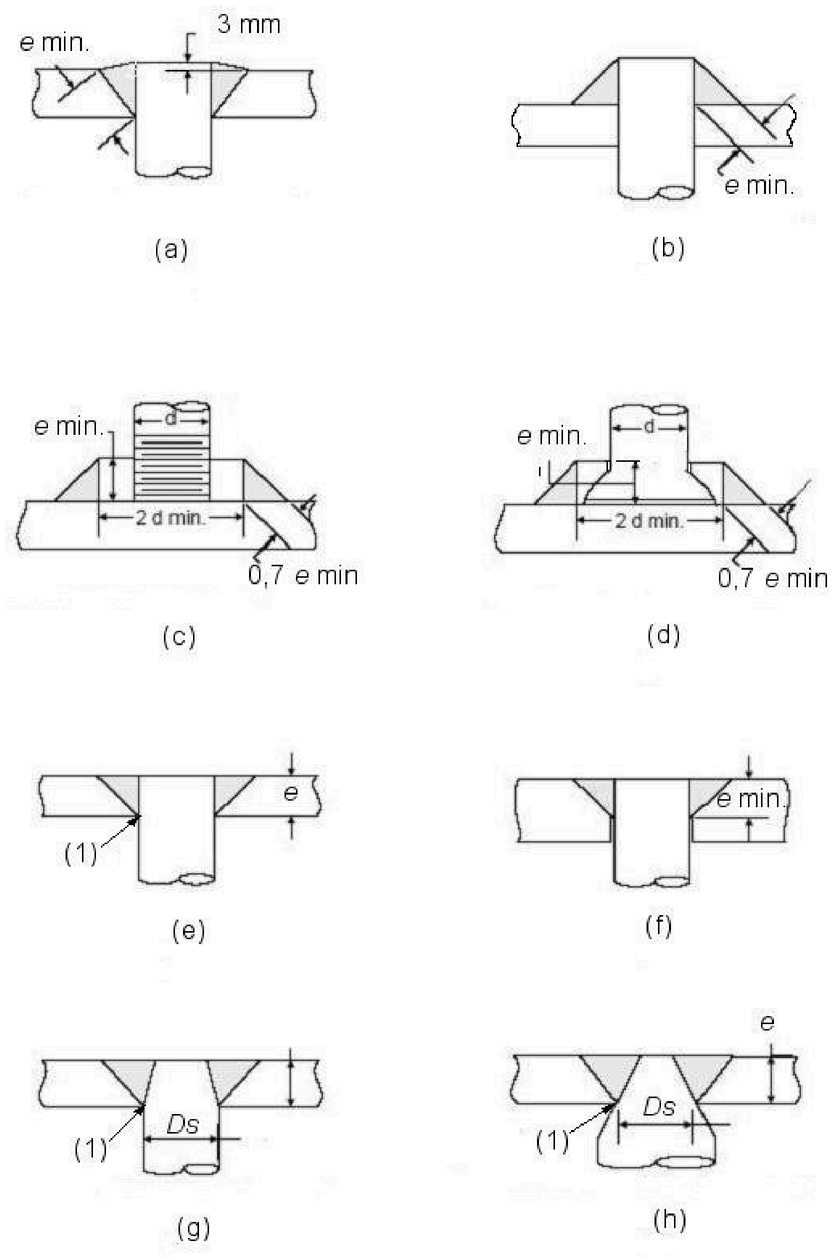
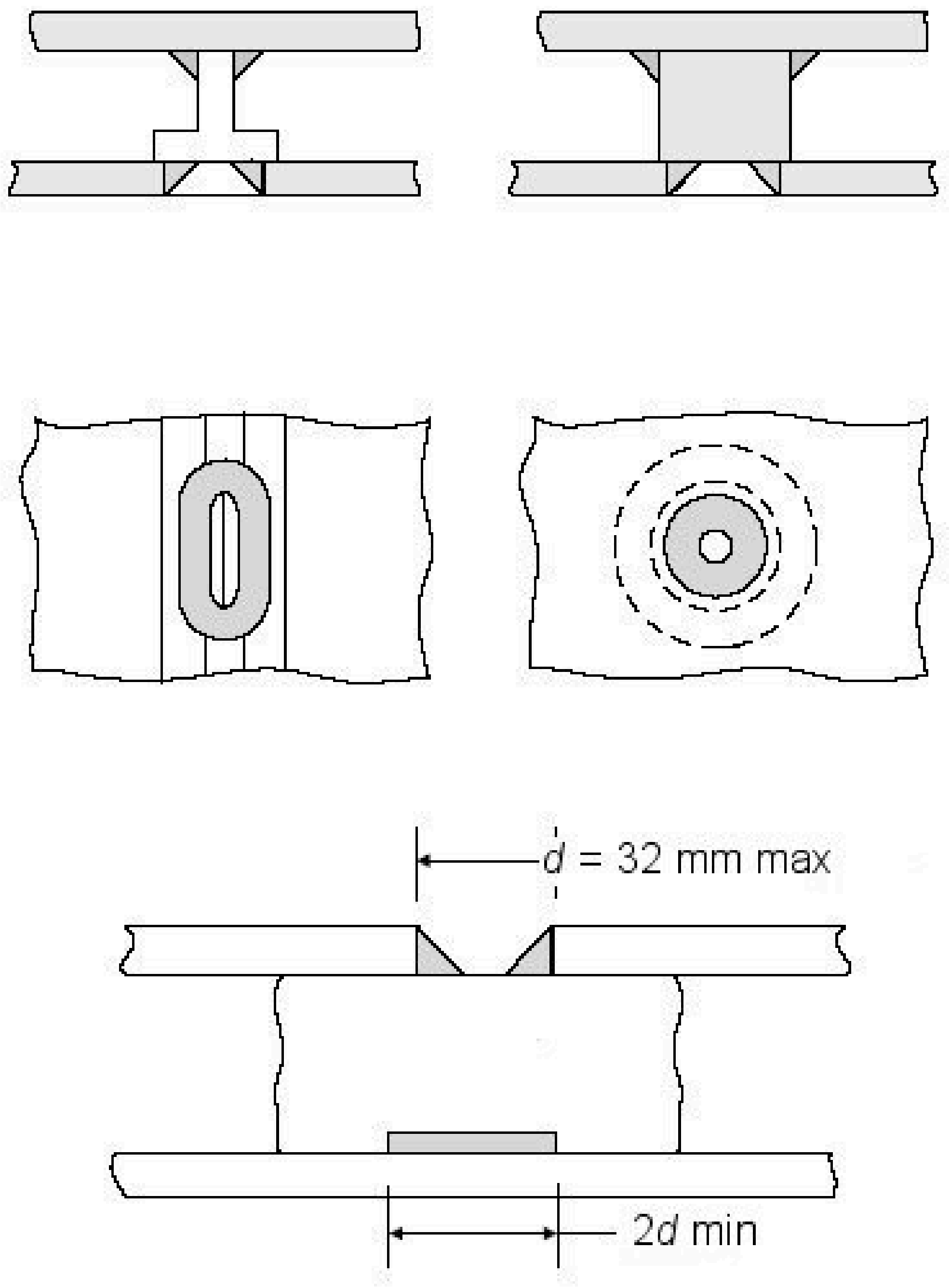


