

Simple unfired pressure vessels designed to contain air or nitrogen —

**Part 4: Aluminium alloy pressure
vessels designed for air braking
equipment and auxiliary pneumatic
equipment for railway rolling stock**

The European Standard EN 286-4:1995 has the status of a
British Standard

UDC 621.642.02-98-034.715:629.4-592:620.1:62-777

Confirmed December 2009

NO COPYING WITHOUT BSI PERMISSION EXCEPT AS PERMITTED BY COPYRIGHT LAW



Document Sharing Hub

Cooperating organizations

The European Committee for Standardization, under whose supervision this European Standard was prepared, comprises the national standards organizations of the following Western European countries:

Austria	Oesterreichisches Normungsinstitut
Belgium	Institut belge de normalisation
Denmark	Dansk Standard
Finland	Suomen Standardisoimisliito, r.y.
France	Association française de normalisation
Germany	Deutsches Institut für Normung e.V.
Greece	Hellenic Organization for Standardization
Iceland	Technological Institute of Iceland
Ireland	National Standards Authority of Ireland
Italy	Ente Nazionale Italiano di Unificazione
Luxembourg	Inspection du Travail et des Mines
Netherlands	Nederlands Normalisatie-instituut
Norway	Norges Standardiseringsforbund
Portugal	Instituto Português da Qualidade
Spain	Asociación Española de Normalización y Certificación
Sweden	Standardiseringskommissionen i Sverige
Switzerland	Association suisse de normalisation
United Kingdom	British Standards Institution

This British Standard, having been prepared under the direction of the Engineering Sector Board, was published under the authority of the Standards Board and comes into effect on 15 February 1995

© BSI 07-1999

The following BSI references relate to the work on this standard:
Committee reference PVE/17
Draft for comment 90/81699 DC

ISBN 0 580 21850 3

Amendments issued since publication

Amd. No.	Date	Comments

Contents

	Page
Cooperating organizations	Inside front cover
National foreword	ii
Foreword	2
Text of EN 286-4	5
National annex NA (informative) Committees responsible	Inside back cover
National annex NB (informative) Cross-references	Inside back cover

National foreword

This British Standard has been prepared under the direction of the Pressure Vessel Standards Policy Committee and is the English language version of EN 286-4:1994 *Simple unfired pressure vessels designed to contain air or nitrogen — Part 4: Aluminium alloy pressure vessels designed for air braking equipment and auxiliary pneumatic equipment for railway rolling stock*, published by the European Committee for Standardization (CEN).

EN 286-4 was produced as a result of international discussions in which the UK took an active part.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, the EN title page, pages 2 to 38, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

UDC 621.642.02-98-034.715:629.4-592:620.1:62-777

Descriptors: Railway rolling stock, brakes, pneumatic equipment, pressure vessels, tanks containers, aluminium alloys, design, computation, production control, weld defects, acceptability, assembling, certification, marking

English version

Simple unfired pressure vessels designed to contain air or nitrogen — Part 4: Aluminium alloy pressure vessels designed for air braking equipment and auxiliary pneumatic equipment for railway rolling stock

Réipients à pression simples, non soumis à la flamme, destinés à contenir de l'air ou de l'azote — Partie 4: Réipients à pression en alliages d'aluminium destinés aux équipements pneumatiques de freinage et aux équipements pneumatiques auxiliaires du matériel roulant ferroviaire

Einfache unbefeuerte Druckbehälter für Luft oder Stickstoff — Teil 4: Druckbehälter aus Aluminiumlegierungen für Druckluftbremsanlagen und pneumatische Hilfseinrichtungen in Schienenfahrzeugen

This European Standard was approved by CEN on 1994-09-09. CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CEN member.

The European Standards exist in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Central Secretariat has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

CEN

European Committee for Standardization
Comité Européen de Normalisation
Europäisches Komitee für Normung

Central Secretariat: rue de Stassart 36, B-1050 Brussels

© 1994 Copyright reserved to CEN members

Foreword

This European Standard was prepared by CEN/TC 54, Unfired pressure vessels, of which the secretariat is held by BSI.

This European Standard has been prepared under a Mandate given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements of the EC Directive(s).

CEN/TC 54 decided to submit the final draft for formal vote by its resolution. The result was positive.

