भारतीय मानक
Indian Standard

IS 16646 : 2017

द्रवीय पेट्रौलियम गैस (एलपीजी) के लिए परिवहनीय योग्य पुनः भरे जाने वाले रैप्ड संमिश्र सिलिंडर — विशिष्टि

Transportable Refillable Fully Wrapped Composite Cylinders for Liquefied Petroleum Gas (LPG) — Specification

ICS 23.020.30; 75.160.30

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Gas Cylinders Sectional Committee, MED 16

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Gas Cylinders Sectional Committee had been approved by the Mechanical Engineering Division Council.

The purpose of this standard is to provide specification for design, manufacture, inspection and testing of fully wrapped fibre in forced composite cylinders used for filling, storage and transportation of LPG.

While formulating this standard, considerable assistance have been derived from ISO 11119-3 : 2013 'Gas cylinders — Refillable composite gas cylinders and tubes — Design, construction and testing — Part 3: Fully wrapped fibre reinforced composite gas cylinders and tubes up to 450 litre with non-load-sharing metallic or non-metallic liners'.

This standard is applicable only for composite cylinders with non-metallic liners (Type 4 cylinders).

Type of cylinders for LPG:

a) *Type 1* Metal cylinders,
b) *Type 2* Metal lined hoop wrapped composite cylinders,
c) *Type 3* Metal lined full wrapped composite cylinders,
d) *Type 4* Non-metal lined full wrapped composite cylinders, and
e) *Type 5* Full wrapped composite cylinders without liner.

This standard refers only to technical sustainability and does not absolve the user from legal obligation relating to health and safety at any stage.

While implementing this standard, the manufacturer and the inspection agency shall ensure compliance with statutory regulations. It is the responsibility of the owners and the users to ensure that the cylinders are periodically tested as per norms laid down in *Gas Cylinder Rules,* 2004 as amended from time-to-time and as enforced by statutory authorities under the rules.

The relevant SI units and corresponding conversion factors are given below for guidance:

Pressure 1Pa (Pascal) = 1 N/m^2

1 kgf/mm^2 = 9.806 65 MPa

The composition of the Committee responsible for the formulation of this standard is given in Annex C.

For the purpose of deciding whether a particular requirement of this standard is complied with the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

TRANSPORTABLE REFILLABLE FULLY WRAPPED COMPOSITE CYLINDERS FOR LIQUEFIED PETROLEUM GAS (LPG) — SPECIFICATION

1 SCOPE

This standard deals with fully wrapped fiber reinforced composite cylinders with non-metallic non-load sharing liner (Type 4 cylinders) intended for storage and transportation of liquefied petroleum gases (*see* IS 4576) exposed to ambient temperature and with the test pressure of 30 bar of nominal capacity exceeding 0.5 litre up to and including 150 litre water capacity. This standard specifies the minimum requirements for the materials, design, manufacture, construction, inspection, testing and marking on these cylinders.

This standard is applicable to fully wrapped fiber reinforced non-metallic non-load sharing liner reinforced by fibres of glass, carbon or aramid or combination thereof.

NOTE — This standard does not address the design, fitting and performance of removable protective sleeves or fixed protective casing, wherever external casing are fitted should meet the test requirements prescribed in this standard.

2 REFERENCES

The standards listed below contain provisions which, through reference in this text constitute provisions of this standard. At the time of publication, the editions were valid. All standards are subject to revision and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below.

IS No./ International Standard	*Title*
4576 : 1999	Liquefied petroleum gases — Specification (*second revision*)
13360 : 2013 (in Various Parts)	Method of testing mechanical properties
IS/ISO 11114-1 : 2012	Transportable gas cylinders — Compatibility of cylinder and valve materials with gas contents — Part 1: Metallic materials
IS/ISO 11114-2 : 2013	Transportable gas cylinders — Compatibility of cylinder and valve materials with gas contents — Part 2: Non-metallic material
ISO 75-3 : 2004	Plastics — Determination of temperature of deflection under load — Part 3: High-strength thermosetting laminates and long-fibre-reinforced plastics
ISO 3341 : 2000	Textile glass — Yarns — Determination of breaking force and breaking elongation
ISO 8521 : 2009	Plastics piping systems — Glass-reinforced thermosetting plastics (GRP) pipes — Test methods for the determination of the apparent initial circumferential tensile strength
ISO 14130 : 1994	Fibre-reinforced plastic composites — Determination of apparent inter laminar shear strength by short-beam method
ASTM D 2196-15	Standard Test Methods for Rheological Properties of Non-Newtonian Materials by Rotational Viscometer
ASTM D 2290-16	Standard Test Method for Apparent Hoop Tensile Strength of Plastic or Reinforced Plastic Pipe
ASTM D 2291-16	Standard Practice for Fabrication of Ring Test Specimens for Glass-Resin Composites
ASTM D 2343-09	Standard Test Method for Tensile Properties of Glass Fiber Strands, Yarns, and Rovings Used in Reinforced Plastics
ASTM D 2344-16	Standard Test Method for Short-Beam Strength of Polymer Matrix Composite Materials and Their Laminates
ASTM D 3418-15	Standard Test Method for Transition Temperatures and Enthalpies of Fusion and Crystallization of Polymers by Differential Scanning Calorimetry
ASTM D 4018-17	Standard Test Methods for Properties of Continuous Filament Carbon and Graphite Fiber Tows

3 TERMINOLOGY

For the purpose of this standard, the following definitions apply.

3.1 Ambient Temperature — Temperature of surroundings

3.2 Aramid Fibre — Continuous filament of aramid laid up in tow form.

3.3 Batch of Non-metallic Liners — Quantity of a maximum of 2 000 liners having the same nominal diameter, length, thickness and design, made successively from the same batch of materials and subjected to the same manufacturing process.

3.4 Batch of Finished Cylinders — Quantity of up to 200 finished cylinders plus cylinders for destructive testing, successively produced by the same manufacturing process of the same nominal diameter, thickness, length and design which may contain different batches of liners (providing the batches are nominally the same and have had the same treatments), fibres and matrix materials.

3.5 Burst Pressure — Highest pressure reached in a liner or cylinder during the relevant burst test.

3.6 Carbon Fibre — Continuous filaments of carbon laid up in a tow form.

3.7 Composite Overwrap — Combination of fibres and matrix.

3.8 Equivalent Fibre — Fibre manufactured from the same nominal raw materials, using the same process of manufacture and having the same physical structure and the same nominal physical properties, and where the average tensile strength and modulus is within ±5 percent of the fibre properties in an approved cylinder design (*see* Annex A).

3.9 Equivalent Liner — Liner that are manufactured from the same nominal raw materials, using the same process of manufacture and having the same physical structure and the same nominal physical properties as in an approved cylinder design (*see* Annex A).

3.10 Exterior Coating — Layers of material applied to the cylinder as protection or for cosmetic purposes.

3.11 Glass Fibre — Continuous filaments of glass laid up in a tow form.

3.12 Liner — Inner portion of the composite cylinder, comprising a non-metallic vessel, whose purpose is both to contain the gas and transmit the gas pressure to the fibres.

3.13 Matrix — Material that is used to bind and hold the fibres in place.

3.14 Non-load Sharing Liner — Liner that has a burst pressure less than 5 percent of the nominal burst pressure of the finished composite cylinder.

3.15 Thermoplastic Material — Plastics capable of being repeatedly softened by increase of temperature and hardened by decrease of temperature.

3.16 Thermosetting Material — Plastics that when cured by the application of heat or chemical means, harden permanently into a substantially infusible and insoluble product.

3.17 Nominal Outside Diameter — Diameter of the cylinder specified by the manufacturer for the type approval including tolerances (for example ±1 percent).

3.18 Working Pressure — Settled pressure of a compressed gas at a reference temperature of 15°C in a full gas cylinder.

3.19 Removable Protective Sleeve — External sleeve intended to provide protection to the cylinder during operation which is not integral part of the design, not permanently fixed to the cylinder but which can be removed during service without destroying the sleeve.

3.20 Protective Casing — A transparent/opaque/coloured protective case fixed on cylinder to keep it in upright position and protect cylinder and valve from external damage.

3.21 Finished Cylinder — Fully wrapped composite cylinder with protective casing.

3.22 Cylinder — Composite cylinder complete with liner, metal boss and fibre reinforcement.

3.23 Test Pressure — For this application, test pressure is 30 bar.

3.17 Fibre Tow — It is an untwisted bundle of continuous filaments.

4 SYMBOLS AND UNITS

4.1 Symbols and Their Designations

Symbol	*Designation*	*Unit*
P_{bl}	Burst pressure of liner	Bar
P_b	Burst pressure of finished cylinder	Bar
P_h	Test pressure	Bar
P_{max}	Maximum developed pressure at 65°C	Bar
P_w	Working pressure	Bar

5 GENERAL

A fully dimensioned sectional drawing of the cylinder, together with material used, design calculations, construction and scheme of manufacture, shall be submitted by the manufacturer to the inspecting agency,

for final approval of the statutory authority.Finite element analysis shall be part of type approval test.

6 MATERIALS

6.1 General

The materials used for manufacture of composite cylinders shall be of uniform and consistent quality. The composite cylinder manufacturer shall verify that each new batch of material 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.

