

Specification for

Simple unfired pressure vessels designed to contain air or nitrogen —

Part 1: Design, manufacture and testing

This European Standard EN 286-1:1991 has the status of a
British Standard

Cooperating organizations

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This British Standard was published under the authority of the Standards Board and comes into effect on 30 August 1991

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The following BSI references relate to the work on this standard:
Committee reference PVE/17
Draft for comment 89/75201 DC

ISBN 0 580 19786 7

Amendments issued since publication

Amd. No.	Date	Comments
7162	June 1992	
8790	November 1995	Indicated by a sideline in the margin

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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 “*Simple unfired pressure vessels designed to contain air or nitrogen — Part 1: Design manufacture and testing*”, published by the European Committee for Standardization (CEN). EN 286-1 was produced as the result of international discussions in which the United Kingdom took an active part.

CEN have notified BSI that a corrigendum is in preparation correcting minor errors in the text, in particular attention is drawn to clause **6.4.8**, line 4, where the word “smaller” should be read as “greater”.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, the EN title page, pages 2 to 68, an inside back cover and a back cover.

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

UDC 621.642.02-98

Key words: Pressure vessels, gas pressure vessels, tank containers, air, nitrogen, classifications, materials specifications, design, welded joints computation, manufacturing, inspection, tests, welded defects

English version

Simple unfired pressure vessels designed to contain air or nitrogen — Part 1: Design, manufacture and testing

Réipients à pression simples, non soumis à la flamme, destinés à contenir de l'air ou de l'azote — Partie 1: Conception, fabrication et essais

Einfache unbefeuerte Druckbehälter für Luft oder Stickstoff — Teil 1: Konstruktion, Herstellung und Prüfung

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CEN

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

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

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Brief history

This draft European Standard was drawn up by CEN/TC 54 “*Simple pressure vessels*”, of which the secretariat is held by the United Kingdom.

This standard is one of a series of four. The other standards cover:

- a) Part 2: Pressure vessels for air braking and auxiliary systems for motor-vehicles and their trailers;
- b) Part 3: Steel pressure vessels designed to contain compressed air for rail rolling stock; and
- c) Part 4: Aluminium pressure vessels designed to contain compressed air for railway rolling stock.

According to the common CEN/CENELEC rules, the following countries are bound to implement this standard: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom

Foreword

This Part of this European Standard has been prepared to be used in conjunction with the informative Annex G of this European Standard.

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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 with a single compartment, here-in-after referred to as vessels, the essential safety requirements of which are given in Annex G and which:

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

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

- a) subjected to an internal gauge pressure greater than 0,5 bar;
- b) the parts and assemblies contributing to the strength of the vessel under pressure to be made either of non-alloy quality steel or of non-alloy aluminium or non-age hardening aluminium alloys;
- 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 10 000 bar litres;
- d) minimum working temperature – 50 °C and maximum working temperature not higher than 300 °C for steel and 100 °C for aluminium or aluminium alloy vessels.

It does not apply to vessels specifically designed for nuclear use, to vessels specifically intended for installation in or the propulsion of ships and aircraft, or to fire extinguishers.

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

1.4 No rules of construction can be written in sufficient detail to ensure good workmanship and construction. Each manufacturer is responsible for taking every necessary step to make sure that the quality of workmanship and construction is such as to ensure compliance with good engineering practice. Aspects of Quality Assurance are dealt with in various clauses and annexes of this Standard, for example in clause 10, Testing, and Annex A, Verification, B, Declaration of conformity — Surveillance, C, Design and manufacturing schedule, D, Type examination, E, Content of manufacturing schedule, and these annexes form Part of this Standard. These are minimum requirements having taken into account EN 29002 and EN 29003 but it is not implied that a Quality Assurance System according to EN 29002 and EN 29003 is necessary.

1.5 For the purposes of calculations required to be made in accordance with this standard, pressures are in bars, dimensions are in millimetres, stresses are in N/mm^2 and temperatures are in °C.

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

2 References

EN 286-2, *Simple unfired pressure vessels designed to contain air or nitrogen — Part 2: Pressure vessels designed to contain compressed air for air braking and auxiliary systems for motor vehicles and their trailers.*

EN 286-3, *Simple unfired pressure vessels designed to contain air or nitrogen — Part 3: Steel pressure vessels designed to contain compressed air for rail rolling stock.*

EN 286-4, *Simple unfired pressure vessels designed to contain air or nitrogen — Part 4: Aluminium pressure vessels designed to contain compressed air for rail rolling stock.*

