IS 15660 (2006): Refillable transportable seamless aluminium alloy gas cylinders [MED 16: Gas Cylinders]

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भारतीय मानक

भरण्य योग्य परिवहनी योग्य जोड़ रहित ऐल्युमिनियम मिश्र धातु के गैस सिलिंडर — विशिष्टि

Indian Standard

REFILLABLE TRANSPORTABLE SEAMLESS ALUMINIUM ALLOY GAS CYLINDERS — SPECIFICATION

ICS 23.020.30

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

June 2006

Price Group 14

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.

This standard is for refillable transportable seamless aluminium alloy gas cylinders for transportation and storage of compressed, permanent and liquefiable gases.

The purpose of this standard is to provide a specification for the design, manufacture, inspection, testing of cylinders in common use and approval of refillable transportable seamless aluminium alloy gas cylinders.

Considerable assistance has been taken from the following:

EN 1975 : 1999 'Transportable gas cylinders — Specification for the design and construction of refillable transportable seamless aluminium and aluminium alloy gas cylinders'

ISO 7539-6 : 1995 'Corrosion of metals and alloys — Stress corrosion testing — Part 6 : Preparation and use of pre-cracked specimens'

ISO 11114-1 : 1997 'Transportable gas cylinders — Compatibility of cylinder and valve materials with gas contents — Part 1 : Metallic materials'

ISO 13769 : 2002 'Gas cylinders — Stamp marking'

While implementing this standard, the manufacturer and the inspection agency shall ensure compliance with statutory regulations.

Owners and users of cylinders should note that cylinders designed to this standard are to operate safely, if used in accordance with specified service conditions. It is the responsibility of the owners and users to ensure that 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.

Gases not to be contained in aluminium alloy cylinders are given in Annex H.

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

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.

AMENDMENT NO. 2 JULY 2010
TO
IS 15660 : 2006 REFILLABLE TRANSPORTABLE SEAMLESS ALUMINIUM ALLOY GAS CYLINDERS — SPECIFICATION

(*Page* 8, *clause* **7.4**, *last para*) — Delete.

(ME 16)

Reprography Unit, BIS, New Delhi, India

AMENDMENT NO. 1 APRIL 2009
TO
IS 15660 : 2006 REFILLABLE TRANSPORTABLE SEAMLESS ALUMINIUM ALLOY GAS CYLINDERS — SPECIFICATION

(*Page* 1, *clause* **3.1**, *second line*) — Substitute ‘manufacturer’ *for* ‘designer’.

[*Page* 3, *Fig.* 1(c)] — Substitute the following for the existing:

[*Page* 3, *Fig.* 1(g)] — Substitute the following for the existing:

(*Page* 7, *clause* **6.4.1.1**) — Substitute the following for the existing:

‘**6.4.1.1** All parallel threads must have at least 6 engaged threads, tight fit, and a factor of safety in shear of at least 10 at the test pressure of the cylinder. The threads must extend completely through the neck.

All straight threads shall meet shear strength and factor of safety requirements as calculated using the following equation:

$$A_{sn} = \pi \times n \times L_e \times (D_s)_{Min} \ \{[1/(2n) + 0.577\,35\,[(D_s)_{Min} - (E_n)_{Max}]\} \quad .....(1)$$

where

π = 3.141 6;

n = number of threads per mm;

$(D_s)_{Min}$ = minimum major diameter of external thread, in mm;

$(E_n)_{Max}$ = maximum pitch diameter of internal thread, in mm;

L_e = length of thread engagement, in mm; and

A_{sn} = shear area of the internal thread, in mm^2.

Thread force exerted on the contain valve.

$$T_f = P_h (\pi \times D_b^2)/4 \quad .....(2)$$

where

π = 3.141 6;

P_h = test pressure, in MPa;

D_b = basic pitch diameter of external threads, in mm; and

T_f = thrust force, in N.

Average shear on internal threads:

$$S_s = \frac{T_f}{A_{sn}} \quad .....(3)$$

where

S_s = average shear stress on internal threads, in MPa;

T_f = thrust force, in N; and

A_{sn} = shear area of the internal thread, in mm^2.

$$\text{Factor of safety (FoS)} = \frac{\text{Ultimate shear strength of opening (UTSO)}}{S_s} \geq 10 \quad ..... (4)$$

Shear stress and factor of safety can be calculated as per examples shown in Annex D.'

(*Page* 7, *clause* **6.7**) — Substitute the following for the existing clause:

'**6.7** A fully dimensioned drawing shall be supplied which includes the specification of the material, details of mechanical properties, neck thread water capacities, corresponding length and weight of cylinder, chemical composition and number of this standard.'

(*Page* 32, *Annex* D) — Substitute the following for the existing Annex:

ANNEX D
(*Clause* 6.4.1.1)

SHEAR STRESS AND FACTOR OF SAFETY CALCULATIONS

D-0 R_g = 325 MPa, ¾″ UNF, 16 TP1 Parallel Threads, P_h = 30 and 35 MPa.

Exemplary calculations are as under.

D-1 SHEAR AREA OF INTERNAL THREAD

$$A_{sn} = \pi \times n \times L_e \times (D_s)_{Min} \{1/(2n) + 0.577\,35\, [(D_s)_{Min} - (E_n)_{Max}]\}$$

		Example 1	*Example* 2	*Example* 3
n	Number of threads per mm	0.629 9	0.629 9	0.629 9
$(D_s)_{Min}$	Minimum major diameter of external threads, mm	18.773 14	18.773 14	18.773 14
$(E_n)_{Max}$	Maximum pitch diameter of external threads, mm	18.183 86	18.183 86	18.183 86
T	Minimum engaged threads	6	6	7
L_e	Length of thread engagement, mm	9.525	9.525	11.112 5
$\boldsymbol{A_{sn}}$	Shear area of the internal thread, mm^2	401.266	401.266	468.145

D-2 THE THRUST FORCE EXERTED ON CONTAINER VALVE

$T_f = P_h\,(\pi \times D_b^2)/4$

		Example 1	*Example* 2	*Example* 3
P_h	Test pressure, MPa	30	35	35
D_b	Basic pitch diameter of external threads, mm	17.980 66	17.980 66	17.980 66
$\boldsymbol{T_f}$	Thrust force, N	7621.080	8890.863	8890.863

D-3 AVERAGE SHEAR STRESS ON INTERNAL THREADS

$S_s = T_f / A_{sn}$

		Example 1	*Example* 2	*Example* 3
$\boldsymbol{S_s}$	Average stress on internal threads, in MPa	18.992 5	22.157 0	18.991 0

NOTE – From examples 2 and 3 above it is clear that to maintain minimum factor of safety at 35 MPa pressure, number of engaged threads needs to be increased from 6 to 7.

Amend No. 1 to IS 15660 : 2006

D-4 FACTOR OF SAFETY (FoS)

$$\text{FoS} = \frac{\text{UTSO}}{S_s} \geq 10$$

$\text{UTSO} = 0.65 \times R_g$

		Example 1	*Example* 2	*Example* 3
R_g	Minimum guaranteed value of tensile strength for the finished cylinder, in MPa	325	325	325
UTSO	Ultimate shear strength of opening, MPa	211.25	211.25	211.25
FoS	Factor of safety	11.120	9.534	11.123
	Is requirement of factor of safety met?	Yes	No	Yes

NOTE – From examples 2 and 3 above it is clear that to maintain minimum factor of safety at 35 MPa pressure, number of engaged threads to be 7.

Indian Standard

REFILLABLE TRANSPORTABLE SEAMLESS ALUMINIUM ALLOY GAS CYLINDERS — SPECIFICATION

1 SCOPE

This standard lays down the minimum requirements for the material, design, construction, workmanship, manufacturing processes and tests of refillable seamless aluminium alloy gas cylinders of water capacities from 0.5 litre up to and including 150 litre for transportable compressed, liquefied gases except liquefied petroleum gases (LPG).

2 REFERENCES

The standards listed below contain provision, 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.	*Title*
1608 : 2005 ISO 6892 : 1998	Metallic materials — Tensile testing at ambient temperature (*third revision*)
3224 : 2002	Valve fittings for compressed gas cylinders excluding liquefied petroleum gas (LPG) cylinders — Specification (*third revision*)
4379 : 1981	Identification of the contents of industrial gas cylinders
5844 : 1970	Recommendations for hydrostatic stretch testing of compressed gas cylinders
7241 : 1981	Glossary of terms used in gas cylinder technology (*first revision*)
7285 (Part 2) : 2004	Refillable seamless steel gas cylinders — Specification: Part 2 Quenched and tempered steel cylinders with tensile strength less than 1 100 MPa (112 kgf/mm^2) (*third revision*)

3 TERMINOLOGY

For the purpose of this standard, the following definitions and those given in IS 7241 except for the following shall apply.

3.1 Design Minimum Burst Pressure — Calculated by the designer based on the minimum tensile strength of the material specified and the minimum wall thickness mentioned on the drawing.

3.2 Yield Stress (R_e) — Value corresponding to 0.2 percent proof stress (non-proportional elongation), $R_{po,2}$ for aluminium alloys.

3.3 Solution Heat Treatment — Thermal treatment which consists of heating the products to a suitable temperature, holding at that temperature long enough to allow constituents to enter into solid solution and cooling rapidly enough to hold the constituents in solution.

3.4 Quenching — Controlled rapid cooling in a suitable medium to retain the solute phase in solid solution.

3.5 Artificial Ageing — Heat treatment process in which the solute phase is precipitated to give an increased yield stress and tensile strength.

3.6 Stabilizing Heat Treatment — Heat treatment applied to some 5000 series aluminium alloys in order to prevent changes in mechanical properties and structure under service conditions.

3.7 Batch — Quantity of up to 200 cylinders plus cylinders for destructive testing of the same nominal diameter, thickness and design, made successively from the same cast and subjected to the same heat treatment for the same duration of time.

3.8 Mass — Mass of a cylinder, expressed in kg, comprising the combined mass of cylinder and permanently attached parts (for example, foot ring, neck ring, etc) but without valve.

3.9 Design Stress Factor (F) (Variable) — Ratio of equivalent wall stress at test pressure (P_h) to guaranteed minimum yield stress (R_e).

3.10 Working Pressure (P_w)/Service Pressure — Working pressure for permanent gas means the settled internal pressure of the gas in the cylinders at a temperature of 15°C.

3.11 Test Pressure (P_h) — Test pressure means the internal pressure required for the hydrostatic test or the hydrostatic stretch test of the cylinders.

NOTE — It is used for cylinder wall thickness calculation.

3.12 Burst Pressure (P_b) — Highest pressure reached in a cylinder during burst test.

4 SYMBOLS

- a = calculated minimum thickness, in millimetres, of the cylindrical shell;
- a' = guaranteed minimum thickness, in millimetres, of the cylindrical shell;
- A = percentage elongation, determined by the tensile test (*see* **8.1.3**);
- b = guaranteed minimum thickness, in millimetres, at the centre of a convex base (*see* Fig. 1);
- d = diameter of former, in millimetres (*see* Fig. 5);
- D = nominal outside diameter of the cylinder, in millimetres (*see* Fig. 1);
- F = design stress factor (variable) (*see* **3.9**);
- H = outside height of domed part (convex head or base end), in millimetres (*see* Fig. 1);
- n = ratio of the diameter of the bend test former to actual thickness of test piece (t);
- P_b = measured burst pressure above atmospheric pressure, in bar;
- P_{lc} = lower cyclic pressure above atmospheric pressure, in bar;
- P_y = observed yield pressure during burst test above atmospheric pressure, in bar;
- P_h = hydraulic test pressure above atmospheric pressure, in bar;
- P_w = working pressure above atmospheric pressure, in bar;
- r = inside knuckle radius, in millimetres (*see* Fig. 1);
- r_i = inside crown radius, in millimetres (*see* Fig. 1);
- R_e = minimum guaranteed value of yield stress (*see* **3.3**) for the finished cylinder, in MPa;
- R_{ea} = actual value of yield stress determined by the tensile test (*see* **8.1.3.4**), in MPa;
- R_g = minimum guaranteed value of tensile strength for the finished cylinder, in MPa;
- R_m = actual value of tensile strength determined by the tensile test (*see* **8.1.3**), in MPa;
- S_o = original cross-sectional area of tensile test piece according to IS 1608, in mm^2; and
- t = actual thickness of test specimen, in millimetres.

NOTE — 1 bar = 10^5 Pa = 0.1 MPa = 0.1 N/mm^2 (1 kgf/mm^2 = 9.80 665 MPa).

5 MATERIALS

5.1 General Provisions

5.1.1 Aluminium alloys used for the fabrication of gas cylinders are those given in Table 1 to produce gas cylinders provided that they satisfy the requirements of the corrosion resistance tests defined in Annex A, meet all other requirements of this standard including Sustained Load Cracking (SLC) resistance test as per Annex B, and are approved by the relevant Authority.

NOTE — Sustained Load Cracking (SLC) resistance test is optional in the case of cylinders made from Aluminium Alloy 6061 subject to the approval of the statutory authority.

5.1.2 The cylinder manufacturer shall identify the cylinders with the particular casts of the alloy from which they are made, and shall obtain and provide certificates of the analyses of the casts used.

5.2 Heat Treatment

5.2.1 *Heat Treatable Alloys*

The manufacturer shall specify on the prototype testing documentation the solution heat treatment and artificial ageing temperatures and the times for which the cylinders have been held at those temperatures. The medium used for quenching after solution heat treatment shall be identified.

5.2.2 *Non-heat Treatable Alloys*

The manufacturer shall specify on the prototype testing documentation the type of metal forming operation carried out (extrusion, drawing, ironing, head forming, etc).

Unless the alloy is subjected to a temperature in excess of 400°C during the forming processes, a stabilizing heat treatment shall be carried out and the manufacturer shall identify the temperature and time.

5.2.3 *Control of Specified Heat Treatment*

During the heat treatment, the manufacturer shall comply with the specified temperatures and durations, within the following tolerances:

a) *Temperatures*

Solution temperature	± 10°C
Artificial ageing temperature	± 5°C
Stabilizing temperature	± 10°C

b) *Durations*

Time cylinders actually spend at temperature during treatments:

Solution treatment	± 30 percent
Artificial ageing treatment	± 20 percent
Stabilizing treatment	± 10 percent

