Refillable seamless steel gas cylinders

0 Introduction

The purpose of this International Standard is to facilitate agreement on the design and manufacture of refillable seamless steel gas cylinders in all countries. The specifications given in clauses 1 to 10 are based on knowledge of, and experience with materials, design requirements, manufacturing processes and control at manufacture of cylinders in common and safe use in many countries of ISO member bodies.

However, some ISO member countries have special requirements :

a) a specified chemical composition of the material for the manufacture of cylinders;

b) proof of safe performance under all conditions of service;

c) a limitation of design stresses;

d) safe-guarding of satisfactory cylinder performance by tests not covered by clauses 1 to 10.

These special requirements are specified in annex D. Cylinders made to ISO 4705 and to which the requirements of annex D have been applied are suitable for worldwide usage subject to approval and control by national authorities.

Users of this International Standard and its annexes are requested to document the manner in which they are applied, to record their experience and transmit this information to the ISO Central Secretariat so that it may be made available to Technical Committee ISO/TC 58 for appropriate future amendment.

1 Scope and field of application

This International Standard specifies minimum requirements for certain aspects concerning material, design, construction and workmanship, manufacturing processes and test at manufacture of refillable seamless steel gas cylinders of water capacities from 1 to 150 L inclusive for compressed, liquefied or dissolved gases, exposed to ambient temperatures.

2 References

ISO 82, *Steel — Tensile testing.*

ISO/R 85, *Bend test for steel.*

ISO 86, *Steel — Tensile testing of sheet and strip less than* 3 mm *and not less than* 0,5 mm *thick.*

ISO 148, *Steel — Charpy impact test (V-notch).*[1]

ISO 2604, *Steel products for pressure purposes — Quality requirements.*

ISO 3166, *Codes for the representation of names of countries.*

ISO 6506, *Metallic materials — Hardness test — Brinell test.*

3 Definitions and symbols

3.1 Definitions

3.1.1 yield stress : See ISO 82 or ISO 86.

Throughout this International Standard, the term "yield stress" means the upper yield stress R_{eH}, or, for steels that do not exhibit a defined yield, the 0,2 % proof stress (non-proportional elongation) $R_{p0,2}$.

3.1.2 normalizing : Heat treatment in which a cylinder is heated to a uniform temperature above the upper critical point (Ac_3) of the steel and then cooled in still air.

3.1.3 quenching : Hardening heat treatment in which a cylinder which has been heated to a uniform temperature above the upper critical point (Ac_3) of the steel is cooled rapidly in a suitable medium.

3.1.4 tempering : Softening heat treatment which follows quenching (or in some cases normalizing), in which the cylinder is heated to a uniform temperature below the lower critical point (Ac_1) of the steel.

3.1.5 batch : A quantity up to 200 cylinders plus cylinders for destructive testing, of the same nominal diameter, thickness and design, made from the same steel and subjected to the same heat treatment at the same time. The lengths of the cylinders in a heat treatment batch may vary by up to 12 %.

1) At present at the stage of draft. (Revision of ISO/R 148-1960.)

3.2 Symbols

a : Calculated minimum thickness, in millimetres, of the cylindrical shell (see figure 1).

a_1 : Guaranteed minimum thickness, in millimetres, of a concave base at the knuckle (see figure 2).

a_2 : Guaranteed minimum thickness, in millimetres, at the centre of a concave base (see figure 2).

A : Percentage elongation.

b : Guaranteed minimum thickness, in millimetres, at the centre of a convex base (see figure 1).

d_1 and d_2 : Burst profile, in millimetres (see figures 7 and 8).

D : Outside diameter of the cylinder, in millimetres (see figure 1).

D_F : Diameter of former, in millimetres (see figure 5).

h : Outside height (concave base end), in millimetres (see figure 2).

H : Outside height of domed part (convex head or base end), in millimetres (see figure 1).

L_o : Original gauge length, in millimetres, according to ISO 82 and ISO 86 (see figure 4).

n : Ratio of diameter of bend test former to actual thickness of test piece.

p_b : Calculated burst pressure, in bar[1)], above atmospheric pressure.

p_h : Hydraulic test pressure, in bar, above atmospheric pressure.

r : Inside knuckle radius, in millimetres (see figures 1 and 2).

R_e : Minimum value of yield stress (see 3.1.1), in newtons per square millimetre, guaranteed by the cylinder manufacturer for the finished cylinder.

R_{ea} : Value of the actual yield stress, in newtons per square millimetre, as determined by the tensile test specified in 7.2.1.

R_g : Minimum value of tensile strength, in newtons per square millimetre, guaranteed by the cylinder manufacturer for the finished cylinder.

R_m : Actual value of tensile strength, in newtons per square millimetre, determined by the tensile test specified in 7.2.1.

S_o : Original cross-sectional area of tensile test piece, in square millimetres, according to ISO 82 and ISO 86.

t : Actual thickness of the test piece, in millimetres.

t_m : Average cylinder wall thickness at the position of testing (see table 4).

w : Width, in millimetres, of tensile test piece [see figure 4a)].

1) 1 bar = 10^5 Pa = 0,1 N/mm^2

4 Materials

4.1 General provisions

4.1.1 The material used for the fabrication of gas cylinders shall be steel, other than rimming quality, with acceptable non-ageing properties.

In cases where examination of this non-ageing property is required by the customer, the criteria by which it is to be specified should be agreed with the customer and inserted in the order.

4.1.2 The cylinder manufacturer shall establish means to identify the cylinders with the casts of steel from which they are made.

4.2 Heat treatment

The cylinder manufacturer shall certify the heat treatment process applied to the finished cylinders.

Quenching in media other than oil is permissible provided that the manufacturer proves that the method produces cylinders free of cracks.

Quenching in water without additives shall not be used.

If the rate of cooling in the medium is greater than 80 % of that in water at 20 °C, without additives, every production cylinder shall be subjected to a method of non-destructive testing.

The tempering temperature for quenched and tempered cylinders and for normalized and tempered cylinders shall be not less than 455 °C.

4.3 Chemical composition

4.3.1 The following limits on sulphur and phosphorus shall not be exceeded in the cast analysis of material used for the fabrication of gas cylinders :

sulphur : 0,04 %

phosphorus : 0,04 %

sulphur plus phosphorus : 0,07 %

4.3.2 The cylinder manufacturer shall obtain and provide certificates of cast (heat) analyses of the steels supplied for the construction of gas cylinders.

Should check analyses be required, they shall be carried out either on specimens taken during manufacture from material in the form as supplied by the steelmaker to the cylinder manufacturer, or from finished cylinders. In any check analysis, the maximum permissible deviation from the limits specified for cast analyses should conform to the values specified in ISO 2604.

4.4 Test requirements

The material of the finished cylinders shall satisfy the requirements of clause 7.

4.5 Failure to meet test requirements

In the event of failure to meet test requirements, retesting or reheat treatment and retesting shall be carried out, as follows.

