

Simple unfired pressure vessels designed to contain air or nitrogen —

Part 1: Pressure vessels for general purposes

The European Standard EN 286-1:1998, incorporating amendments A1:2002 and A2:2005, has the status of a British Standard

ICS 23.020.30

National foreword

This British Standard is the UK implementation of EN 286-1:1998, incorporating amendments A1:2002 and A2:2005 and corrigendum July 2002. It supersedes BS EN 286-1:1991 and BS 5169:1992, which are withdrawn.

Amendment No. 1, 14014 implements CEN amendment A1:2002 and CEN corrigendum July 2002.

The start and finish of text introduced or altered by amendment is indicated in the text by tags **A1** **A1**. Tags indicating changes to CEN text carry the number of the CEN amendment. For example, text altered by CEN amendment A1 is indicated by **A1** **A1**.

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The UK participation in its preparation was entrusted to Technical Committee PVE/17, Air receivers — General.

A list of organizations represented on this committee can be obtained on request to its secretary.

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English version

Simple unfired pressure vessels designed to contain air or nitrogen — Part 1: Pressure vessels for general purposes

Réipients à pression simples, non soumis à la
flamme, destinés à contenir de l'air ou de l'azote —
Partie 1: Réipients pour usage général

Einfache unbefeuerte Druckbehälter für Luft oder
Stickstoff —
Teil 1: Druckbehälter für allgemeine Zwecke

This European Standard was approved by CEN on 30 November 1997.

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This European Standard exists 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.

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CEN

European Committee for Standardization
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Foreword

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

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of an identical text or by endorsement, at the latest by August 1998, and conflicting national standards shall be withdrawn at the latest by August 1998.

It is the revision of the standard adopted by CEN in 1991. Main changes concern:

- scope;
- materials;
- weld joint design;
- calculations coefficient;
- flange calculations;
- reinforcement of openings;
- supports;
- testing and inspection;
- instruction and marking;
- corrosion allowance.

Although the requirements of this standard support the essential safety requirements of the Simple pressure vessel Directive 87/404/EEC, that directive does not make compliance with this standard mandatory. This standard includes an interpretation of the conformity assessment requirements of the directive and thus the national implementing legislation. These interpretations cannot be taken as having any formal status and carry the risk of misinterpretation. Users of this standard should, therefore, refer to the applicable national legislation for the definitive conformity assessment requirements. A further revision of this standard is being prepared to remove any misleading provisions.

This standard is one of four within the series *Simple unfired pressure vessels designed to contain air or nitrogen*. The other standards are:

Part 2: Pressure vessels for air braking equipment 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;

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

This Part of this European Standard has been prepared for use in conjunction with the informative Annex G of this European Standard.

No rules of construction can be written in sufficient detail to ensure good workmanship and construction. Each manufacturer is 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. Aspects of quality assurance are dealt with in various clauses and annexes of this standard; for example in Clause 10, Testing; and in Annex A, Verification; Annex B, Declaration of conformity — Surveillance; Annex C, Design and manufacturing schedule; Annex D, Type examination; Annex E, Content of the manufacturing record, all of which form part of this standard. These are minimum requirements, having taken into account EN ISO 9002 *Quality systems — Model for quality assurance in production, installation and servicing* and EN ISO 9003 *Quality systems — Model for quality assurance in final inspection and test*, but it is not implied that a quality system in accordance with EN ISO 9002 and EN ISO 9003 is necessary.

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 EU Directive(s).

The general layout of the standard was not changed and accordingly is not in full conformity with the recent CEN rules for harmonized standards.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

Foreword to amendment A1

This document (EN 286-1:1998/A1:2002) has been prepared by Technical Committee CEN/TC 54, Unfired pressure vessels, the Secretariat of which is held by BSI.

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 January 2003, and conflicting national standards shall be withdrawn at the latest by January 2003.

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

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Foreword to amendment A2

This European Standard (EN 286-1:1998/A2:2005) has been prepared by Technical Committee CEN/TC 54 “Unfired pressure vessels”, the secretariat of which is held by BSI.

This Amendment to the European Standard EN 286-1:1998 shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by April 2006, and conflicting national standards shall be withdrawn at the latest by April 2006.

This amendment incorporates requirements for peaking in a new Annex H.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

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1 Scope

1.1 This part of this European Standard applies to the design and manufacture of welded, simple unfired pressure vessels manufactured in series, with a single compartment, hereinafter referred to as vessels, the essential safety requirements of which are given in Annex G.

It only applies to vessels that:

- a) include fabrication by welding, but some designs can entail the use of bolts;
- b) have a simple geometry enabling simple-to-use production procedures; this is achieved by either:
 - 1) a cylindrical part of circular cross-section closed by outwardly dished and/or flat ends which revolve around the same axis as the cylindrical part; or
 - 2) two outwardly dished ends revolving around the same axis;
- c) have branches not larger in diameter than 0,5 of the diameter of the cylinder to which they are welded.

1.2 It applies to vessels which are intended to contain air or nitrogen which are not intended to be fired and which operate within the following constraints:

- a) subjected to an internal gauge pressure greater than 0,5 bar;
- b) the parts and assemblies contributing to the strength of the vessel under pressure to be made either of non-alloy quality steel or of non-alloy aluminium or non-age-hardening aluminium alloys;

NOTE In this part of the standard, the term “aluminium” covers non-alloy aluminium and aluminium alloys.

- c) the maximum working pressure is not greater than 30 bar. The product of the maximum working pressure and the capacity of the vessel ($PS \times V$) is greater than 50 bar·l but does not exceed 10 000 bar·l. Below 50 bar·l, use of this standard is considered to fulfil the requirements of sound engineering practice;

- d) the minimum working temperature is not lower than -50 °C , and the maximum working temperature is not higher than 300 °C for steel and 100 °C for aluminium or aluminium alloy vessels.

It does not apply to vessels specifically designed for nuclear use, to vessels specifically intended for installation in, or the propulsion of, ships and aircraft, nor to fire extinguishers.

The standard does not apply to transportation vessels nor to vessels which also contain substances other than air or nitrogen which could adversely affect their safety. For vessels designed to contain compressed air for the braking systems of road vehicles and their trailers, see also EN 286-2. For vessels designed to contain compressed air for the braking systems of rail-mounted vehicles, see also EN 286-3 and EN 286-4.

1.3 It applies to the vessel proper, from the inlet connection to the outlet connection and to all other connections required for valves and fittings. If bosses/pipes are used, the requirements specified herein begin or end at the weld where flanges, if used, would have been fitted.

1.4 For the purposes of calculations required to be made in accordance with this standard, dimensions are in millimetres, pressures are in bars (except where otherwise specified), stresses are in newtons per square millimetre and temperatures are in degrees Celsius.

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 287-1, *Approval testing of welders: Fusion welding — Part 1: Steels*.

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

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

EN 288-3, *Specification and approval of welding procedures for metallic materials — Part 3: Welding procedure tests for arc welding of steels*.

