INTERNATIONAL STANDARD

ISO 21172-1

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Gas cylinders — Welded steel pressure drums up to 3 000 litres capacity for the transport of gases — Design and construction —

Part 1: Capacities up to 1 000 litres

Bouteilles à gaz — Fûts soudés de capacité inférieure ou égale à 3000 litres destinés au transport des gazes —

Partie 1: Capacité jusqu'à 1000 litres

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ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established 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. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT), see the following URL: Foreword — Supplementary information.

The committee responsible for this document is ISO/TC 58, *Gas cylinders*, Subcommittee SC 3, *Cylinder design*.

ISO 21172 consists of the following parts, under the general title *Gas cylinders — Welded steel pressure drums up to 3000 l capacity for the transport of gases — Design and construction*:

— *Part 1: Capacities up to 1 000 litres*

Capacities up to 3 000 litres will form the subjects of future Part 2.

Introduction

The purpose of this part of ISO 21172 is to provide a specification for the design, manufacture, inspection, and approval of welded steel gas pressure drums.

The specifications given are based on knowledge of and experience with, materials, design requirements, manufacturing processes, and control during manufacture of steel drums in common use in the countries of the participating members. Pressure drums is intended to be designed, manufactured, and closed so that during normal conditions of transport including the effects of handling, temperature, vibration, humidity, or pressure, there will be no release of dangerous goods that would endanger public safety.

This part of ISO 21172 is intended to be used under a variety of national and international regulatory regimes. Where there is any conflict between this International Standard and any applicable regulation, the regulation always takes precedence.

This part of ISO 21172 has been written so that it is suitable to be referenced in the UN Model Regulations.

Gas cylinders — Welded steel pressure drums up to 3 000 litres capacity for the transport of gases — Design and construction —

Part 1: Capacities up to 1 000 litres

1 Scope

This part of ISO 21172 specifies the minimum requirements for the material, design, fabrication, construction and workmanship, inspection, and testing at manufacture of refillable welded steel gas pressure drums, hereafter referred to as drums, of volumes 150 l to 1 000 l and up to 300 bar test pressure for compressed and liquefied gases. Only cylindrical and spherical containers are covered.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 148, *Steel — Charpy impact test (V-notch)*

ISO 1106-1, *Recommended practice for radiographic examination of fusion welded joints — Part 1: Fusion welded butt joints in steel plates up to 50 mm thick*

ISO 2063, *Thermal spraying — Metallic and other inorganic coatings — Zinc, aluminium and their alloys*

ISO 3834-2, *Quality requirements for fusion welding of metallic materials — Part 2: Comprehensive quality requirements*

ISO 4136, *Destructive tests on welds in metallic materials — Transverse tensile test*

ISO 4978, *Flat rolled steel products for welded gas cylinders*

ISO 5817, *Welding — Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded) — Quality levels for imperfections*

ISO 6892, *Metallic materials — Tensile testing at ambient temperature*

ISO 7438, *Metallic materials — Bend test*

ISO 9328-1, *Steel flat products for pressure purposes — Technical delivery conditions — Part 1: General requirements*

ISO 9328-2, *Steel flat products for pressure purposes — Technical delivery conditions — Part 2: Non-alloy and alloy steels with specified elevated temperature properties*

ISO 9328-3, *Steel flat products for pressure purposes — Technical delivery conditions — Part 3: Weldable fine grain steels, normalized*

ISO 9328-4, *Steel flat products for pressure purposes — Technical delivery conditions — Part 4: Nickel-alloy steels with specified low temperature properties*

ISO 9328-5, *Steel flat products for pressure purposes — Technical delivery conditions — Part 5: Weldable fine grain steels, thermomechanically rolled*

ISO 9606-1, *Qualification testing of welders — Fusion welding — Part 1: Steels*

ISO 9712, *Non-destructive testing — Qualification and certification of NDT personnel*

ISO 10920, *Gas cylinders — 25E taper thread for connection of valves to gas cylinders — Specification*

ISO 11114-1, *Gas cylinders — Compatibility of cylinder and valve materials with gas contents — Part 1: Metallic materials*

ISO 11114-2, *Gas cylinders — Compatibility of cylinder and valve materials with gas contents — Part 2: Non-metallic materials*

ISO 11114-4, *Transportable gas cylinders — Compatibility of cylinder and valve materials with gas contents — Part 4: Test methods for selecting metallic materials resistant to hydrogen embrittlement*

ISO 11116-1, *Gas cylinders — 17E taper thread for connection of valves to gas cylinders — Part 1: Specifications*

ISO 13769, *Gas cylinders — Stamp marking*

ISO 15607, *Specification and qualification of welding procedures for metallic materials — General rules*

ISO 15613, *Specification and qualification of welding procedures for metallic materials — Qualification based on pre-production welding test*

ISO 15614-1, *Steel welding procedure qualifications*

ISO 17637, *Non-destructive testing of welds — Visual testing of fusion-welded joints*

ISO 17638, *Non-destructive testing of welds — Magnetic particle testing*

EN 462-3, *Non-destructive testing — Image quality of radiographs — Image quality classes for ferrous metals*

ASTM A285/ASTM A285M-03 (2007), *Standard specification for pressure vessel plates, carbon steel, low and intermediate tensile strength*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
yield strength
stress value corresponding to the lower yield strength, R_{eL} or, for steels that do not exhibit a defined yield point, the 0,2 % proof strength, $R_{p0,2}$ for carbon steels; and 1 % proof strength for austenitic stainless steels, $R_{p1,0}$

3.2
normalizing
heat treatment given to the steel by heating to an uniform temperature above the upper critical point (AC_3) of the steel and then cooled in a controlled atmosphere or still air

3.3
stress relieving
heat treatment given to reduce the residual stresses of the steel

3.4
batch
quantity of finished drums of a specific type made to the same design, size, and material specifications; using the same welding procedures and heat-treated under the same conditions of temperature and duration

3.5
test pressure
pressure applied to the drum after completion of all fabrication

3.6
finished drum
drum which is fully assembled and appropriately stamp marked, but without any external coatings

3.7
rolling bands
circumferential rings attached to the drum to protect it from external damage

3.8
hot pressure welding (forged)
solid state joining of two metallic parts by the application of heat and pressure

4 Inspection and testing

Evaluation of conformity should be performed in accordance with the regulations recognized by the country(ies) where the drums are intended to be used.

To ensure that the drums conforms to the requirements of ISO 21172-1, they shall be subject to inspection and testing in accordance with Clause 16 by an inspection body (hereafter referred to as "the inspector") authorized by the applicable regulation.

Equipment used for measurement, testing, and examination during production shall be maintained and calibrated within a documented quality management system.

5 Materials

5.1 General provisions

5.1.1 Materials for the pressure envelope

Materials for the pressure envelope shall conform to ISO 4978 or ISO 9328-1 to ISO 9328-4 for carbon steels and ISO 9328-5 for austenitic stainless steels and austeno-ferritics steels.

For drums made using hot pressure welded heads according to Annex D, the materials shall conform to ASTM specification A285/285M, Grade A and have a minimum tensile strength of 310 MPa.

5.1.2 The materials used for the drum

The materials used for the drum, including welded zones, shall be compatible with the intended gas service and meet the applicable requirements of ISO 11114-1, ISO 11114-2, and ISO 11114-4.

Components (e.g. bolts and studs) in contact with the gas shall meet the applicable requirements of ISO 11114-1, ISO 11114-2, and ISO 11114-4.

5.1.3 All parts welded to the drum

All parts welded to the drum shall be made of material that is compatible with respect to weldability and strength (e.g. from ISO 9327).

5.1.4 Welding consumables

The welding consumables shall be such that they are capable of giving consistent welds with the material properties at least equal to that specified for the parent material in the finished drum.

5.1.5 Conformance

The manufacturer shall obtain and provide certificates to verify conformance to the material specifications for the steel used for the construction of pressure retaining parts of the drum. If the minimum values of the yield strength of the material guaranteed by the steel manufacturer for austenitic stainless steels are greater than the minimum specified in the material standard, then this higher figure can be used in the design calculations, up to a maximum enhancement of 15 %. It shall be ensured that the heat treatment (if any) will not affect this minimum guaranteed value.

For all pressure bearing parts of the drum, the manufacturer shall ensure the traceability of the steel casts that they have been manufactured from.

5.2 Heat treatment

Completed drums made of carbon steels shall be stress relieved or normalized. Stress relieving parameters shall be in accordance with the material specification listed in 5.1.

The manufacturer shall record that the drums have been heat treated after completion of all welding and shall record the temperature and duration of the heat treatment applied.

Localized heat treatment is not permitted.

6 Design

6.1 Design stress

At the test pressure, the design stresses

a) f_c (maximum allowable stress for the cylindrical section of a drum),

b) f_e (maximum allowable stress for the dished ends of a drum,

c) f_p (maximum allowable stress for the pad material of a drum), and

d) f_s (maximum allowable stress for the spherical section of a drum).

It shall not exceed 0,77 Y, where Y is the minimum guaranteed value of yield strength of the material in the relevant part of the finished drum).

6.2 Design temperature

The minimum design reference temperature shall be equal to or less than –20 °C, and the maximum equal to or more than +65 °C.

When deciding the test temperature, the actual drum wall thickness shall be taken into account (see ISO 21028-2 which explains the reason).

