

Simple unfired pressure vessels designed to contain air or nitrogen

Part 2. Specification for pressure vessels for air braking and auxiliary systems for motor vehicles and their trailers

The European Standard EN 286-2 : 1992 has the status of a British Standard

Réceptacles à pression simples, non soumis à la flamme, destinés à contenir de l'air ou de l'azote:
Partie 2: Réceptacles à pression pour circuits de freinage et circuits auxiliaires des véhicules routiers et leurs remorques

Einfache unbefeuerte Druckbehälter für Luft oder Stickstoff:
Teil 2: Druckbehälter für Druckluftbremsanlagen und Hilfseinrichtungen in Kraftfahrzeugen und deren Anhängerfahrzeugen

UDC: 621.642.02-98:629.114:620.1

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United Kingdom	British Standards Institution

This British Standard, having been prepared under the direction of the Pressure Vessel Standards Policy Committee, was published under the authority of the Standards Board and comes into effect on 15 November 1992

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AMD 7570

**Amendment No. 1
published and effective from 15 December 1992
to BS EN 286 : Part 2 : 1992**

**Simple unfired pressure
vessels designed to contain air or nitrogen
Part 2. Specification for pressure vessels for
air braking and auxiliary systems for motor
vehicles and their trailers**

Corrections

**AMD 7570
December 1992**

Clause 2 Normative references

Delete 'ISO 148' and its title and substitute the following.

'EN 10045-1 Metallic materials – Charpy impact test – Part 1 : Test method'

At the end of the title of ISO 4136 insert ⁽¹⁾.

At the end of the title ISO 5173 insert ⁽¹⁾.

Delete 'ISO 5817' and its title and substitute the following.

'EN 25817 Arc-welded joints in steel – Guidance on quality levels for imperfections'

**AMD 7570
December 1992**

Clause 8.2.1 Welded joints on steel

In items 5) and 6) delete 'ISO 5817' and substitute 'EN 25817'.

**AMD 7570
December 1992**

Clause 10.3.2.2

In paragraph 7, in items 5 and 6 delete 'ISO 148' and substitute 'EN 10045-1'.

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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 286-2 : 1992 *Simple unfired pressure vessels designed to contain air or nitrogen : Part 2 : Pressure vessels for air braking and auxiliary systems for motor vehicles and their trailers*, published by the European Committee for Standardization (CEN). It supersedes BS AU 221 : 1988 which is withdrawn, and partially supersedes BS 3256 : 1960 which will be withdrawn upon the publication of BS EN 286 : Part 3.

EN 286-2 was produced as a result of international discussions in which the United Kingdom took an active part.

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

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Descriptors: Road vehicles, trailers, braking systems, pressure vessels, compressed air, tanks, containers, steels, aluminium, computation, welded construction, manufacturing, tests, inspection, welded defects, marking

English version

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This European Standard was approved by CEN on 1992-09-28. 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.

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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

Foreword

This Part of this European Standard was drawn up by CEN/TC 54 'Simple unfired pressure vessels', of which the secretariat is held by the United Kingdom.

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

Part 1: Design, manufacture and testing

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 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 1993, and conflicting national standards shall be withdrawn at the latest by March 1993.

In accordance with the Common CEN/CENELEC Rules, the following countries are bound to implement this European Standard: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, 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 simple unfired serially made pressure vessels, herein after referred to as vessels, designed for air braking equipment and auxiliary systems for motor vehicles and their trailers, and which:

- a) include fabrication by welding;
- b) have a simple geometry enabling simple-to-use production procedures. This is achieved by either:
 - 1) a cylindrical shell of circular cross section closed by outwardly dished and/or flat ends having the same axis of revolution as the shell; or
 - 2) two dished ends having the same axis of revolution;
- 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 intended to contain only compressed air, and which operate within the following constraints:

- a) subjected to an internal 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;
- c) maximum working pressure 30 bar, the product of that pressure and the capacity of the vessel ($PS.V$) is greater than 50 bar litres and not exceeding 1500 bar litres;
- d) capacity not exceeding 150 litres;
- e) minimum working temperature not lower than $-50\text{ }^{\circ}\text{C}$ and maximum working temperature not higher than $100\text{ }^{\circ}\text{C}$.

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, or to fire extinguishers.

1.3 The essential safety requirements are given in annex G.

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 288-1	Specification and approval of welding procedures for metallic materials - Part 1 : General rules for fusion 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 10002-1	Metallic materials - tensile testing - Part 1 : Method of test (at ambient temperature)
EN 10025	Hot rolled products of non-alloy structural steels - Technical delivery conditions (annex F only)
EN 10028-1	Flat products made of steels for pressure purposes - Part 1 : General requirements
EN 10028-2	Flat products made of steels for pressure purposes - Part 2 : Non-alloy and alloy steels with specified elevated temperature properties
EN 10207	Steels for simple pressure vessels - Technical delivery requirements for plates, strips and bars
EN 26520	Classification of imperfections in metallic fusion welds, with explanations
ISO 148	Steel-Charpy impact test (V-notch)
ISO 209-1	Wrought aluminium and aluminium alloys - Chemical composition and forms of products - Part 1 : Chemical composition

ISO 209-2	Wrought aluminium and aluminium alloys - Chemical composition and forms of products - Part 2 : Forms of products
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 1106-3	Recommended practice for radiographic examination of fusion welded joints - Part 3 : Fusion welded circumferential joints in steel pipes of up to 50 mm wall thickness
ISO 2107	Aluminium, magnesium and their alloys - Temper designations
ISO 2409	Paints and varnishes - Cross-cut test
ISO 2604-1	Steel products for pressure purposes - Quality requirements - Part 1 : Forgings
ISO 2604-2	Steel products for pressure purposes - Quality requirements - Part 2 : Wrought seamless tubes
ISO 2604-3	Steel products for pressure purposes - Quality requirements - Part 3 : Electric resistance and induction-welded tubes
ISO 4136	Fusion-welded butt joints in steel - Transverse tensile test
ISO 5173	Fusion welded butt joints in steel - Transverse root and face bend test
ISO 5817	Arc-welded joints in steel - Guidance on quality levels for imperfections ¹⁾
ISO 6361-2	Wrought aluminium and aluminium alloy sheets, strip and plates - Part 2 : Mechanical properties
ISO 6362-2	Wrought aluminium and aluminium alloy extruded rods/bars, tubes and profiles - Part 2 : Mechanical properties
ISO 7253	Paints and varnishes - Determination of resistance to neutral salt spray
ISO 10042	Arc-welded joints in aluminium and its weldable alloys - Guidance on quality levels for imperfections ¹⁾

3 Definitions and symbols

3.1 Definitions

For the purposes of this standard, the following definitions apply.

3.1.1 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).

3.1.2 verification

The procedure adopted at the choice of the manufacturer to check and certify that vessels manufactured comply with this standard (see annex A).

3.1.3 declaration of conformity

The procedure whereby the manufacturer certifies vessels with a product *PS.V* not exceeding 1500 bar litres to be in conformity with this European Standard (see annex B).

3.1.4 surveillance

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

3.1.5 design and manufacturing schedule

A dossier issued by the manufacturer which describes the construction, material and fabrication, and includes the certificates (see annex C).

3.1.6 manufacturing record

A record retained by the manufacturer of all the relevant information on the vessels manufactured to this European Standard.

3.1.7 report on the examinations and tests

A report of the examinations and tests carried out by the manufacturer.

3.1.8 manufacturer's inspector

A person/persons employed by the manufacturer, but sufficiently independent from the production personnel, qualified and responsible for inspections, examinations and tests to be carried out on vessels by him or under his responsibility by competent staff.

3.1.9 qualification of the inspector

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.

¹⁾This ISO Standard is registered in the programme of work of CEN/TC 121 'Welding' and should be implemented as an EN Standard.

3.1.10 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.

3.1.11 non-automatic welding

All types of welding other than that defined in 3.1.10.

3.1.12 type of vessel

Vessels are of the same type if they simultaneously:

- have similar geometrical form (i.e. shell rings and ends or only ends, in both cases ends of the same shape);
- have wall material and thickness within the limit of validity of the weld procedure, including those for bosses and inspection openings;
- have the same type of bosses and of inspection openings; numbers and positions may vary;
- have the same design temperature limitations.

3.1.13 batch

A batch of vessels consists at the most of 3000 vessels of the same type.

3.1.14 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.

3.1.15 family

Vessels form part of the same family if they differ only in diameter and/or in the length of their cylindrical portion.

3.1.16 subfamily

Consists of vessels of the same family with the same wall thicknesses, the same material, the same welding procedure, the same construction of details; the vessels may vary in number and position of attachments and bosses.

3.1.17 maximum design temperature

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

3.1.18 minimum design temperature

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

3.1.19 maximum working temperature, $T_{\max}$.

The highest stabilized temperature which the wall of the vessel may attain under normal conditions of use.

3.1.20 minimum working temperature, $T_{\min}$.

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

3.1.21 maximum working pressure, PS

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

3.1.22 design pressure, P

The pressure chosen by the manufacturer and used to determine the thickness of the pressurized parts.

3.1.23 inspection slip

A document by which the producer certifies that the products delivered meet the requirement of the order and in which he sets out the results of the routine in-plant inspection test, in particular chemical composition and mechanical characteristics, performed on products made by the same production process as the supply, but not necessarily on products delivered (see G.2.1).

This corresponds to test report '2.2' defined in EN 10204 : 1991.

3.2 Symbols

For the purposes of this standard, the following symbols apply.

$A, A_{80 \text{ mm}}$	Elongation after rupture	%	e_{rs}	Wall thickness of shell contributing to reinforcement	mm
A_f	Cross-sectional area effective as compensation	mm ²	e_s	Wall thickness of the shell	mm
A_{fb}	Cross-sectional area effective as compensation of the boss	mm ²	f	Nominal design stress	N/mm ²
A_{fs}	Cross-sectional area effective as compensation of the shell	mm ²	g	Throat thickness of a weld	mm
A_p	Area of pressurized zone	mm ²	h	Height of a dished end	mm
A_c, A_R	See 5.1.7	mm ²	$h_b, h_{be}, h_{be1}, h_{be2}$	See 5.1.6.1 and figure 3	mm
C	Calculation coefficient for unpierced flat ends	—	K_c	Calculation coefficient which depends on the welding process	—
c	Absolute value of the negative tolerance taken from the material standard or as stated in the drawing plus the absolute value of the reduction of wall thickness by the forming process	mm	KCV	Failure energy (impact test)	J/cm ²
c_b	As before for a branch or boss	mm	KV	Failure energy (impact test)	J
D	Inside diameter of an unpierced flat end	mm	L	See 5.1.7	mm
D_o	Outside diameter of the shell	mm	l_b	Length between adjacent bosses	mm
D_c	Outside diameter of the crown section of a torispherical end measured to the tangent between crown and knuckle	mm	l_{rb}	Length of boss contributing to reinforcement	mm
d	Diameter of hole	mm	l_{rs}	Length of shell contributing to reinforcement	mm
d_{ib}	Internal diameter of a boss	mm	m	See 10.5.3	—
d_{ob}	Outside diameter of a boss	mm	N	See 6.1.3.1 and 10.5.3	—
e	Nominal wall thickness	mm	P	Design pressure ²⁾ (which shall not be less than PS)	bar
e_a	Actual wall thickness	mm	P_h	Test pressure ²⁾	bar
e_{act}	Actual wall thickness of the shell before the pressure test	mm	PS	Maximum working pressure ²⁾	bar
e_{ah}	Actual wall thickness of the end	mm	R	Inside radius for shells and ends	mm
e_{as}	Actual wall thickness of the shell	mm	R_e	Minimum yield strength specified in the material standard	N/mm ²
e_c	Calculated thickness	mm	$R_{e \text{ act}}$	Yield strength of the shell material as determined in the tensile test	N/mm ²
e_{cb}	Calculated wall thickness of a branch or a fictitious branch with the same internal diameter as the boss	mm	R_{eT}	Minimum yield strength at maximum working temperature specified in the material standard	N/mm ²
e_{ch}	Calculated wall thickness of the dished end	mm	R_m	Minimum tensile strength specified in the material standard or guaranteed in the inspection slip by the material manufacturer	N/mm ²
e_{cs}	Calculated wall thickness of the shell	mm	$R_{m \text{ act}}$	Tensile strength of the shell material as determined in the tensile test	N/mm ²
e_h	Nominal wall thickness of the dished end	mm	r	Inside knuckle radius for torispherical ends	mm
e_n	e_{act} - corresponding nominal wall thickness as stated in the design drawing	mm	T	Temperature	°C
e_{rb}	Wall thickness of boss contributing to reinforcement	mm	$T_{max.}$	Maximum working temperature	°C
			$T_{min.}$	Minimum working temperature	°C
			$T'_{min.}$	Minimum ambient temperature	°C
			u_i	Is the circumferential length at cross section i after the pressure test	mm
			u_{i0}	Is the circumferential length at cross section i before the pressure test	mm
			V	Capacity of the vessel	litre

²⁾All pressures are gauge pressures.

4 Materials

4.1 Main pressurized parts

4.1.1 Steel vessels

The following materials shall be used:

- a) Plate, strip and bar according to EN 10207 (grades SPH 235, SPH 265 and SPHL 275), or to EN 10028 : Part 1 and Part 2 (grades PH 235 and PH 265).

For these grades of steel the compliance to the essential safety requirements indicated in annex G according to the average failure energy KV of steels at the minimum working temperature may be checked by the use of annex F.

- b) Tubes according to ISO 2604 : Part 2 (grades TS5 and TS9) and ISO 2604 : Part 3 (grades TW5 and TW9).
- c) Forgings according to ISO 2604 : Part 1 (grade F9)

For a), b) and c), the materials shall be accompanied by an inspection slip verifying the suitability of the material, including all the criteria required by annex G. In the case of materials according to b) and c) the inspection slip shall contain specific references to the requirements of annex G.2.1.1.

4.1.2 Aluminium vessels

The following materials shall be used (see table 1). For other products (i.e. bars and rods), materials according to ISO 6362 : Part 2 should be used so far as they fulfil the requirements of annex G.2.1.2.