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

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

- EN 288-2, *Specification and approval of welding procedures for fusion welding of metallic materials — Part 2: Welding procedure specification for arc welding of metallic materials.*
- EN 288-3, *Specification and approval of welding procedures for fusion welding of metallic materials — Part 3: Welding procedure tests for arc welding of steels.*
- EN 288-4, *Specification and approval of welding procedures for fusion welding of 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.*
- EN 10028, *Steel plate, sheet and strip with elevated temperature properties.*
- EN 10207-1, *Steels for simple pressure vessels — Part 1: Technical delivery requirements for plates, strips and bars.*
- EN 10204, *General technical delivery requirements steel and iron and steel products. Certification and inspection documents.*
- EN 29002, *Quality systems — model for quality assurance in production and installation.*
- EN 29003, *Quality systems — model for quality assurance in final inspection and test.*
- EN, *(Welding consumables — In course of preparation).*
- ISO 7-1, *Pipe threads where pressure-tight joints are made on the threads — Part 1: Designation, dimensions and tolerances.*
- ISO 209-2, *Wrought aluminium and its alloys — Chemical compositions and forms of products — Part 2: Forms of products.*
- ISO 228-1, *Pipe threads where pressure tight joints are not made on the threads — Part 1: Designation, dimensions and tolerances.*
- ISO 898-1, *Mechanical properties of fasteners — Part 1: Bolts, screws and studs.*
- ISO 898-2, *Mechanical properties of fasteners — Part 2: Nuts with specified proof load values.*
- 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 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: Welded tubes.*
- ISO 6361-2, *Wrought aluminium and aluminium alloy sheets, strips 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 6520, *Classification of imperfections in metallic fusion welds, with explanations.*
- ISO 7005-1, *Metallic flanges — Part 1: Steel flanges (In course of preparation).*

3 Definitions and notations

3.1 Definitions

For the purposes of this Standard the following definitions apply.

3.1.1

automatic welding

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

3.1.2

non-automatic welding

all types of welding other than that defined in 3.1.1 (To be amended on advice from ISO/TC 121.)

3.1.3

batch

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

3.1.4

type of vessel

vessels are of the same type if they:

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

3.1.5

declaration of conformity

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

3.1.6

verification

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

3.1.7

surveillance

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

3.1.8

type examination

the procedure by which an approved inspection body ascertains and certifies that a specimen of a vessel satisfies the provision of this Standard (See Annex D.)

3.1.9

design and manufacturing schedule

to be issued by the manufacturer. The purpose of the design and manufacturing schedule is to describe the construction, material and fabrication including the certificates (see Annex C)

3.1.10

manufacturing record

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

3.1.11 design temperature

3.1.11.1

maximum design temperature

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

3.1.11.2

minimum design temperature

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

3.1.12**minimum working temperature, $T_{\min}$**

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

3.1.13**maximum working temperature, $T_{\max}$**

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

3.1.14**shell design pressure, P**

the pressure used in design calculations, and which is never less than the maximum working pressure PS . (Table 11 and Table 12 require the design pressure to be $1,25 \times$ maximum working pressure, and it is this value which is used in design calculations.)

3.1.15**maximum working pressure, PS**

the maximum gauge pressure which may be exerted under normal conditions of use. (The set pressure of the pressure relief device is never greater than PS , but after pressure relief has commenced the pressure may exceed PS by 10 % maximum.)

3.1.16**manufacturer's inspector**

a person(s) employed by the manufacturer, but sufficiently independent from the production personnel, qualified and responsible for inspections, examinations and tests to be carried out by him on vessels
qualification means technical competency on the different inspections, examinations and tests to be carried out under the manufacture's responsibility, as well as necessary experience. It is the responsibility of the manufacturer to ascertain that the inspector is competent

3.1.17**report on the examinations and tests**

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

3.1.18**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 annex G.2.1.)

this corresponds to "works certificate" defined in EN 10204: clause 2.2

3.1.19**series manufacture**

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

3.2 Notations

For the purposes of 6.4.5.2, 6.4.5.3, 6.4.6, 6.4.7, 6.4.8 and 6.5 the following symbols apply:

A	outside or inside diameter of the flange, in mm (see Figure 14 or Figure 20)
A_b	actual cross sectional area of bolts, in mm^2
A_c	required reinforcement area, in mm^2
A_{fb}	cross sectional compensation area of branch, in mm^2
A_f	cross sectional compensation area, in mm^2
A_{fm}	cross sectional compensation area of main body, in mm^2
A_{fp}	cross sectional compensation area of compensation plate, in mm^2
A_m	total required cross sectional area of bolts taken as the greater of A_{m1} and A_{m2} , in mm^2