The manufacturer shall collect documentation from the suppliers of raw materials to be able to identify the batch of materials used in the manufacture of cylinders and shall ensure that their properties meet the design requirements.

Materials for each part of the cylinder shall be compatible with Liquefied Petroleum Gas (LPG) and as specified in IS/ISO 11114-1and IS/ISO 11114-2.

6.2 Liner Material

The liner (including metal boss) shall be manufactured from the material compatible with the liquefied petroleum gas (LPG). The liner material shall be evaluated by the manufacturer as suitable for the application and approved by the statutory authority.

Metal boss, made of forged metal, attached to a non-metallic liner shall fulfil the performance requirement of this standard.

6.3 Composite Materials

The overwrap material shall be carbon fibre or glass fibre or aramid fibre, or any combination thereof.

The matrix shall be a polymer suited to the application, environment and intended life of the composite cylinders for example epoxy or modified epoxy with Amine or Anhydride curing agents.

Batches of the material shall be identifiable and documented for traceability

7 DESIGN AND MANUFACTURE

7.1 General

Fully wrapped composite cylinders for LPG shall be manufactured with non-metallic non-load sharing liner. The cylinder shall have following parts:

a) An internal non-metallic liner,
b) Metal boss for thread connections,
c) A composite overwrap formed by layers of continuous fibre in the matrix, and
d) An external protection casing.

The thickness of the cylinder including the liner shall be determined by satisfactory completion of the performance test described in **9**.

The cylinder may also include an external coating and/or additional parts such as valve shrouds/handles, bases, cages. Where these are integral part of the design, they shall be fixed to the cylinder such that they cannot be removed without the use of special tools only by the manufacturer or the testing stations approved by the statutory authority.

The location of openings for service connection shall be restricted to one end of the cylinder and it shall be along the central axis only. Where it is necessary for production reasons to have an opening on both ends, the non- service opening shall be permanently sealed before completion of the cylinder.

7.2 The fully wrapped composite cylinder for LPG with a non-load sharing non-metallic liner shall be designed for non-limited life.

The re-qualification period for these cylinders shall be as approved by the statutory authority.

7.3 The cylinders shall be designed to be suitable for the temperature range of –40°C to 65°C. The design shall bear the temperatures beyond this range during filling or discharge for short duration.

7.4 Liners

The liner (including metal boss) shall be manufactured from a material suitable for the gas to be contained as per IS/ISO 11114-1 and IS/ISO 11114-2. Furthermore, the liner materials shall be evaluated by the manufacturer and approved by the statutory authority as suitable for the specific application. Metal bosses attached to a non-metallic liner shall fulfil the performance requirements of this standard.

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

The manufacturer shall collect documentation from the suppliers of raw materials to be able to identify the batch of materials used in the manufacture of cylinders and shall ensure that their properties meet the design requirements.

7.5 Composite Overwrap

7.5.1 The overwrap materials shall be carbon fibre or aramid fibre or glass fibre, or combination thereof.

The suppliers of the filament material, the matrix component materials and, if applicable, the adhesive component material 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.

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

The manufacturer shall collect documentation from the suppliers of raw materials to be able to identify the batch of materials used in the manufacture of cylinders and shall ensure that their properties meet the design requirements.

Batches of the material shall be identifiable and documented for traceability.

7.5.2 *Winding*

Procedure shall be defined for the winding and curing process to ensure good repeatability and traceability.

For all cylinders, the following parameters shall be defined and monitored:

a) Batch number of fiber used;
b) Number of strand used;
c) Winding tension of strand;
d) Winding speed;
e) Winding angle and/or pitch for each layer;
f) The number and order of layer;
g) Percentages of the components of the matrix system and their batch number;
h) Resin bath temperature range; and
j) The procedure used to obtain correct impregnation.

7.5.3 *Protective Casing*

All the cylinders shall have a protective casing to keep it in upright position and protect cylinder and valve from external damages.

The shape/construction and material shall be designed by the manufacturer and shall meet the requirement of **9.12**, **9.22** and **9.23**.

NOTE — An external sleeve may be fixed intended to protect the cylinder during operation, which is not an integral part of the cylinder, which can be removed during service.

7.6 Design Submission

The design submission for each new design of cylinder shall include a detailed drawing along with documentation of the design including materials, manufacturing and inspection particulars as detailed in **7.6.1**, **7.6.2** and **7.6.3**.

7.6.1 *Liner and Metal Boss(es)*

Following documentation for the liner and metal boss(es) shall be include (but not be limited to):

a) Material, including limits of chemical analysis;
b) Dimensions, minimum thickness, straightness and out of roundness with tolerances;
c) Process and specification of manufacture;
d) Inspection procedures (minimum requirements);
e) Material properties;
f) Dimensional details of valve threads and any other permanent features; and
g) Method of sealing boss to liner for bonded bosses.

7.6.2 *Composite Overwrap*

Following documentation for composite overwrap shall be included (but not be limited to):

a) Fiber material, specification and mechanical properties requirements;
b) Minimum composite thickness;
c) Thermosetting matrix — specifications (including resin, curing agent and accelerator) and resin batch temperature where applicable;
d) Thermoplastic matrix system – main component materials, specifications and process temperatures;
e) Overwrap construction including the number of strands used, number of layers, layer orientation and tensioning of the fiber at wrapping where applicable; and
f) Curing process, temperatures, duration and tolerances.

7.6.3 *Finished Composite Cylinder*

Following documentation for the finished composite cylinder shall be include (but not be limited to):

a) Nominal water capacity in litres at ambient conditions;
b) List of intended contents if intended for dedicated gas service;
c) Working pressure, P_w that shall not exceed 2/3 times test pressure;
d) Test pressure, P_h;
e) Minimum design burst pressure;
f) Design life in years;
g) Nominal weight of the finished composite cylinder, including tolerances;

h) Details of components which are permanently attached and form part of the qualified design (for example neck rings, protective boots, casing etc); and

j) Change of structural design of protective casing.

7.7 Manufacturing

The liner and metal boss wherein incorporated shall be manufactured in accordance with the manufacturer's design as approved by the statutory authority.

The composite cylinders shall be fabricated using a non-load sharing liner fully overwrapped with layers of continuous fibers in a matrix applied under controlled tension to develop the design, composite thickness as specified in **7.6.2**.

After wrapping is completed the composite shall be cured using a controlled temperature profile as specified in the documentation. The maximum temperature shall be such that the mechanical properties of the liner material and composite overwrap are not adversely affected.

The internal and external surface of the finished cylinder shall be free of defects which can adversely affect the safe working of the cylinder. There shall be no visible foreign matter (for example resin, water, plastic particles, foreign particles or other debris) present inside the cylinder.

NOTE — If cylinders are subjected to fibre tensioning during wrapping, the tensioning shall be monitored and recorded.

8 PROCEDURE FOR APPROVAL AND CERTIFICATION

8.1General

This section describes tests to be conducted on fully wrapped composite cylinders, cylinder liners and the material used in the manufacture of cylinders for:

a) prototype testing of new cylinder design;

b) design variant testing; and

c) production testing.

The lists of tests which are mandatory or optional are identified in the schedule of testing and inspection in Table 1.

Prototype testing or design variant shall be approved by statutory authority.

NOTE — Appropriate safety precautions should be taken in order to reduce the risk to testing person while handling / testing pressurized cylinders. If necessary, during positioning and handling of cylinders, they can be depressurized between individual tests.

8.2 Prototype Testing of Cylinder Design

8.2.1 Prototype testing shall be carried out on each new design of cylinder.

All the tests shall be carried out on cylinders of identical design (that is materials, liner, and manufacturing process) from the same factory (where approval is granted).The tests shall be performed on cylinders having the same nominal dimensions (that is same diameter, length, liner wall thickness and composite thickness).

8.2.2 A minimum of 30 cylinders that are guaranteed by the manufacturer to be representative of the new design, shall be made available for prototype testing. Inspector shall select and mark the cylinder for various tests.