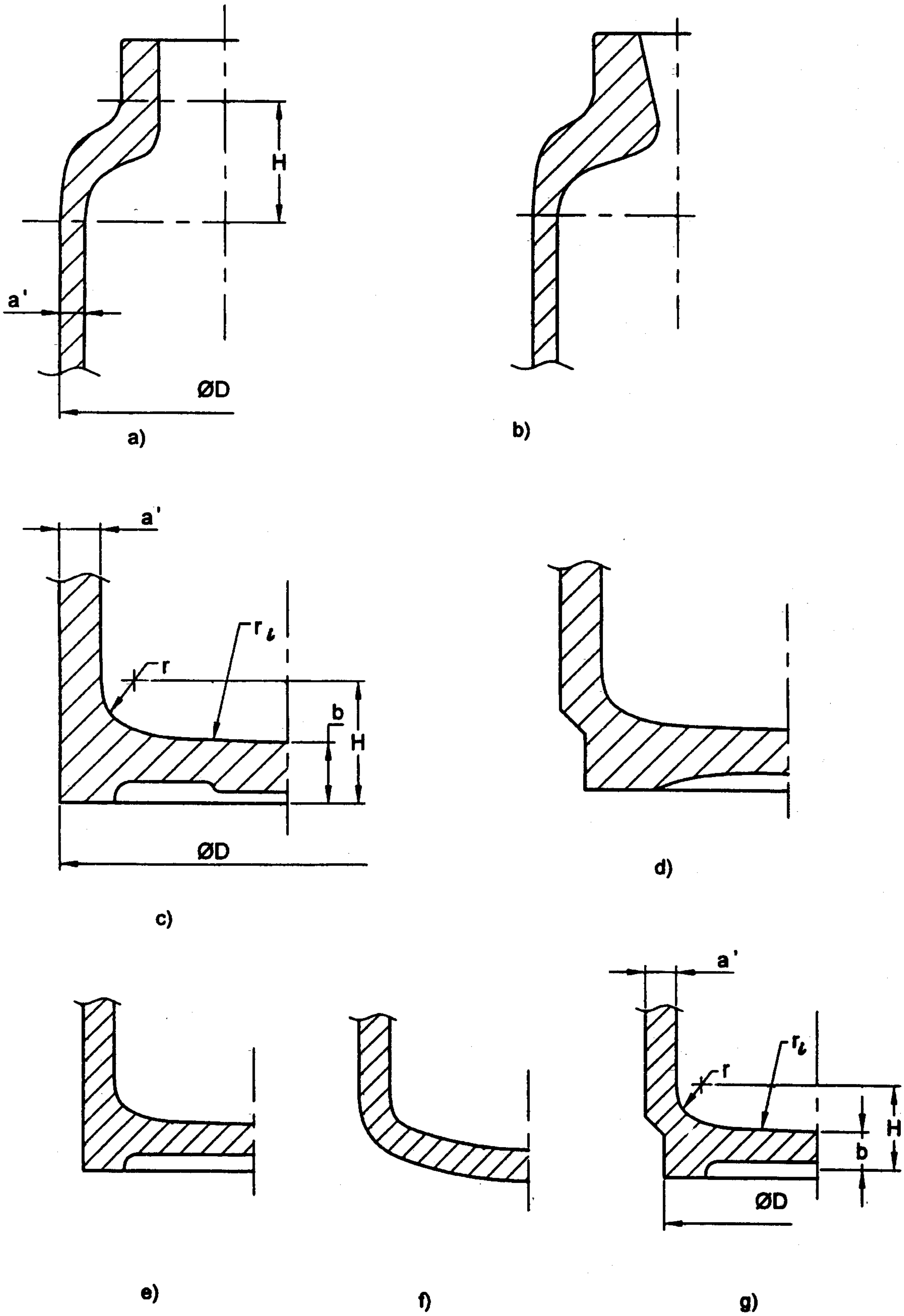


FIG. 1 EXAMPLES OF CONVEX ENDS — *Continued*

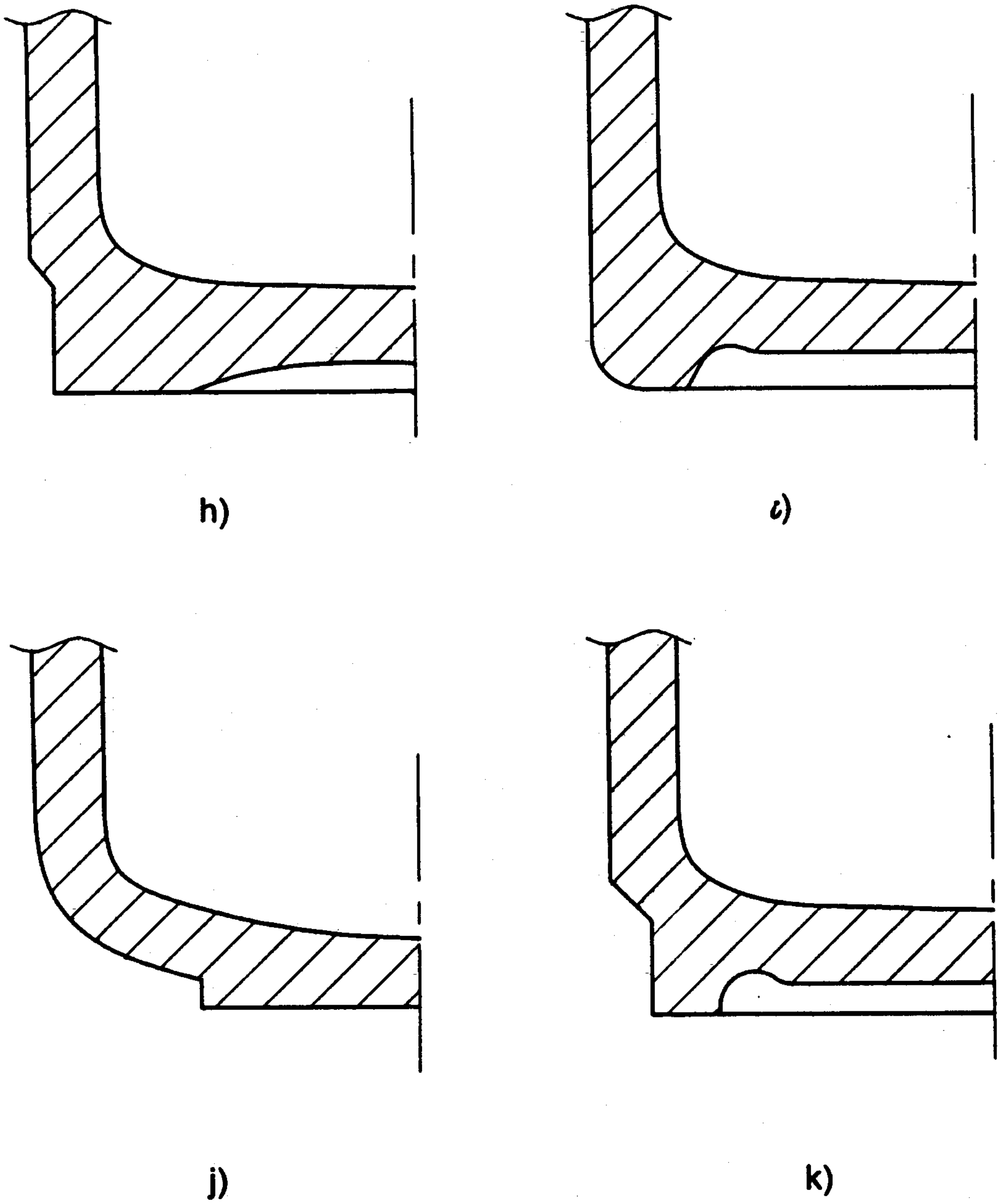


FIG. 1 EXAMPLES OF CONVEX ENDS

Table 1 Chemical Composition of Aluminium Alloys

(*Clause*, 5.1.1)

Sl No.	IS Designation[1)]	Type of Alloys AA[2)] Registered	Marking Code Reference		Chemical Composition Weight, Percent													
					Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Zr	Pb	Others		Aluminium
																Each	Total	
(1)	(2)	(3)	(4)		(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
i)	55300	5283 A	5283	*Min*	—	—	—	0.50	4.5	—	—	—	—	—	—	—	—	Remainder
				Max	0.30	0.30	0.30	1.0	5.1	0.05	0.03	0.10	0.03	0.05	0.0030	0.05	0.15	
ii)	65028	6061 A	6061	*Min*	0.40	—	0.15	—	0.8	0.04	—	—	—	—	—	—	—	Remainder
				Max	0.8	0.7	0.40	0.15	1.2	0.35	—	0.25	0.15	—	0.0030	0.05	0.15	
iii)	64430	6082 A	6082	*Min*	0.7	—	—	0.40	0.6	—	—	—	—	—	—	—	—	Remainder
				Max	1.3	0.50	0.10	0.1	1.2	0.25	—	0.20	0.10	—	0.0030	0.05	0.15	
iv)	63430	6351 A	6351	*Min*	0.7	—	—	0.40	0.4	—	—	—	—	—	—	—	—	Remainder
				Max	1.3	0.50	0.10	0.8	0.8	—	—	0.20	0.20	—	0.0030	0.05	0.15	
v)	77258	7060	7060	*Min*	—	—	1.8	—	1.3	0.15	—	6.1	—	—	—	—	—	Remainder
				Max	0.15	0.20	2.6	0.20	2.1	0.25	—	7.5	0.05	0.05	0.0030	0.05	0.15	

NOTE — Where a melt contains scrap or other re-used material the bismuth shall not exceed 0.003 0 percent.

1) *See* IS 6051 for guidance.

2) AA is the Aluminium Association Inc., 900 19th Street N.W. Washington DC, 20006-2168, USA.

6 DESIGN

6.1 General Provisions

6.1.1 The calculation of the wall thickness of the pressure-containing parts shall be related to the yield stress (R_e) of the material to ensure elastic behaviour.

6.1.2 For calculation purposes the value of the yield stress (R_e) is limited to a maximum of 0.90 R_g for aluminium alloys.

6.1.3 The internal pressure upon which the calculation of wall thickness is based shall be 5/3 times of the working pressure (P_w).

6.2 Calculation of Cylindrical Wall Thickness

The guaranteed minimum thickness of the cylindrical shell (a') shall not be less than the thickness calculated using the equation:

$$a = \left[\frac{D}{2} \; 1 - \sqrt{\frac{10 F R_e - \sqrt{3} P_h}{10 F R_e}} \right]$$

where the value of F is the lesser of $\frac{0.65}{(R_e / R_g)}$ or 0.77

R_e/R_g shall be limited to 0.90.

The calculated minimum thickness shall also satisfy the equation:

$$a \geq \frac{D}{100} + 1 \text{ mm}$$

With an absolute minimum of a = 1.5 mm.

When choosing the minimum guaranteed value of the thickness of the cylindrical shell (a'), the manufacturer shall take into account all requirements for prototype and production testing, particularly the burst and yield pressure test requirements of **8.2.1.3**.

For examples of wall thickness calculations, *see* Annex C.

6.3 Design of Ends (Heads and Bases)

The thickness and shape of the base and head of the cylinders shall be such as to meet the requirements of the tests laid down in **8.2** and **8.3**.

In order to achieve satisfactory stress distribution, the cylinder wall thickness shall increase progressively in the transition zone between the cylindrical shell and the ends, particularly the base. For example, typical shapes of convex heads and base ends are shown in Fig. 1. The thickness at any part of the base shall not be less than the guaranteed minimum thickness of the cylindrical part.

The inside knuckle radius (r) shall not be less than 10 percent of the inside diameter of the shell.

For convex ends, the inside crown radius (r_i) shall not be greater than 1.2 × the inside diameter of the shell.

The designed bottom thickness limit shall be +15 percent maximum.

6.4 Torque Values for Taper and Parallel Threads

6.4.1 The external diameter and thickness of the formed neck end of the cylinder shall be adequate for the torque applied in fitting the valve to the cylinder. The torque may vary according to the diameter of thread, the form, and the sealant used in fitting of the valve. The cylinder shall have threads as per IS 3224 or any other threads specification approved by statutory authority. Threads shall be full form, clean cut, even and without check, machined into

Table 2 Torque Values for Taper and Parallel Threads

(*Clauses* 6.4.1 *and* 6.4.1.1)

a) **Taper Threads**			
Taper Valve Stem Size	Torque N.m		
	Minimum	Maximum	
		Without cylinder neck reinforcement	With cylinder neck reinforcement
17E	75	95	140
25E	95	110	180

b) **Parallel Threads**		
Parallel Valve Stem Size	Torque N.m	
	Minimum	Maximum
M 18	85	100
M 25	95	130
M 30	95	130

gauge and concentric with axis of cylinder. Valving torques for aluminium alloy cylinders shall conform to Table 2.

6.4.1.1 All parallel threads must have at least 6 engaged threads, tight fit, and a factor of safety in shear of at least 10 at the test pressure of the cylinder. The threads must extend completely through the neck.

All straight threads shall meet shear strength and factor of safety requirements as calculated using the following equation:

$$A_{sn} = 3.14116 \times n \times L_e \times (D_s)_{,Min} \{1/(2n) + 0.019\,866\,[(D_s)_{,Min} - (E_n)_{,Max}]\} \quad \dots (1)$$

where

n = number of threads per inch;

$(D_s)_{,Min}$ = minimum major diameter of external thread, in mm;

$(E_n)_{,Max}$ = maximum pitch diameter of internal thread, in mm;

L_e = length of thread engagement, in mm; and

A_{sn} = shear area of the internal thread, in mm^2.

Thread force exerted on the container valve.

$$T_f = P_h (\pi \times D_b^2)/400 \quad \dots (2)$$

where

P_h = test pressure, in MPa;

D_b = basic pitch diameter of external threads, in mm; and

T_f = thrust force, in N.

Average shear on internal threads:

$$S_s = \frac{T_f}{A_{sn}} \quad \dots (3)$$

where

S_s = average shear stress on internal threads, in MPa;

T_f = thrust force, in N; and

A_{sn} = shear area of the internal thread, in mm^2.

$$\text{Factor of safety (FoS)} = \frac{\text{Ultimate shear strength of opening (UTSO)}}{S_s} \geq 10 \quad \dots (4)$$

Shear stress and factor of safety can be calculated as per examples shown in Annex D.

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

6.5 Neck Rings

When a neck ring, is provided, it shall be of material compatible with that of the cylinder, and shall be securely attached by a method other than welding, brazing or soldering.

The manufacturer shall ensure that the axial load required to remove the neck ring is greater than 10 times the weight of the empty cylinder and not less than 1 000 N, also that the minimum torque required to turn the neck ring is greater than 100 Nm.

6.5.1 The cylinder valve if fitted shall be tightened to required torque as given in Table 2 using suitable tape or by suitable sealant.

6.6 Foot Rings

As agreed between the parties, a foot ring, if provided, shall be sufficiently strong and made of material compatible with that of the cylinder. In addition, the shape should preferably be cylindrical and shall give the cylinder sufficient stability. The foot ring shall be secured to the cylinder by a method other than welding, brazing or soldering. Any gaps, which may form water traps, shall be sealed to prevent ingress of water, by a method other than welding, brazing or soldering.

6.7 Design Drawing

A fully dimensioned drawing shall be supplied which includes the specification of the material, details of mechanical properties, neck thread water capacities, chemical composition and number of this standard.

6.8 Water Capacity

The water capacity of cylinders shall have the tolerance $^{+5.0}_{0.0}$ percent nominal water capacity.

7 CONSTRUCTION AND WORKMANSHIP

7.1 General

The cylinder shall be produced by:

a) Cold or hot extrusion from cast or extruded or rolled billet;

b) Cold or hot extrusion followed by cold drawing, from cast or extruded or rolled billet;

c) Cupping, flow forming, spinning and cold drawing sheet or plate; and

d) Open necking at both ends of an extruded or cold drawn tube (*see* Fig. 2).

7.2 Welding

Welding of seamless aluminium and aluminium alloy gas cylinders is not permitted under any circumstances.

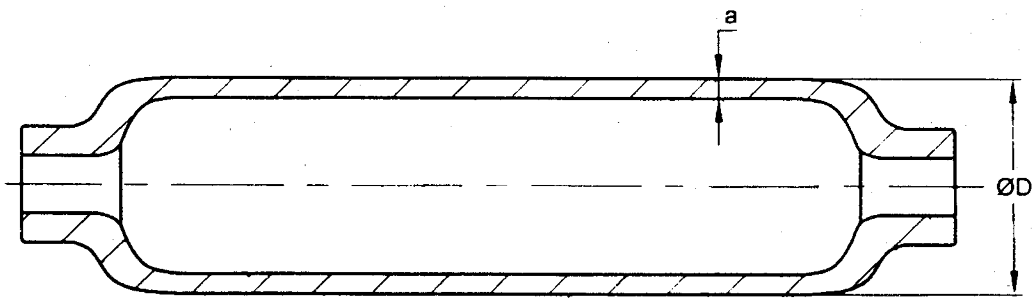


FIG. 2 NECKED ENDS FROM TUBE

7.3 Wall Thickness

Each cylinder shall be examined for thickness and for external and internal surface defects. The wall thickness at any point shall not be less than the minimum thickness specified.

7.4 End Forming

The ends shall be formed by an appropriate method, for example forging, swaging and spinning. Prior to and/or after the closing – in operation, all significant remnants of the as-cast structure of the open end of the shell shall be removed.

When heat has to be applied in order to form the cylinder neck/shoulder, uniform heat distribution shall be achieved prior to the forming operation. This heat distribution shall be achieved independent of the process employed for the manufacture of the shell.

For 6000 series alloys special precautions shall be taken to achieve a fine grain structure in the neck of the finished cylinder.

Regardless of the method used for the closing-in operation, the tools used for the head forming process shall facilitate metal flow and result in smooth surfaces of the cylinder especially in the neck/shoulder areas. There shall be no sudden contour changes or significant folds (*see* 7.7), which can act as stress raisers during the cylinder's eventual service conditions.

For free standing cylinders, the base thickness must be at least two times the minimum wall thickness along the line of contact between the cylinder base and the floor when the cylinders are in the vertical position.

7.5 Surface Defects

The internal and external surfaces of the finished cylinder shall be free from defects, which would adversely affect the safe working of the cylinder. Such defects shall be removed by local dressing. The wall thickness of any dressed area shall not be less than the minimum thickness specified.

7.6 Neck Threads

The internal neck threads shall conform to a recognized standard agreed to between the parties to permit the use of a corresponding valve thus minimizing neck stresses following the valve torquing operation. Internal neck threads shall be checked using gauges corresponding to the agreed neck thread or by an alternative method agreed between the parties.

Particular care shall be taken to ensure that neck threads are accurately cut, are of full form and free from any sharp profiles, for example, burrs.

7.7 Examination for Surface Imperfections and Neck Folds

Each cylinder shall be examined for neck folds by a suitable means (for example intro-scope, bore-scope, dental mirror, tactile, ultrasonic). Folds that are visible as a line running into the threaded portion, as shown on the left hand side of Fig. 3, shall be removed by a machining operation until the lines are no longer visible.

After the machining operation the thickness of the machined area and the thread characteristics shall be at least that required to pass all necessary testing. The whole internal shoulder area shall be re-inspected to verify that folding or its lines have been removed.

7.8 Out of Roundness

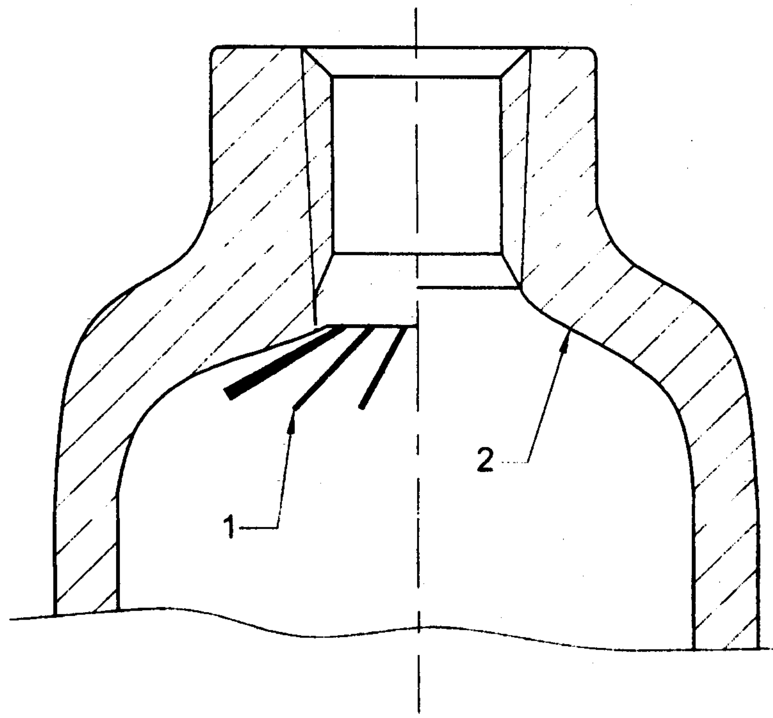
The out of roundness of the cylindrical shell, that is the difference between the maximum and minimum outside diameters at the same cross-section, shall not exceed 2 percent of the mean of these diameters.

7.9 Straightness

The maximum deviation of the cylindrical part of the shell from a straight line shall not exceed 3 mm/m length.

7.10 Stability

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



Key

1. Folds
2. Machine Away

FIG. 3 EXAMPLES OF CYLINDER NECK FOLDS BEFORE AND AFTER MACHINING

7.11 Mean Diameter

The mean external diameter shall not deviate more than ±1 percent from the nominal design diameter.

7.12 Ultrasonic Testing

After heat treatment each cylinder should be checked for internal defects flaws by ultrasonic test as per Annex B of IS 7285 (Part 2).

8 TESTS

8.1 Mechanical Test

8.1.1 *General Requirement*

All mechanical tests for checking the quality of the material used for gas cylinders shall be carried out on material taken from cylinders on which all operations affecting mechanical properties have been completed. They do not need to have been pressure tested.

8.1.2 *Types of Test and Evaluation of Test Results*

On every test cylinder there shall be carried out one tensile test in a longitudinal direction and four bend tests in a circumferential direction. For location of test pieces, *see* Fig. 4.