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

EN 473, *Qualification and certification of NDT personnel — General principles.*

EN 485-2, *Aluminium and aluminium alloys — Sheet, strip and plates — Part 4: Tolerances on shape and dimensions for cold rolled products.*

EN 573-3, *Aluminium and aluminium alloys — Chemical composition and form of wrought products — Part 3: Chemical composition.*

EN 573-4, *Aluminium and aluminium alloys — Chemical composition and form of wrought products — Part 4: Forms of products.*

EN 754-2, *Aluminium and aluminium alloys — Wrought products — Cold drawn rod/bar and tubes — Part 2: Mechanical properties.*

EN 755-2, *Aluminium and aluminium alloys — Wrought products — Extruded rod/bar, tube and profile — Part 2: Mechanical properties.*

EN 875, *Welding — Welded joints in metallic materials — Specimen location and notch orientation for impact tests.*

EN 910, *Welding — Welded butt joints in metallic materials — Bend tests.*

EN 1418, *Welding personnel — Approval testing of welding personnel for fully mechanized and automatic welding of metallic materials.*

EN 1435, *Non-destructive examination of welds — Radiographic examination of welded joints.*

EN 10002-1, *Metallic materials — Tensile testing — Part 1: Method of test (at ambient temperature).*

EN 10028-2, *Flat products made of steels for pressure purposes — Part 2: Non-alloy and alloy steels with specified elevated temperature properties.*

EN 10204, *Metallic products — Types of inspection documents.*

EN 10207, *Steels for simple pressure vessels — Technical delivery requirements for plates, strips and bars.*

EN 10216-1, *Seamless steel tubes for pressure purposes — Technical delivery conditions — Part 1: Non-alloy steels with specified room temperature properties.*

(based on ISO 9329-1)

EN 10217-2, *Welded steel tubes for pressure purposes — Technical delivery conditions — Part 2: Unalloyed and alloyed steels with specified elevated temperature properties.*

(based on ISO 9330-2)

EN 10222-4, *Steel forgings for pressure purposes — Part 4: Weldable fine grain steel with high proof strength.*

EN 10226-1, *Pipe threads where pressure tight joints are made on the thread — Part 1: Designation, Dimensions and tolerances.*

EN 20898-1, *Mechanical properties of fasteners — Part 1: Bolts, screws and studs.*

EN 20898-2, *Mechanical properties of fasteners — Part 2: Nuts with specified proof load values.*

EN 25817, *Arc-welded joints in steel — Guidance on quality level for imperfections.*

EN 30042, *Arc-welded joints in aluminium and its weldable alloys — Guidance on quality levels for imperfections.*

EN ISO 2409:1994, *Paints and varnishes — Cross-cut test.*

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

ISO 3057, *Non-destructive testing — Metallographic replica techniques of surface examination.*

ISO 7005-1, *Metallic flanges — Part 1: Steel flanges.*

ISO 7253:1996, *Paints and varnishes — Determination of resistance to neutral salt spray.*

3 Definitions, symbols and units

3.1

Definitions

For the purposes of this standard the following definitions apply.

3.1.1

automatic welding

welding in which all the welding parameters are automatically controlled; some of these parameters may be adjusted to a limited amount (manually or automatically by mechanical or electronic devices) during welding to maintain the specified welding conditions

3.1.2

non-automatic welding

all types of welding other than that defined in 3.1.1

3.1.3

batch

a batch of vessels consists at the most of 3 000 vessels of the same type

3.1.4

type of vessel

vessels are of the same type if the five following conditions are met:

- they have similar geometrical form (i.e. shell rings and ends, or only ends; in both cases, ends of the same shape);
- they belong to the same class (see Clause 4);
- they have wall material and thickness within the limit of validity of the weld procedure, including those for branches, nozzles and inspection opening;
- they have the same type of inspection opening; (sightholes, handholes, headholes and manholes are examples of different types of inspection opening);
- they have the same design temperature limitations.

3.1.5

declaration of conformity

the procedure whereby the manufacturer certifies vessels to be in conformity with this European Standard (see Annex B)

3.1.6

verification

the procedure adopted to check and certify that vessels manufactured comply with this European Standard (see Annex A)

3.1.7

surveillance

the procedure carried out by an approved inspection body during manufacture to ensure that the manufacturer duly fulfils the requirements of this European Standard (see B.3.2)

3.1.8

type examination

the procedure by which an approved inspection body ascertains and certifies that a specimen of a vessel satisfies the provisions of this European Standard (see Annex D)

3.1.9

design and manufacturing schedule

a schedule, issued by the manufacturer, the purpose of which is to describe the construction, material and fabrication including the certificates (see Annex C)

3.1.10

manufacturing record

a record, kept by the manufacturer, of all the relevant information on the vessels manufactured to this standard

3.1.11 *Design temperature*

3.1.11.1

maximum design temperature

the temperature that is used in the design calculations, and which is never less than the maximum working temperature

3.1.11.2

minimum design temperature

the lowest temperature used in the selection of materials, and which is never greater than the minimum working temperature

3.1.12

minimum working temperature, $T_{\min}$

the lowest stabilized temperature in the wall of the vessel under normal conditions of use

3.1.13

maximum working temperature, $T_{\max}$

the highest stabilized temperature which the wall of the vessel can attain under normal conditions of use

3.1.14

design pressure, P

the pressure used in design calculations, and which is never less than the maximum working pressure PS

3.1.15

maximum working pressure, PS

the maximum gauge pressure which may be exerted under normal conditions of use

(the set pressure of the pressure relief device is never greater than PS , but after pressure relief has commenced, the pressure can exceed PS by 10 % maximum)

3.1.16

manufacturer's inspector

person(s) employed and authorized by the manufacturer, but independent from the production personnel, qualified and responsible for inspections, examinations and tests to be carried out by him on vessels

qualification means technical competency on the different inspections, examinations and tests to be carried out under the manufacturer's responsibility, as well as necessary experience. It is the responsibility of the manufacturer to ascertain that the inspector is competent

3.1.17

report on the examinations and tests

a report of the examinations and tests carried out by the manufacturer

3.1.18

test report

document in which the manufacturer certifies that the products supplied comply with the requirements of the order, and in which he supplies test results based on non-specific inspection and testing
[2.2 in EN 10204]

NOTE 1 This corresponds to "inspection slip" defined in the Directive.

NOTE 2 In this definition, "manufacturer" means material manufacturer.

3.1.19

series manufacture

more than one vessel of the same type manufactured during a given period by a continuous manufacturing process, in accordance with a common design and using the same manufacturing process

3.1.20**main body**

main body means main shell and/or ends

3.2 General symbols and units

International System (SI) units are used in the standard, as follows:

— dimensions (thickness, diameter, length, ...):	mm
— areas:	mm ²
— loads, forces:	N
— moments:	N·mm
— pressures:	bar or N/mm ² (see note)
— stresses, yield strength, tensile strength:	N/mm ²

NOTE Concerning the design pressure P , the unit N/mm² is used throughout 6.4 in order to have a coherent system of units for the formula. The unit bar is used throughout the other clauses in order to meet the terminology of the Directive.

The following general symbols are used (specific symbols are defined in the relevant clauses):

A	elongation after rupture
D_i	inside diameter of main body
D_o	outside diameter of main body
d	diameter of openings
d_{ib}	internal diameter of branch
d_{ob}	external diameter of branch
d_{ip}	internal diameter of pad
d_{op}	external diameter of pad
d_{is}	internal diameter of shell
e	nominal thickness of wall
e_s	nominal thickness of shell
e_b	nominal thickness of branch
e_p	nominal thickness of compensating plate or of pad
e_c	calculated thickness
e_a	actual thickness
e_{as}	actual thickness of shell
e_{ab}	actual thickness of branch
e_{am}	actual thickness of main body
e_{ap}	actual thickness of compensating plate or of pad
f	nominal design stress at design temperature
K_c	calculation coefficient, which depends on the welding process (see 6.4.2)
K_s	shell coefficient, which depends on the extent of testing (see 6.4.2)
KCV	impact energy
l_b	effective length of branch contributing to reinforcement
l_{bi}	effective length for inside part of set-through branch
l_m	effective length of main body, contributing to reinforcement
l_p	width of compensating plate
l_{rp}	width of pad minus corrosion allowance and tolerances
P	design pressure (never less than PS), in bars or in newtons per square millimetre (see note at the beginning of 3.2)
PS	maximum working pressure
R_{eT}	value at the maximum working temperature, T_{max} , of: — the upper yield point R_{eH}, for a material with both a lower and upper yield point; — the proof stress $R_{p0.2}$; — or the proof stress $R_{p1.0}$ in the case of non-alloy aluminium.
R_m	minimum value of tensile strength at room temperature specified in the material standard

4 Classifications and certification procedures

This standard specifies three classes of vessels, for which the applicable certification procedures are shown in Table 4.1.