6.3 Calculation of thickness

6.3.1 Cylindrical wall

The minimum cylindrical section wall thickness, a_1, shall be not be less than the maximum value of thickness calculated using Formula (1), Formula (2), and Formula (3) [or Formula (4), if applicable].

$$a_{1(1)} = \frac{p_h \times D_0}{20 f_c + p_h} \quad (1)$$

$$a_{1(2)} = K\frac{p_h \times D_0}{20T + p_h} \quad (2)$$

where

p_h is the test pressure;

D_0 is the maximum outside diameter of the drum;

f_c is the maximum allowable stress for the cylindrical section of a drum;

K is the shape factor of the dished ends;

T is the minimum value of tensile strength guaranteed by the drum manufacturer.

The value of K is given in 6.3.3.2 and the minimum thickness of the cylindrical shell is given by Formula (3):

$$a_2 = \frac{D_0}{250} + 2 \quad (3)$$

where

D_0 is the maximum outside diameter of the drum.

where a_2 is the minimum thickness of cylindrical shell or dished end based on handling criterion for highly toxic gases whose $LC_{50\ is}$ less than 200 ppmV is given by Formula (4):

$$a_2 = \frac{D_0}{250} + 4 \quad (4)$$

where

D_0 is the maximum outside diameter of the drum.

6.3.2 Spherical shell

The minimum thickness of a wall of spherical section shall not be less than the maximum value of thickness calculated using Formula (5) and (6).

$$s_{1(1)} = \frac{p_h \times D_0}{40 f_s + P_h} \quad (5)$$

where

p_h is the test pressure;

D_0 is the maximum outside diameter of the drum;

f_s is the maximum allowable stress for the spherical section of a drum.

$$s_{1(2)} = 2{,}25\frac{P_h \times D_0}{40T + P_h} \quad (6)$$

where

p_h is the test pressure;

D_0 is the maximum outside diameter of the drum;

T is the minimum value of tensile strength guaranteed by the drum manufacturer.

6.3.3 Dished ends

6.3.3.1 Types of dished end

For a drum with concave ends, the minimum thickness, b_1, of the wall of a torispherical end or ellipsoidal dished end shall be not less than:

$$b_1 = K \cdot a_1 \tag{7}$$

where

K is the shape factor of the dished ends; the value of K (see Figure 1) varies with the shape of the ends. The value of K shall not be taken as less than 1,0;

a_1 is the minimum cylindrical section wall thickness calculated in 6.3.1.

If a drum is made of two dished ends, the thickness of the straight cylindrical part shall be not less than a_1 as calculated according to 6.3.1. If a drum is made of two hemispherical ends, their thickness shall be calculated according to 6.3.2.

6.3.3.2 Shape factor

The shape factor K is determined and taken from Figure 1, using the appropriate values of H_e/D_0 and b_1/D_0.

where:

H_e is the equivalent height of a dished end for determining the shape factor;

H_0 is the external height of the domed part of the end;

D_0 is the maximum outside diameter of the drum.

The value for H_e is determined using Formula (7) and Formula (8). See Annex B for a calculated example.

For an ellipsoidal end:

$$H_e = H_0 \tag{8}$$

For a torispherical end:

$$He = \text{the minimum value of either } H_0, or \ \frac{(D_0)^2}{4R_0} \text{ or } \sqrt{\frac{D_0 r_0}{2}} \tag{9}$$

where

H_e is the equivalent height of a dished end for determining the shape factor;

H_0 is the external height of the domed part of the end;

D_0 is the maximum outside diameter of the drum;

R_0 is the external radius of the crown of a torispherical dished end;

r_0 is the external radius of the knuckle of a torispherical dished end.

The external height of the domed end for a torispherical end shall be calculated as:

$$H_0 = R_0 - \sqrt{\left(R_0 - \frac{D_0}{2}\right)\left(R_0 + \frac{D_0}{2} - 2r_0\right)} \tag{10}$$

where

H_0 is the external height of the domed part of the end;

R_0 is the external radius of the crown of a torispherical dished end;

D_0 is the maximum outside diameter of the drum;

r_0 is the external radius of the knuckle of a torispherical dished end.

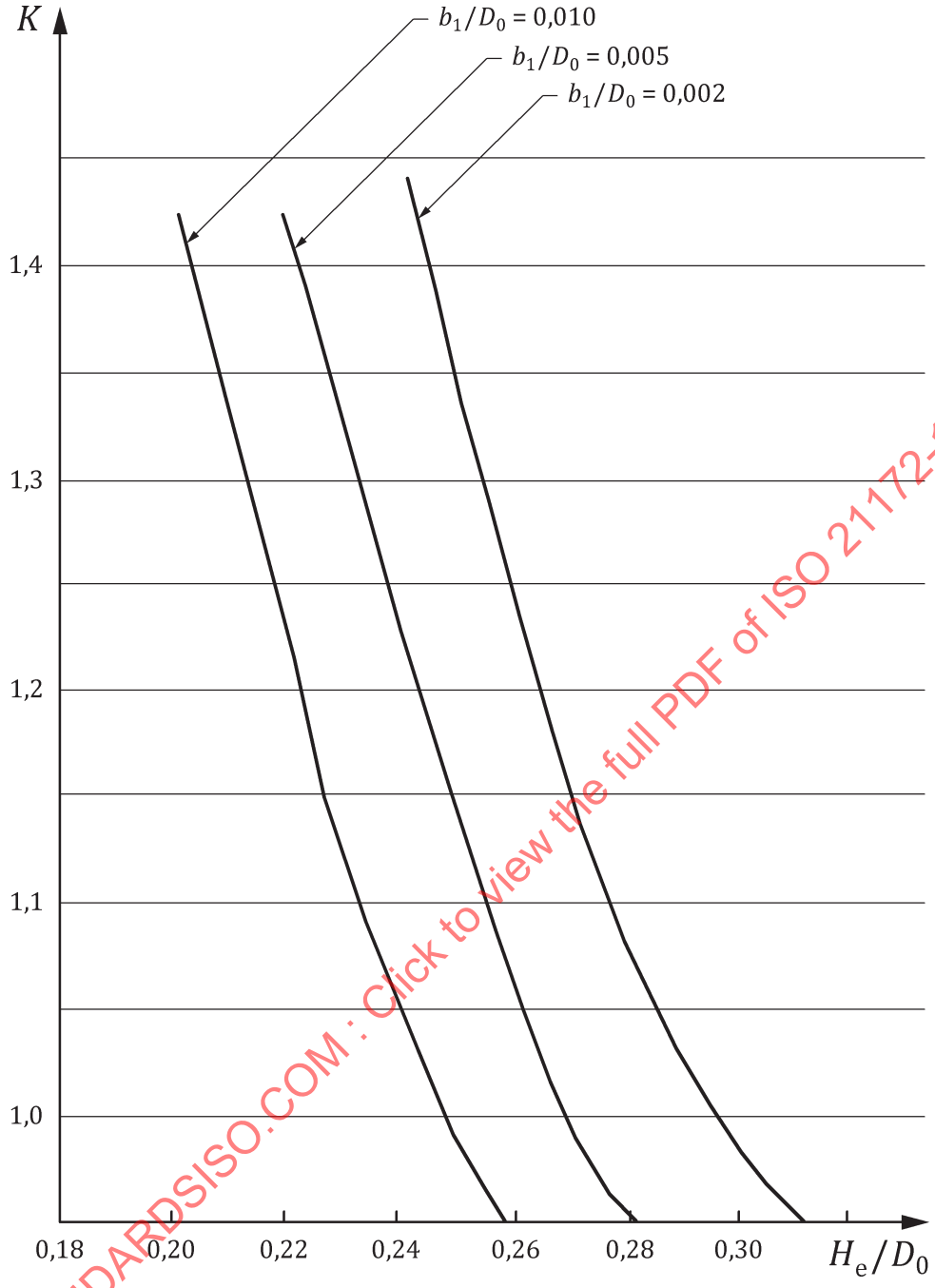


Figure 1 — Shape factor (*K*)

6.3.3.3 Limitations of shape

For a torispherical end, R_0, shall not be greater than D_0, and r_0 shall not be less than $0{,}1D_0$ nor less than four times the thickness of the dished end as manufactured.

For an ellipsoidal end, the ratio $\frac{H_e}{D_0}$ shall be not less than 0,192.

In all cases, S_f shall not be less than $0{,}3\sqrt{D_0 t_e}$

where

R_0 is the external radius of the crown of a torispherical dished end;

D_0 is the maximum outside diameter of the drum;

r_0 is the external radius of the knuckle of a torispherical dished end;

H_e is the equivalent height of a dished end for determining the shape factor;

S_f is the length of straight flange on a torispherical or ellipsoidal dished end;

t_e is the thickness of unpierced end in location of an opening.

6.3.3.4 Dished ends convex to pressure

In the case of convex dished ends, the design shall be confirmed by a burst test and a fatigue test (see 16.2.1.2).

The arrangement of the end weld shall be such that it can be inspected by radiography or an equivalent NDT method. Figure 2 gives an example.

Dished ends convex to pressure shall not be used for drums designed to contain corrosive substances.