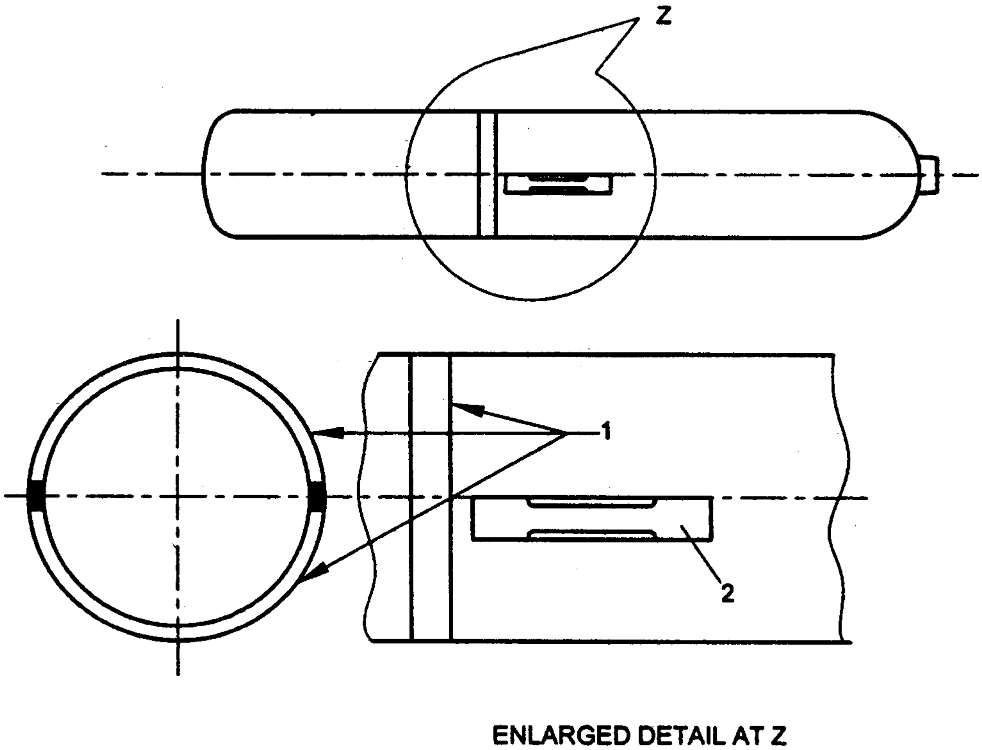
8.1.3 *Tensile Test*

8.1.3.1 The test piece on which the tensile test is carried out shall be in accordance with the provisions of IS 1608 with a gauge length of $5.65\sqrt{S_0}$ where S_0 is the areas of cross-section at gauge length. The two faces of test piece representing the inside and outside surface of the cylinder shall not be machined but shall represent the surface of the container as manufactured. The ends only may be flattened for gripping in the testing machine.

8.1.3.2 With regard to the heat treatable alloys referred to Table 1, elongation after fracture (A) shall not be less than 12 percent.

8.1.3.3 With regard to the non-heat treatable alloys referred to in Table 1, the elongation after fracture shall not be less than 12 percent, where the tensile test is carried out on a single test piece taken from the cylinder wall. The tensile test may also be carried out on four test pieces distributed uniformly throughout the cylinder wall. The results shall be as follows:

a) No individual value may be less than 11 percent, and
b) Average of the four measurements shall be at least 12 percent.



Key

1. Bend test pieces
2. Tensile test pieces

FIG. 4 LOCATION OF TEST PIECES

8.1.3.4 The value obtained for tensile strength shall not be less than R_g. The yield stress (R_{ea}) to be determined during the tensile strength test shall be that used in accordance with **3.2** for the cylinder calculation. The value obtained for the yield stress shall not be less than R_e.

8.1.4 *Bend Test*

8.1.4.1 The bend tests shall be carried out on four test pieces obtained by cutting either one or two rings of width $3a'$ (± 1mm) into equal parts; in no case shall the width of the test piece be less than 25 mm. Each test piece shall be of sufficient length to permit the bend test to be carried out correctly. Each ring may be machined only on the edges. These edges may be rounded to a radius of no more than 1/10 of the thickness of the test pieces or chamfered at an angle of 45° and a width of less than 1/10 of the thickness of the test pieces.

8.1.4.2 The bend tests shall be carried out using a former of diameter d and two rollers separated by a distance of $d + 3a'$. During the test, the inside face of the ring shall remain in contact with the former. Several test pieces can be tested at the same time on the same test machine (*see* Fig. 5).

8.1.4.3 The test piece shall not crack when bent inwards around the former until the inside edges are not further apart than the diameter of the former (*see* Fig. 5).

8.1.4.4 The ratio (n) between the diameter of the former and the thickness of the test piece shall not exceed the values given in Table 3.

Table 3 Bend Test Requirements

Sl No.	Actual Tensile Strength, R_m MPa	Value of n
(1)	(2)	(3)
i)	$R_m < 220$	5
ii)	$220 < R_m < 330$	6
iii)	$330 < R_m < 440$	7
iv)	$R_m > 440$	8

8.2 Hydraulic Burst Test

8.2.1 *Test Conditions*

8.2.1.1 The hydraulic burst test shall be carried out using a test-rig, which allows pressure to be increased at a controlled rate until the cylinder bursts and

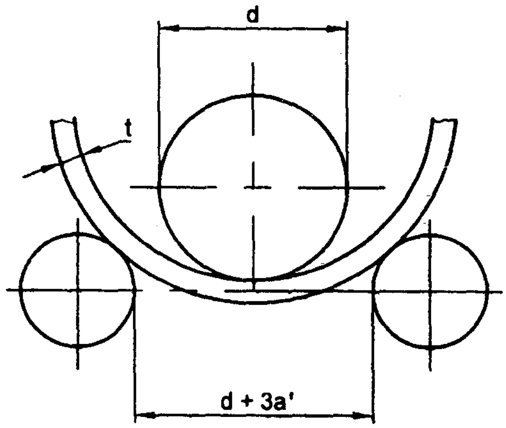


FIG. 5 ILLUSTRATION OF BEND TEST

the curve of pressure variation *versus* volumetric expansion or time to be produced. The test shall be carried out at room temperature (*see* Fig. 6). During burst test, rate of pressurization should not exceed 14 kgf/cm²/s.

8.2.1.2 During the first stage (elastic deformation), the rate of increase in pressure shall be approximately constant up to the level at which plastic deformation starts. In second stage, the pump discharge rate shall be maintained as constant as possible until the cylinder bursts.

8.2.1.3 *Interpretation of test*

a) The interpretation of the burst test shall involve:

   1) Determination of the burst pressure (P_b) and of the yield pressure (P_y) attained during the test;
   2) Examination of the tear and of the shape of its edges; and
   3) Verification, in the case of cylinders with a concave base, that the base of the cylinder has not been reversed.

   For the result of a bursting test to be considered satisfactory, the following requirements shall be met:

   1) The measured burst pressure (P_b) shall be $P_b = 1.6 \times P_h$,
   2) The observed yield pressure (P_y) shall be $P_y = 1/F \times P_h$,

b) The burst test shall not cause fragmentation of the cylinder;

c) The main tear shall not be of a brittle type, that is the edges of the fracture shall not be radial but be sloping in relation to a diametrical plane and shall display a reduction of area;

d) For cylinders of actual wall thickness 13 mm or less (*see* Fig. 7), the fracture shall be acceptable only, if it conforms to one of the following descriptions:

   1) The greater part of the fracture shall be unmistakably longitudinal except for cylinders where the ratio of length to outside diameter is less than 3 to 1,
   2) At each end of the fracture, no more than two branches shall be allowed provided that the shorter branch at each end is less than 20 mm long,
   3) The fracture shall not extend more than 90° around the circumference on either side of its main part,
   4) The fracture shall not extend into those parts of the cylinder of thickness more than 1.5 times the maximum thickness measured halfway up the cylinders with convex bases, the fracture shall not reach the center of the cylinder base.

e) For cylinders of actual wall thickness over 13 mm the greater part of the fracture shall be longitudinal; and

f) The tear shall not reveal any obvious defect in the metal.

8.3 Pressure Cycling Test

This test shall be carried out with a non-corrosive liquid subjecting the cylinders to successive reversals at an upper cyclic pressure which is equal to the hydraulic test pressure (P_h). The cylinders shall withstand 12 000 cycles without failure.

For cylinders with hydraulic test pressure (P_h) > 450 bar, the upper cyclic pressure may be reduced to two-thirds of this test pressure. In this case the cylinders shall withstand 80 000 cycles without failure.

The value of the lower cyclic pressure (P_{lc}) shall not exceed 10 percent of the upper cyclic pressure, but shall have an absolute maximum of 30 bar.

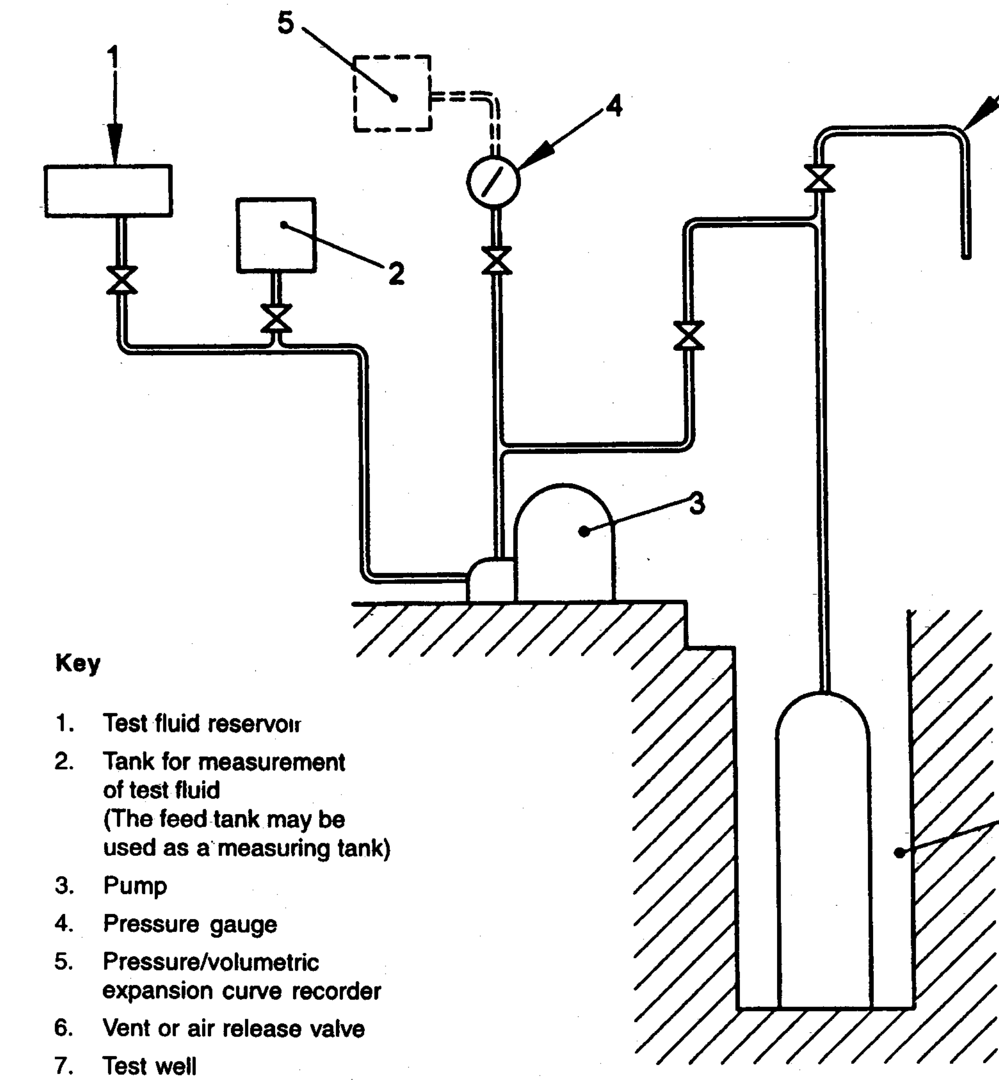


FIG. 6 TYPICAL HYDRAULIC BURST TEST INSTALLATION

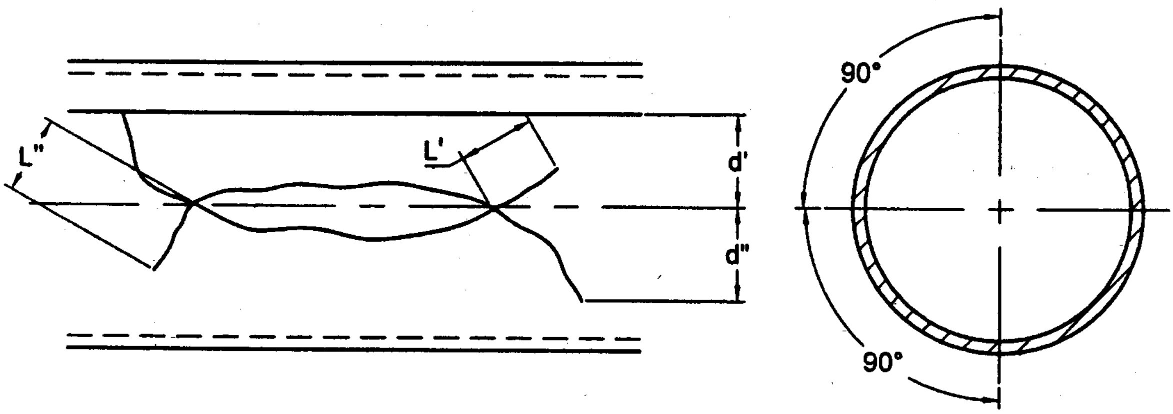


FIG. 7 ILLUSTRATION OF BRANCHING AND CIRCUMFERENTIAL DEVELOPMENT OF FRACTURE

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

The frequency of reversals of pressure shall not exceed 0.25 Hz (15 cycles/min). The temperature measured on the outside surface of the cylinder shall not exceed 50°C during the test.

After the test, the cylinder base shall be sectioned in order to measure the thickness and to ensure that this thickness is no more than 15 percent above the minimum base thickness prescribed in the design.

The test shall be considered satisfactory, if the cylinder attains the required number of cycles without developing a leak.

8.4 Hydraulic Test

Hydraulic proof pressure test or hydrostatic stretch test shall be performed on each cylinder.

8.4.1 *Proof Pressure Test*

The water pressure in the cylinder shall increase at a controlled rate until the pressure P_h is reached. The pressure may exceed P_h by 3 percent of P_h or10 bar, whichever is the least.

8.4.2 The cylinder shall remain under pressure P_h for at least 30 s to establish that the pressure does not fall and that there are no leaks.

8.4.3 After the test, the cylinder shall show no visible permanent deformation.

8.4.4 Any cylinder which does not fulfill this test requirement shall be rejected.

8.4.5 *Hydraulic Stretch Test*

Each cylinder shall be subjected to hydraulic stretch test at test pressure in accordance with the method specified in IS 5844. Permanent stretch suffered by the cylinder due to application of test pressure shall not exceed 10 percent of the total stretch suffered during the test.

8.5 Check on the Homogeneity of a Batch

This test, which is carried out by the manufacturer on each cylinder, involves checking by means of a hardness or electrical conductivity test that no error has been made in the choice of the original billets or in carrying out the heat treatment.

9 CONFORMITY EVALUATION

Prototype testing and production testing shall be carried out in accordance with Annex E.

10 CYLINDER MARKING

10.1 Each cylinder shall be permanently stamped with the following marking which shall be legible and bold:

a) Serial number;
b) Identification of manufacturer;
c) Month and year of hydrostatic test such as 06-2005 for June 2005;
d) The number of this standard and aluminium alloy type/designation;
e) Test pressure, in kgf/cm²;
f) The tare weight in kg and nominal water capacity, in litres;
g) Inspector's official mark;
h) Filling pressure at 15°C in case of permanent gases in bar or kgf/cm² and filling ratio; in case of liquefiable gases; and
j) Name of chemical symbol of the gas for which cylinder is to be used.

10.2 The marking shall not be made on the body of the cylinder but shall be at areas in the formed neck where the thickness of metal is greater than the minimum design thickness and where it is adequate for marking to be carried out.

10.2.1 The characters in marking shall normally be at least 4 mm in height and shall not be of excessive depth.

10.2.2 The stamps used for marking shall have small radius at change of section to avoid the formation of sharp edges in the stamped cylinder.

11 BIS CERTIFICATION MARKING

The cylinders may also be marked with the Standard Mark.

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

12 COLOUR IDENTIFICATION

The cylinder shall be painted externally in accordance with the colour scheme specified in IS 4379 or as specified by statutory authority.

12.1 Cylinder manufactured for export shall be painted externally as agreed to between the purchaser and the manufacturer.

13 RECORDS

Records shall be kept of all the tests made at the cylinder manufacturer's works and copies shall be forwarded to the purchaser of the cylinder and the inspecting authority.

14 PREPARATION FOR DESPATCH

Before being despatched from the manufacturer's works, all cylinders shall be thoroughly cleaned and all particles of grit, filings or other matter which may have collected inside the cylinder in the course of manufacture, heat treatment and testing shall be removed completely and the cylinder dried internally by heating uniformly to a temperature not exceeding 75°C. The outside surface of the cylinder shall be given a suitable protective coating before despatch.

ANNEX A

(*Clause* 5.1.1)

CORROSION TESTS

A-1 TEST FOR ASSESSING SUSCEPTIBILITY TO INTER-CRYSTALLINE CORROSION

The method described below consists of simultaneously immersing the specimens taken from the finished cylinder under test in a corrosive solution and examining them after a specified etching time in order to detect any signs of inter-crystalline corrosion and determine the nature and degree of such corrosion. The propagation of inter-crystalline corrosion is determined metallo-graphically on polished surfaces cut transversely to the etched surface.

A-1.1 Taking Specimens

Specimens are taken from the head, body and base of the cylinder (*see* Fig. 8) so that the tests with the solution as defined in **A-1.3.2.1** can be carried out on metal from three parts of the cylinder.

Each specimen shall be of the general shape and the dimensions indicated in Fig. 9.

The faces $a_1 a_2 a_3 a_4$, $b_1 b_2 b_3 b_4$, $a_1 a_2 b_2 b_1$, $a_4 a_3 b_3 b_4$ are all sawn with a band saw and then carefully trimmed with a fine file. The surfaces $a_1 a_4 b_4 b_1$ and $a_2 a_3 b_3 b_2$, which correspond respectively to the inner and outer faces of the cylinder, are left in their rough manufactured state.

A-1.2 Preparation of Surface Before Corrosive Etching

A-1.2.1 *Products Required*

a) HNO_3 for analysis, density 1.33;
b) HF for analysis, density 1.14 (at 40 percent); and
c) de-ionized water.

A-1.2.2 *Method*

Prepare the following solution in a beaker:

a) HNO_3 : 63 cc;
b) HF : 6 cc; and
c) H_2O : 931 cc.

Bring the solution to a temperature of 95°C.

Treat each specimen, suspended on an aluminium wire, in this solution for 1 min.

Wash in running water and then in de-ionized water.

Immerse the specimen in nitric acid, as defined in **A-1.2.1** for 1 min at room temperature to remove any copper deposit, which may have formed.

Rinse in de-ionized water.

To prevent oxidation of specimens, they should be plunged, as soon as they have been prepared, in the corrosion bath intended for them (*see* **A-1.3.1**).

A-1.3 Performance of Test

A-1.3.1 *Corrosive Solution*

The corrosive solution to be used contains 57 g/l sodium chloride and 3 g/l hydrogen peroxide.

A-1.3.2 *Preparation of the Corrosive Solution*

A-1.3.2.1 *Products required*

a) NaCl : crystallized, for analysis;
b) H_2O_2 : 100 to 110 volumes – medicinal;
c) $KMnO_4$: for analysis;
d) H_2SO_4 : for analysis, density 1.83 g/cc; and
e) de-ionized water.

