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Simple unfired pressure vessels designed to contain air or nitrogen – Part 3: Steel pressure vessels designed for air braking equipment and auxiliary pneumatic equipment for railway rolling stock

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English version

Simple unfired pressure vessels designed to contain air or nitrogen — Part 3 : Steel pressure vessels designed for air braking equipment and auxiliary pneumatic equipment for railway rolling stock

Récipients à pression simple, non soumis à la flamme, destinés à contenir de l'air ou de l'azote — Partie 3: Récipients à pression en acier destinés aux équipements pneumatiques de freinage et aux équipements pneumatiques auxiliaires du matériel roulant ferroviaire

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

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

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

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

Part 1: *Design, manufacture and testing*

Part 2: *Pressure vessels for air braking and auxiliary systems for motor vehicles and their trailers*

Part 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of an identical text or by endorsement, at the latest by March 1995, and conflicting national standards shall be withdrawn at the latest by March 1995.

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

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1 Scope

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

It defines three types of vessel A, B and C (see table 1) corresponding to the current practice of European railway networks.

1.2 The vessels to this standard are:

a) made from a single shell;

b) made from non-alloy steel;

c) fabricated by welding;

d) used at a maximum working pressure of 10 bar;

e) the product of the maximum working pressure (in bar) and the volume (in litre):

50 bar litres $< PV \leq$ 10 000 bar litres;

f) made of a cylindrical part of circular cross-section called the shell with two outwardly dished torispherical ends, that is two dished ends with the same axis of rotation. This standard therefore does not apply to vessels with one or two flat ends or those made up of several compartments;

g) calculated with a design pressure P (see **5.1.4.1.2**);

h) designed for a working temperature of between −40 °C and +100 °C;

i) fastened to the vehicles:

1) by straps for types A and B vessels;

2) by welded brackets for types B and C vessels.

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

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

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

Table 1. Definitions of types of vessel

Criterion	Type A	Type B	Type C	Reference clause in this standard
Nominal design stress f	$0,6R_{eT}$ or $0,3R_m$		$0,6R_{eT}$ or $0,3R_m$	**5.1.4.1**
		$0,3R_m/1,4$ with $R_m \leq 360$ N/mm^2		**5.1.4.2**
Radii of curvature of the end	$R = D_o$ $r = 0,1D_o$		$R = D_o$ $r = 0,1D_o$	**5.1.3.1.1**
		$R = D_o$ $r \geq 0,06D_o$		**5.1.3.1.2**
Shell ring/end assembly	Butt weld or swaged end. Full penetration weld		Butt weld or swaged end. Full penetration weld	**5.1.5.2.1**
		Inserted end		**5.1.5.2.2**
Thread of inspection, branch and drainage boss	ISO 228-1 ISO 261	ISO 7-1 ISO 228-1 ISO 261	ISO 7-1 ISO 228-1 ISO 261	**5.2.1**
Weld of drainage boss	Full penetration weld of the vessel wall for penetrating boss	Full penetration weld of the vessel wall for penetrating boss. Convex weld for surface mounted boss	Full penetration weld of the vessel wall for penetrating boss. Convex weld for surface mounted boss	**5.2.4.2**
Method of fixing to the vehicle	Fixing by steel straps	Fixing by straps or welded brackets	Fixing by welded brackets	Annex F
Service surveillance	Annex G	Annex H	Annex H	

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

This Part of this standard gives:

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

b) in annex G, recommendations for the service surveillance of type A vessels;

c) in annex H, recommendations for the service surveillance of types B and C vessels.

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

2 Normative references

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

EN 287-1	*Approval testing of welders — fusion welding —* Part 1 : *Steels*
EN 288-1	*Specification and approval of welding procedures for metallic materials —* Part 1 : *General rules for fusion welding*
EN 288-2	*Specification and approval of welding procedures for metallic materials —* Part 2 : *Welding procedure specification for arc welding*
EN 288-3	*Specification and approval of welding procedures for metallic materials —* Part 3 : *Welding procedure tests for the arc welding of steels*
EN 10025	*Hot rolled products of non-alloy structural steels — Technical delivery conditions*
EN 10045-1	*Metallic materials — Charpy impact test* Part 1 : *Test method*
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 7-1	*Pipe threads where pressure-tight joints are made on the threads —* Part 1 : *Designation, dimensions and tolerances*
ISO 228-1	*Pipe threads where pressure-tight joints are not made on the threads —* Part 1 : *Designation, dimensions and tolerances*
ISO 261	*ISO general purpose metric screw threads — General plan*
ISO 1101	*Technical drawings — Geometrical tolerancing — Tolerancing of form, orientation, location and run-out — Generalities, definitions, symbols, indications on drawings*
ISO 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 5173	*Fusion welded butt joints in steel — Transverse root and face bend test*