4.1.3 Additional materials and products

Any materials not included in 4.1.1 and 4.1.2, which are manufactured according to a recognized national or international standard for quality steels, aluminium or aluminium alloy and which conform to the essential safety requirements of annex G will be acceptable subject to approval by an approved inspection body in order to have type examination of the vessel and include the suitability of the material. Such materials shall be accompanied by an approved inspection body certificate verifying the suitability of the materials.

4.2 Accessories contributing towards the strength of vessels

These accessories (pipes/tubes, bosses etc.) shall be made from steel, aluminium or aluminium alloy, which is compatible with materials used for the manufacture of pressurized parts. They shall have an elongation after rupture, A , on test pieces taken in the length of at least 14 %. (See EN 10002 : Part 1.)

4.3 Non-pressurized parts

All unpressurized parts of welded vessels shall be of materials that are compatible with that of the components to which they are welded.

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

$$C \leq 0,25 \%, S \leq 0,05 \%, P \leq 0,05 \% \text{ and } R_m \text{ max.} < 580 \text{ N/mm}^2$$

Aluminium and aluminium alloys shall be as given in 4.1.2.

4.4 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.³⁾

5 Determination of the wall thickness

The manufacturer may determine the wall thickness of pressurized parts by either the calculation method given in 5.1 or by the experimental method given in 5.2.

The actual wall thickness of the cylindrical section and ends shall be not less than 2 mm in the case of steel vessels and not less than 3 mm in the case of aluminium or aluminium alloy vessels. That means: the minimum nominal wall thickness is 2 mm + c for pressure vessels made of steel and 3 mm + c for pressure vessels made of aluminium alloys.

5.1 Calculation method

5.1.1 Nominal design stress

The nominal design stress, f , shall not exceed the lower value of $0,6 R_{eT}$ or $0,3 R_m$, where R_{eT} and R_m are the values specified in the material standard.

5.1.2 Nominal thickness

The nominal thickness of shells and ends shall be equal to or greater than

$$e \geq e_c + c \quad (1)$$

5.1.3 Calculated thickness of shells

$$e_{cs} = \frac{P D_o}{20f + P} K_c \quad (2a)$$

$K_c = 1,0$ or $1,15$, depending on the welding process. The type of testing adopted, see tables 8 to 11 of 10.3.2.2, depends on the value of K_c and P .

³⁾European Standard in preparation.

Table 1. Aluminium materials									
ISO designation ¹⁾	International registration record ¹⁾	Temper designation ²⁾	Maximum temperature °C	Temperature °C			Design temperature ³⁾ °C		
				20	50	100	20	50	100
				Minimum proof stress ⁴⁾ N/mm ²			Minimum design stress N/mm ²		
A199,8 (A)	1080 A	0	100	22	20	18	13	12	11
A199,7	1070 A	0	100	25	23	20	15	14	13
A199,5	1050 A	0	100	30	29	27	18	17	16
A1Mg1 (B)	5005 A	0	100	35	35	35	21	21	21
A1Mg2	5251	0	100	60	60	60	36	36	36
A1Mg2Mn0,8	5049	0	100	80	80	70	48	48	42
A1Mg2,5	5052	0	100	60	60	57	36	36	34
A1Mg3	5754	0	100	80	80	70	48	48	42
A1Mg3Mn	5454	0	100	90	90	90	54	54	54
A1Mg3,5 (A)	5154 A	0	100	90	90	90	54	54	54
A1Mg4	5086	0	65	100	100	90 ⁵⁾	60	60	54 ⁵⁾
A1Mg4,5Mn0,7	5083	0	65	125	125	120 ⁵⁾	75	75	72 ⁵⁾
A1Mn1	3103	0	100	35	35	30	21	21	18
A1Mn0,5Mg0,5	3105	0	100	40	40	37	24	24	22

¹⁾ISO designation and international registration record, see ISO 209 : Parts 1 and 2.
²⁾Temper designation, see ISO 2107.
³⁾For intermediate design temperature, linear interpolation may be used.
⁴⁾ $R_{p1,0}$ for aluminium, $R_{p0,2}$ for aluminium alloys.
⁵⁾For interpolation purposes only, temperature limit 65 °C.

5.1.4 Calculated thickness of unpierced dished ends

5.1.4.1 Limitations

Dished ends shall fulfil the following limitations:

- a) hemispherical ends: $0,002 D_o \leq e_{ch} \leq 0,16 D_o$
- b) ellipsoidal ends: $0,002 D_o \leq e_{ch} \leq 0,08 D_o$
 $h_e = h \geq 0,18 D_o$
- c) torispherical ends: $0,002 D_o \leq e_{ch} \leq 0,08 D_o$
 $r \geq 0,06 D_o$
 $r \geq 3e_{ch}$
 $R \leq D_o$

The values of the limitation conditions for R are nominal ones; tolerances up to 4 % are allowed. It should be noted that the two relationships in b) or the four relationships in c) should be fulfilled simultaneously.

In no case, except in figure 5b, shall the thickness of the cylindrical or straight flange 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.

5.1.4.2 Calculations for hemispherical ends

The thickness of hemispherical ends shall be determined using equation:

$$e_{ch} = \frac{P D_o}{40f + P} K_c \quad (2b)$$

K_c see 5.1.3.

5.1.4.3 Calculations for ellipsoidal and torispherical ends

This calculation may be performed by the following procedure.

- a) Calculate $P/(10f)$ from the design pressure P and the design stress f . Calculate h_e/D_o where, for torispherical ends, h_e is the smallest of the three values

$$D_o^2/[4(R + e_{ch})] \text{ or } \sqrt{D_o(r + e_{ch})/2} \text{ or } h,$$

where

$$h = R + e_{ch} - \sqrt{(R - r)^2 - (D_o/2 - e_{ch} - r)^2}$$

- b) Enter figure 2 with this value, read up to the appropriate h_e/D_o line for the proposed end shape and then across to the e_{ch}/D_o axis for the corresponding e_{ch}/D_o value.

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

NOTE. The values which correspond to figure 2 are given in table 2.

- c) Multiply this e_{ch}/D_o value by D_o to obtain the end thickness e_{ch} .

NOTE. When the ends have no straight flange, the end thickness e_{ch} must be multiplied by K_c .

The thickness of the spherical portion of a torispherical end may be determined as for a hemispherical end of spherical radius R with the area of diameter $D_c - 2z$, where

$$z = 0,5 \sqrt{R \times \text{torispherical thickness}}$$

Figure 2 may be used with the values of h_e and D_o based on internal dimensions, provided $h_e/D_o < 0,27$; beyond this value external dimensions are to be used.

5.1.5 Calculated thickness of unpierced flat ends

The minimum thickness of an unstayed flat end without opening is given by the following equation:

$$e = C D \sqrt{\frac{P}{10f}} \quad (3)$$

where

$$C = 0,5.$$

5.1.6 Compensation calculation for cylindrical shells and dished end with openings(bosses)

- 5.1.6.1 Compensation calculation is not required if
 - the internal diameter of the opening is

$$d \leq 0,14 \sqrt{(D_o - e_a) e_a} \quad (4a)$$

or if

- the internal diameter of the opening is:

$$d \leq 2 \frac{e_a - e_c - c}{e_c} \sqrt{(D_o - e)e} - 2(e_{cb} + c_b) \quad (4b)$$

or if

- the following conditions for the dimensions of the boss and the opening are fulfilled (see figure 3)

$$h_{be} \cdot e_{rb} \geq \frac{d}{2} \cdot e_c \quad (4c)$$

$$d_b \leq 40 \text{ mm}$$

h_{be} the smaller of the two values of h_b or $6 e_c$ (in case of figures 3a and 3b) respectively or the smaller of the two values of h_b or $10 e_c$ under the restrictions of $h_{be1} \leq 6 e_c$ and $h_{be2} \leq 6 e_c$ (in case of figure 3c).

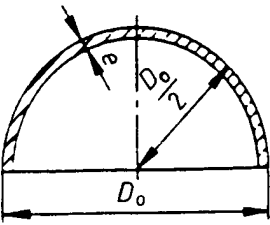


Figure 1a. Hemispherical end

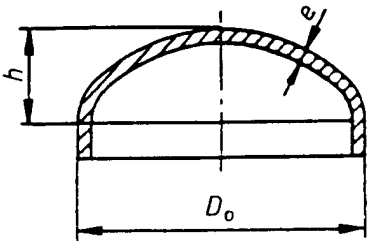


Figure 1b. Ellipsoidal end

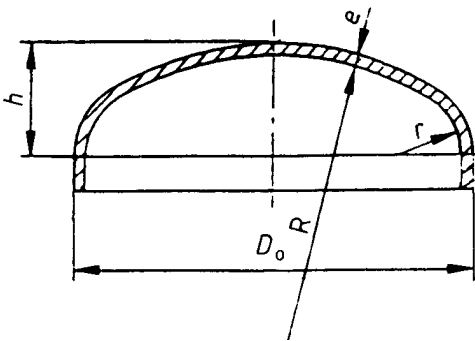


Figure 1c. Torispherical end

Figure 1. Types of ends

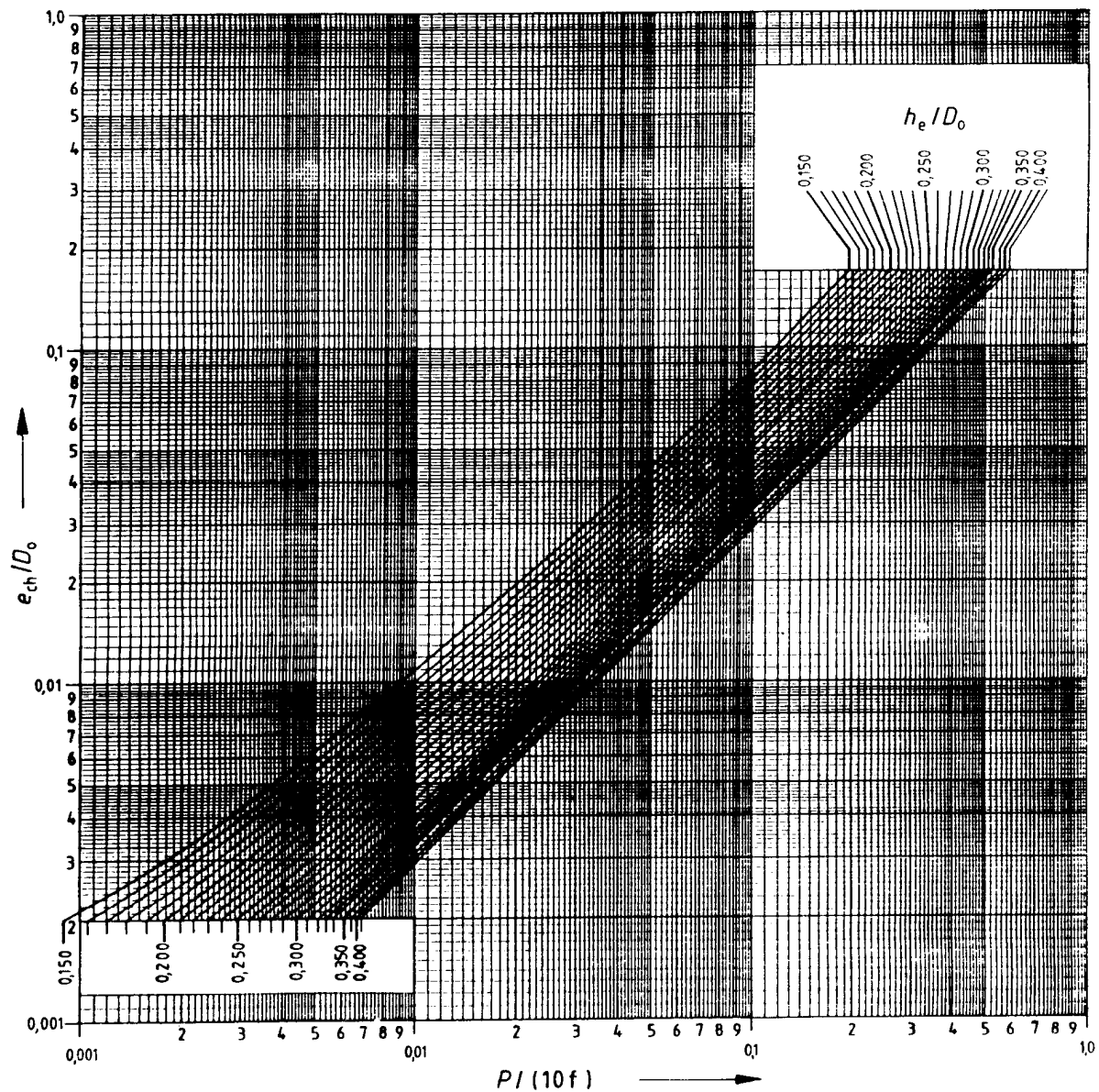
Table 2. Values of $(e_{ct}/D_o) \cdot 10^3$ for unpierced dished ends in terms of h_e/D_o and $P/(10f)$

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

NOTE 1. This table is not valid for values of $(e_{ct}/D_o) \times 10^3 < 2,00$.

NOTE 2. Intermediate values may be obtained by logarithmic interpolation.

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



NOTE. The scale is logarithmic.

Figure 2. Design curves for dished ends

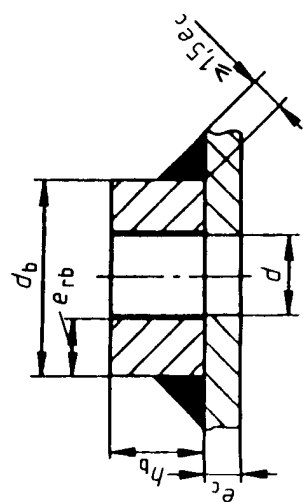


Figure 3a

NOTE. In case of figure 3b also the area $[(d - d_{\text{hp}})/2]$ e_c is effective if full penetration welding is applied.

