International Standard 4705

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION•МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ•ORGANISATION INTERNATIONALE DE NORMALISATION

Refillable seamless steel gas cylinders

Bouteilles à gaz sans soudure en acier destinées à être rechargées

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Descriptors : gas cylinders, steel products, chemical composition, heat treatment, design, manufacturing, tests, mechanical tests, test specimens, bend tests, tension tests, impact tests, hydraulic tests, burst tests, pressure tests, hardness tests, gas permeability tests, certification, marking.

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards institutes (ISO member bodies). The work of developing International Standards is carried out through ISO technical committees. Every member body interested in a subject for which a technical committee has been set up has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 4705 was developed by Technical Committee ISO/TC 58, *Gas cylinders*, and was circulated to the member bodies in July 1978.

It has been approved by the member bodies of the following countries :

Australia	Ireland	Romania
Belgium	Israel	South Africa, Rep. of
Canada	Italy	Sweden
Czechoslovakia	Korea, Rep. of	Switzerland
Denmark	Mexico	United Kingdom
France	Netherlands	USSR
Germany, F. R.	New Zealand	Yugoslavia
India	Norway	

The member bodies of the following countries expressed disapproval of the document on technical grounds :

Austria
Japan
USA

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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

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

except that the wall thickness shall also satisfy the formula

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

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 :

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

— or, for ends formed from plates :

$b \geqslant a$ for $H/D \geqslant 0,40$

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.