3 Symbols

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

A	Elongation at rupture	%
A_{fb}	Cross sectional area effective as compensation of the boss	mm^2
A_{fp}	Cross sectional area effective as compensation of the reinforcing plate	mm^2
A_{fs}	Cross sectional area effective as compensation of the shell	mm^2
A_p	Area of the pressurized zone	mm^2
c	Absolute value of the minus rolling tolerance for sheets as quoted in the standard	mm
D_o	Outside diameter of the shell of the vessel	mm
d_{ib}	Internal diameter of the boss	mm
d_{ob}	Outside diameter of the boss	mm
e	Nominal wall thickness	mm
e_c	Calculated thickness	mm
e_{ch}	Calculated thickness of the end	mm
e_{cs}	Calculated thickness of the shell	mm
e_h	Nominal thickness of the end	mm
e_{rb}	Wall thickness of the boss contributing to reinforcement	mm
e_{rp}	Wall thickness of the reinforcing plate contributing to reinforcement	mm
e_{rs}	Wall thickness of the shell contributing to reinforcement	mm
f	Nominal design stress at the design temperature	N/mm^2
f_b	Permitted stress of the boss	N/mm^2
g	Throat thickness of a weld	mm
h	External height of the dished part of an end (see figure 4)	mm
h_1	External height of the cylindrical part of the end (see figure 4)	mm
h_2	Internal height of a dished part of the end (see figure 4)	mm
K_c	Design coefficient which is a function of the welding process	—
K_V	Impact energy at break (V-notch test piece)	J
L	Total length of the vessel	mm
L_1	Distance between the axis of a drainage opening and the end of the vessel	mm
l_{rb}	Length of the boss contributing to reinforcement	mm
l_{rbi}	Length of inward projecting boss contributing to reinforcement	mm
l_{rp}	Length of the reinforcing plate contributing to reinforcement, measured along the mid-surface	mm
l_{rs}	Length of the shell contributing to reinforcement, measured along the mid-surface	mm
P	Design pressure[1)] which is a function of the maximum working pressure, the welding process and inspection used	bar
P_S	Maximum working pressure[1)]	bar
R	Internal radius of the spherical part of the end	mm
R_{eT}	Minimum yield point at the maximum working temperature	N/mm^2
R_i	Local internal radius at the location of the opening in question	mm
R_m	Minimum tensile strength specified by the manufacturer or by the standard defining the steel	N/mm^2
r	Internal radius of the torispherical part of the end	mm
S	Corrosion allowance	mm
T_{min}	Minimum working temperature	°C
T_{max}	Maximum working temperature	°C
T^*	Temperature at which the mean value of the energy absorbed at break (V-notch), $K_V \geq 28$ J, is guaranteed longitudinally	°C
V	Volume of the vessel	l

1) All pressures are gauge pressures.

4 Materials

4.1 Pressurized parts

4.1.1 *Shell and ends*

The shell and ends shall be made of steel sheet grade SPH 235 or SPH 265 as specified in EN 10207.

These steels shall be accompanied by a test report drawn up by the material manufacturer.

The mean value of energy absorbed at break K_V determined on three longitudinal test pieces shall be at least 28 J at the minimum working temperature T_{min}.

This essential safety requirement may be met as follows:

a) *For types A, B and C vessels*

— by carrying out impact bending tests at the minimum temperature of −40 °C, at the responsibility of the material manufacturer;

— or by using steels for which the appropriate guarantee of energy absorbed at break at the minimum temperature of −40 °C is given by a particular standard;

— or at a temperature T^* equal to or less than that obtained by extrapolation using the graph from figure 1.

Examples of use:

— example no. 1: if e = 10 mm and T^* = −10 °C, T_{min} = −35 °C;

— example no. 2: if T^* = −20 °C and T_{min} = −40 °C, e_{max} = 12,7 mm.

b) *For type B vessels only*

By ensuring that brittle fracture does not occur at the minimum service temperature −40 °C, using the fracture mechanics theory through the use of a recognized standard or code and by applying knowledge of the physical and metallurgical properties at the temperature T of a steel defined in a specific standard, whilst taking into account the stresses (primary and secondary stresses) and the thickness of the materials of the vessel.