4.5.1 If there is evidence of a fault in carrying out a test, or an error of measurement, a second test shall be performed. If the results of this second test are satisfactory, the first test shall be ignored.

4.5.2 If the test has been carried out satisfactorily, the procedure detailed in 4.5.2.1 or 4.5.2.2 shall be followed.

4.5.2.1 Two further cylinders shall be selected and subjected to the tests stipulated in 7.1.3.1 and/or 7.1.3.2, as appropriate. If the results of the tests on both cylinders meet the specified requirements, the batch of cylinders shall be deemed to comply with this International Standard. If either cylinder fails, the batch of cylinders shall be rejected or reheat treated and retested.

4.5.2.2 The batch of cylinders represented by the test shall be reheat treated and retested.

4.5.3 Reheat treatment

4.5.3.1 Normalized cylinders may be tempered or renormalized.

4.5.3.2 Normalized and tempered cylinders shall be retempered or renormalized and tempered.

4.5.3.3 Quenched and tempered cylinders shall be retempered or requenched and tempered.

4.5.3.4 Whenever cylinders are reheat treated, the minimum design wall thickness shall be maintained.

4.6 Hardness requirements

The material shall satisfy the requirements of 8.2.

5 Design

5.1 General provisions

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

5.1.2 For calculation purposes, the value of the yield stress (R_e) is limited to a maximum of 0,75 R_g for normalized and tempered cylinders, and 0,90 R_g for quenched and tempered cylinders.

5.1.3 The internal pressure upon which the calculation of wall thickness is based shall be the hydraulic test pressure (p_h).

5.2 Calculation of cylindrical shell thickness

The wall thickness of the cylindrical shell shall be not less than that calculated using the formula

$$a = \frac{p_h D}{\frac{20 R_e}{1,3} + p_h}$$

except that the wall thickness shall also satisfy the formula

$$a > \frac{D}{250} + 1 \text{ mm}$$

with an absolute minimum of a = 1,5 mm.

5.3 Calculation of convex ends (heads as well as base ends)

The shapes shown in figure 1 are typical of convex heads and base ends. Shapes A and B are base ends formed from tubing, shapes D and E are base ends formed during the piercing of a billet, and shapes C and F are heads.

5.3.1 The thickness (b) at the centre of a convex end shall be not less than that required by the following criteria :

where the inside knuckle radius (r) is not less than 0,075 D, then,

— for ends forged from billets or tubes :

$b > 1,5\, a$ for $H/D > 0,20$

— or, for ends formed from plates :

$b > a$ for $H/D > 0,40$

In order to obtain a satisfactory stress distribution in the region where the end joins the shell, any thickening of the end that may be required shall be gradual from the point of juncture. For the application of this rule, the point of juncture between the shell and the end is defined by the horizontal line indicating dimension H in figure 1.

Shape B shall not be excluded by this requirement.

5.3.2 Where these conditions are not fulfilled, the cylinder manufacturer shall prove by the prototype test detailed in annex A that the design is satisfactory.

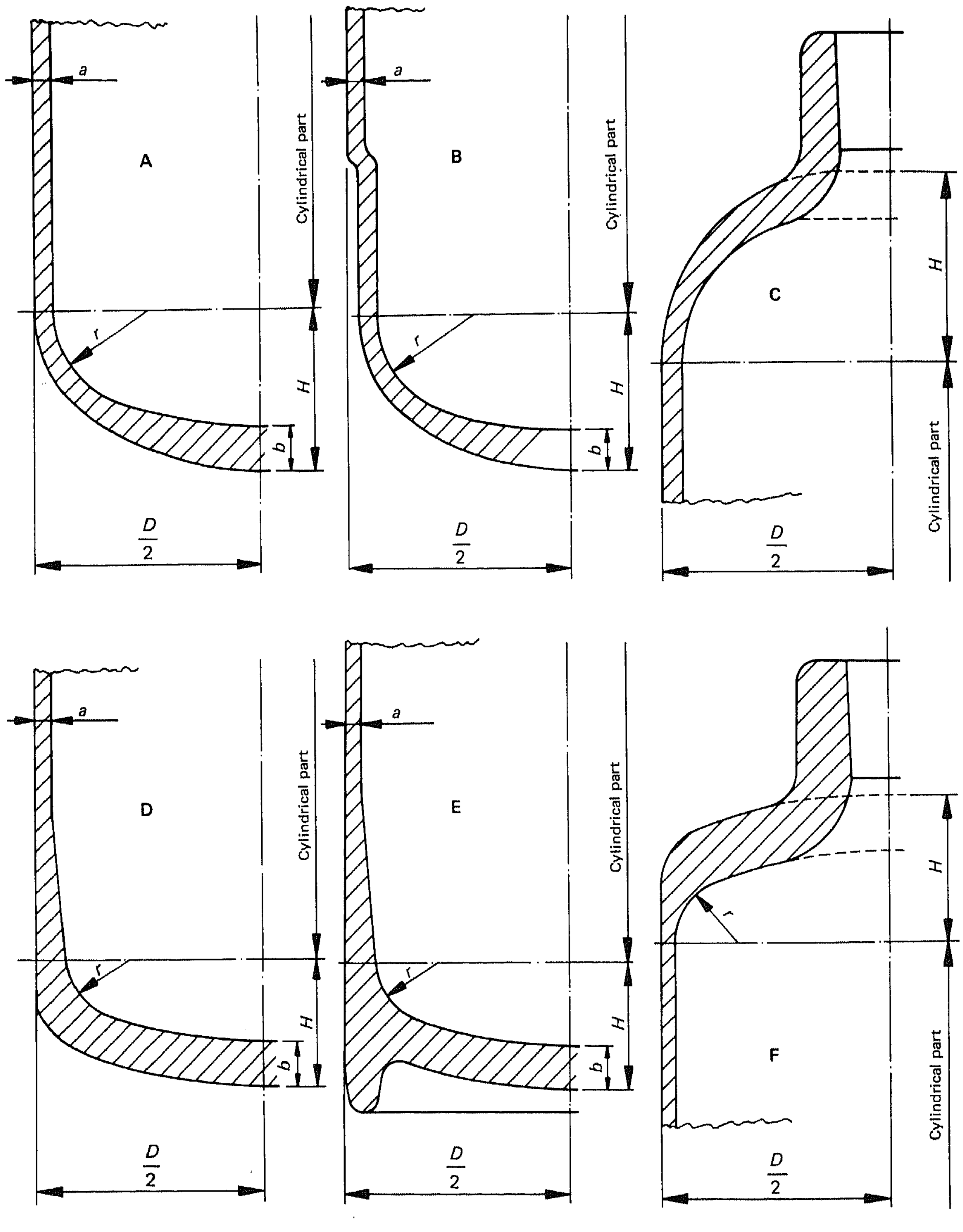


Figure 1 — Typical convex ends

5.4 Calculation of concave base ends

When concave base ends (see figure 2) are used, the design shall be such that the following minimum values can be guaranteed by the cylinder manufacturer :