A-1.3.2.2 *Titration of hydrogen peroxide*

Since the hydrogen peroxide is not very stable, it is essential to check its titre before use. To do this:

a) take 10 cc of hydrogen peroxide with a pipette, dilute to 1 000 cc (in a gauged flask) with de-ionized water, thus obtaining a hydrogen peroxide solution which will be called C. With a pipette, place in an Erlenmeyer flask:
b) 10 cc of the hydrogen peroxide solution C; and
c) 2 cc approximately of sulphuric acid, density 1.83.

A solution of potassium permanganate at 1.859 g/l is used for the titration. The potassium permanganate itself serves as an indicator.

A-1.3.2.3 *Explanation of titration*

The reaction of the potassium permanganate on the hydrogen peroxide in a sulphuric medium is expressed as:

$$2\,KMnO_4 + 5\,H_2O_2 + 3\,H_2SO_4 \rightarrow K_2SO_4 + 2\,MnSO_4 + 8\,H_2O + 5\,O_2$$

which gives the equivalence : 316 g $KMnO_4$ = 170 g H_2O_2.

Therefore 1 g of pure hydrogen peroxide reacts on

1 859 g of potassium permanganate; hence the use of a 1.859 g/l solution of potassium permanganate, which saturates, volume for volume, 1 g/l hydrogen peroxide. Since the hydrogen peroxide was diluted 100 times to begin with, the 10 cm of the test sample represent 0.1 cc of the original hydrogen peroxide.

Multiplying by 10 the number of cubic centimetres of potassium permanganate solution used for the titration, the titre *T* of the original hydrogen peroxide in g/l is obtained.

A-1.3.2.4 *Preparation of the solution*

Method for 10 litres:

Dissolve 570 g of sodium chloride in de-ionized water to obtain a total volume of about 9 litre. Add the quantity of hydrogen peroxide calculated below. Mix and then make up the volume to 10 litre with de-ionized water.

Calculation of the volume of hydrogen peroxide to be put into the solution:

Quantity of pure hydrogen peroxide required: 30 g.

If the hydrogen peroxide contains *T* gram of H_2O_2 per litre, the volume required, expressed in cc, will be:

$$\frac{1\,000 \times 30}{T}$$

A-1.3.3 *Etching Conditions*

A-1.3.3.1 The corrosive solution is placed in a crystallizer (or possibly a large beaker), itself placed in a water bath. The water bath is stirred with a magnetic stirrer and the temperature is regulated with a contact thermometer.

The specimen is either suspended in the corrosive solution by means of an aluminium wire or placed in the solution so that it rests only on the corners, the second method being preferable. The etching time is 6 h and the temperature fixed at 30 ± 1°C. Care should be taken to ensure that the quantity of reagent is at least 10 cc/cm² of specimen surface.

After etching, the specimen is washed in water, immersed for about 30 s in 50 percent dilute nitric acid, washed again in water and dried with compressed air free of oil.

A-1.3.3.2 A number of specimens may be etched at the same time provided that they are of the same type of alloy and that they are not in contact. The minimum quantity of reagent per unit of specimen surface shall be adhered to.

A-1.4 Preparation of Specimens for Examination

A-1.4.1 Products required are:

a) Casting dishes with, for example, the following dimensions:
   1) External diameter : 40 mm;
   2) Height : 27 mm; and
   3) Wall thickness : 2.5 mm.
b) Resin, and
c) Hardener.

A-1.4.2 *Method*

Each specimen is placed vertically in a casting dish so that it rests on its face $a_1\, a_2\, a_3\, a_4$. Around it is poured a mixture of resin and hardener in the appropriate proportion.

The usual setting time is about 24 h.

A certain amount of material is removed from the face $a_1\, a_2\, a_3\, a_4$ preferably by lathe, so that the section $a_1'\, a_2'\, a_3'\, a_4'$ examined under the microscope cannot show corrosion from the surface $a_1\, a_2\, a_3\, a_4$. The distance between the faces $a_1\, a_2\, a_3\, a_4$ and $a_1'\, a_2'\, a_3'\, a_4'$, that is the thickness removed by the lathe, shall be at least 2 mm (*see* Fig. 9 and 10).

The section for examination is polished mechanically with alumina, first on paper and then on felt.

A-1.5 Micrographic Examination of Specimens

The examination consists of noting the intensity of inter-crystalline corrosion on the part of the perimeter of the section to be examined (*see* **A-1.6**). When doing this account is taken of the properties of the metal both on the outer and inner surfaces of the cylinder and in the thickness of the latter.

The section is first examined at low magnification (for example × 40) in order to locate the most corroded areas, and then at a higher magnification, usually about × 300, in order to assess the nature and extent of the corrosion.

A-1.6 Interpretation of the Micrographic Examination

This consists of verifying that inter-granular corrosion is superficial.

a) For alloys with equiaxed crystallization, the depth of corrosion round the entire perimeter of each section shall not exceed the higher of the following two values:
   1) three grains in the direction perpendicular to the face examined; and
   2) 0.2 mm.

   However, it is permissible for these values to be exceeded locally provided that they are not exceeded in more than four fields of examination at × 300 magnifications.

   In no case shall the depth be greater than 0.3 mm.

b) For alloys with crystallization set in one direction through cold working, the depth of the corrosion into each of the two faces, which make up the internal and external surfaces of the cylinder, shall not exceed 0.1 mm.

A-2 TESTS FOR ASSESSING SUSCEPTIBILITY TO STRESS CORROSION

The method described below consists of the subjection to stress of rings cut from the cylindrical part of the cylinder, their immersion in brine for a specified period, followed by removal of the brine and exposure to the air for a longer period and repetition of this cycle for 30 days. If there are no cracks in the rings after the period of 30 days, the alloy can be considered suitable for the manufacture of gas cylinders.

A-2.1 Taking Specimens

Three rings with a width of $4a'$ or 25 mm, whichever is the greater, are cut from the cylindrical part of the cylinder (*see* Fig. 11). The specimens shall have a 60° cut-out and be subjected to stress by means of a threaded bolt and two nuts (*see* Fig. 12).

Neither inner nor outer surfaces of the specimens are to be machined.

A-2.2 Surface Preparation Before Corrosion Test

All traces of grease, oil and adhesive used with stress gauges (*see* **A-2.3.2.3**) shall be removed with a suitable solvent.

A-2.3 Performance of the Test

A-2.3.1 *Preparation of the Corrosive Solution*

A-2.3.1.1 The brine is prepared by dissolving 3.5 ± 0.1 parts by mass of sodium chloride in 96.5 parts by mass of water.

A-2.3.1.2 The *p*H value of the freshly prepared solution shall be in the range **6.4** to **7.2**.

A-2.3.1.3 The *p*H may be corrected only by using dilute hydrochloric acid or dilute sodium hydroxide.

A-2.3.1.4 The solution shall not be topped up by adding the salt solution described in **A-2.3.1.1** but only by adding distilled water up to the initial level in the vessel. Topping up may be carried out daily if necessary.

A-2.3.1.5 The solution shall be completely replaced every week.

A-2.3.2 *Applying the Stress to the Rings*

A-2.3.2.1 Three rings are to be compressed so that the outer surface is under tension.

A-2.3.2.2 The tensile stress reached on the external face of the test specimen shall be equal to $R_e/1.3$.

A-2.3.2.3 The actual stress may be measured by electric stress gauges.

A-2.3.2.4 The diameter of the compressed ring to achieve the required stress may be calculated using the following equation:

$$D' = D - \frac{\pi R (D-t)^2}{4\,Etz}$$

where

D' = diameter of the ring when compressed, in mm;

D = external diameter of the cylinder, in mm;

t = cylinder wall thickness, in mm;

$R = \dfrac{R_e}{1.3}$ MPa

E = modulus of elasticity, in MPa = 70 000 Mpa approximately; and

z = correction factor (*see* Fig. 13).

A-2.3.2.5 It is essential for the nuts and bolt to be electrically insulated from the rings and protected from corrosion by the solution.

A-2.3.2.6 The three rings shall be completely immersed in the saline solution for 10 min.

A-2.3.2.7 They are then removed from the solution and exposed to the air for 50 min.

A-2.3.2.8 This cycle shall be repeated for 30 days or until ring breaks, whichever happens first.

A-2.3.2.9 The specimens are to be inspected visually for any cracks.

A-2.4 Interpretation of the Results

The alloy shall be considered acceptable for the manufacture of gas cylinders, if none of the rings subjected to stress develops any cracks visible to the necked eye, or visible at low magnification (× 10 to × 30), at the end of the 30 day test period.

A-2.5 Possible Metallographical Examination

A-2.5.1 In the event of doubt about the presence of cracks (for example, line of pitting), uncertainty may be removed by means of an additional metallographical examination of a section taken perpendicular to the axis of the suspect area (*see* Fig. 11). A comparison is made of the form (inter-or transcrystalline) and depth of penetration of the corrosion on the faces of the ring subject to tensile and compressive stress.

A-2.5.2 The alloy shall be considered acceptable, if the corrosion on both faces of the ring is similar.

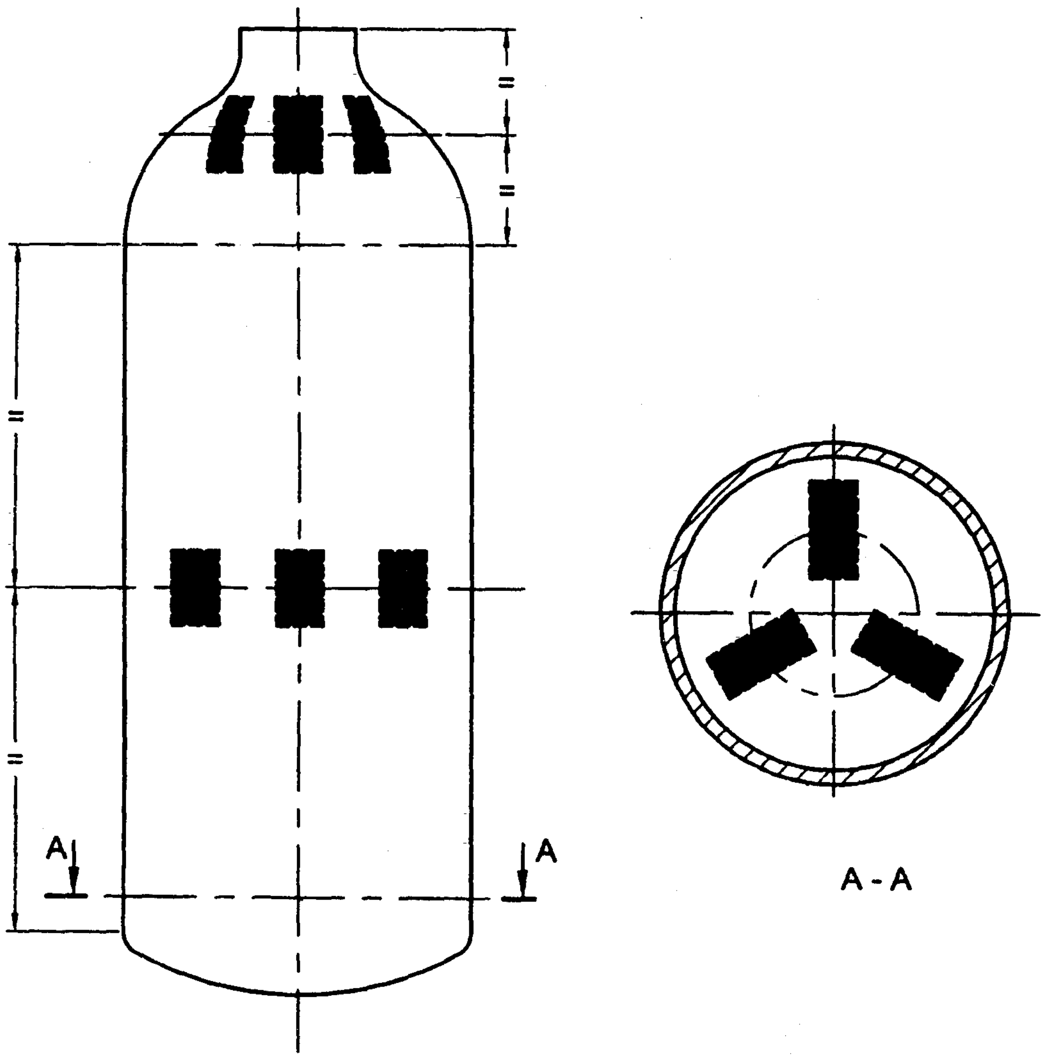


FIG. 8 LOCATION OF SPECIMENS

If the outer face of the ring reveals inter-crystalline cracks, which are clearly deeper than the corrosion affecting the inner face, the ring shall be considered to have failed the test.

A-2.6 Reports

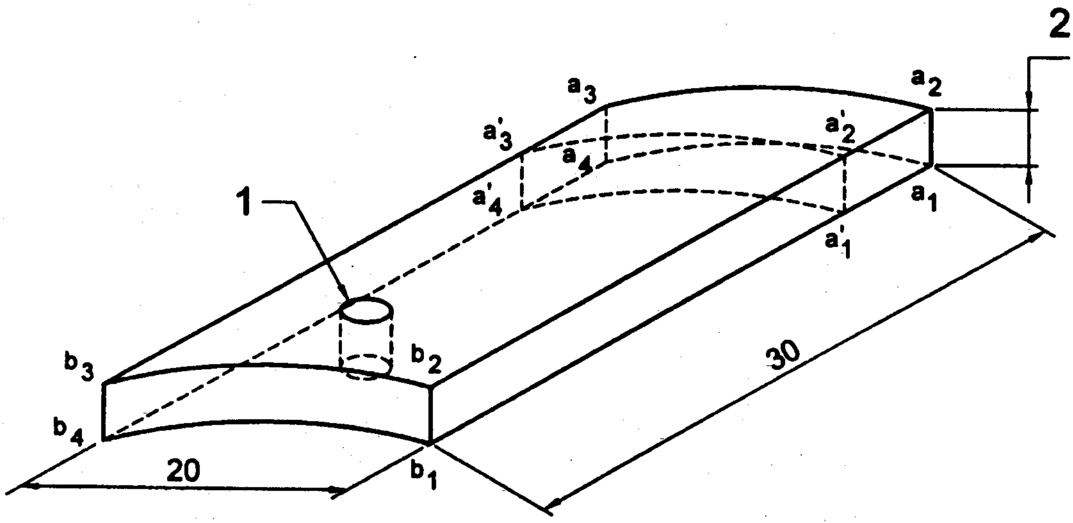
A-2.6.1 Name of the alloy and/or its standard number shall be indicated.

A-2.6.2 Composition limits of the alloy shall be given.

A-2.6.3 Actual analysis of the cast from which the cylinders were manufactured shall be mentioned.

A-2.6.4 Actual mechanical properties of the alloy shall be reported, together with the minimum mechanical property requirements.

A-2.6.5 Result of the test shall be given.

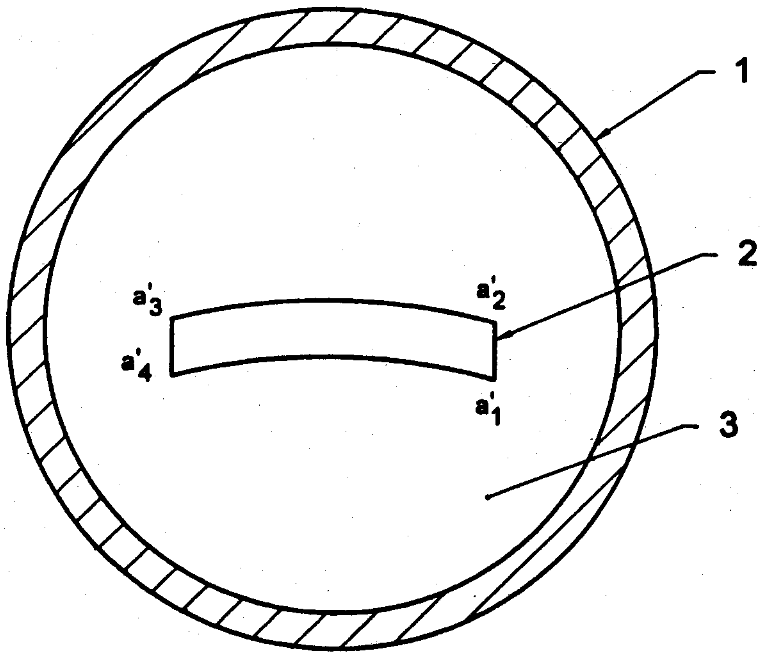


Key

1. Hole Ø 3
2. Thickness of the cylinder

All dimensions in millemetres.