4.1.2 *Inspection bosses, pipe connection branches and drainage bosses*

The bosses shall be manufactured from bar or tube of a steel grade compatible with the grades of steel sheet comprising the vessel and shall be of weldable quality. The product analysis of this steel shall meet the following requirements:

— R_m < 580 N/mm²;

— C < 0,25 %, S < 0,05 % and P < 0,05 %.

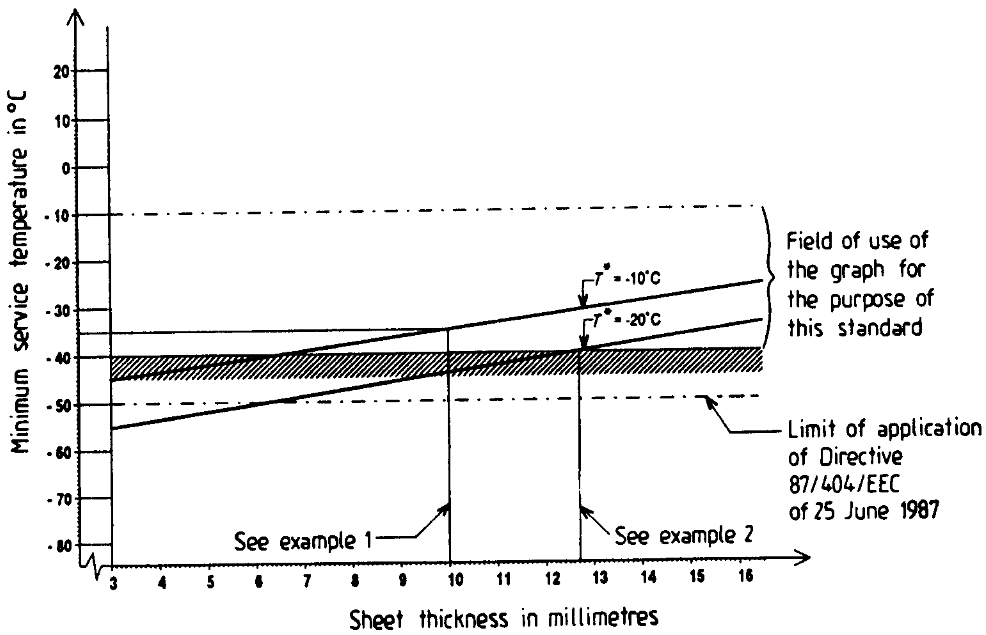

Figure 1. Extrapolation of the guaranteed energy absorbed at break at temperature T_{min}

4.2 Non-pressurized parts

Accessories to be welded to the vessel, but which do not contribute to its strength, shall be made of steel grades compatible with the grades of steel sheet comprising the vessel and shall be of weldable quality.

The product analysis of this steel shall meet the following requirements:

— $R_m \leq 580$ N/mm^2;

— C ≤ 0,25 %, S ≤ 0,05 % and P ≤ 0,05 %.

4.3 Welding materials

The filler materials used for welding onto the vessels or welding the vessels themselves shall be suitable and compatible with the parent materials.

They shall correspond to EN ... (in preparation).

5 Design

5.1 Shell and ends

5.1.1 *General*

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

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

NOTE. Examples of installation and maintenance requirements are given in informative annexes F, G and H.

5.1.2 *Design of the shell*

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

Longitudinal weld seams of parts of the shell shall:

— not be located on the lower part of the vessel defined by an angle of 30° on either side of the vertical axis (see figure 2);

— be sufficiently far apart such as to form an angle greater than 40° (see example in figure 3).

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

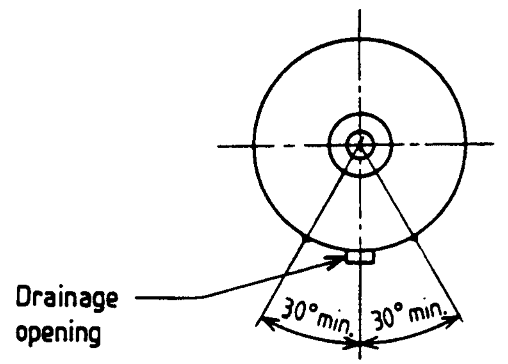

Figure 2. Position of longitudinal welds on the bottom of the shell

5.1.3 *Design of the ends*

5.1.3.1 ***Shape and dimensions of the ends***

The torispherical ends shall be made from a single sheet.