$a_1 = 2\,a$

$a_2 = 2\,a$

$H = 0{,}12\,D$

$r = 0{,}075\,D$

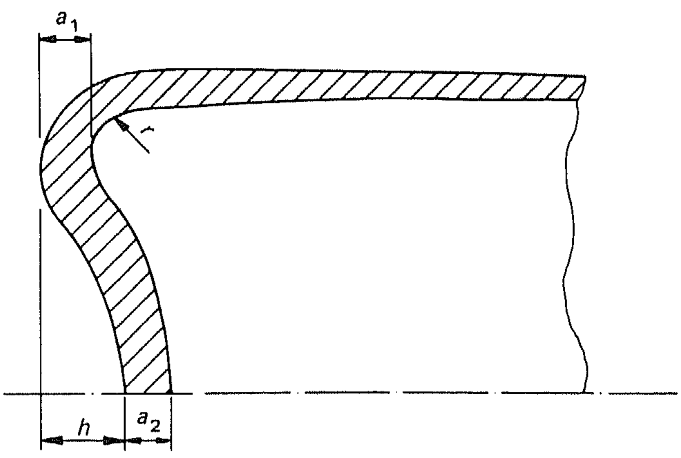


Figure 2 — Concave base end

In order to obtain a satisfactory stress distribution, the thickness of the cylinder shall increase progressively in the transition region between the cylindrical part and the base, and the wall shall be free from defects.

If these guarantees cannot be given, the cylinder manufacturer shall prove by the prototype test detailed in annex A that the design is satisfactory.

5.5 Neck design

5.5.1 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 of thread, and the sealant used in the fitting of the valve.

5.5.2 In establishing the minimum thickness, consideration shall be given to obtaining a thickness of wall in the cylinder neck which will prevent permanent expansion of the neck during the initial and subsequent fittings of the valve into the cylinder without support of an attachment, such as a neck ring.

5.6 Manufacturing drawing

A fully dimensioned drawing shall be supplied which includes the specification of the material.

6 Construction and workmanship

6.1 The cylinder shall be produced by either forging or drop forging from a solid ingot or billet, or by manufacturing from seamless tube, or by pressing from a flat plate. Metal shall not be added in the process of closure of the end.

6.2 Each cylinder shall be examined, before the closing-in operations, for thickness and for external and internal surface defects. The wall thickness at any point shall be not less than the minimum thickness specified.

6.3 The internal and external surfaces of the finished cylinder shall be free from defects which would adversely affect the safe working of the cylinder.

6.4 The out-of-roundness of the cylindrical shell, i.e. the difference between the maximum and minimum outside diameters in the same cross-section, shall not exceed 2 % of the mean of these diameters.

6.5 The neck ring, if required, shall be of material compatible with that of the cylinder, and shall be securely attached by a method other than welding, brazing or soldering.

6.6 When a foot ring is provided, it shall be sufficiently strong and made of material compatible with that of the cylinder. 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, by a method other than welding, brazing or soldering, to prevent ingress of water.

6.7 Valves of cylinders of more than 5 L water capacity shall be effectively protected from damage by either the design of the cylinder (for example protective shroud) or a strong cap which is screwed on or fitted in an equally strong manner. The means of attachment shall be other than welding, brazing or soldering.

Where cylinders are intended to be conveyed in cases or crates, these forms of protection need not apply.

7 Batch tests

7.1 General provisions

7.1.1 All tests for checking the material quality of gas cylinders shall be carried out on material from finished cylinders.

7.1.2 The tests specified in 7.1.3 shall be carried out on each batch of cylinders.

7.1.3 For each batch, the following tests are required :

7.1.3.1 On one cylinder :

a) one tensile test in the longitudinal direction (see 7.2);

b) four bend tests in a circumferential direction (see 7.3);

c) three impact tests in a longitudinal direction when the thickness of the cylinder permits the machining of a test piece at least 3 mm thick (see 7.4).

For location of test pieces, see figure 3.

7.1.3.2 On a second cylinder :

one hydraulic bursting test when the thickness of the cylinder is not greater than 7,5 mm (see 7.5).

7.2 Tensile test

7.2.1 The tensile test shall be carried out according to ISO 82 or ISO 86 on a test piece :

a) according to figure 4a) and with a gauge length $L_o = 5{,}65\sqrt{S_o}$, when the calculated wall thickness (a) is equal to or greater than 3 mm;

b) according to figure 4b), when the calculated wall thickness (a) is less than 3 mm;

c) according to figure 4c), when the calculated wall thickness (a) is less than 2 mm and the dimensions of the cylinder are such that a test piece as shown in figure 4b) cannot be obtained.

The two faces of the test piece representing the inside and the outside surfaces of the cylinder shall not be machined.

7.2.2 The percentage elongation shall be not less than the following values :

a) for cylinders made from normalized carbon, carbon-manganese, molybdenum and chromium-molybdenum steels :

1) with a calculated wall thickness not less than 3 mm :

$$A = \frac{2\,500}{0{,}224\,R_m} \text{ with an absolute minimum of 14 \%}$$

2) with a calculated wall thickness less than 3 mm but not less than 2 mm :

$$A = \frac{2\,500}{0{,}285\,R_m} \text{ with an absolute minimum of 11 \%}$$

3) with a calculated wall thickness less than 2 mm :