8.2.3 The inspector shall verify that the batch of liners, prior to being wrapped, complies with the design requirements and is inspected and tested in accordance with **10.1**

8.2.4 The inspector shall verify that the composite material(s) prior to the cylinders being wrapped, comply with the design requirements and are tested in accordance with **10.2**

8.2.5 The inspector shall verify that all cylinders in the batch produced for new design approval comply with the design submission and are tested in accordance with **9.**

8.2.6 Following tests shall be conducted for type approval tests:

i) Liner material test , in accordance with **9.1**;

ii) Composite material test, in accordance with **9.2**;

iii) Liner burst test, in accordance with **9.3**;

iv) Hydraulic proof test, in accordance with **9.4**;

v) Resin shear test, in accordance with **9.5**;

vi) Cylinder burst test, in accordance, with **9.6**;

vii) Ambient pressure cycle test, in accordance with **9.7**;

viii) Vacuum test, in accordance with **9.8**;

ix) Environmental cycle test, in accordance with **9.9**;

x) Stress rupture test (creep test), in accordance with **9.10**;

xi) Flaw test, in accordance with **9.11**;

xii) Drop test, in accordance with **9.12**;

xiii) High velocity impact (gunfire) test, in accordance with **9.13**;

xiv) Fire resistance test, in accordance with **9.14**;

xv) Permeability test, in accordance with **9.15**;

xvi) Torque test, in accordance with **9.16**;

xvii) Leak test, in accordance with **9.17**;

xviii) Pneumatic cycle test, in accordance with **9.18**;

Table 1 Type Approval /Design Variant Tests with Quantity
(*Clause* 8.1)

Sl No.	Clause No.	Test	Quantity	New Design	Design Variant Changes									
					Length		Diameter		Liner Thickness > 10%	Equivalent Fiber	Composite Thickness or Pattern or Liner Base Form	Neck Boss	Equivalent Matrix	Thread
					>5% ≤ 50%	>50%	≤ 20%	≤ 20% < 50						
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
i)	**9.1**	Liner material test	—	X										
ii)	**9.2**	Composite material test	—	X						X			X	
iii)	**9.3**	Liner burst test	01	X		X		X	X					
iv)	**9.4**	Hydraulic proof test	02	X	X	X	X	X	X	X	X	X	X	
v)	**9.5**	Resin shear test	01	X									X	
vi)	**9.6**	Cylinder burst test	03	X	X	X	X	X	X	X	X	X	X	
vii)	**9.7**	Ambient pressure cycle test	02	X	X	X	X	X	X	X	X	X	X	
viii)	**9.8**	Vacuum test[3)]	01	X				X	X[4)]			X		
ix)	**9.9**	Environmental cycle test	02	X								X	X	
x)	**9.10**	Stress rupture (Creep test)	02	X				X		X	X	X	X	
xi)	**9.11**	Flaw test	02	X				X		X	X	X	X	
xii)	**9.12**	Drop test	02	X		X		X		X	X	X	X	
xiii)	**9.13**	High velocity impact test (Gun fire test)	02	X				X[1)]						
xiv)	**9.14**	Fire resistance test	02	X		X		X				X[2)]		
xv)	**9.15**	Permeability test	02	X				X	X			X		
xvi)	**9.16**	Torque test[6)]	01	X								X		X
xvii)	**9.17**	Leak test	02	X			X	X	X			X		
xviii)	**9.18**	Pneumatic cycle test	01	X		X		X	X			X	X	
xix)	**9.19**	Leakage test with service valve[5)]	02	X										X[5)]
xx)	**9.20**	Spike puncture Test	01	X						X	X		X	
xxi)	**9.21**	Lifting test	02	X		X		X						
xxii)	**9.22**	Straightness	02	X		X		X						
xxiii)	**9.23**	Verticality	02	X		X		X						

X — Test is applicable
[1)] Test to be conducted for reduction in diameter only or if an increase in diameter requires only or if increase in diameter requires a larger caliber.
[2)] Only if cylinder in previous fire test leaked at the neck boss.
[3)] Optional test, required according to the design and intended use of the cylinder.
[4)] For liner thickness decrease only.
[5)] Only if type of valve is known.
[6)] When a cylinder design has only a different thread compared to an approved design only the torque test, in accordance with **9.16** shall be performed.

xix) Leakage test with service valve, in accordance with **9.19**;

xx) Spike puncture test, in accordance with **9.20**;

xxi) Lifting test, in accordance with **9.21**;

xxii) Straightness test, in accordance with **9.22**; and

xxiii) Verticality test, in accordance with **9.23**.

8.2.7 After completion of each test, the cylinder shall be destroyed to ensure that it does not mix with new batch and go for pressurizing again. The Inspector shall ensure that tested cylinders are destroyed and recorded.

8.2.8 If the results of the verification according to **8.2.3**, **8.2.4**, **8.2.5**, and **8.2.6** as applicable are satisfactory, the statutory authority shall issue a design approval certificate.

8.2.9 After completion of type approval, the design parameters, manufacturing process, raw material specifications shall be frozen and no alteration shall be made without approval of the statutory authority.

8.3 New Design

A cylinder of new design shall require complete type approval tests as specified in **9**.

8.3.1 A cylinder shall be considered as a new design when it conforms to any of the following conditions:

a) If cylinders are manufactured in a different factory.

b) If there is a change in the manufacturing process.

c) The nominal outside diameter has changed by 50 percent or more from the approved design.

d) The cylinder is manufactured with a different class of fibre (for example glass, aramid or carbon) or the fibre is produced from a different precursor or a different winding pattern is used.

e) The matrix material (resin, curing agent, accelerator) are different, not chemically equivalent to the original design (for example change from epoxy to polyester or *vice versa*).

NOTE — Where a new matrix material has been prototype tested for an existing design, then all the manufacturer' existing prototype tested designs are regarded as prototype tested with the new matrix system without the need for any additional prototype testing.

6) The material of the liner is changed to different composition.

7) Liner is manufactured by a different process.

8.4 Design Variant

A reduced testing programme may be carried out for cylinders within the definition of a design variant compared with that required for a prototype testing. Design variant testing shall be conducted for each design variant of the cylinder.

8.4.1 A cylinder shall be considered to be a design variant, compared with a previously prototype tested cylinder, when any of the following conditions apply:

a) The nominal length of the cylinder has changed by more than 5 percent

b) The nominal outside diameter has changed by less than 50 percent

c) There have been changes to the composite thickness or wrap pattern other than the changes necessary to accommodate the changes of diameter and/or length;

d) The minimum wall thickness of the liner has increased by more than 10 percent

e) The design or method of joining of neck boss to the liner has changed

f) Matrix material that is resin, curing agent and accelerator are from different suppliers but are chemically equivalent to the original design.

g) Equivalent fibre are manufactured from the same nominal raw materials, using the same process of manufacture and having the same physical structure and the same nominal physical properties and where the average tensile strength and modulus is within ±5 percent of the fibre properties in an approved cylinder design.

h) Where a new equivalent fibre has been prototype tested for an existing design, all the manufacturer's existing prototype tested designs are regarded as prototype tested with the new fibre without the need for any additional prototype testing.

j) Equivalent liners are manufactured from equivalent raw materials, using the same process of manufacture and having the same physical structure and the same nominal physical properties as in an approved cylinder design.

k) The equivalent liner material shall be subjected to the material tests specified in **9.1** for polymer liners and the liner burst test specified in **9.3** and shall meet the minimum requirements specified in **9.3.2** and the criteria of **9.3**

m) Where a new equivalent liner has been prototype tested for an existing design, all the manufacturer's existing prototype tested designs are regarded as prototype tested with the new liner without the need for any additional prototype testing.

8.4.2 When, cylinder design has only a different thread compared to an approved design only the torque test, in accordance with **9.16**, shall be performed.

NOTE — The standard thread shall be ¾" 14 NGT or any thread accepted by the statutory authority, but for some special application thread size may change.

8.4.3A cylinder approval by a reduced series of tests (a design variant) shall not be used as a basis for a second design variant approval with a reduced set of tests, that is multiple changes from an approved design are not permitted. If a test has been conducted on a design variant (A) that falls within the testing requirements for a second variant (B) then the result for (A) can be applied to the new design variant (B) test programme. However design variant (A) shall not be used as the reference for determining the testing required for any new design variant.

Where a design variant involves more than one parameter change all the tests required by those parameter changes shall be performed once only.

The statutory authority shall determine the level of reduced testing if not defined in Table 1, but a fully approved design shall always be used as a reference for the new design variant (that is new design variants shall not be approved by reference only to a previous design variant).

9 TEST PROCEDURES AND CRITERIA

9.1 Liner Material Test

Following tests to be carried out on the non-metallic liner material as per the test procedure specified in IS 13360.

a) *for thermoplastic materials* — viscosity, melting point, water content, density, melting flow index and chemical resistance.

b) *for thermo set and elastomeric materials* — viscosity, elongation at break, tensile strength, chemical resistance and glass transition temperature.

NOTE — Alternative standards are acceptable providing that they give equivalent results.

Criteria — The properties of the material shall be within the tolerances set by the material manufacturer and as laid down under design requirements.

9.2 COMPOSITE MATERIAL TEST

9.2.1 *Procedure*

Tests on the composite materials to establish their mechanical properties shall be carried in accordance with

a) for tensile properties of fiber
   1) For glass ,aramid — ISO 8521, ASTM D 2290 and ASTM D 2291; ISO 3341 or ASTM D 2343
   2) For carbon — ASTM D 4018

b) Shear properties for composite material: ISO 14130 or ASTM D 2344.

c) Matrix properties: glass transition temperature as per ASTM D 3418, heat distortion temperature as per ISO 75-3, viscosity as per ASTM D 2196.

Equivalent tests in accordance with alternative standards or test specifications acceptable to the inspecting authority may be applied.

Criteria — Mechanical properties shall meet the minimum requirements as specified by the manufacturer.

9.3 Liner Burst Test

9.3.1 *Procedure*

The hydraulic burst test shall be carried out at ambient temperature, on liner complete with metal boss. The liner shall be pressurized at a controlled rate not exceeding 5 bar/s until failure. The pressure against time curve shall be plotted.

The maximum pressure achieved during the test shall be recorded as the liner burst pressure (P_{bl}).

9.3.2 *Criteria*

The burst pressure of liner (P_{bl}) shall be equal to or greater than the minimum design burst pressure of the liner as specified in the design documents. The liner shall remain in one piece.