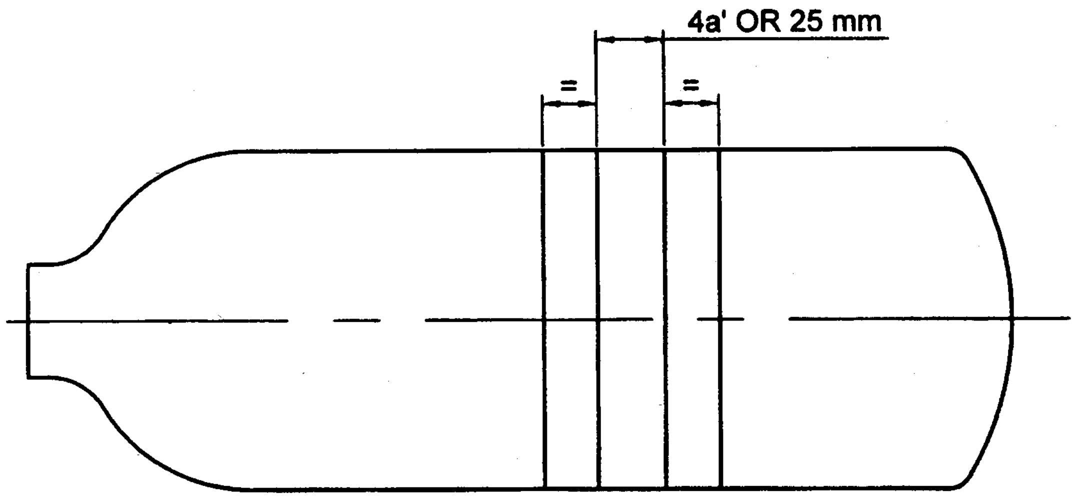
FIG. 9 SPECIMEN SHAPE AND DIMENSIONS



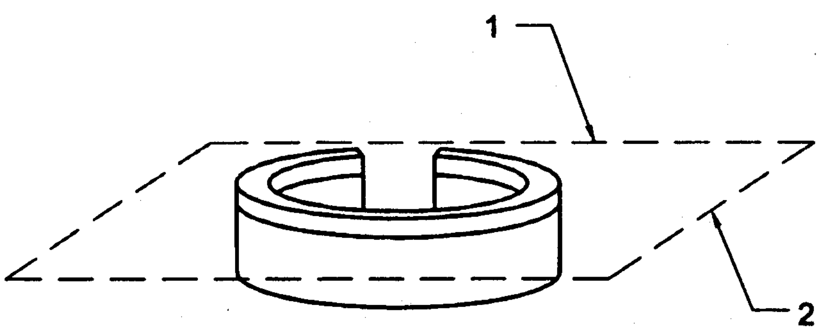
Key

1. Casting dish
2. Cylinder specimen
3. Resin matrix

FIG. 10 SPECIMEN IN CASTING DISH



a) LOCATION OF SPECIMEN RINGS

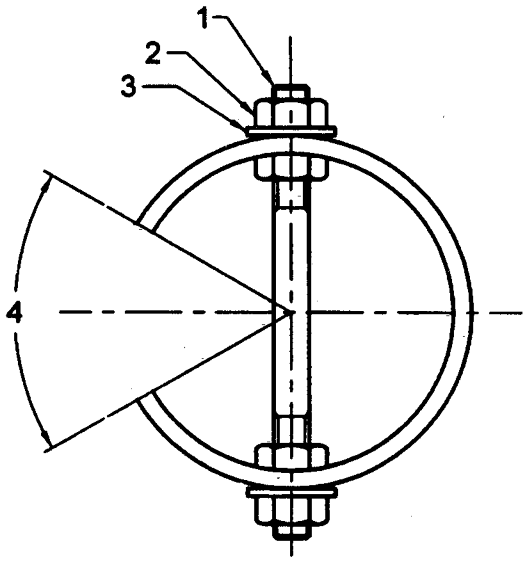


Key

1. Axis
2. Perpendicular plane

b) SECTION FOR ADDITIONAL METALLOGRAPHICAL EXAMINATION

FIG. 11 SPECIMEN RINGS



Key

1. Threaded bolt
2. Nut
3. Insulating washer
4. Approx. 60°

FIG. 12 STRESS BY COMPRESSION

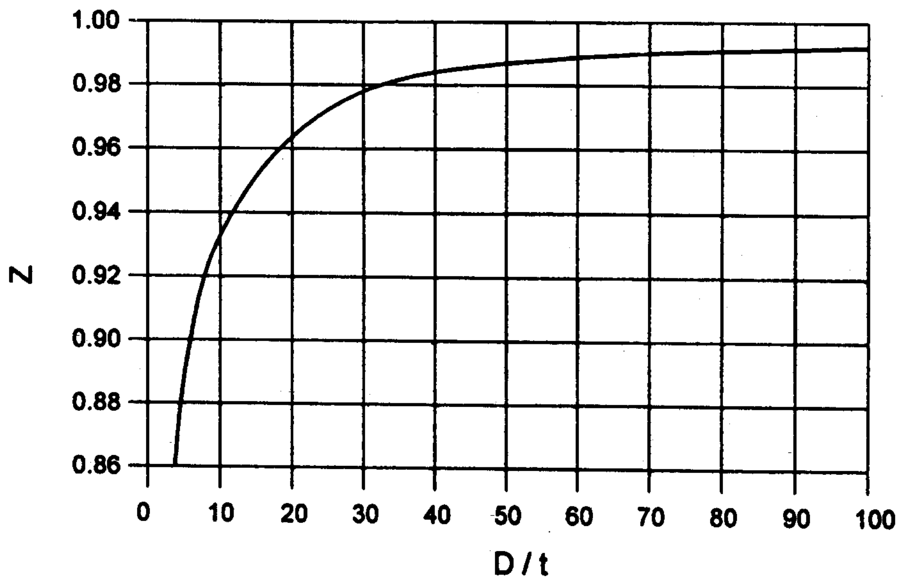


FIG. 13 CORRECTION FACTOR Z

ANNEX B

(*Clause* 5.1.1)

TEST METHOD TO DETERMINE SUSTAINED-LOAD-CRACKING (SLC) RESISTANCE OF ALUMINIUM ALLOY CYLINDERS

B-1 PRINCIPLE

A fatigue pre-cracked specimen is loaded by a constant load or constant displacement method to a stress-intensity K_{IAPP} equal to a defined value. The specimen is kept in the loaded condition for a specified time and temperature. After the test period, the specimen is examined to assess whether the initial fatigue crack did or did not grow.

If the test specimen exhibits less than or equal to a specified amount of crack growth, then the material is characterized as suitable for gas cylinders with respect to the sustained-load-cracking resistance requirement.

B-2 GENERAL

B-2.1 This method covers determination of sustained-load-cracking resistance for aluminium alloy cylinders. The test can be performed in a recognized/approved in house or approved outside laboratory.

B-2.2 Following the initial qualification for resistance to sustained-load-cracking, this procedure shall only be repeated, if any of the conditions (a), (b), (c) and (d) listed in **E-1.1** apply.

B-2.3 Cylinders with nominal neck and shoulder wall thickness equal to or less than 7 mm are exempted from the sustained-load-cracking tests. The inspector shall ensure that the neck/shoulder wall thickness of the actual cylinders reasonably represents the quoted nominal figure. Figure 14 illustrates the neck and shoulder thickness.

B-3 DEFINITIONS AND SYMBOLS

The definitions and symbols apply to this Annex are as follows:

r = notch radius;

K_t = theoretical elastic stress concentration factor;

K_t' = appearent crack tip stress intensity factor calculated on the basis of the notch depth and applied load;

M = bending moment;

μ = poisson's ratio;

SLC = sustained-load-cracking;

K_{IAPP} = applied elastic stress intensity, MPa.m$^{1/2}$;

V = crack mouth opening displacement (CMOD), in millimetres, defined as the mode 1 (also called opening-mode) component of crack displacement due to elastic and plastic deformation, measured at the location on a crack surface that has the greatest elastic displacement per unit load;

E = modulus of elasticity, in MPa;

K_{ISCC} = threshold stress intensity factor for susceptibility to stress corrosion cracking; and

R_{eSLC} = average of measured yield stress of two specimens from the test cylinder representing the SLC test specimens location at room temperature, in MPa. For location of the specimens refer to **B-4.3**.

B-4 SPECIMEN CONFIGURATIONS AND NUMBER OF TESTS

B-4.1 Any one or a combination of specimen geometries of the following listed specimens shall be used for the tests:

a) Compact tension test specimen, *see* Fig. 16;
b) Double cantilever beam specimen, *see* Fig. 17;
c) T-type wedge opening specimen, *see* Fig. 18; and
d) C-shaped specimen, *see* Fig. 19.

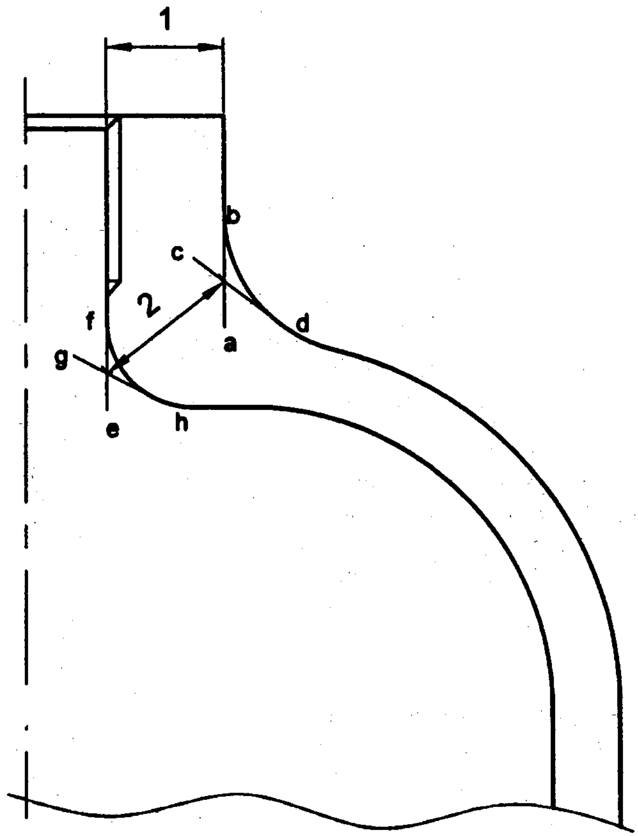
B-4.2 Specimen orientation shall be Y-X or Y-Z as shown in Fig. 15.

B-4.3 At least three specimens from the cylinder wall and if possible three specimens from the shoulder and three specimens from the neck shall be tested. At each location the three specimens shall be taken as close to each other as possible. One specimen from each location shall be used for SLC testing and two from each location for tensile testing (*see* Fig. 15).

B-4.4 Flattening of specimen blanks is not allowed.

B-4.5 If test specimen thickness cannot be obtained from the specified location or locations to meet the **B-6.6** validity requirements, then the thickest possible specimen shall be tested. The specimen shall be taken when the mechanical properties have been fully developed in the cylinder, but before any external machining of the neck/shoulder area.

B-4.6 When it is impossible to obtain full size tensile specimens, small size specimens are permitted for determination of yield stress.

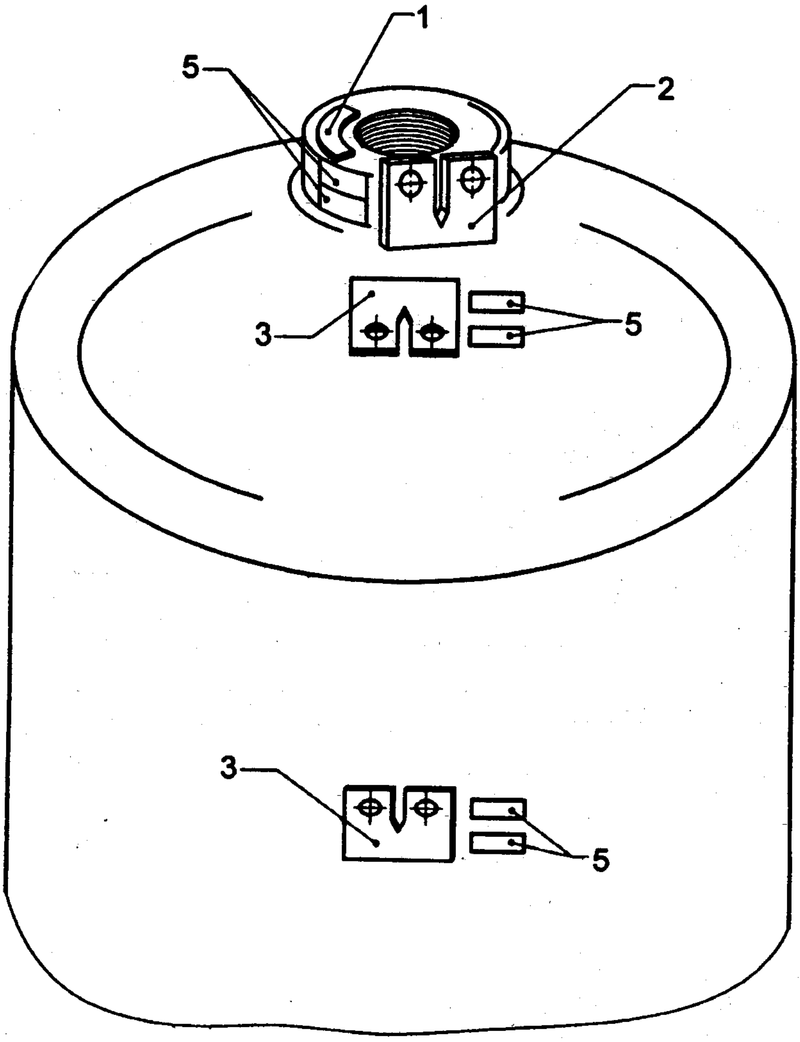


Key

1. Nominal neck thickness
2. Nominal shoulder thickness

NOTE — *a-b*, *c-d*, *e-f* and *g-h* are tangents initiating at intersecting surfaces.

FIG. 14 ILLUSTRATION OF NECK AND SHOULDER THICKNESS

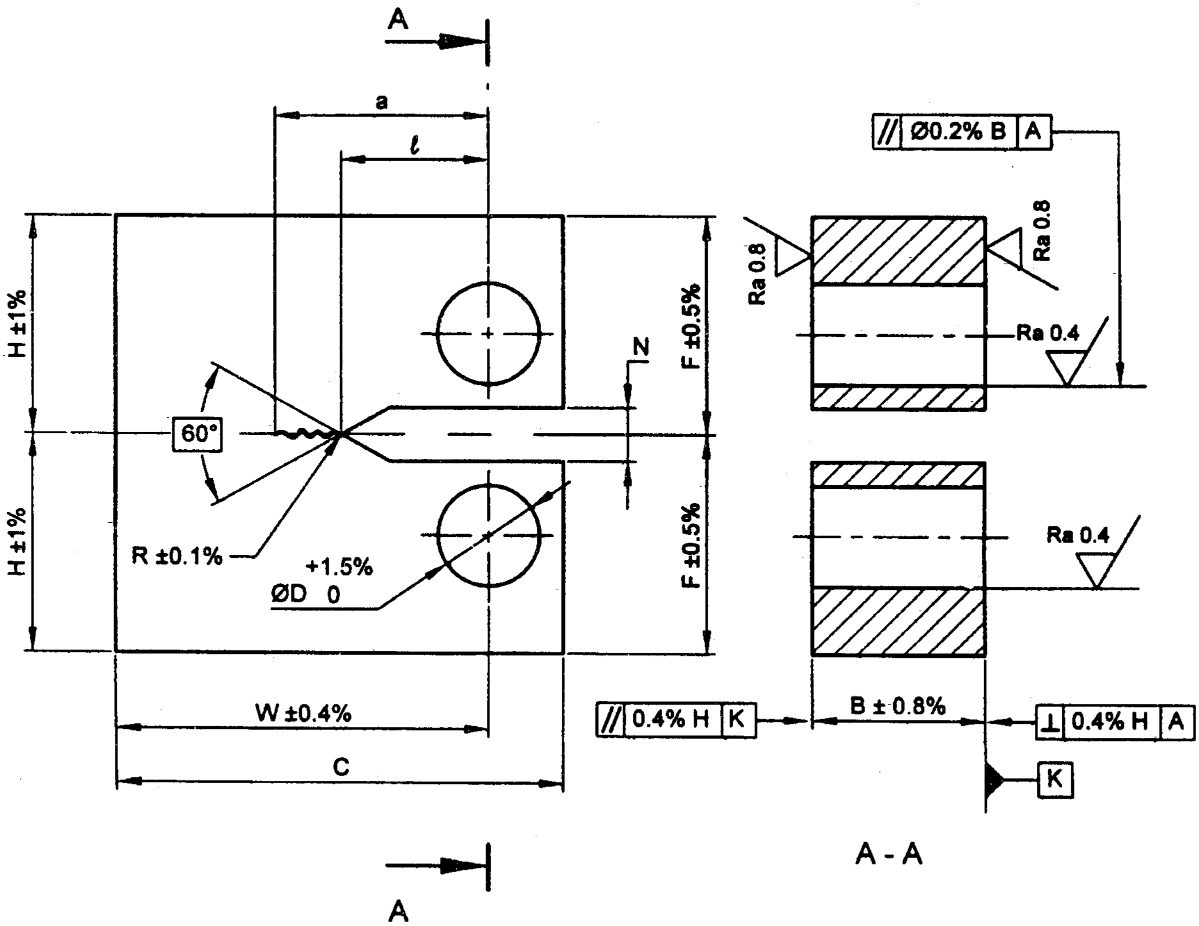


Key

1. Neck specimen Y-Z
2. Neck specimen Y-X
3. Shoulder specimen Y-X
4. Cylinder wall specimen Y-X
5. Tensile specimens

NOTE — Specimen should be taken as close as possible to neck. Notch direction shall be toward the neck, as shown.

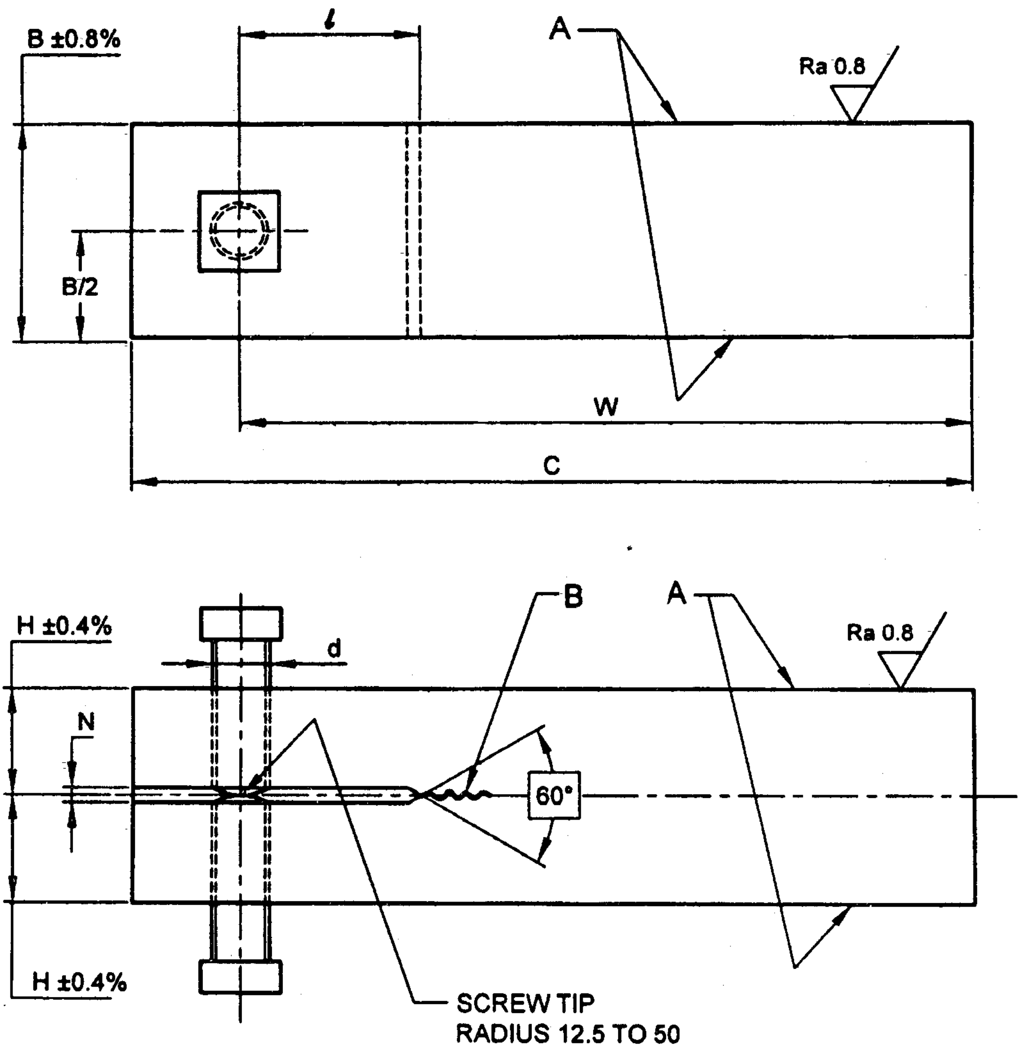
FIG. 15 ORIENTATION OF NECK, SHOULDER AND CYLINDER WALL SPECIMENS



Net width	= *W*
Total width, *C*	= 1.25 *W, Min*
Thickness, *B*	= 0.5 *W*
Half height, *H*	= 0.6 *W*
Hole diameter, *D*	= 0.25 *W*
Half distance between hole outer edges, *F*	= 1.6 *D*
Notch width, *N*	= 0.065 *W, Max*
Effective notch, length, *l*	= 0.25 *W* to 0.40 *W*
Effective crack, length, *a*	= 0.45 *W* to 0.55 *W*

All dimensions in millimetres.