$$A = \frac{2\,500}{0{,}27\,R_m} \text{ with an absolute minimum of 12 \%}$$

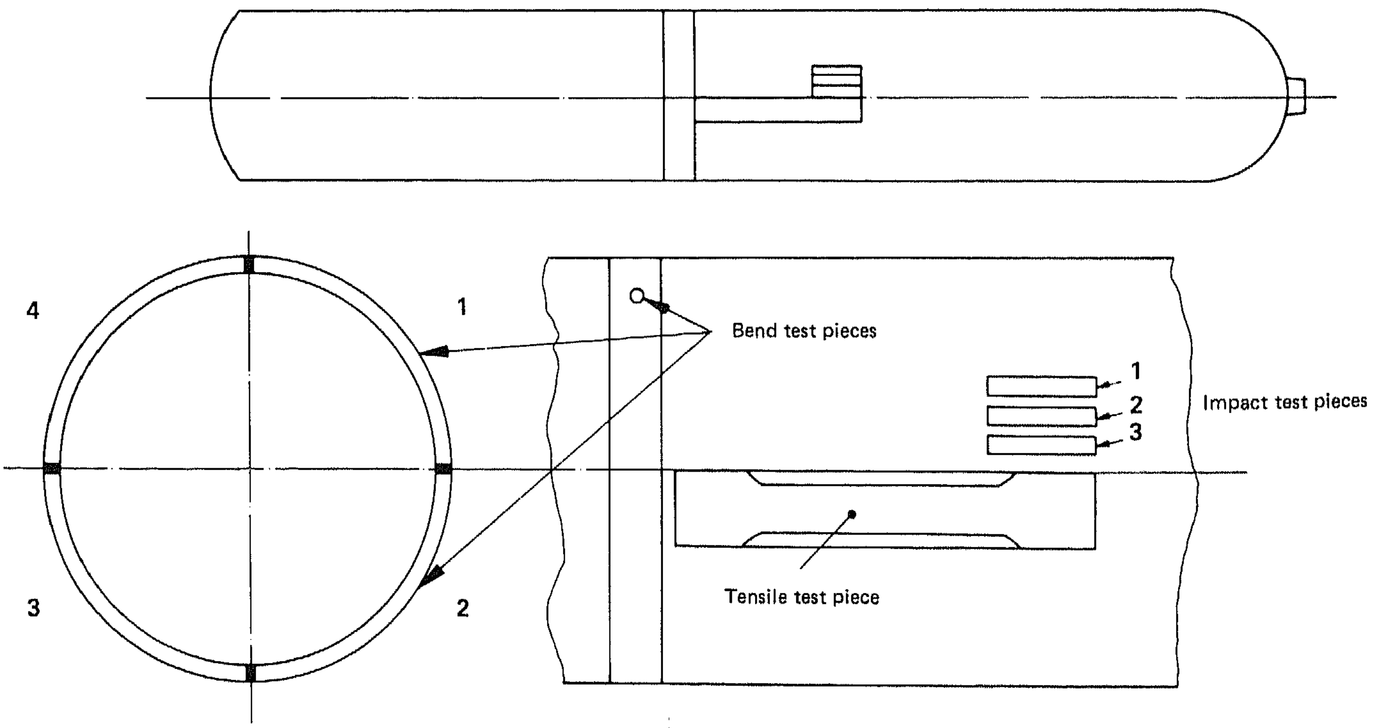


Figure 3 — Location of test pieces

b) for cylinders made from quenched and tempered steels :

1) with a calculated wall thickness not less than 3 mm :

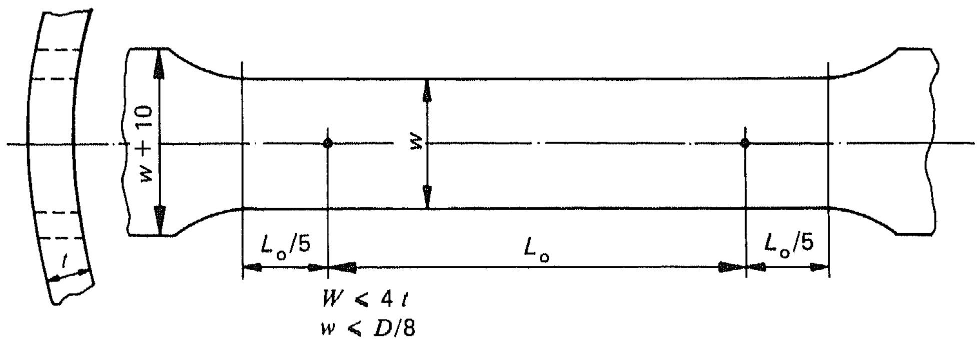
$$A = \frac{2\,500}{0{,}224\ R_m} \text{ with an absolute minimum of 14 \%}$$

2) with a calculated wall thickness less than 3 mm :

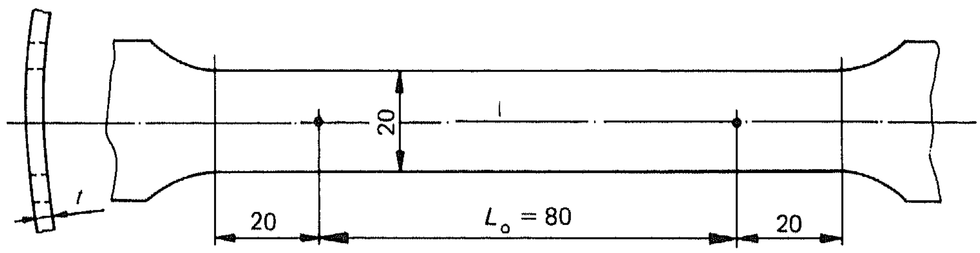
$$A = \frac{2\,500}{0{,}306\ R_m} \text{ with an absolute minimum of 9 \%}$$

NOTE — Attention is drawn to the method of measurement of elongation described in ISO 82, particularly in cases where the tensile test piece is tapered, resulting in a point of fracture away from the middle of the gauge length.

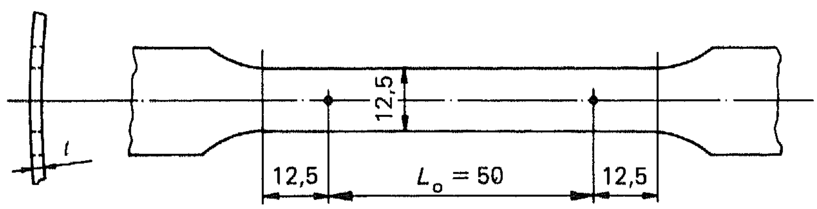
Dimensions in millimetres



a) Test piece when t > 3 mm



b) Test piece when t < 3 mm



c)Test piece when t < 2 mm and when dimensions in figure 4b) canot be obtained

Figure 4 — Tensile test pieces

7.3 Bend test

7.3.1 The bend test shall be carried out in accordance with ISO/R 85 on four test pieces obtained by cutting either one or two rings of width 25 mm or four times the thickness t, whichever is the greater. Each test piece shall be of sufficient length to permit the bend test to be carried out correctly. Only the edges of each strip may be machined.

7.3.2 The strip shall remain uncracked when bent inwards, i.e. in the direction of curvature of the cylinder wall, around a former until the interior edges are at a distance apart not greater than the diameter of the former (D_F)(see figure 5).

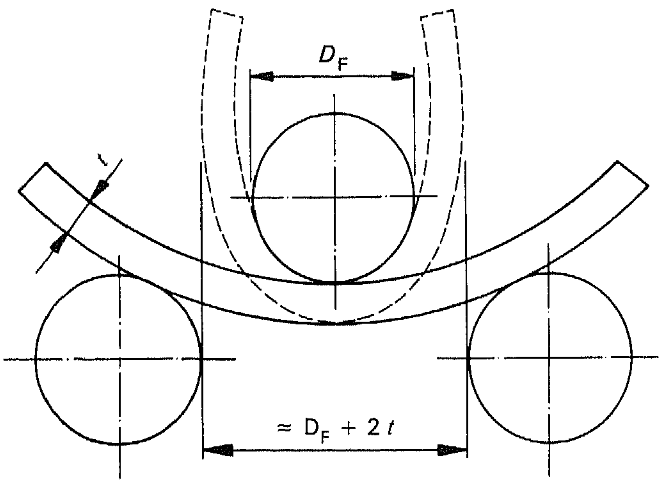


Figure 5 — Illustration of bend test

7.3.3 The diameter of the former (mandrel) shall be established from the tensile strength of the material to be tested by means of table 1, which shows the relationship between the actual tensile strength (R_m) of the material of the finished cylinder and the ratio (n) of the diameter of the former to the actual thickness of the test piece.

