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Simple unfired pressure vessels designated to contain air or nitrogen – Part 2: Pressure vessels for air braking and auxiliary systems for motor vehicles and their trailers

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Postadress: SIS, Box 3295, 103 66 STOCKHOLM
Telefon: 08-613 52 00. *Telefax* 08-11 70 35

Upplysningar om **sakinnehållet** i standarden lämnas av TKS.
Telefon: 08-653 49 68. *Telefax* 08-653 49 95

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English version

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

Récipients à pression simples, non soumis à la flamme, destinés à contenir de l'air ou de l'azote:
Partie 2: Réipients 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 Anhangefahrzeugen

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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

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of an identical text or by endorsement, at the latest by March 1993, and conflicting national standards shall be withdrawn at the latest by March 1993.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.

Contents

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 exceedPSg 1500 bar litres;

d) capacity not exceeding 150 litres;

e) minimum working temperature not lower than – 50 °C and maximum working temperature not higher than 100 °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 posit ion of attachmlents 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, $A_{80\ mm}$	Elongation after rupture	%
A_f	Cross-sectional area effective as compensation	mm^2
A_{fb}	Cross-sectional area effective as compensation of the boss	mm^2
A_{fs}	Cross-sectional area effective as compensation of the shell	mm^2
A_p	Area of pressurized zone	mm^2
A_c, A_R	See **5.1.7**	mm^2
C	Calculation coefficient for unpierced flat ends	—
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
c_b	As before for a branch or boss	mm
D	Inside diameter of an unpierced flat end	mm
D_o	Outside diameter of the shell	mm
D_c	Outside diameter of the crown section of a torispherical end measured to the tangent between crown and knuckle	mm
d	Diameter of hole	mm
d_{ib}	Internal diameter of a boss	mm
d_{ob}	Outside diameter of a boss	mm
e	Nominal wall thickness	mm
e_a	Actual wall thickness	mm
e_{act}	Actual wall thickness of the shell before the pressure test	mm
e_{ah}	Actual wall thickness of the end	mm
e_{as}	Actual wall thickness of the shell	mm
e_c	Calculated thickness	mm
e_{cb}	Calculated wall thickness of a branch or a fictitious branch with the same internal diameter as the boss	mm
e_{ch}	Calculated wall thickness of the dished end	mm
e_{cs}	Calculated wall thickness of the shell	mm
e_h	Nominal wall thickness of the dished end	mm
e_n	e_{act} - corresponding nominal wall thickness as stated in the design drawing	mm
e_{rb}	Wall thickness of boss contributing to reinforcement	mm
e_{rs}	Wall thickness of shell contributing to reinforcement	mm
e_s	Wall thickness of the shell	mm
f	Nominal design stress	N/mm^2
g	Throat thickness of a weld	mm
h	Height of a dished end See **5.1.6.1** and figure 3	mm
h_b, h_{be}, h_{be1}, h_{be2}		
K_c	Calculation coefficient which depends on the welding process	—
KCV	Failure energy (impact test)	J/cm^2
KV	Failure energy (impact test)	J
L	See **5.1.7**	mm
l_b	Length between adjacent bosses	mm
l_{rb}	Length of boss contributing to reinforcement	mm
l_{rs}	Length of shell contributing to reinforcement	mm
m	See **10.5.3**	—
N	See **6.1.3.1** and **10.5.3**	—
P	Design pressure[2] hich shall not be less than *PS)*	bar
P_h	Test pressure[2]	bar
PS	Maximum working pressure[2])	bar
R	Inside radius for shells and ends	mm
R_e	Minimum yield strength specified in the material standard	N/mm^2
$R_{e\ act}$	Yield strength of the shell material as determined in the tensile test	N/mm^2
R_{eT}	Minimum yield strength at maximum working temperature specified in the material standard	N/mm^2
R_m	Minimum tensile strength specified in the material standard or guaranteed in the inspection slip by the material manufacturer	N/mm^2
$R_{m\ act}$	Tensile strength of the shell material as determined in the tensile test	N/mm^2
r	Inside knuckle radius for torispherical ends	mm
T	Temperature	°C
$T_{max.}$	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_{io}	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:

$C \leq 0{,}25$ %, $S \leq 0{,}05$ %, $P \leq 0{,}05$ % and $R_{m\ max} < 580$ 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

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

5.1.3 *Calculated thickness of shells*

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

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	Temperature °C			Design temperature[3] °C		
				20	50	100	20	50	100
			°C	Minimum proof stress[4] N/mm²			Minimum design stress N/mm²		
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: $0{,}002\ D_o \leq e_{ch} \leq 0{,}08\ D_o$

$h \geq 0{,}18\ D_o$

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:

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

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 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 DO 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 $h/D_o < 0,27$; 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:

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

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

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

or if

- the internal diameter of the opening is:

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

or if

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

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

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

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).