# Welded static non-pressurized thermoplastic tanks —

## Part 3: Design and calculation for single skin rectangular tanks

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ICS 23.020.10

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# National foreword

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- — aid enquirers to understand the text;
- — present to the responsible European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;
- — monitor related international and European developments and promulgate them in the UK.

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**Summary of pages**

This document comprises a front cover, an inside front cover, the EN title page, pages 2 to 33 and a back cover.

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This British Standard, having been prepared under the direction of the Sector Committee for Materials and Chemicals, was published under the authority of the Standards Committee and comes into effect on 15 November 2000

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EUROPEAN STANDARD

NORME EUROPÉENNE

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# EN 12573-3

March 2000

ICS 23.020.10

English version

# Welded static non-pressurized thermoplastic tanks - Part 3: Design and calculation for single skin rectangular tanks

Cuves statiques soudées en matières thermoplastiques sans pression - Partie 3: Conception et calcul des cuves parallélépipédiques rectangles à simple paroi

Geschweißte ortsfeste drucklose Behälter (Tanks) aus Thermoplasten - Teil 3: Konstruktion und Berechnung von einwandigen Rechteckbehältern (-tanks)

This European Standard was approved by CEN on 14 February 2000.

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Ref. No. EN 12573-3:2000 E

## Contents

## Foreword

This European Standard has been prepared by Technical Committee CEN/TC 266, Thermoplastic static tanks, the Secretariat of which is held by BSI.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by September 2000, and conflicting national standards shall be withdrawn at the latest by September 2000.

The informative Annex A gives some construction details of rectangular tanks as examples.

EN 12573:2000 "Welded static non-pressurized thermoplastic tanks" consists of:

| | |
|---|---|
| Part 1: | General principles |
| Part 2: | Calculation of vertical cylindrical tanks |
| Part 3: | Design and calculation of single skin rectangular tanks |
| Part 4: | Design and calculation of flanged joints |

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

## 1 Scope

This standard specifies the design and calculation for single skin rectangular tanks, fabricated from the following thermoplastics:

Polyethylene (PE)
Polypropylene (PP)
Poly (vinyl chloride) (PVC)
Poly (vinylidene fluoride) (PVDF)

The tanks may be strengthened on the outside by means of ribs or frames made of the same or other materials. This standard is only applicable to tanks which are not intended to withstand internal pressure or vacuum, other than that which may occur during the transfer of fluids (including gases) in their normal operation. The calculation takes into account short-term and long-term active pressures as well as the hydrostatic loading. The following values are long-term pressures and represent the limiting values:

Overpressure: 0,0005 N/mm$^2$ (0,005 bar)
Low pressure: 0,0003 N/mm$^2$ (0,003 bar)

Plate theory was used as the basis of the calculation in this document. Reference to membrane theory is given in Annex B.

## 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 12573-1:2000 | Welded static non-pressurized thermoplastic tanks – Part 1: General principles |
| EN 1778 | Characteristic values for welded thermoplastic constructions – Determination of allowable stresses and moduli for design of thermoplastic equipment |

## 3 Definitions, symbols and abbreviations

For the purposes of this part of this standard the following definitions, symbols and abbreviations apply:

### 3.1 Definitions

**3.1.1** **Skin:** Basic structural element of the tank.

**3.1.2** **Stiffener:** Section attached horizontally or vertically to the skin of the tank.

**3.1.3** **Wall:** Skin of the tank plus stiffeners.

**3.1.4** **Panel:** Area of the skin between stiffeners.

**3.1.5** **U-frame:** Stiffener running beneath the base and vertically up the side of the tank.

### 3.2 Symbols and abbreviations

| | |
|---|---|
| E | is the elastic modulus of the stiffener material (with plastics, this corresponds to $E_c$), in Newtons per square millimetre |
| $E_{c(al.)D}$ | is the allowable creep modulus at the design condition for deformation (temperature, stress, time, medium), in newtons per square millimetre, see EN 1778 |
| F | is the force, in newtons |
| f | is the maximum deflection, in millimetres |
| J | is the moment of inertia of stiffener, in millimetres to the fourth power |
| k | is the correction coefficient for the deflection of the wall |
| M | is the bending moment, in newton millimetres |
| N | is the rigidity coefficient |
| p | is the excess pressure on the tank base, in newtons per square millimetre |
| $p_D$ | is the uniformly distributed load acting on the cover, in newtons per square millimetre |
| $p_m$ | is the mean value of excess pressure for calculation of skin thickness, in newtons per square millimetre |
| $p_1$ | is the mean value of excess pressure for calculation of the stiffener, in newtons per square millimetre |
| t | is the skin thickness, in millimetres |
| W | is the moment of resistance of rim stiffeners, in cubic millimetres |
| x | is the length of the tank or distance between the vertical stiffeners, in millimetres |
| x' | is the effective length of panels assigned to stiffeners, in millimetres |
| y | is the depth of the tank or distance between the horizontal stiffeners, in millimetres |
| y' | is the effective depth of panels assigned to stiffeners, in millimetres |
| z | is the width of the tank or panel, in millimetres |
| $\alpha_1 \dots \alpha_5$ | is the deformation coefficient |
| $\beta_1 \dots \beta_5$ | is the stress coefficient |
| $\sigma_{al.}$ | is the allowable stress, in newtons per square millimetre, see EN 1778 |

## 4 General considerations in design calculations

General principles in accordance with EN 12573-1:2000.

Calculation methods are given only for the tank designs illustrated in Figures 1 to 5.

Welds should be situated in regions of low bending moments; the maximum bending moments are shown in Figures 6, 7 and 8.

> NOTE: The design should take account of the effects of thermal expansion between the tank wall and any external stiffening.

The maximum deflection shall not be larger than the half skin thickness.

$f \leq 0{,}5\ t$

For construction details of rectangular tank see Annex A.

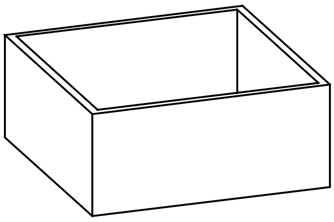


**Figure 1: Unstiffened tank**

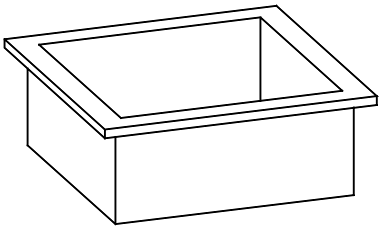


**Figure 2: Tank with a horizontal rim stiffener**

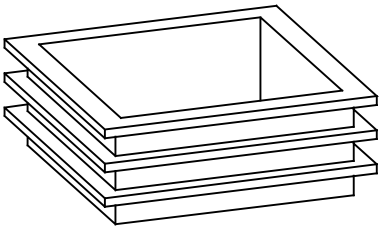


**Figure 3: Tank with intermediate horizontal stiffeners**

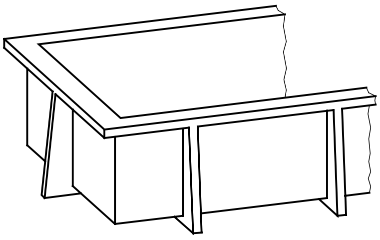


Figure 4: Tank with vertical stiffeners

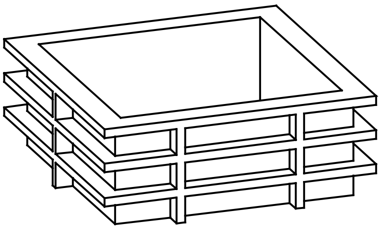


Figure 5: Tank with cross-ribbed horizontal and vertical stiffeners

## 5 Unstiffened tanks sitting on a continuous flat rigid surface

### 5.1 General

The calculation of the minimum skin thickness depends on the ratio between the length (x) and depth (y) (see Figure 6). The thickness of the base shall be of similar magnitude to the actual thickness of the skin.