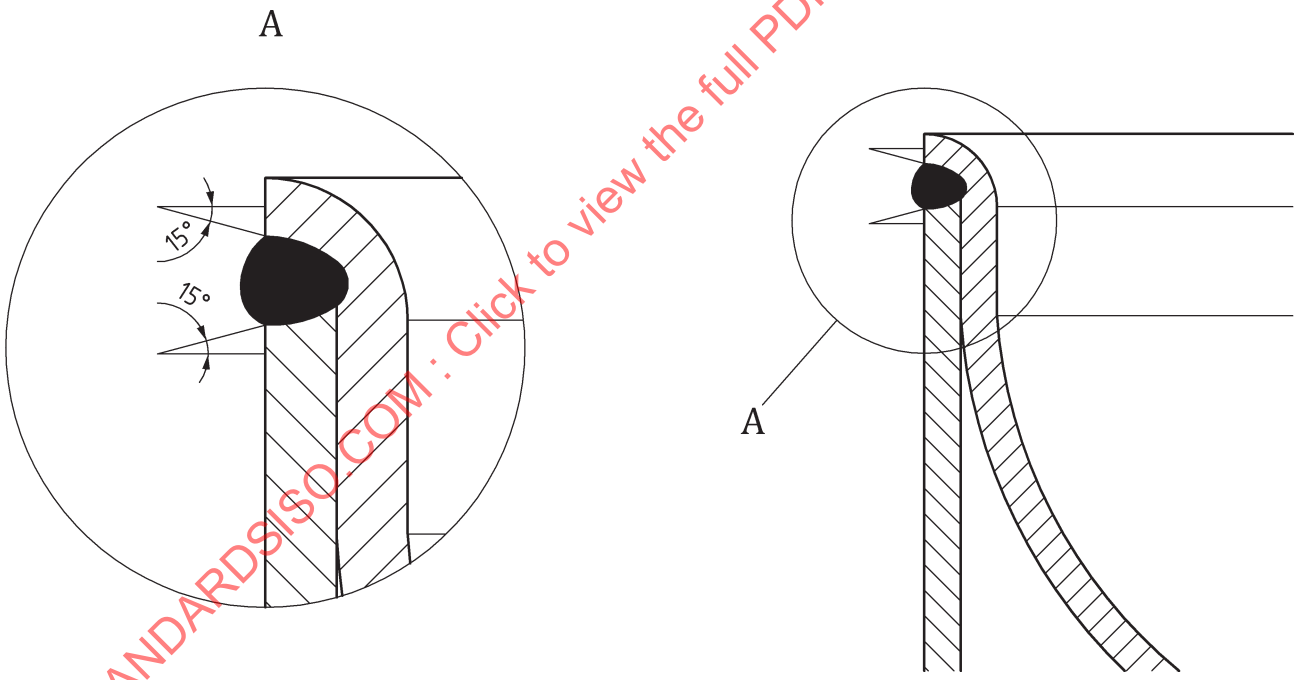


Figure 2 — Limits on vessel or shroud edge dimensions

6.4 Minimum thickness for handling

The thicknesses of the ends calculated from the pressure conditions (see 6.3) shall be increased if they are less than the value calculated using Formula (3) and Formula (4).

If shell and ends are made of different materials, the calculation shall be carried out for each component using the appropriate properties.

6.5 Fittings

6.5.1 General

Fittings (e.g. relief and level devices, eductor tubes…) shall be attached as defined in 6.5.2 to 6.5.5. While there is no restriction on the number of apertures, their number shall be kept to the minimum consistent with safe operation.

Openings shall be located only in the dished ends or spherical sections of the drum.

Threads should be tapped to gauge, clean cut, even, and without cracks.

For opening greater than 15 mm, the fittings shall be attached to parts of the drum that are locally reinforced by a pad, or to a flange or access plate of adequate thickness bolted to a flange. For reinforcement details, see 6.5.6.

NOTE Thread standards acceptable to the competent authority can be used (e.g. NGT…).

6.5.2 Screwed fittings

6.5.2.1 Fittings up to 80 mm thread diameter can be screwed. If a tapered thread is used with sealing of the pressure on the threads, then a sealant (e.g. PTFE tape, PTFE dispersion, a lead ferrule or an aluminium ferrule) shall be inserted between the threaded components to effect a seal. If parallel threads are used, the torques used for assembly shall be set both to ensure a seal on the gasket, and to prevent unloosening in transit.

6.5.2.2 For valves with taper threads, the requirements of ISO 10920 and ISO 11116-1 shall be met.

6.5.3 Bolted connections

Bolted connections shall be made with at least three bolts/studs.

Studs shall be threaded to their ends.

Joining surfaces shall be flat and true in accordance with the flatness, parallelism, and perpendicularity tolerances specified on the design drawings (e.g. in accordance with ISO 1392).

6.5.4 Protection of fittings

6.5.4.1 General

Drums shall be such that all fittings are protected and are situated inside the contour of the end shrouds or support structure, or in the case of those with reverse dished ends, the end of the drum.

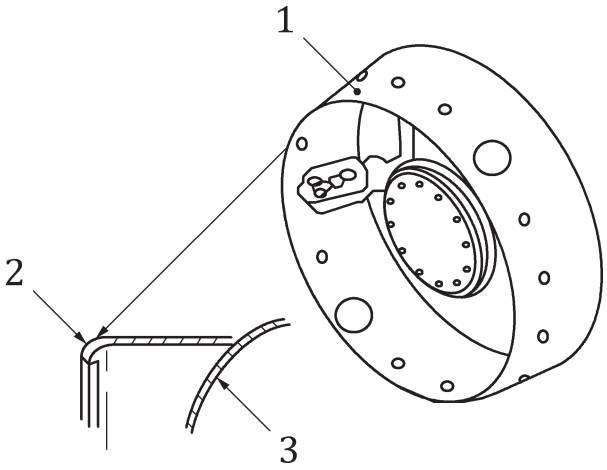
6.5.4.2 End shrouds

End shrouds not fitted with a reinforcing ring or if their shape is not as shown in Figure 3 shall have a minimum thickness of 10 mm.

End shrouds fitted with a reinforcing ring or those do have a shape as shown in Figure 3, might have a reduced thickness of 7 mm.

Shrouds shall have holes or cutaways to allow for drainage.

The top of the shroud shall be higher than the top of the valve protective cap so as to prevent damage occurring to the valve/connector if the drum is dropped or hit.



Key

1 end shrouds
2 shape for reinforcing
3 dished ends

Figure 3 — End shroud reinforcing ring

6.5.4.3 Frame protection

Drums designed to be carried in their vertical position might have a frame structure.

Bottom outlets and their external pipework shall be protected from impact.

6.5.5 Fittings and valves protection

6.5.5.1 In addition to the general protection specified in 6.5.4, fittings shall be provided with local protection.

6.5.5.2 When the drum is intended to be used for a toxic gas (LC_{50} less than 5 000 ppm.V), valves shall be covered by a metal dome or individual caps, having thickness of greater than 2.5 mm when calculated using Formula (11):

$$\sqrt{\frac{D_d}{15}} \tag{11}$$

where

D_d is the diameter of the dome in mm.

A dome shall be capable of being hinged or moved to allow access for filling or emptying, and secured for transport.

In case of leakage, there shall be a facility within the dome to allow venting of any gas within it.

6.5.5.3 Where the gas carried is not toxic, the protection of the valves shall be either a cap or a fixed steel shroud mounted around the fittings.

The shroud shall allow access to the valves and fittings.

6.5.5.4 In the case of a container that is designed to remain vertical, additional protection is not required where the clearance between the fittings and the edge of the shroud or frame is at least 100 mm vertically.

6.5.5.5 Blank plugs, fusible plugs, and pressure relief valves shall not be obstructed and do not require additional protection provided that they are mounted at a diameter of not more than 75 % of the diameter of the shroud and do not protrude more than 30 mm from the surface of the drum.

6.5.6 Compensation of openings

6.5.6.1 Openings shall be placed on the ends and have their largest dimension, N, less than 0,5 D_o (see Figure 4).

6.5.6.2 The total cross-sectional area to be compensated (B) required in any given plane shall not be less than:

$$B = N \cdot S \tag{12}$$

where

S is the thickness of an un-pierced dished end or spherical section calculated using one of Formula (1), Formula (2), Formula (3), and Formula (4) (see 6.3.1);

N is the largest dimension of the opening.

The area of compensation in the parts available for replacement shall be not less than B (see Figure 4).