9.3.3 *Parameter to Monitor and Record*

Following shall be examined and recorded:

Burst pressure, number of pieces after test, description of failure, that is brittle fracture, ductile fracture etc, pressure / time curve or pressure / volume curve.

9.4 Hydraulic Proof Test

9.4.1 *Procedure*

The cylinder shall be pressurized gradually and continuously until the test pressure P_h is reached. The pressure shall be held for a period of minimum 30 s. The tolerance of applied test pressure shall be – 0/+5 percent.

9.4.2 *Criteria*

The cylinder pressure shall remain steady.

There shall be no leaks.

There shall be no visible permanent deformation after the cylinder is depressurized.

9.4.3 *Parameters to Monitor and Record*

a) Test pressure;
b) Leakages, if any; and
c) Graph between pressure *versus* time.

NOTES

1 Cracking of resin is not necessarily a sign of permanent deformation.

2 Alternatively a pneumatic pressure can be used provided that appropriate measures are taken to ensure safe operation and to contain any energy that can be released, which is considerably more than in hydraulic test.

9.5 Resin Shear Test

Prototype matrix materials shall be tested on a sample coupon representative of the composite overwrap in accordance with ISO 14130 or an equivalent standard acceptable to the competent authority. This test shall be repeated when matrix materials are changed and are not chemically equivalent to those used in the original design.

9.6 Cylinder Burst Test

The cylinder burst test shall be carried out using a test rig which allows pressure to be increased at a controlled rate.

9.6.1 *Procedure*

The test shall be carried out at ambient temperature, the cylinder shall be pressurized hydraulically gradually and regularly at a constant rate of not more than 10 bar/s. Prior to commencement of the test, it shall be ensured that no air is trapped in the cylinder. The cylinder shall be pressurized until failure, that is leakage through the pressure envelope or burst. The pressure against time curve or pressure against volume curve shall be plotted.

9.6.2 *Criteria*

The burst pressure shall be greater than or equal to the manufacturer's minimum specified design burst pressure and shall not be less than the below specified criteria. The cylinder shall burst without fragmentation or disbanding / loosening of fibre, in any portions other than the area of rupture.

The cylinder shall not leak below the required burst pressure as specified below:

a) The burst pressure, P_b for cylinders with carbon fibre reinforcement shall be not less than the test pressure, $P_h \times 2.0$.
b) The burst pressure, P_b, for cylinders with aramid fibre reinforcement shall be not less than test pressure, $P_h \times 2.1$.
c) The burst pressure, P_b, for cylinders with glass fibre reinforcement shall be not less than the test pressure $P_h \times 2.4$.

9.6.3 *Parameters to Monitor and Record*

The following shall be monitored and recorded:

a) Burst pressure;
b) Location of burst and number of pieces;
c) Description of failure, that is brittle fracture, ductile fracture etc; and
d) Pressure / time curve or pressure / volume curve.

9.7 Ambient Pressure Cycle Test

9.7.1 *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 suspends the test when the cylinder has failed, either by leakage or rupture.

The test shall be carried out with a non-corrosive liquid subjecting the cylinder to successive reversals at an upper cyclic pressure not less than 30 bar. The value of the lower cyclic pressure shall not exceed 3 bar. The frequency of reversals of pressure shall not exceed 15 cycles per minute.

The cycle tests shall be carried out at ambient conditions and the temperature on the outside surface of the cylinder shall not exceed 50°C during the test. The temperature of the external surface of the cylinder shall be continuously monitored.

The number of cycles achieved during the test shall be recorded. After completion of this test, the cylinder shall be subjected to leak test according to **9.17** and followed by burst test as per **9.6**.

9.7.2 *Criteria*

The cylinders shall withstand 12 000 cycles without leakage. If the cylinder is designed to pass 12 000 hydraulic cycles to test pressure and achieves this level consistently in the test, it shall not be necessary to limit the design life of the cylinder. The cylinder shall satisfy the requirement of leak test according to **9.17** as well as burst test as specified in **9.6** after the cycle test.

9.7.3 *Parameters to Monitor and Record*

The following shall be monitored and recorded:

a) Number of cycles achieving upper cycle pressure;
b) Minimum and maximum cycle pressure;
c) Temperature of the external surface of the cylinder;
d) Pressure cycle frequency;

e) Test medium used;
f) Mode of failure, if appropriate; and
g) Burst pressure achieved.

9.8 Vacuum Test

When this test is carried out, cylinder shall be subjected to a vacuum test prior to the environmental cycle test. When this test is not carried out, a warning shall be permanently marked on the cylinder.

9.8.1 *Procedure*

The cylinder shall be subjected to a series of cycles from atmospheric pressure to a vacuum as follows:

The cylinder contents shall be evacuated to reduce the pressure to a pressure of 0.2 bar absolute at ambient temperature. The vacuum shall be maintained at this level for at least one minute. Pressure in the cylinder shall then be returned to atmospheric pressure. The above procedure shall be repeated for 50 cycles.

9.8.2 *Criteria*

After cycling, the interior of the liner shall be inspected for damage. Any evidence of disbonding, folding or other damage shall be noted. If the cylinder then passes the environmental cycle test it shall also be deemed to have passed the vacuum test.

9.8.3 *Parameters to monitor and record*

The parameters that shall be monitored and recorded are:

a) number of cycles achieving lower cyclic pressure;
b) minimum and maximum cyclic pressure;
c) cycle frequency; and
d) results of visual inspection like delamination, disbonding, blister formation, folding of liner, cracks or any other damage.

9.9 Environmental Cycle Test

When the vacuum test (*see* **9.8**) is carried out, the vacuum tested cylinder shall be used for the environmental cycle test. When the vacuum test is not conducted, fresh cylinders shall be taken, the manufacturer shall ensure a warning is marked on the cylinder, "Not for Vacuum". These tests shall be performed in an environmental chamber. Cylinder shall be without paint and any removable protective coating/ casing.

9.9.1 *Procedure*

The cylinder and the contained pressurizing medium shall be conditioned for 48 h at atmospheric pressure, at between 60°C and 70°C and at a relative humidity greater than or equal to 90 percent. The intent of this requirement can be met by spraying with a continuous fine spray or mist of water in a chamber held between 60°C and 70°C.

The hydraulic pressurizing medium, located in the circuit 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 20 bar. The cylinder skin temperature shall be maintained between 60°C and 70°C by regulating the environmental chamber and the cycle frequency. The cycle frequency shall not exceed 10 cycles/ minute.

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

The temperature shall then be reduced and the cylinder and its contained pressurizing medium is stabilized at a temperature between –40° C and –50 °C.

The hydraulic pressurizing medium external to the cylinder under test, shall commence the cycle testing at ambient temperature. 5 000 cycles shall be applied from a pressure less than 2 bar to 20 bar (two-third of the test pressure). The cylinder skin temperature shall be maintained between –40°C and –50°C by regulating the environmental chamber and the cycle frequency. The cycle frequency shall not exceed 10 cycles/ minute. The fluid shall also be selected to ensure that it functions at the temperatures specified in the various cycle tests.

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

The cylinder shall then be subjected to leak test.

On completion of the above tests, the cylinder shall be subjected to burst test.

9.9.2 *Criteria*

There shall not be any leakage/rupture during cycle test.

a) The burst pressure shall be greater than 85 percent of the minimum design burst pressure;
b) The burst pressure, P_b, for cylinders with carbon fibre reinforcement shall be not less than the test pressure, $P_h \times 1.7$;
c) The burst pressure, P_b, for cylinders with aramid fibre reinforcement shall be not less than the test pressure, $P_h \times 1.9$; and
d) The burst pressure, P_b, for cylinders with glass fibre reinforcement shall be not less than the test pressure, $P_h \times 2.2$.

9.9.3 *Parameters to Monitor and Record*

The following shall be monitored and recorded:

a) Temperature of cylinder body during each part of test;
b) Humidity during first part of test;
c) Test media used;
d) number of cycles achieving upper cyclic pressure at each stage;
e) minimum and maximum cyclic pressure;
f) frequency of cycles;
g) visual inspection;
h) burst pressure meeting requirements as per **9.6;** and
j) Pressure time curve / pressure volume curve.

9.10 Stress Rupture Test — Exposure to Elevated Temperature Test (Creep Test)

9.10.1 *Procedure*

The test shall be conducted at (70 ± 5)°C and a relative humidity e”95 percent.

Two cylinders shall be hydraulically pressurized to 30 bar and kept at the test temperature and shall be maintained at this pressure, temperature and humidity for 2 000 h.

The use of a water spray or suspending the cylinder over a water bath are both methods that can be used to meet the requirements of this test.

After this test, the cylinders shall be subjected to leak test (*see* **9.17**) and burst test (*see* **9.6**).

9.10.2 *Criteria*

The cylinder shall not exhibit any visible deformation or loose fibres (unraveling) and shall satisfy the criteria of the leak test **9.17**. The burst pressure shall be equal to or greater than 100 percent of the minimum burst level required in the burst test *see* **9.6** for the relevant fibre.

9.10.3 *Parameters to Monitor and Record*

The following shall be monitored and recorded:

a) Temperature and relative humidity at least twice a day;
b) Cylinder pressure at least twice a day; and
c) Burst pressure and parameters specified for burst test.