(1) Complete penetration

(2) Details in (c) and (d) consider a round anchor bloc to be fitted between the staybolt and the wall

(3) In Details (g) and (h) *Ds* is the stay diameter to be used in the calculations according to 20.5, after consideration of corrosion and possible negative material tolerances

Figure 20.9-2 — Typical forms of welded staybolts



Min. width of stay bar = *d*

Figure 20.9-3 — Use of plug and slot welds for staying plates

21 Circular flat ends with radial reinforcement ribs

21.1 Purpose

The purpose of the rules in this Clause is to allow the design of circular flat ends reinforced by radial ribs, with or without uniformly distributed peripheral bending moment, subject to pressure.

The components considered in this Clause consist of a circular flat end, reinforced by radial uniformly spaced ribs; the height of the ribs is generally constant, however their profile may be slightly inclined at the outer edge (see Figures 21.2-1, 21.2-2, 21.2-3 and 21.2-4).

The ribs shall be connected with each other at the centre of the end; this may be obtained either by welding them together, or by welding them to a central ring or to a rigid plug. The number of the ribs should be neither smaller than 3 nor greater than 24.

These rules do not deal with the calculation for leak tightness of the connection between the end and the corresponding flange on the vessel; in case the leak tightness has to be assured, the required thickness of the end might be greater than the thickness required by the static calculation, at least in the area of the gasket and relevant bolting.

This kind of construction is not recommended in case of cyclic loadings or in case of external corrosion.

21.2 Specific definitions

The following definitions are in addition to those in Clause 3.

21.2.1
reinforcing rib
rectangular plate located along the radius of a circular flat end, located perpendicularly to its plane and welded to it from both sides

21.2.2
continuous weld
weld between the rib and the end, located on both sides of the rib, for its entire length

21.2.3
intermittent weld
weld between the rib and the end, located on both sides of the rib, composed by different segments interesting only a portion of its length.