A_{m1}	total cross sectional area of bolts at least diameter under stress required of operating = W_{m1}/S_b , in mm^2
A_{m2}	total cross sectional area of bolts at least diameter under stress required for gasket seating = W_{m2}/S_a , in mm^2
A_p	pressure loading area, in mm^2
A_R	available reinforced area, in mm^2
B	inside or outside diameter of the flange, in mm (see Figure 14 and Figure 20)
b	effective gasket seating width for narrow gaskets, in mm = $\frac{G_o - G_I}{4}$
b'	effective gasket seating width for full face flanges, in mm = $4\sqrt{G_o - C}$
$2b''$	the effective gasket contact width under pressure for full face gaskets = 5 mm
$b_{\min}$	minimum effective gasket seating width, in mm
$b_{\max}$	maximum effective gasket seating width, in mm
C	bolt circle diameter, in mm
c	absolute value of negative tolerance, in mm
D	design diameter of flat ends and covers (see 6.4.4.1), in mm
D_i	inside diameter of shell, in mm
D_o	outside diameter of shell/dished end, in mm
d_h	diameter of bolt holes, in mm
d	diameter of openings (see Figure 23), in mm
d_{ib}	internal diameter of branch, in mm
d_{is}	internal diameter of shell, in mm
e	nominal thickness of plate, in mm
e_{act}	actual wall thickness of shell before pressure test, in mm
e_c	calculated thickness, in mm
e_{fn}	nominal thickness of narrow flange (less corrosion), in mm
e_m	nominal wall thickness of main body, in mm
e_n	nominal wall thickness of shell, in mm
e_p	thickness of compensation plate, in mm
e_{rm}	fictitious thickness, e_m minus allowances, in mm
F_i	= F_L or F_I — factors for loose type flanges shown in Figure 3 a), Figure 3 e), Figure 3 f) and Figure 3 g) for which Figure 17 and Figure 18 apply or for integral type flanges shown in Figure 3 b), Figure 3 h) and Figure 3 i) for which Figure 15, Figure 16 and Figure 19 apply
f	nominal design stress, in N/mm^2 , at design temperature
f_I	hub stress correction factor (see Figure 19)
G	mean diameter of the gasket contact face for narrow gaskets, in mm
G'	diameter at location of gasket load reaction H'_p for full face gaskets, in mm
G_I	inside diameter of the gasket or contact surface whichever is the greater, in mm
G_O	outside diameter of the gasket or contact surface or outside diameter of flange whichever is the less, in mm
g_1	thickness of hub at back of flange, in mm (= 0 for loose type flanges [Figure 3 e), Figure 3 f) and Figure 3 g])
g_0	thickness of hub at small end, in mm
H_D	hydrostatic end force on area inside flange, in N

H_G	gasket load = $2b\pi Gm \frac{PS}{10}$ for operating conditions = W for bolting up conditions
H_T, H'_T	hydrostatic end force due to pressure on flange face, in N
H_P	compression load on gasket in full face flanges, in N
H_R	balancing reaction force in full face flanges acting outside bolt circle in opposition to moments due to H_D , H'_P and H'_T in N
h	hub length, in mm or outside height of head, in mm (sub-clause 6.4.7.2)
h_D	radial distance from bolt circle to circle on which H_D acts, in mm
h_G	radial distance from gasket load reaction to bolt circle, in mm
h_T	radial distance from bolt circle to circle on which H_T acts, in mm
h'_T	radial distance from bolt circle to circle on which H'_T acts, in mm
h'_P	radial distance from bolt circle to circle on which H'_P acts, in mm
h_o	$\sqrt{Bg_o}$, in mm
K	ratio of the outside to inside diameter of the flange
K_c	calculation coefficient, which depends on the welding process (see clause 10)
I_b	effective length of branch, in mm
I_{bi}	effective length for inside part of set-through branch, in mm
I_m	effective length of main body, in mm
I_P	width of compensation plate, in mm
M_{atm}	total moment acting upon flange for gasket seating, in N mm
M_{op}	total moment acting upon the flange for operating conditions, in N mm
m	gasket factor obtained from Table 5
n	number of bolts
P	design pressure, in bar (never less than PS)
PS	maximum working pressure, in bar
R_e	guaranteed minimum yield strength, in N/mm ²
$R_{e act}$	actual yield strength, in N/mm ²
R_m	guaranteed minimum tensile strength, in N/mm ²
$R_{m act}$	actual tensile strength, in N/mm ²
r_{ih}	inside radius of curvature of spherical portion of head, in mm
r_{im}	inside radius of curvature of main body, in mm
S_a	bolt nominal design stress at atmospheric temperature from Table 4, in N/mm ²
S_b	bolt nominal design stress at design temperature from Table 4, in N/mm ²
S_{FA}	nominal design stress of flange material at atmospheric temperature, in N/mm ²
S_{FO}	nominal design stress of flange material at design temperature, in N/mm ²
T	a factor involving K , $T = \frac{K^2(1 + 8,55246 \log_{10} K) - 1}{(1,0472 + 1,9448 K^2)(K - 1)}$
U	a factor involving K , $U = \frac{K^2(1 + 8,55246 \log_{10} K) - 1}{1,36136 (K^2 - 1)(K - 1)}$
u_i	circumferential length at cross section i after pressure test, in mm
U_{io}	circumferential length at cross section i before pressure test, in mm
V_i	= V_I or V_L factor for flanges in Figure 3 e), Figure 3 f) and Figure 3 g) for which Figure 18 applies, and Figure 3 h) and Figure 3 i) for which Figure 16 applies
W	flange design bolt load, in N