9.11 Flaw Test

Two cylinders shall be tested in accordance with the following procedure:

9.11.1 *Procedure*

Two flaws, one longitudinal and the other transverse shall be made on each of the two cylinders in the mid length of the cylindrical part, along two planes forming an angle of approximately 120 degrees as shown in Fig. 1.

The flaws shall be made with a 1 mm thick cutter to a depth equal to at least 40 percent of the composite overwrap thickness but not more than 2.5 mm deep and to a length between the centre of the cutter equal to five times the composite overwrap thickness (*see* Fig. 1).

After introducing the flaws one of the two cylinders shall be subjected to burst test. The other cylinder shall be subjected to ambient pressure cycle test, except that the upper cyclic pressure shall be 20 bar and the number of cycles shall be not less than 5 000, after reaching the same, the test shall be suspended. After completion of above ambient temperature cycle test the cylinder shall be destroyed (for example bursting) or made incapable of holding pressure.

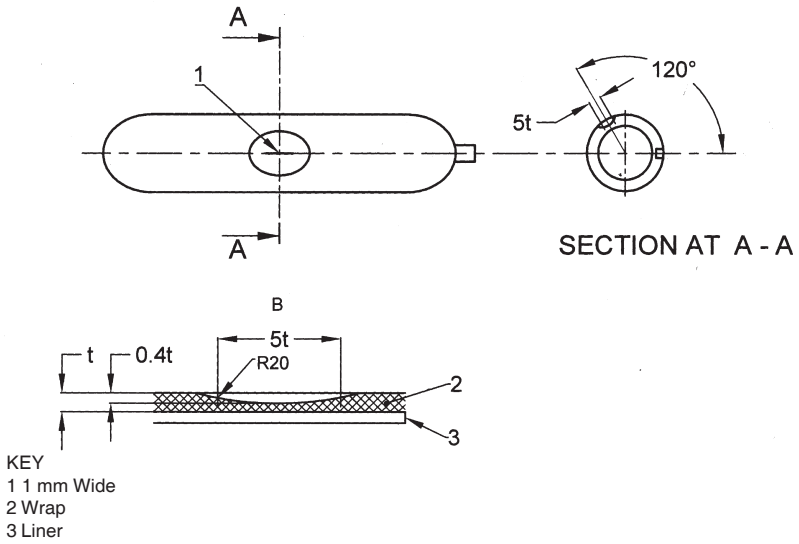


FIG. 1 FLOW TEST PROCEDURE

9.11.2 *Criteria*

For the first cylinder the burst pressure shall be greater than or equal to 40 bar.

The second cylinder shall withstand at least 1 000 pressure cycles to 20 bar without leakage. If the cylinder leaks after 1 000 cycles, it shall be deemed to have passed the test, however if the cylinder bursts within 5 000 cycles, the cylinder shall be considered as failed the test.

9.11.3 *Parameters to Monitor and Record*

The following shall be monitored and recorded:

a) Dimensions of flaws;
b) Temperature of the cylinder;
c) Number of cycles achieving upper cyclic pressure;
d) Minimum and maximum cyclic pressures;
e) Cycle frequency;
f) Test medium used; and
g) Mode of failure, if appropriate

9.12 Drop Test

Drop test shall be conducted on finished cylinders, including any foot ring and / or valve protection and any removable/fixed protective sleeve/cover.

9.12.1 *Procedure*

Test cylinders shall be filled with water to 50 percent capacity. The opening shall be sealed by fitting a plug, flush with the end of each cylinder. The surface for drop shall consist of a steel plate, not less than 10 mm thick, sufficiently flat so that the difference between any two points in diameter of 1 m on the surface is no more than 2 mm.

The steel plate shall rest on a flat, smooth concrete bed, at least 100 mm thick. The plate shall be in full contact with the concrete so that it is fully supported and locked. The cylinders shall be dropped twice on to a flat surface from a height of 1.2 m, in each of the five different orientations as illustrated in Fig. 2.

On completion of all 10 drops, cylinder shall be inspected for any cracks/leaks,

One cylinder shall be subjected to a burst test and the other be subjected to ambient pressure cycle test.

9.12.2 *Criteria*

The valve shall remain fully protected after the test is performed. Outer protection casing shall not crack/fallout/ open up from joints. The cylinder shall not leak. The cylinder subject to burst test shall meet the requirements of the test. The cylinder subject to Ambient Pressure Cycle test shall meet the requirements of the test

9.12.3 Parameters to Monitor and Record

a) Visual appearance before and after the drop;
b) Record position of damage if any, after the drop;
c) Record location of leakage if any after the drop;
d) Record parameters as specified in burst test; and
e) Record parameters as specified in ambient pressure cycle test.

9.13 High Velocity Impact (Gunfire) Test

A holding fixture shall be made to hold cylinder in position.

9.13.1 *Procedure*

One cylinder shall be filled to 20 bar pressure, with air or nitrogen. The cylinder shall be positioned in such a way that the point of impact of the projectile shall be in the cylinder side wall at a nominal angle of 45° and

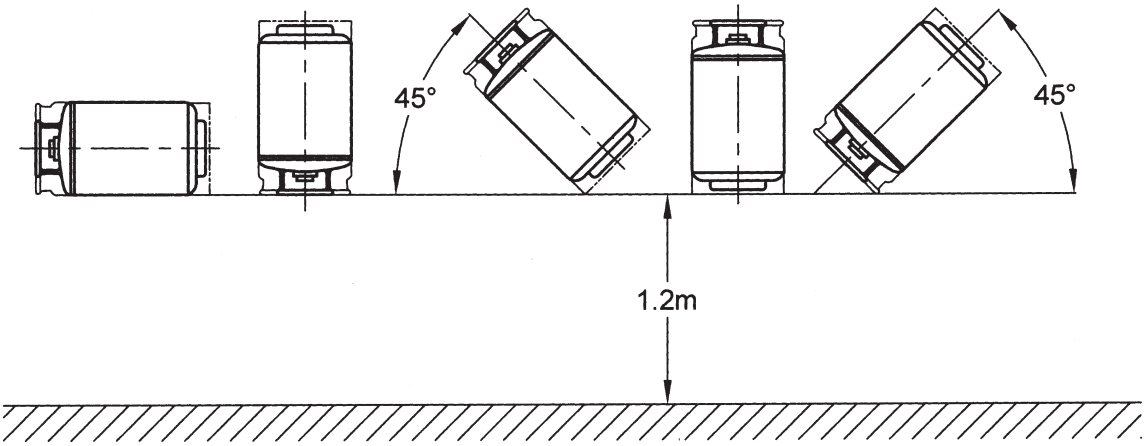


FIG. 2 DROP TEST POSITION

such that the bullet would also exit through the cylinder side wall. The bullet shall penetrate one wall of the cylinder at least. If this does not occur, the energy of the bullet shall be increased until penetration is achieved. Cylinders with diameter above 120 mm shall be impacted by a 7.62 mm (0.3 calibre) armour-piercing projectile (of length between 37 mm and 51 mm) with a nominal speed of about 850 m/s. Cylinders with diameter of 120 mm and below shall be impacted by a 5.6 mm armour piercing (or similar) bullet with a nominal speed of 850 m/s. The bullet shall be fired from a distance of not more than 45 m. The dimensions of the entrance and exit openings shall be measured and recorded. After the test the cylinder shall be rendered unserviceable.

9.13.2 *Criteria*

The cylinder shall remain in one piece and shall reveal no evidence of a fragmentation failure

9.13.3 *Parameter to Monitor and Record*

a) Type of projectile;
b) Initial pressure in cylinder;
c) Description of bullet;
d) Description of failure; and
e) Approximate size of the entrance and exit openings.

9.14 Fire Resistance Test

9.14.1 *Procedure*

Cylinders shall be fitted with the valve intended for use. The cylinder shall be charged with LPG to its design capacity. A suitable fire shall be created with either wood, gas or hydrocarbon fuel.

The cylinder shall be fire-resistant tested one each in the vertical and horizontal position as follows:

Surface temperatures shall be monitored by thermocouples located along the bottom of the cylinder and spaced not more than 0.75 m apart and shielded from direct flame impingement with metallic shielding of a minimum 0.4 mm thickness. Thermocouple temperatures and the cylinder pressure shall be recorded at intervals of every 30 s or less during the test.

A uniform fire source of 1.65 m length shall be used that is capable of enveloping the entire diameter of the cylinder, when in the horizontal position, and producing a temperature greater or equal to 590 °C, measured within 2 min on the bottom surface of the cylinder.

The timing of the fire test shall start when the thermocouple temperature reaches 590°C and atleast one thermocouple must register a temperature greater or equal to 590°C for the remainder of the test.

Any fuel may be used for the fire source provided it supplies uniform heat sufficient to maintain the specified test temperatures until the cylinder is vented. The selection of a fuel should take into consideration pollution concerns.

The cylinders shall be tested in both the vertical or horizontal position as follows:

Vertical — One cylinder shall be placed in an 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 0.1 m from the surface of the liquid in a fuel-based fire. The relief device shall be shielded from direct flame impingement.