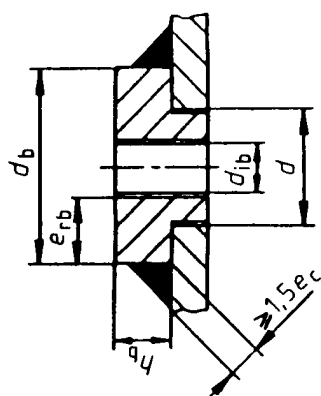


Figure 3b

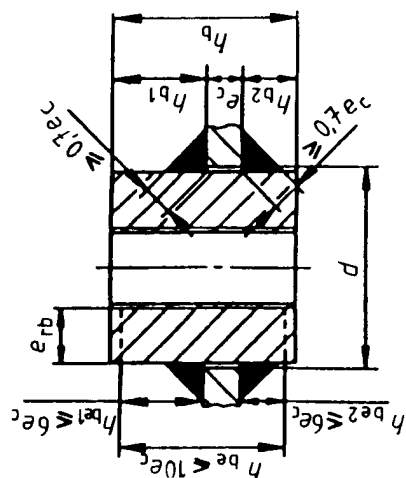


Figure 3c

Figure 3. Shell or dished end with opening compensated by a boss

5.1.6.2 If conditions under **5.1.6.1** are not fulfilled, the design method specified as follows shall apply to cylindrical shells and dished ends having circular openings, where the assumptions and conditions specified in **5.1.6.3** and **5.1.6.4** are satisfied.

5.1.6.3 The distance between two openings, measured from the outside, must not be less than $10 e$. If the distance between openings is greater than or equal to $2 l_{rs}$, where:

$$l_{rs} = \sqrt{(2R + e_{rs}) e_{rs}^4} \quad (5)$$

then the necessary reinforcement shall be calculated according to **5.1.6.6**, case A or C.

If the distance between openings is smaller than $2 l_m$, the necessary reinforcement shall be calculated according to **5.1.6.6**, case B or D.

5.1.6.4 The reinforcement of the main body can be obtained alternatively by:

- set-in welded bosses
 - set-on welded bosses
 - increased wall thickness.
- } including projection
welding and friction
welding

5.1.6.5 The reinforcement area of the main body with openings cannot be calculated directly but shall be assumed in the first instance. That assumption may be verified by means of the method laid down in the following clause. The applied method is derived from equation (2a) for cylindrical shells and from equation (2b) for spherical shells and spherical sections of dished ends respectively and leads to relationships between a pressure loaded area A_p and a stress loaded cross-sectional area A_f . Under certain circumstances the calculation may need to be repeated using a corrected assumption of the reinforcement area.

5.1.6.6 The calculation of reinforcement is to be performed as shown in table 3 in combination with figures 4a to 4d. For ends the calculation of A_p , A_{fs} and A_{fb} is evident from figures 4a to 4d. For cylindrical shells the figures 4a to 4d can be used for calculation of the effective area (A_{fs} and A_{fb}) but it should be noted that

$$A_p = R \left(l_{rs} + \frac{d}{2} \right) \quad (6)$$

if the distance between holes $\geq 2 l_{rs}$
and

$$A_p = R \left(l_b + \frac{d_1}{2} + \frac{d_2}{2} \right) \quad (7)$$

if the distance between holes $< 2 l_{rs}$ but $\geq 10 e$.

5.1.7 Compensation calculation for flat ends

Flat ends that have an opening of $D/2$ or less shall be provided with reinforcement by the following equation:

$$A_R \geq A_c \quad (8)$$

The area A_R is obtained by multiplying the difference between the adopted plate thickness and the plate thickness (calculated in accordance with **5.1.5**) $\times$ length L .

The area A_c is given by $d/2 \times$ calculated thickness e in accordance with **5.1.5**.

L is given by the greater of the 3 values of $2.5 e$ or $(e + 75 \text{ mm})$ or $d/2$.

NOTE 1. This method of compensation is widely used and experience has proved it to be satisfactory for a wide range of applications. However because of the simplified nature of the calculations, its use is limited.

NOTE 2. This method of compensation takes account of the cross-sectional area of locally disposed material.

5.2 Experimental method

In order to determine the wall thickness by means of a pressure test, the plastic deformation of one pressure vessel (prototype, which represents the worst case) of every subfamily must be ascertained. The test is to be carried out at an ambient temperature of $20 \pm 5 \text{ }^\circ\text{C}$ and consists of:

- a pressure test followed by
- a burst test; and
- a tensile test on the plate/coil used for the shell of the prototype.

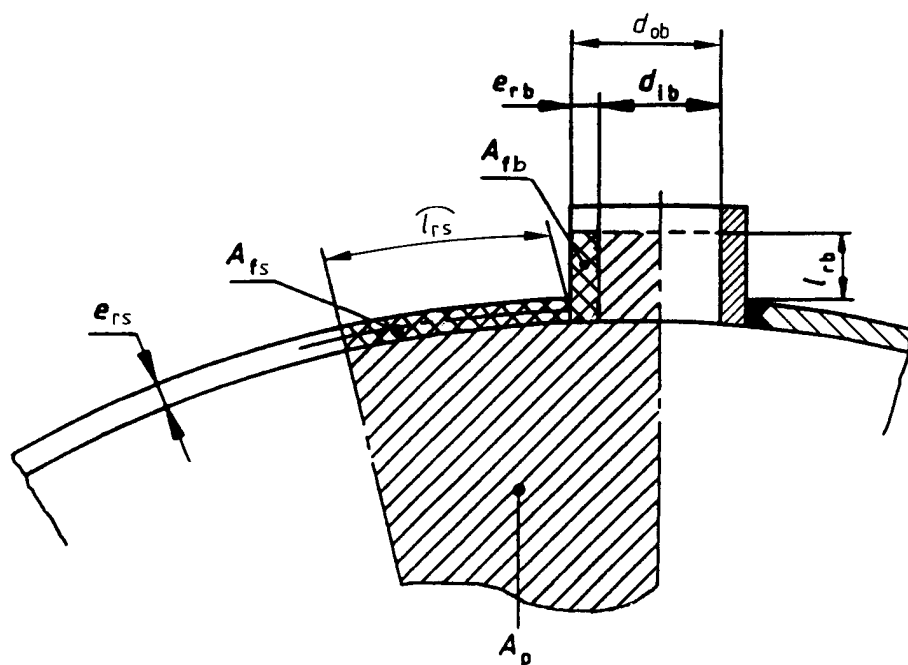
The assessment of the worst case(s) shall be agreed upon by manufacturer and inspection body and the tests be carried out or witnessed and certified by the inspection body.

5.2.1 General

During the pressure test, the average rate of pressure increase shall be not greater than 1.0 bar/s , until the prescribed test pressure has been reached. The test pressure should continue to be exerted for at least 5 min. During this time no leaks shall become apparent. The pressure test shall be performed on a finished product, but with no surface treatment applied.

⁴⁾See also condition in **6.1.3.5**.

Table 3. Calculation of reinforcement (see also figures 4a to 4d)	
Reinforcement by set-in or set-on bosses	Reinforcement by increased wall thickness
Distance between holes $\geq 2 l_{rs}$ Case A (figure 4a) The effective height of the boss¹⁾ l_{rb}: $l_{rb} = 0,8 \sqrt{(d_{fb} + e_{rb}) e_{rb}}$ The effective area²⁾ of the boss A_{fb}: $A_{fb} = l_{rb} \cdot e_{rb}$ The effective length²⁾ of the wall l_{rs} The effective area²⁾ of the wall A_{fs}: $A_{fs} = l_{rs} \cdot e_{rs}$	Case C (figure 4C) The effective length²⁾ of the wall l_{rs} The effective area²⁾ of the wall A_{fs}: $A_{fs} = l_{rs} \cdot e_{rs}$ When calculating the thickness of walls with only one hole the effective length of the wall is: $l_{rs} = 1,0 \sqrt{(2R + e_{rs}) e_{rs}}$
Distance between holes $< 2 l_{rs}$ Case B (figure 4b) The effective height of the boss¹⁾ l_{rb}: $l_{rb} = 0,8 \sqrt{(d_{fb} + e_{rb}) e_{rb}}$ The effective area²⁾ of the boss A_{fb}: $A_{fb} = l_{rb} \cdot e_{rb}$ The effective length²⁾ of the wall l_b The effective area²⁾ of the wall A_{fs}: $A_{fs} = l_b \cdot e_{rs}$ but $\geq 10e$	Case D (figure 4d) The effective length²⁾ of the wall l_b: The effective area²⁾ of the wall A_{fs}: $A_{fs} = l_b \cdot e_{rs}$
In both cases the following condition shall be satisfied: $\frac{P}{10} \left(\frac{A_p}{A_{fs} + A_{fb}} + 0,5 \right) \leq f$	In both cases the following condition shall be satisfied: $\frac{P}{10} \left(\frac{A_p}{A_{fs}} + 0,5 \right) \leq f$
¹⁾If the actual height of the boss is smaller than l_{rb}, then the actual height is to be used. ²⁾The effective length and the effective area, respectively, mean the length and area to be taken into account for the purpose of compensation of the opening.	

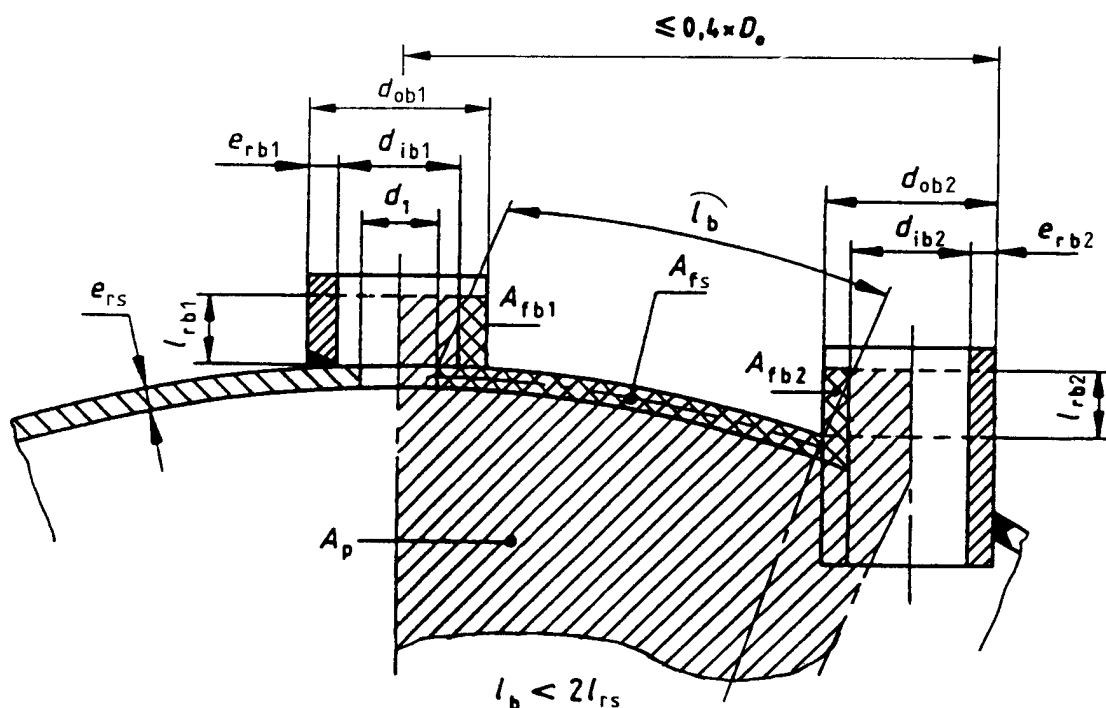


NOTE 1. Can also be used for bosses of the set-on type.

NOTE 2. If the boss is of the set-in type with inside parts then the effective area of the inside parts of the wall is also to be considered.

NOTE 3. If full penetration welds are used. If not, the boss cannot be used for reinforcement.

Figure 4a. Effective areas and pressure loaded areas for calculation of reinforcement (case A)



NOTE 1. If full penetration welds are used. If not, the boss cannot be used for reinforcement.

Figure 4b. Effective area and pressure loaded areas for calculation of reinforcement (case B)

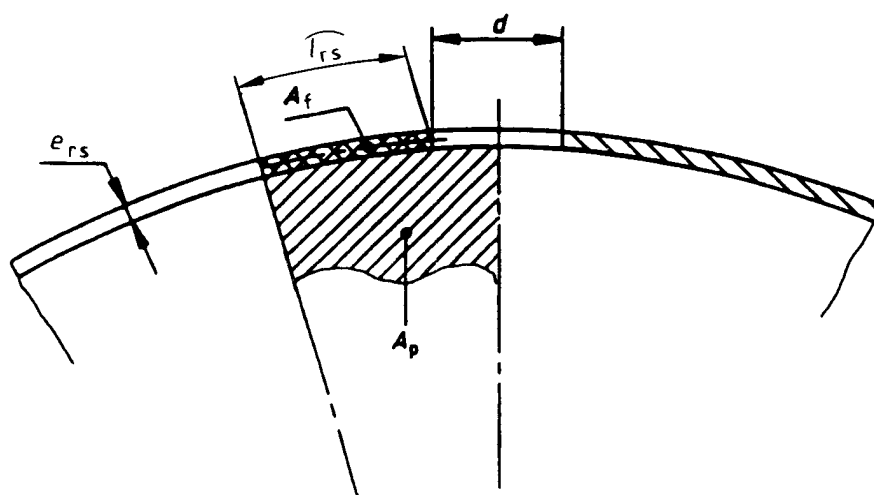


Figure 4c. Effective areas and pressure load areas for calculation of reinforcement (case C)

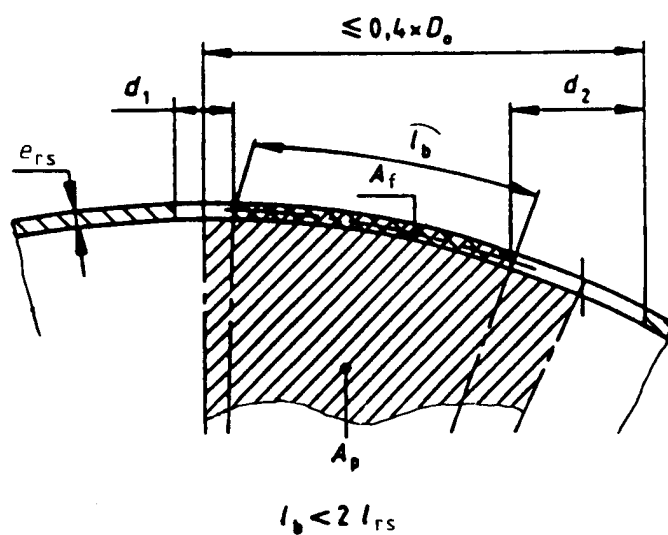


Figure 4d. Effective areas and pressure loaded areas for calculation of reinforcement (case D)

5.2.2 Pressure test

The pressure test is to be carried out at a pressure of at least five times the maximum working pressure (5 *PS*), with a permanent circumferential deformation such that the following condition is fulfilled:

$$100 \cdot \frac{u_i - u_{i0}}{u_{i0}} \cdot \frac{R_{e \text{ act}}}{R_e} \cdot \frac{e_{\text{act}}}{e_n - c} \leq l \quad (9)$$

The pressure shall be measured with an accuracy of 1 %.