W_{m1} minimum required bolt load for operating conditions, in N

W_{m2} minimum required bolt load for gasket seating, in N

$$Y = \frac{1}{K-1} \left(0,66845 + 5,71690 \frac{K^2 \log_{10} K}{K^2 - 1} \right)$$

y gasket seating stress from Table 5, in N/mm²

$$Z = \frac{K^2 + 1}{K^2 - 1}$$

$$\lambda \quad \text{a factor} = \frac{e_{fn} \cdot \frac{F_i}{h_0} + 1}{T} + \frac{V_i}{U} \cdot \frac{e_{fn}^3}{h_0 \cdot g_0^2}$$

subscript i $\left\{ \begin{array}{l} = I \text{ for integral flanges in Figure 3 b), Figure 3 h), Figure 3 i)} \\ = L \text{ for loose flanges in Figure 3 a), Figure 3 e), Figure 3 f), Figure 3 g)} \end{array} \right.$

4 Classifications and certification procedures

This standard specifies three classes of vessels and the certification procedure applicable to them as shown in Table 1.

Table 1 — Classification of vessels

Classification	PS.V	Certification procedure		Remarks
Class 1	Above 3 000 bar.l up to and including 10 000 bar litres	Type examination ^a (see Annex D) or Design and manufacturing schedules approval ^a (see C.2)	Verification	See Annex A
Class 2	Above 200 bar.l up to and including 3 000 bar.l		Verification ^a or Declaration of conformity ^a and surveillance (and special documents)	See Annex A See Annex B
Class 3	Above 50 bar.l up to and including 200 bar.l		Verification ^a or Declaration of conformity ^a (and special documents)	See Annex A See Annex B
NOTE For those vessels subject to verification the mark of the inspection body shall be affixed.				
^a At the choice of the manufacturer.				

5 Materials

5.1 Main pressurized parts (see also 5.2)

5.1.1 Steel vessels

The following materials shall be used.

a) Plate, strip and bar according to EN 10207-1, grades SPH 235, SPH 265, and SPHL 275 and EN 10028, grades PH 235 and PH 265 shall be used. (Standards in course of preparation.)

Until materials according to the above standards are available, Annex F materials may be used. When suitable EN 10207 materials are available Annex F will be withdrawn.

b) Tubes according to ISO 2604-II, Grades TS 5 and TS 9 and ISO 2604-III, Grades TW5 and TW9.

c) Forgings according to ISO 2604-I, 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 reference to the requirements of annex G.2.1.1.

5.1.2 Aluminium vessels

The materials shown in Table 2 shall be used:

Table 2 — Aluminium materials

ISO 209-2 or ISO 6361-2 Grade or alloy respectively	International designation	Temper designation	Maximum working temperature	Temperature (°C)			Designation temperature ^b (°C)		
				20	50	100	20	50	100
				Minimum guaranteed proof stress ^a (N/mm ²)			Allowable design stress (N/mm ²)		
A199,8 (A)	1080 A	0	100 °C	22	20	18	13	12	11
A199,7	1070 A	0	100 °C	25	23	20	15	14	13
A199,5	1050 A	0	100 °C	30	29	27	18	17	16
A1Mg1 (B)	5005 A	0	100 °C	35	35	35	21	21	21
A1Mg2	5251	0	100 °C	60	60	60	36	36	36
A1Mg2Mn0,8	5049	0	100 °C	80	80	70	48	48	42
A1Mg2,5	5052	0	100 °C	60	60	57	36	36	34
A1Mg3	5754	0	100 °C	80	80	70	48	48	42
A1Mg3Mn	5454	0	100 °C	90	90	90	54	54	54
A1Mg3,5 (A)	5154 A	0	100 °C	90	90	90	54	54	54
A1Mg4	5086	0	65 °C	100	100	(90) ^c	60	60	(54) ^c
A1Mg4,5Mn0,7	5083	0	65 °C	125	125	(120) ^c	75	75	(72) ^c
A1Mn1	3103	0	100 °C	35	35	30	21	21	18
A1Mn0,5Mg0,5	3105	0	100 °C	40	40	37	24	24	22

^a $R_{p1,0}$ for aluminium, $R_{p0,2}$ for aluminium alloys.
^b For intermediate design temperatures linear interpolation may be used.
^c For interpolation purposes only, temperature limit 65 °C.