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

The torispherical end (see figure 4) shall meet the requirements of **5.1.3.1.1** and table 2 or **5.1.3.1.2** as applicable.

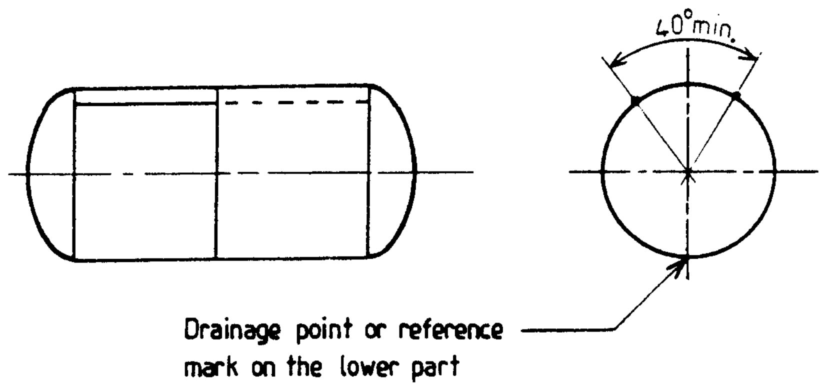

Figure 3. Position of longitudinal welds on the shell

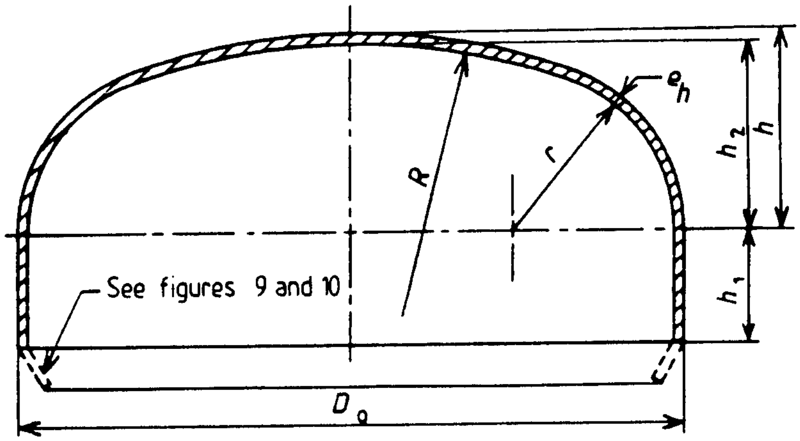

Figure 4. Torispherical end

5.1.3.1.1 *Types A and C vessels*

R (nominal) = D_o

r (nominal) = $0,1D_o$

Table 2. Height of the cylindrical portion of ends

Dimensions in millimetres

e_h	3	4	5	6	8	10	11	12
h_{1min}	12	16	20	24	32	40	44	48
h_{1max}	25		40		50		55	

5.1.3.1.2 *Type B vessels*

R (nominal) = D_o

r (nominal) ≥ $0,06D_o$

$26 \leq h_1 \leq 40$ mm (see **5.1.5.2.2**).

5.1.3.2 *Heat treatment of ends after forming*

Steel ends obtained by cold forming:

a) the nominal sheet thicknesses of which are equal to or less than 6 mm, can be used without postforming heat treatment;

b) the nominal sheet thicknesses of which are greater than 6 mm and not more than 8 mm, shall undergo postforming heat treatment if the minimum temperature of the impact bending test (V-notch) required is less than − 10 °C;

c) the nominal sheet thicknesses of which are greater than 8 mm, shall not be used without postforming heat treatment.

Where required, heat treatment after cold forming is a normalizing treatment (see above), i.e. heating beyond the range of critical temperatures followed by air cooling.

The heating temperature shall be greater than the upper limit of the critical range (usually called point A3) but as close to it as possible.

NOTE. For the steels specified in clause **4**, the heat treatment temperature is between 890 °C and 950 °C. If this range does not feature in the standard, the actual normalizing temperature should be stated by the steel producer.

5.1.4 ***Calculation of shell and end thicknesses***

5.1.4.1 *Type A vessels*

5.1.4.1.1 *General*

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

$$e \geq e_c + c + S$$

The value of e_c shall in no case be less than 2 mm.

The corrosion allowance S is taken as equal to 1 mm.

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

5.1.4.1.2 *Calculation of the shell thickness* e_{cs}

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

The nominal design stress f shall not be greater than the smaller of the values: $0,6R_{eT}$ and $0,3R_m$.