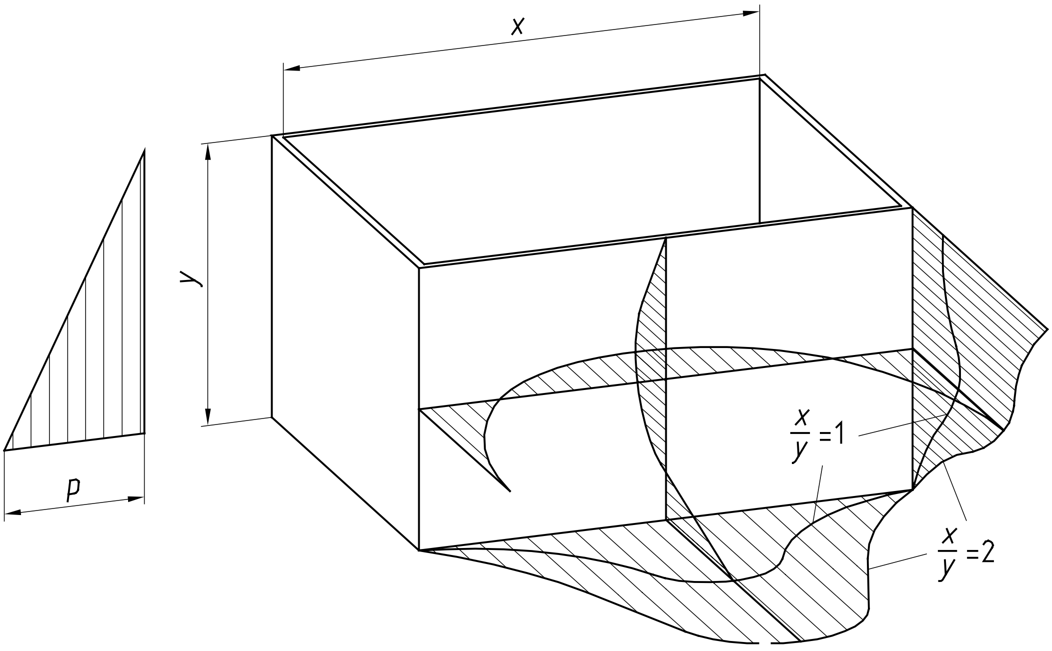


Figure 6:Principal distribution of bending moments in an unstiffened tank

## 5.2 Aspect ratio x/y < 0,5

The minimum skin thickness shall be calculated according to equation (1).

$$t = \sqrt{\frac{p\,x^2}{2{,}5\,\sigma_{\text{al.}}}} \tag{1}$$

NOTE 1: In equation (1) for the skin thickness (t), the skin has been assumed as a beam fixed at both ends with the load distributed uniformly between these two points. This leads to a factor of 2 in the denominator. To provide better agreement with measured values, the factor was increased to 2,5.

The maximum deflection of the skin shall be calculated according to equation (2).

$$f = \frac{p\,x^4}{32\,k\,E_{c(\text{al.})_D}\,t^3} \tag{2}$$

The correction coefficient k is either 1 when $x < y$ or 2 when $x/y \approx 0{,}5$.

NOTE 2: In equation (2) for the deflection, there is a factor of 32 in the denominator when a beam is fixed at both ends with the load distributed uniformly between these two points. However, it is possible to use equations based on plate theory which exactly correspond to the particular load case and lead to a factor of 68 if $x/y \approx 0{,}5$. Therefore, an additional correction coefficient k was introduced, which, depending on x/y, gives sufficiently accurate results.

## 5.3 Aspect ratio 0,5 ≤ x/y ≤ 4

The minimum skin thickness shall be calculated according to equation (3).

$$t = \sqrt{\beta_1 \frac{p\,y^2}{\sigma_{\text{al.}}}} \tag{3}$$

The maximum deflection of the skin shall be calculated according to equation (4).

$$f = \frac{\alpha_1\,p\,y^4}{E_{c(\text{al.})_D}\,t^3} \tag{4}$$

The values for $\beta_1$ and $\alpha_1$ shall be taken from Table 1.

## 5.4 Aspect ratio x/y > 4

The minimum skin thickness shall be calculated according to equation (5).

$$t = \sqrt{\frac{p\,y^2}{\sigma_{al.}}} \qquad (5)$$

The maximum deflection of the skin shall be calculated according to equation (6).

$$f = \frac{p\,y^4}{2{,}5\,E_{c(al.)_D}\,t^3} \qquad (6)$$

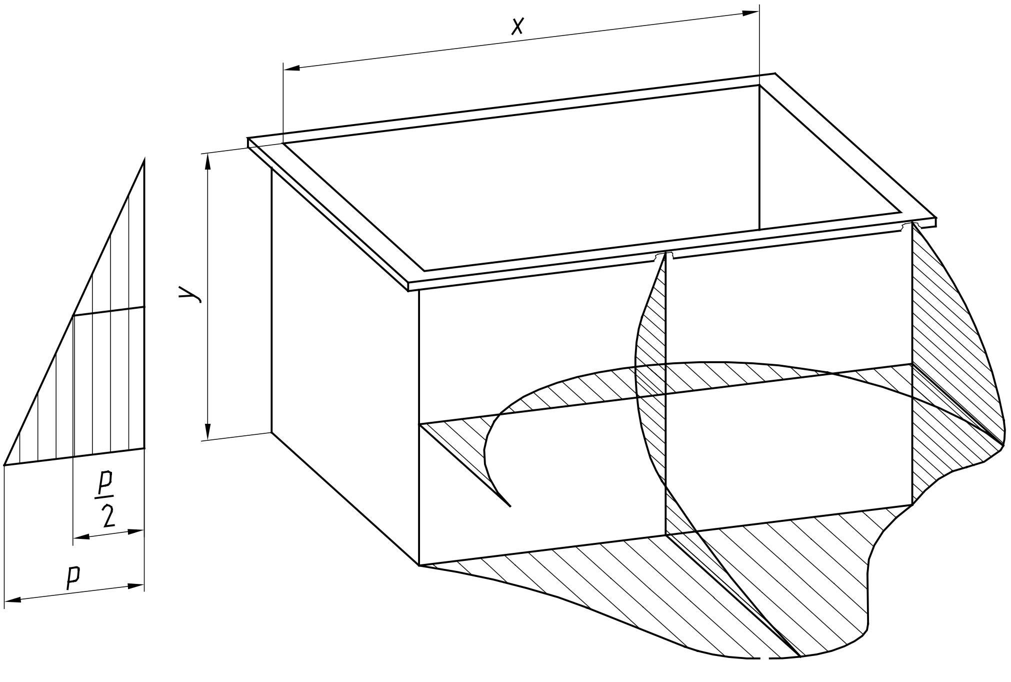
NOTE: The tank wall here is considered as a cantilever with a triangular load.

# 6 Tanks with rim stiffening supported on a continuous flat rigid surface

## 6.1 Calculation of the skin thickness

### 6.1.1 General

The calculation of the minimum skin thickness is based on the assumption that the rim stiffening constitutes a firm support. The thickness of the base shall be of similar magnitude to the actual thickness of the skin (see Figure 7).



$\frac{p}{2}$ = average area load

Figure 7: Principal distribution of bending moments in a tank with rim stiffening

### 6.1.2 Aspect ratio x/y < 0,5

The minimum skin thickness shall be calculated according to equation (7).

$$t = \sqrt{\frac{p\,x^2}{3\,\sigma_{al.}}} \qquad (7)$$

NOTE 1: In equation (7) for the skin thickness (t), the skin has been assumed as a beam, fixed at both ends with the load distributed uniformly between these two points. This leads to a factor of 2 in the denominator. To provide better agreement with measured values, the factor was increased to 3.

The maximum deflection of the skin shall be calculated according to equation (8).

$$f = \frac{p\,x^4}{32\,k\,E_{c(al.)_D}\,t^3} \qquad (8)$$

The correction coefficient k is either 1 when x < y or 2 when x/y ≈ 0,5.

NOTE 2: In equation (8) for the deflection, there is a factor of 32 in the denominator when a beam is fixed at both ends with the load distributed uniformly between these two points. However, it is possible to use equations based on plate theory which exactly correspond to the particular load case and lead to a factor of 68 if x/y ≈ 0,5. Therefore, an additional correction coefficient k was introduced, which, depending on x/y, gives sufficiently accurate results.

### 6.1.3 Aspect ratio 0,5 ≤ x/y ≤ 2

The minimum skin thickness shall be calculated according to equation (9).

$$t = \sqrt{\frac{\beta_2\,p\,y^2}{\sigma_{al.}}} \qquad (9)$$

The maximum deflection of the skin shall be calculated according to equation (10).

$$f = \frac{\alpha_2\,p\,y^4}{E_{c(al.)_D}\,t^3} \qquad (10)$$

The values for $\beta_2$ and $\alpha_2$ shall be taken from Table 1.

### 6.1.4 Aspect ratio x/y > 2

The minimum skin thickness shall be calculated according to equation (11).

$$t = \sqrt{\frac{p\,y^2}{2{,}5\,\sigma_{al.}}} \tag{11}$$

The maximum deflection of the skin shall be calculated according to equation (12).

$$f = \frac{p\,y^4}{35\,E_{c(al.)_D}\,t^3} \tag{12}$$

NOTE: The tank wall here is considered on the one hand as a fixed beam and on the other hand as a freely supported beam with triangular load.