Before the pressure test, the actual wall thickness of the cylindrical shell shall be determined, and the circumferential lengths of the vessel shall be measured at least at three different cross sections with an accuracy of 0,1 %.

After the pressure test, the circumferential lengths at the same cross sections shall be determined.

5.2.3 Burst test

Then the pressure shall be re-applied and increased gradually until rupture of the reservoir wall occurs. The pressure at which rupture occurs shall be not less than:

$$5 \text{ PS} \frac{R_{m \text{ act}}}{R_m} \cdot \frac{e_{\text{act}}}{e_n - c} \quad (10)$$

No parts shall become detached, nor splinters projected, and rupture shall not originate in any weld.

5.2.4 The pressure test and the burst test shall be performed using water.

5.2.5 In the condition given in 5.2.2 and in the limit value for the burst pressure given in 5.2.3, limit values for *c*, *R_e* and *R_m* different from those stated in the material standard may be used if:

- these limit values or the limit values for the products $(e - c) R_e$ and $(e - c) R_m$ are stated on the drawing and
- one coil or one plate of a coil is checked accordingly with respect to the specified values.

6 Construction and fabrication

6.1 Construction

6.1.1 General

No rules of construction can be written in sufficient detail to ensure good workmanship and construction. Each manufacturer is responsible for taking every step necessary to ensure that the quality of workmanship and construction is such as to ensure compliance with good engineering practice.

The manufacturers shall have their own competent supervisory personnel and specialists for production. If the production work, such as forming or heat treatment, is assigned to other bodies, such bodies shall also satisfy the conditions for the work to be performed.

6.1.2 Design of openings

The distance between two openings, measured from the outside, must not be less than 10 *e*.

6.1.3 Weld joint design

6.1.3.1 Circular and longitudinal seams shall be made using full penetration welds or welds of equivalent effectiveness.

Convex ends other than hemispherical ones shall have a cylindrical edge.

Allowed types of weld joint design (circular seams), see figures 5a1 to 5a3 and 5c.

Additionally a weld joint design corresponding to figures 5b1 and 5b2 is acceptable under definite additional conditions. These conditions are:

- 1) The nominal design stress, *f*, shall not exceed the lower value of 0,6 *R_{eT}*/1,4 or 0,3 *R_m*/1,4 where *R_{eT}* and *R_m* are the values specified in the material standard.
- 2) The material tensile strength *R_m* used in the calculation of the dished end or shell shall be less than or equal to 360 N/mm² (limit only for calculation purpose).
- 3) The shell diameter *D_o* shall be limited to 400 mm in the case of figure 5b1 and 350 mm in the case of figure 5b2.
- 4) The thickness *e_{as}* shall be less than 5 mm, and greater or equal to *e_{ah}* for satisfactory welding.
- 5) The maximum working pressure, *PS*, shall be less than or equal to 12 bar.
- 6) The circumferential welds, leaving aside their possible repair, have to be carried out by an automatic process.
- 7) In addition, for weld joint design of figure 5b2 only, the fit up tolerance is 0,25 mm for not less than 270° and 1,00 mm for not more than 90°.
- 8) Systematic prototype test shall be done according to the procedure described in 5.2.3.
- 9) In addition, for weld joint design of figure 5b2 only, the circumferential weld shall undergo a fatigue test under the following conditions:

Number of cycles: $N = 10^5$

Pressure range: 0,1 *PS* to 1,0 *PS*, where *PS* is the value shown on the identification plate.

These conditions are tabulated in table 4.

6.1.3.2 Longitudinal welds shall not be closer than 30° to the bottom axis (see figure 6).

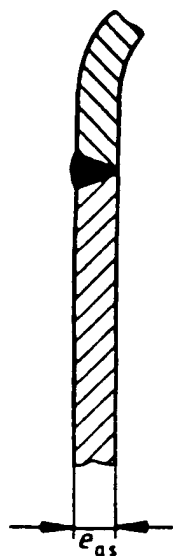


Figure 5a1. Straight end

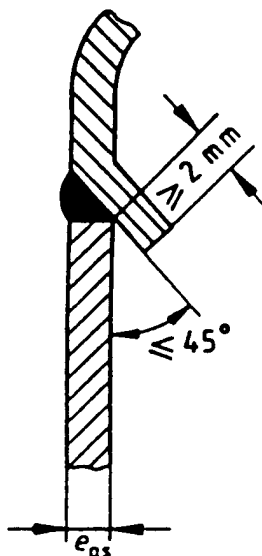


Figure 5a2. Tbed-in end



Figure 5a3. Joggled end

Figure 5a. Types of weld joint design (dished ends/shells)

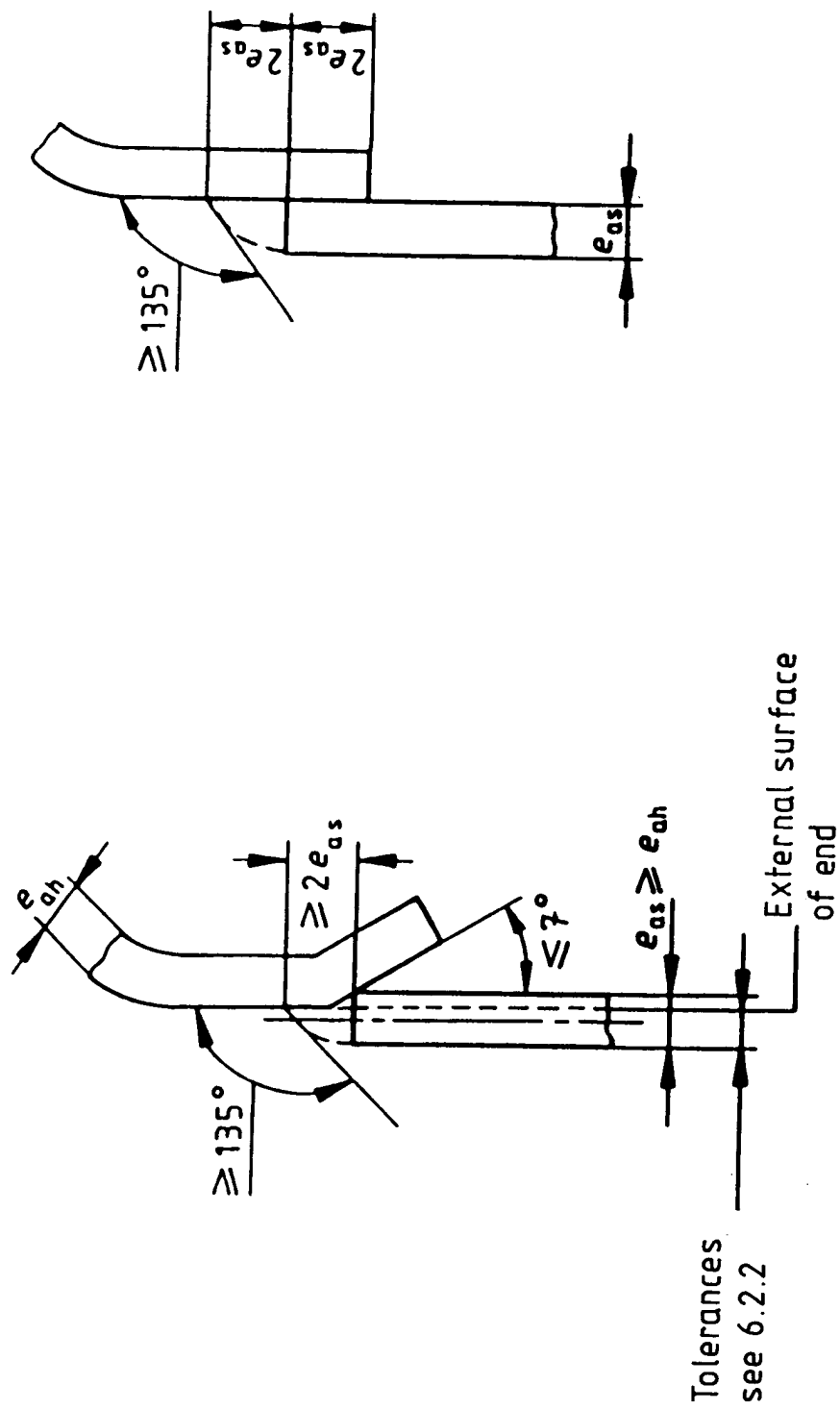


Figure 5b1. Toed-in end

Figure 5b. Types of weld joint design (dished ends/shells) (see 6.1.3.1)

Figure 5b2. Inserted end

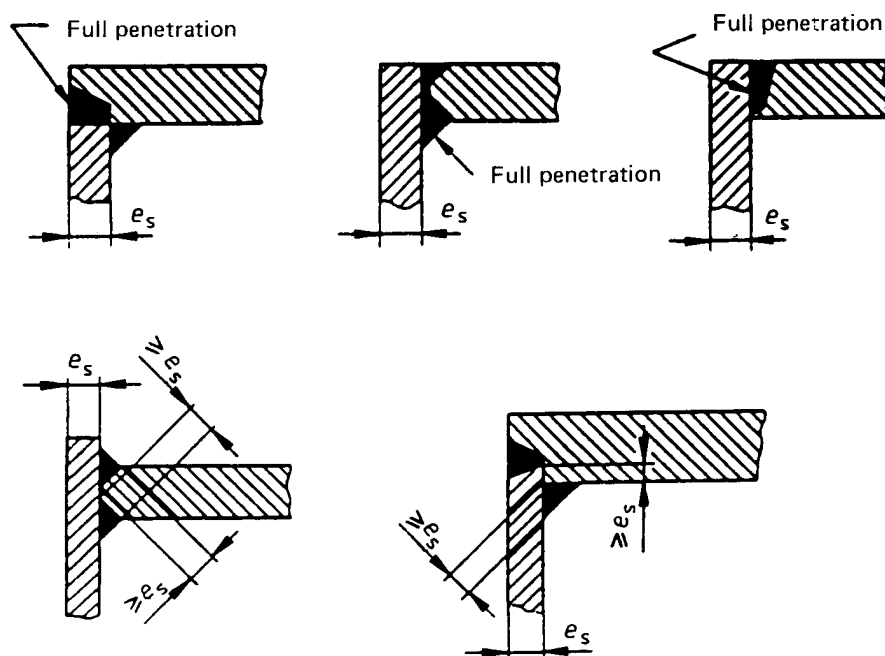


Figure 5c. Allowed types of weld joint design (flat ends/shells)

Table 4. Conditions for using weld joint design as in figure 5b			
Conditions ¹⁾		figure 5b1	figure 5b2
Calculation			
1	- nominal design stress f (N/mm ²)	lower value of 0,6 $R_{eT}/1,4$ and 0,3 $R_m/1.4$	
2	- tensile strength R_m to be used (only for calculation purpose) (N/mm ²)	≤ 360	
Dimensions and pressure			
3	- D_o (mm)	≤ 400	≤ 350
4	- e_{as} (mm)	$5 \geq e_{as} \geq e_{ab}$	
5	- PS (bar)	≤ 12	
Fabrication			
6	- welding	automatic process ²⁾	
7	- gap between shell and end (mm)	—	≤ 0,25 for not less than 270° and ≤ 1,00 for not more than 90°
Testing			
8	- prototype test	corresponding procedure of 5.2.3 (only burst test)	
9	- fatigue test	—	number of cycles $N = 10^5$; pressure range 0,1 PS to 1,0 PS ³⁾

¹⁾In addition to the represented conditions in the sketches.

²⁾Leaving aside its possible repair.

³⁾PS the value shown on the identification plate.

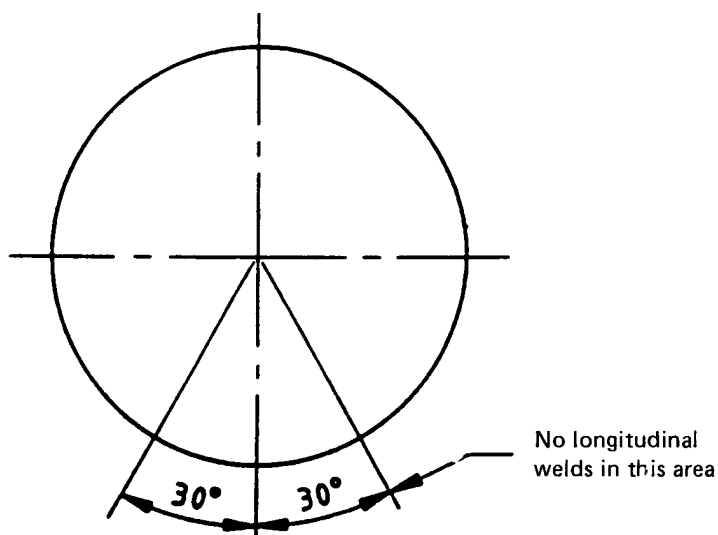


Figure 6. Position of longitudinal welds of casings

6.1.3.3 A single partial penetration weld is permitted in the case of bosses whose outside diameter does not exceed 65 mm. The throat thickness g of the weld shall be at least 1,5 times the thickness e_a of the thinnest part.

If the boss is not considered as a reinforcement of the opening, the throat thickness may be reduced in order to be $\geq 1,0 e_a$.

If double welds are used, each weld shall have a throat thickness g of at least 0,7 times the thickness e_a of the thinnest part.

Allowed types of partial penetration welds of bosses are shown in figure 7.

Bosses may also be attached by projection welding and friction welding.