This part is one of a series of four. The other Parts are:

- *Part 1: Design, manufacture and testing;*
- *Part 2: Pressure vessels for air braking and auxiliary systems for motor vehicles and their trailers;*
- *Part 3: Steel pressure vessels designed for air braking equipment and auxiliary pneumatic equipment for railway rolling stock.*

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by March 1995, and conflicting national standards shall be withdrawn at the latest by March 1995.

According to the CEN/CENELEC Internal Regulations, the following countries are bound to implement this European Standard:

Austria, Belgium, Denmark, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain and United Kingdom

Contents

	Page
Foreword	2
1 Scope	5
2 Normative references	5
3 Symbols	6
4 Materials	7
5 Design	7
6 Inspection and drainage bosses	15
7 Marking	15
8 Corrosion protection	16
9 Qualification of welding procedures	19
10 Qualification of welders and welding operators	19
11 Testing of the vessels	19
12 Certification procedures	25
13 Information to be supplied at the time of invitation to tender and time of order	25
14 Delivery	25
15 Documentation to accompany the vessel	25
Annex A (normative) Verification	26
Annex B (normative) Declaration of conformity — Surveillance	26
Annex C (normative) Design and manufacturing schedules	28
Annex D (normative) Type examination	29
Annex E (normative) Content of the manufactured record	29
Annex F (informative) Assembly of the vehicles	30
Annex G (informative) Service surveillance of vessels	35
Figure 1 — Position of longitudinal welds on the bottom of the shell	8
Figure 2 — Position of longitudinal welds on the shell	8
Figure 3 — Torispherical end	9
Figure 4 — Theoretical curves for dished ends	10
Figure 5 — Butt weld with centre lines aligned	10
Figure 6 — Butt weld with centre lines offset	11
Figure 7 — Butt welds with centre lines offset and connecting slope	11
Figure 8 — Weld of the shell ring to end with necked edge	11
Figure 9 — Position of a hole in an end	14

	Page		Page
Figure 10 — Distance between two welds measured from the end of the edge preparation	12	Table 1 — Aluminium alloy materials	7
Figure 11 — Reinforcement of opening	12	Table 2 — Height of the cylindrical portion of ends	8
Figure 12 — Fixing of a boss by an external weld	13	Table 3 — Diameters and locations of bosses	9
Figure 13 — Fixing of a boss by internal and external welds	13	Table 4 — Amount of testing required for welds made by a non-automatic process	10
Figure 14 — Fixing of a boss by internal and external fillet welds	13	Table 5 — Amount of testing required for welds made by an automatic procedure with $P \geq 1,15P_s$	10
Figure 15 — Fixing of a drainage boss by an external weld	14	Table 6 — Amount of testing required for welds made by an automatic procedure with $P \geq 1,15P_s$	11
Figure 16 — Fixing of a drainage boss by internal and external welds	14	Table 7 — Acceptance levels of defects in butt-welds, detected by visual examination	11
Figure 17 — Fixing of a drainage boss with drainage groove	14	Table 8 — Acceptance levels of defects in butt-welds, detected by X-ray examination	11
Figure 18 — Dip tube fixed to an end	14	Table 9 — Maximum permissible reinforcement for longitudinal and circular welds	24
Figure 19 — Dip tube fixed to the shell of a horizontal vessel	14	Table 10 — Classification of vessels	12
Figure 20 — Dip tube fixed to the shell of a vertical vessel	14	Table F.1 — Dimensions of straps	31
Figure 21 — Dip tube fixed to a top end of a vertical vessel	14	Table F.2 — Tightening torques	31
Figure 22 — Dip tube fixed to the upper part of the shell of a horizontal vessel	15	Table G.1 — Service surveillance of vessels used at $P_s \leq 6$ bar	36
Figure 23 — Fixing of a dip tube	15	Table G.2 — Service surveillance of vessels used at $6 \text{ bar} < P_s \leq 10 \text{ bar}$	36
Figure 24 — Fixing of a dip tube to a boss	15	Table G.3 — Annual sampling examination	36
Figure 25 — Recessed fixing of a dip tube to a boss	15		
Figure 26 — Location of openings	16		
Figure 27 — Location of identity and service marks	17		
Figure 28 — Marking plate	18		
Figure 29 — Identity and service marks	19		
Figure 30 — Reinforcement thickness	24		
Figure F.1 — Fixing by straps of a vessel in the horizontal position	31		
Figure F.2 — Fixing by straps of a vessel in the vertical position	31		
Figure F.3 — End of straps with angle brackets	32		
Figure F.4 — Ends with straps folded and reinforced	32		
Figure F.5 — Ends of straps with welded bolt	33		
Figure F.6 — Ends of straps with grooved welded bolt	33		
Figure F.7 — Fixing to the vehicle with a bolt	34		
Figure F.8 — Fixing to the vehicle with a nut	34		