## 6.2 Calculation of rim stiffeners

The deflection of the rim stiffeners shall be calculated as a mean between a freely supported (f = 5/384) and a fixed beam (f = 1/384) with a uniformally distributed load. The rim stiffening takes up 1/5th of the wall load as uniformally distributed load. To allow the rim stiffening to be assumed as a fixed support, its deflection shall not be greater than 1 % of the length or depth. The smaller distance has the greatest effect. The deflection of the rim stiffener shall be calculated according to equation (13).

$$f = \frac{p\,y\,x^4}{1\,280\,E\,J} \tag{13}$$

NOTE: The ratio p/1 280 comes from: $\dfrac{0{,}5\,p}{2 \times 5 \times (\frac{5}{384} + \frac{1}{384})}$

The maximum bending moment (M) in the rim stiffener shall be calculated according to equation (14).

$$M = \frac{p\,y\,x^2}{100} \tag{14}$$

The moment of resistance (W) of the rim stiffener shall be calculated according to equation (15).

$$W = \frac{p\,y\,x^2}{100\,\sigma_{al.}} \tag{15}$$

When the deflection (f) is used in the design calculations the moment of inertia (J) of the stiffener shall be calculated according to equation (16).

$$J = \frac{p\,y\,x^4}{1\,280\,E\,f} \tag{16}$$

NOTE: The bending moment of a beam with a linear load, which is considered as a mean between freely supported and fixed beam is:

$$M = \frac{F\,x}{10}$$

The tank wall is considered to be fixed at the bottom and to be freely supported at the rim stiffener. Consequently the load at the rim is 1/5th of the load on the tank wall.

Hence,

$$F = \frac{1}{5}\,\frac{p\,x\,y}{2}$$

when p is the pressure at the base of the tank.

This leads to the equation:

$$M = \frac{p\,y\,x^2}{100}$$

The same procedure is adopted for the deflection [see equation (13)].

## 7 Tanks with intermediate horizontal stiffeners supported on a continuous flat rigid surface

### 7.1 General

This design is principally for large tanks. The skin thicknesses shall be calculated individually for each panel. The depths of the panels can be determined so that, as far as possible, equal skin thicknesses result. On the other hand, the panel depths may be fixed so that each stiffener is subjected to an equal load. The weight of the stiffeners shall not contribute significant additional loading to the tank wall. If necessary, the stiffeners shall be supported independently of the tank wall.

The thickness of the base shall be of similar magnitude to the actual thickness of the skin.

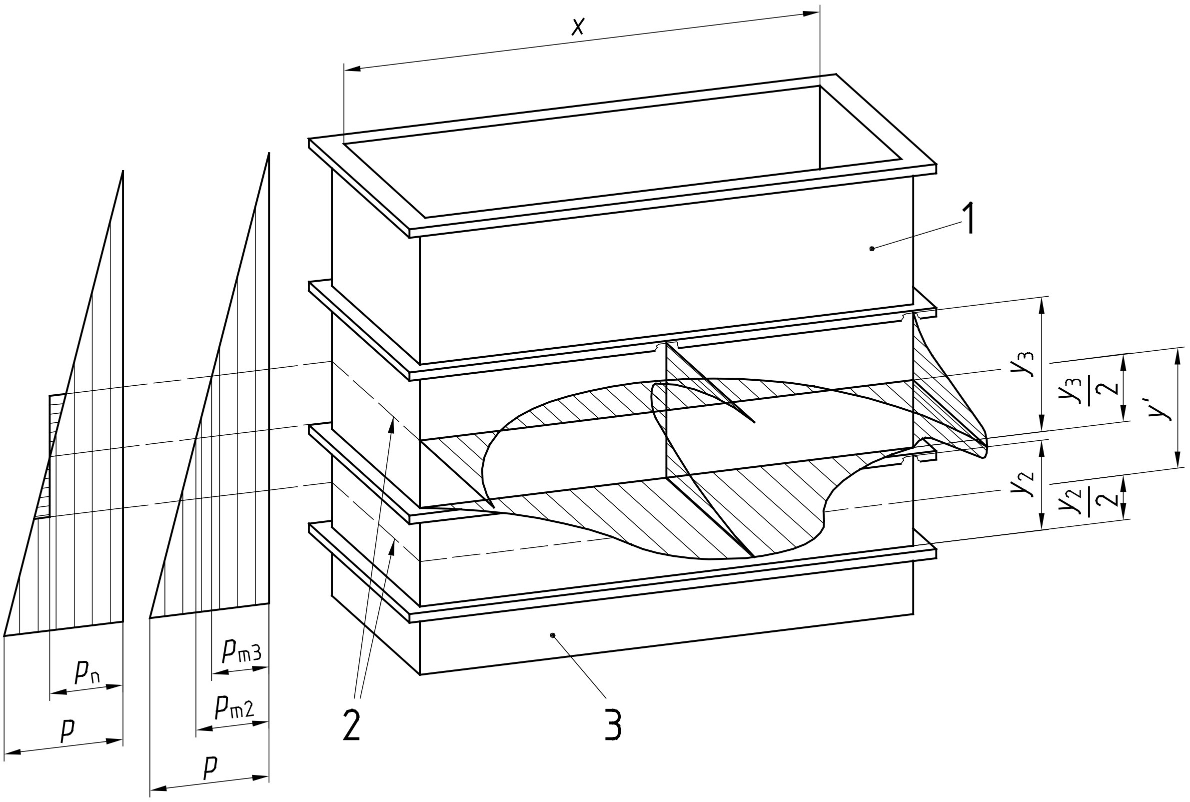
### 7.2 Calculation of the minimum skin thickness

#### 7.2.1 General

The method of calculation for the individual panels depends upon their position and their aspect ratios. The free panel depth $y_n$ (n = 1, 2, 3 ...) shall be substituted for y in the equation.

#### 7.2.2 Calculation for the top panel

The equations detailed in 6.1 shall be used. In this case, the pressure at the stiffener immediately adjacent to the rim stiffener shall be substituted in the equations for the surface pressure (p). The depth of the top panel shall be substituted for the overall tank depth (y).



1 Top panel
2 Bottom panel
3 Intermediate panels

**Figure 8: Principal distribution of bending moments in a tank with intermediate horizontal stiffeners**

### 7.2.3 Calculation for the intermediate and bottom panels

**7.2.3.1** General

For the calculation, a mean value of excess pressure $p_m$ shall be assumed (see Figure 8).

**7.2.3.2** Aspect ratio x/y < 0,5

The equations detailed in 6.1.2 shall be used.

**7.2.3.3** Aspect ratio 0,5 ≤ x/y ≤ 2

The minimum skin thickness shall be calculated according to equation (17).

$$t = \sqrt{\frac{\beta_3 \, p_m \, y^2}{\sigma_{al.}}} \qquad (17)$$

The maximum deflection of the skin shall be calculated according to equation (18).

$$f = \frac{\alpha_3 \, p_m \, y^4}{E_{c(al.)_D} \, t^3} \tag{18}$$

The values for $\beta_3$ and $\alpha_3$ shall be taken from Table 1.

**7.2.3.4** Aspect ratio x/y > 2

The minimum skin thickness shall be calculated according to equation (19).

$$t = \sqrt{\frac{p_m y^2}{2 \sigma_{al.}}} \tag{19}$$

The maximum deflection of the skin shall be calculated according to equation (20).

$$f = \frac{p_m \, y^4}{32 \, E_{c(al.)_D} \, t^3} \tag{20}$$

NOTE: This is the equation for the uniformly loaded plate fixed on all sides.

## 7.3 Calculation of the horizontal stiffeners

The stiffeners shall be assumed to be a mean between freely supported and constrained beams. This statement is correct only for rigid corner joints of the stiffeners. The corresponding panel load is obtained from an excess pressure $p_n$ (n = 1, 2, 3 ...) averaged over half the top and bottom panel depth (see Figure 8). The dimensions of the bottom stiffener shall be such that its deflection does not exceed 1 % of the bottom panel depth. This restricts the stress applied to the weld on the tank base. The properties of the stiffeners, with the exception of the rim stiffener, shall be calculated according to equations (21), (22) and (23).

$$f = \frac{p_n \, y' \, x^4}{128 \, E \, J} \tag{21}$$

$$M = \frac{p_n \, y' \, x^2}{10} \tag{22}$$

$$W = \frac{p_n \, y' \, x^2}{10 \, \sigma_{al}} \tag{23}$$

These expressions provide the basis on which the section size and profile of the stiffener can be determined. Precise details of dimensions and profile shape shall be agreed between the tank manufacturer and the supplier of the profile sections.

The rim stiffening shall be calculated in accordance with 6.2. For this purpose, the pressure at the intermediate stiffener adjacent to the rim stiffener is used in the equations for surface pressure p. For y, the top panel depth is employed.

# 8 Tanks with cross-ribbed horizontal and vertical stiffeners supported on a continuous rigid surface

## 8.1 Calculation of the minimum skin thickness, base thickness and properties of horizontal stiffeners

The minimum skin thickness, base thickness and properties of horizontal stiffeners shall be calculated using the relevant equations given in clause 7.