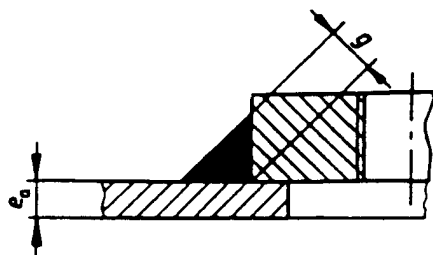


Figure 7a. Welded on boss

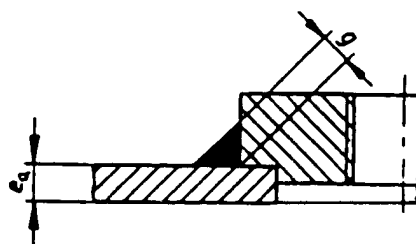


Figure 7b. Inserted boss (single weld)

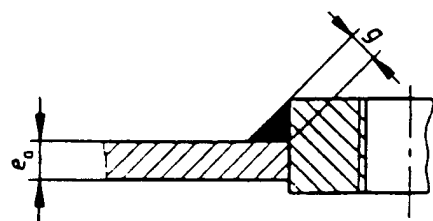


Figure 7c. Inserted boss (single weld)

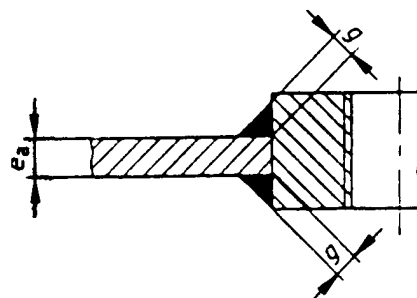


Figure 7d. Inserted boss (double welds)

NOTE. The weld throat of a single partial penetration weld may be reduced in order to be $\geq 1,0 e_a$ if the boss is not considered as a reinforcement of the opening.

Figure 7. Permitted types of partial penetration welding of bosses

6.1.3.4 The maximum distance from the centre of the dished end and the outer edge of any boss shall not be greater than $0,4 D_o$ (see figure 8).

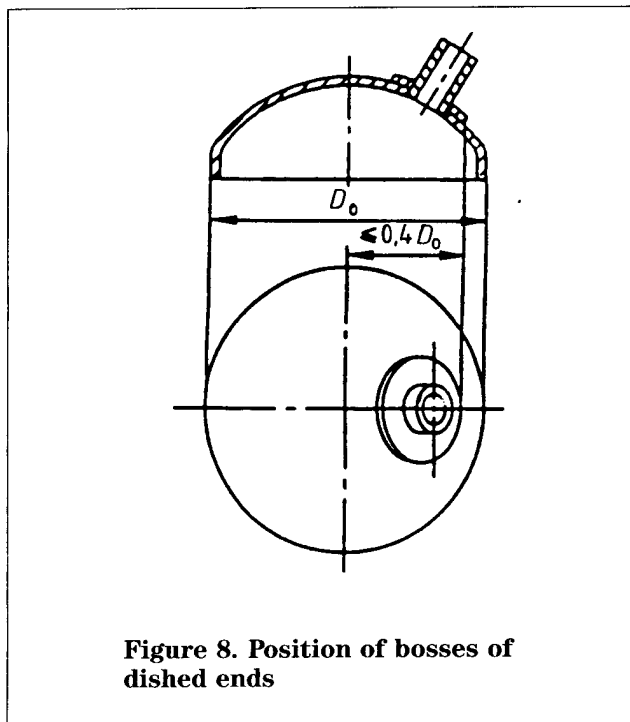


Figure 8. Position of bosses of dished ends

6.1.3.5 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, or the distance between any two welds be less than 4 times the actual shell thickness, and in no case shall the distance to any circumferential seam be less than: $0,50 \sqrt{D_o \cdot e_s}$

NOTE. In the case of using the calculation method with the design also see formula (5) in 5.1.6.3.

6.1.3.6 If the backing strips are used on longitudinal seams they shall be removed.

6.1.3.7 Joggle joints shall not be used for longitudinal seams.

6.1.4 Inspection openings

All vessels shall be provided with openings adequate in size and number to allow internal direct or indirect visual inspection. Two openings of at least 14 mm internal diameter shall be provided.

Openings such as drainage ports, bosses etc., may be used as examination holes, if, by their dimensions and position, a general view of the interior, particularly the seams, is provided.

6.1.5 Drainage openings

The design shall include at least one opening in each compartment, intended to be used for purposes of draining the vessel. Alternatively, the instructions for use shall specify the provision of other means of preventing build-up of condensate. The drainage openings shall be placed in the lowest points of the vessels.

6.1.6 Attachments

The vessel shall be fitted by tightening straps or welded brackets. The tightening straps should be so fitted that they are not near the welds of the ends. All parts welded to the body of the vessel shall be welded to the vessel before testing.

Unpressurized attachments shall suit the curvature of the shell or end and shall be positioned so that the welds are not less than $6 e$ from any existing weld in the vessel, where e is the thickness of the vessel plate at the point of attachment.

6.2 Fabrication

6.2.1 Forming of plates

6.2.1.1 Flat and dished ends shall be formed from a single plate.

6.2.1.2 Dishing and flanging shall be carried out by a mechanical forming procedure, e.g. by pressing, spinning or flow forming; hand beaten forming is not permitted. Care shall be taken when galvanizing vessels made with cold formed non-heat treated ends.

6.2.1.3 Cold formed ends made from aluminium alloys shall not be used without post-forming heat treatment, unless the aluminium alloy manufacturer, the vessel manufacturer, and the inspection body agree that in a special case heat treatment is not necessary, depending on the chosen aluminium alloy grade and the selected forming process.

6.2.2 Tolerances on fit-up

Longitudinal joints of shells (same thickness):
The maximum misalignment at the surface of the plates shall be not more than 0,25 times the thickness.

Circumferential joints between ends and shells (same or different thicknesses):

For figures 5a1, 5a2 and 5a3 the maximum misalignment at the surface of the plates shall not be more than the greatest of the values 0,25 e (e = thickness of the thickest plate) or 0,7 mm (for e = 2,0 mm up to 2,9 mm) or 1,0 mm (for $e \geq 3,0$ mm), respectively.

A misalignment of 0,75 times the thickness of the shell is allowed under certain conditions (see figure 5b1).

6.2.3 Heat treatment for aluminium alloy

The heat treatment after cold forming is to be soft annealing. The holding time and the temperature shall be selected from the relevant material standard (see ISO 6361 : Part 2). Care shall be taken that heating is carried out uniformly.

6.2.4 Welding

There shall be no welding carried out once the pressure test has been successfully completed. If a manual root run on the reverse side is made prior to a second run made by an automatic process then the root weld shall be gouged out to the sound metal to remove any inclusions, i.e. slag, etc.

7 Qualification of welders, welding operators and welding inspectors

The manufacturers shall have at their disposal qualified welders, welding operators and welding inspectors. Testing and approval of welders and welding operators shall be in accordance with EN 287, Parts 1 and 2, as applicable.

The testing and approval shall be carried out by an approved inspection body.

8 Qualification of welding procedures

8.1 Conduct of tests

Manufacturers of welded pressure vessels shall provide the approved inspection body with evidence that they are fully capable of using the welding procedure applied and they shall do this in the form of a welding procedure qualification test adapted to the manufacturing procedure.

The suitability of the welding procedure shall be established in accordance with EN 288 : Part 1 : clause 6.6 by means of welding procedure qualification tests, for steel according to EN 288, Part 3 and for aluminium and aluminium alloys according to EN 288, Part 4.

The testing and approval shall be carried out by an approved inspection body.

8.2 Requirements

8.2.1 Welded joints on steel

The following requirements shall be satisfied when testing the specimen for the welding procedure qualification tests.

1) *Tensile test transverse to weld*

Tensile strength shall not be less than the minimum prescribed in the base metal specification.

2) *Notch bar impact test*

The specimen shall be taken from the middle of the weld metal for materials with thicknesses greater than 5 mm.

The impact energy *KV* must be equal to or greater than 28 J at the minimum working temperature, or at $-10\text{ }^{\circ}\text{C}$, whichever is lower.

Testing is not required on materials with thicknesses up to and including 5 mm.

3) *Bend test*

The specimen shall be bent to 180° over a mandrel of diameter $2a$ where a is the wall-thickness. The specimen shall not reveal open defects in any direction greater than 3 mm.

4) *Hardness test*

The hardness test can be dispensed with.

5) *Non-destructive examination NDE*

The specimen shall meet the requirements of ISO 5817 Level B.

6) *Visual examination*

The requirements of ISO 5817 Level B shall be met.

8.2.2 Welded joints on aluminium

The following requirements shall be satisfied when testing the specimen for the welding procedure qualification tests.

1) *Tensile test transverse to weld*

Tensile strength shall not be less than the minimum prescribed in the base metal specification.

2) *Bend test*

The specimen shall be bent to 180° over a mandrel

- of diameter $2a$ for material group 21 of EN 288 : Part 4;

- of diameter $4a$ for material group 22 of EN 288 : Part 4 where a is the wall thickness.

The specimen shall not reveal open defects in any direction greater than 3 mm.

3) *Non-destructive examination NDE*

The specimen shall meet the requirements of ISO 10042 Level B.

4) *Visual examination*

The requirements of ISO 10042 Level B shall be met.

9 Resistance to corrosion

Vessels shall, bearing in mind their prescribed use, be adequately protected against corrosion.

9.1 Steel vessels

Steel vessels are adequately protected against corrosion if a reliable and durable protection against corrosion is present inside and outside, which shall be tested according to 10.5.

9.2 Aluminium vessels

Neither a protection against corrosion nor a corrosion allowance is required.

10 Tests and certificates

10.1 Tests and certificates prior to production

In accordance with this standard the manufacturer, or his authorized representative, shall at his own choice (see table 5):

- either inform an approved inspection body which, after examining the design and manufacturing schedule referred to in annex C, shall draw up a certificate of adequacy referred to in annex C.2 attesting that the schedule is satisfactory;
- or submit a prototype vessel for the type examination referred to in annex D.

Table 5. Tests and certificates prior to production

$PS \cdot V$ (bar.l)	Tests and certificates	Remarks
> 50 ≤ 1500	Certificate of adequacy or type examination	see annex C.2 or D respectively

10.2 Tests and certificates prior to vessels being placed on the market

Vessels manufactured in accordance with this standard or with the approved prototype shall, prior to their being placed on the market, be subject (see table 6):

- either to the declaration of conformity referred to in annex B;
- or to the verification referred to in annex A.

In addition, where the product of PS and V exceeds 200 bar litres, the approved inspection body shall during manufacture:

- ensure that the manufacturer actually checks series-produced vessels;
- take random samples at the places of manufacture or at the place of storage of vessels for inspection purposes.

Table 6. Tests and certificates prior to vessels being placed on the market

$PS \cdot V$ (bar.l)	Tests and certificates	Remarks
> 50 ≤ 200	Declaration of conformity or verification	see annex B or A respectively
> 200 ≤ 1500	Declaration of conformity and surveillance or verification	see annex B or A respectively

10.3 Tests to be carried out during manufacture

10.3.1 General requirement

All production vessels shall have 100 % visual examination. For acceptance levels of profile defects in butt welds see table 7.

10.3.2 Vessels designed by the calculation method

10.3.2.1 Tests to be carried out during manufacture consist, at the choice of the manufacturer, either of tests of the welds in accordance with **10.3.2.2**, or of burst tests in accordance with **10.3.2.3**.

10.3.2.2 Test of welds to be conducted by the manufacturer's inspector or inspection body are detailed in tables 8 to 11.

It is understood that the amount of testing specified in tables 8 to 11 is that required for each welder or operator without change of welder qualification or welding procedure.

The calculation coefficient K_c depends on the type of welding (automatic or non automatic) and the ratio P/PS .

When a manual root run is completed by automatic welding process the calculation coefficient $K_c = 1$ shall be used. The manual root shall be taken back to sound metal before the automatic welding process is carried out.

Condition of acceptance: If any portion of a weld has been repaired, the whole area of the repair shall be checked by NDT. If any weld fails, all welds shall be NDT-tested on all vessels produced since start of the production period or since the last accepted NDT or since the last accepted DT.

For radiographic levels of defects in butt welds of the steel vessels see table 12. The radiographic examination shall be performed in accordance with ISO 1106 : Part 1 or 3. The density of the film shall correspond to class B with a minimum density of 2 and a maximum density of 4.

Table 7. Acceptance levels of profile defects in butt welds detected by visual examination		
Defect	EN 26520 reference	Acceptance limit
Lack of penetration	402	Not permitted
Undercut	5011 5012	Slight and intermittent permitted provided not sharp and does not exceed 0.5 mm depth
Shrinkage groove	5013	As undercut
Root concavity	515	As undercut
Excessive penetration	504	3 mm maximum
Excess weld metal	502	3 mm maximum
Irregular surfaces	514 509 511 513 517	Reinforcement to be of continuous and regular shape with complete filling of groove
Overlap	506	Not permitted
Linear misalignment (surface)	507	See 6.2.2

Table 8. Amount of testing required for welds made by automatic welding where $P \geq PS$; $K_c = 1.0^{1)2)}$			
Testing by the manufacturer			Verification by the approved inspection body when required
Tests on:	NDT	DT	Verification DT
Each vessel	100 % visual inspection	—	One test plate per batch of longitudinal welds
Each welding machine, each weld procedure and each welder	After any new setting or		Tests: See 10.3.2.2 and annexes A to E
			
	1 film with a minimum length of 200 mm of the longitudinal weld	1 coupon plate as an extension from the first longitudinal weld	
	During manufacture and		In the case of circumferential welds, made with a different procedure, one test coupon per batch, same tests as for longitudinal welds
			
	1 film with a minimum length of 200 mm of the longitudinal weld including at least one T junction for 100 vessels but not less than 1 film per day. In the case of circumferential welds made with different welding procedures, also when only circumferential welds are used, the same tests as for longitudinal welds but at the rate of 1 film per 500 vessels or at least one per week	1 coupon plate as an extension from the first longitudinal weld for 200 vessels manufactured	

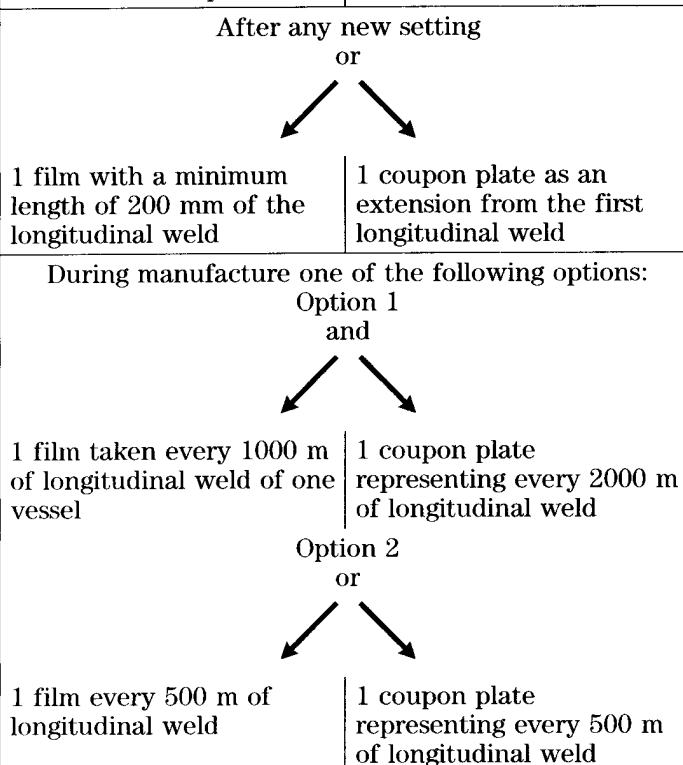
¹⁾It is advisable to take checks on welds that are produced after a halt in production.