Table 1

Actual tensile strength, R_m N/mm^2	Value of n
$R_m < 430$	2
$430 < R_m < 510$	3
$510 < R_m < 590$	4
$590 < R_m < 690$	5
$690 < R_m < 780$	6
$780 < R_m < 890$	7
$R_m > 890$	8

7.4 Impact test

7.4.1 The impact test shall be carried out generally in accordance with ISO 148.

The impact test pieces shall be taken longitudinally from the wall of the cylinder. The notch shall be perpendicular to the face of the cylinder wall. The test piece shall be machined all over (on six faces); if the wall thickness does not permit a final test piece width of 10 mm, the width shall be as near as practicable to the nominal thickness of the cylinder wall.

7.4.2 No impact value obtained shall be less than that indicated for each case in table 2.

7.4.3 For cylinders to be used in cold climates, the impact tests shall be conducted at – 50 °C. Impact test values obtained at that temperature shall not be less than those in table 2.

Table 2

Type of steel		Carbon steel or carbon-manganese steel		Chromium-molybdenum steel or other alloyed steels	
Heat treatment		Normalized, normalized and tempered, or quenched and tempered		Quenched and tempered	
Width of test piece, mm		3 to 5	Over 5 to 10	3 to 5	Over 5 to 10
Test temperature, °C		– 20	– 20	– 20	– 20
Impact strength, J/cm^2	Mean of three specimens	36	33	60	50
	Individual specimen	29	26	50	40

7.5 Hydraulic bursting test

7.5.1 Procedure

The test shall be carried out in accordance with annex C.

7.5.2 Interpretation of test results

The following procedures shall be used for the interpretation of the test results :

a) examination of the pressure/time curve, to permit determination of the pressure at which plastic deformation of the cylinder commences, together with the bursting pressure;

b) measurement of the volume of water used from the start of the pressure rise to the moment the cylinder bursts, to permit calculation of the volumetric expansion of the cylinder;

c) examination of the tear and its edges.

7.5.3 Acceptance criteria

For the results of a bursting test to be considered satisfactory, the following requirements shall be met.

7.5.3.1 The actual burst pressure shall be greater than the calculated burst pressure established from the formula

$$p_b = 1{,}05 \frac{20\, a\, R_g}{D - a}$$

7.5.3.2 The pressure at which plastic deformation begins shall be not less than four-thirds of the hydraulic test pressure (p_h).

7.5.3.3 The cylinder shall remain in one piece and shall not fragment; the fracture in the cylindrical portion may present one of the following configurations (shown in figures 6, 7 and 8) :

a) for quenched and tempered cylinders :

1) longitudinal, without branching [figure 6];

2) longitudinal, with a side branching at each end which in no case extends beyond the longitudinal plane normal to the fracture plane [figure 7].

b) for normalized and normalized and tempered cylinders :

1) longitudinal, without branching [figure 6];

2) longitudinal, with a side branching at each end which in no case exceeds half the cylinder circumference [figure 8a)];

3) with "fishtails" at either or both ends, having side branches not exceeding half the cylinder circumference [figures 8b) and 8c)].

7.5.3.4 The main fracture in the cylindrical portion shall not be brittle, i.e. the fracture edges shall be inclined with respect to the wall.

7.5.3.5 The tear shall not reveal a significant defect in the metal.

7.5.3.6 The total volumetric expansion shall bear comparison with that usually obtained with cylinders of the same type.

7.5.4 Batch acceptance

Figures 6, 7 and 8 illustrate satisfactory results of burst tests, and batches represented by such results shall be accepted.

If the configuration of the fracture does not conform to figures 6, 7 or 8, the cylinder shall be submitted to a further examination to enable a decision to be reached as to the acceptance or rejection of the batch.

8 Hydraulic and hardness tests

Following heat treatment, all cylinders, except those selected for testing in clause 7, shall be submitted to a hydraulic test and a hardness test.

8.1 Hydraulic test

8.1.1 This test requires that the water pressure in the cylinder increases gradually and regularly until the test pressure p_h is reached. The cylinder test pressure shall be held for a sufficiently long period to ascertain that there is no tendency for the pressure to decrease and that tightness is guaranteed.

8.1.2 When mutually agreed by the cylinder manufacturer and the purchaser, the following procedure may be used to perform the hydraulic test.

Each new cylinder shall be given a hydraulic pressure test in which the volumetric expansion of each cylinder is measured under the test pressure (p_h) and compared with the volumetric expansion of the cylinder after the pressure is released. A cylinder shall be rejected if it shows a permanent expansion (i.e. volumetric expansion after the pressure has been released) in excess of 10 % of the total volumetric expansion measured under the test pressure (p_h).

The total and permanent expansion readings shall be recorded, together with the corresponding serial number of each cylinder tested, so that the elastic expansion (i.e. total expansion less permanent expansion) under the test pressure is available for each cylinder.

Figure 6 — Acceptable burst profile in all cases

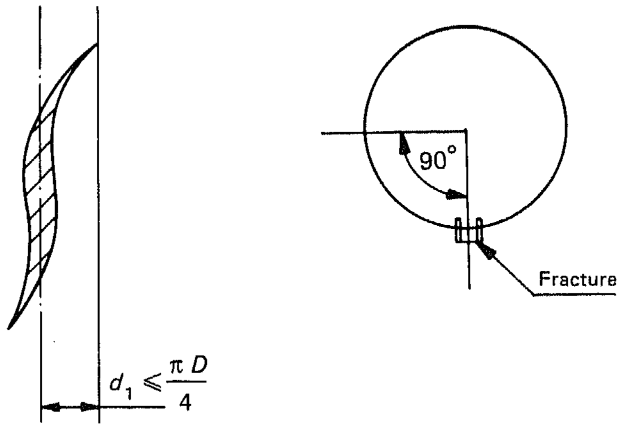
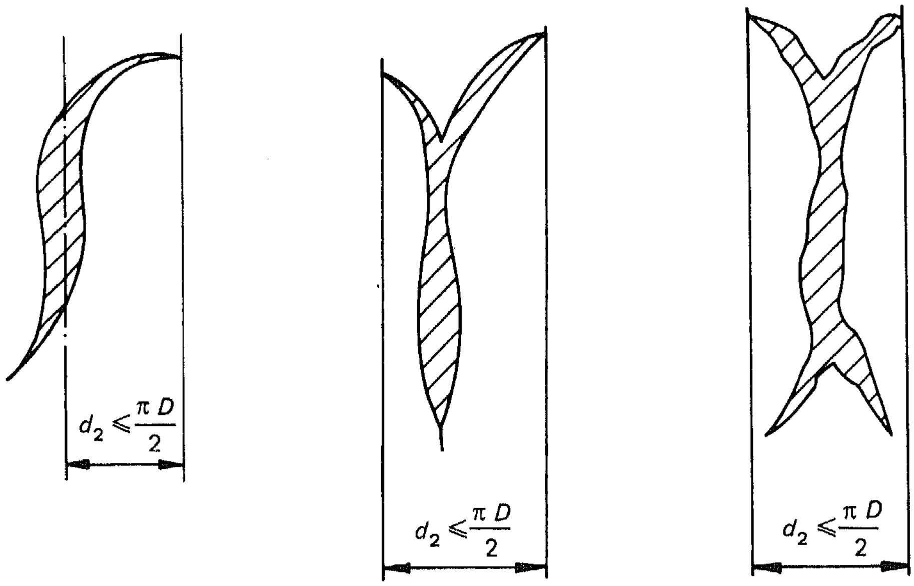