Materials according to ISO 6362-2 for other products (i.e. bars and rods) so far as they fulfil the requirements of annex **G.2.1.2**.

5.1.3 Additional materials and products

Any material not included in 5.1.1 and 5.1.2, which is manufactured according to a recognized National or International Standard for quality steels, aluminium or aluminium alloy and which conform to the essential safety requirement 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. In approving the testing requirements of the products the requirements of clause 10 shall be taken into account.

5.2 Accessories contributing towards the strength of vessels

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

Bolts and screws equivalent to ISO 898-1 Grades 5.6, or 8.8 and nuts to ISO 898-2 Grades 5 or 8 but with an elongation of at least 12 %, are considered to be suitable.

Steel bolts for working temperatures colder than $-10\text{ }^{\circ}\text{C}$ shall have an impact strength, KCV , for 3 longitudinal test pieces at minimum working temperature of not less than 35 joules/cm^2 . Not more than one of the three figures may be less than 35 joules/cm^2 with a minimum of 25 joules/cm^2 . This property shall be checked.

5.3 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 shell shall be made of non-alloy steel which meets the following requirements:

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

Aluminium and aluminium alloys shall be as given in 5.1.2.

5.4 Welding consumables

The welding consumables used to manufacture the welds on or of the vessel shall be appropriate to and compatible with the materials to be welded and shall correspond to EN --- (in course of preparation).

6 Design

6.1 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 .

Branches shall not be larger in diameter than 0,5 of the diameter of the cylinder to which they are fitted.

6.2 Weld joint design

6.2.1 Partial penetration design of welds is not permitted except in cases of branches, flat ends and flanges which are fixed to the main shell by means of two welds of adequate thickness, see 6.2.8. The type of edge preparation is dependent on the welding procedures used.

Where full penetration is not used for branches, welds shall be as shown in Figure 5 a) to Figure 5 d) with each weld having a throat thickness, g , of at least 0,7 times the thickness of the thinnest part.

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

The branch may be considered as reinforcement for weld joints shown in Figure 4 a), Figure 4 b) and Figure 5 a) to Figure 5 d).

The branch shall not be considered as reinforcement for weld joints shown in Figure 5 e) to Figure 5 h).

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

For horizontally mounted vessels longitudinal welds shall not be closer than 30° to the base of the vessel, see Figure 1.

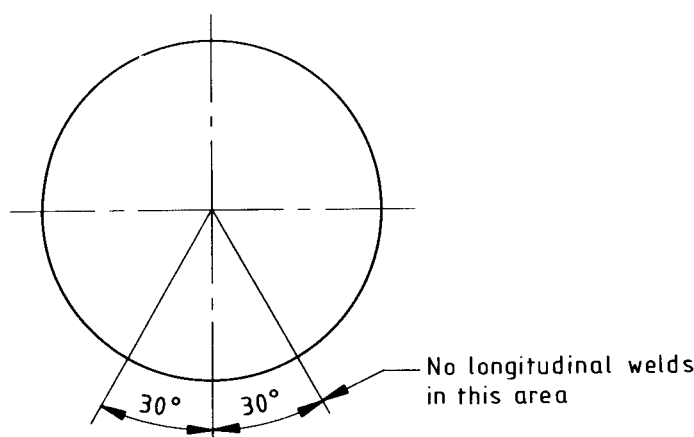


Figure 1 — Positioning of longitudinal welds

6.2.4 The maximum distance from the centre of the dished end and the outer edge of any attachment of reinforcement shall not be greater than $0,4 D_o$ (see Figure 2).