²⁾When two hemispherical ends are welded together without a straight flange, the weld is to be tested as a longitudinal weld.

Table 9. Amount of testing required for welds made by non-automatic welding where $P \geq PS$; $K_C = 1,15^{1)2)}$			
Testing by the manufacturer			Verification by the approved inspection body when required
Tests on:	NDT	DT	Verification DT
Each vessel	100 % visual inspection	—	One test plate per batch of longitudinal welds
Each welding machine, each weld procedure and each welder	During manufacture and 		Tests: See 10.3.2.2 and annexes A to E
	1 film taken every 20 m of longitudinal weld covering 100 % of the longitudinal weld of one vessel	1 coupon plate representing every 40 m of longitudinal weld	Circumferential welds - none

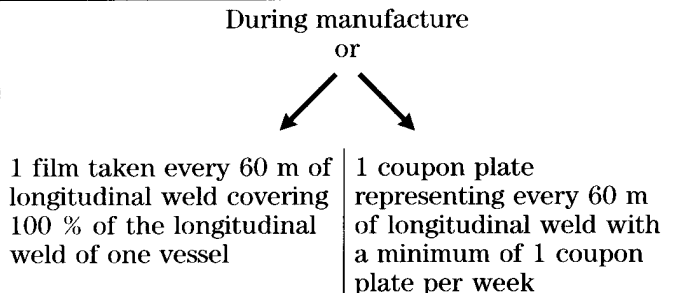
¹⁾It is advisable to take checks on welds that are produced after a halt in production.

²⁾When two hemispherical ends are welded together without a straight flange, the weld is to be tested as a longitudinal weld.

Table 10. Alternative amount of testing required for welds made by automatic welding when $P \geq 1,25 PS$ (only for shells); $K_c = 1,0^{1)2)}$			
Testing by the manufacturer			Verification by the approved inspection body when required
Tests on:	NDT	DT	Verification DT
Each vessel	100 % visual inspection	—	Longitudinal welds - one test coupon per batch.
Each welding machine, each weld procedure and each welder	After any new setting or  <pre> graph TD A[After any new setting or] --> B[1 film with a minimum length of 200 mm of the longitudinal weld] A --> C[1 coupon plate as an extension from the first longitudinal weld] B --> D[During manufacture one of the following options:] C --> D D --> E[Option 1 and] D --> F[Option 2 or] E --> G[1 film taken every 1000 m of longitudinal weld of one vessel] E --> H[1 coupon plate representing every 2000 m of longitudinal weld] F --> I[1 film every 500 m of longitudinal weld] F --> J[1 coupon plate representing every 500 m of longitudinal weld] </pre>		Circumferential welds - if welding procedure is different coupon plates representative of the weld procedure and the welds being produced. (Spot visual examination of welds)

¹⁾It is advisable to take checks on welds that are produced after a halt in production.

²⁾When two hemispherical ends are welded together without a straight flange, the weld is to be tested as a longitudinal weld.

Table 11. Alternative amount of testing required for welds made by non-automatic welding when $P \geq 1,25 PS$ (only for shells); $K_c = 1,15^{1)2)}$			
Testing by the manufacturer			Verification by the approved inspection body when required
Tests on:	NDT	DT	Verification DT
Each vessel	100 % visual inspection	—	Longitudinal welds - one test coupon per batch (with only macro test)
Each welding machine, each weld procedure and each welder	During manufacture or  <pre> graph TD A[During manufacture or] --> B[1 film taken every 60 m of longitudinal weld covering 100 % of the longitudinal weld of one vessel] A --> C[1 coupon plate representing every 60 m of longitudinal weld with a minimum of 1 coupon plate per week] </pre>		Circumferential welds - none.

¹⁾It is advisable to take checks on welds that are produced after a halt in production.

²⁾When two hemispherical ends are welded together without a straight flange, the weld is to be tested as a longitudinal weld.

Table 12. Acceptance levels of defects in butt welds detected by radiographic examination		
Defect	EN 26520 reference	Acceptance limit
Cracks and lamellar tears	100	Not permitted
Porosity (Isolated and grouped)	2011 2013 2017	Individual diameter $e/4$, but not more than 2 mm, for a 2 % projected area maximum ¹⁾
Porosity (Uniformly distributed)	2012	Individual diameter $e/4$ but not more than 2 mm for a 2 % projected area maximum ¹⁾
Porosity (Linear)	2014	Check for lack of fusion before accepting. Otherwise as 2011/2012/2013
Crater pipes	2024	Not permitted
Slag and flux inclusions and elongated cavities (individual and parallel to weld axis)	3011 3021 2015	Individual length maximum $e/3$ Summation of length = e max. in $12e$ length if separation $< 6 \times$ longest defect
Slag and flux inclusions and wormholes (random not parallel to weld axis)	3012 3013 3022 3023 2016	Individual length maximum $e/3$
Tungsten inclusions	3041	As porosity
Copper inclusions	3042	Not permitted
Lack of fusion (side, root or inter-run)	401	Not permitted
¹⁾ Area = maximum length of weld affected $\times$ local width of weld.		

The following production DT shall be carried out during production on test coupon plates (containing welds) by the manufacturer, the test coupon plates being taken from the running production:

- one face bend test (see ISO 5173);
- one root bend test (see ISO 5173);
- one macro test;
- impact test at service temperature only for service temperatures colder than $-10\text{ }^{\circ}\text{C}$ and all thickness above 5 mm and only in the case of steels vessels;
- three Charpy 'V' notch (see ISO 148) on weld material;
- three Charpy 'V' notch (see ISO 148) in the HAZ only on the first test coupon per batch in case of verification, and on two test coupons per batch in case of declaration of conformity.

The following verification tests shall be carried out and performed by the approved inspection body, see last column of tables 8 to 11.

- one transverse reduced tensile test (see ISO 4136);
- one macro test.

For the tensile test, the tensile strength shall not be less than the specified minimum value of the parent metal specifications. For the bend test, the crack length after testing shall not reveal any open defects in any direction greater than 3 mm.

For the macro test, the etched surface of the macro test specimen, viewed macroscopically, must display the image of a well-performed welded joint with sufficient penetration, free from inclusions of any importance or from other defects. For the impact test, see 4.1.1.

If, in the calculation of cylindrical shells, a design pressure, P , of at least 1,25 times the maximum working pressure, PS , is used the amount of testing in tables 10 and 11 suffices.

10.3.2.3 Burst tests (instead of tests of the welds) to be conducted by the manufacturer's inspector are to be performed as prescribed for vessels designed by the experimental method in 10.3.3.2 to 10.3.3.6 except 10.3.3.3.

Additionally a prototype-burst test shall be performed as described in 5.2.3.

10.3.3 Vessels designed by the experimental method

10.3.3.1 Tests to be carried out during manufacture consist of a hydraulic pressure test followed by a burst test as follows.

10.3.3.2 Number of samples: 1 sample per 1000 vessels of the same subfamily and of the same type of filler material with guaranteed chemical properties.

Alternatively, the manufacturer shall select one vessel at the beginning of the day, one at the end of the day, and one at any re-adjustment (including changes of consumables, i.e. a new batch of material) and in the case of non-automatic welding, at least one per welder/operator per day.

10.3.3.3 Amount of the pressure and condition for the permanent deformation: pressure five times the maximum working pressure, deformation not greater than 1 %.

1 % does not apply in the case of aluminium vessels.

10.3.3.4 Amount of the pressure at which rupture occurs: the pressure shall not be less than five times the maximum working pressure.

10.3.3.5 Evaluation after rupture: no parts shall become detached, nor splinters projected when the wall of the pressure vessel ruptures and rupture shall not originate in any weld.

10.3.3.6 Requirements when sample fails with deformation test or with burst test: two other samples are to be tested; if one or both of these samples fail then the whole batch is to be rejected unless the cause of the failure can be determined and all necessary steps can be taken to restore conformity of the product.

10.4 Pressure test

Each vessel shall undergo a pressure test, either hydraulic or pneumatic.

For a hydrostatic test, the P_h shall be the value given by the following equation:

$$P_h = 1,5 PS$$

Subject to agreement of the approved inspection body, a pneumatic test on each vessel may be performed using the value P_h above.

The test pressure shall be held at the specified value long enough to allow all the surfaces and joints to be examined visually. The vessel shall not show any sign of plastic deformation or leakage.

Methods other than visual examination of surfaces and joints are permissible. For checking vessels for leakage when using a pneumatic test, the pressure may be reduced to 1,0 PS with the agreement of the approved inspection body.

Every vessel which fails the pressure test shall be rejected. Repair of such vessels is permissible, but in these cases the pressure test shall be repeated.

If compressed air is used for the pressure test, precautions shall be taken to ensure the safety of personnel in the vicinity.

WARNING NOTE. It should be borne in mind that pneumatic testing is potentially a much more dangerous operation than hydraulic testing; in fact that, irrespective of vessel size, any failure during test is likely to be of a highly explosive nature. It should, therefore, only be undertaken after consultation with the inspection authority and after ensuring that the safety measures taken comply with relevant legislation.

10.5 Test of the protection against corrosion

10.5.1 Test samples

For the purposes of the following described tests, a vessel typical of those to be produced is divided up into four parts (samples), which comprise 50 % of an end and 25 % of the cylindrical shell.

This test is to be carried out once per 10 000 vessels or per six months, whichever comes first, or when changing the coating procedure (type of material, method of application, processing etc.)

A reliable and enduring protection against corrosion according to 9.1 is present if the following requirements are met with the four samples.

10.5.2 Grid test of paints

The apparatus, procedure to be used and evaluation of the grid test see ISO 2409, sections 2, 5 (except for 5.1.1 and 5.1.2) and 6.

The surface of the sample shall accord to the classification 0 or 1 of the ISO 2409, 6.1.

10.5.3 Salt spray test

The test solution, apparatus, method of exposure and procedure to be used shall be in accordance with ISO 7253 : 1984, clauses 3, 4, 7 and 8.

The samples shall be stored in the open air for minimum 72 h until the paint is fully hardened and then be subjected to the salt spray test for a period of 96 h.

After completion of the salt spray test, the samples shall be gently washed or dipped in clean running water not warmer than 38 °C to remove salt deposits from their surface, and then immediately dried. Drying shall be accomplished with a stream of clean, compressed air.

A careful and immediate examination shall be made for the extent of corrosion of the dry test samples. The following acceptance parameters apply:

- a) signs of blistering, and loss of adhesion of coatings are not allowed;
- b) corrosion spots not exceeding 1 mm diameter at a frequency not exceeding 1 % shall be allowed.

Edges or areas damaged in sample preparation, purposely unpainted areas such as threads and areas purposely damaged by the grid test (see 10.5.2) shall be disregarded in the corrosion evaluation.

For the purposes of assessing the frequency of corrosion spots, divide the area of the sample into significant surface areas not less than 5000 mm² each. Divide the area of the significant surface of the sample hypothetically into squares of 5 mm side. This is easily done by placing a graticule made of fully flexible transparent plastics material, on the sample so as to cover the most corroded area.

Count the number N of 5 mm squares in the significant area of the sample and the number m of such squares containing one or more corrosion spots.

When evaluating the sample, squares more than half occupied by the sample shall be counted as full squares; those less than half occupied shall be ignored.

If a spot appears to lie in more than one square it shall be counted only once in the evaluation.

Determine the frequency of the corrosion spots as a percentage, from the expression

$$\text{frequency} = 100 \frac{m}{N}$$

An illustration of a 1 % frequency is shown in figure 9.

11 Marking

The vessel or data plate shall bear at least the following information:

- the maximum working pressure; PS in bar
- the maximum working temperature; $T_{\max}$ in °C
- the minimum working temperature; $T_{\min}$ in °C
- the capacity of the vessel; V in litres
- the name or mark of the manufacturer;
- the type and serial or batch identification (i.e. number, which shall be unique) of the vessel and year of manufacture;
- the number and date of this standard, i.e. EN 286-2 : 1992.

Where a data plate is used, it shall be corrosion-resistant and be so designed that it cannot be reused and shall include a vacant space to enable other information to be provided.

NOTE. Vessels complying with the EEC Directive 87/404 have to bear additionally the CE mark provided for in Article 16 of the Directive.