1 Scope

1.1 This Part of this European Standard is applicable to simple unfired aluminium alloy pressure vessels, referred to as “vessel” in this standard, designed for air braking equipment and auxiliary pneumatic equipment for railway rolling stock (see **1.6**).

1.2 The vessels to this standard are:

- a) made from a single shell;
- b) made from aluminium alloy;
- c) fabricated by welding;
- d) used at a maximum working pressure of 10 bar;
- e) the product of the maximum working pressure (in bar) and the volume (in litre):
 $500 \text{ bar litres} < PV \leq 10\,000 \text{ bar litres}$;
- f) made of a cylindrical part of circular cross-section called the shell with two outwardly dished torispherical ends, that is two dished ends with the same axis of rotation. This standard therefore does not apply to vessels with one or two flat ends or those made up of several compartments;
- g) calculated with a design pressure P (see **5.1.4.2**);
- h) designed for a working temperature of between -50 °C and $+100\text{ °C}$ [$+65\text{ °C}$ for certain grades of aluminium alloy (see **4.1.1**)];
- j) fastened to the vehicles by straps;

1.3 In normal service, a momentary overpressure of 1 bar of the maximum working pressure is permitted (10 % of P_s).

1.4 This Part of this European Standard applies to the vessel proper, from the inlet connection to the outlet connection and to all other connections and fittings belonging to the vessel.

1.5 This Part of this European Standard gives the requirements to be met for the calculation, design, fabrication, inspection during fabrication and certification of the vessel, and fittings for assembly to the vehicle.

These requirements cannot be written in sufficient detail to ensure good workmanship or proper construction. Each manufacturer is therefore responsible for taking every necessary step to make sure that the quality of workmanship and construction is such as to ensure compliance with good engineering practice.

This Part of this standard gives:

- a) in Annex F, recommendations for assembly to the vehicles;

- b) in Annex G, recommendations for the service surveillance of vessels.

1.6 The requirements of this Part of this European Standard apply to vessels designed to be fitted to rail vehicles used on the main national networks, urban networks, underground railways, trams, private networks (regional railways, company railways, ...).

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies.

EN 287-2, *Approval testing of welders — fusion welding — Part 2: Aluminium and aluminium alloys*.

EN 288-1, *Specifications and approval of welding procedures for metallic materials — Part 1: General rules for fusion welding*.

EN 288-2, *Specification and approval of welding procedures for metallic materials — Part 2: Welding procedure specification for arc welding*.

EN 288-4, *Specification and approval of welding procedures for metallic materials — Part 4: Welding procedure tests for the arc welding of aluminium and its alloy*.

EN 10025, *Hot rolled products of non-alloy structural steels — Technical delivery conditions*.

EN 26520, *Classification of imperfections in metallic fusion welds, with explanations*.

ISO 209-1, *Wrought aluminium and aluminium alloys — Chemical composition and forms of product — Part 1: Chemical composition*.

ISO 209-2, *Wrought aluminium and aluminium alloys — Chemical composition and forms of product — Part 2: Forms of products*.

ISO 228-1, *Pipe threads where pressure-tight joints are not made on the threads — Part 1: Designation, dimensions and tolerances*.

ISO 261, *ISO general purpose metric screw threads — General plan*.

ISO 1101, *Technical drawings — Geometrical tolerancing — Tolerancing of form, orientation, location and run-out — Generalities, definitions, symbols, indications on drawings*.

ISO 2081, *Metallic coatings — Electroplated coating of zinc on iron or steel*.