Horizontal — One cylinder shall be placed in a horizontal position with the centre of the fire at the mid-point of the cylinder and 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 0.1 m from the surface of the liquid in a fuel-based fire. The relief device shall be shielded from direct flame impingement.

9.14.2 *Criteria*

a) For cylinders intended to be fitted with a specified pressure-relief devices the cylinders shall vent through the pressure-relief devices. (This test shall be repeated if another design of pressure-relief device is specified and used). A leak through the cylinder wall is acceptable.
b) The cylinder shall not burst during a period of 2 min from the start of the fire test. Cylinders may leak through the cylinder wall or other surfaces.

9.15 Permeability Test

9.15.1 *Procedure*

The test cylinder shall be weighed empty, before and after the test and the difference noted to avoid errors due to moisture pick up. The cylinder shall be pre pressurized to 20 bar with air or nitrogen and the valve and the junction of the non- metallic liner with the metallic bosses or rings shall be visually checked for leaks, example with soapy water (bubble test or by dipping in water tub). Any leaks shall be eliminated before proceeding with the test. The cylinder shall be depressurized.

The cylinder shall be hydraulically cycled 1 000 times from zero to 20 bar, before being emptied and thoroughly dried and valve shall be refitted and the empty weight recorded. The cylinder shall then be filled with liquefied petroleum gas (LPG) to the maximum capacity of gas as defined in design specifications. The cylinder shall then be weighed again and the weight of the gas stored shall be recorded. The cylinder shall be stored in covered area away from sunlight at ambient

temperature. The cylinder shall be periodically weighed (at least) 1st day, 7th day, 14th day, 21st day and 28th day.

9.15.2 *Criteria*

The maximum rate of weight loss shall not exceed 1 mg/h/litre of water capacity.

9.15.3 *Parameters to Monitor and Record*

The following shall be monitored and recorded:

a) Test gas used;
b) Cycle test medium;
c) Number of cycles achieving upper cyclic pressure;
d) Cycle frequency;
e) Environmental temperature and humidity twice a day;
f) Cylinder weights; and
g) Rate of weight loss.

9.16 Torque Test

9.16.1 *Procedure*

The body of the cylinder shall be held in such a manner as to prevent it rotating except where the manufacturer specifies that the cylinder is to be held by the neck for valve insertion. In this case the manufacturer's directions shall be used.

The minimum design torque for valve tightening shall be 175 Nm.

The cylinder shall be fitted with a corresponding valve and tightened to 150 percent of the maximum torque recommended in design parameters by the manufacturer of the cylinders or as recommended by the manufacturer of valves or as per the relevant material of Boss.

The valve shall be removed after the first installation and the neck thread and Boss inspected using gauges corresponding to the agreed neck threads to ensure that it is within tolerance.

The valve shall then be reinstalled as specified above.

A test for leaks (Bubble test) in the cylinder neck area shall be conducted as follows:

a) Pressurize the cylinder to 20 bar of pressure with air or nitrogen;
b) Maintain pressure in the cylinder at 20 bar for at least 2 h; and
c) Conduct a bubble leak test for at least 10 min.

9.16.2 *Criteria*

The neck thread and Boss shall show no significant deformation and shall remain within drawing and gauge tolerance. Leakage greater than 1 bubble/2 min in the bubble leak test shall constitute a failure of the test.

9.16.3 *Parameter to Monitor and Record*

The following shall be monitored and recorded:

a) Type of valve.
b) Valving procedure,
c) Applied torque,
d) Condition of threads after torque, and
e) Results of bubble test.

9.17 Leak Test

9.17.1 *Procedure*

a) Leak testing shall be conducted on the completed cylinder;
b) The cylinder shall be pressurized to 20 bar using dry air or nitrogen or gas; and
c) The test can be conducted by bubble test or measurement of trace gases using a mass spectrometer.

9.17.2 *Criteria*

No leakage shall be there. Leakage greater than 1 bubble/2 min shall be constituted as failure.

9.18 Pneumatic Cycle Test

9.18.1 *Procedure*

Prior to conducting this test cylinder shall be preconditioned by passing the test requirements of leak test (*see* **9.17**), hydraulic proof test (*see* **9.4**) and ambient pressure cycle test (*see* **9.7**) except for the number of cycles is reduced to half.

Cylinder shall be pressurized to 20 bar with air or nitrogen. The cylinder pressure shall be held at 20 bar for 72 h. The cylinder shall then be subjected to 1 000 pneumatic pressure cycles (not more than 5 cycles per minute) between 10 percent of working pressure and the working pressure (20 bar). Unless otherwise specified by the manufacturer, care shall be taken to ensure that temperatures during filling and venting do not exceed the defined service conditions.

After cycling, the cylinder pressure shall be held at 20 bar for 72 h. The pressure shall be released by venting through the valve.

The liner and liner/end boss interface (if accessible), shall be visually inspected on the internal surfaces for evidence of any deterioration, such as blistering or liner collapse, fatigue cracking or electrostatic discharge.

After visual inspection, the cylinder shall be subjected to the ambient cycle test as per **9.7**, except the number of cycles be reduced to half.

9.18.2 *Criteria*

The cylinder shall have successfully passed the leak test and it must not display excessive deterioration (such

as fatigue cracking, blistering or electrostatic discharge) that would prevent it from completing its intended service life.

A cylinder that demonstrates three successive pneumatic hold and cycle tests as provided above and meeting the requirements of the leak test and the ambient temperature pressure cycle test (except for the number of cycles is reduced by half) shall be deemed to have met the requirements of pneumatic cycle test.

9.18.3 *Parameter to Monitor and Record*

a) Temperature of cylinder;
b) Number of cycles achieving upper cyclic pressure;
c) Minimum and maximum cyclic pressure;
d) Cycle frequency;
e) Test medium used;
f) Visual appearance of the liner after the pneumatic hold and cycle;
g) Parameters as specified in ambient cycle test; and
h) Mode of failure if appropriate.

9.19 Leakage Test with Service Valve

This test is to ensure there is no leakage after fixing service valve, through threads of metal boss or valve.

9.19.1 *Procedure*

After fixing the valve to required torque, the cylinder shall be pressurized to 12 bar using dry air or nitrogen or gas. The test can be conducted by bubble test or measurement of trace gases using a mass spectrometer.

9.19.2 *Test Criteria*

No leakage shall be there. Leakage greater than 1 bubble/2 min shall be constituted as failure. Duration of test shall be 6 min.

9.19.3 *Parameter to monitor and record*

a) Cylinder Serial No.;
b) Filled pressure; and
c) Number of bubbles coming in 2 min.

9.20 Spike Test

9.20.1 *Procedure*

The cylinder shall be filled with water to its 50 percent water capacity and be pressurized to a pressure of 20 bar.

It shall be impacted on a steel spike, 10 mm diameter having a sharp point as per Fig. 3 from a height of 3 m in a horizontal position to ensure that pin completely punctures the cylinder wall. The point of impact shall be in the cylindrical part of the cylinder.

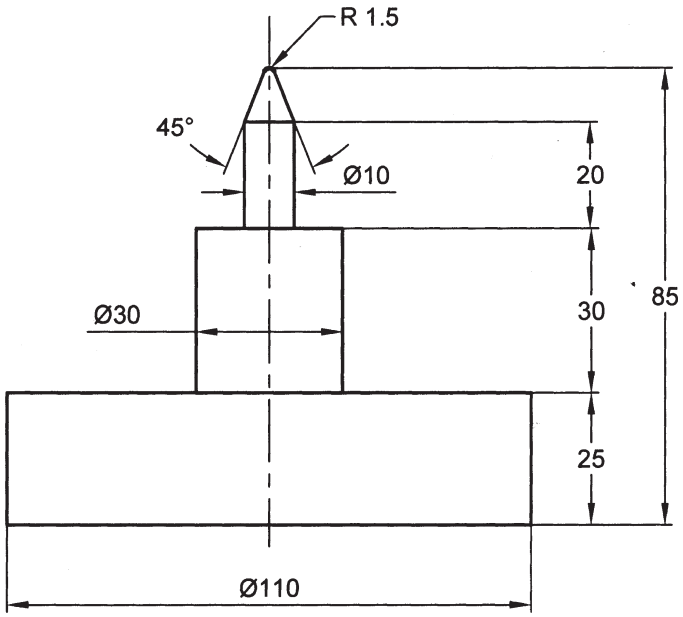
9.20.2 *Criteria*

The tested cylinder shall reveal no evidence of a fragmentation failure.

9.20.3 *Parameters to Monitor and Record*

The following shall be monitored and recorded:

a) Description of the spike;
b) Test pressure;



All dimensions are in millimetres.

FIG. 3 ILLUSTRATION OF SPIKE PROFILE

c) Description of failure; and
d) Approximate size and location of the puncture opening.

9.21 Lifting Test

9.21.1 *Procedure*

The cylinder shall be filled with water to its 100 percent water capacity and be raised by minimum 300 mm above from ground using single hook on valve protection ring for a period of 3 h. The test shall be repeated by placing hook on diametrically opposite position.