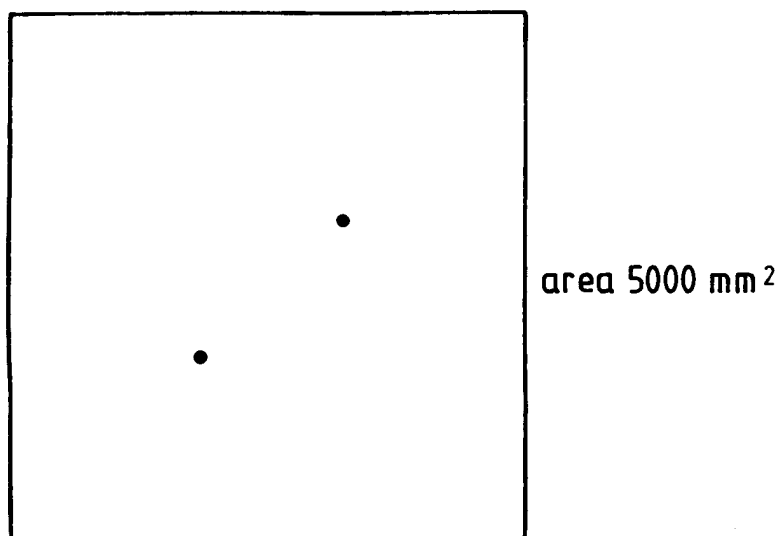


Figure 9. Illustration of a 1 % frequency of corrosion spots

12 Documentation to accompany the vessel

The documentation to be presented to the user or first buyer shall include:

- a) Information that the vessel:
 - is only for use as a storage reservoir on air brake and auxiliary systems on motor vehicles and their trailers, intended to contain only compressed air;
 - complies with EN 286-2.
- b) Particulars given on the vessel including the identification number.
- c) Declaration of conformity if applicable.
- d) Approval number.
- e) Installation requirements referring to:
 - fitting the vessel
 - draining the vessel or means of preventing build up of condensate.
- f) Maintenance requirements.
- g) Information that there shall be no welding operation or heat treatment on pressurized parts of the vessel.

The documentation shall be in the official language or languages of the user or first buyer.

The requirements on the documentation may be simplified when the reservoirs are delivered in batches.

Annex A (normative)

Verification

A.1 General

Verification shall be performed by an inspection body on batches of vessels submitted by their manufacturer or by his authorized representative. Batches shall be accompanied by the type-examination certificate (see annex D) or by the certificate of approval of the design and manufacturing schedule (certificate of adequacy) (see annex C).

When a batch is examined, the inspection body shall ensure that the vessels have been manufactured and checked in accordance with the design and manufacturing schedule and shall perform a hydrostatic test or, subject to the agreement of the inspection body, a pneumatic test on each vessel in the batch at a pressure P_h equal to 1,5 times the vessel's maximum working pressure. Moreover, the inspection body shall carry out tests on test-pieces taken from a representative production test-piece or from a vessel, as the manufacturer chooses, in order to examine weld quality. The tests shall be carried out on longitudinal welds. However, where differing welding techniques are used for longitudinal and circumferential welds, the tests shall be repeated on representative test pieces of circumferential welds.

A.2 Construction verification

The approved inspection body shall perform the following checks and examinations.

A.2.1 Check of the manufacturing record (see annex E.)

A.2.2 External and internal inspection, dimensional check

The inspection body shall check the identification of the vessel, e.g. the data-plate, and shall inspect the vessels visually, externally and internally for defects, especially the seams.

The inspection shall be performed before any permanent coatings or linings are applied.

The inspection body shall check dimensions of shells, ends, nozzles, bolts and other parts, that are of importance to the safety of the vessel, for conformity with the drawings. Distances important for safety (e.g. distance between nozzles) shall be checked if considered necessary.

NOTE. Normally it is adequate if 10 % of vessels are checked and inspected, these to be selected by the approved inspection body.

A.2.3 Destructive testing

Destructive testing as required by the final column of tables 8 to 11 and 10.3 shall be witnessed by the approved inspection body and the results certified.

A.2.4 Non-destructive testing

Non-destructive testing of butt weld seams as required by 10.3.2.2 shall be checked by the approved inspection body. This includes spot checks of films. If the films are not available, spot NDT shall be performed according to tables 8 to 11.

Annex B (normative)

Declaration of conformity — Surveillance

B.1 General

B.1.1 Declaration of conformity

Vessels in accordance with this standard whose product of PS and V exceeds 50 bar litres but which do not exceed 1500 bar litres are, at the choice of the manufacturer, subject to verification, (see annex A) or subject to the declaration of conformity (see 3.1.3).

B.1.2 Surveillance

By the declaration of conformity, the manufacturer becomes subject to surveillance (see 3.1.4) in the case where the product of PS and V exceeds 200 bar litres. The purpose of surveillance is to ensure that the manufacturer duly fulfils the obligations required by this standard.

In the case of vessels manufactured in accordance with an approved specimen, for which a type examination certificate exists, surveillance shall be the responsibility of the approved inspection body which issued this type examination certificate.

In this case of vessels not manufactured in accordance with an approved specimen, surveillance shall be the responsibility of the approved inspection body which issued the certificate of approval of the design and manufacturing schedule (certificate of adequacy), (see C.2).

B.2 Procedures required before commencement of manufacture of vessels subject to a declaration of conformity

B.2.1 Responsibilities of the manufacturer

Before commencing manufacture, the manufacturer shall submit to the approved inspection body which issued the type examination certificate or the certificate of approval of design and manufacturing schedule, certificate of adequacy (see annex C), a document describing the manufacturing processes and all of the predetermined, systematic measures taken to ensure conformity of the vessels with this standard.

This document shall include the design and manufacturing schedule and the documents referred to in **B.2.1.1** to **B.2.1.5**.

The manufacturer shall appoint a management representative who, irrespective of other responsibilities, shall have independent authority and responsibility for ensuring that the requirements of this standard are implemented and maintained.

B.2.1.1 A description of the means of manufacture and inspection appropriate to the construction of the vessels.

B.2.1.2 An inspection document describing the appropriate examinations and tests to be carried out during manufacture together with the procedures thereof and the frequency with which they are to be performed.

B.2.1.3 An undertaking to carry out the examinations and tests in accordance with the inspection document referred to above and to have a hydrostatic test carried out on each vessel in accordance with this standard.

B.2.1.4 The addresses of the places of manufacture and storage and the date on which manufacture is to commence.

B.2.1.5 In addition, when the product of *PS* and *V* exceeds 200 bar litres, the manufacturer shall authorize access to the said places of manufacture or storage by the body responsible for the surveillance, for inspection purposes, and allow that body to select sample vessels and provide it with all necessary information and in particular:

- the design and manufacturing schedule;
- the inspection report;
- the type examination certificate or certificate of adequacy, where appropriate;
- a report on the examinations and tests carried out.

B.2.2 Responsibilities of the approved inspection bodies

The inspection body responsible for the surveillance shall examine the documents referred to in **B.2.1.1** and **B.2.1.3** in order to check their conformity with the requirements of this standard and with:

- a) the conditions stated in the design and manufacturing approval certificates; or
- b) the design and manufacturing record and the conditions stated in the type examination certificate.

Manufacturing cannot commence before the approved inspection body has issued written approval of this document.

B.3 Procedure required during manufacture of vessels subject to a declaration of conformity

B.3.1 Responsibilities of the manufacturer

The manufacturer shall ensure that the inspection and testing is carried out in accordance with the documented procedures to complete the evidence of full conformance of the vessel to this standard. The inspection and test status of vessels shall be identified by using markings, authorized stamps, tags, labels, inspection records, physical location or other suitable means which indicate conformance or non-conformance of vessels with regard to inspection and tests performed. Records shall identify the inspection authority responsible for the release of conforming vessels.

The manufacturer shall maintain control of vessels that do not conform to the requirements of this standard. All non-conforming vessels shall be clearly identified and segregated, to prevent unauthorized use, delivery or mixing with conformity vessels.

Repaired or reworked vessels shall be reinspected in accordance with documented procedures.

B.3.2 Responsibilities of the approved inspection bodies

For vessels whose product of *PS* and *V* exceeds 200 bar litres, the inspection body responsible for surveillance shall, during fabrication:

- a) ensure that the manufacturer manufactures and checks the vessels in accordance with the documents described in **B.2.1**;
- b) take random samples - two at each visit (see also **B.3.4.2**) - at the place of manufacture or storage of vessels for inspection purposes as given in **B.3.3** and **B.3.4**.

B.3.3 Frequency of inspection body operation

Initial operation a) and b) of **B.3.2** shall be carried out within 2 months of the commencement of manufacture and, afterwards, random checks will be made at the normal rate of one visit per year if the rate of production of vessels of the same type is up to 3000/year and twice if production is more than 6000/year. For production quantities between these, the rate of visit will be adjusted accordingly.

B.3.4 Surveillance checks and tests

To ensure that the manufacturer produces and checks vessels subject to the declaration of conformity in accordance with this standard, the inspection body responsible for the surveillance shall perform the following checks, inspections, examinations and tests.

B.3.4.1 Check of the design and manufacturing record, the inspection report and the report on the examinations and tests carried out, in particular with respect to completeness, consistency, validity of certificates, qualification of personnel, etc.

B.3.4.2 The inspection body shall select at random at least two vessels in such a manner that at least one vessel per family is selected per year. On these vessels it shall perform an external and internal inspection, a dimensional check, a non-destructive test of all butt welds (radiographic examination) and a hydrostatic test (see **A.1**).

If the burst test is selected as the production test method in the type approval submission, the approved inspection body shall perform tests in accordance with **10.3.2.3** instead of the non-destructive test.

B.3.4.3 The inspection body shall make available to the manufacturer a copy of the surveillance report that has been prepared.

Annex C (normative)

Design and manufacturing schedules

C.1 Content

The design and manufacturing schedules shall contain the name of the manufacturer and the place of manufacture and shall give the following information:

- a detailed manufacturing drawing of the vessel type;
- the instructions;
- a document describing:
 - a) the materials selected;
 - b) the welding processes used;
 - c) the checks to be carried out;
 - d) any pertinent details as to the vessel design including the design pressure;
 - e) the certificates relating to the suitable qualification of the welding procedures and of the welders or operators;
 - f) if the certificates for the welding procedures, welders or operators are not available, this shall not prevent the approved body from evaluating the other documents. However, they shall be submitted before approval is given or manufacturing commences;
 - g) the inspection slips for the materials used for the manufacture of parts and assemblies contributing to the strength of the pressure vessel or a specimen of these inspection slips;
 - h) a specimen of the proposed report on examination and tests.

C.2 Approval of design and manufacturing schedule (certificate of adequacy)

If vessels are not manufactured on the basis of a type examination certificate, the manufacturer or his authorized representative shall submit to an approved inspection body an application for design approval and enclose three copies of this design and manufacturing schedule (see **C.1**).

Various vessels or vessel families can be included in one design and manufacturing schedule, but all vessel details (including branches, bosses and attachments) of the production envisaged shall be included.

The approved inspection body shall examine these documents in order to check the conformity of the design, of the required tests, and of the qualifications with the requirements of this standard. If they are in agreement with the requirements of this standard the approved inspection body shall issue a certificate of adequacy which shall be forwarded to the applicant.

Annex D (normative)

Type examination

Type examination is the procedure by which an approved inspection body ascertains and certifies that a prototype vessel satisfies the provisions of this Part of this standard. The manufacturer or his authorized representative shall submit to an approved inspection body an application for type examination.

The application shall include three copies of the design and manufacturing schedule (see annex C) and a prototype vessel which is representative of the production envisaged.

If the application is lodged for various vessels, a prototype vessel is required for each vessel type.

Various vessels or vessel types can be included in one design and manufacturing schedule, but all vessel details (including branches, bosses and attachments) of the production envisaged shall be included.

The approved inspection body shall examine the documents in order to check the conformity of design, qualifications and the proposal tests with the requirements of this standard.

The approved inspection body shall also verify that the vessel has been manufactured in conformity with the design and manufacturing schedule and is representative of the type, and perform appropriate examinations and tests (including 100 % NDT of main seams and a hydrostatic test) to check that the vessel complies with the requirements of this standard.

If the design and manufacturing schedule and the prototype(s) comply with the provisions of this part of this standard, the approved inspection body shall draw up a type-examination certificate (per vessel type) which shall be forwarded to the applicant. The certificate shall state the conclusions of the examination, indicate any conditions to which its issue may be subject and be accompanied by the descriptions and drawings necessary for identification of the approved prototype.

NOTE. Type examination according to the procedures of this annex is also applicable for vessels which do not comply completely with all the requirements of clauses 1 to 10 of this standard. In this case the general safety requirements laid down in annex G have to be taken into account.

Annex E (normative)

Content of the manufacturing record

The manufacturing record for vessels shall contain (at least) the following information.

E.1 General information

- a) the name or mark of the manufacturer;
- b) the place of manufacture;
- c) the qualification certificates for the welding procedures and the welders or welding operators;
- d) the reports of the examinations and tests performed, or descriptions of the proposed verifications.

E.2 Specific information

- a) the identification codes of the vessels specific to the manufacturer (example No.... to....);
- b) the type approval number or the certificate of adequacy;
- c) the diameter of the vessels;
- d) the volume of the vessels;
- e) the maximum working pressure;
- f) the maximum working temperature;
- g) the minimum working temperature, if below $-10\text{ }^{\circ}\text{C}$;
- h) the test pressure;
- j) the drawing number(s);
- k) the date of manufacture;
- l) the size of the batch;
- m) the inspection documents for the materials used in the manufacture of main pressurized parts;

for parts, other than shells and ends with diameters not exceeding 250 mm, a declaration by the manufacturer stating that only materials complying with the required documents have been used, is acceptable;

- n) the date of the hydrostatic test signed by the manufacturer's inspector and, in the case of verification, by the inspector from the approved inspection body.

E.3 Records

Records shall contain information required by E.1 and E.2 in such a way as to allow traceability. For the purposes of traceability, records shall be maintained of the vessel number/customer. Records shall be kept for at least 10 years.

Annex F (normative)

KV requirements on plate and strip materials (steel)

The compliance to the essential safety requirements quoted in annex G regarding the average failure energy KV at the minimum working temperature may be checked by the use of the graph shown below.

From the value of the temperature T^* at which the value $KV \geq 28\text{ J}$ is guaranteed for the longitudinal test piece, it is possible to assume the minimum working temperature at which the average failure energy is not less than 28 J for a given thickness (see following examples) to meet the essential requirements of annex G.

A value of KV equal to 27 J for a transverse test piece is considered as equivalent to a value of KV equal to 28 J for a longitudinal test piece.