Table 4.1 — Classification of vessels

Classification	$PS \times V$ bar·l	Certification procedure ^a	
		Design stage	Fabrication stage
Class 1	Above 3 000, up to and including 10 000	At manufacturer's choice: type examination (see Annex D) or design and manufacturing schedules approval (see Annex C.2)	Verification (see Annex A)
Class 2	Above 200, up to and including 3 000		At manufacturer's choice: verification ^b (see Annex A) or declaration of conformity and surveillance (see Annex B), and special documents
Class 3	Above 50, up to and including 200		At manufacturer's choice: verification ^b (see Annex A) or declaration of conformity (see Annex B), and special documents
—	Below or equal to 50	See note	

^a This requirement is not part of the EC Directive and therefore is not part of the harmonized standard.

^b For those vessels subject to verification, the identification of the approved inspection body shall be stamped on the data plate (see Clause 12).

NOTE Use of this standard is considered to fulfil the requirements of sound engineering practice. It is the responsibility of the manufacturer to comply with the rules of this standard and to mark the vessel in accordance with Clause 12, with the exception of the CE marking and of the approved inspection body mark.

5 Materials

5.1 Main pressurized parts (see also 5.2)

5.1.1 General

The essential requirements for materials are given in Annex G.

The materials shall be delivered with at least a test report (type 2.2 in accordance with EN 10204). Inspection certificates of types 3.1.A, 3.1.B or 3.1.C are also acceptable.

5.1.2 Steel vessels

The following materials should be used:

- a) plate, strip and bar: steel grades P235S, P265S, and P275SL in accordance with EN 10207; steel grades P275N, P275NH, P275NL1 and P275NL2 in accordance with EN 10028-2;
- b) tubes: steel grades P235T2 and P265T2 in accordance with EN 10216-1 and EN 10217-2;
- c) forgings: steel grade P285QH in accordance with EN 10222-4.

5.1.3 Aluminium vessels

The materials stated in Table 5.2, in accordance with EN 573-4, should be used:

- a) plates in accordance with EN 485-2;
- b) bars in accordance with EN 755-2.

Table 5.2 — Aluminium materials in accordance with EN 573-4

Material designation		Maximum working temperature °C
Numerical	Chemical symbol	
EN AW-1080A	EN AW-Al 99,8(A)	100
EN AW-1070A	EN AW-Al 99,7	100
EN AW-1050A	EN AW-Al 99,5	100
EN AW-5005	EN AW-Al Mg1(B)	100
EN AW-5251	EN AW-Al Mg2	100
EN AW-5049	EN AW-Al Mg2Mn0,8	100
EN AW-5052	EN AW-Al Mg2,5	100
EN AW-5754	EN AW-Al Mg3	100
EN AW-5454	EN AW-Al Mg3Mn	100
EN AW-5154A	EN AW-Al Mg3,5(A)	100
EN AW-5086	EN AW-Al Mg4	65
EN AW-5083	EN AW-Al Mg4,5Mn0,7	65
EN AW-3103	EN AW-Al Mn1	100
EN AW-3105	EN AW-Al Mn0,5Mg0,5	100

5.1.4 Other standard materials

Any material not included in 5.1.2 and 5.1.3, which is manufactured in accordance with a national or International Standard for quality steels, aluminium or aluminium alloy, will be acceptable, subject to approval by an approved inspection body.

5.2 Accessories contributing towards the strength of vessels

These accessories (bolts, nuts, pipes, tubes, bosses etc.) shall be made from steel, aluminium or aluminium alloy which is compatible with materials used for the manufacture of the main pressurized parts. They shall have an elongation after rupture, *A*, on longitudinally oriented test-pieces of at least 14 % (see EN 10002-1).

Bolts and screws in accordance with EN 20898-1, property classes 5.6 or 8.8, and nuts to EN 20898-2, property classes 5 or 8, but with an elongation of at least 12 %, are considered to be suitable.

Steel bolts for working temperatures colder than $-10\text{ }^{\circ}\text{C}$ shall have an average impact strength, *KCV*, for three longitudinal test-pieces, at the minimum working temperature, of not less than 35 J/cm^2 . Not more than one of the three values may be less than 35 J/cm^2 , with a minimum of 25 J/cm^2 . The corresponding material shall be delivered with at least a test report (type 2.2 in accordance with EN 10204). Inspection certificates of types 3.1.A, 3.1.B or 3.1.C are also acceptable.

5.3 Non-pressurized parts

All non-pressurized parts of welded vessels shall be of materials that are compatible with those of the components to which they are welded.

To this end, supports and accessories fitted by welding on the shell of steel vessels shall be made of killed non-alloy steel which meets the following requirements:

$$C \leq 0,25 \% ; S \leq 0,05 \% ; P \leq 0,05 \% ;$$

$$\text{and } R_{m \max} < 580 \text{ N/mm}^2$$

Aluminium and aluminium alloys shall be as given in 5.1.3.

5.4 Welding consumables

The welding consumables used to manufacture the welds on or of the vessel shall be appropriate to and compatible with the materials to be welded, and shall comply with available European Standards.

6 Design

6.1 General

When designing the vessel, the manufacturer shall define the use to which it will be put, and shall select:

- the minimum working temperature, $T_{\min}$;
- the maximum working temperature, $T_{\max}$;
- the maximum working pressure, PS .

When the intended use of the vessel implies additional loads or fatigue, this shall be taken into account in the design.

$\square A_2$ Requirements for peaking (out-of-roundness caused by misalignment of (welded) joints or local irregularities in vessel profile) are given in Annex H. $\square A_2$

6.2 Weld joint design

6.2.1 Welds of partial penetration type are not permitted, except in the case of branches, flat ends and flanges which are fixed to the main shell by means of two welds of adequate thickness, see 6.2.5. The type of edge preparation is dependent on the welding procedures used.

Where full penetration welds are not used for branches, welds shall be as shown in Figure 6.2-1a to Figure 6.2-1d, with each weld having a throat thickness, g , of at least 0,7 times the thickness of the thinnest part.

Branches may be considered as reinforcement of the main body if the weld joints are made as shown in Figure 6.2-1a to Figure 6.2-1d, Figure 6.2-2a and Figure 6.2-2b.

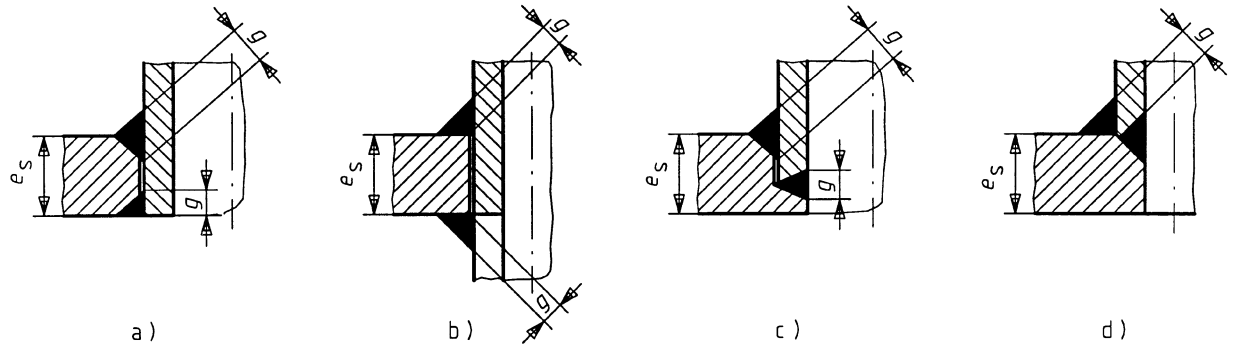
6.2.2 A single partial penetration weld is permitted in the case of branch pipes and sockets whose outside diameter does not exceed 65 mm. The throat thickness, g , of the weld shall be at least 1,5 times the thickness of the thinnest part (see Figure 6.2-1e, Figure 6.2-1f, Figure 6.2-1g and Figure 6.2-1h).

Branches shall not be considered as reinforcement if the weld joints are made as shown in Figure 6.2-1e to Figure 6.2-1h and the thickness of the main body to which the branch is attached is greater than 6 mm.