FIG. 16 PROPORTIONAL DIMENSIONS AND TOLERANCES FOR COMPACT TENSIONS TEST PIECES



Half height, *H*	= *H*
Thickness, *B*	= 2 *H*
Net width	= 10 *H, Min*
Total width, *C*	= *W* + *d*
Screw diameter, *d*	= 0.75 *H, Min*
Notch width, *N*	= 0.14 *H, Max*
Effective notch, length, *l*	= 2 *H*

NOTES

1 "*A*" surfaces should be perpendicular and parrallel as aplicable to within 0.002 *H* TIR.

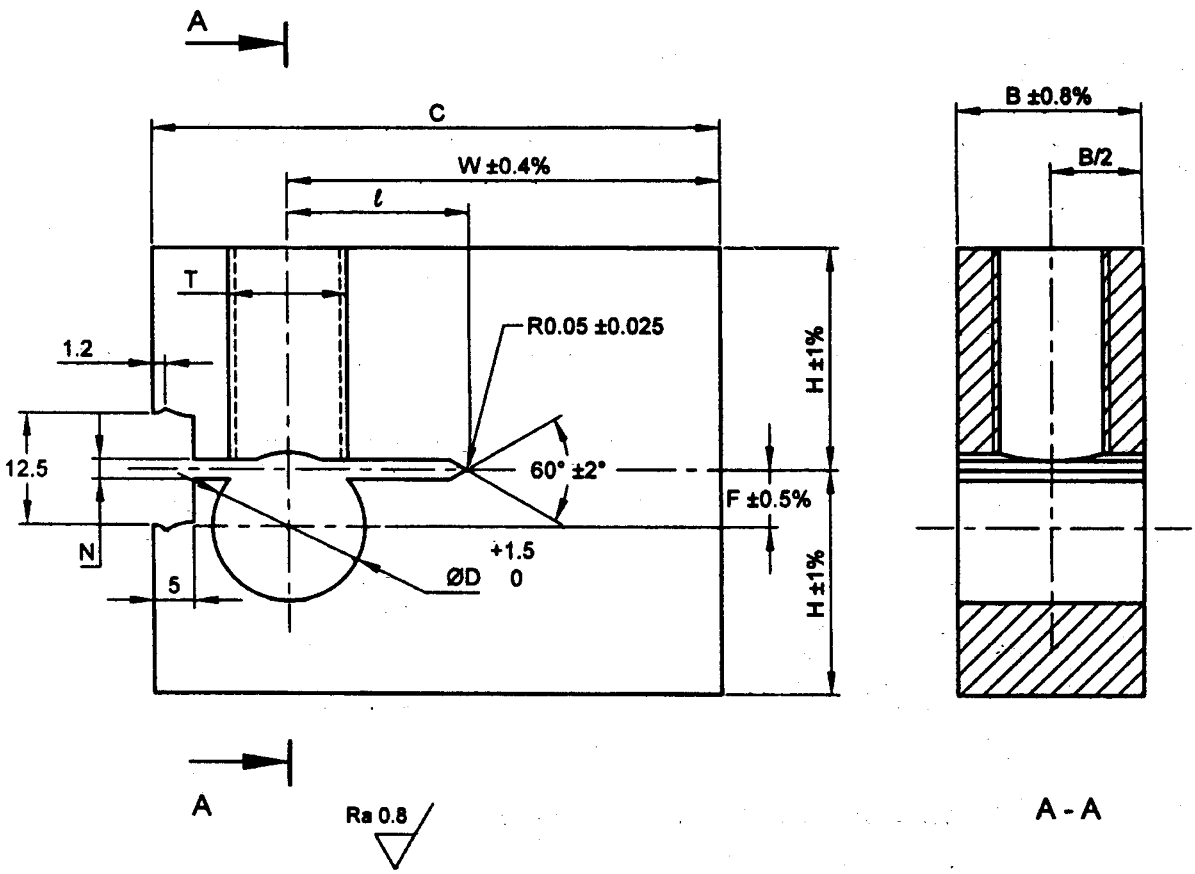
2 At each side point "*B*" should be equidistant from the top to bottom surface to within 0.001 *H*.

3 The bolt centreline should be normal to the specimen centreline to within 1°.

4 The bolt material should be similar to that of the specimen, fine threaded with a square or Allen-screw head.

All dimensions in millimetres.

FIG. 17 PROPORTIONAL DIMENSIONS AND TOLERANCES FOR DOUBLE CANTILEVER BEAM TEST PIECES



a) All over

Thickness, *B*	= *B*
Net width, *W*	= 2.55 *B*
Total width, *C*	= 3.20 *B*
Half height, *H*	= 1.24 *B*
Hole diameter, *D*	= 0.718 *B* + 0.003 *B*
Effective notch, length, *l*	= 0.77 *B*
Notch width, *N*	= 0.06 *B*
Thread diameter, *T*	= 0.625 *B*
Distance from hole centreline to notch centreline, *F*	= 0.239 *B*

NOTES

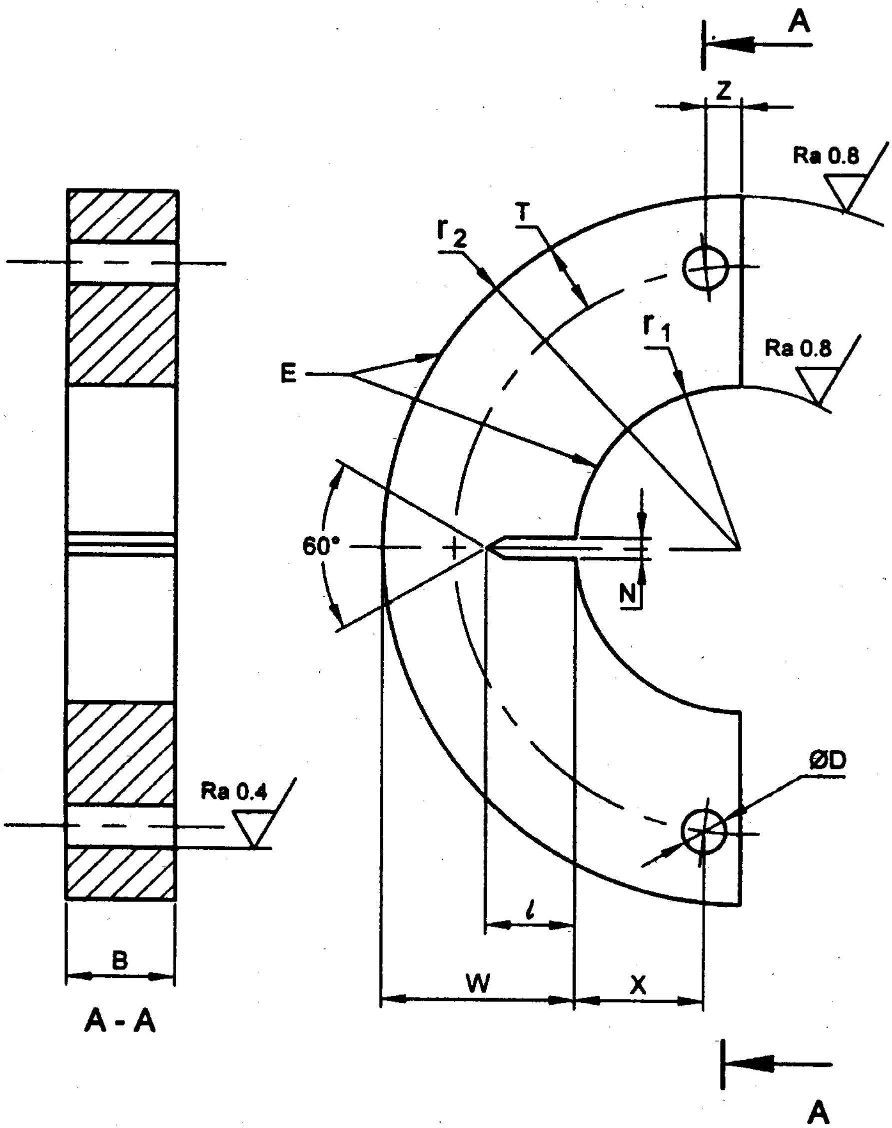
1 Surface should be perpendicular and parallel as aplicable to within 0.002 *H* TIR.

2 The bolt centreline should be normal to the specimen centreline to within 1°.

3 The bolt material should be similar to that of the specimen, fine threaded with a square or Allen-screw head.

All dimensions in millimetres.

FIG. 18 PROPORTIONAL DIMENSIONS AND TOLERANCE FOR MODIFIED WEDGE OPENING LOADED TEST PIECES



Net width	= *W*
Thickness, *B*	= 0.5 *W* ± 0.01 *W*
Distance from hole axes to tangent with the inner surface, *X*	= 0.50 *W* ± 0.005 *W*
Notch width, *N*	= 1.5, *Min* (0.1 *W*, *Max*)
Notch length, *l*	= 0.3 *W*
Distance from the hole axes to face of the specimen, *Z*	= 0.25 *W* ± 0.001 *W*
Distance from the hole axes to outer surface, *T*	= 0.25 *W* ± 0.001 *W*
Diameter of holes, *D*	= 0.25 *W* ± 0.005 *W*

NOTE — Surface should be perpendicular and parrallel as applicable to within 0.002 *W* TIR and "E" surfaces should be perpendicular to "Y" surfaces to within 0.02 *W* TIR.

All dimensions in millimetres.

FIG. 19 PROPORTIONAL DIMENSIONS AND TOLERANCES FOR C-SHAPED TEST PIECES

B-5 INITIATION AND PROPAGATION OF FATIGUE CRACKS

B-5.1 The machine used for fatigue cracking shall have a means of loading such that the stress distribution is symmetrical about the notch and the applied load shall be known to an accuracy of ± 2.5 percent.

B-5.2 The environmental conditions apparent during fatigue pre-cracking, as well as the stressing conditions, can influence the subsequent behaviour of the specimen during stress corrosion testing. In some materials, the introduction of the stress corrosion test environment during the pre-cracking operation will promote a change from the normal ductile transgranular mode of fatigue cracking to one that more closely resembles stress corrosion cracking. This may facilitate the subsequent initiation of stress corrosion cracking and lead to the determination of conservative initiation values of K_{ISCC}. However, unless facilities are available to commence stress corrosion testing immediately following the pre-cracking operation, corrodent remaining at the crack tip may promote blunting due to corrosive attack.

Furthermore, the reproducibility of results may suffer when pre-cracking is conducted in the presence of an aggressive environment because of the greater sensitivity of the corrosion fatigue fracture mode to the cyclic loading conditions. In addition, more elaborate facilities may be needed for environmental control purposes during pre-cracking. For these reasons, it is recommended that, unless agreed otherwise between the parties, fatigue pre-cracking shall be conducted in the normal laboratory air environment.

B-5.3 The specimens shall be pre-cracked by fatigue loading with an R value in the range 0 to 0.1 until the crack extends at least 2.5 percent W or 1.25 mm beyond the notch at the side surfaces, whichever is greater. The crack may be started at K_I values higher than the expected K_{ISCC} but, during the final 0.5 mm of crack extension, the fatigue pre-cracking shall be completed at as low a maximum stress intensity as possible (less than 60 percent of the expected K_{ISCC}).

B-5.4 The fatigue crack length (a, mm) requirement should be satisfied by the following equation:

$$a > 1.27 \left(\frac{K_{IAPP}}{R_{eSLC}}\right)^2 (1\,000)$$

B-5.5 In order to avoid the interaction of the stress field associated with the crack with that due to the notch, the crack shall lie within the limiting envelope as shown in Fig. 20 in which examples for bend and tensile pieces are shown. For the example valid for bend or tensile test pieces, if the apex of the envelope is located at the tip of the fatigue crack, the whole of the machined notch shall lie within the envelope as is shown in Fig. 20 (c).

B-5.6 In order to ensure the validity of the stress intensity analysis, the fatigue crack shall be inspected on each side of the specimen to ensure that no part of it lies in a plane the slope of which exceeds an angle of 10° from the plane of the notch and that the difference in lengths does not exceed 5 percent W.

B-6 SPECIMEN TESTING PROCEDURE

B-6.1 Load the fatigue pre-cracked specimens to a stress-intensity K_{IAPP} determined from the following equation:

$$K_{IAPP} = 0.056\ R_{eSLC}$$

Specimens shall be loaded by a suitable constant displacement or constant load method.

B-6.2 The specimens loaded by constant displacement method shall meet the following requirements:

a) At the end of the test, record the crack mouth opening displacement (CMOD) before unloading;
b) Unload the specimen; and
c) Reload the specimen up to the measured CMOD in a device suitable for load measurement. Record the load and use this load in the K_{IAPP} calculations. This calculated K_{IAPP} shall be equal to or greater than the calculated K_{IAPP} value from **B-6.1**.

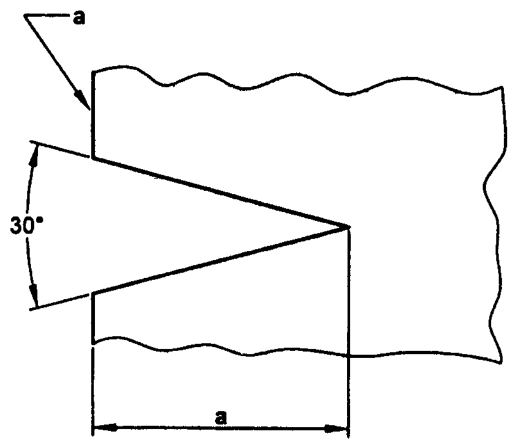
B-6.3 For testing of compact tension specimen (CTS) specimens at a constant displacement loading, use the following equations to determine V:

$$V = \frac{(K_{IAPP})(\sqrt{w})}{(0.032)(E)[f(x)](\sqrt{B/B_N})}$$

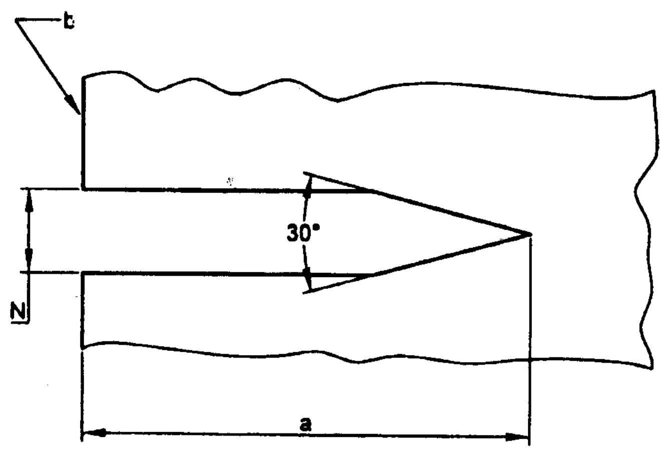
$$f(x) \frac{2.24(1.72 - 0.9x + x^2)(\sqrt{1} - x)}{(9.85 - 0.17x + 11x^2)}$$

where

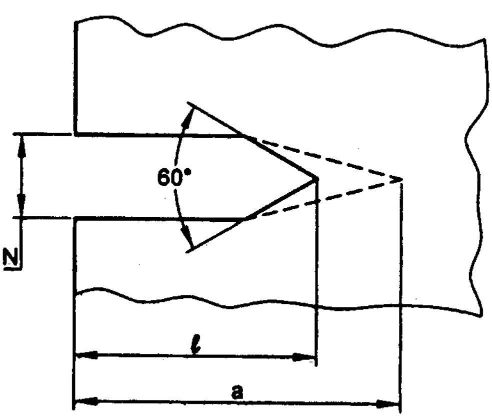
w = specimen width,
N = notch width,
B = specimen thickness,
B_N = reduced thickness at side groove,
E = modulus of elasticity,
x = a/w,
a = crack length,
w = specimen width, and
$f(x)$ = function of x.



a) BEND TEST PIECE



b) TENSILE TEST PIECE



c) BEND OR TENSILE TEST PIECE

a — Edge of test piece

b — Loading line of test piece

FIG. 20 ENVELOPE LIMITING SIZE AND FORM OF NOTCH AND FATIGUE CRACK

B-6.4 For testing of C-shaped specimen at a constant displacement loading, use the following equations to determine V:

For specimens with $X/W = 0$:

$$V = \frac{(K_{IAPP})(\sqrt{W})(P_1)[0.43(1-r_1/r_2)+Q_1]}{(0.032)(E)(Y)}$$

For specimens with $X/W = 0.5$:

$$V = \frac{(K_{IAPP})(\sqrt{W})(P_2)[0.45(1-r_1/r_2)+Q_1]}{(0.032)(E)(Y)}$$

where

Y = shear intensity factor cocfficient (*see* Fig. 21),

P_1 = $(1 + a/W)/(1 - a/W)^2$,

Q_1 = $0.542 + 13.137(a/W) - 12.316(a/W)^2 + 6.576(a/W)^3$,

P_2 = $(2 + a/W)/(1 - a/W)^2$,

Q_2 = $0.399 + 12.63(a/W) - 9.838(a/W)^2 + 4.66(a/W)^3$, and

H = half height of the specimen.

B-6.5 The loaded specimens shall be tested for 90 days at room temperature.

B-6.6 All specimens shall meet the validity requirements except as exempted in **B-4.5**.

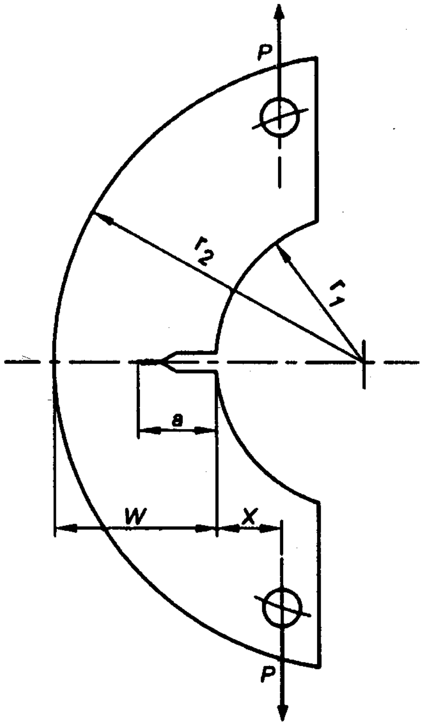
$$a, B, B_n, (W-a) \geq 1.27 \left(\frac{K_{IAPP}}{R_{eSLC}}\right)^2 \times 1\,000$$

B-7 CRACK GROWTH EXAMINATION

B-7.1 After the specified test period, unload the specimen, fatigue the specimen at maximum stress-intensity not to exceed 0.6 K_{IAPP} until the cracks advances by at least 1 mm. After fatigue cracking break open the specimen.