Example 1: material PH 235 (EN 10028)

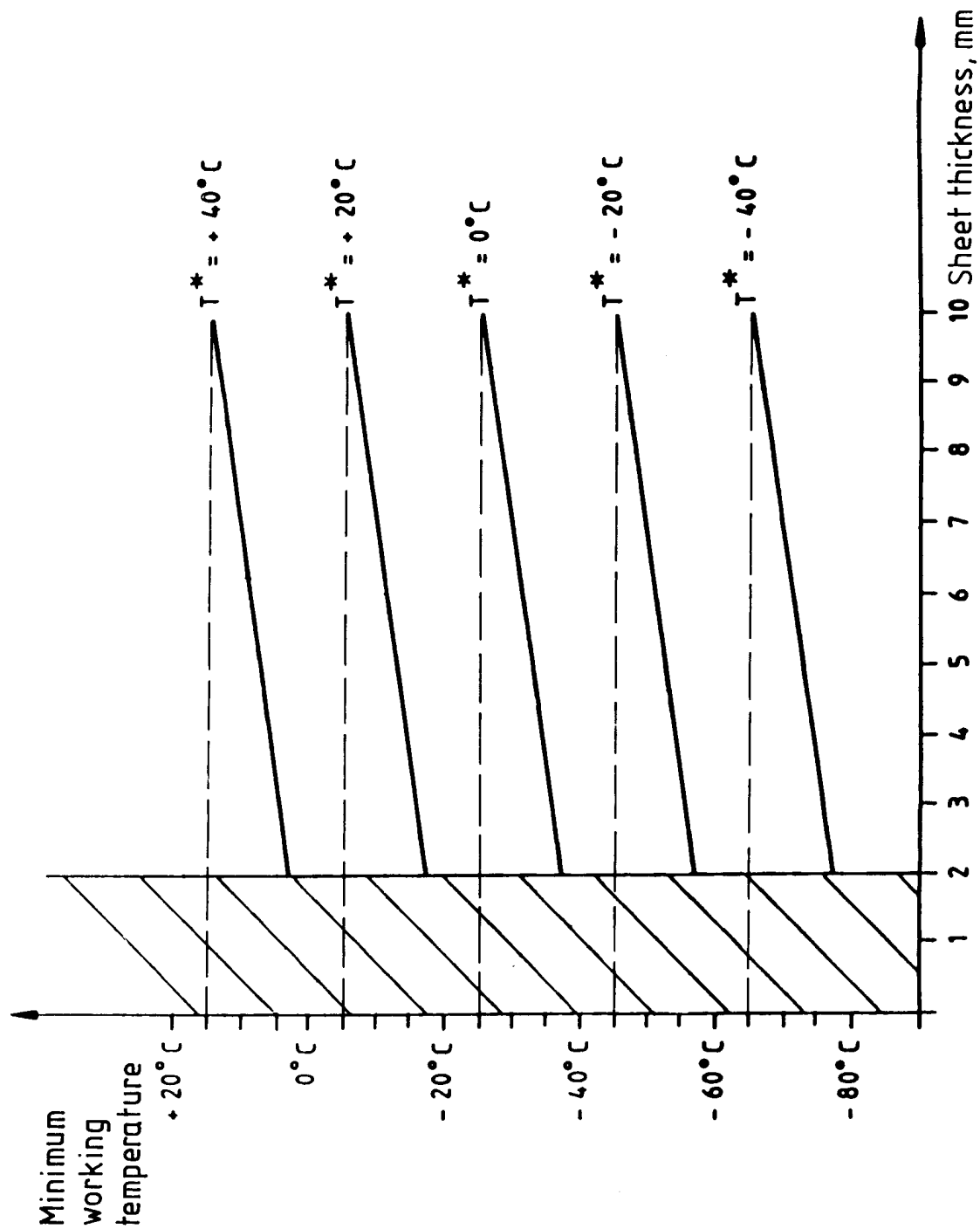
$$T^* = 0\text{ }^{\circ}\text{C}$$

$$\text{if } e = 6,5\text{ mm } T_{\min.} = -30\text{ }^{\circ}\text{C}$$

Example 2: material Fe 360 D₁ (EN 10025)

$$T^* = -20\text{ }^{\circ}\text{C}$$

$$\text{if } e = 4\text{ mm } T_{\min.} = -55\text{ }^{\circ}\text{C}$$



NOTE. The temperature T^* at which the value $KV \geq 28$ J for the longitudinal test piece shall be guaranteed by the material producer.

Figure F.1. Temperatures/thickness relationship

Annex G (informative)

Essential safety requirements given in Directive 87/404/EEC

G.1 General

This annex gives general requirements for any welded simple pressure vessel manufactured in series and having:

- 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;
- two outwardly dished ends revolving around the same axis.

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:

- subjected to an internal gauge pressure greater than 0,5 bar;
- the parts and assemblies contributing to the strength of the vessel under pressure shall be made either of non-alloy quality steel or of non-alloy aluminium or non-age hardening aluminium alloys;
- maximum working pressure 30 bar, and the product of that pressure and the capacity of the vessel ($PS.V$) is greater than 50 bar litres and not exceeding 10 000 bar litres;
- minimum working temperature $-50\text{ }^{\circ}\text{C}$ and maximum working temperature not higher than $300\text{ }^{\circ}\text{C}$ for steel vessels and $100\text{ }^{\circ}\text{C}$ 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, or to fire extinguishers.

G.2 Materials

G.2.1 Pressurized parts

The material referred to in G.1 used for manufacturing the pressurized parts shall be:

- capable of being welded by appropriate welding processes;
- ductile and tough, so that rupture at minimum working temperature does not give rise to either fragmentation or brittle type fracture;
- not adversely affected by ageing.

They shall also comply with the special provisions in G.2.1.1 to G.2.1.2 and shall be accompanied by an inspection slip drawn up by the producer of the material.

The inspection slip is the document by which the producer certifies that the products delivered meet the requirements of the order and in which he sets out the results of the routine in-plant inspection test, in particular chemical composition and mechanical characteristics, performed on products made by the same production process as the supply, but not necessarily on products delivered.

G.2.1.1 Steel vessels

Non-alloy quality steels shall meet the following requirements:

- be non-effervescent steels and be supplied after normalization treatment, or in an equivalent state;
- the carbon content per product shall be less than 0,25 %, and that of sulfur and phosphorus shall each be less than 0,05 %;
- they shall have the following mechanical properties per product:

- the maximum tensile strength, $R_{m\text{ max.}}$, shall be less than 580 N/mm^2 ;

- the elongation after rupture shall be:

1) on test pieces taken parallel to the direction of rolling:

thickness $\geq 3\text{ mm}$: $A \geq 22\%$

thickness $< 3\text{ mm}$: $A_{80\text{ mm}} \geq 17\%$

2) on test pieces taken perpendicular to the direction of rolling:

thickness $\geq 3\text{ mm}$: $A \geq 20\%$

thickness $< 3\text{ mm}$: $A_{80\text{ mm}} \geq 15\%$

- the mean impact strength, KCV , determined on 3 longitudinal test pieces at minimum working temperature, shall be 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 .

In the case of steels used in the manufacture of vessels whose minimum working temperature is lower than $-10\text{ }^{\circ}\text{C}$ and whose wall thickness exceeds 5 mm, this property shall be checked.

G.2.1.2 Aluminium vessels

Non-alloy aluminium shall have an aluminium content of at least 99,5 % and aluminium/magnesium alloy shall display adequate resistance to intercrystalline corrosion. The materials shall be supplied in an annealed state.

They shall have the following mechanical properties per product:

- the maximum tensile strength, $R_{\max.}$, shall be not more than 350 N/mm²;
- the elongation after rupture shall be:
 - $A \geq 16 \%$ if the test piece is taken parallel to the direction of rolling;
 - $A \geq 14 \%$ if the test piece is taken perpendicular to the direction of rolling.

G.2.2 Welding materials

The welding materials used to manufacture the welds on or of the vessel shall be appropriate to and compatible with the materials to be welded.

G.2.3 Accessories contributing towards the strength of the vessel

These accessories (e.g. bolts and nuts etc.) shall be made of a material specified in G.2.1 or of other kinds of steel, aluminium or an appropriate aluminium alloy compatible with materials used for the manufacture of pressurized parts.

The latter materials shall, at minimum working temperature, have appropriate rupture elongation and toughness.

G.2.4 Non-pressurized parts

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

G.3 Vessel design

G.3.1 General

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

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

However, should a minimum working temperature exceeding $-10\text{ }^{\circ}\text{C}$ be selected, the qualities required of the material shall be satisfied at $-10\text{ }^{\circ}\text{C}$.

The manufacturer shall also take account of the following provisions:

- it shall be possible to inspect the inside of vessels;
- it shall be possible to drain the vessels;
- the mechanical qualities shall be maintained throughout the period of use of the vessel for the intended purpose;
- the vessels shall, bearing in mind their prescribed use, be adequately protected against corrosion,

and the fact that under the conditions of use envisaged:

- the vessels will not be subjected to stresses likely to impair their safety in use;
- internal pressure will not permanently exceed the maximum working pressure PS ; however, it may momentarily do so by up to 10 %.

Circumferential and longitudinal seams shall be made using full penetration welds or welds of equivalent effectiveness. Convex ends other than hemispherical ones shall have a cylindrical edge.

G.3.2 Wall thickness

G.3.2.1 General

If the product $PS \cdot V$ is not more than 3 000 bar litres, the manufacturer shall select one of the methods described in G.3.2.2 and G.3.2.3 for determining vessel wall thickness. If the product of PS and V is more than 3 000 bar litres, or if the maximum working temperature exceeds $100\text{ }^{\circ}\text{C}$, such thickness shall be determined by the method described in G.3.2.2.

The actual wall thickness of the cylindrical section and ends shall, however, be not less than 2 mm in the case of steel vessels and not less than 3 mm in the case of aluminium or aluminium alloy vessels.

G.3.2.2 Calculation method

The minimum thickness of pressurized parts shall be calculated having regard to the intensity of the stresses and to the following provisions:

- the calculation pressure to be taken into account shall not be less than the maximum working pressure selected;
- the permissible general membrane stress shall not exceed the lower of the values $0,6 R_{eT}$ or $0,3 R_m$. The manufacturer shall use the R_{eT} and R_m minimum values guaranteed by the material manufacturer in order to determine the permissible stress.

However, where the cylindrical portion of the vessel has one or more longitudinal welds made using a non-automatic welding process, the thickness calculated as above shall be multiplied by the coefficient 1,15.

G.3.2.3 *Experimental method*

Wall thickness shall be so determined as to enable the vessels to resist at ambient temperature a pressure equal to at least five times the maximum working pressure, with a permanent circumferential deformation factor of no more than 1 %.

G.4 Manufacturing processes

G.4.1 *General*

Vessels shall be constructed and subjected to production checks in accordance with the design and manufacturing schedule referred to in annex C.

G.4.2 *Preparation of the component parts*

Preparation of the component parts (e.g. forming and chamfering) shall not give rise to surface defects or cracks or changes in the mechanical characteristics likely to be detrimental to the safety of the vessels.

G.4.3 *Welds on pressurized parts*

The characteristics of welds and adjacent zones must be similar to those of the welded materials and shall be free of any surface or internal defects detrimental to the safety of the vessels.

Welds must be performed by qualified welders or operators possessing the appropriate level of competence, in accordance with approved welding processes. Such approval and qualification tests must be carried out by inspection bodies.

The manufacturer must also, during manufacture, ensure consistent weld quality by conducting appropriate tests using adequate procedures. These tests must be the subject of a report.

G.5 Placing in service of the vessel

Vessels shall be accompanied by the instructions drawn up by the manufacturer as referred to in clause 12 of this standard.

National annex NA (informative)

Committees responsible

The United Kingdom participation in the preparation of this European Standard was entrusted by the Pressure Vessel Standards Policy Committee (PVE/-) to Technical Committee PVE/17, upon which the following bodies were represented:

Associated Offices Technical Committee
BEAMA Ltd.
British Compressed Air Society
British Railways Board
British Steel Industry
Department of Trade and Industry
(Mechanical Engineering and Manufacturing Technology Division (Mmt))
Electricity Industry in United Kingdom
Health and Safety Executive
Independent Engineering Insurers Committee
Process Plant Association
Railway Industry Association of Great Britain
Society of Motor Manufacturers and Traders Limited
Transmission and Distribution Association (BEAMA Limited)

National annex NB (informative)

Cross-references

Publication referred to	Corresponding British Standard
	BS EN 287 Approval testing of welders for fusion welding
EN 287-1 : 1992	Part 1 : 1992 Steels
EN 287-2 : 1992	Part 2 : 1992 Aluminium and aluminium alloys
	BS EN 288 Specification and approval of welding procedures for metallic materials
EN 288-1 : 1992	Part 1 : 1992 General rules for fusion welding
EN 288-2 : 1992	Part 2 : 1992 Welding procedure specification for arc welding
EN 288-3 : 1992	Part 3 : 1992 Welding procedure tests for the arc welding of steels
EN 288-4 : 1992	Part 4 : 1992 Welding procedure tests for arc welding of aluminium and its alloys
	BS EN 10002 Tensile testing of metallic materials
EN 10002-1 : 1990	Part 1 : 1990 Method of test at ambient temperatures
EN 10025 : 1990	BS EN 10025 : 1990 Specification for hot rolled products of non-alloy structural steels and their technical delivery conditions
	BS EN 10028 Specification for flat products made of steels for pressure purposes
EN 10028-1 : 1992	Part 1 : 1992 General requirements
EN 10028-2 : 1992	Part 2 : 1992 Non-alloy and alloy steels with specified elevated temperature properties
EN 10207 : 1991	BS EN 10207 : 1992 Steels for simple pressure vessels — Technical delivery requirements for plates, strips and bars
EN 26520 : 1991	BS EN 26520 : 1992 Classification of imperfections in metallic fusion welds, with explanations
	BS 3900 Methods of test for paints
	Group E. Mechanical tests on paint films
ISO 2409 : 1972	Part E6 : 1974 Cross-cut test
	Group F. Durability tests on paint films
ISO 7253 : 1984	Part F12 : 1985 Determination of resistance to neutral salt spray

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