9.21.2 *Criteria*

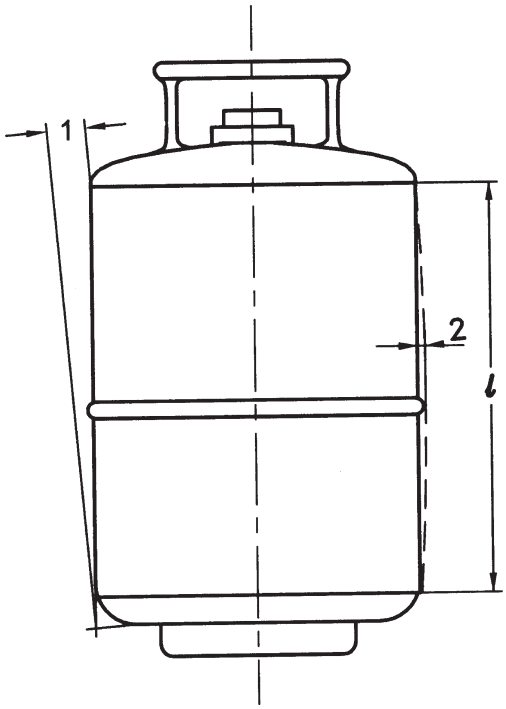
After the test, the protective casing of the cylinder shall retain its mechanical intergrity without any deformation.

9.22 Straightness

The maximum deviation of the finished cylinder from a straight line shall not exceed 0.3 percent of length subject to a minimum of 3 mm across the parallel length (*see* detail 2 in Fig. 4).

9.23 Verticality

Deviation from vertical shall not exceed 10 mm/m of the cylinder length (*see* detail 1 in Fig. 4).



1 = Measure of vertically of composite cylinder
2 = Measure of straightness of composite cylinder

FIG. 4 ILLUSTRATION OF DEVIATION OF CYLINDRICAL PART OF SHELL FROM A STRAIGHT LINE AND FROM VERTICAL

10 BATCH INSPECTION AND TESTING REQUIREMENTS

Production batch testing shall be conducted on finished cylinders representing normal production lot. The batch shall be considered as specified in **3.4**. These tests are to ensure the compliance of the production lot with the design specifications.

10.1 Liner Batch Test and Inspection

10.1.1 *Liner Material*

For each batch of liner material (*see* **3.3**), liner material test is to be conducted as per **9.1**. The materials used for manufacture of composite cylinders shall be of uniform and consistent quality. The composite cylinder manufacturer shall verify that each batch of material 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.

The manufacturer shall collect sufficient documentation from the suppliers of raw materials to be able to identify fully the batch of materials used in the manufacture of cylinders and to ensure that their properties meet the design requirements.

10.1.2 *Liner*

Following inspection and tests shall be carried out on every batch of liners from a given batch of liners as specified in Table 2 below:

a) One liner shall be tested to confirm that the declared material has been used and to verify that the required mechanical minimum properties have been achieved and meet the minimum design requirements. On every test liner two tensile specimens shall be tested. The tensile strength and the elongation shall be tested in accordance with this standard.
b) Acceptance of liners shall be made taking into account the following verifications:
   1) The process parameters during liner manufacturing shall be within the tolerances agreed during type approval;
   2) The material properties of the liner shall be within the tolerances required by the design requirements.

Table 2 Testing of Liners
(*Clause* 10.1.2)

Sl. No.	Test/Inspection	No./Extent of Test Per Batch
i)	Material Test	1
ii)	Thickness Test	1
iii)	Visual Inspection	5 Percent
iv)	Dimensional Check	5 Percent
v)	Weight	5 Percent

The Inspector shall verify the material properties of the liner are within the tolerance required by design specifications as declared by the manufacturer.

10.1.3 If any of the test results is not satisfactory, and if the inspector is satisfied that this was due to an error in performing the test, a re-test shall be authorized using the same liner or if that is not possible, then the test in question shall be repeated on a liner or test ring from the same batch, and if the results are satisfactory the batch shall be accepted.

10.2 Composite Material Batch Test and Inspection

One sample per lot of fibres shall be tested to verify tensile strength and shear strength.

The inspector shall verify the specifications of material (resin, hardener, accelerator and glass fibre) used for the production lot and submitted, are matching with the design specifications as declared by the manufacturer.

10.3 Testing and Inspection of Cylinder

10.3.1 Non-Destructive *Tests*

The inspection shall be carried out on a batch of finished cylinders with liners as follows:

a) Visual inspection of internal and external surface finish — 100 percent,
b) Dimensional check — 10 percent per batch,
c) Weight check — 10 percent per batch,
d) Water capacity check — 2 percent per batch. The water capacity check shall be done by weighing method. The tolerance for water capacity shall be +5/-0 percent for cylinders up to and including 13 litre water capacity and +3/-0 percent or 0.65 litre whichever is more for cylinder above 13 litre water capacity,
e) Torque of valve — 10 percent per batch,
f) Compliance of marking — 100 percent per batch,
g) Hydraulic Proof Test (**9.4**) — on 100 percent cylinder,
h) Leakage Test — on 100 percent cylinders,
j) Leakage test with Service Valve — on 100percent cylinders, and
k) Cleanliness — on 100 percent cylinder — Internal and external surfaces shall be free from defects and residues from the manufacturing process which would adversely affect the safe working of the cylinder.

NOTE — For (b), (c), (d) and (e) if one unacceptable cylinder is found then 100 percent of the cylinders in the batch shall be inspected.

10.3.2 *Destructive Tests*

The following tests shall be carried out on a batch of finished cylinders:

a) Hydraulic Burst test on one cylinder per batch, and
b) Pressure Cycle test on minimum one cylinder per batch.

NOTES

1) At discretion of the Inspector, the cylinder subjected to pressure cycle test may be used for hydraulic burst test.

2) All the cylinders after testing (used for test a & b) shall be destroyed, so that they are not mixed with production lot and pressurized.

10.4 Batch Acceptance Certificate

If the results of the checks and tests are satisfactory, test certificate for the batch of production shall be issued.

NOTE — A sample of production batch testing certificate is given in Annex B

10.5 Cylinder Failure During Type Approval or Batch Testing

In case results are not satisfactory, proceed as described in **11**.

11 FAILURE TO MEET TEST REQUIREMENTS

11.1 Failure of Liners

If the test results on the liners are not satisfactory, and if the Inspector is satisfied that this was due to an error carrying out the test, a re-test maybe authorized using the same liner or another from the same batch.

The test in question shall be repeated on 2 specimens, one from the same liner as for the first test and one from a new liner from the same batch and if both results are satisfactory the batch maybe accepted or the batch maybe retreated and re-tested according to **9.1** and if results are satisfactory the batch maybe accepted.

11.2 Failure of Complete Cylinder

11.2.1 In the event of failure to meet test requirements either during a production batch test or design qualification tests (Type approval tests) do not give satisfactory results, an investigation into the cause of failure and re-testing shall be carried out as follows:

11.2.2 If there is evidence of a fault in carrying out a test or an error of measurement, a second test shall be performed on the same cylinder, if possible. If this is not possible, then a second test shall be performed on a cylinder selected at random from the batch. If the results of this test are satisfactory, the first test shall be ignored.

11.2.3 If the test has been carried out in a satisfactory manner either:

a) the cause of failure shall be identified and the procedure detailed in **11.2.4** or **11.2.5** shall be followed; or
b) the batch shall be rejected and made unserviceable.

11.2.4 If the cause of failure is identified, the defective cylinders may be reclaimed (only for failure in test (a), (i) and (j) of **10.3.1** by an approved method or shall be rejected. All cylinders of the batch (of failed cylinder) shall be subjected to the test in which failure has been observed. If more than one cylinder fail in one or more tests, then entire batch shall be tested for all tests. The batch can be accepted if all cylinders pass in all tests.

11.2.5 If a batch fails the second series of tests as mentioned in **11.2.4**, the batch of cylinders shall be rendered unserviceable. The manufacturer shall ensure that the cylinders do not enter service.

12 MARKINGS

Each finished composite cylinder which satisfies the requirement of this standard, shall be permanently and legibly marked in accordance with requirements of Gas Cylinder Rules and the Statutory Authority.

12.1 The markings can be made on the metal boss and handle(s) of the outer protective casing. The markings can be Laser Marked or embossed or other markings of permanent type as approved by the Statutory Authority. The size of the letters shall not be less than 5 mm high and shall be clearly visible.

12.2 Each cylinder complying with this standard shall have following marking:

a) Name of manufacturer;
b) Owner of the cylinder;
c) Unique serial number of the cylinder;
d) Month and year of manufacture of cylinder;
e) Applicable standard;
f) Capacity of the cylinder;
g) Cylinder type and statutory authorities approval number;
h) Working pressure;
j) Test pressure;
k) The word “LPG”;
m) Due date of re-testing;
n) Date of last hydrostatic test;
p) Tare weight of cylinder;
q) Net weight of gas;
r) Maximum permissible torque for valve tightening;
s) Type of screw thread;
t) Maximum operating temperature; and
u) Service life of the cylinders in years.

In case cylinder is not designed for vacuum the following word shall be marked clearly and legibly “Warning this cylinder must not be subjected to vacuum”.