In calculating the area of compensation, only material up to a distance, P, from the actual surface of the shell can be considered, where:

$$P = \sqrt{N \times t_e} \tag{13}$$

where

P maximum dimension of pads that can be considered as compensation;

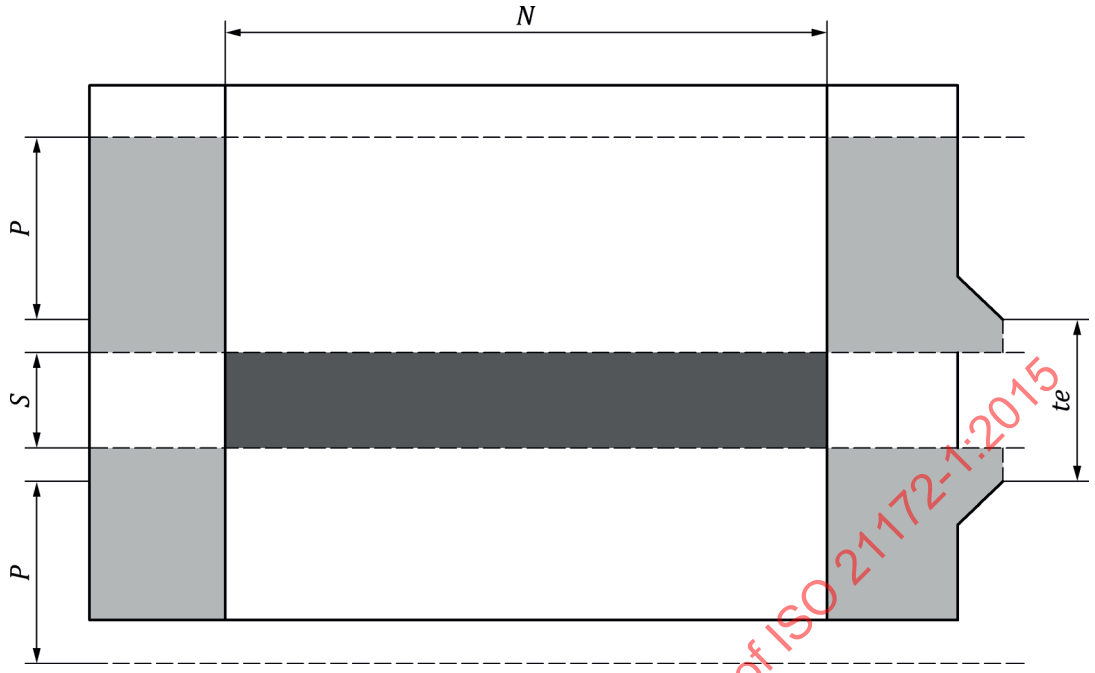
N is the largest dimension of the opening;

t_e thickness of un-pierced end in location of an opening.

6.5.6.3 Where the pad is made from a material of strength different from the part to be compensated, the area available to be considered as compensation shall be multiplied by the ratio of the allowable stresses (f_p/f_s or f_p/f_e) as appropriate. S shall not be less than b_1 or s_1, except when:

a) the opening and its compensation are located entirely within the spherical portion of a torispherical dished end, then S shall not be less than the thickness required for a sphere equal to the spherical portion of a dished end;

b) the opening and its compensation are located in an ellipsoidal end and are entirely within a circle having the radius measured from the centre of 0,40 D_0, S is the thickness required for a sphere having the equivalent radius, Q, taken from Table 2. Intermediate values can be taken from Figure 5.



Key

area of compensation

area removed

Figure 4 — Opening compensation

Table 1 — Radius, *Q*, of equivalent sphere

	Q											
H/D_i	0,17	0,18	0,19	0,21	0,23	0,25	0,28	0,31	0,36	0,4	0,45	0,5
Q/D_i	1,36	1,27	1,18	1,08	0,99	0,9	0,81	0,73	0,65	0,59	0,54	0,5

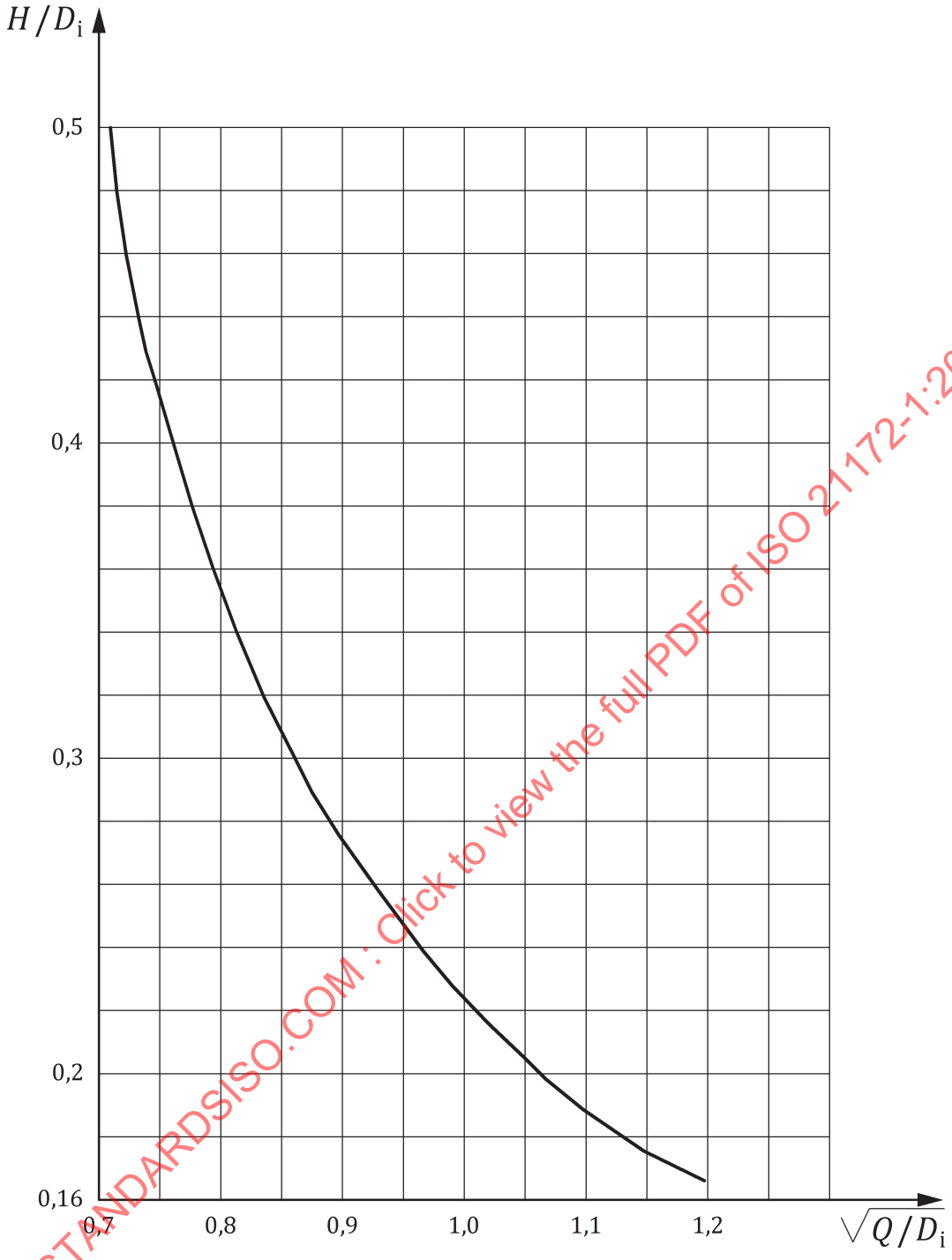


Figure 5 — Radius, *Q*, of equivalent sphere

7 Lifting attachments and rolling bands

7.1 Vertical and spherical drums

7.1.1 Drums designed to be carried in the vertical position shall have structural steel members of minimum thickness 5 mm to take the forks of a fork-lift inserted into the bottom structure. The configuration of the pockets/structures shall protect the drum from being damaged during normal handling.

The fork apertures shall be positioned symmetrically about the drum centre of gravity and their size shall be appropriate to accommodate the fork-lift forks which are to be used to move the drum.

The fork apertures shall be designed such that the drum cannot accidentally disengage from the forks.

7.1.2 If lifting lugs are fitted to the drum, they shall be designed to withstand a design load of 2 × drum maximum gross weight.

Drums with more than one lifting eye shall be designed such that a minimum sling leg angle of 45° to the horizontal can be achieved during lifting using the lifting eyes.

Where four lifting eyes are used, their design shall be such that they are strong enough to allow the drum to be lifted by only two.

Where two or four lifting eyes are used, diametrically opposite lifting eyes shall be aligned with each other to allow for correct lifting using shackle pins.

7.2 Horizontal drums

Requirements for lifting lugs shall be as specified in 7.1.2.

7.3 Rolling bands

Where rolling bands are fitted to the pressure containing part of the shell

a) they shall be attached by continuous fillet welds on either side of the band,

b) the leg length of these fillet welds shall be not less than 5 mm, and

c) the proof of welding penetration at the welded junctions between the ends of rolling bands shall be not less than 10 mm, or with full penetration of the thickness of the rolling band if it is a U profile.

If rolling bands are fitted to a non-pressure part (e.g. a shroud) then intermittent welds of not less than 50 % of the circumference are permissible.

For carbon steel vessels to be used in the horizontal position, external rolling bands are required unless the drum used is vertical or transported on supporting tray and if the external surface is protected from aggression.

For metallic coating, the requirements of ISO 2063 shall be met.

8 Manufacturing process — Welding procedures

The manufacturer, before proceeding with the production of a given design shall qualify the specific welding procedures and welders to be in accordance with the requirements of ISO 15607, ISO 15614-1, and ISO 9606-1 respectively. Records of such qualification shall be kept on file by the drum manufacturer for a period of at least 10 years or as required by National Regulations.

Procedural qualification tests shall be performed in such a manner that the welds shall be representative of those made in production.

Requalifying of the procedure, as well as the welder, shall be required if there is a change in any of the requirements included in ISO 9606-1, ISO 15614-1, and ISO 15607.