ISO 2107, *Aluminium, magnesium and their alloys — Temper designations.*

ISO 2437, *Recommendation practice for the X-ray inspection of fusion welded butt joints for aluminium and its alloys and magnesium and its alloys 5 to 50 mm thick.*

ISO 4520, *Chromate conversion coatings on electroplated zinc and cadmium coatings.*

ISO 6361-2, *Wrought aluminium and aluminium alloy sheet, strip and plate — Part 2: Mechanical properties.*

ISO 6362-2, *Wrought aluminium and alloy extruded rods/bars, tubes and profiles — Part 2: Mechanical properties.*

3 Symbols

For the purpose of this standard, the following symbols apply:

A	Elongation at rupture	%
A_{fb}	Cross sectional area effective as compensation, of the boss	mm ²
A_{fp}	Cross sectional area effective as compensation, of the reinforcing plate	mm ²
A_{fs}	Cross sectional area effective as compensation, of the shell	mm ²
A_p	Area of the pressurized zone	mm ²
c	Absolute value of the minus rolling tolerance for sheets as quoted in the standard	mm
D_o	Outside diameter of the shell of the vessel	mm
d_{ib}	Internal diameter of the boss	mm
d_{ob}	Outside diameter of the boss	mm
e	Nominal wall thickness	mm
e_c	Calculated thickness	mm
e_{ch}	Calculated thickness of the end	mm
e_{cs}	Calculated thickness of the shell	mm
e_h	Nominal thickness of the end	mm
e_{rb}	Wall thickness of the boss contributing to reinforcement	mm
e_{rp}	Wall thickness of the reinforcing plate contributing to reinforcement	mm
e_{rs}	Wall thickness of the shell contributing to reinforcement	mm
f	Nominal design stress at the design temperature	N/mm ²

f_b	Permitted stress of the boss	N/mm ²
g	Throat thickness of a weld	mm
h	External height of the dished part of an end (see Figure 3)	mm
h_1	External height of the cylindrical part of the end (see Figure 3)	mm
h_2	Internal height of a dished part of the end (see Figure 3)	mm
K_c	Design coefficient which is a function of the welding process	—
L	Total length of the vessel	mm
L_1	Distance between the axis of a drainage opening and the end of the vessel	mm
l_{rb}	Length of the boss contributing to reinforcement	mm
l_{rbi}	Length of inward projecting boss contributing to reinforcement	mm
l_{rp}	Length of the reinforcing plate contributing to reinforcement, measured along the mid surface	mm
l_{rs}	Length of the shell contributing to reinforcement, measured along the mid surface	mm
P	Design pressure ^a which is a function of the maximum working pressure, the welding process and inspection used	bar
P_s	Maximum working pressure ^a	bar
R	Internal radius of the spherical part of the end	mm
R_i	Local internal radius at the location of the opening in question	mm
R_m	Minimum tensile strength specified by the manufacturer or by the standard defining the material	N/mm ²
$R_{p0,2}$	Minimum proof stress	N/mm ²
r	Internal radius of the torispherical part of the end	mm
T_{min}	Minimum working temperature	°C
T_{max}	Maximum working temperature	°C
V	Volume of the vessel	l

^a All pressures are gauge pressures.

4 Materials

4.1 Pressurized parts

The aluminium alloys used in the fabrication of the pressurized parts of the vessels shall fulfil the following conditions:

- a) $R_m \leq 350 \text{ N/mm}^2$
- b) elongation after rupture A shall be:
 - if the test piece is taken parallel to the direction of rolling $\geq 16 \%$;
 - if the test piece is taken perpendicular to the direction of rolling $\geq 14 \%$.

4.1.1 Shell and ends

The shell and ends shall be made of aluminium alloy sheet or strip of one of the grades given in Table 1.

4.1.2 Inspection bosses, pipes connection branches and drainage bosses

The bosses shall be made of 5083, 5086, 5454 or 5754 aluminium alloy bars or tubes in condition M in accordance with ISO 6362-2.

4.2 Non-pressurized parts

The accessories to be welded to the vessel, but which do not contribute to its strength, shall be made of aluminium alloy compatible with the aluminium alloy from which the pressurized parts of the vessel are made. The product analysis of the aluminium alloy shall meet the following requirements:

- $R_m \leq 350 \text{ N/mm}^2$;
- $\text{Cu} \leq 0,5 \%$ and $\text{Zn} \leq 0,25 \%$.