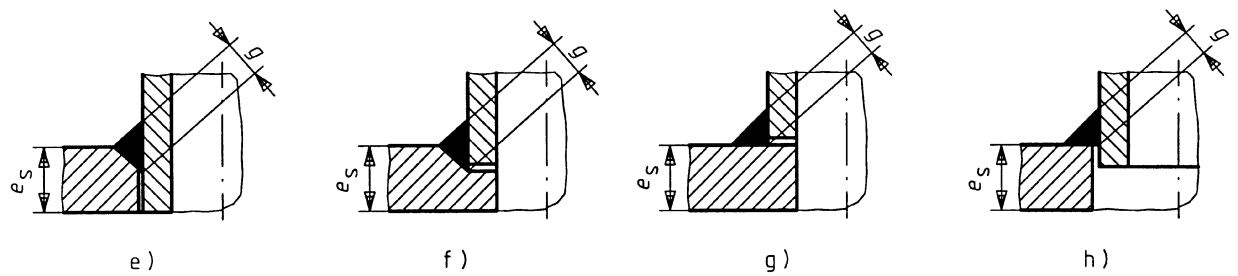
6.2.3 If a shell is manufactured from more than one ring, the alignment between the centre-lines of the longitudinal welds shall be as far apart as possible but not less than 50 mm.

For horizontally mounted vessels, longitudinal welds shall not be closer than 30° to the lowest line along the surface of the vessel parallel to its centre-line (see Figure 6.2.3-1).

6.2.4 Openings in cylindrical shells and end plates shall be placed as far as practical from any welded seam, but in no instance shall the seam in the shell be pierced. The distance between any two welds taken from the extremity of the edge preparation shall not be less than 4 times the actual shell thickness, e_{as} , and in no case shall the distance to any circumferential seam be less than $0,5 \sqrt{D_o e_s}$.



NOTE g is at least 0,7 times the thinnest part.



NOTE g is at least 1,5 times the thinnest part.

Figure 6.2-1 — Alternative welds for tubes, branches, pipes and sockets

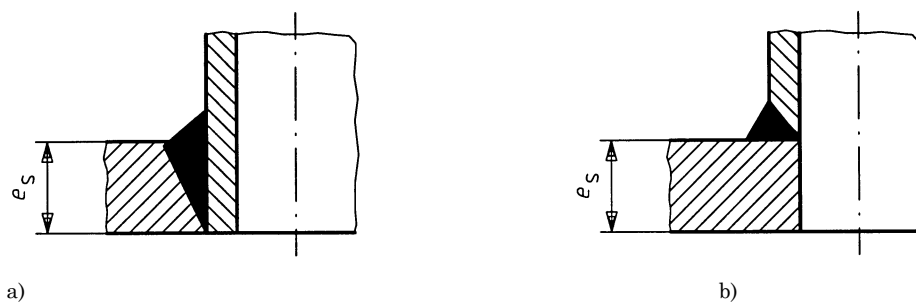
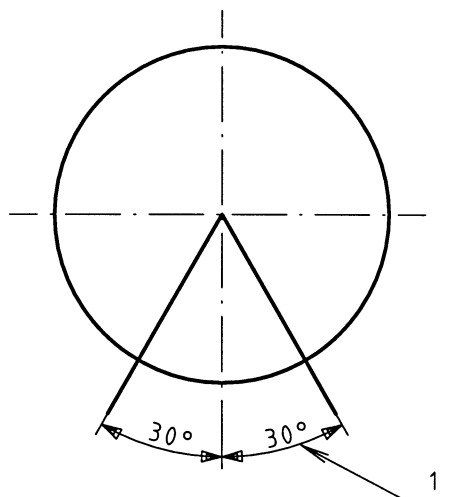


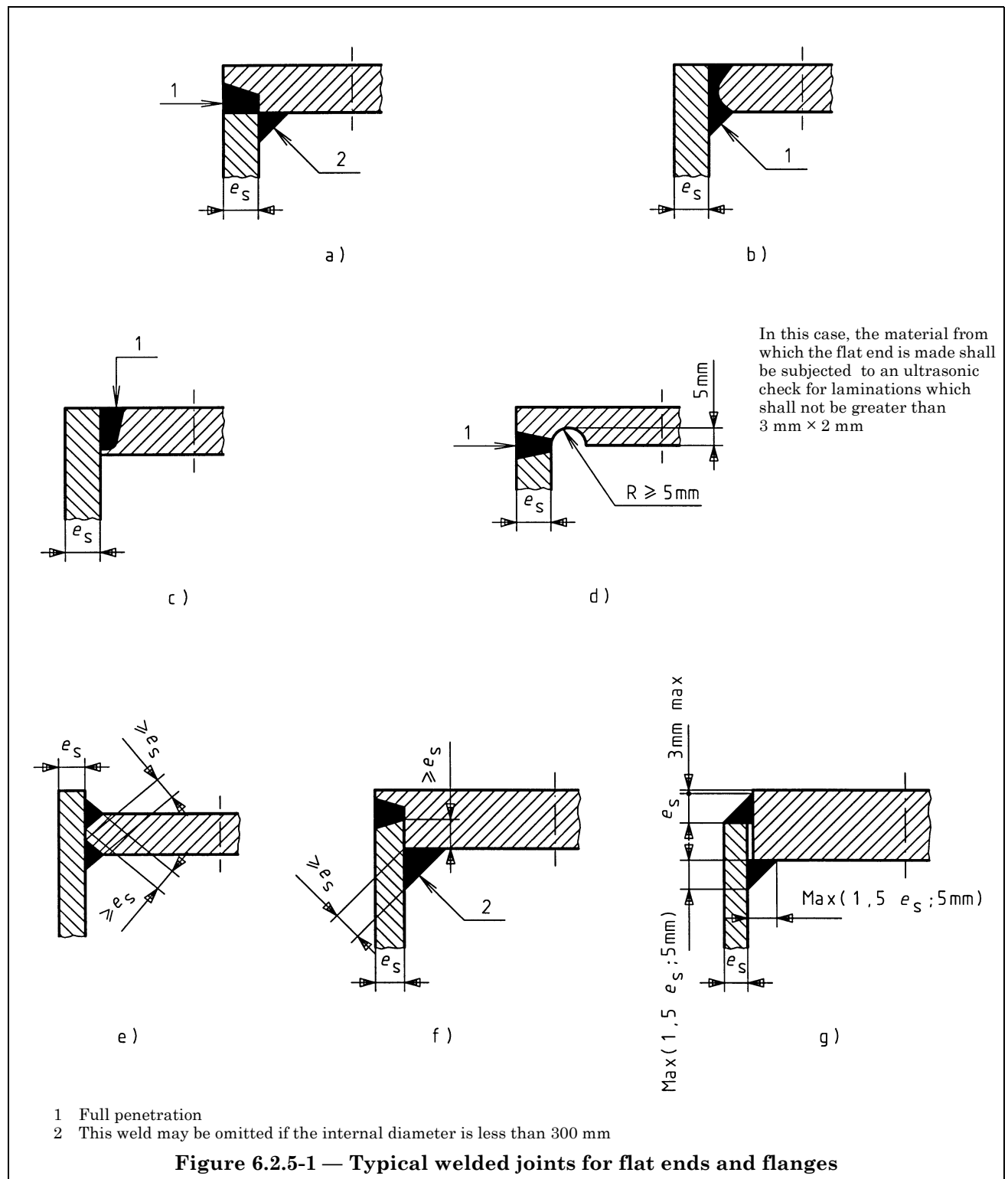
Figure 6.2-2 — Full penetration welds for tubes, branches, pipes and sockets