## 8.2 Calculation of the properties of vertical stiffeners

The method of calculation is based on the assumption that the deflection of the rim stiffener is taken as the mean between the deflection of a freely supported beam and a fixed beam with a linear increasing load. In order that it can be assumed to be a fixed support, the deflection of the rim stiffener shall not be greater than 1 % of the depth or length of the top panel which ever is the shorter.

As the marginal reinforcement shall serve as a support for the vertical carrier, it shall be dimensioned with the total length x (distance between the vertical stiffeners).

The properties of the stiffeners shall be calculated according to equations (24), (25) and (26).

$$f = \frac{p\,x'\,y^4}{255\,E\,J} \tag{24}$$

$$M = \frac{p\,x'\,y^2}{17{,}5} \tag{25}$$

$$W = \frac{p\,x'\,y^2}{17{,}5\,\sigma_{\mathrm{al.}}} \tag{26}$$

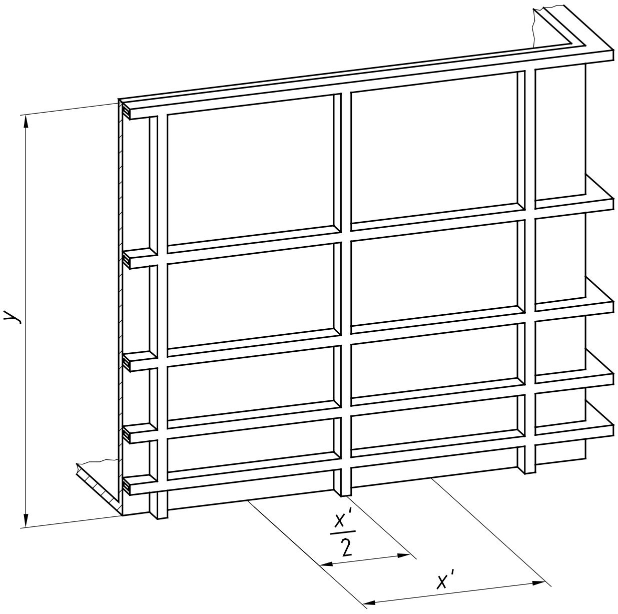
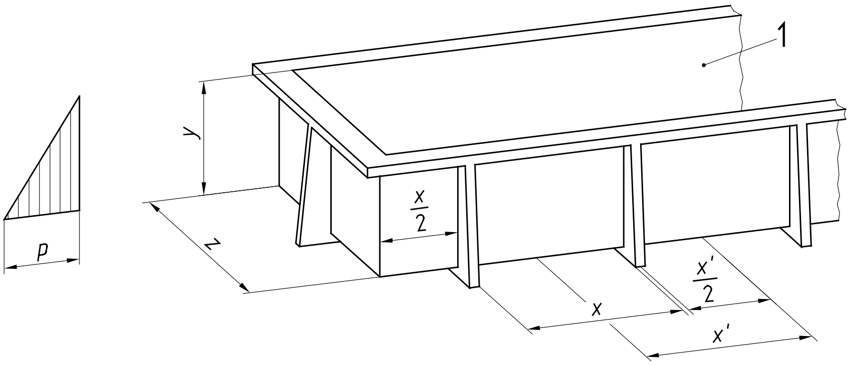


Figure 9: Tank with cross-ribbed horizontal and vertical stiffeners

# 9 Rectangular tanks with U-frame

## 9.1 General

This form of construction is used in cases where a horizontal stiffener is impracticable, e.g. very long tanks as in Figure 10.



1 Skin, a sheet of thermoplastic

NOTE: Distribution of bending moments is as shown in Figure 7.

**Figure 10: Tank with U-frame stiffening**

## 9.2 Calculation of the skin thickness of the side walls

The equations detailed in 6.1 shall be used.

## 9.3 Determination of the tank base

### 9.3.1 Aspect ratio x/z < 0,5

The minimum skin thickness shall be calculated according to equation (27).

$$t = \sqrt{\frac{p\,x^2}{3\,\sigma_{\text{al.}}}} \tag{27}$$

The maximum deflection of the skin shall be calculated according to equation (28).

$$f = \frac{p\,x^4}{16\,k\,E_{c(\text{al.})_D}\,t^3} \tag{28}$$

The correction coefficient k is either 1 when $x < z$ or 2 when $x/z \approx 0{,}5$.

### 9.3.2 Aspect ratio 0,5 ≤ x/z ≤ 2

The minimum skin thickness shall be calculated according to equation (29).

$$t = \sqrt{\frac{\beta_3 \, p \, z^2}{\sigma_{al.}}} \qquad (29)$$

The maximum deflection of the skin shall be calculated according to equation (30).

$$f = \frac{\alpha_3 \, p \, z^4}{E_{c(al.)_D} \, t^3} \qquad (30)$$

### 9.3.3 Aspect ratio x/z > 2

The minimum skin thickness shall be calculated according to equation (31).

$$t = \sqrt{\frac{p \, z^2}{2 \, \sigma_{al.}}} \qquad (31)$$

The maximum deflection of the skin shall be calculated according to equation (32).

$$f = \frac{p \, z^4}{32 \, E_{c(al.)_D} \, t^3} \qquad (32)$$

## 9.4 Calculation of the U-frame stiffening

The size of the U-frame stiffening shall be calculated, assuming they are continuous beams on two supports with cantilevers on either side. These cantilevers are subjected to triangular load and the beam is loaded at a stress equivalent to the pressure at the base of the tank.

# 10 Determination of the tank cover

## 10.1 General

Plate theory is used in these calculations. The preferred design of the cover is without stiffening. If the temperature exceeds 60 °C any stiffener shall be fitted on the top of the cover. If the cover is still prone to warping, diagonal stiffeners shall be fitted. The letter (x) always designates the longer side.

## 10.2 Freely supported tank cover

The minimum skin thickness of a freely supported tank cover (see Figure 11) shall be calculated according to equation (33).

$$t = \sqrt{\frac{\beta_5 \, p_D \, x^2}{\sigma_{al.}}} \qquad (33)$$

The maximum deflection of the cover shall be calculated according to equation (34).

$$f = \frac{\alpha_5 p_D x^4}{E_{c(al.)_D} t^3} \tag{34}$$

The values for $\alpha_5$ and $\beta_5$ shall be taken from Table 1.

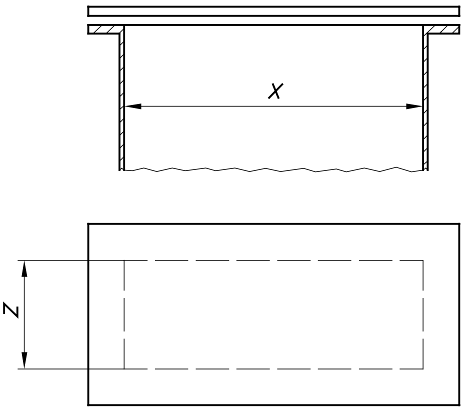


**Figure 11: Reference dimensions for tank cover**

## 10.3 Fixed tank cover

### 10.3.1 General

Figures 12 and 13 detail reference dimensions for the effect of internal and external pressure on the tank cover.

### 10.3.2 Aspect ratio 1 ≤ x/z ≤ 2

The minimum skin thickness shall be calculated according to equation (35).

$$t = \sqrt{\frac{\beta_3 p_D x^2}{\sigma_{al.}}} \tag{35}$$

The maximum deflection of the skin shall be calculated according to equation (36).

$$f = \frac{\alpha_3 p_D x^4}{E_{c(al.)_D} t^3} \tag{36}$$

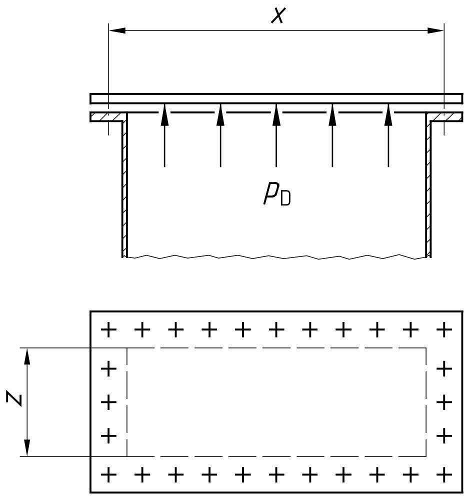
### 10.3.3 Aspect ratio x/z > 2

The minimum skin thickness shall be calculated according to equation (37).

$$t = \sqrt{\frac{p_D x^2}{2 \sigma_{al.}}} \tag{37}$$

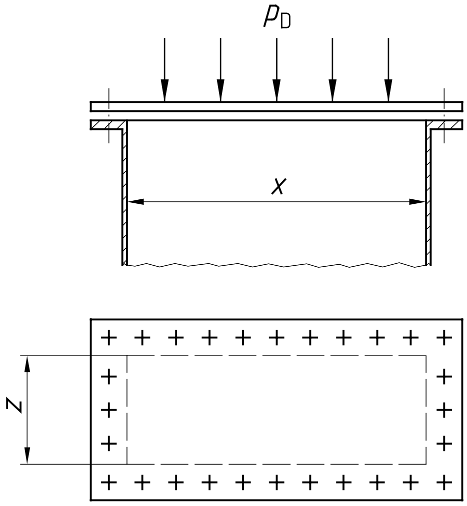
The maximum deflection of the skin shall be calculated according to equation (38).

$$f = \frac{p_D x^4}{32 E_{c(al.)_D} t^3} \tag{38}$$



↑ $p_D$ - Direction of force due to pressure

Figure 12: Reference dimensions for internal pressure on the tank cover



↓ $p_D$ - Direction of force due to pressure

Figure 13: Reference dimensions for external pressure on the tank cover

## 10.4 Stiffened tank cover

### 10.4.1 Calculation of skin thickness and deflection

The equations detailed in 10.3.2 or  10.3.3 shall be used.