Figure 7 — Acceptable burst profile for quenched and tempered cylinders



a) longitudinal, with side branching at each end

b) with "fishtail" at one end

c) with "fishtail" at both ends

Figure 8 — Acceptable burst profiles for normalized and tempered cylinders

8.2 Hardness test

A hardness test in accordance with ISO 6506 shall be carried out by the manufacturer after the final heat treatment. The hardness values thus determined shall be within the limits specified for the material, dependent upon the heat treatment used for the production of the cylinder.

NOTE — Methods for measuring the surface of the indentation, other than that given in sub-clause 7.8 of ISO 6506, may be used subject to agreement between the parties concerned.

8.3 Leakage test

The manufacturer shall employ such manufacturing techniques and apply such tests as will demonstrate to the satisfaction of the inspecting authority that the cylinders do not leak.

9 Acceptance

All inspection and testing shall, where necessary, be carried out to the satisfaction of the administrative authority or its approved independent inspecting body competent for the acceptance of cylinders.

10 Marking

Each cylinder shall be stamped on the shoulder or on a reinforced part of the cylinder or on a permanently fixed collar or neck ring with the marks detailed in 10.1 to 10.4. They shall be located in the positions given in 10.5.

After satisfactory test results, each cylinder shall be stamped in the position indicated in 10.5 with the ISO identification and the supplementary symbol K2 or K5 to indicate those cylinders impact tested at either − 20 °C or − 50 °C respectively (for example, ISO 4705, K2).

10.1 Material

a) a whole number, indicating the value R_e used for the calculation of wall thickness, in newtons per square millimetre (see 5.2);

b) a symbol

— the symbol N for normalized and tempered cylinders, or

— the symbol T for cylinders quenched in oil or some other medium having a cooling rate of not more than 80 % of that in water without additives, at 20 °C, and tempered, or

— the symbol W for cylinders quenched in a medium having a cooling rate greater than 80 % of that in water without additives, at 20 °C, and tempered.

10.2 Hydraulic test pressure

The value of the hydraulic test pressure (p_h) stating units (bar or MPa).

10.3 Cylinder capacity, mass and tare

a) the water capacity, in litres;

b) the mass of the cylinder with the attached parts (for example, foot ring, neck ring) but without valve, in kilograms;

c) if known, the tare of the cylinder including the attached parts (for example, foot ring, neck ring) and the valve in kilograms (for liquefied gases only).

The water capacity, mass and the tare shall each be expressed to three significant figures, the third figure being determined by rounding down for the water capacity and rounding up for the mass or tare.

Examples :

Measured capacity, mass or tare :	1,064 5	10,675	106,55
Capacity to be expressed as :	1,06	10,6	106
Mass or tare to be expressed as :	1,07	10,7	107

10.4 Manufacturing details

a) the manufacturer's mark;

b) a two-letter symbol indicating the country of origin, according to ISO 3166;

c) the cylinder serial or manufacturing number;

d) the inspection mark;

e) the month and year of the hydraulic test.

10.5 Identification marks

The above identification marks shall be stamped in one of the following arrangements. The meaning of the numbers used is shown in annex B.

Arrangement a)

			5	9	7 kg *	
1	2	3	4	8	10	11
			6 (kg)	10		

* This mark is to be stamped if the tare is known and if the cylinder is intended for liquefied gases.

Example :

	40,7	DE	70,6 kg
ISO 4705 K2 450 N	225 bar	AB	TUV 3/68
	69,1 kg	60 000	

If the above stamping arrangement cannot be applied, then the following arrangement b) can be used :

Arrangement b)

1 2 3 5 4 6 (kg) 9 8 10 7 (kg) * 11 12

Example :

ISO 4705 K2 450 N 40,7/225 bar/69,1 kg DE/AB 60 000 70,6 kg TUV 3/68

In exceptional circumstances, with the approval of the inspecting authority, a different arrangement of the marks may be permitted. In such a case, the arrangement of the marks shall not be liable to cause any confusion in their interpretation, and for this purpose, where applicable, the markings shall include the units concerned.

10.6 Stamps

The stamps used for marking shall have such radii as are necessary to prevent the formation of sharp notches in the stamped marking.

10.7 Certificate

Each batch of cylinders shall be covered by a certificate signed by the inspecting authority's representative to the effect that the cylinders meet the requirements of this International Standard in all respects. An example of a suitably worded certificate is given in annex B. (It should be noted that this certificate gives more information than that required by this International Standard.)

* This mark is to be stamped if the tare is known and if the cylinder is intended for liquefied gases.

Annex A

Special prototype test

For the purpose of this test, three cylinders which are guaranteed by the manufacturer to be reasonably representative of the minimum bottom thickness prescribed by the design shall be filled with a non-corrosive liquid and subjected to successive reversals of hydraulic pressure.

This test shall be carried out at an upper cyclic pressure either :

a) two-thirds of the test pressure, in which case the cylinder shall be subjected to 75 000 cycles without failure, or

b) equal to the test pressure, in which case the cylinder shall be subjected to 10 000 cycles without failure.

NOTE — These two values are provisional and will be reconsidered in due course when the results of tests are available.

The value of the lower cyclic pressure shall not exceed 10 % of the upper cyclic pressure.

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 bases shall be sectioned in order to measure the wall thickness and to ascertain that this thickness is sufficiently close to the minimum thickness prescribed in the design.

Annex B
Example of acceptance certificate

ACCEPTANCE CERTIFICATE FOR SEAMLESS STEEL GAS CYLINDERS No. . . . . .

A batch of . . . . cylinders have been inspected and tested
[quantity]

for . . . . according to ISO 4705/ISO 4705 annex D[1)]
[designation or type of gas]

Manufacturer's Nos. . . . . . to . . . . .

Owner's Nos.[2)] . . . . . to . . . . .

Manufacturer : Name Address	Symbol :
Country	
Owner[1)] Name Customer[1)] Address	

TECHNICAL DATA

Water capacity : nominal[1)] minimum[1)]	L L	Nominal length (without cap and without valve) :	mm
Test pressure, p_h :	unit to be stated	Outside diameter D :	mm
Max. filling pressure[1)] at . . . . . °C :	unit to be stated	Minimum wall thickness, a :	mm
Max. filling mass[1)] at . . . . . °C :	kg	Drawing No.	