Qualification of the forge welding procedure shall be by hydrostatic internal pressurization. Pressure shall be applied until the deformation of the joint is such that the head reverses itself. If the joint separates prior to the head deforming, the welding procedure is unacceptable.

9 Fabrication

9.1 Shell sections

The cylindrical shell shall be made from a single plate.

9.2 Dished ends

The dished ends shall each be pressed from a single plate.

All forming shall be done by stamping, rolling, or pressing machine. Local heating or hammering is not permissible.

9.3 Cold pressed dished ends

Cold-formed dished ends shall be normalized after pressing by using a heat treatment process at a temperature above 650 °C.

Ends distorted during heat treatment beyond the allowable limits shall be re-aligned, and if it is done by cold deformation (e.g. in a press), a further heat treatment for stress relieving is required.

9.4 Hot pressed dished ends

Dished ends pressed from plates heated to above 650 °C do not require heat treatment after forming.

10 Welded joints

Plates and heads that are being welded shall be fitted, aligned, and retained in position during the welding operation. Bars, jacks, clamps, or other appropriate devices, including tack welds, can be used to hold in alignment the edges to be welded.

The welding of the longitudinal and circumferential seams shall be by an automatic or a semi-automatic process. The longitudinal weld, of which there shall be no more than one in a cylindrical section, shall be a full penetration butt weld, and any backing bars shall be removed after welding.

The weld bead reinforcement shall have a gradual transition from its maximum allowable crown to the plane of the base metal surface.

The circumferential welds shall be a butt weld, joggle joint weld or hot pressure weld (forged). See Annex D.

Vessels for use with corrosive gases shall not use joggle joints.

11 Surface finish of material

The internal surface finish shall be specified and take account of the intended service of the drum. Any scale or corrosion shall be removed using an appropriate method (e.g. shot blasting).Any surface defects (e.g. pits, scrapes, rolled-in scale or press marks), shall be ground out so that the reduced thickness is blended into the rest of the plate at an angle not less than 1:20.

The depth of any defects shall be limited to 1,5 mm. The thickness at all such locations shall be measured and proved to be greater than the minimum specified.

For carbon steel drums, before painting the finish of the external surface shall be specified.

12 Assembly

12.1 Temporary attachments

Any attachments (e.g. tacking strips and cleats) temporarily welded to the drum to facilitate manufacture shall be of the same material as the drum and shall be completely and carefully removed so as not to damage the drum. Any surface imperfections remaining after removal shall be made good by repair welding.

The repaired areas shall be dressed to a smooth finish level with the surface of the adjacent parent material and be subjected to a check for surface cracks using an appropriate non-destructive testing (e.g. dye penetrant test in accordance with ISO 3879 or a magnetic particle examination in accordance with ISO 9934).

12.2 Alignment of joints

The plate edges at all butt seams shall not be out of alignment by more than the limits specified in ISO 5817 level C.

Where joggle joints are used, the fit of the mating parts shall be such that there is no gap greater than 0,5 mm before welding. When a joggling operation is performed on a cylindrical section, those lengths of weld that are deformed by the joggle shall be ground flush with the parent plate before the joggling operation and shall be crack detected before welding them into circumferential seams.

12.3 Attachments and fittings

Any external attachments (e.g. shrouds or skirts) shall fit the contour of the part of the drum. Any local gaps shall not exceed 2,5 mm and any change in the gap shall be gradual.

Attachments to the pressure envelope (e.g. shrouds and skirts) shall have all their welds visually inspected and 10 % of their welds using non-destructive test (e.g. dye penetrant test in accordance with ISO 3879 or a magnetic particle examination in accordance with ISO 9934) prior to fitting to the pressure drum.

If any defects are detected by the non-destructive test used, then all the attachment welds shall be inspected using the same non-destructive test method chosen.

13 Weld defect repairs

Unacceptable defects found during the manufacturing process described in Clause 15 and Clause 16 shall be removed and re-examined to ensure complete removal.

Defects shall be repaired (e.g. by chipping, grinding, or machining out to sound metal) and re-welded. Whenever a defect is removed by grinding or machining and subsequent repair by welding is not required, the excavated area shall be blended into the surrounding surface so as to avoid sharp notches, crevices, or corners. Care shall be taken to ensure proper weld penetration and complete fusion of the fresh weld deposit with the plates and previously deposited weld metal.

Flame gouging could be used as an alternative method for cutting out defects provided the edges are subsequently machined or ground back to sound material.

Where welding is required after removal of a defect, the area shall be cleaned and welding performed using the same processes and qualified welders that are employed in the manufacture of the pressure drum.

After a defect has been removed, and prior to making weld repairs, the area shall be examined by suitable methods as specified in 15.5 to ensure that the imperfection has been eliminated. After repairs have been made, the repaired area shall be blended into the surrounding surface so as to avoid sharp notches, crevices, or corners, and re-examined using the same non-destructive examination method that failed the initial repair, and by all other methods of examination that were required for the affected area. After all repairs have been completed, it shall be ensured that the remaining thickness of the drum meets the minimum design wall and head thicknesses.

14 Construction and workmanship

14.1 Thickness measurement

To ensure maintenance of the minimum thickness as specified on the drawing, each finished drum shall be checked ultrasonically on a grid basis at a minimum side size 500 mm.

The measurements will be made with a precision of 1/10 mm.

14.2 Out of roundness

The out-of-roundness of the cylindrical shell shall be limited so that the difference between the maximum and the minimum outside diameter in the same cross-section is not more than 2 % of the mean of these diameters for two piece drums and 3 % for three piece drums and for spheres.

14.3 Straightness

The maximum deviation of the cylindrical part of the shell from a straight line shall not exceed 0,3 % of the cylindrical length.

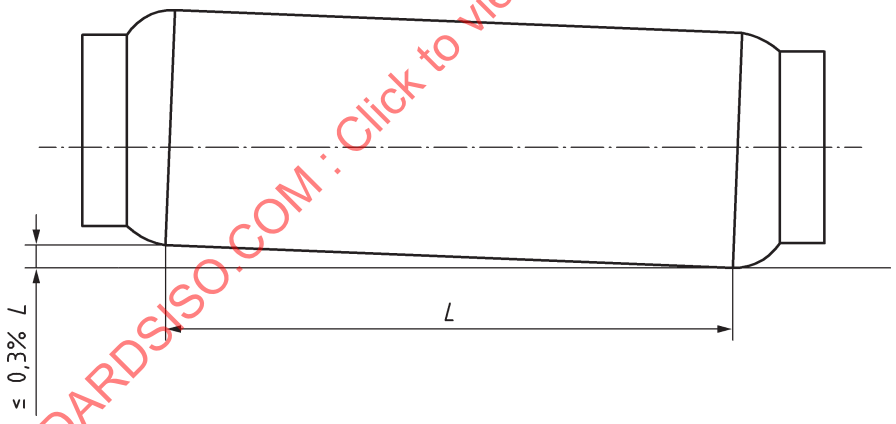


Figure 6 — Straightness

15 Testing and examination

15.1 Test plates

The tests on test plates shall take into account the design temperature of the drum with a minimum equal to or less than –20 °C, and a maximum equal to or more than +65 °C.

Test plates for mechanical tests shall be provided as specified in 6.2 on one drum in every 50 drums manufactured, except that for the first 40 drums of a new design, test plates shall be provided for 1 in every 10 drums.

If different welding materials or different welding processes are used on the manufacturing of the batch, tests plates as specified above shall be provided for each of them.

15.2 Provision of welded test plates

15.2.1 Test plates shall be provided at the end of a longitudinal seam, except in the case of spherical vessels where separate flat test plates shall be provided.

15.2.2 The combined length of weld in each set of test plates shall be sufficient to provide material for the tests required together with any re-tests which might be necessary with suitable allowance for discards and cutting.

15.2.3 The material used for the test plates shall be from the same cast or to the same specification as the shell plates of the drum and shall be of the same thickness as that of the shell plates represented. The test plates shall be attached at the end of the longitudinal seam in order to be welded at the same time as the longitudinal weld of the drum and shall be suitably clamped or reinforced to prevent excessive distortion or warping. Alternatively, test plates can be made by making an overlong cylindrical section and cutting off a complete ring using a process not involving excessive heat or in the case of spherical vessels, made separately.

When impact tests are required, the test plate shall be oriented the same as the cylindrical body plates with respect to mill rolling and weld directions.

The test plate shall be heat treated at the same time and conditions as the drum.

Alternatively the test plate can be taken from a fully heat treated drum.

15.2.4 For the bend test, the test plates welds shall be dressed smooth and flush with, but not below, the surface of the adjacent plates.

15.2.5 Straightening of the test plates that have warped during fabrication shall be carried out cold.

15.2.6 Test plates shall be subjected to non-destructive examination to the same standard as the main seams. If the non-destructive examination of a test plate reveals the presence of flaws, which in a main seam would normally require repair, these flaws shall be avoided in the selection of the test pieces. Repair of welded test plates shall not be permitted.

15.3 Number of test specimens

The number of specimens required from each set of test plates shall be in accordance with Table 2.

When more than one specimen of a particular type is required, the specimens shall be taken as far apart as possible.