### 10.4.2 Determination of the dimensions of stiffeners used with a tank cover

The moment of resistance (W) of a stiffened tank cover (see Figure 14) shall be calculated according to equation (39).

$$W = \frac{x^2 z p_D}{8 \sigma_{al.}} \qquad (39)$$

When the deflection (f) is used in the design calculations the moment of inertia (J) of the stiffeners shall be calculated according to equation (40).

$$J = \frac{5 p_D z x^4}{384 E f} \qquad (40)$$

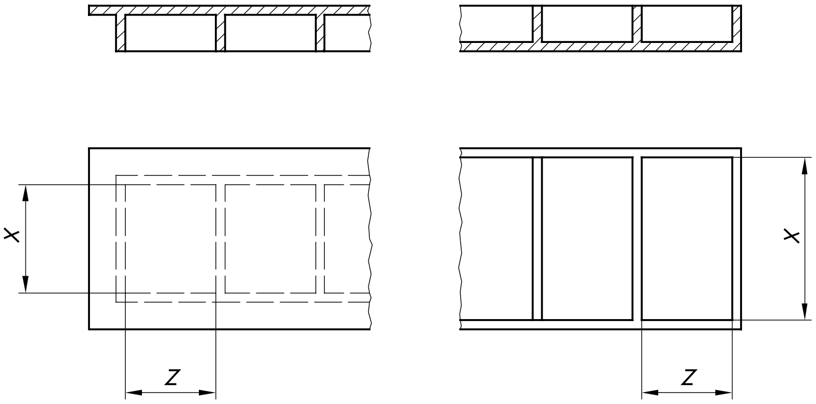


Figure 14: Reference dimensions of stiffened tank cover

**Table 1: Deformation coefficients $\alpha$ and skin thickness coefficients $\beta$**

| x/y and x/z | $\alpha_1$ | $\beta_1$ | $\alpha_2$ | $\beta_2$ | $\alpha_3$ | $\beta_3$ | $\alpha_5$ | $\beta_5$ |
|---|---|---|---|---|---|---|---|---|
| 0,5 | 0,0009 | 0,09 | 0,00092 | 0,074 | 0,0019 | 0,13 | - | - |
| 0,6 | 0,0020 | 0,10 | 0,0020 | 0,097 | 0,0037 | 0,17 | - | - |
| 0,7 | 0,0035 | 0,12 | 0,0032 | 0,12 | 0,0061 | 0,22 | - | - |
| 0,8 | 0,0055 | 0,15 | 0,0049 | 0,15 | 0,0090 | 0,26 | - | - |
| 0,9 | 0,0075 | 0,18 | 0,0068 | 0,18 | 0,012 | 0,29 | - | - |
| 1,0 | 0,011 | 0,21 | 0,0088 | 0,21 | 0,015 | 0,31 | 0,045 | 0,29 |
| 1,2 | 0,017 | 0,27 | 0,013 | 0,26 | 0,021 | 0,39 | 0,063 | 0,38 |
| 1,4 | 0,028 | 0,33 | 0,017 | 0,31 | 0,025 | 0,44 | 0,078 | 0,45 |
| 1,6 | 0,046 | 0,43 | 0,020 | 0,34 | 0,028 | 0,47 | 0,09 | 0,52 |
| 1,8 | 0,061 | 0,45 | 0,022 | 0,35 | 0,029 | 0,49 | 0,10 | 0,57 |
| 2,0 | 0,082 | 0,50 | 0,024 | 0,36 | 0,031 | 0,50 | 0,11 | 0,61 |
| 2,5 | 0,138 | 0,64 | 0,0258 | 0,37 | 0,031 | 0,50 | 0,13 | 0,68 |
| 3,0 | 0,194 | 0,74 | 0,0260 | 0,37 | 0,031 | 0,50 | 0,14 | 0,71 |
| 4,0 | 0,259 | 0,87 | 0,0264 | 0,38 | 0,031 | 0,50 | 0,14 | 0,74 |
| $\infty$ | 0,4 | 1,0 | 0,029 | 0,4 | 0,031 | 0,50 | 0,14 | 0,75 |

Linear interpolation shall be used to establish intermediate values.

# Annex A (informative)

# Construction details for rectangular tanks

## A.1 General design principles

General rules for design and dimensions of welded joints should be in accordance with Annex B of EN 12573-1:2000.

Significant differences in expansion between the stiffeners and the tank wall, caused by temperature changes, should be allowed for in the construction.

Any stresses on nozzles caused by fittings and pipework (for example through thermal expansion and weights) shall be avoided by using compensators or appropriate arrangement and installation of the pipework.

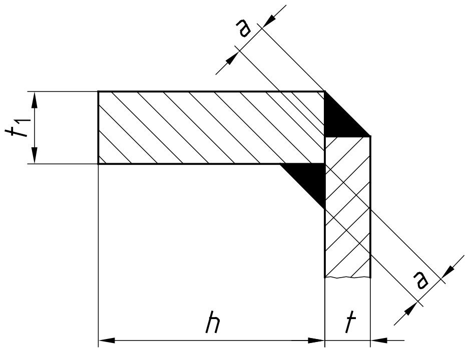
## A.2 Symbols and abbreviations

For the purposes of this annex of this part of this standard the following symbols and definitions apply:

| | |
|---|---|
| a | is the depth of weld seam, in millimetres |
| d | is the depth of a U-profile, in millimetres |
| $f_1$ | is the depth of the weld undercut, in millimetres |
| $f_2$ | is the height of the external weld build, in millimetres |
| h | is the width of stiffener, in millimetres |
| l | is the distance between the end of the curved section and any weld, in millimetres |
| R | is the radius of a construction element, in millimetres |
| $t_n$ | is the thickness of a construction element, in millimetres |
| u | is the protrusion of the base beyond the tank skin, in millimetres |
| $\alpha$ | is the included angle, in degree (for the Figures A.2, A.3 and A.9 between 45° and 90°) |

## A.3 Design examples

### A.3.1 Horizontal rim stiffeners



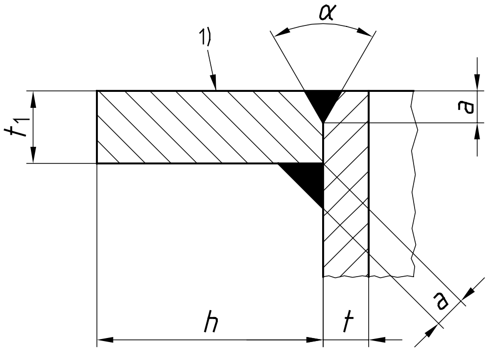
$t_1 > t$

$a = 0,7 \times t$

$h/t_1 \leq 8$

1) Prepared if necessary.