The values of R_{eT} and R_m are stated in the material standard. For steels for which R_{eT} is not guaranteed at 100 °C, the stress f is taken as equal to $0,6R_{eT} \times 0,9$.

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

a) case no. 1: $P \geq P_S$ and $K_c = 1$ for automatic welding and when tests are carried out in accordance with **11.1.2.1**;

b) case no. 2: $P \geq 1,25P_S$ and $K_c = 1$ for automatic welding and when tests are carried out in accordance with **11.1.2.2;**

c) case no. 3: $P \geq 1,25P_S$ and $K_c = 1,15$ for welding by a non-automatic process and when tests are carried out in accordance with **11.1.1.**

5.1.4.1.3 *Calculation of the thickness of the ends* e_{ch}

The end thickness shall be calculated in the following manner.

a) Calculate the value of $P/(10f)$. For the value of f see **5.1.4.1.2**.

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

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

where:

$e_{ch} = e_{cs}$;

$$h = e_h + h_2$$
$$= e_h + D_o - \sqrt{(D_o - r)^2 - (D_o/2 - e_h - r)^2}$$

(take $e_h = e_{cs} + 1 + 0,3$).

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

c) Determine e_{ch}/D_o from figure 5.

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

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

Example of calculation of thickness e_{ch} of an end of steel SPH 235 in accordance with EN 10207, $R_{eT} = 235$ N/mm^2 ($e \leq 16$ mm) for a vessel of diameter $D_o = 400$ mm.

$P = 1{,}25P_S = 1{,}25 \times 10 = 12{,}5$ bar (case no. 2 in **5.1.4.1.2**) for the shell

$P = P_S = 10$ bar for the ends

$K_c = 1$

$R = D_o = 400$ mm

$r = 0{,}1D_o = 40$ mm

$f = 108$ N/mm^2: the smaller of the two values:

$0{,}3R_m = 108$;

$0{,}6R_{eT} = 141$.

Therefore $P/10f = 10/(10 \times 108) = 0{,}00926$

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

a) $h = e_h + D_o -$

$$- \sqrt{(D_o - r)^2 - (D_o/2 - e_h - r)^2}$$
$$= 3{,}6 + 400 -$$
$$- \sqrt{(400 - 40)^2 - (400/2 - 3{,}6 - 40)^2}$$
$$= 79{,}35$$

b) $$\frac{D_o^2}{4(R + e_{ch})} = 99{,}42$$

c) $$\sqrt{\frac{D_o(r + e_{ch})}{2}} = 91{,}97$$

when e_{ch} is taken as equal to e_{cs}

$$= \frac{PD_o}{20f + P} K_c$$
$$= \frac{12{,}5 \times 400}{20 \times 108 + 12{,}5} \times 1$$
$$= 2{,}3$$

thus $e_h = 2{,}3 + 1 + 0{,}3 = 3{,}6$

giving $h_e = 79{,}35$ and $h_e/D_o = 0{,}198$

From figure 5: $e_{ch}/D_o = 0{,}0072$

$e_{ch} = 0{,}0072 \times 400 = 2{,}88$

The verification of the calculation with e_{ch} = 2,88 in place of e_{cs} = 2,3 gives:

$e_{ch} = 2{,}9$

5.1.4.2 *Type B vessels*

5.1.4.2.1 *General*

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

$$e \geq e_c + c + S$$

The value of e_c shall in no case be less than 2 mm.

The corrosion allowance S is taken as equal to 1 mm.

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

5.1.4.2.2 *Calculation of the shell thickness* e_{cs}

The shell thickness e_{cs} is calculated from the formula given in **5.1.4.1.2**.

However:

— the value of the nominal design stress f is taken as equal to $0{,}3R_m/1{,}4$;

— the rupture strength of the steel used R_m is equal to or less than 360 N/mm^2.

Where the vessel is attached to the vehicle by means of fixing brackets welded onto the shell, the manufacturer shall take into account the secondary stresses described in **5.3**.

The shell thickness e_{cs} shall be less than 5 mm.

5.1.4.2.3 *Calculation of the thicknesses of the ends* e_{ch}

The thickness of the ends e_{ch} is obtained by applying the method described in **5.1.4.1.3**.

However:

— the value of the nominal design stress f is taken as equal to $0{,}3R_m/1{,}4$;

— the rupture strength of the steel used R_m is equal to or less than 360 N/mm^2.

The value of e_{ch} shall comply with the requirement:

$$0{,}002D_o \leq e_{ch} \leq 0{,}08D_o.$$