B-7.2 Measure the SLC growth between the two pre- and post-fatigue crack marking by scanning electron microscope (SEM). Measurements shall be taken perpendicular to the pre- and post-fatigue crack markings at 25 percent, 50 percent and 75 percent of the specimen thickness.

B-7.3 The measured SLC growth on any specimen at any of the above locations shall not exceed 0.16 mm.



$$Y = \left(18.23\sqrt{\frac{a}{W}} - 106.2\sqrt{\frac{a^3}{W}} + 397.7\sqrt{\frac{a^5}{W}} - 582.0\sqrt{\frac{a^7}{W}}\ 369.1\sqrt{\frac{a^9}{W}}\right) \times \left(1 + 1.54\frac{X}{W} + 0.5\frac{a}{W}\right) \times \left[1 + 0.22\left(1 - \sqrt{\frac{a}{W}}\right)\left(1 - \frac{r_1}{r_2}\right)\right]$$

NOTE — The inaccuracy of the expression is considered to be no greater than 1 percent over the range $0.45 \leq \frac{a}{W} \leq 0.55$. However, it can be used over the wider range $0.3 \leq \frac{a}{W} \leq 0.7$ when $0 \leq \frac{X}{W} \leq 0.7$ and $0 \leq \frac{r_1}{r_2} \leq 1$, in which case the accuracy is believed to be no greater than 2 percent.

FIG. 21 STRESS INTENSITY FACTOR SOLUTION FOR C-SHAPED SPECIMENS

B-8 CYLINDER THICKNESS QUALIFICATION

If the validity requirements of **B-6.6** are not met, then the material is suitable up to the maximum thickness of the cylinder location from where the specimens are taken provided the specimens meet the other requirements of this test method. The material is suitable for all thickness, if the specimens meet the validity requirements of **B-6.6** and the other requirements of this test method.

B-9 REPORT

The report shall indicate if the validity criteria are met or not and shall include an SEM micrograph as per **B-7.2**. The report shall be kept permanently as a record that the cylinder alloy/process has been tested and found acceptable.

ANNEX C

(*Clause* 6.2)

EXAMPLES OF WALL THICKNESS CALCULATION

C-1 This Annex provides examples of wall thickness calculations, using the criteria and formula given in **6**.

Example 1:

D = 150 mm p_h = 300 bar

R_e = 320 MPa R_g = 330 MPa

$$\frac{R_e}{R_g} = \frac{320}{330} = 0.970 > 0.90$$

Therefore this combination of R_e and R_g is not acceptable.

Example 2:

D = 150 mm P_h = 300 bar

R_e = 297 MPa R_g = 330 MPa

$$\frac{R_e}{R_g} = \frac{297}{330} = 0.90$$

This combination of R_e and R_g is acceptable.

$$F = \frac{0.65}{R_e / R_g} = \frac{0.65}{297/330} = 0.722 < 0.77$$

The value of F to be used is 0.722.

$$a = \frac{D}{2}\left(1-\sqrt{\frac{10 \times F \times R_e - \sqrt{3} \times P_h}{10 \times F \times R_e}}\right) = \frac{150}{2}$$

$$\left(1-\sqrt{\frac{10 \times 0.722 \times 297 - \sqrt{3} \times 300}{10 \times 0.722 \times 297}}\right) = 9.71 \text{ mm}$$

The calculated wall thickness shall also satisfy the following conditions:

$$a \geq \frac{D}{100} + 1 = \frac{150}{100} + 1 = 2.5 \text{ mm; and } a \geq 1.5 \text{ mm}$$

Both conditions are met.

Therefore the calculated minimum thickness, a = 9.71 mm.

Example 3:

D = 150 mm P_h = 300 bar

R_e = 250 MPa R_g = 330 MPa

$$\frac{R_e}{R_g} = \frac{250}{330} = 0.758 < 0.90$$

This combination of R_e and R_g is acceptable.

$$F = \frac{0.65}{R_e / R_g} = \frac{0.65}{250/330} = 0.858 > 0.77$$

The F value is limited to 0.77. The value of F to be used is therefore 0.77.

$$a = \frac{D}{2}\left(1-\sqrt{\frac{10 \times F \times R_e - \sqrt{3} \times P_h}{10 \times F \times R_e}}\right) = \frac{150}{2}$$

$$\left(1-\sqrt{\frac{10 \times 0.722 \times 297 - \sqrt{3} \times 300}{10 \times 0.77 \times 250}}\right) = 10.92 \text{ mm}$$

The calculated wall thickness shall also satisfy the following conditions:

$$a \geq \frac{D}{100} + 1 = \frac{150}{100} + 1 = 2.5 \text{ mm; and } a \geq 1.5 \text{ mm}$$

Both conditions are met.

Therefore the calculated minimum thickness, a = 10.92 mm.

Example 4:

D = 150 mm P_h = 50 bar

R_e = 290 MPa R_g = 330 MPa

$$\frac{R_e}{R_g} = \frac{290}{330} = 0.879 < 0.90$$

This combination of R_e and R_g is acceptable.

$$F = \frac{0.65}{R_e / R_g} = \frac{0.65}{290/330} = 0.740 < 0.77$$

The F value to be used is 0.740.

$$a = \frac{D}{2}\left(1 - \sqrt{\frac{10 \times F \times R_e - \sqrt{3} \times P_h}{10 \times F \times R_e}}\right) = \frac{150}{2}$$

$$\left(1 - \sqrt{\frac{10 \times 0.740 \times 290 - \sqrt{3} \times 50}{10 \times 0.740 \times 290}}\right) = 1.53 \text{ mm}$$

The calculated wall thickness shall also satisfy the following conditions:

$$a \geq \frac{D}{100} + 1 = \frac{150}{100} + 1 = 2.5 \text{ mm; and } a \geq 1.5 \text{ mm}$$

The first condition is not met.

Therefore the calculated minimum thickness, $a = 2.5$ mm.

ANNEX D

(*Clause* 6.4.1.1)

SHEAR STRESS AND FACTOR OF SAFETY CALCULATIONS

D-0 R_g = 325 MPa, ¾ "UNF, 16 TP1 Parallel Threads, P_h = 300 and 350 bar.

Examplary calculations are as under.

D-1 $A_{sn} = 3.141\,16 \times n \times L_e \times (D_s)_{Min} \{1/(2n) + 0.019\,866\,[(D_s)_{Min} - (E_n)_{Max}]\}$

		Example 1	*Example* 2	*Example* 3
n	Number of threads per inch	16	16	16
$(D_s)_{Min}$	Minimum major diameter of external threads, mm	18.65	18.65	18.65
$(E_n)_{Max}$	Maximum pitch diameter of external threads, mm	17.98	17.98	17.98
T	Minimum engaged threads	6	6	7
L_e	Length of thread engagement, mm	9.53	9.53	9.53
A_{sn}	**Shear area of the internal thread, mm²**	**3.98**	**3.98**	**4.64**

D-2 THE THRUST FORCE EXERTED ON CONTAINER VALVE

$$T_f = P_h(\pi \times D_b^2)/400$$

		Example 1	*Example* 2	*Example* 3
	P_h =	300	350	350
P_h	Test pressure, MPa	30.00	35.00	35.00
D_b	Basic pitch diameter of external threads, mm	18.01	18.01	18.01
T_f	**Thrust force, N**	**76.4**	**89.2**	**89.2**

NOTE — From example 2 and 3 it is clear that to maintain minimum factor of safety at 350 bar pressure, number of engaged threads needs to be increase from 6 to 7.

D-3 AVERAGE SHEAR STRESS ON INTERNAL THREADS

$$S_s = T_f / A_{sn}$$

		Example 1	*Example* 2	*Example* 3
S_s	**average stress on internal threads, in MPa**	**19.20**	**22.41**	**19.21**

D-4 FACTOR OF SAFETY (FoS)

$$FoS = \frac{UTSO}{S_s} \geq 10$$

$$UTSO = 0.65 \times R_g$$

		Example 1	*Example* 2	*Example* 3
R_g	Minimum guaranteed value of tensile strength for the finished cylinder, in MPa	325	325	325
UTSO	Ultimate Shear Strength of Opening, MPa	211.25	211.25	211.25
FoS	**Factor of safety**	**11.0**	**9.4**	**11.0**
	Is requirement of factor of safety met?	Yes	No	Yes

NOTE — From example 2 and 3 it is clear that to maintain minimum factor of safety at 350 bar pressure, number of engaged threads to be 7.

ANNEX E

(*Clause* 9)

PROTOTYPE TESTING AND PRODUCTION TESTING

E-1 PROTOTYPE TESTING

E-1.1 Prototype testing shall be carried out for each new design of cylinder. 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;

b) It is manufactured by a different process (this includes the case when major process changes are made during the production period);

c) It is manufactured from an alloy of different specified composition limits from that used in the original prototype test;

d) It is given a different heat treatment that is outside the tolerances specified in **5.2.3**;

e) The base profile has changed. For example concave, convex, hemispherical or there is a change in the base thickness;

f) The overall length of the cylinder has increased by more than 50 percent (cylinders with a length/diameter ratio less than 3 shall not be used as reference cylinders for any new design with this ratio greater than 3);

g) The nominal outside diameter has changed;

h) The guaranteed minimum thickness *a′* has been decreased;

j) The hydraulic test pressure has been changed (where a cylinder is to be used for a lower pressure duty than that for which design approval has been given, it shall not be deemed to be of a new design); and

k) The guaranteed minimum yield stress (R_e) and/or the guaranteed minimum tensile strength (R_g) have changed.

E-1.2 The applicant for prototype testing shall, for each new design of cylinder, submit the documentation necessary for the checks specified below and make available to the relevant authority a batch of at least 50 cylinders from which the number of cylinders required for the tests referred to below shall be taken together with any additional information required.

However, if the total production is less than 50 cylinders, enough cylinders shall be made to complete the prototype test required, in addition to the production quantity, but in this case the approval validity is limited to this particular production batch or batches of this size.

In particular, the applicant shall indicate the type of heat treatment and mechanical treatment, and the temperature and the duration of treatment under **5.2**. He shall provide cast analysis certificates for materials used in the manufacture of the cylinders. Every cylinder submitted to any test shall be identified to the batch.

E-1.3 In the course of the prototype testing process, the relevant authority shall:

a) Verify that:

1) Thickness of the walls and ends of two of the cylinders taken for tests meet the requirement of **6.2** and **6.3**, the measurements being taken on three transverse sections of the cylindrical part and over the whole of a longitudinal section of the base and the head;

2) Requirements of **5.1** (material) are complied with;

3) Geometrical requirements of **7.8** to **7.11** are complied with for all cylinders selected by the relevant authority;

4) Internal and external surfaces of the cylinders are free of any defect which might make them unsafe to use (*see* Annex D); and

5) Sustained-load-cracking test (*see* Annex B) has been completed satisfactorily.

b) Witness the following tests on the cylinders selected:

1) Tests for resistance to corrosion on one cylinder, or two if the size of the cylinder does not allow it (inter-crystalline corrosion and stress corrosion as described in Annex A);

2) It is not necessary to carry out these when only condition **E-1.1** (e) applies and/or when the nominal outside diameter has changed by less than 20 percent;

3) Tests specified in **8.1** (tensile and bend tests) on two cylinders; where the length of the cylinder is 1 500 mm or more, the tensile tests in a longitudinal direction and the bend tests shall be carried out on test pieces taken from the upper and lower regions of the shell;

4) Tests specified in **8.2** (hydraulic burst test) on two cylinders; and

5) Tests specified in **8.3** (pressure cycling test), on two cylinders.

E-1.4 If the results of the checks are not satisfactory, proceed as described in **E-3**.

If the results of the test are satisfactory, the relevant authority shall issue a prototype testing certificate. This prototype testing certificate may be in the form of a type approval certificate, a typical example of which is given in Annex G.

E-2 PRODUCTION TESTING

E-2.1 For the purpose of production testing, the cylinder manufacturer shall provide in inspection body with:

a) prototype testing certificate;

b) cast ingot analysis certificates of the materials used for the manufacture of the cylinders;

c) means of identifying the cast of material from which each cylinder was made. Every cylinder shall be identifiable to the batch;

d) a statement of the processes utilized as specified in **5.2** and the relevant documentation relating to the heat and mechanical treatment (*see* Annex G);

e) serial number of the cylinders; and

f) a statement of the thread checking method used and results thereof.

E-2.2 During production testing the inspection body shall:

a) ascertain that the prototype testing certificate has been obtained and that the cylinders conform to it;

b) check the documents which give data concerning the materials;

c) check whether the technical requirement set out in **5**, **6** and **7** have been met and in particular check by an external and, if physically possible, internal, visual examination of the cylinders whether their construction and the checks carried out by the manufacturer in accordance with **7.5**, **7.6** and **7.7** are satisfactory; the visual examination shall cover at least 10 percent of the cylinders manufactured. If one unacceptable defect is found (as described in Annex D), 100 percent of the cylinders shall be inspected;

If an internal visual examination is not physically possible, an alternative inspection method and the percentage of cylinders to be checked shall be agreed by the manufacturer and the inspection body;

d) witness the two types of test prescribed in **8.1** and **8.2** carried out on two cylinders that shall be taken at random from each batch of cylinders or part thereof that have been made from the same cast and have undergone the specified heat treatment in identical circumstances; one of the cylinders shall be subjected to the tests in **8.1** (mechanical tests) and the other to the test prescribed in **8.2** (burst test);

e) supervise the selection of specimens and all the tests to be carried out;

f) assess the result of the checks on the homogeneity of the batch carried out on every cylinder by the manufacturer in accordance with **8.5** (homogeneity); and

g) check the marking (*see* **10**).

E-2.3 After all the tests specified have been carried out, all the cylinders in the batch shall be subjected to the hydraulic test specified in **8.4**.

E-2.4 If the results of the checks are satisfactory, the inspection body shall stamp the cylinders in accordance with marking as given in **10** and shall issue a production test certificate, a typical example of which is given in Annex F. If the results of the checks are not satisfactory, proceed as described in **E-3**.

E-3 FAILURE TO MEET TEST REQUIREMENTS

The following procedure can be used both for prototype and production testing. In the event of failure to meet test requirements, retesting or reheat treatment and retesting shall be carried out, as follows:

E-3.1 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 the results of this test are satisfactory, the first test shall be ignored.

E-3.2 If the test has been carried out in a satisfactory manner, the cause shall be identified or the batch shall be scrapped:

a) If the failure is due to the heat treatment applied, the manufacturer may subject all the cylinders of the batch to further reheat treatment(s) for maximum 2 times.
b) The cylinders may be re-solution treated and artificially aged, or alternatively additional time at the ageing treatment temperature may be given.
c) If the failure is not due to the heat treatment applied, all the identified defective cylinders shall be scrapped or repaired by an approved method. The remaining and repaired cylinders shall then be considered as a new batch.

In both cases, this new batch shall be re-tested by the inspection body. All the prototype or production tests shall be performed again. If any test or part of a test is unsatisfactory, all the cylinders of the batch shall be scrapped.

ANNEX F

(*Clause* E-2.4)

DESCRIPTION, EVALUATION OF MANUFACTURING DEFECTS AND CONDITIONS FOR REJECTION OF SEAMLESS ALUMINIUM ALLOY GAS CYLINDER AT TIME OF VISUAL INSPECTION

F-1 INTRODUCTION

Several types of defects can occur during the manufacture of a seamless aluminium alloy gas cylinder.

Such defects can be mechanical or material. They can be due to the basic material used, the manufacturing process, heat treatment, manipulations, necking, machining or marking operations and other occurrences during manufacture.

The aim of this Annex is to identify the manufacturing defects most commonly met and to provide rejection criteria to the inspectors who shall perform the visual inspection.

Nevertheless extensive field experience and good judgment are necessary by the inspector to detect and to be able to evaluate and judge a defect at time of the visual inspection.

F-2 GENERAL

F-2.1 It is essential to perform the visual internal and external inspection in good conditions.

The surface of the metal and particularly of the inner wall shall be completely clean, dry and free from oxidation products, corrosion and scale since these could obscure other more serious defects. Where necessary, the surface shall be cleaned under closely controlled conditions by suitable methods before further inspection.

Appropriate sources of illumination with sufficient intensity shall be used.

After the cylinders have been closed and the threads have been cut, the internal neck area shall be examined by means of an introscope, dental mirror or other suitable appliance.

F-2.2 Small defects may be removed by local dressing, grinding, machining, or other appropriate method.

Great care shall be taken to avoid introducing new injurious defects.

After such a repair, cylinders shall be re-examined and, if necessary, the wall thickness shall be rechecked.

F-3 MANUFACTURING DEFECTS

The most commonly found manufacturing defects and their definitions are listed in Table 4.

Rejection limits for repair or scrap are included in this table. These rejection limits have been established following considerable field experience. They apply to all sizes and types of cylinders and service conditions. Nevertheless some customer specifications, some types of cylinders or some special service conditions may require more stringent criteria.