Figure A.1: Web with filled welds

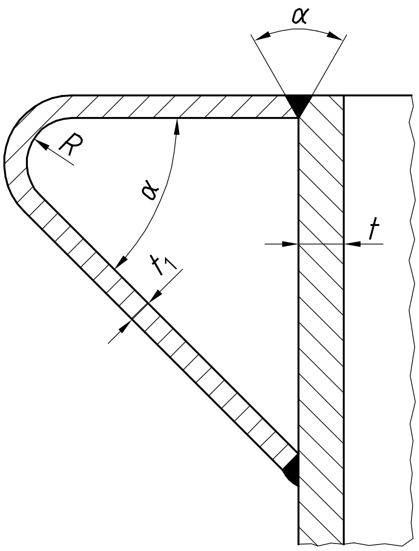


$t_1 > t$

$a = 0,7 \times t$

$h/t_1 \leq 8$

Figure A.2: Web with fillet and single-V weld



$t_1 < t$

$R \leq 2 \times t_1$, but not smaller than 10 mm, or swivel-bending weld

Figure A.3: Triangle section

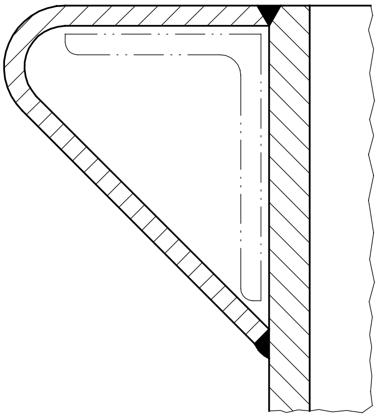
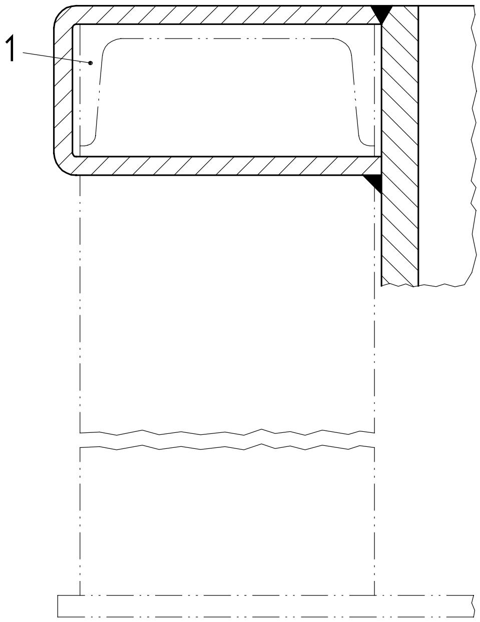


Figure A.4: Triangular section with steel frame insert

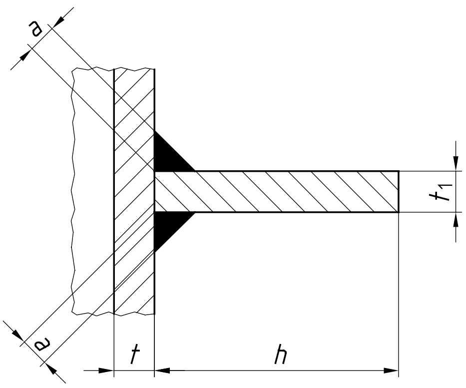


1) steel

For the supporting frame, a variety of section profiles may be used. In the case of heavy profiles leading to increased vertical loads, the resultant forces should be taken up by vertical supports. Instead of welding by bending using a heated tool, simple bending may also be considered, e.g. for PVC.

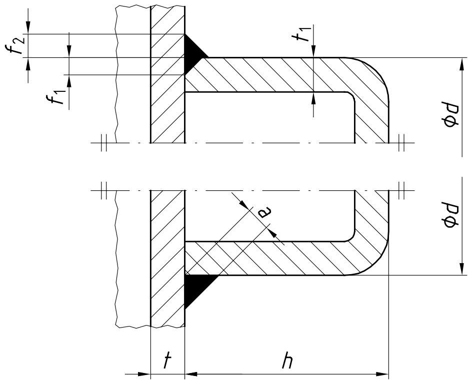
Figure A.5: Rectangular section with steel insert

### A.3.2 Horizontal intermediate stiffeners



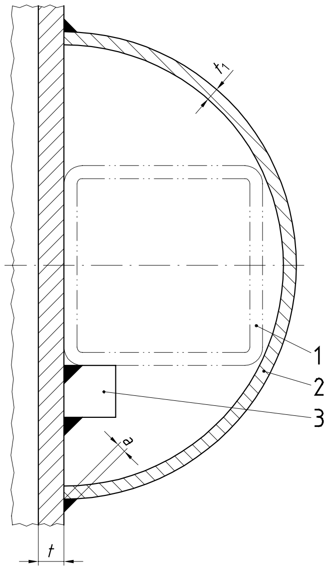
$t_1 \geq t$
$a = 0{,}7 \times t$
$h/t_1 \leq 8$

Figure A.6: Flat section



$h/t_1 \leq 12$
$f_2 = 0{,}7 \times t_1$
$f_1 = 0{,}5 \times t_1$
$a = 0{,}7 \times t_1$
$d \leq h$

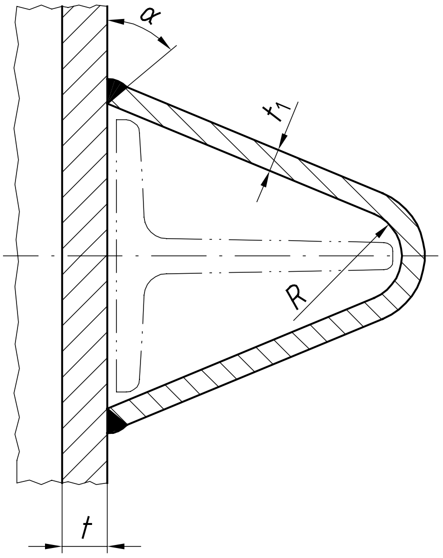
Figure A.7: U-section profile



1) Sectional steel frame
2) Halved pipe
3) Support
$t_1 < t$
$a = 0{,}7 \times t_1$

Length of support approx. 100 mm
Distance approx. 1 000 mm

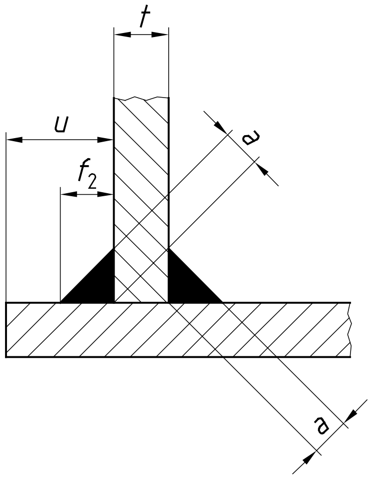
Figure A.8: Enclosed square steel pipe



$t_1 < t$
$R \leq 2 \times t_1$, but not smaller than 10 mm,
or swivel-bending weld

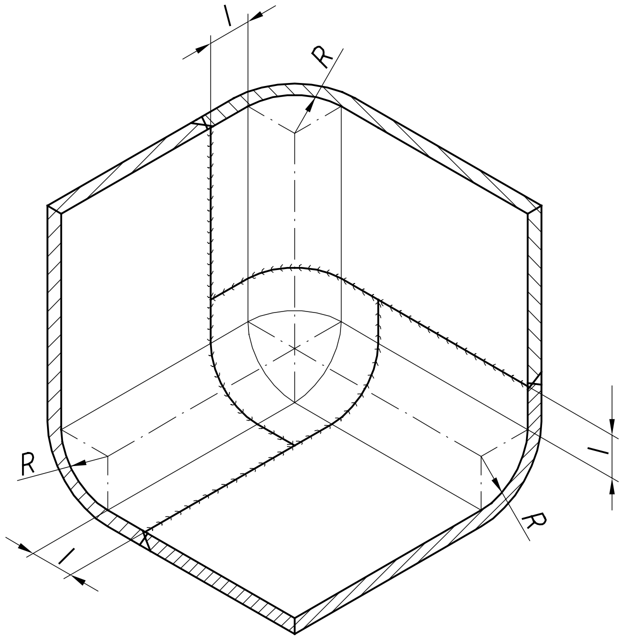
Figure A.9: Enclosed T-section steel frame

### A.3.3 Joint between outer wall and tank base



$f_2 < u \leq f_2 + 10$ mm depending
on welding process
$a = 0,7 \times t$

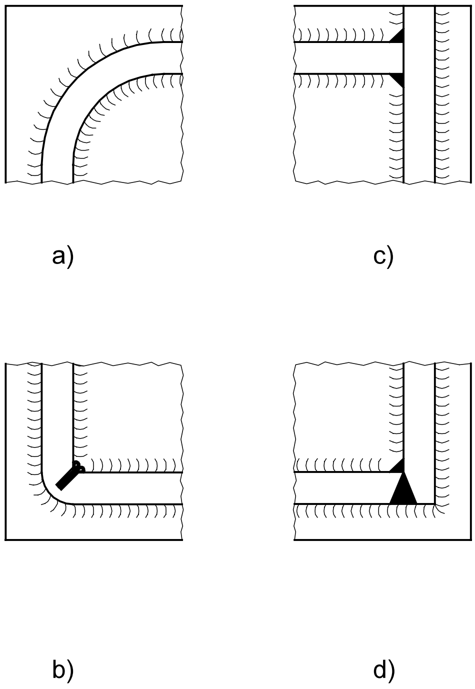
**Figure A.10: T-joint with double fillet weld**