Table 2 — Number of test specimens required

Test specimen	Plate thickness	
	10 mm or less	over 10 mm
Macro examination	1	1
Transverse tensile	1	1
Root bend	1[b]	1[a]
Face bend	1	—
Charpy	3	3

[a] For a butt joint made from only one side.

[b] Not necessary in case of joggle joint.

15.4 Mechanical tests

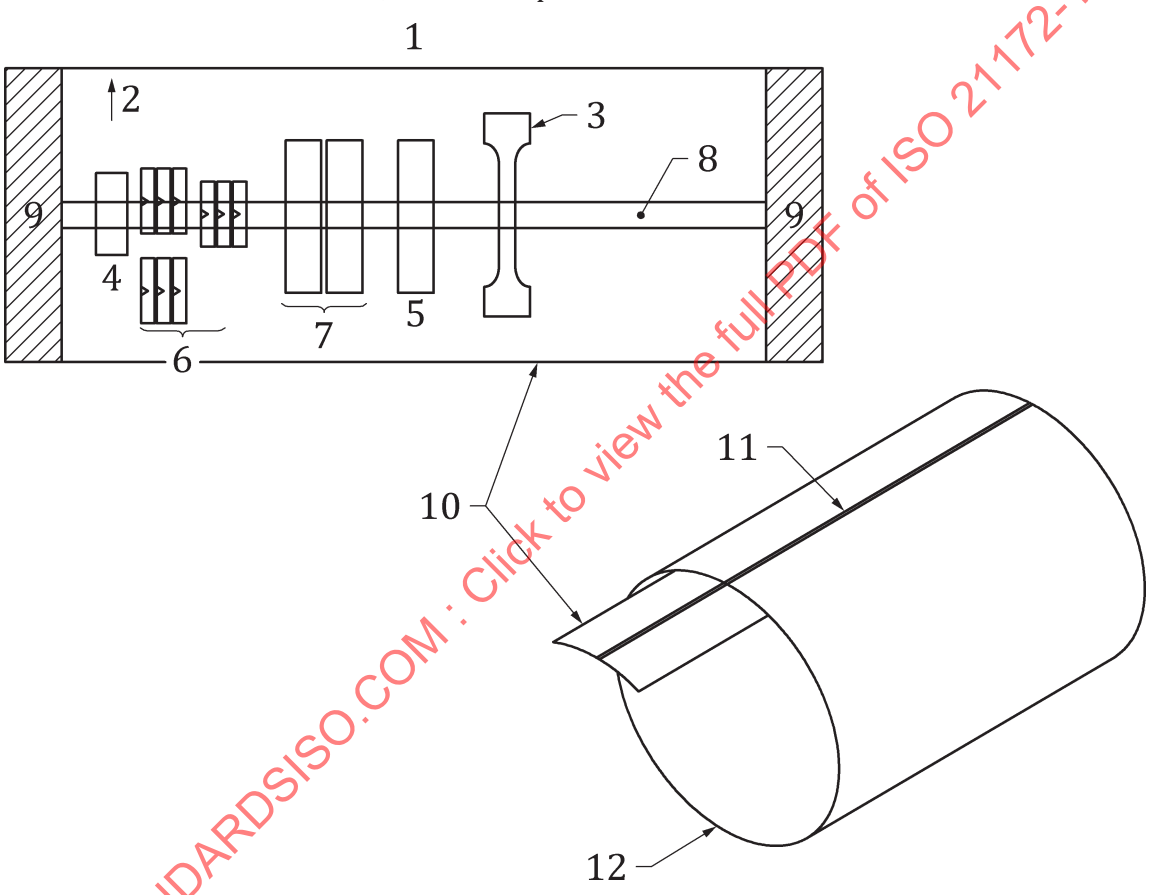
15.4.1 Tensile tests

Tensile testing shall be carried out as specified in ISO 4136 and ISO 6892.

Tensile strength shall be not less than the specified minimum value for the parent metal.

Except for stress relieved drums or if the information is already available from the material certificate, tensile specimens T1 and T2 (see Figure 7) shall be made from strips cut in accordance with the requirements of 16.2. The tensile specimen T3 shall be taken perpendicular to the longitudinal welded seam (see Figure 7).

The form and dimensions of the test specimen shall be as specified in ISO 4136. The face and back of the test specimen shall not be machined, but shall represent the surface of the drum as manufactured.



Keys

1	test plate detail	7	root bend test
2	rolling direction	8	longitudinal welded seam
3	tensile test	9	discard this area
4	macro	10	test plate
5	face bend test	11	longitudinal seam
6	charpy	12	shell

Figure 7 — Test specimen location for tensile testing

15.4.2 Bend tests

Bend test specimens and the conditions and the method for carrying out the tests shall be in accordance with ISO 7438.

Bend specimen un-machined surfaces representing the outside or inside of the vessel shall only be lightly dressed so that the rolled surface of the parent metal is not wholly removed. Where the rolled surfaces of abutting plates are not level with one another, one plate can be machined at each face to a depth not exceeding 1 mm.

Bend test specimens shall be cut transversely to the welded seam. They shall be the full thickness of plates and shall have a width not less than 1,5 times the plate thickness. The edges shall be rounded to a radius not exceeding 10 % of the thickness tested.

Two transverse bend tests shall be made. One test piece shall be tested with the surface corresponding with the outer surface of the vessel in tension, and the other with the surface corresponding with the inner surface of the vessel in tension. The diameter of the former, around which the test specimens are bent, shall not be more than three times the thickness of the test specimen, and the test is to be continued until the two limbs are parallel.

On completion of the test there shall be no visible cracks or defects at the outer surface of the specimen.

15.4.3 Impact test

15.4.3.1 Except for the requirements set out in this clause, the impact test (Charpy V-notch) shall be carried out in accordance with the requirements of ISO 148.

For drums made with hot pressure welded heads using ASTM specification A285/285M Grade A material, the impact test (Charpy V—notch) shall not be required.

15.4.3.2 The test temperature shall be, with a minimum design reference temperature of –20 °C.

15.4.3.3 Three impact test samples shall be taken from (see Figure 7):

a) each parent material (not necessary for stress relieved drums, or if available from the material certificate or for austenitic stainless steel drums);

b) each longitudinal weld;

c) one of the circumferential welds (not necessary if the welding procedure is identical to that for the longitudinal weld).

15.4.3.4 For the parent material samples, the transverse impact test pieces shall be taken from the wall of the drum. The notch shall be perpendicular to the face of the wall. The test pieces shall be machined only on four faces with the inner and outer face of the drum remaining unmachined.

15.4.3.5 For the welds, impact test pieces transverse to the weld shall be taken. The notch shall be in the centre of the weld and shall be perpendicular to the face of the pressure drum. The test pieces shall be machined on all 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.

The average of three specimens shall meet a value of 27 J/cm^2 for the test impact energy.

No specimen shall show a value less than 70 % of the average test impact energy value.

15.4.4 Macro examination

The macroscopic examination (see ISO 17639) shall show complete fusion and shall be free of any assembly faults or an unacceptable defect.

15.5 Non-destructive examination of completed welds

15.5.1 General

Following a full external visual examination all welded seams shall be examined by radiography/radioscopy or other method if the method is proved to be as sensitive as radiography.

Personnel performing non-destructive examination shall be qualified at least to level 1 and supervised by personnel certified at least to level 2 in accordance with ISO 9712. Additionally, the manufacturer shall put in force a welding quality system (e.g. as described in ISO 3834-2).

15.5.2 Radiography/radioscopy

Radiographs shall be taken of the entire length of each weld seam, together with the seams in the corresponding test plates. Sufficient overlap shall be ensured to cover the whole of the welded seam. The welds shall be radiographed in accordance with the general principles for X-ray radiography as specified in ISO 1106-1.

The image quality shall be in accordance with Class B of EN 462-3 (or equivalent) images shall be retained.

As circumferential welds in hot forged welded drums cannot be adequately radiographed, they shall be tested using an alternative NDT method.

15.5.3 Rejection criteria

Acceptance criteria shall allow for the detection of all significant indications and as specified to level C in ISO 5817 or level 2 in ISO 1106-1.

15.6 Failure to meet test requirements

If any test fails to meet the above requirements, two re-tests of the same type as that which failed shall be taken from the same test plate and both of these shall conform to the above requirements. If one or both of these re-tests fail to conform, the drums represented by these tests shall be rejected.

15.7 Lifting points

Where lifting points are fitted, the design shall be proven by a type test in which a sample attachment is tested to two times the maximum gross weight without failure or significant deformation.

In production, each lifting point shall be subjected to a lift test at the gross weight. These tests can be carried out by attaching external weights to the drum. After completion of the lifting test, all lifting eyes and their associated attachment welds shall be tested for crack defects on 10 % of the batch in accordance with ISO 9934-1 and ISO 17638. If a defect is detected, then the entire batch shall be tested.

All structural welded joints shall be tested for defects, on 10 % of the batch. If a defect is detected, then the entire batch shall be tested.

It is not necessary to carry out lifting test on drums which are to be lifted via fork lift pockets.

16 Type approval procedure

16.1 General requirements

A technical specification of each new design of drums, or drums family as defined hereunder, including design drawings, design calculations, steel details, manufacturing process, and heat treatment details, shall be submitted by the manufacturer to the inspector. The type approval tests detailed in the present clause shall be carried out on each new design under the supervision of the inspector.