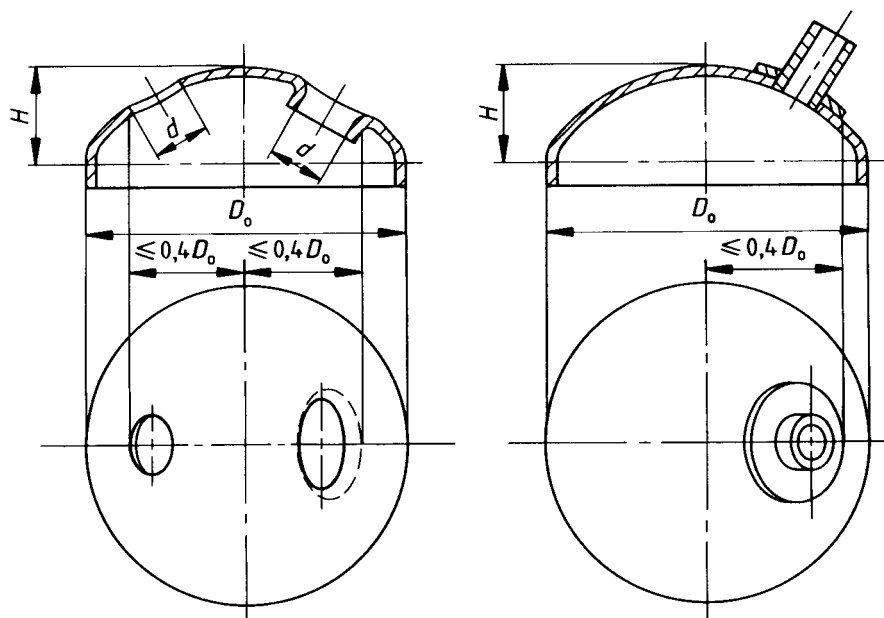


Figure 2 — Positioning of openings in dished ends

6.2.5 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 taken from the extremity of the edge preparation be less than 4 times the actual shell thickness, and in no case shall the distance to any circumferential seam be less than $0,5 \sqrt{D_o e_s}$

where

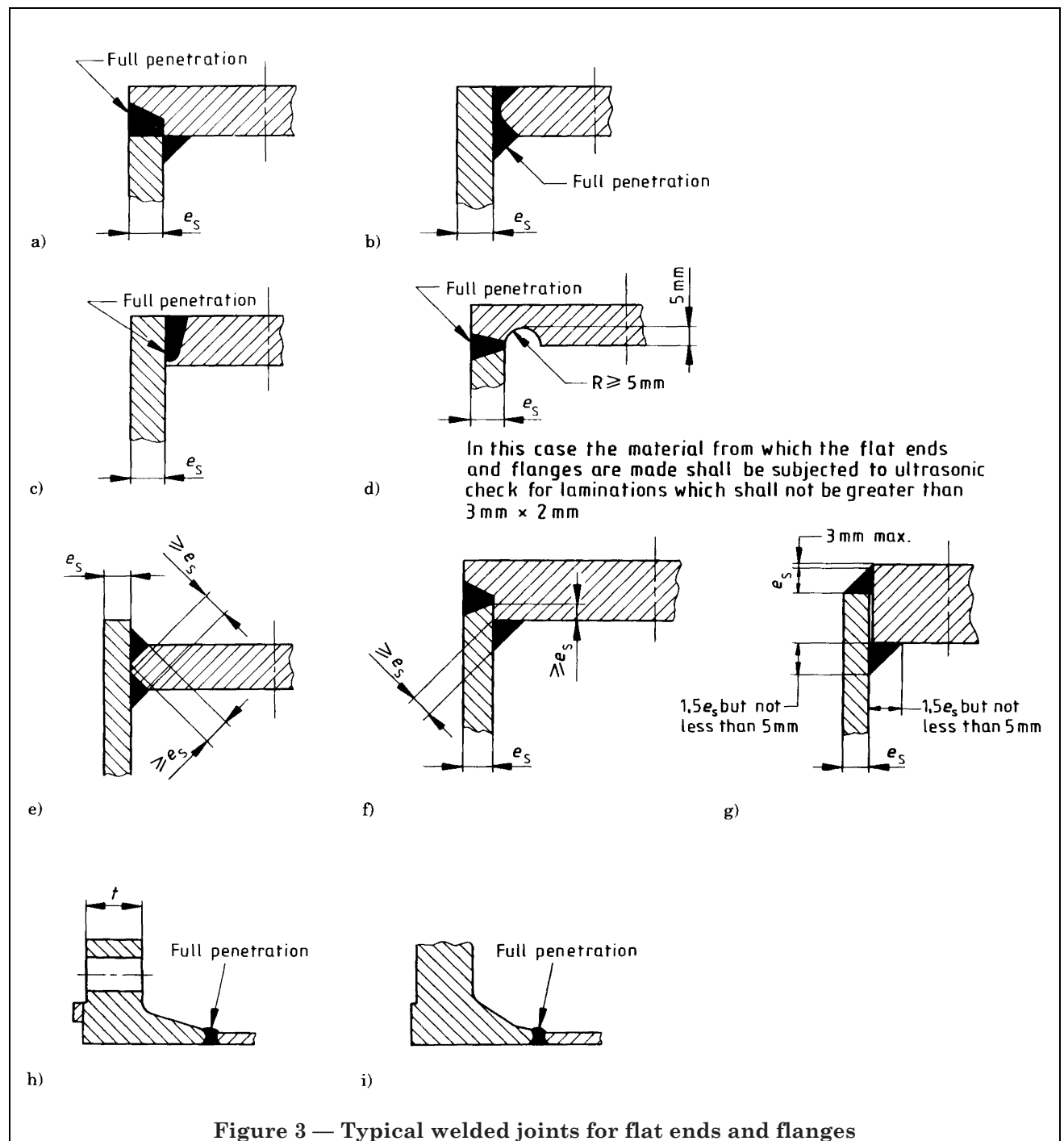
D_o is the outside diameter of the cylinder

e_s is the adopted shell thickness.