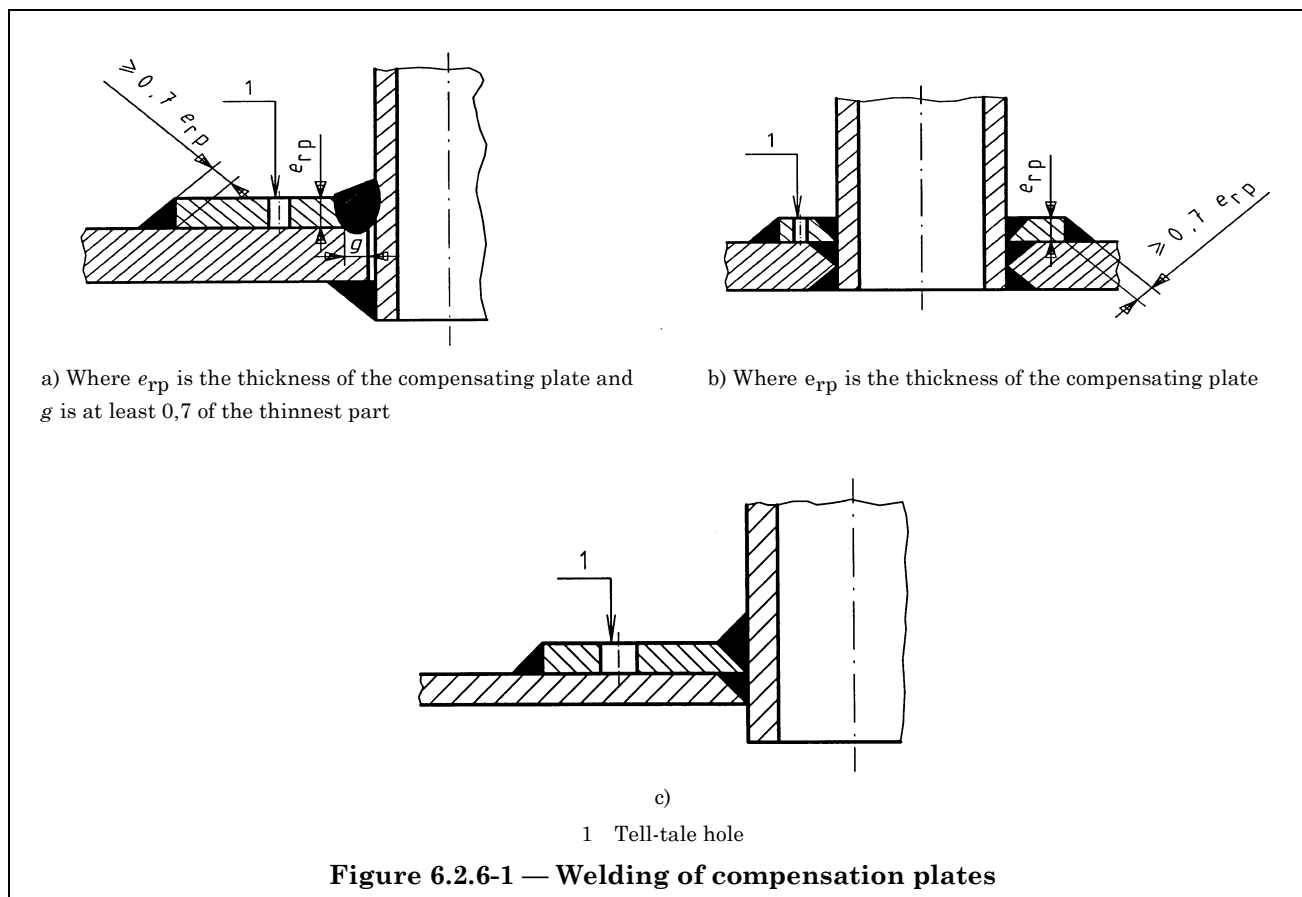
1 No longitudinal welds in this area

Figure 6.2.3-1 — Positioning of longitudinal welds

6.2.5 Welded joints for flat ends and flanges shall be of the types shown in Figure 6.2.5-1.



6.2.6 Welding of compensation plates shall be as shown in Figure 6.2.6-1.



6.3 Determination of wall thicknesses

6.3.1 Choice of the method

The wall thicknesses shall be determined, in the corroded conditions, using the calculation method (see 6.4) or the experimental method (see 6.5), at the manufacturer's choice, in accordance with the following criteria.

- If the product of PS and V is more than 3 000 bar·l, or if the maximum working temperature exceeds 100 °C, the calculation method shall be used.
- If the product of PS and V is not more than 3 000 bar·l, or if the maximum working temperature does not exceed 100 °C, the calculation method or the experimental method may be used, at manufacturer's choice.

6.3.2 Actual wall thicknesses

The actual wall thickness e_a of a component (shell, head or flange) is the nominal thickness of the component corrected for tolerance, thinning and corrosion (see Figure 6.3.2-1):

$$e_a = e - t - m - c \quad (6.3.2-1)$$

where

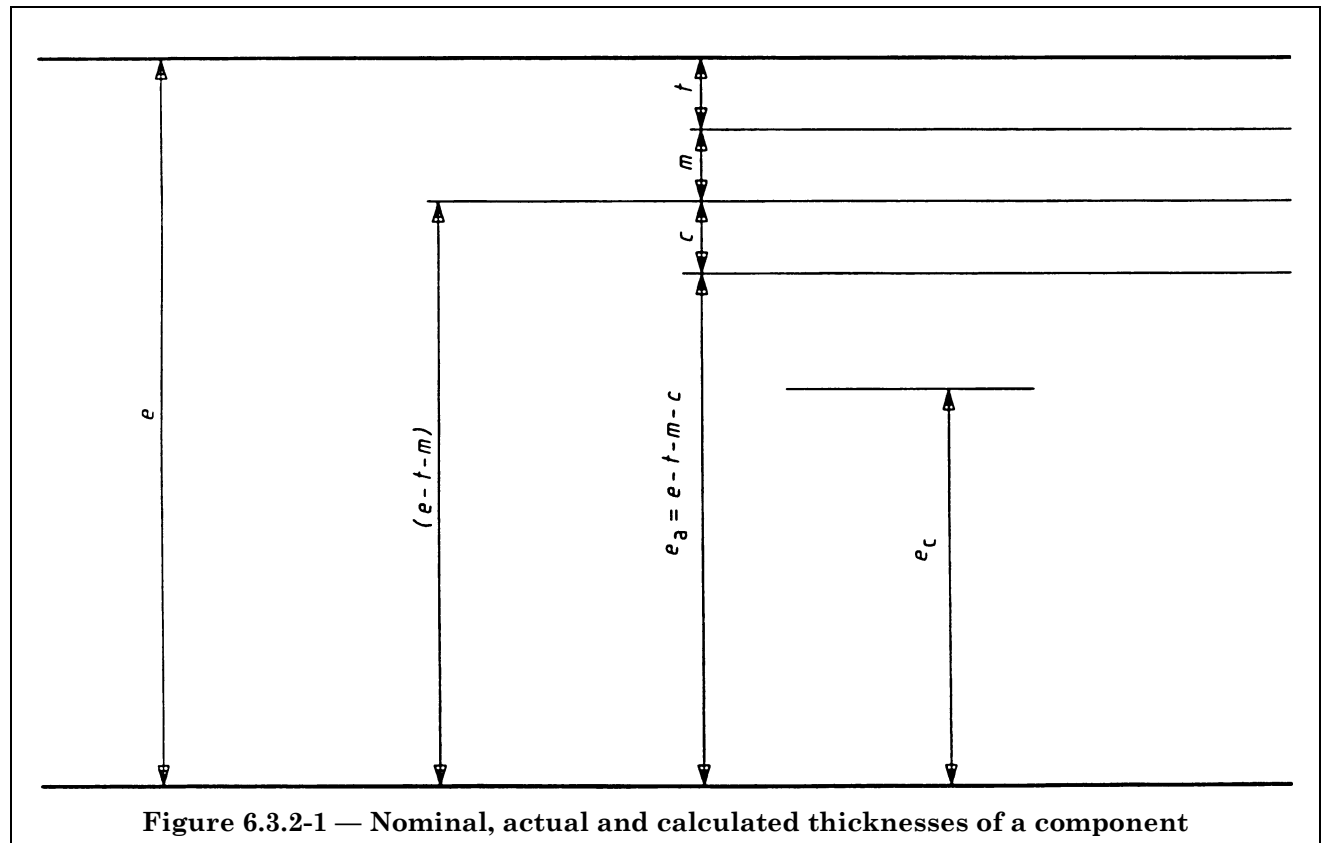
- e is the nominal thickness of the component;
- c is the corrosion allowance (see 6.3.3);
- t is the absolute value of the negative tolerance taken from the material standard;
- m is the thinning during the manufacturing process.