$l \geq 50$ mm; $R \geq 50$ mm

**Figure A.11: Rounded transition between outer wall and tank base**

### A.3.4 Vertical tank corners

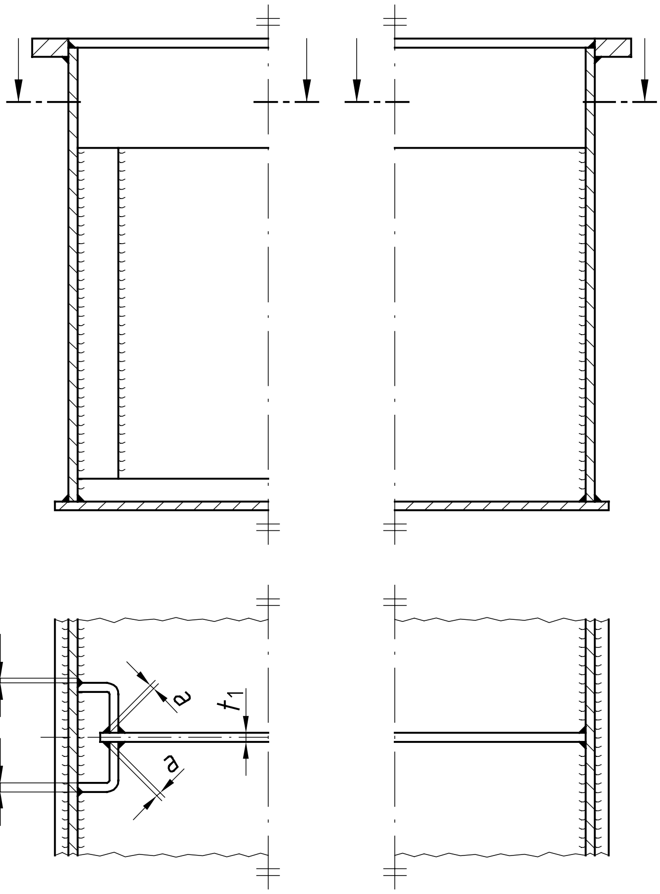

a)
c)
b)
d)

a) hot-formed
b) hot bent weld
c) T-joint with double fillet weld
d) joint with fillet and single V-weld

In general types a) and b) should be used. Where the walls are sufficiently stiff, types c) and d) are also permissible.

**Figure A.12: Different types of corners**

### A.3.5 Partition walls



**a)** **b)**

$t_2 \leq t_1$

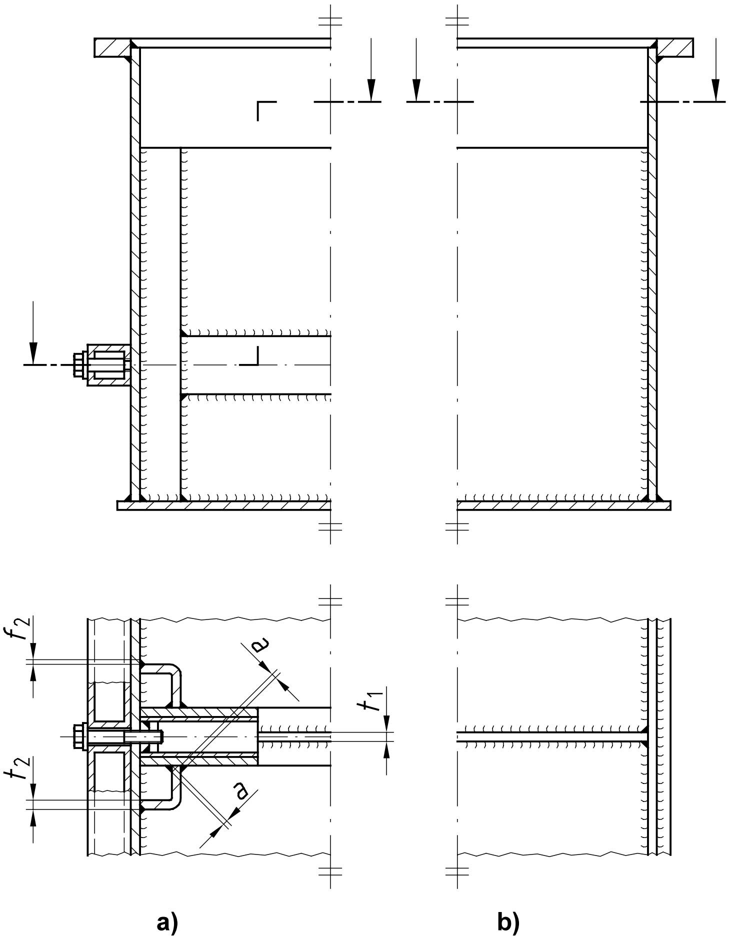
$a = 0{,}5 \times t_2$

$f_2 = 0{,}5 \times t_2$

a) Partition wall with compensation to reduce the stress on the welds. If the partition wall is welded to the base, compensation on both sides is necessary.

b) The partition wall also acts as a tie bar. The weld connection is to be dimensioned accordingly.

**Figure A.13: Partition wall stressed uniformly on both sides**



$t_2 \leq t_1$

$a = 0,5 \times t_2$

$f_2 = 0,5 \times t_2$

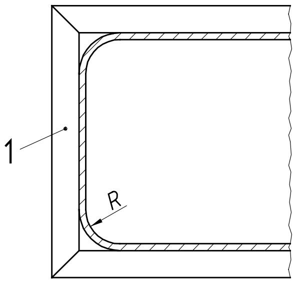
Welding details as for Figure A.13.

a) The steel strengthening of the partition wall also acts as a tie bar. The calculation length of the horizontal intermediate stiffener is thereby reduced.

b) The partition wall also acts as a tie bar. The weld connection is to be dimensioned accordingly.

**Figure A.14: Partition wall stressed on one side only**

### A.3.6 Construction arrangements to take up differences in expansion between stiffeners and the tank wall

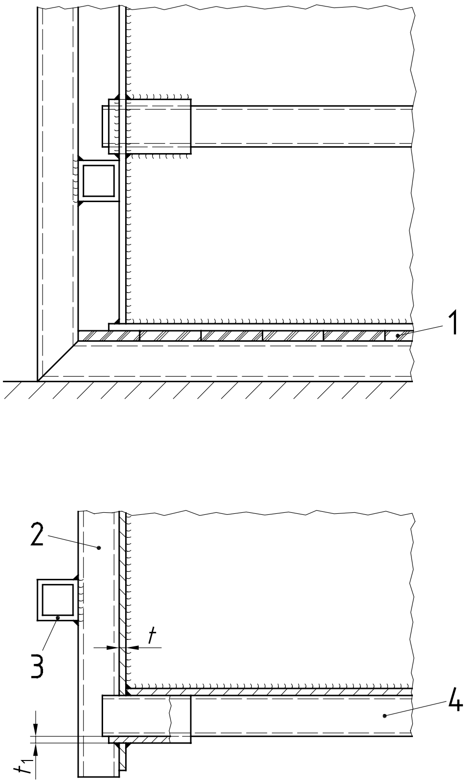


Strengthening borders on the tank. Differences in expansion are taken up in corner regions.

R ≥ 50 mm

1) Steel frame

**Figure A.15: Rounded corners to allow expansion**



The tank can slide in the longitudinal direction within the steel structure.

$t = t_1$

1) Continuous support e.g.of timber

2) Longitudinal beam

3) Yoke

4) End beam

**Figure A.16: Longitudinal and end beam independent of each other**

### A.3.7 Tank nozzles

Nozzles of small nominal bore (DN ≤ 50) require stiffening in the form of ribs, cones or the like, as shown in Figures A.17 and A.18.

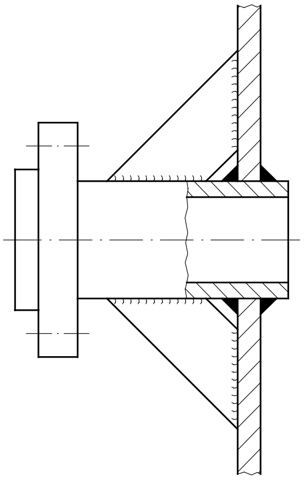


Figure A.17: Nozzles with rib stiffeners

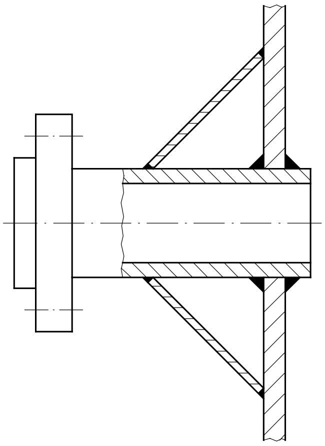
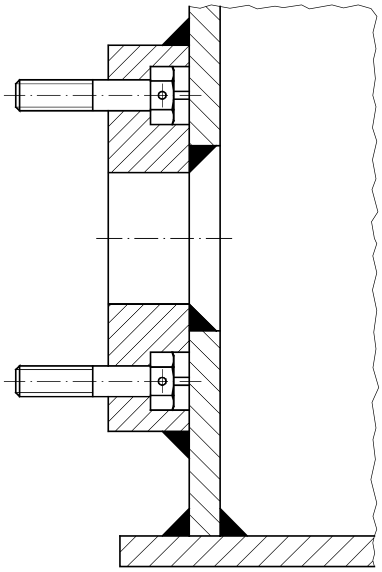