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

6.2.7 Joggle joints shall not be used for longitudinal seams.

6.2.8 Welded joints for flat ends and flanges shall be of the types shown in Figure 3.



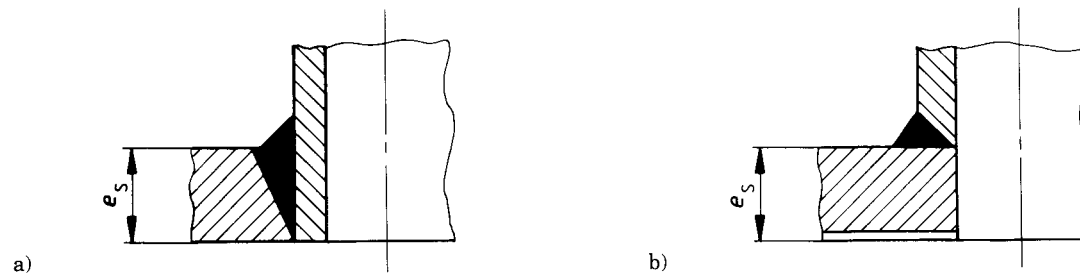
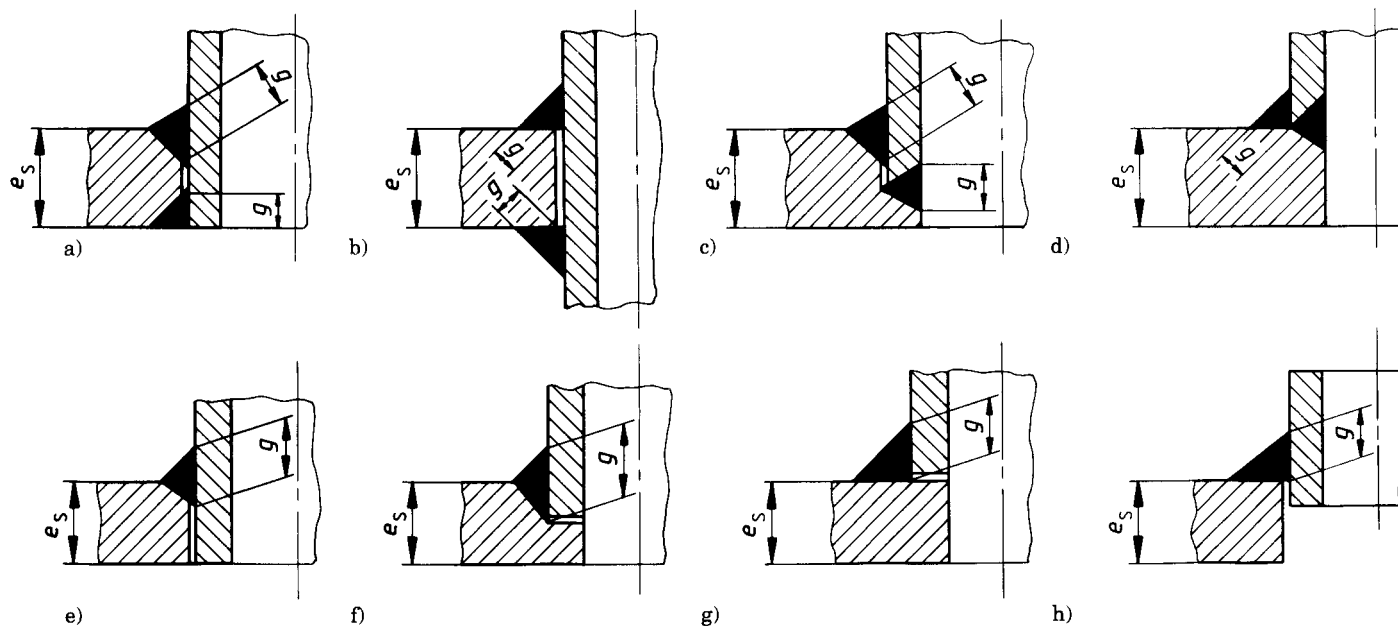