12.2.1 Minimum markings on the metal boss of the cylinder shall be as under:

a) Name of manufacturer,
b) Owner of the cylinder,
c) Unique serial number and batch of the cylinder,
d) Month and year of manufacture of cylinder,
e) Inspector’s marking,
f) Net weight of gas to be filled,
g) The word “LPG”, and
h) Maximum working pressure.

13 BIS CERTIFICATION MARKING

13.1 Each cylinder may also be marked with the Standard Mark.

13.2 The use of the Standard Mark is governed by the provisions of the *Bureau of Indian Standards Act*, 1986 and the Rules and Regulations made thereunder. The details of conditions under which the license for the use of the Standard Mark may be granted to the manufacturers or producers may be obtained from the Bureau of Indian Standards.

ANNEX A

(*Clause* 3.8 *and* 3.9)

TEST REPORT FOR EQUIVALENCY

Verification Bodies Report On:

The Testing of Liner Materials and/or Composite Materials to Prove Equivalency with Approved Materials from a Previous Type Approval

Inspection Body _____

The inspector's mark _____

Certificate No. _____

Place _____ Date _____

Cylinders manufactured by _____

Manufacturer's mark _____

Manufactured for _____

Consigned to _____

LINER MATERIALS

Documentation for the liner and metal boss(es) shall include (but not be limited to)

- Equivalent liners are manufactured from the same nominal raw materials, using the same process of manufacture and having the same physical structure and the same nominal physical properties as in an approved cylinder design.
- The equivalent liner material shall be subjected to the material tests and the liner burst test and shall meet the minimum requirements and the criteria.

DESIGN CRITERIA	APPROVED DESIGN	EQUIVALENT DESIGN
Liner material including limits of chemical analysis		
Process of manufacture		
Physical structure and nominal physical properties		
Material tests in **9.1** or **9.2**		
Liner burst test in **9.3**		

COMPOSITE MATREIAL

Documentation for composite overwrap shall include (but not be limited to)

DESIGN CRITERIA	APPROVED DESIGN	EQUIVALENT DESIGN
Fibre material, raw materials, process of manufacture physical structure		
Average tensile strength and modulus		

WE HEREBY CERTIFY that each of the above liner materials and/or fibre materials are equivalent to liner materials and/or fibre material in a previously approved cylinder design according to the requirements of this standard.

For and on behalf of the manufacturer _____

For and on behalf of the Inspection Body _____

Specimen test reports (continued)

1. Mechanical tests on liners					
Batch no.	Code	Test piece dimensions (mm)	0.2 percent yield strength (MPa)	Tensile strength (MPa)	Elongation (Percentage)

Certified by _____ on behalf of _____ Date _____
(for manufacturer)

Certified by _____ Date _____
(Inspection Body)

ANNEX B

(*Clause* 10.4)

SPECIMEN TEST REPORTS

Verification Bodies Report On:

The Manufacture Of Composite Gas Cylinders With Non-Load Sharing Non-Metallic Liners
Inspection Body _____
The inspector's mark _____
Certificate No. _____
Place _____ Date_____

Cylinders manufactured by _____
Manufacturer's mark _____
Manufactured for _____
Consigned to _____
Quantity _____ Overall size (mm) _____ Outside diameter by _____
Serial numbers _____ to _____ inclusive

Standard

Drawing No. _____
Date of hydraulic pressure test _____
Test pressure (bar) _____
Water capacity (l) _____
Gas _____
Filling ratio (liquefied) (bar) _____
Mass of container (kg) Minimum _____ Maximum _____ without valve
Minimum _____ Maximum _____ with valve

Each cylinder was produced by over-wrapping a seamless liner with resin-impregnated filament reinforcement.

Liner material designated as ____ was supplied by _____ and the analysis was within the required limits.

Each liner was produced by an approved process. The results of the mechanical tests have been found Satisfactory.

Overwrap was applied by wrapping under controlled tension.
Glass/ Carbon /Aramid

designated_____
supplied by _____

impregnated with resin designated _____
manufactured by _____

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

Filaments strand strength and reinforcement were verified and found satisfactory.

Calculated stress levels on the reinforcement filaments satisfy design requirements.

Each cylinder was subjected to a hydraulic proof pressure test at the test pressure stated above.

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

Each cylinder has been marked as required by this standard.

WE HEREBY CERTIFY that each of the above cylinders meets, in full, the requirements of this standard.

For and on behalf of the manufacturer _____

For and on behalf of the Inspection Body _____

1. Mechanical Tests on Liners					
Batch no.	Code	Test piece dimensions (mm)	0.2 % yield strength (MPa)	Tensile strength (MPa)	Elongation (%)

Certified by _____ on behalf of _____ Date _____
(for manufacturer)

Certified by _____ Date _____
(Inspection Body)

ANNEX C

(*Foreword*)

COMMITTEE COMPOSITION

Gas Cylinders Sectional Committee, MED 16

Organization	*Representative(s)*
Petroleum and Explosive Safety Organization, Nagpur	Shri N. T. Shahu (***Chairman***) Shri Ashendra Singh (*Alternate*)
All India Industrial Gases Manufacturers Association, New Delhi	Shri Anish Patel Shri K. R. Sahasranam (*Alternate*)
Ashok Leyland Limited, Chennai	Shri M. Ravi Shri Ved Prakash Gautam (*Alternate*)
Bharat Petroleum Corporation Ltd, Mumbai	Shri Sumit Roy Shri A. Prabhakar (*Alternate*)
Bhiwadi Cylinders Pvt Ltd, New Delhi	Shri Manvinder Singh Shri Rajneesh Chopra (*Alternate*)
Everest Kanto Cylinder Ltd, Mumbai	Shri P. M. Samvatsar Shri A. K. Khamkar (*Alternate* 1) Shri H. D. Khatri (*Alternate* 2)
GSPC Gas Co Ltd, Ahmedabad	Shri K. S. R. Prasad
Hindustan Petroleum Corporation Ltd, Mumbai	Shri P. N. Kanth Shri Debashish Chakraverty (*Alternate*)
Indian Oil Corporation Ltd, Mumbai	Shri Ashutosh Tiwari Shri S. M. Rambhal (*Alternate*)
Indraprastha Gas Limited, Delhi	Shri Praveen K. Pandey Shri Alok Sharma (*Alternate*)
INOX India Ltd, Vadodara	Shri Deepak V. Patwardhan Shri Nikhile K. Garg (*Alternate*)
International Industrial Gases Ltd, Kolkata	Shri Devendra K. Garg Shri Deepak V. Acharya (*Alternate*)
Kabsons Gas Equipments Ltd, Hyderabad	Shri Satish Kabra Shri S. Gopalaiah (*Alternate*)
Kosan Industries Ltd, Mumbai/Surat	Shri Sunil K. Dey Shri S. B. Bolmal (*Alternate*)
LINDE India Ltd, Kolkata	Shri Ramana Vutukuru Shri Pradeep (*Alternate*)
LPG Equipment Research Centre, Bangalore	Shri K.K. Thakur Shri A.K. Bera (*Alternate*)
Mahanagar Gas Limited, Mumbai	Shri S. Murali Shri Arun Nayak (*Alternate*)
Ministry of Defence (DGQA), Pune	Shri J. P. Tiwari Shri K. Sudhakaran (*Alternate*)
Research & Development Estt (Engineers), Pune	Shri P. K. Chattopadhyay Shri A. Basu (*Alternate*)
Sakha Engineers Pvt Ltd, New Delhi	Shri Amarjit S. Kohli
SICGIL India Ltd, Chennai	Shri Farooque Dadabhoy Shri R. Padmanaban (*Alternate*)
Society of Indian Automobile Manufacturers (SIAM), New Delhi	Shri K. K. Gandhi Shri Amit Kumar (*Alternate*)
Steel Authority of India Ltd, RDCIS, Ranchi	Shri Debashis Karmakar Dr Anjana Deva (*Alternate*)
Supreme Cylinders Ltd, Delhi	Shri M. L. Fathepuria

Organization	*Representative(s)*
Tata Motors Ltd, Pune	Shri Pallipalayam Gowrishankar Shri Shaillendra Dewangan (*Alternate*)
Tekno Valves, Kolkata	Shri Y. K. Behani Shri R. Behani (*Alternate*)
The Automotive Research Association of India, Pune	Dr S. S. Thipse Shri S. D. Rairikar (*Alternate*)
Trans Valves (India) Pvt Ltd, Hyderabad	Shri A. K. Jain Shri P. K. Mathur (*Alternate*)
Vanaz Engineers Ltd, Pune	Shri S. J. Vispute Shri A.S Latke (*Alternate*)
BIS Directorate General	Shri A. Rengarajan Science 'E' and Head (MED) [Representing Director General (*Ex-Officio*)]

Member Secretary
Shri Chandan Gupta
Scientist 'C' (MED), BIS

Low Pressure Gas Cylinders Subcommittee, MED 16:2

Hindustan Petroleum Corporation Ltd, Mumbai	Shri P. N. Kanth (***Convener***) Shri Debashish Chakraverty (*Alternate*)
All India Industrial Gases Manufacturer Association, Delhi	Shri Anish Patel Shri K. R. Sahasranam (*Alternate*)
Bharat Petroleum Corporation Ltd, Mumbai	Shri. Sumit Roy Shri A. Prabhakar (*Alternate*)
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