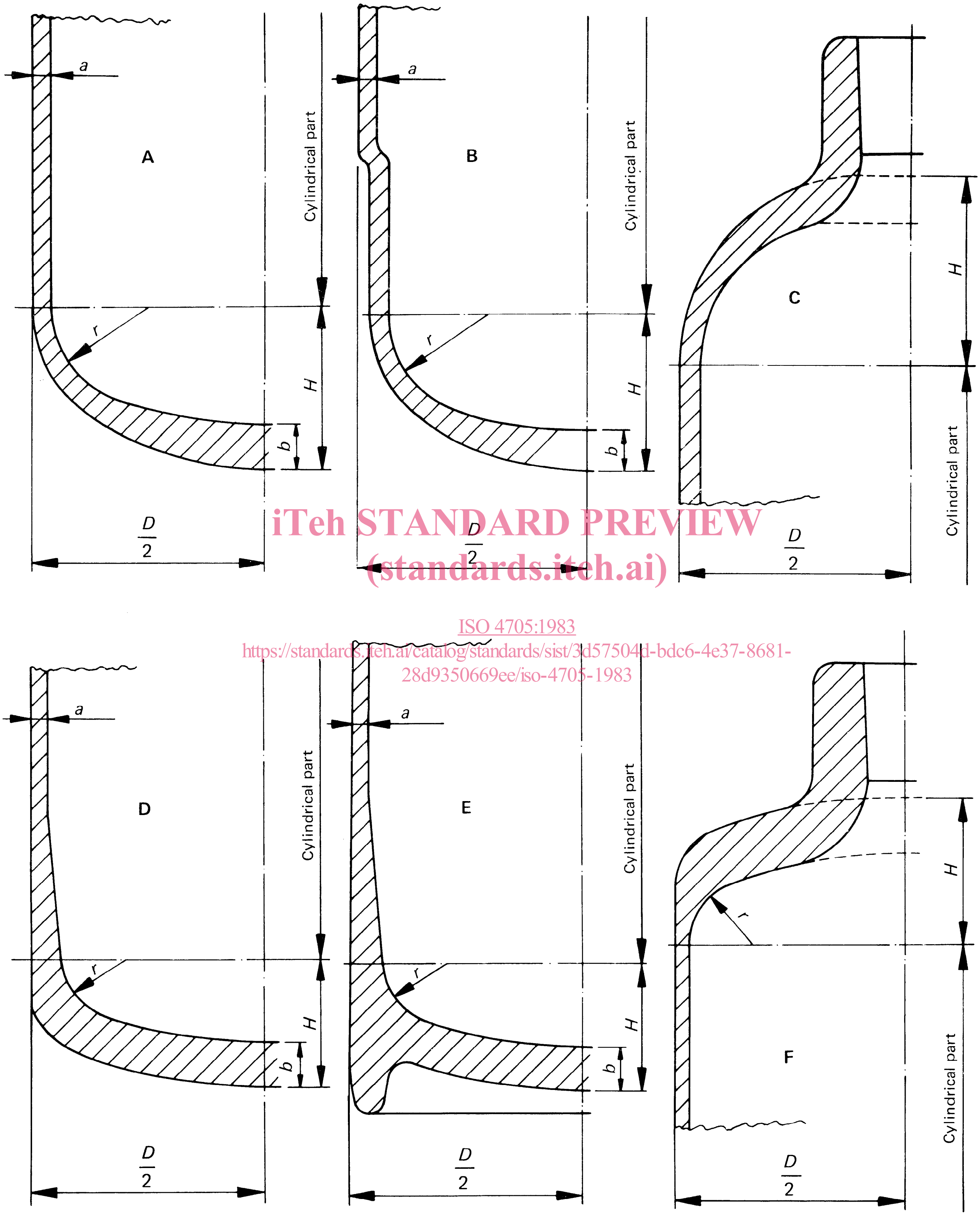


Figure 1 — Typical convex ends

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 :

$a_1 = 2\,a$

$a_2 = 2\,a$

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

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

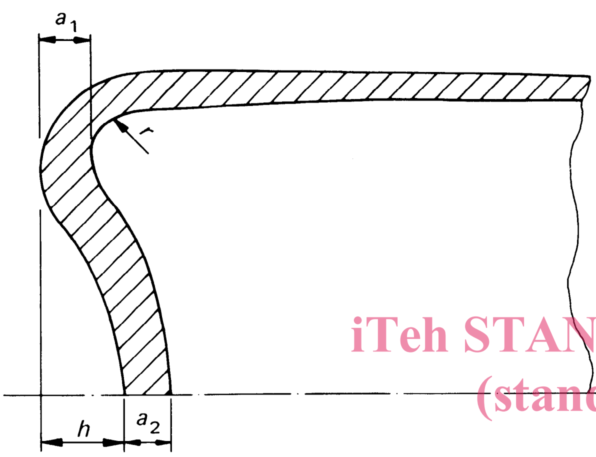


Figure 2 — Concave base end

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 :