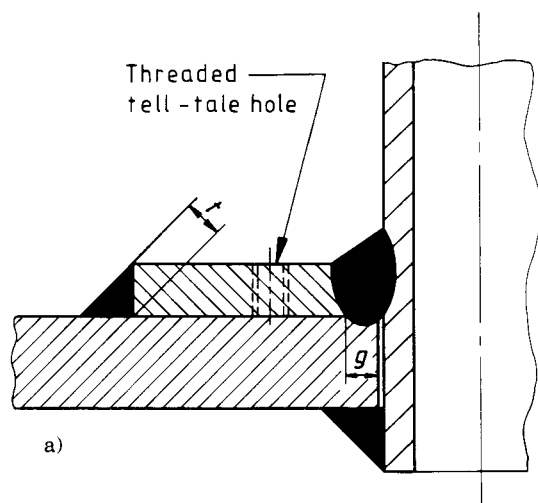
Figure 4 — Full penetration welds for tubes, branches, pipes and sockets



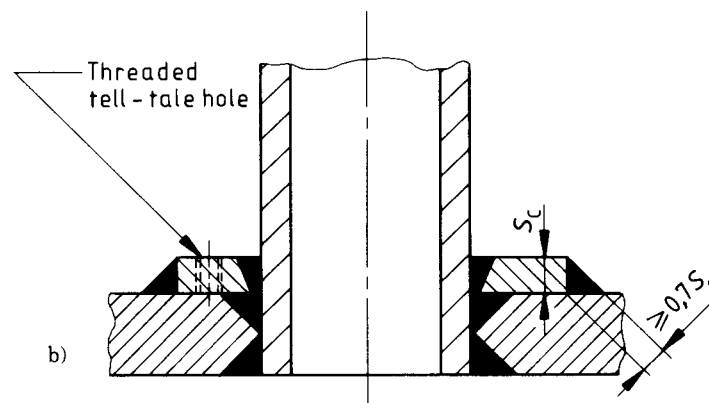
NOTE g is at least 0,7 of the thinnest part.

Figure 5 — Alternative welds for tubes, branches, pipes and sockets

6.2.9 Welding of compensation plates shall be as shown in Figure 6.



Where t is at least 0,7 of the compensation plate and g is at least 0,7 of the thinnest part



Where S_c = thickness of the compensating plate

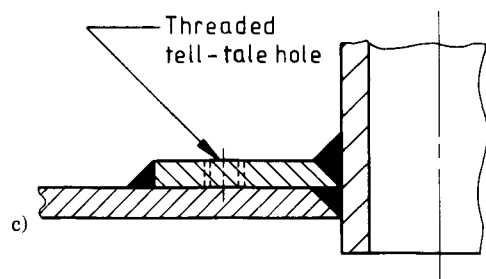


Figure 6 — Welding of compensation plates

6.3 Wall thicknesses

6.3.1 The wall thicknesses shall be determined by the manufacturer using the calculation method (see 6.4) or the experimental method (see 6.5) according to the following criteria:

- If the product of PS and V is more than 3 000 bar.l, or if the maximum working temperature exceeds 100 °C, the calculation method shall be used.
- If the product of PS and V is more than 50 bar.l the experimental method may be used only if the type examination procedure is chosen for approval.

6.3.2 The minimum nominal wall thicknesses of the cylindrical section and ends shall not be less than $3 + c$ mm, in the case of steel vessels this includes 1 mm corrosion allowance, where c is the absolute value of the minus tolerance taken from the material standard, in mm.

6.4 Calculation method

6.4.1 General

(Nominal design stress, nominal thickness) (see also 5.1.1). 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.

The nominal thickness of the material of shells, ends and flanges shall be

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

where

- e_c is the calculated thickness, in mm
- S is the corrosion allowance, in mm. Corrosion allowance $S = 1$ mm for steel, $S = 0$ for aluminium or aluminium alloy
- c is the absolute value of the negative tolerance taken from the material standard, in mm

NOTE The manufacturer will have to apply a further correction factor to allow for thinning during the manufacturing process such that the actual thickness in the finished state, after the production process is not less than $e_c + S$.

6.4.2 Calculated thickness of shells e_{cs}

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

6.4.3 Calculated thickness of dished ends, e_{ce}

Dished ends shall fulfil the following limitations:

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

where

- D_o is the outside diameter of the shell
- h_e is the smallest of the three values h or $D_o^2/[4(R + e_{ce})]$ or $\sqrt{D_o(r + e_{ce})}/2$
- r is the inside knuckle radius, for torispherical ends
- R is the inside spherical radius, for torispherical ends.

It should be noted that the two relationships in b) or the four relationships in c) have to be fulfilled simultaneously.

In no case shall the thickness of the cylindrical or straight flange [see Figure 7 a) and Figure 7 b)] 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.