The actual wall thickness of the shell and ends shall not be less than 2 mm in the case of steel vessels and not less than 3 mm in the case of aluminium vessels:

$$e_a \geq 2 \text{ mm for steel vessels} \quad (6.3.2-2)$$

$$e_a \geq 3 \text{ mm for aluminium vessels} \quad (6.3.2-3)$$

The wall thickness of the shell to be indicated on the data plate (see Clause 12) is the actual thickness e_a .



6.3.3 Corrosion allowance

Bearing in mind their prescribed use, the vessels shall be adequately protected against corrosion.

6.3.3.1 Steel vessels are adequately protected against corrosion if either:

- a reliable and durable internal coating is present, which shall be tested in accordance with Annex F and checked by the approved inspection body, who shall indicate its acceptability by stamping “F” on the data plate (see Clause 12); or
- an adequate corrosion allowance is specified, which shall not be less than 0,5 mm;

unless no corrosion risk is to be expected during the lifetime of the vessel.

The adopted corrosion allowance shall be indicated on the data plate (see Clause 12).

6.3.3.2 Aluminium vessels do not require protection against corrosion, nor a corrosion allowance.

6.4 Calculation method

6.4.1 General

6.4.1.1 The nominal design stress, f , shall not exceed the lower value of $0,6 R_{eT}$ or $0,3 R_m$.

6.4.1.2 All calculations shall be made for the vessel in the corroded condition.

6.4.1.3 For the purposes of this clause, pressure P is in newtons per square millimetre.

6.4.1.4 The actual thickness e_a of the shell, ends and flanges shall not be less than the calculated thickness of the component:

$$e_a \geq e_c \quad (6.4.1.4-1)$$

where e_c is the calculated thickness.

6.4.2 Calculated thickness of shells, e_{cs}

$$e_{cs} = \frac{PD_o}{2f + P} K_c K_s \quad (6.4.2-1)$$

where

K_c is the calculation coefficient depending on the welding process:

$K_c = 1$ for welds made by automatic welding process (see Table 10.2.1-1 and Table 10.2.1-3);

$K_c = 1,15$ for welds made by non-automatic welding process (see Table 10.2.1-2 and Table 10.2.1-4);

K_s is the shell coefficient depending on the amount of testing:

$K_s = 1$ for normal amount of testing (see Table 10.2.1-1 and Table 10.2.1-3);

$K_s = 1,25$ for alternative amount of testing (see Table 10.2.1-2 and Table 10.2.1-4).

6.4.3 Calculated thickness of dished ends, e_{ce}

Dished ends shall fulfil the following limitations:

a) hemispherical ends:

$$0,002 D_o \leq e_a \leq 0,16 D_o \quad (6.4.3-a1)$$

b) elliptical ends:

$$0,002 D_o \leq e_a \leq 0,08 D_o \quad (6.4.3-b1)$$

$$h \geq 0,18 D_o \quad (6.4.3-b2)$$

c) torispherical ends:

$$0,002 D_o \leq e_a \leq 0,08 D_o \quad (6.4.3-c1)$$

$$r \geq 0,06 D_o \quad (6.4.3-c2)$$

$$r \geq 3e_a \quad (6.4.3-c3)$$

$$R \leq D_o \quad (6.4.3-c4)$$

where

h is the outside height of the end;

r is the inside knuckle radius, for torispherical ends;

R is the inside spherical radius, for torispherical ends.

(see Figure 6.4.3-1)

The two relationships in **6.4.3b** or the four relationships in **6.4.3c** shall be fulfilled simultaneously.

In no case shall the thickness of the cylindrical or straight flange (see Figure 6.4.3-1a and Figure 6.4.3-1b) of a dished end be less than the thickness of a seamless unpierced cylindrical shell of the same diameter and material for the same design pressure and temperature.

6.4.3.1 Hemispherical ends

The thickness of hemispherical ends shall be determined using equation:

$$e_{ce} = \frac{PD_o}{4f + P} \quad (6.4.3.1-1)$$

NOTE When two hemispherical ends are welded together without a straight flange, the formula is multiplied by the appropriate K_c factor (this being the calculation coefficient shown in Table 10.2.1-1 to Table 10.2.1-4).

6.4.3.2 Elliptical and torispherical ends

Typical configurations are shown on Figure 6.4.3-1.

The thickness of elliptical and torispherical ends shall be determined using the following procedure.

- a) Calculate P/f .
- b) Enter Figure 6.4.3.2-1 with this value, read up to the appropriate h_e/D_o line for the proposed end shape and then across to the e_{ce}/D_o axis for the corresponding e_{ce}/D_o value, where h_e is the design height of the end:

$$h_e = \min \left[(h); \left(\frac{D_o^2}{4(R + e_a)} \right); \left(\sqrt{\frac{D_o(r + e_a)}{2}} \right) \right] \quad (6.4.3.2-b1)$$

NOTE For elliptical ends, use:

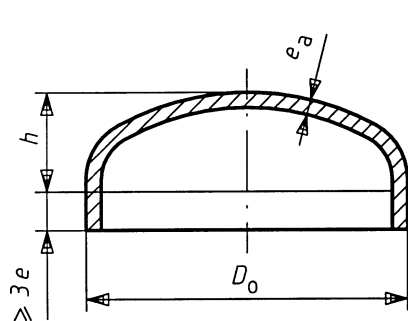
$$h_e = h \quad (6.4.3.2-b2)$$

- c) Multiply by D_o to obtain the calculated end thickness.

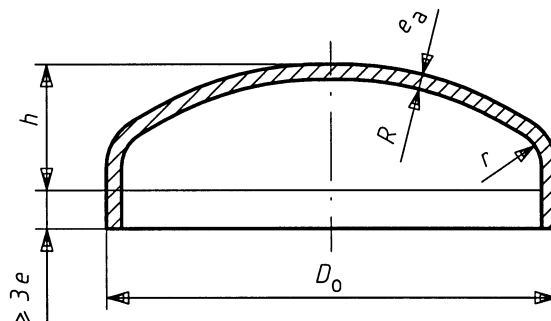
Numerical values of Table 6.4.3.2-1 may be used instead of curves of Figure 6.4.3.2-1.

Interpolation between h_e/D_o curves is permissible, or, alternatively, values may be read from the next higher h_e/D_o curve.

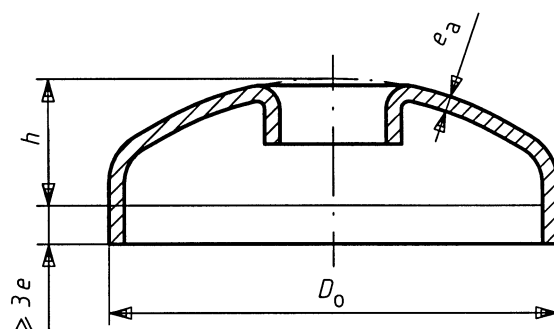
NOTE Figure 6.4.3.2-1 may be used with values of h_e and D_o based on internal dimensions, provided that $h_e/D_o < 0,27$; beyond this value, external dimensions are to be used.



a) Elliptical end



b) Torispherical end



c) End with manhole (elliptical torispherical)