4.3 Welding materials

The filler material and gas fluxes shall be suitable for the parent metals.

The recommended grades of filler material to be used are 5183 and 5356. These grades are suitable for welding the grades listed in 4.1 and 4.2.

Aluminium-silicon grades shall not be used.

The suitability of the welding products used is verified during the qualification of the procedures described in clause 9.

5 Design

5.1 Shell and ends

5.1.1 General

The vessels are of simple geometrical form, composed of a cylindrical body of circular cross-section and two outwardly dished torispherical ends.

The design of the vessels shall take into account the installation and maintenance conditions. The installation and maintenance conditions shall be given by the manufacturer or the user (see clause 13)

NOTE Examples of installation and maintenance requirements are given in informative Annex F and Annex G.

5.1.2 Design of the shell

Shells are generally made from a single sheet. If the shell is made of several welded parts, the number of circular welds shall be kept to a minimum.

Longitudinal weld seams of parts of the shell shall:

- not be located on the lower part of the vessel defined by an angle of 30° on either side of the vertical axis (see Figure 1);
- be sufficiently far apart such as to form an angle greater than 40° (see example in Figure 2).

All welds, even of a temporary nature, located outside the designed seams are prohibited.

Table 1 — Aluminium alloy materials

ISO designation ^a	International registration record ^a	Temper designation ^b	Maximum temperature °C	Temperature °C			Design temperature ^c °C			
				20	50	100	20	50	65	100
				Minimum proof stress N/mm ²			Minimum design stress N/mm ²			
AlMg2Mn0,8	5049	0	100	80	80	70	48	48	46 ^e	42
AlMg3	5754	0	100	80	80	70	48	48	46 ^e	42
AlMg3Mn	5454	0	100	90	90	90	54	54	54 ^e	54
AlMg4	5086	0	65	100	100	90 ^d	60	60	58 ^e	54 ^d
AlMg4,5Mn0,7	5083	0	65	125	125	120 ^d	75	75	74 ^e	72 ^d

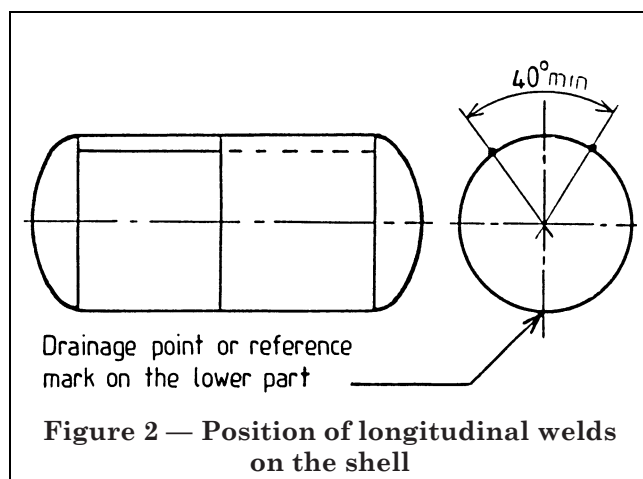
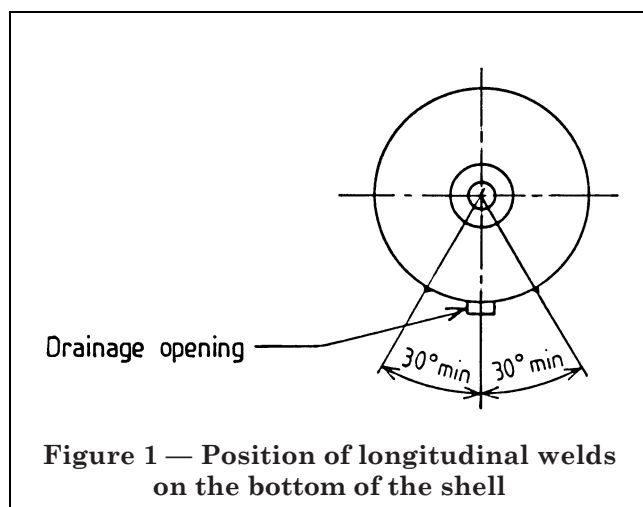
^a ISO designation and International registration record see ISO 209-1 and ISO 209-2.