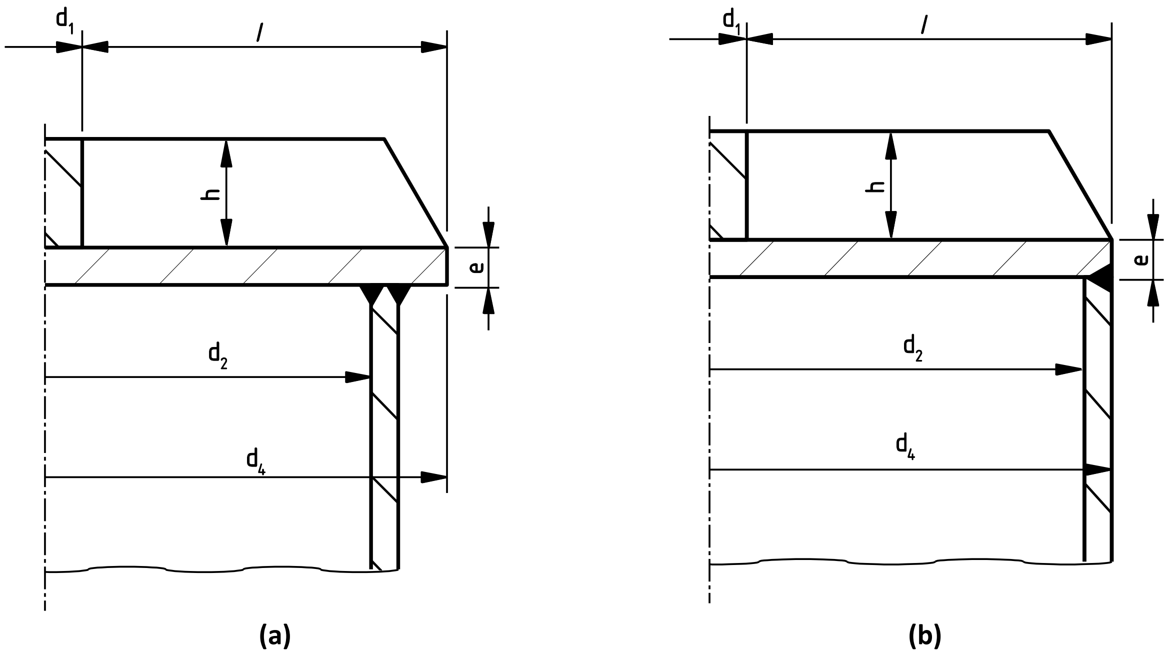


Figure 21.2-1 Welded ends with ribs

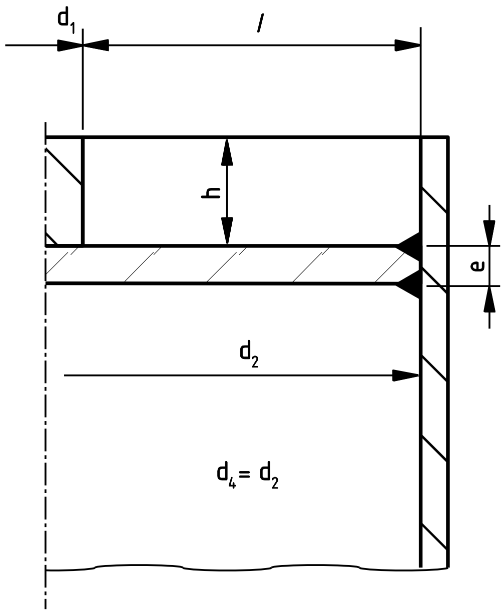


Figure 21.2-2 Welded end with ribs (Ribs welded to a protruding shell)

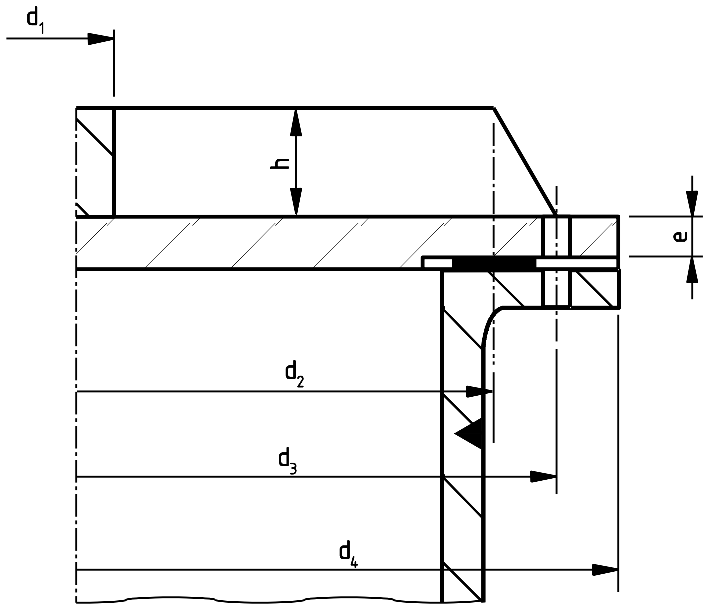
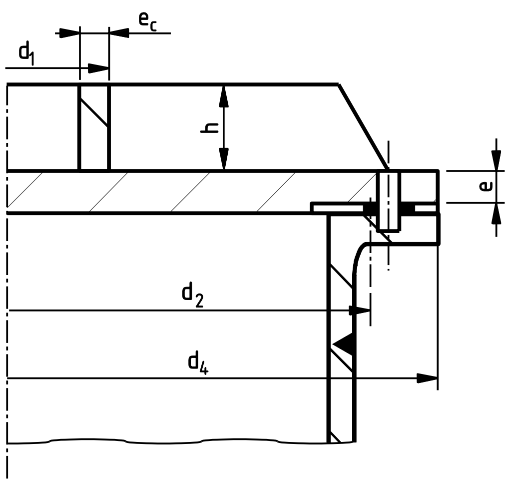