A drum shall be considered to be of a new design (family), compared with an existing approved design, when at least one of the following applies:

a) it is manufactured in a different factory;

b) it is manufactured by a different process;

c) it is manufactured according to a different material standard according to Clause 5;

d) it is given a different heat treatment;

e) the protections of fittings are not in the limitation of 6.5.4;

f) the number of the opening has increased;

g) the inside diameter of an opening has increased by 50 % or more;

h) the minimum design wall thickness or end thickness is changed by 25 % or more;

i) the water capacity has change by more than 30 %.

16.2 Type approval tests

16.2.1 Prototype tests

16.2.1.1 Pressure cycling test

A drum representative of the design shall be subjected to 12 000 cycles, the upper pressure being the test pressure p_h, the lower pressure not exceeding 10 % of p_h.

The design shall pass if there is no leakage of pressure at the end of the test. A representative finished drum shall be used for the prototype work. This drum shall be scrapped after the completion of the cycling testing.

The pressure cycling test is not required where:

a) welding procedures meet requirements of ISO 15614-1 and ISO 15613;

b) at test pressure, the design stresses f_c, f_e, f_p, and f_s do not exceed 0,75 Y and 0,5 Rm.

16.2.1.2 Hydraulic burst test

A drum representative of the design and manufacture, including the nameplate (which might be the drum designed for the fatigue test), shall be subjected (after the batch tests described on 18.2) to a burst test. The pressure shall be raised at a rate not exceeding 5 bar/min.

The design shall pass if reversal of an end, or other plastic deformation does not occur at a pressure less than 20 % above p_h. The final burst test shall be without fragmentation. The minimum burst pressure shall be

a) 2,25 p_h for a test pressure of less than 60 bar, and

b) 2,0 p_h for a test pressure greater than or equal to 60 bar.

The burst test is not required where:

c) the rolling bands are not directly welded on the shell, but on intermediate plates fully welded on the shell;

d) welding procedures meet the requirements of ISO 15614-1 and ISO 15613.

16.2.1.3 Additional test

In addition, tests required in 15.1 to 15.7 shall have been performed.

16.3 Manufacturing tests on each drum

16.3.1 Volume check

The minimum volume (water capacity) of the drum shall be checked against specification and recorded by the manufacturer.

16.3.2 Tare weight check

Each drum shall be weighed to an accuracy of 1 %, and the value stamp marked on the name plate. The tare weight shall include all non-removable fittings and internal and external coatings, consistent with normal filling procedures.

16.3.3 Proof pressure test

Each drum shall be subjected to a hydraulic proof pressure test at the test pressure, p_h, after all welding operations and heat treatment of the vessel have been completed, but before any lining or internal or external coating processes.

The water pressure in the vessel shall be increased at a controlled rate until the test pressure, p_h is reached.

The vessel shall remain under pressure, p_h, for at least 10 min to establish that the pressure does not fall and that there is no leakage.

The gaskets used on all pads, bosses, and other attachments for the test shall be of the same material and to the same dimensions as specified for the operating duty.

During the test the outside of the drum shall be dry, and it shall be possible (with good access and illumination) to examine the welded seams. There shall be no leakage and no visible permanent deformation. There shall be no pressure drop at the end of the test.

If bolted connections leak, they shall be disassembled, the cause identified and corrected and the vessel re-tested. It is not permissible to apply excess torque to cure a leak.

16.3.4 Pneumatic test

Alternatively, provided adequate safety precautions are taken, the hydraulic pressure test can be replaced by a pneumatic test at the same test pressure. Measures shall be taken to ensure safe operation considering the larger amount of stored energy, relative to the hydraulic test. The pressure source shall be isolated and vented; during 10 min the settled test pressure shall not decline by more than 1 %.

The pressure shall then be reduced to 6 bar, and all seams and joints examined for leaks by an appropriate detection method (e.g. soap solution testing).

WARNING — It should be noted that pneumatic pressure tests require more precautions than hydraulic pressure tests since, regardless of the size of the container, any error in carrying out this test is highly likely to lead to a rupture under gas pressure. Therefore, these tests shall be carried out only after ensuring that the safety measures satisfy the safety requirements.

16.3.5 Final inspection

Each drum shall have a final internal and external examination. If a drum fails to meet the specification, it shall be rectified or rejected. Information to be marked.

16.3.6 Tightness test

Each drum shall be subjected to a leak test at a minimum pressure of 6 bar (e.g. using dry air or nitrogen as the pressure medium) when fitted as for use with studs, nuts, joints and valves.

The joints shall be tested for leaks using a soap solution, or a method of equal sensitivity.

17 Marking

17.1 Drums

Each drum shall be permanently and legibly marked in accordance with the requirements of ISO 13769.

Requirements for marking in relevant regulations override the requirements given in this part of ISO 21172.

17.2 Hot pressure welded drums

For hot pressure welded drums, the symbol "X" shall be added immediately following the ISO number.

17.3 Pressure drums for very toxic gases (LC_{50} less than 200 ppmV)

For pressure drums approved for very toxic gases, the symbol "T" shall be added immediately following the ISO number.

17.4 Position and size of marking

All markings shall be made on a plate either welded to the head of the drum, or on a plate securely fixed to a shroud, support or other part that is a permanent part of the drum. The plate shall have space to mark re-test dates. It shall be positioned so that it is accessible for re-stamping, but is not damaged under normal handling. The drum serial number shall be in characters at least 10 mm high. Other drum markings shall be at least 5 mm high.

18 Certification

18.1 Type approval

For each batch of drums, a certificate of type approval shall be made and issued by the inspector, certifying that the design conforms to the standard. A unique number shall be assigned to this type approval. A type approval number can be used for several batches of manufacture.

The approval certificate shall include details of any special tests that have been necessary.

18.2 Manufacturing conformance

Certification shall also be produced that confirms that all the drums made in a batch have been fabricated in accordance with the standard.

Drum certification shall at least include:

a) the serial number;

b) the test pressure used;

c) the minimum water capacity;

d) a detailed drawing;

e) the construction materials used.

19 Certificate

Each batch of drums shall be certified to state that they conform to the requirements of this part of ISO 21172.

A certification signed by the independent inspector indicating that all tests and verification were performed with satisfactory results and that his mark has been applied on all pressure drums covered by the report and accepted by the inspector as being in conformance with the requirements set out in this part.

An example of a certificate is given in Annex C.

Annex A
(informative)

Description and evaluation of manufacturing of a welded steel pressure drums at the time of visual inspection

A.1 General

A.1.1 Several types of defects can occur during the manufacturing of a welded steel drum. Such defects can be mechanical or material. They can be due to the basic material used, the manufacturing process, and heat treatments, 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 judgement are necessary by the inspector to detect and to be able to evaluate and judge a defect at the time of the visual inspection (see ISO 5817).

A.1.2 Visual examination shall be carried out in accordance with ISO 17637. It is essential to perform the visual internal and external inspection in good conditions. Appropriate sources of illumination with sufficient intensity shall be used (e.g. 50 lux).

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

When this visual inspection is carried out after the circumferential welding, the internal neck area shall be examined by means of an introscope, dental mirror or other suitable appliance.

A.1.3 Defects can be repaired in accordance with Table E.1. It shall be ensured that any repair method used will not impair the safety of the drums. Great care shall be taken to avoid introducing new defects. After such repair, the drum shall be re-examined, and, if necessary, the wall thickness shall be rechecked.

A.2 Manufacturing defects

The most commonly found manufacturing defects and their definitions are listed in Table E.1. Rejection limits for repair or reject are included in this table. These rejection limits have been established following considerable field experience. They apply to all sizes and types of drums and service conditions. Nevertheless, some customer specifications, some types of drum, or some special service conditions might require more stringent criteria. Rejection limits for repair or reject of weld defects shall be in accordance with ISO 5817 level C.

A.3 Rejected drums

All rejected drums shall be rendered unserviceable.

Annex B
(informative)

Example of calculation note for determination of thickness for shell and dished end for pressure drums according to 6.4

B.1 Drum characteristics

A horizontal pressure drum for use with non-toxic gas will:

a) have an external diameter (D_0) of 800 mm;

b) be able to withstand a test pressure (p_h) of 30 bar;

c) have a burst pressure factor (k) of 2,25 (see 16.2.1.2);

d) be made from P355N in accordance with the requirements of ISO 9328-3;

e) have a material yield stress (Y) of 355 Mpa;

f) have a maximum design stress (0,77Y) of 273,35 MPa;

NOTE The design stresses f_c, f_e, f_p, and f_s at the test pressure shall not exceed 0,77 Y.

g) have a material tensile strength (T) of 490 Mpa.

