in addition to the production quantity, but in the case the approval validity is limited to this particular production batch.

In the course of the type approval process, the Approved Inspection Body shall:

- a) Select the necessary cylinders for testing in accordance with the following:
 - 1 Pressure test of finished cylinders at ambient temperature in accordance with Clause 5.2.2.

- 2 Burst test under hydraulic pressure at ambient temperature in accordance with Clause 5.2.3.
- 3 Resistance to pressure cycles up to internal test pressure (Ph), at ambient temperature in accordance with Clause 5.2.4.
- 4 Exposure to elevated temperature at test pressure in accordance with Clause 5.2.5.
- 5 Drop test in accordance with Clause 5.2.6.
6. Flawed cylinder test in accordance with Clause 5.2.7.
7. Extreme temperature cycle test in accordance with Clause 5.2.8.
- 8 Fire resistance test in accordance with Clause 5.2.9.
- 9 High velocity impact (bullet) test in accordance with Clause 5.2.10.
- 10 Permeability test in accordance with Clause 5.2.11.
- 11 Torque test in accordance with Clause 5.2.12.
- 12 Neck strength in accordance with Clause 5.2.13.
- 13 Cylinder stability test in accordance with Clause 5.2.14.
- 14 Neck ring test in accordance with Clause 5.2.15.

b) Verify that the:

- the design conforms to the requirements of Clause 4
- the internal and external surfaces of the cylinders are free of any defect which might make them unsafe to use.

c) Witness or carry out the tests as stipulated above a).

A.2.4. Type approval certificate

If the results of the checks are satisfactory, the Approved Inspection Body shall issue a type approval certificate to the manufacturer.

If the results are not satisfactory proceed as described in Clause 5.3.

A.3 DESIGN VARIANT TESTING

A.3.1 General

For cylinders similar to an approved design a reduced qualification testing programme may only be required. Design variant approval shall be issued for each design variant of cylinder.

A.3.2 DEFINITION OF A "DESIGN VARIANT"

A.3.2.1 Conditions to be satisfied

A previously approved cylinder shall be considered to be of a design variant when any of the following conditions apply:

- a) the fibres in the design are equivalent to the fibres in a previously approved cylinder (see A.3.2.2)
- b) the cylinder conforms to the conditions in A.3.2.3.

A.3.2.2 Equivalent Fibre

For a fibre having similar nominal mechanical and physical characteristics to the approved fibre system, its equivalency shall be verified as follows before the fibre can be considered as a design variant.

The new fibre with the existing approved resin system must be subjected to the test in Clause 5.2.1 (Test No. 1).

The mechanical properties shall be within $\pm 5\%$ of the properties of the approved fibre.

Note: Where a new equivalent fibre has been approved for an existing design, then all the manufacturers existing approved designs are approved with the new fibre without the need for any additional qualification tests.

A.3.2.3 Cylinder Variant

A cylinder shall be considered a design variant if any of the following conditions apply:

- a) The nominal length of the cylinder has changed to below 2 x diameter or has increased by more than 50% of the original design length.
- b) The nominal outside diameter has changed by more than 2% and less than or equal to 50%.
- c) The hydraulic test pressure has changed by less than or equal to 60%.
- d) There have been changes to the composite thickness or wrap pattern to improve the qualified design.
- e) The new fibre is equivalent to the fibre in the approved design as specified in A.3.1.
- f) The thread size is changed.

Note 1: The accredited authority shall determine the level of testing required and may request other tests than those specified to approve a design variant, where it is considered necessary or for special applications.

Note 2: Any change(s) are with reference to the original type approval.

A.3.3 Design variant test requirements

For each design of cylinder variant the applicant for design variant approval shall submit the documentation necessary for the checks specified below. The applicant shall also make available to the Approved Inspection Body a batch of cylinders equal to twice the quantity of cylinders required for design

variant testing together with any additional information required. In addition the type approval certificate of the original type approval shall be presented.

In the course of the design variant approval process, the accredited authority shall:

- a) consider the changes of the design variant against the original type approval and determine the required level of testing
- b) select the necessary cylinders for testing in accordance with Table A.5.
- c) verify that:
 - the design conforms to the requirements of Clause 4
 - the design is in accordance with the manufacturing drawing
 - the internal and external surfaces of the cylinders are free of any defect which might make them unsafe to use
- d) witness or carry out the tests as stipulated in Clause 5.2.

A.4 PRODUCTION TESTS

A.4.1 General

These tests are a series which shall be carried out on either the whole or part of the production batch to ensure the compliance of the batch with the design specification.

A.4.2 Production test requirements

A.4.2.1 For the purpose of production testing, the cylinder manufacturer shall provide the Approved Inspection Body with:

- a) the type approval certificate or the design variant approval certificate
- b) certificates stating that the raw materials used in the manufacturing process, meets the specification drawn up jointly by manufacturer and the supplier
- c) the serial numbers of the cylinders
- d) a statement of the thread checking method used and results thereof.

A.4.2.2 During production testing, the Approved Inspection Body shall:

- a) ascertain that the type approval has been obtained and that the cylinders conform to it
- b) check whether the information supplied by the manufacturer referred to in A.4.2.1 is correct

- c) check whether the requirements set out in Clause 4 have been met and carry out the inspections in accordance with Clause A.4.4.2
- d) select the necessary cylinders for testing in accordance with Clause A.4.4.1.