Table 4 Manufacturing Defects

(*Clause* F-3)

Sl No. (1)	Defect (2)	Description (3)	Conditions and/or Actions (4)	Repair or Scrap (5)
i)	Bulge	Visible swelling of the wall	All cylinders with such a defect	Scrap
ii)	Dent	A visible depression in the wall that has neither penetrated nor removed metal. (*see* Fig. 22) (*see also* excessive grinding or machining)	a) When the depth of the dent exceeds 2 percent of the external diameter of the cylinder, or 2 mm, whichever is the smallest b) When the diameter of the dent is less than 30 times its depth NOTE — On small diameter cylinders these general limits may have to be adjusted. Consideration of appearance also plays a part in the evaluation of dents, especially in the case of small cylinders.	Scrap
iii)	Cut, gouge metallic or scale impression	An impression in the wall where metal has been removed or re-distributed (due basically to the introduction of foreign bodies on the mandrel or matrix during extrusion or drawing operations)	*Inside defect:* If more than 5 percent of the wall thickness, if remaining wall thickness below the defect is less than *a′*, if with sharp notches or if the length exceeds 5 times the thickness of the cylinder NOTE — Consideration of appearance and localization (in thicker parts with lower stresses) can be taken into account	Scrap
			Outside defect: Where the depth exceeds 5 percent of the wall thickness, or the remaining wall thickness below defect is less than *a′*	Scrap
			Outside defect: Where the depth is less than 5 percent of the wall thickness and the remaining wall thickness below defect is greater than *a′*	Repair, if possible (*see* **F-2.2**)
iv)	Dent containing cut or gouge	A depression in the wall which contains a cut or gouge (*see* Fig. 23)	All cylinders with such defects	Scrap
v)	Excessive grinding or Machining[1)]	Local reduction of wall thickness by grinding or machining	a) When the wall thickness is reduced to below the minimum design thickness	Scrap
			b) When it results in the formation of a dent	*See* 'dent'
vi)	Ridge or rib[1)]	A longitudinal raised surface with sharp corners (*see* Fig. 24)	*Inside defect:* If the height exceeds 5 percent of the wall thickness	Scrap
			Outside defect: Where the height exceeds 5 percent of the wall thickness	Repair, if possible (*see* **F-2.2**)
vii)	Groove	A deep longitudinal notch (*see* Fig. 25)	*Inside defect:* If the depth exceeds 5 percent of the wall thickness or if the remaining wall thickness below the defect is less than *a′*	Scrap
			Outside defect: Where the depth exceeds 5 percent of the wall thickness or the remaining wall thickness below the defect is less than *a′*	Repair, if possible (*see* **F-2.2**)

Table 4 (*Continued*)

Sl No. (1)	Defect (2)	Description (3)	Conditions and/or Actions (4)	Repair or Scrap (5)
viii)	Lamination[1)]	Laying of the material within the cylinder wall and sometimes appearing as a discontinity, crack, lap or bulge at the surface (*see* Fig. 26)	*Inside defect:* All cylinders with such defect	Scrap
			Outside defect: All cylinders with such defect	Repair, if possible (*see* **F-2.2**)
ix)	Blister[1)]	Small bulge on the wall containing a continuous layer of inclusions	*Inside defect:* All cylinders with such defect	Scrap
			Outside defect: All cylinders with such defect not necessary to repair if clearly insignificant to cylinder performance	Repair, if possible (*see* **F-2.2**)
x)	Crack	A split or rift in the metal	All cylinders with such defects	Scrap
xi)	Neck cracks	Appear as lines which run vertically down the thread and across the thread faces (they should not be confused with tap marks or thread machining marks) (*see* Fig. 27)	All cylinders with such defects	Scrap
xii)	Shoulder folds	Folding with peaks and troughs situated in the internal shoulder area, which can propagate into the threaded area of the shoulder (*see* Fig. 28)	Folds or cracks that are visible as a line of oxide running into the threaded portion shall be removed by a machining operation until the lines of oxide are no longer visible (*see* Fig. 27). After machining, the whole area shall be re-inspected carefully and the wall thickness verified	Repair
xiii)	And/or Shoulder cracks	Can start from folds in the internal shoulder area and propagate into the cylindrical machined or threaded area of the shoulder (*see* Fig. 29 shows where shoulder cracks start and how they propagate)	If folding or lines of oxide have not been removed by machining, if cracks are always visible or if wall thickness is unsatisfactory	Scrap
			If folding or lines of oxide have been removed by machining and the wall thickness is satisfactory	Acceptable
			Folds which extend beyond the machined area and are clearly visible as open depressions where no oxides have been trapped into the metal, shall be accepted provided that the peaks are smooth and the root of the depression is rounded	Acceptable
xiv)	Internal threads damaged or out of tolerance	Threads damaged, with dents, cuts, burrs or out of tolerance	a) When the design permits, threads may be re-tapped and re-checked by the appropriate thread gauge and carefully visually re-examined. The appropriate number of effective threads shall be achieved.	Repair
			b) If not repairable	Scrap

Table 4 *(Concluded)*

Sl No. (1)	Defect (2)	Description (3)	Conditions and/or Actions (4)	Repair or Scrap (5)
xv)	Pitting	Pitting due to bad acid cleaning or corrosion due to storage in bad conditions	*Inside defects:* All cylinders with such defects	Scrap
			Outside defects: All cylinders with such defects	Repair, if possible (*see* F-2.2)
xvi)	Non-conformity with design drawing[1)]	Non-conformity with design drawing (for example neck or bottom form and dimensions, out of straightness, stability, lack of thickness)	All cylinders presenting such a defect	Repair, if possible or scrap
xvii)	Neck ring not secure	Neck ring turns under application of low torque or pulls off under low axial load (*see* 6.4.3)	All cylinders presenting such a defect	Repair, if possible or scrap
xviii)	Arc or torch burns	Partial burning of the cylinder metal, the addition of weld metal or the removal of metal by scarfing or cratering	All cylinders presenting such a defect	Scrap

NOTE — Lubrication marks which arise during the extrusion process, as a result of the metal working lubricant failing to provide a continuous lubricating film over the full length of the extrusion stroke and which can be inside or outside are subject to a standard agreed between manufacturer, relevant inspection authority and user or customer. Such marks may cause the cylinder to be scrapped.

1) This inside defect, when detected before necking, can be repaired if possible prior to closure.

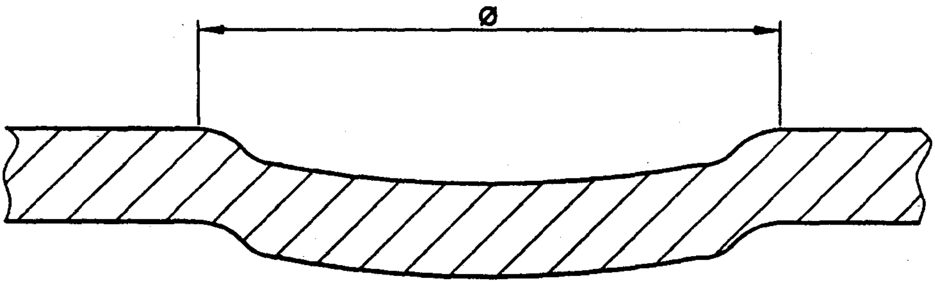


FIG. 22 DENT

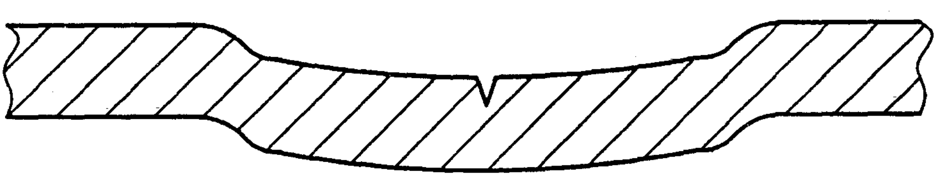


FIG. 23 DENT CONTAINING CUT OR GOUGE

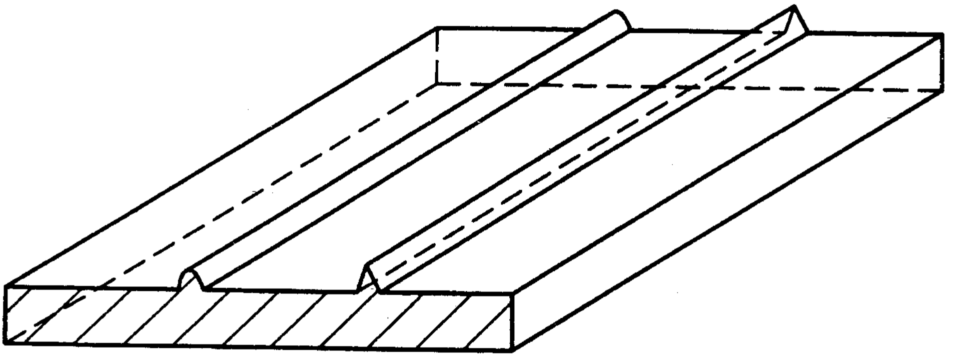


FIG. 24 RIDGES OR RIBS

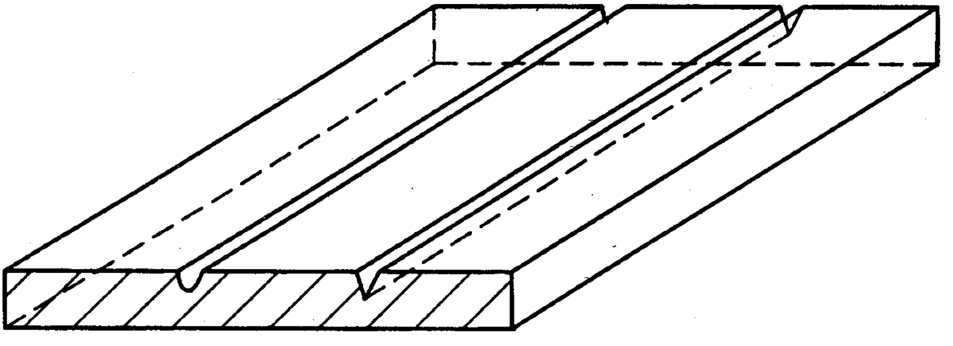


FIG. 25 GROOVES

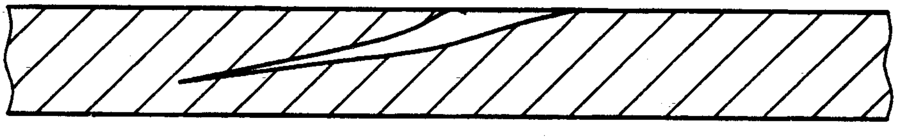
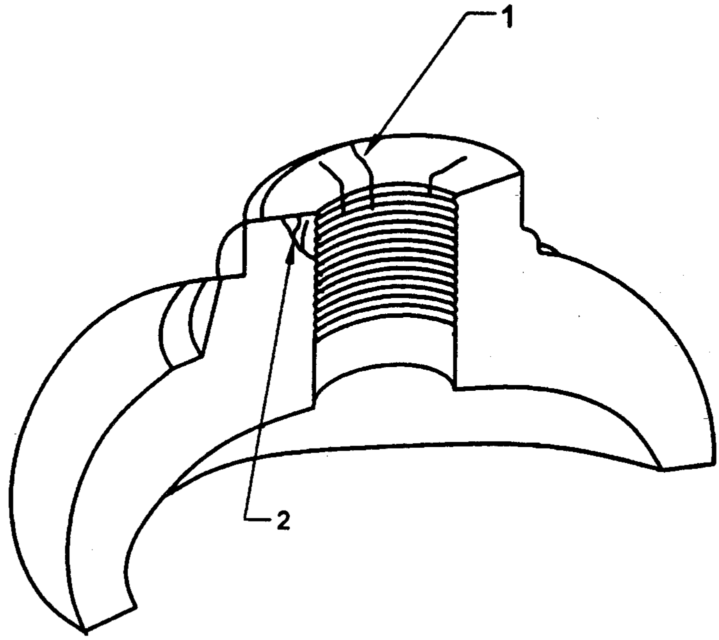


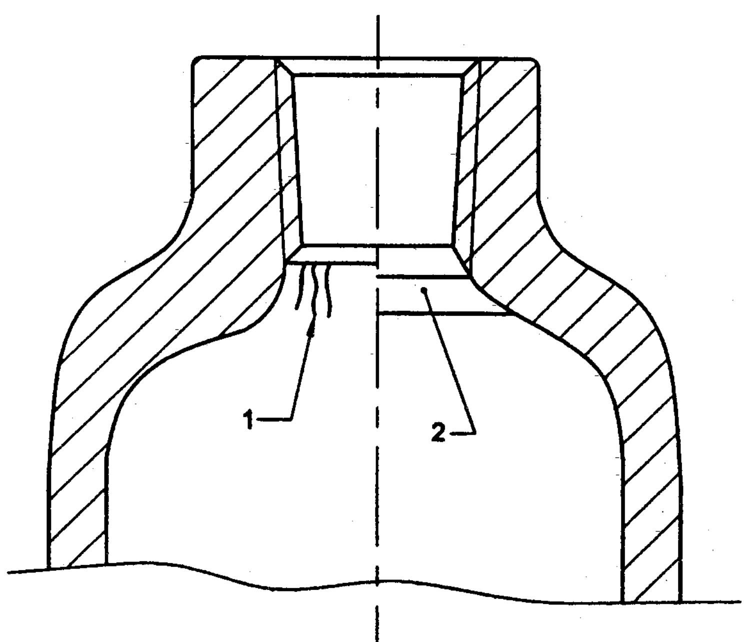
FIG. 26 LAMINATION



Key

1. Neck cracks
2. Propagated crack in the neck

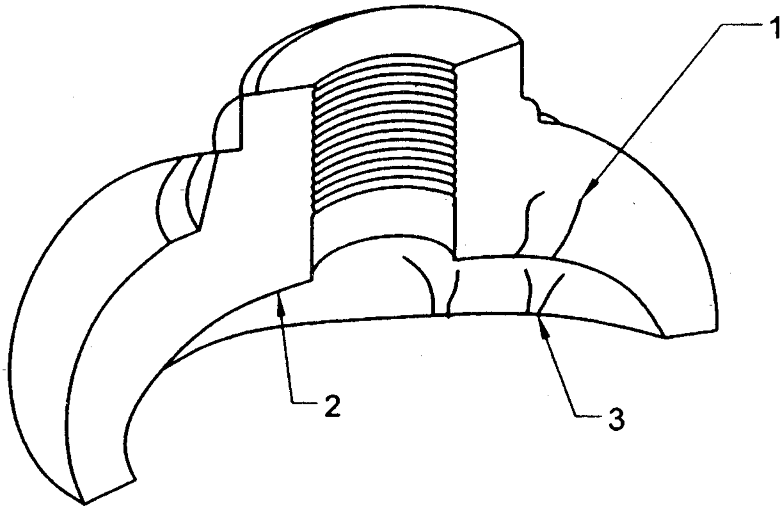
FIG. 27 NECK CRACKS



Key

1. Folds or cracks
2. After machining

FIG. 28 CYLINDER SHOULDER FOLDS OR CRACK BEFORE AND AFTER MACHINING



Key

1. Shoulder cracks
2. Propagated crack in the shoulder
3. Folds

FIG. 29 SHOULDER CRACKS

ANNEX G

(*Clauses* E-1.4 *and* E-2.1)

EXAMPLE OF TYPE APPROVAL AND PRODUCTION TESTING CERTIFICATES

G-1 TYPE APPROVAL CERTIFICATE

Issued by .... (*Relevant authority*) .... on the basis

of .... applying

IS: .... concerning seamless aluminium alloy gas cylinders

Approval No. .... Date ....

Type of cylinder .... (Description of the family of cylinders which has received type approval)

....

P_h .... D_{Min} .... D_{Max} .... a' .... b ....

L_{Min} .... L_{Max} .... V_{Min} .... V_{Max} ....

Manufacturer or agent .... (Name and address of manufacturer or its agents) ....

....

....

....

Type approval mark ....

Details of results of the examination of the type for type approval and the main features of the type are attached (*see* Table 5 and Table 6).

All information may be obtained from .... (Name and address of the approving body) ....

....

....

....

Date .... Place ....

....

Signature ....

G-2 COMMENTS FOR USE WITH TYPE APPROVAL CERTIFICATE

a) Result of type approval examination of the type with type approval details should be attached.

b) Main features of the type should be shown, in particular:

1) Longitudinal cross-section drawing of the type of cylinder which has received type approval, showing:

i) Minimum and maximum nominal external diameter, D_{Min} and D_{Max}, with an indication of the design tolerances laid down by the manufacturer;

ii) Guaranteed minimum thickness of the cylinder wall (a);

iii) Guaranteed minimum thickness of the base (b) and of the head with an indication of the design tolerances laid down by the manufacturer;

2) Minimum and maximum length (s), L_{Min}, L_{Max}, (L being the distance from the outside of the base of the shell to the top surface of the cylinder neck);

3) Water capacity or capacities, V_{Min}, V_{Max};

4) Hydraulic test pressure, P_h;
5) Name of the manufacture/Number of the drawing and date;
6) Name of the type of cylinder;
7) Alloy in accordance with 5 [nature/chemical composition/method of manufacture/hear treatment/ guaranteed mechanical characteristics (tensile strength, yield stress)].

G-3 PRODUCTION TEST CERTIFICATE

Application of IS ....

Inspection body ....

....

Date ....

Type approval No. ....

Description of cylinders ....

Production testing No. ....

Manufacturing batch No. .... to ....

Manufacturer .... (Name and address) ....

....

Country .... Mark ....

Owner .... (Name and address) ....

....

Customer .... (Name and address) ....

....

Table 5 Production Tests — Measurements of Sample Cylinders

(*Clause* G-1)

Sl No.	Test No.	Batch Consisting of No .... to No	Water Capacity litre	Mass Empty kg	Minimum Measured Thickness	
					Of the Wall mm	Of the Base mm
(1)	(2)	(3)	(4)	(5)	(6)	(7)

Table 6 Production Tests — Mechanical Tests Carried Out on Sample Cylinders
(*Clause* G-1)

Test/ Batch	Cast No.	Heat Treatment	Tensile Test Test-Pieces in Accordance with IS 1608 Yield Stress R_{ea}, MPa Tensile Strength R_m, MPa Elongation, *A* percent	Bend Test 180° Without Cracking	Hydraulic Burst Test Pressure	Description of the Fracture
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Minimum values specified						

I, the undersigned hereby declare that I have checked that the requirements of **E-2** of IS 15660 have been carried out satisfactorily.

Special remarks ....

....

General remarks ....

....

Certified on (date) .... Place ....

.... Signature of the inspector ....

On behalf of .... (Inspection body) ....

ANNEX H

(Foreword)

GASES NOT TO BE CONTAINED IN ALUMINIUM ALLOY CYLINDERS

H-1 Subject to the exceptions stated, the following gases shall not be contained in aluminium alloy cylinders. Certain of these gases may however be contained in aluminium alloy cylinders in small quantities as components of gas mixtures. Approval for such use shall be sought from the competent authority.

a) Acetylene,

b) Boron trifluoride,

c) Bromotrifluoroethylene,

d) Carbonyl chloride,

e) Chlorine,

f) Chlorine trifluoride,

g) Cyanogen chloride,

h) Fluorine,

j) Hydrogen bromide,

k) Hydrogen chloride,

m) Hydrogen fluoride,

n) Methyl bromide,

p) Methyl chloride, and

q) Nitrosyl chloride.

ANNEX J

(Foreword)

COMMITTEE COMPOSITION

Gas Cylinders Sectional Committee, ME 16

Organization	*Representative(s)*
Petroleum and Explosives Safety Organization (PESO), Nagpur	SHRI M. ANBUNATHAN (***Chairman***) SHRI C. R. SURENDRANATHAN (*Alternate*)
All India Industrial Gases Manufacturers Association, New Delhi	SHRI R. P. KHATOR SHRI S. DEB (*Alternate*)
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This Indian Standard has been developed from Doc : No. **ME 16 (0774).**

Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

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Printed at New India Printing Press, Khurja, India