Material : . . . . . . Steelmaker and steel identification mark :	National authority approving material
Specified analysis : C Si Mn P S Cr Mo Ni	
Proportion by mass % : max. . . . . . min.	National authority approval references
Heat treatment[1)] : T W N	

STAMP MARKING

ISO identification and impact test temperature symbol or annex D symbol (D or DC)	(1)	Mass of cylinder without valve, kg	(6)
Minimum yield stress, R_e, N/mm^2	(2)	Tare of cyinder, kg (for liquefied gases)	(7)
Symbol T, W or N for heat treatment	(3)	Manufacturer's mark	(8)
Test pressure, p_h, (unit to be stated)	(4)	Mark indicating country of origin	(9)
Actual water capacity, litres	(5)	Manufacturer's No.	(10)
		Inspection mark	(11)
		Date of testing	(12)

These identification marks are stamped according to the following arrangement[1)] :

			5	9	7	
1	2	3	4	8		12
			6(kg)	10	11	

1 2 3 4 4 6 (kg) 9 8 10 7 (kg) 11 12

. . . .
The manufacturer

. . . .
Date

1) Delete as applicable.

2) If required by customer.

ACCEPTANCE TESTS

1. MEASUREMENTS

Test No.	Batch constituted of No. ... to No. ...	Measured data of test cylinders		
		Water capacity L	Mass empty kg	Minimum measured thickness mm mm

2. MECHANICAL TESTS

Test No.	Heat No.	Tensile test				Impact test (ISO 148)		Bend test[1] (ISO/R 85)	Flattening test[1]	Hardness test[1]
		Test piece to figure No.	Yield stress R_{ea} N/mm^2	Tensile strength R_m N/mm^2	Elongation A %	Charpy V impact at ... °C Test piece width ... mm		180° without a crack	Flat without a crack	
						Mean J	Min. J			
Specified minimum										

This is to certify that the cylinders have passed the hydraulic pressure test/hydraulic volumetric expansion test[3] and the other tests and analyses required, and that they are in accordance with ISO 4705/ISO 4705 annex D[3].

. . . .
Signature of Inspector

. . . .
Date

1) Only one of these tests need be carried out if the cylinders are intended for international traffic.

2) This test is not required if a hydraulic volumetric expansion test is carried out in accordance with annex D.

3) Delete as applicable.

Annex C

Hydraulic bursting test

C.1 Scope

This annex specifies the procedure for carrying out the hydraulic bursting test as one of the batch tests used during the production of seamless steel gas cylinders designed in accordance with this International Standard.

C.2 Selection of test cylinders

Unless otherwise specified, the test cylinders shall be selected in accordance with 7.1.2 and 7.1.3.

C.3 Test installation

The test equipment shall be capable of operation in accordance with the test conditions specified in C.4 and of accurately producing the information required by 7.5.2 and 7.5.3.

An example of a test installation is shown in figure 9.

C.4 Test conditions

C.4.1 As the cylinder and test equipment are being filled with water, care shall be taken to ensure that no air is trapped in the circuit, by operating the hydraulic pump until water is discharged from the purge vent or air-release valve.

C.4.2 During the test, pressurization shall be carried out in two successive stages.

C.4.2.1 In the first stage, the pressure shall be increased at a rate of not more than 5 bar/s up to a pressure value corresponding to the start of plastic deformation.

C.4.2.2 In the second stage, the pump discharge rate shall be maintained at as constant a level as is possible until the cylinder bursts.

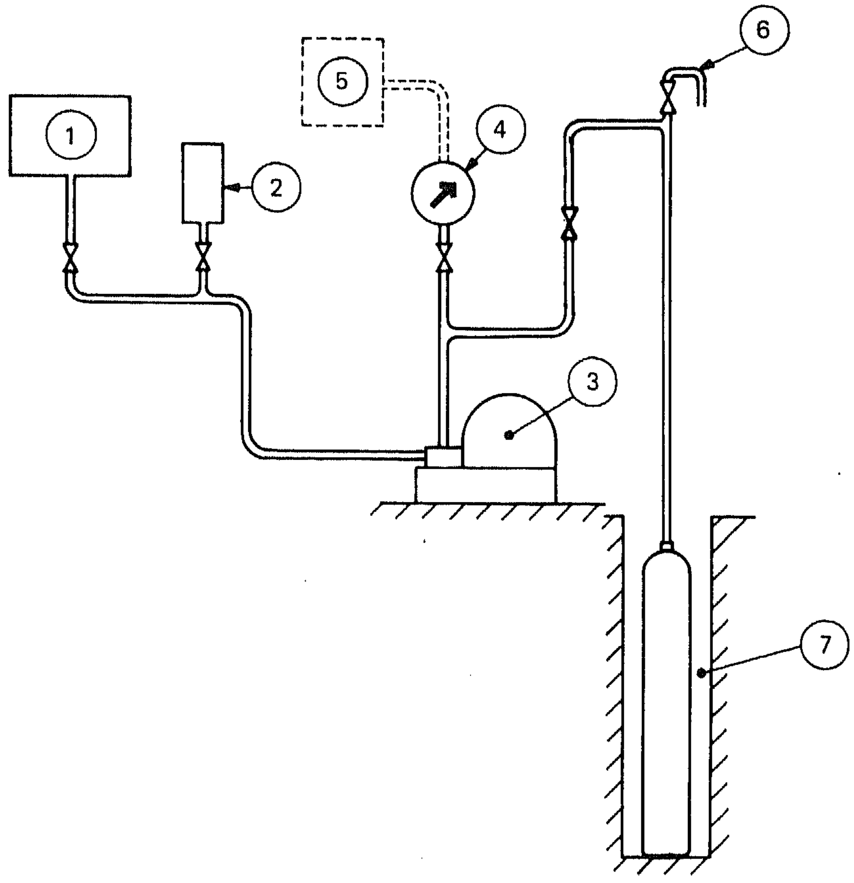


Figure 9 — Typical hydraulic bursting test installation

(1) Feed tank or other device for containing either water or another suitable hydraulic fluid

(2) Tank for measurement of water or hydraulic fluid required for each test (the feed tank may be used as the measuring tank)

(3) High-pressure pump

(4) Pressure gauge

(5) Appropriate device for plotting the pressure/time curve

(6) Pipe-line, with an air vent or release valve at the extreme top, for connecting the fixed installation to the cylinder under test. With certain installations it may be necessary to install more than one air vent to ensure that no air is trapped in the circuit

(7) Appropriate safety device to prevent injury to personnel during the test

Annex D

Additional requirements for worldwide usage

(This annex does not form an integral part of the standard.)

D.1 General

This annex contains provisions for the construction of cylinders that are acceptable for service in all countries, provided that the cylinders are manufactured in accordance with the main content of this International Standard and the following additional or modified requirements :

a) the composition of the construction material;

b) the heat treatment to which the cylinder shall be subjected;

c) the limiting design stress for the construction material;

d) the tests required.