Figure 6.4.3-1 — Dished ends

AC1

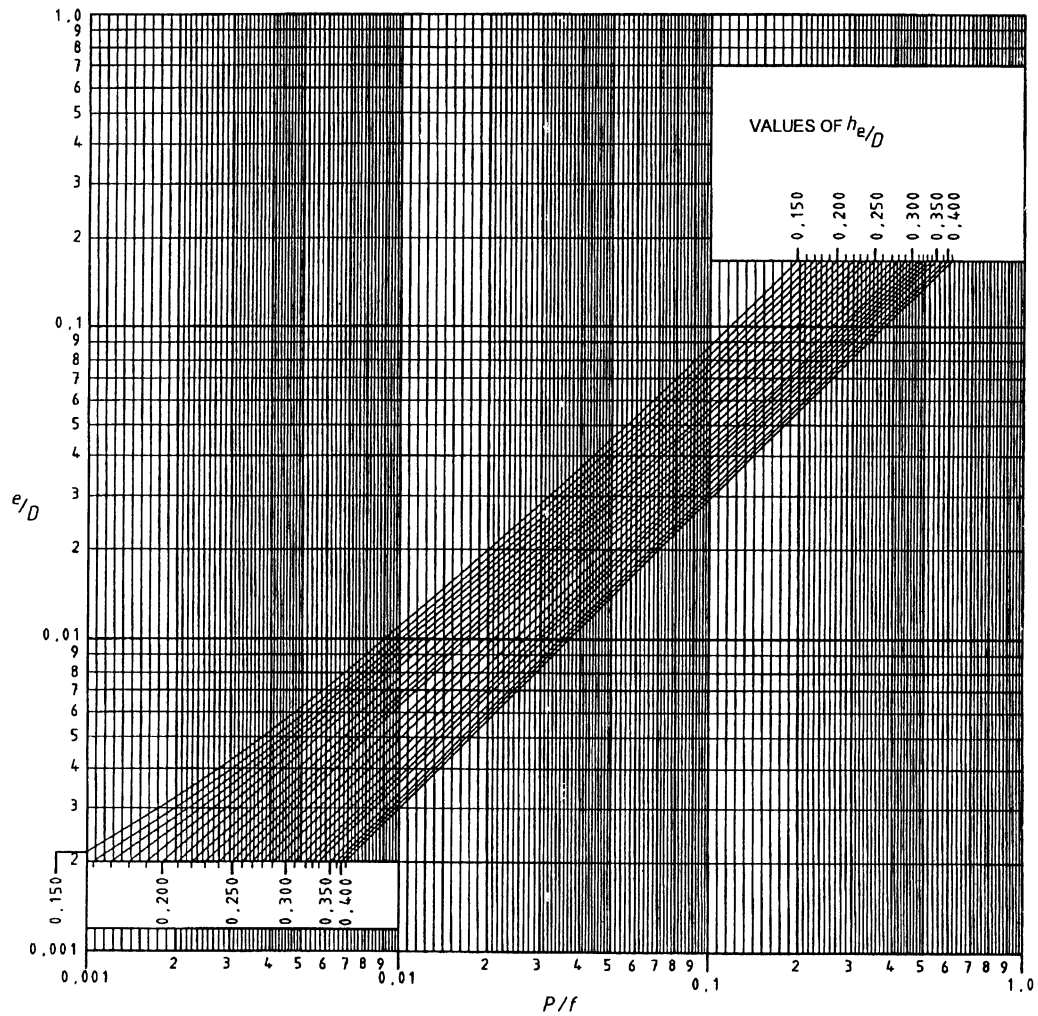


Figure 6.4.3.2-1 — Design curves for elliptical and torispherical ends

AC1

Table 6.4.3.2-1 — Values of $e_{ce}/D_o \times 10^3$ for unpierced elliptical and torispherical ends in terms of h_e/D_o and P/f

$\frac{h_e}{D_o}$	P/f									
	0,001	0,0015	0,0025	0,004	0,006	0,010	0,015	0,025	0,050	Greater values
0,15	2,13	2,70	3,73	5,22	7,20	10,9	15,4	24,0	44,5	$880 \times P/f$
0,16	(1,95)	2,50	3,50	4,90	6,70	10,2	14,3	22,2	41,5	$810 \times P/f$
0,17	(1,80)	2,30	3,24	4,58	6,30	9,6	13,5	21,0	39,2	$770 \times P/f$
0,18	(1,65)	2,11	2,99	4,23	5,80	8,8	12,6	19,7	37,0	$730 \times P/f$
0,19	—	(1,95)	2,77	3,95	5,43	8,3	11,8	18,5	35,0	$695 \times P/f$
0,20	—	(1,80)	2,55	3,64	5,00	7,7	11,0	17,3	33,0	$650 \times P/f$
0,21	—	(1,65)	2,39	3,42	4,75	7,3	10,4	16,2	$620 \times P/f$	—
0,22	—	(1,52)	2,22	3,20	4,45	6,84	9,7	15,4	$585 \times P/f$	—
0,23	—	(1,40)	2,08	2,95	4,12	6,30	9,1	14,5	$555 \times P/f$	—
0,24	—	—	(1,92)	2,76	3,83	5,90	8,5	13,6	$530 \times P/f$	—
0,25	—	—	(1,75)	2,58	3,56	5,50	7,8	$500 \times P/f$	—	—
0,26	—	—	(1,64)	2,40	3,34	5,15	7,35	$475 \times P/f$	—	—
0,27	—	—	(1,52)	2,25	3,12	4,80	6,80	$445 \times P/f$	—	—
0,28	—	—	(1,41)	2,12	2,93	4,50	6,45	$425 \times P/f$	—	—
0,29	—	—	—	(2,00)	2,73	4,20	$405 \times P/f$	—	—	—
0,30	—	—	—	(1,86)	2,54	3,95	$385 \times P/f$	—	—	—
0,31	—	—	—	(1,71)	2,41	3,80	$370 \times P/f$	—	—	—
0,32	—	—	—	(1,61)	2,30	3,65	$358 \times P/f$	—	—	—
0,33	—	—	—	(1,52)	2,20	3,50	$345 \times P/f$	—	—	—
0,34	—	—	—	(1,45)	2,10	$335 \times P/f$	—	—	—	—
0,35	—	—	—	—	$325 \times P/f$	—	—	—	—	—
0,36	—	—	—	—	$319 \times P/f$	—	—	—	—	—
0,38	—	—	—	—	$307 \times P/f$	—	—	—	—	—
0,40	—	—	—	—	$295 \times P/f$	—	—	—	—	—

NOTE This table is not valid for values of $e_{ce}/D_o \times 10^3 < 2,00$.

NOTE 2 Intermediate values may be obtained by logarithmic interpolation.

NOTE 3 Values in parentheses are provided for purposes of interpolation.

6.4.4 Calculated thickness of flat ends and covers

6.4.4.1 Flat ends without openings

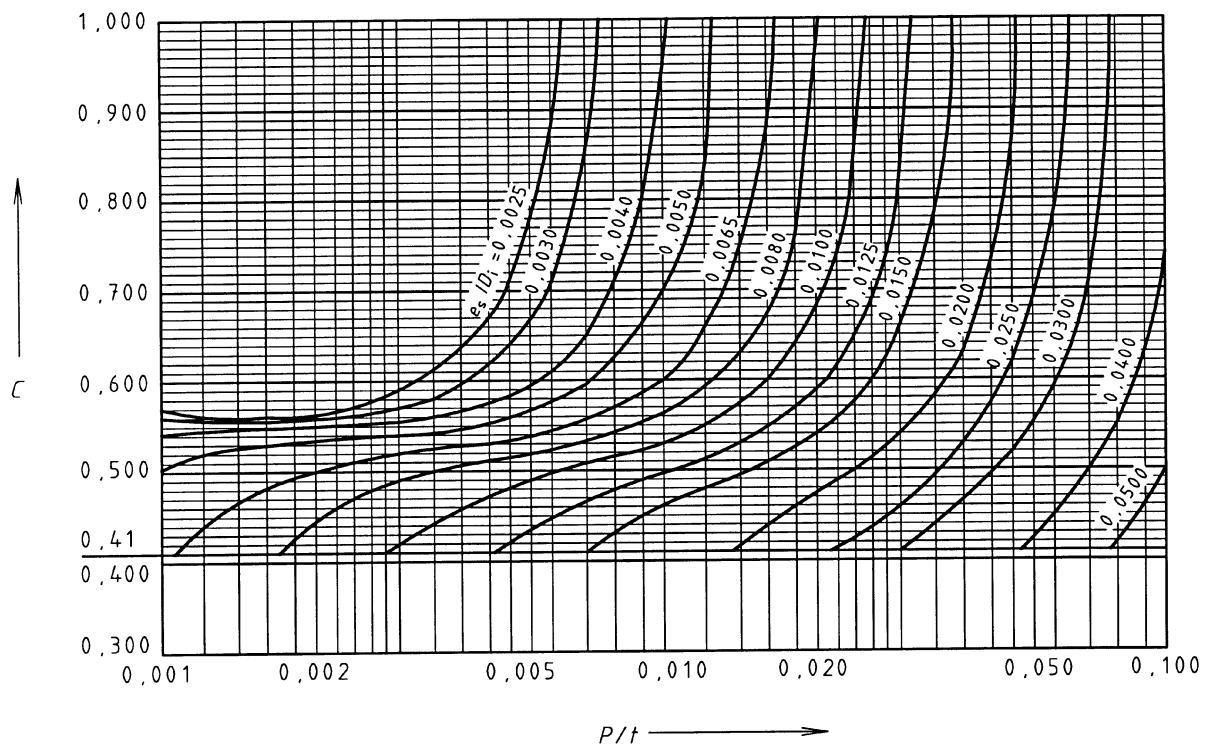
The calculated thickness of a flat end is given by the following equation:

$$e_{ce} = CD_i \sqrt{\frac{P}{f}} \quad (6.4.4.1-1)$$

where

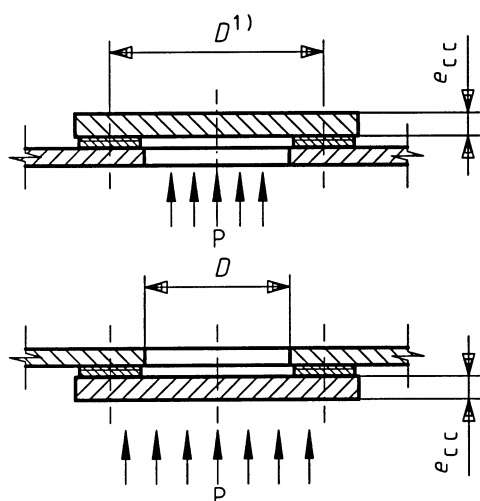
C is obtained from Figure 6.4.4.1-1;

D_i is the internal diameter of the end (see Figure 6.4.4.1-2c).



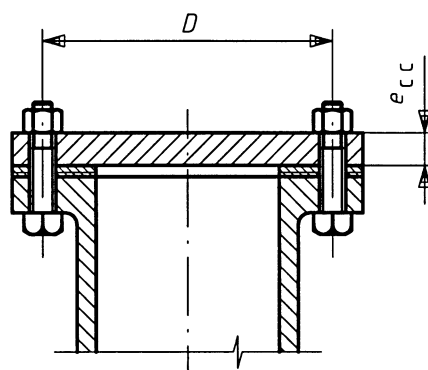
NOTE The minimum value of C is equal to 0.41

Figure 6.4.4.1-1 — Values for coefficient C for welded flat ends

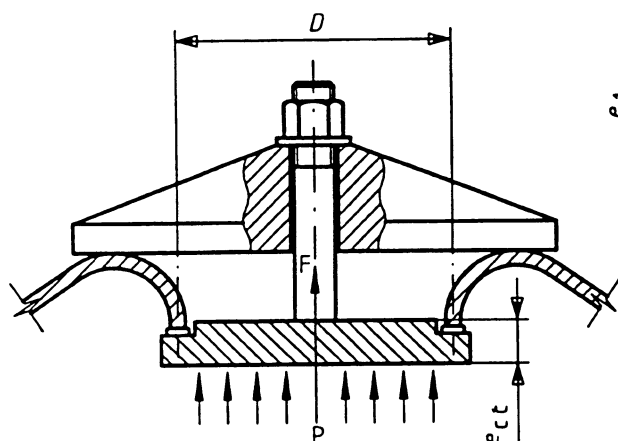


¹⁾ D is the mean gasket diameter.

a1) Flat cover with a full-faced gasket, $C = 0,41$

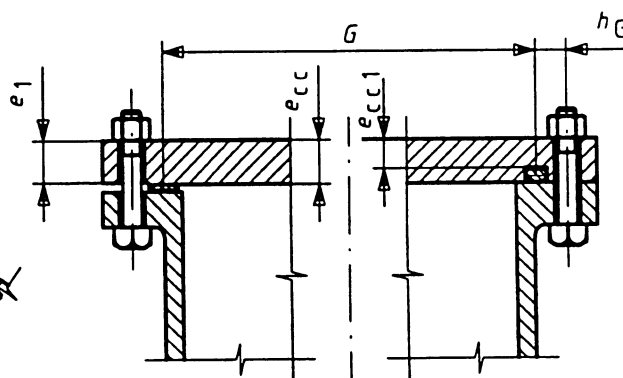


a2) Cover with a full-faced $C = 0,41$

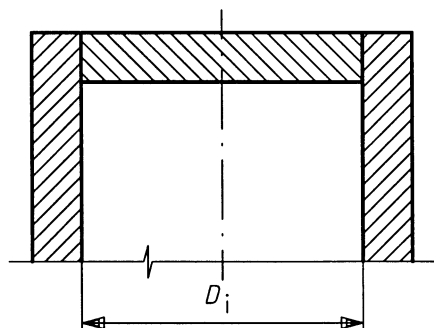


This configuration to be used in connection with configuration 6.4.3.1c and 6.4.6.3-11

a3) Cover with self-sealing joint



b) Cover with gasket entirely within the bolt circle



NOTE 1 See Figure 6.2.5-1 for details of welded joints.

c) Welded flat end

Figure 6.4.4.1-2 — Typical flat ends and covers

6.4.4.2 Covers without opening

The calculated thickness of a cover is calculated from the appropriate following equation.

- a) For covers with full-faced gasket or with self-sealing joint (Figure 6.4.4.1-2a1, Figure 6.4.4.1-2a2 and Figure 6.4.4.1-2a3):

$$e_{cc} = CD \sqrt{\frac{P}{f}} \quad (6.4.4.2-a1)$$

where

D is the design diameter shown in Figure 6.4.4.1-2a1, Figure 6.4.4.1-2a2 and Figure 6.4.4.1-2a3;

$C = 0,41$ for full-faced gasket covers (Figure 6.4.4.1-2a1 and Figure 6.4.4.1-2a2);

$c = \sqrt{0,17 + 0,75 \frac{F}{H}}$ for self-sealing joint (Figure 6.4.4.1-2a3) (6.4.4.2-a2);

where

F is the total bolt load;

H is the total hydrostatic end load.

- b) For covers with gasket entirely within the bolt circle (Figure 6.4.4.1-2b):

- 1) For circular covers the following equations apply:

$$e_{cc} = \max \left[\left(\sqrt{\frac{0,3 G^2 P}{f_{F,op}} + \frac{1,91 W_{m,op} h_G}{G f_{F,op}}} \right); \left(\sqrt{\frac{1,91 W h_G}{G f_{F,b}}} \right) \right] \quad (6.4.4.2-b1-1)$$

$$e_{cc1} = \max \left[\left(\sqrt{\frac{1,91 W_{m,op} h_G}{G f_{F,op}}} \right); \left(\sqrt{\frac{1,91 W h_G}{G f_{F,b}}} \right) \right] \quad (6.4.4.2-b1-2)$$

where

e_{cc} and e_{cc1} are shown in Figure 6.4.4.1-2b;

$W, W_{m,op}, h_G, G$ are given in 6.4.5.1.1;

$f_{F,op}, f_{F,b}$ are the nominal design stress of the cover for operating conditions or bolting-up condition.

- 2) For non-circular covers the following equations apply:

$$e_{cc} = \max \left[\left(\sqrt{\frac{0,3 G^2 P Z_0^2}{f_{F,op}} + \frac{6 W_{m,op} h_G}{n p f_{F,op}}} \right); \left(\sqrt{\frac{6 W h_G}{n p f_{F,b}}} \right) \right] \quad (6.4.4.2-b2-1)$$

$$e_{cc1} = \max \left[\left(\sqrt{\frac{6 W_{m,op} h_G}{n p f_{F,op}}} \right); \left(\sqrt{\frac{6 W h_G}{n p f_{F,b}}} \right) \right] \quad (6.4.4.2-b2-2)$$