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

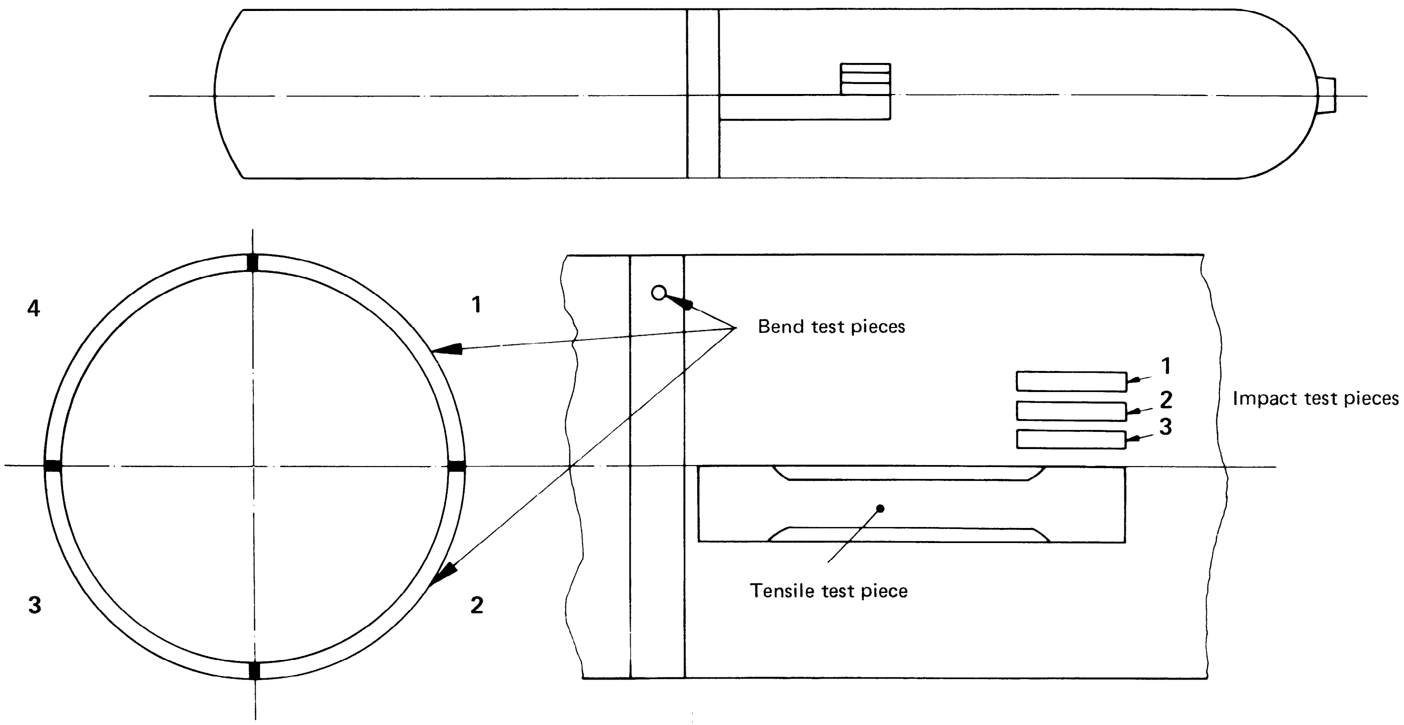


Figure 3 — Location of test pieces

b) for cylinders made from quenched and tempered steels :

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

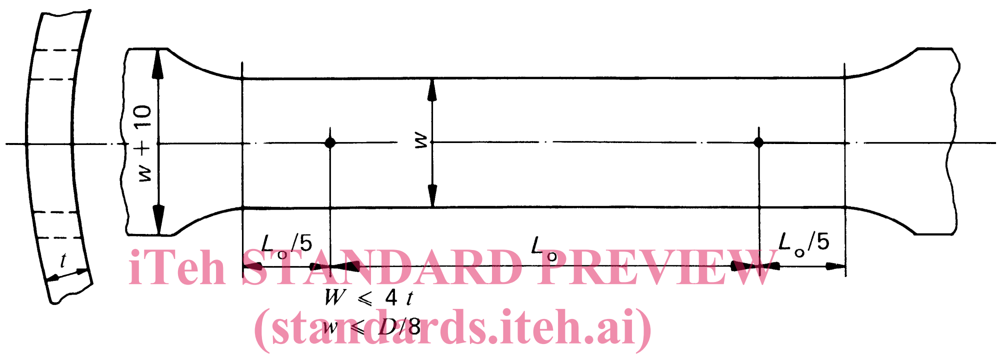
$$A = \frac{2\,500}{0{,}224\,R_m} \text{ with an absolute minimum of 14 \%}$$

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

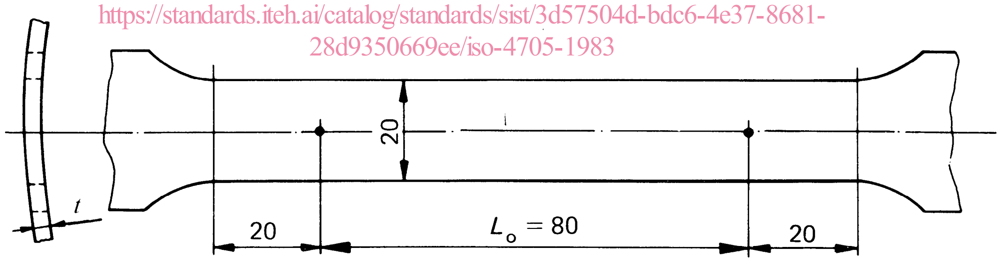
$$A = \frac{2\,500}{0{,}306\,R_m} \text{ with an absolute minimum of 9 \%}$$

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.

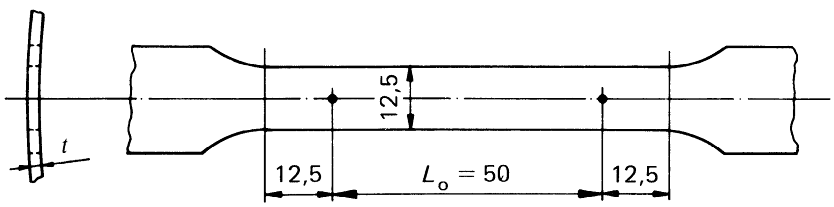
Dimensions in millimetres



a) **Test piece when $t \geqslant 3$ 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