D.2 Material

D.2.1 In order to be selected for manufacture of cylinders intended for international use, a steel shall :

a) have been approved by the national authority of the country of an ISO member body for service no less stringent than that which will be encountered in the proposed international service; and

b) have been used for the manufacture of either at least 20 000 cylinders in satisfactory service for two years or at least 5 000 cylinders manufactured from no less than 10 casts and in satisfactory service for two years.

D.2.2 The chemical composition of a steel shall be defined in terms of the maximum content of each element and the range of content that is permitted, as detailed in table 3.

Table 3

Element	Maximum content	Permitted range %
Carbon	< 0,30 % > 0,30 %	0,06 0,07
Manganese	all values	0,30
Silicon	all values	0,30
Chromium	< 1,50 % > 1,50 %	0,30 0,50
Nickel	all values	0,40
Molybdenum	all values	0,15
Vanadium	all values	0,10

If other elements are added, the permitted range shall be agreed with the national authority which grants approval. In all cases the sulphur and phosphorus shall be within the limits set out in 4.3.1.

Elements not included in the declared chemical composition shall not be deliberately added and their contents shall be representative of good steelmaking practice.

Steels used for cylinders intended for service with corrosive gases shall be approved by the national authority of an ISO member country for this service.

D.3 Heat treatment

The heat treatment of cylinders shall be carried out in accordance with 4.2 taking into account the following controls on temperature.

D.3.1 Temperature for normalizing or quenching

The actual temperature shall not deviate by more than ± 25 °C from the temperature declared for the type of steel. At the moment of quenching the temperature shall not be less than the upper critical point (Ac_3).

D.3.2 Tempering temperature

The actual temperature for a given tensile strength of a declared type of steel shall not deviate by more than ± 35 °C from that indicated by the cylinder manufacturer.

D.4 Limiting design stress

D.4.1 Where there is no risk of stress corrosion, the maximum value of the tensile strength is limited by the ability of the steel to meet the requirements of D.5.

D.4.2 For calculation of the wall thickness of quenched and tempered cylinders the R_e/R_g ratio shall be a maximum of 0,85 for all gases which tend to induce stress corrosion cracking.

D.4.3 Where there is risk of stress corrosion cracking of cylinders in service, the maximum value of the tensile strength as determined in D.5 shall be 880 N/mm²; a maximum value of 950 N/mm² may be used provided that the ratio R_{ea}/R_m does not exceed 0,90[1].

D.5 Testing

D.5.1 Prototype test

The prototype test detailed in annex A shall be carried out on each new design of cylinder. The acceptance values shall be either 80 000 cycles without failure when the upper cyclic pressure is two thirds of the test pressure, or 12 000 cycles without failure when the upper cyclic pressure is equal to the test pressure.

A cylinder shall be considered to be of a new design, compared with an existing approved design, when it meets any of the following points :

a) it is manufactured in a different factory;

b) it is manufactured by a different process;

c) it is manufactured from a steel of different nominal chemical composition;

d) it is given a different heat treatment;

e) the base profile and the base thickness have changed relative to the cylinder diameter and calculated minimum wall thickness;

f) the guaranteed minimum yield stress has changed by more than 50 N/mm²;

g) the length of the cylinder has increased by more than 50 % (cylinders with an L/D ratio less than 3 shall not be used as reference cylinders for any new design with an L/D ratio greater than 3);

h) the diameter has changed by more than 5 %;

j) an increase in hydraulic test pressure requires a change in design wall thickness (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).

Cylinders complying with D.2.1 are deemed to be of an existing approved design.

1) Where values in excess of 0,90 are obtained, they shall be approved by the national authority approving the steel.

D.5.2 Batch test

The tests specified in clause 7 shall be carried out on cylinders selected from each batch, testing requirements being modified as noted in D.5.2.1, D.5.2.2 and D.5.2.3.

Where alternative tests are permitted, the purchaser and manufacturer shall agree which tests are to be carried out.

D.5.2.1 Tensile test

A tensile test shall be carried out on material taken from the cylindrical part of the cylinder by adopting either of the following procedures.

D.5.2.1.1 Rectangular specimens prepared in accordance with 7.2.1, acceptance values for elongation being in accordance with 7.2.2.

D.5.2.1.2 Machined round specimens having the maximum diameter practicable, the elongation measured on a gauge length of five times the specimen diameter being no less than 16 %. It is recommended that machined round specimens are not used for wall thicknesses less than 3 mm.

D.5.2.2 Bend and flattening tests

Either the bend test, described in D.5.2.2.1, or the flattening test, described in D.5.2.2.2, shall be carried out.

D.5.2.2.1 The bend test is as detailed in 7.3 but using n values given in table 4.

D.5.2.2.2 The flattening test is performed on one cylinder selected from each batch after heat treatment.

The test cylinder shall be flattened between knife edges, wedge-shaped with a 60° included angle of arc, the edges being rounded to a nominal radius of 13 mm. The lengths of the wedges shall not be less than the width of the flattened cylinder. The longitudinal axis of the cylinder must be at approximately a 90° angle to the knife edges.

The test cylinder shall be flattened until the distance between the knife edges is in accordance with table 4. No cracks shall appear on the surface.

Table 4

Actual tensile strength, R_m N/mm^2	Value of n	Distance between knife edges × t_m*
$R_m < 500$	2	6
$500 < R_m < 670$	3	6
$670 < R_m < 800$	4	6
$800 < R_m < 880$	5	7
$880 < R_m < 950$	6	8
$R_m > 950$	7	9

* where t_m is the average cylinder wall thickness at the position of testing.

D.5.2.3 Impact test

All impact tests shall be carried out at − 50 °C. The impact values obtained shall be in accordance with those specified in table 2.

D.5.3 Hydraulic and hardness test

Either a hydraulic proof test to 8.1.1 or a hydraulic volumetric expansion test to 8.1.2 shall be carried out. When the hydraulic volumetric expansion test is carried out, it is not necessary to carry out the hardness test in 8.2.

D.6 Marking

All cylinders manufactured in accordance with this International Standard and with the additional or modified requirements of annex D shall be stamped with a mark "D" to indicate those cylinders as defined in D.4.1 or "DC" to indicate cylinders as defined in D.4.3. This mark shall follow the ISO symbol and replaces the impact temperature symbol (see clause 10).

The following examples show the layout of the marking :

Arrangement a)

40,7	DE	70,6 kg
ISO 4705 DC 450 N 225 bar	AB	TUV 3/88
69,1 kg	60 000	

Arrangement b)

ISO 4705 DC 450 N 40,7/225 bar/69,1 kg DE/AB 60 000 70,6 kg TUV/3/68

D.7 Certificate

Each batch of cylinders shall be covered by a certificate signed by the inspecting authority's representative to the effect that the cylinders meet the requirements of this International Standard and of this annex in all respects.