A.4.4 Tests and inspections of the finished cylinder

A.4.4.1 Tests

The manufacturer shall apply tests appropriate to the manufacturing process to demonstrate that the cylinder does not leak.

The tests to be carried out on a batch of finished cylinders are specified in Table A.4, as follows:

- a) the proof pressure test on all cylinders (Test No. 2)
- b) a burst test on one cylinder per batch (Test No. 3)
- c) a pressure cycling test of 1 per 1,000 cylinders (Test No. 4)

A.4.4.2 Inspections

The inspections to be carried out on a batch of finished cylinders are specified in Table A.4, as follows:

- a) visual inspection - 10% minimum (for requirements see Clause 4.4.3)
- b) weight check - 10% minimum
- c) water capacity check - 10%
- d) compliance of marking - 100%

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

A.4.5 Batch acceptance certificate

If the results of the checks and tests are satisfactory, the Approved Inspection Body shall issue a batch acceptance certificate.

If the results are not satisfactory proceed as described in Clause 5.3.

Table A.4: Tests on completed cylinders

Test	Type approval	Production
Visual inspection	100%	10% 1)
Dimensional check	100%	10% 1)
Weight check	100%	10%
Marking compliance	100%	100%
Water capacity	100%	10%
Test No. 2 Hydraulic (proof) test	100%	100%
Test No. 3 Hydraulic pressure burst test	3	1
Test No. 4 Pressure cycling test	2	Minimum of 1 per 5 batches
Test No. 5 Exposure to elevated temperature at test pressure	2	-
Test No. 6 Drop test	2	-
Test No. 7 Flaw test	2	-
Test No. 8 Extreme temperature cycle test	1	-
Test No. 9 Fire resistance	2	-
Test No. 10 High velocity impact (bullet) test	1	-
Test No. 11 Permeability test	2	-
Test No. 12 Torque test	1	-
Test No. 13 Neck strength test	1	-
Test No. 14 Stability test	1	-
Test No. 15 Neck ring	1	-

Note: The numbers in the table represent the number of cylinders that shall be subjected to the relevant test.

1) If one unacceptable defect is found, 100% of the cylinders in the batch shall be inspected.

Table A.5: Qualification test requirements for design variant approvals

Test No.	Test	Design Variant Changes								
		New Design	Design Test Pressure +60%	Nominal Length-L		Nominal Diameter-D		Composite Thickness or Wrap Pattern	Fibre	Thread Change
				<2D	>1.5L	<20%	>20% <50%			
1	Composite Material Test	✓						✓(e)		
2	Hydraulic (proof) Test	✓	✓	✓	✓	✓	✓	✓	✓	
3	Burst Test	✓	✓	✓	✓	✓	✓	✓	✓	
4	Resistance to pressure cycles	✓	✓	✓	✓	✓	✓	✓	✓	
5	Exposure to elevated temperature	✓	✓(d)				✓(d)	✓(d)		
6	Drop Test	✓	✓		✓		✓	✓	✓	
7	Flawed cylinder Test	✓					✓	✓		
8	Extreme temperature cycle Test	✓						✓		
9	Fire resistance Test	✓					✓(c)			
10	High velocity impact (bullet) Test	✓								
11	Permeability Test	✓					✓			
12	Torque Test	✓								✓
13	Neck strength	✓				✓	✓			✓
14	Cylinder stability a)	✓			✓	✓	✓			
15	Neck ring b)	✓								

a) Free standing cylinders.

b) Cylinder with neck rings fitted only.

c) For cylinders leaking in the type approval fire test at a pressure > test pressure it is not necessary for this test to be carried out.

d) Where $P_b \text{ min}/P_h$ ratio for design variant is less than manufacturers specified P_b/P_h ratio type approval, then Test No. 8 shall be carried out.

e) For equivalent fibre testing.

APPENDIX B - SPECIMEN REPORT

APPROVED INSPECTION BODY'S REPORT ON:

**THE MANUFACTURE OF FULL WRAPPED LINERLESS TRANSPORTABLE
PRESSURE RECEPTACLES TO SPECIFICATION HSE-LL-FW4**

Approved Inspection Body

Approved Inspection Body's Mark _____

Certificate No. _____

Place _____ Date _____

Cylinders Manufactured by _____

Manufacturer's Mark

Manufactured for _____

—

Consigned to _____

Quantity _____ Overall size _____ Outside Diameter by
_____ long

Serial Numbers _____ to _____
inclusive

Specification HSE-LL-FW4

Drawing No _____

Date of Hydrostatic Pressure Test _____

Test Pressure _____

Water Capacity _____

Mass of Container (in kg) Minimum _____ Maximum _____
Without valve

With valve

Minimum _____ Maximum _____

(Note: Items in brackets below refer to the Clauses of specification HSE-LL-FW4)

Each cylinder was manufactured from two fully wrapped parts joined together in accordance with manufacturers procedures

Dry winding was applied using procedure (4.2.2.1)_____.

Fibre batch No. (4.2.2.1. A) _____supplied by _____

Injection moulding procedure (4.2.2.2) _____

Matrix batch No. (4.2.2.2.A)_____supplied by _____

Adhesive batch No. (4.3.3)_____supplied by _____

Each cylinder was subjected to a hydrostatic pressure test (5.2.2) at the test pressure stated above and no visible permanent distortion was noted.

The results of the batch pressure cycle (5.2.4) and burst tests (5.2.3) were satisfactory.

Each cylinder has been marked as required by the Specification (7).

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 ...