B.2 Calculation

B.2.1 Thickness of cylindrical wall

B.2.1.1 Calculation at test pressure using Formula (1) (see 6.3.1)

$$a_{1(1)} = \frac{p_h \times D_0}{20 f_c + p_h} \tag{B.1}$$

where

a_1 is the minimum thickness of the cylindrical part of the drum based on pressure criteria;

p_h is the test pressure;

D_0 is the maximum outside diameter of the drum;

f_c is the maximum allowable stress for the cylindrical section of a drum.

and substituting the values from B.1:

$$a_{1(1)} = \frac{30 \times 800}{(20 \times 273{,}35) + 30} = 4{,}366 \text{ mm} \cong 4{,}37 \text{ mm} \tag{B.2}$$

where

a_1 is the minimum thickness of the cylindrical part of the drum based on pressure criteria;

B.2.1.2 Calculation at burst pressure using Formula (2) (see 6.3.1)

$$a_{1(2)} = k\frac{p_h \times D_0}{20T + p_h} \tag{B.3}$$

where

a_1 is the minimum thickness of the cylindrical part of the drum based on pressure criteria;

k is the safety factor ratio between minimum required burst pressure and test pressure;

p_h is the test pressure;

D_0 is the maximum outside diameter of the drum;

T is the minimum value of tensile strength guarantee by the drum manufacturer.

and substituting the values from B.1:

$$a_{1(2)} = 2{,}25\frac{30\times 800}{(20\times 490)+30} = 5{,}493\ \text{mm} \cong 5{,}5\ \text{mm} \tag{B.4}$$

where

a_1 is the minimum thickness of the cylindrical part of the drum based on pressure criteria.

B.2.1.3 Calculation for handling condition

Using Formula (3) (see 6.3.1) and Formula (9) (see 6.3.3.2):

$$a_2 = \frac{D_0}{250} + 2 \tag{B.5}$$

where

a_2 is the minimum thickness of cylindrical shell or dished end based on handling criterion;

D_0 is the maximum outside diameter of the drum.

and substituting the values from B.1:

$$a_2 = \frac{800}{250} + 2 = 5{,}2\ \text{mm} \tag{B.6}$$

where

a_2 is the minimum thickness of cylindrical shell or dished end based on handling criterion.

B.2.2 Thickness for dished ends

B.2.2.1 Ellipsoidal ends

For a drum with an ellipsoidal end and using Formula (7) (see 6.3.3.1 and Figure B.1):

$$H_e = H_0$$

and with:

$$H_e = H_0 = 213\ \text{mm}\ (\text{manufacturer value})$$

then:

$$\frac{H_e}{D_0} = \frac{213}{800} = 0{,}266 \tag{B.7}$$

where

H_e is the equivalent height of a dished end for determining the shape factor;

D_0 is the maximum outside diameter of the drum.

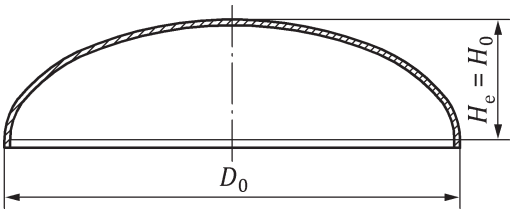


Figure B.1 — Ellipsoidal end equivalent height

B.2.2.2 Torispherical ends

For a drum with a torispherical end and using (see NOTE in 6.3.3.1 and Figure B.2):

$$H_0 = R_0 - \sqrt{\left(R_0 - \frac{D_0}{2}\right)\left(R_0 + \frac{D_0}{2} - 2(r_0)\right)}$$

and with

H_0 is the external height of the domed part of the end;

R_0 = 805 mm (manufacturer value);

D_0 = 800 mm (manufacturer value);

r_0 = 85 mm (manufacturer value).

then:

$$H_0 = 805 - \sqrt{\left(805 - \frac{800}{2}\right)\left(805 + \frac{800}{2} - 2(85)\right)} = 157{,}563\,\text{mm} \cong 158\,\text{mm} \tag{B.8}$$

where

H_0 is the external height of the domed part of the end.

therefore:

$$\frac{H_e}{D_0} = \frac{158}{800} = 0{,}197\ 5 \tag{B.9}$$

where

H_e is the equivalent height of a dished end for determining the shape factor;

D_0 is the maximum outside diameter of the drum.

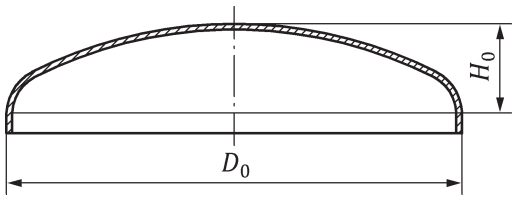


Figure B.2 — Torispherical end equivalent height

B.2.2.3 Concave ends

For a drum with concave ends, the minimum thickness, b_1, of the wall of a torispherical end or ellipsoidal dished end shall be not less than:

$$b_1 = K \cdot a_{1(1)}$$

where the value of K varies with the shape of the ends (see Figure 2).

In all cases, the value of K shall not be taken as less than 1,0.

To define the shape factor K, it is necessary to estimate the value of b_1 (e.g. $b_1 = a_1$).

If b_1 = 4,37 (see B.2.1) then:

$$\frac{b_1}{D_0} = \frac{4{,}37}{800} = 0{,}005\ 4$$

where

b_1 is the calculated minimum thickness of dished ends;

D_0 is the maximum outside diameter of the drum.

Using Figure B.3 and plotting the curve for $\frac{b_1}{D_0} = 0{,}005\ 4$, it can be read from the graph that at an $\frac{H_e}{D_0}$ value of 0,266 (see B.2.2.1), the corresponding value of K is 1,03. The position of the curve for $\frac{b_1}{D_0}$ is made by iteration.

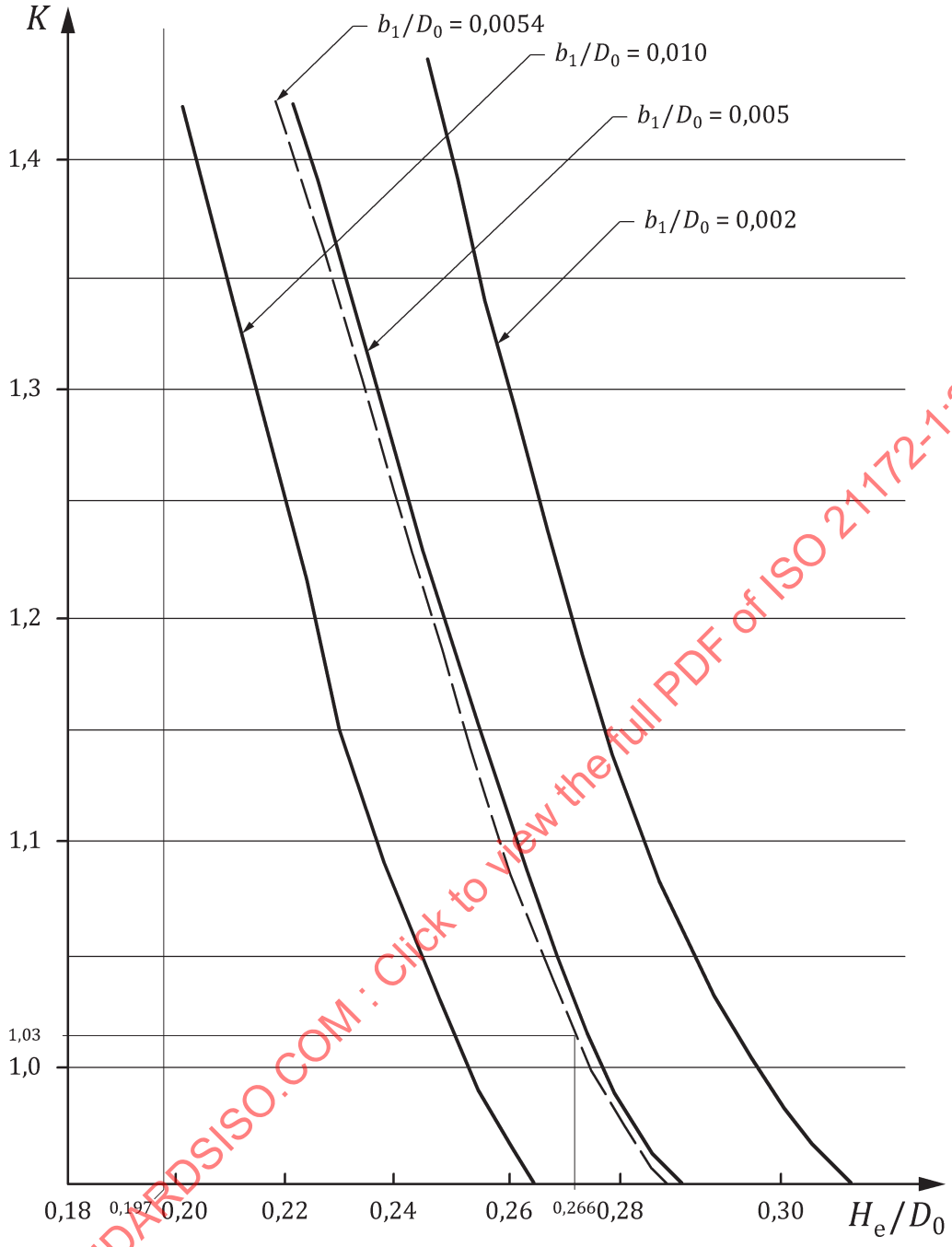


Figure B.3 — Shape factor *K*

B.3 Results

B.3.1 Ellipsoidal ends

For an ellipsoidal end: $K = 1{,}03$.

Therefore, as $b_1 = K^* a_{1(1)}$ and $a_{1(1)} = 4{,}37$ mm (see B.2.1)

$$b_1 = 4{,}5\,\text{mm}$$