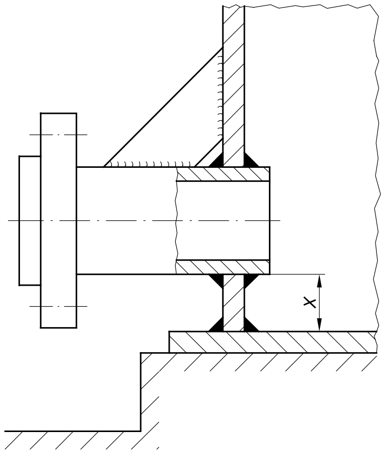
Figure A.18: Nozzles with conical stiffeners



In this flange configuration bolts need to be secured prevent twisting, for example by:

- Hot pressing bolt head into reverse of plate (drill holes equal to distance across bolt heads flats), or
- A wire ring passed through bolt heads, or
- A complete steel ring with threaded studs welded to it.

Figure A.19: Blind flange



The distance "x" should provide sufficient to clearance for welding.

Figure A.20: Nozzle close to base

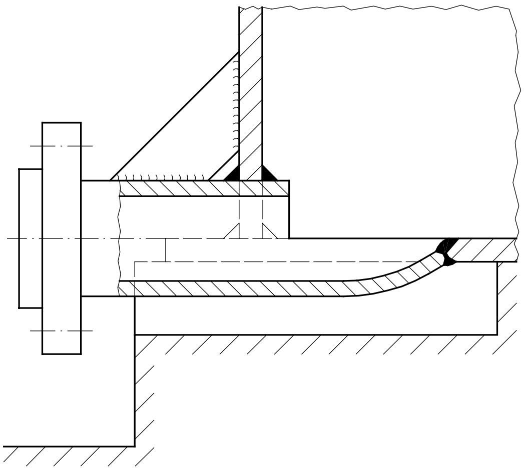


Figure A.21: Lateral outlet nozzle on tank base

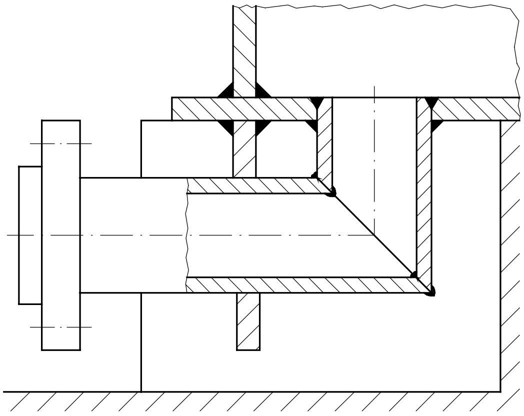


Figure A.22: Outlet nozzle on tank base

# Annex B (informative)

## Special cases

The use of the annex is optional but if used for special cases the content becomes normative.

### B.1 Intermittently supported tank bases

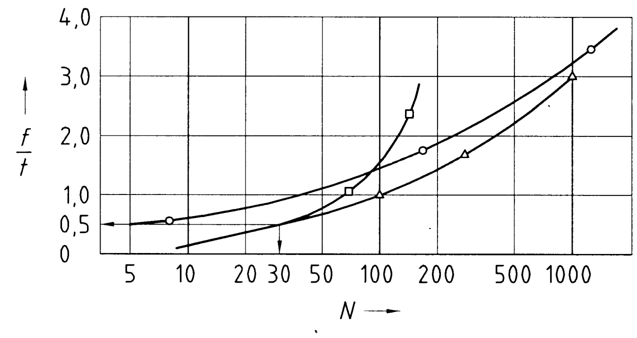
In those cases where the tank does not rest evenly on the ground but stands in or on a supporting frame, the properties of the tank base should be calculated according to 9.3.

### B.2 Limits of validity for the plate theory design method

### B.2.1 General

Because unreinforced plastics have low stiffness, this limits their ability to absorb external bending loads especially if the component has a high surface area. When the deflection of a panel amounts to more than half the panel wall thickness, a considerable portion of the load is absorbed by membrane forces, i. e. tensile forces, (see Figure B.1). This means that in the calculations a distinction between several cases needs to be made.The cases are distinguished on the basis of rigidity N. The value of N is calculated in accordance with equation B.1.

$$N = \frac{p\,y^4}{E_{c(al.)_D}\,t^4} \qquad \text{(B.1)}$$



□ rigid plate
O membrane
∈ plate and membrane

Figure B.1: Regions of validity of plate and membrane theory

### B.2.2 Rigidity coefficient N ≤ 30

The equations detailed in clause 6 and 9.3 should be used.

### B.2.3 Rigidity coefficient N > 30

The equations for bending and tensile stress may be used. For a plate fixed on four sides where the load is distributed uniformly and has an aspect ratio x/y = 1, $\alpha_4$ = 0,32 and $\beta_4$ = 0,24 the minimum skin thickness shall be calculated according to equation (B.2),

$$t = \sqrt{A^2 + B} - A \tag{B.2}$$

where

$$A = \frac{\beta_3}{2\,\beta_4} \times y \sqrt{\frac{\sigma_{al.}}{E_{c(al.)_D}}}$$

$$B = \frac{p\,y^2\,\beta_3}{\sigma_{al.}}$$

The maximum deflection of the skin shall be calculated according to equation (B.3),

$$f = \sqrt[3]{C + \sqrt{C^2 + D}} \tag{B.3}$$

where

$$C = \frac{\alpha_4^3}{2} \times \frac{p\,y^4}{E_{c(al.)_D}\,t}$$

$$D = \frac{\alpha_4^9\,t^6}{27\,\alpha_3^3}$$

### B.2.4 Rigidity coefficient N > 1 000

In the case of very high N values, equations based on membrane theory may be used. (For N = 1 000, the error is about 6 % when compared with the expressions for N > 30 and x/y = 1.)

The minimum skin thickness shall be calculated according to equation (B.4).

$$t = \beta_4\,p\,y \sqrt{\frac{E_{c(al.)_D}}{\sigma_{al.}^3}} \tag{B.4}$$

The maximum deflection of the skin should be calculated according to equation (B.5).

$$f = \alpha_4 \sqrt[3]{\frac{y^4\,p}{t\,E_{c(al.)_D}}} \tag{B.5}$$

The values for $\beta_3$, and $\alpha_3$ shall be taken from Table 1. The values for $\alpha_4$ and $\beta_4$ according to B.2.3.

# Annex C (informative)

## A-deviations

A-deviation: National deviation due to regulations, the alteration of which is for the time being outside the competence of the CEN/CENELEC member.

This European Standard does not fall under any Directive of the EU. In the relevant CEN/CENELEC countries these A-deviations are valid instead of the provisions of the European Standard until they have been removed.

### Germany

- Verordnung über Anlagen zur Lagerung, Abfüllung und Beförderung brennbarer Flüssigkeiten zu Lande (Verordnung über brennbare Flüssigkeiten - VbF)

Ausgabe 12.96: Paragraph 4 Absatz 1 und Anhang II Punkt 1.2.1 Absatz a) und Punkt 2.1.2 Absatz (6)

In addition to the requirements of this European Standard the following is valid in Germany:

Walls of tanks for the storage of flammable liquids with flash points below 55 °C or of tanks which shall be installed in a potentially explosive atmosphere shall be constructed in a way that operational processes cannot cause dangerous electrostatic charge.

Therefore the following requirements shall be fullfilled:

- All metal parts of the tanks as well as the electrically conductive layers of the wall shall be conductively connected with each other. The resistance between the conductive parts and the earth shall not exceed $10^6$ Ω.

- The bleeder resistor of accessible surfaces inside and outside of the tank shall not exceed $10^8$ Ω.

- The surface resistance of the tank walls having no electrically conductive layers shall not exceed $10^9$ Ω.

### Sweden

- Act (1989:868) and Ordinance (1989:1145) on Flammables and Explosives

- Regulations on Storage and Handling of Flammables, SIND-FS 1981:2 Kap. 3 and SÄIFS 1995:7 Kap. 5.

In addition to the requirements of this European Standard the following is valid in Sweden:

Tanks for flammables have limitations for use. They are only accepted for flammables with flashpoints > 55 °C as heating oil and diesel fuel.

The tanks have to be approved by a C-type body according to EN 45000 and according to technical requirements issued by the Inspectorate.

Installation of tanks for these flammables are only accepted indoors and with requirements on fire resistance linked to the volume.

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