^b Temper designation, see ISO 2107.

^c For intermediate design temperatures linear interpolation may be used.

^d For interpolation purposes only as temperature limit of 65 °C

^e Interpolated value.



5.1.3 Design of the ends

5.1.3.1 Shape and dimensions of the ends

The torispherical ends shall be made from a single sheet.

Dishing and flanging shall be carried out by a mechanical forming procedure, for example by pressing or spinning. Hand forming is not permitted.

The torispherical end shall meet the requirements of Figure 3 and Table 2.

Table 2 — Height of the cylindrical portion of ends

Dimensions in millimetres

e_h	3	4	5	6	8	10
h_{1min}	12	16	20	24	32	40
h_{1max}	25		40		50	

5.1.3.2 Heat treatment after forming

The parameters of the heat treatment to which ends are subjected after forming cannot be specified in this standard as they vary according to the following criteria:

- the grade of aluminium alloy;
- the type of oven (other than direct radiation, convection, etc.);
- the forming process (hot or cold drawing).

The heat treatment shall not affect the values of $R_{p0,2}$ and R_m used in calculating the thickness.

In addition, after heat treatment the material shall satisfy the following conditions:

- tensile strength $R_m \leq 350 \text{ N/mm}^2$;
- elongation after rupture $A \geq 16 \%$.

The suitability of the heat treatment parameters shall be checked by the approved inspection body when the manufacturing record is submitted for the certification procedure (see clause 12).

5.1.4 Calculation of shell and end thicknesses

5.1.4.1 General

The nominal thickness e of the shells and ends shall be such that:

$$e \geq e_c + c$$

The value of e_c shall in no case be less than 3 mm.

The manufacturer shall apply a correction to allow for thinning resulting from the manufacturing process.

5.1.4.2 Calculation of the shell thickness e_{cs}

$$e_{cs} = \frac{PD_o}{20f + P} K_c$$

The minimum design stress shall be taken from Table 1.

NOTE It has been established from the standards quoted in this part that $0,3R_m$ is always greater than $0,6R_{p0,2}$.

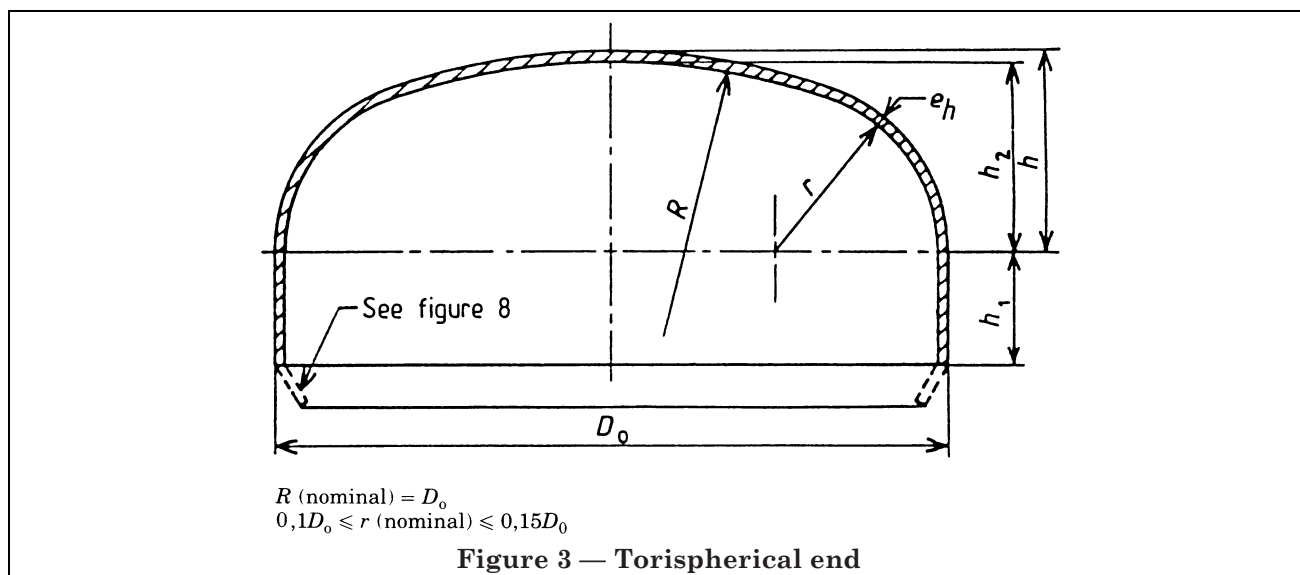
The values of P and K_c to be taken into account are:

- case no. 1: $P \geq 1,15P_s$ and $K_c = 1$ for automatic welding and when tests are carried out in accordance with 11.1.2.1;
- case no. 2: $P \geq 1,3P_s$ and $K_c = 1$ for automatic welding and when tests are carried out in accordance with 11.1.2.2;
- case no. 3: $P \geq 1,25P_s$ and $K_c = 1,15$ for welding using a non-automatic process and when tests are carried out according to 11.1.1.

5.1.4.3 Calculation of the thickness of the ends e_{ch}

The end thickness shall be calculated in the following manner:

- Select the values of f from Table 1, and with $P = P_s$, calculate $P/10f$.



b) Calculate h_e/D_o with h_e the smaller of the three values:

$$h, \frac{D_o^2}{4(R + e_{ch})} \text{ and } \sqrt{\frac{D_o(r + e_{ch})}{2}}$$

where:

$$\begin{aligned}
 e_{ch} &= e_{cs}; \\
 h &= e_h + h_2 \\
 &= e_h + D_o - \sqrt{(D_o - r)^2 - (D_o/2 - e_h - r)^2} \\
 (\text{take } e_h &= e_{cs} + 0,3).
 \end{aligned}$$

NOTE 0,3 is the minus rolling tolerance for the sheet.

c) Determine e_{ch}/D_o from Figure 4.

d) Multiply the value found by D_o to obtain the thickness e_{ch} .

e) Verify the calculation with this value in place of that of e_{cs} .

Example of calculation of thickness e_{ch} of an end of aluminium alloy 5083 in accordance with ISO 6361-2 for a vessel of diameter $D_o = 400$ mm and a maximum service temperature of 65 °C.

$P = 1,15P_s = 1,15 \times 10 = 11,5$ bar (case no. 1 in 5.1.4.2) for the shell

$P = P_s = 10$ bar for the ends

$K_c = 1$

$R = D_o = 400$ mm

$r = 0,1D_o = 40$ mm

$T_{max} = 65$ °C

$f = 74$ N/mm² from Table 1

Therefore $P/(10f) = 10/(10 \times 74) = 0,0135$

Calculate h_e/D_o , with h_e = smallest of 3 values:

$$\begin{aligned}
 \text{a) } h &= e_h + D_o - \sqrt{(D_o - r)^2 - (D_o/2 - e_h - r)^2} \\
 &= (3,38) + 400 - \\
 &\quad \sqrt{(400 - 40)^2 - [400/2 - 3,38 - 40]^2} \\
 &= 79,24
 \end{aligned}$$

$$\text{b) } \frac{D_o^2}{4(R + e_{ch})} = 99,23$$

$$\text{c) } \sqrt{\frac{D_o(r + e_{ch})}{2}} = 92,82$$

when e_{ch} is taken as

$$\begin{aligned}
 \text{equal to } e_{cs} &= \frac{PD_o}{20f + P} K_c \\
 &= 3,08
 \end{aligned}$$

thus $e_h = 3,08 + 0,3 = 3,38$

giving $h_e = 79,24$ and $h_e/D_o = 0,198$

From Figure 4: $e_{ch}/D_o = 0,0101$

$$e_{ch} = 0,0101 \times 400 = 4,04.$$

The verification of the calculation with $e_{ch} = 4,04$ in place of $e_{cs} = 3,08$ gives:

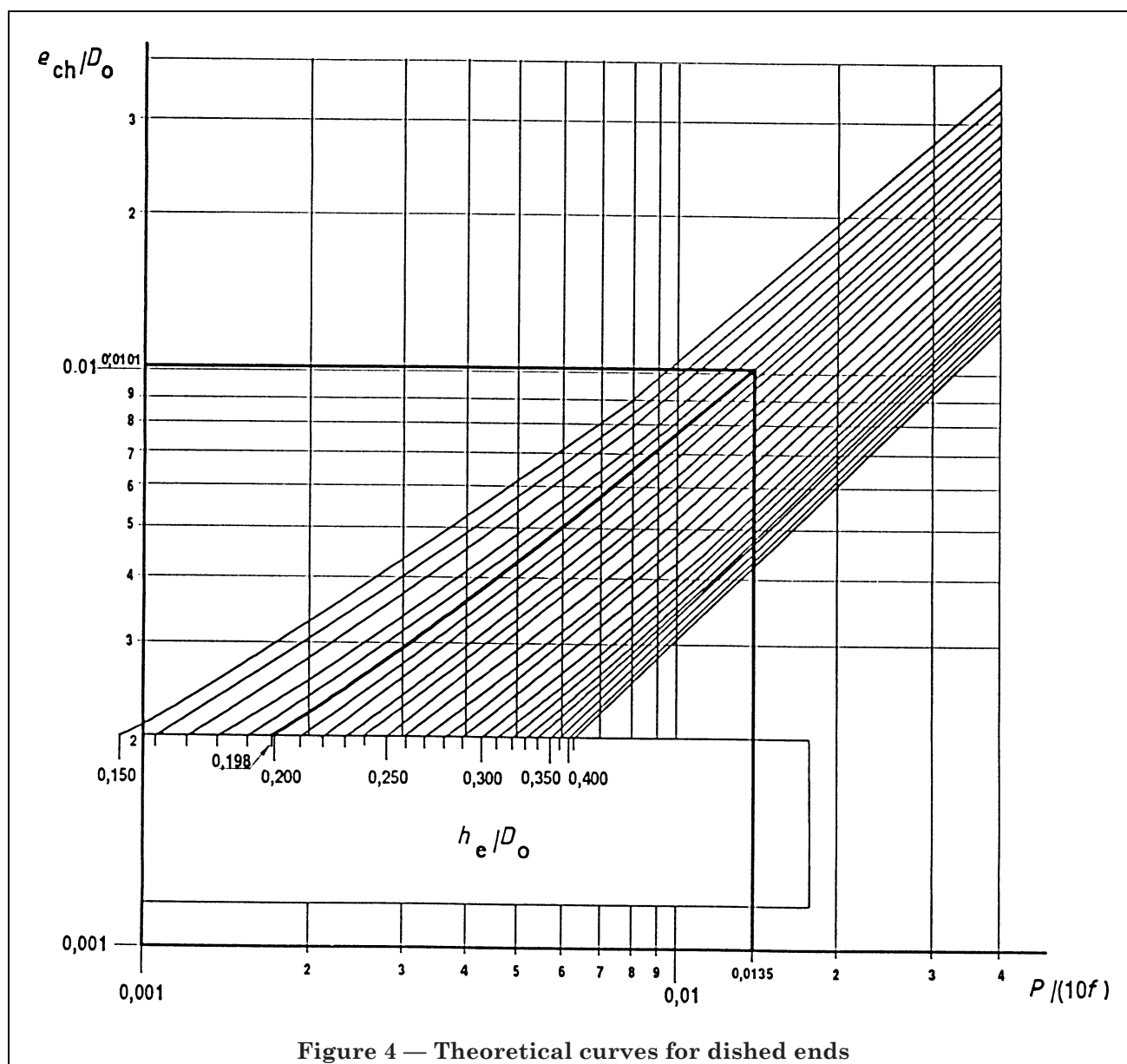
$$e_{ch} = 4.$$

5.1.5 Welded joints of shells and ends

5.1.5.1 Longitudinal welds

The welds shall be full penetration butt welds.

Backing strips, even of a temporary nature, are not permitted.



5.1.5.2 Circular welds

The shell/end joints permitted are those shown in Figure 5 to Figure 8. The welds in Figure 5 to Figure 7 shall be of the full penetration type of the shell/end wall; and for Figure 8 full penetration of the shell wall.

For welding of sheets of different nominal thicknesses (shell/end weld), there shall be alignment either of the neutral axes (Figure 5) or of the walls of the internal face or external face, the connecting slope not exceeding 25 % (14°) (see Figure 6 and Figure 7) and the misalignment of the neutral axes not exceeding 1 mm. If the misalignment of the neutral axes is greater than 1 mm, levelling shall be carried out as shown in Figure 7a and Figure 7b.