Figure 21.2-3 Bolted end with ribs and additional peripheral bending moment



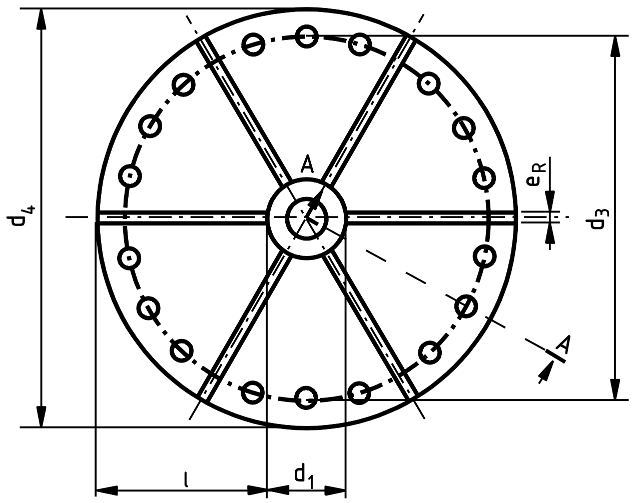


Figure 21.2-4 — Bolted end with ribs without additional peripheral bending moment

21.3 Specific symbols and abbreviations

The following symbols and abbreviations are in addition to those in Clause 4.

d_1 diameter of central plug or ring

d_2 diameter subject to pressure

d_3 diameter of bolt circle

d_4 outside diameter of end

e thickness of end

e_R thickness of reinforcing ribs

e_C thickness of central circular ring

f nominal design stress of end at design temperature

f_R nominal design stress of rib at design temperature

f_B nominal design stress of bolts at design temperature

f_C nominal design stress of central ring at design temperature

NOTE Design temperature means the temperature of the condition to be assessed (bolting-up, operating or testing).

g_o minimum required throat thickness of the weld between end and reinforcing rib

g_1 …… g_i throat thicknesses of the intermittent welds between end and reinforcing ribs (Figure 21.7-1)

h height of reinforcing ribs

l length of reinforcing ribs

l_o in case of intermittent welds is the length of the most external weld between end and reinforcing rib

l_1 …… l_i lengths of the intermittent welds between end and reinforcing ribs

n_V number of reinforcing ribs

p_A maximum allowable pressure in operating or testing conditions

t spacing between two consecutive ribs calculated on the diameter d_2

W total bolt load in the different conditions (bolting-up, operating and testing) as defined in Clause 11

z_R joint efficiency of the weld between the end and the reinforcing ribs

z_C joint efficiency of the weld in the central ring

β angle of the circular sectors free of openings

21.4 Ends without additional peripheral bending moment

21.4.1 Maximum allowable pressure

The maximum allowable pressure shall be the smaller of the values calculated with the following formulae:

$$P_{max} = \left(\frac{e}{C\ d_2} \right)^2 f \qquad (21.4\text{-}1)$$

$$P_{max} = \frac{0{,}25}{K} \left\{ \left(\frac{h}{l} \right)^2 - u + \sqrt{\left[\left(\frac{h}{l} \right)^2 - u \right]^2 + 4 \left(\frac{h}{l} \right)^2} \right\} f_R \left(\frac{e_R}{d_2} \right) \qquad (21.4\text{-}2)$$

where

C and K are taken from Figures 21.4-1 and 21.4-2 respectively, while u is equal to 0,5 for continuous welds between the end and the ribs; when these welds are intermittent as in Figure 21.7-1, and are composed by m segments having each one the length l_i, , u shall be calculated with the following formula:

$$u = 0{,}9 - \frac{1}{2l} \sum_{i=1}^{i=m} l_i \qquad (21.4\text{-}3)$$

NOTE 1 The length l of the reinforcing ribs shall be extended, whenever possible, up to the external diameter d_4, in any case at least up to the diameter d_3.

NOTE 2 When a central ring as in Figure 21.2-4 is provided, this one shall comply with the provisions of 7.4.2.

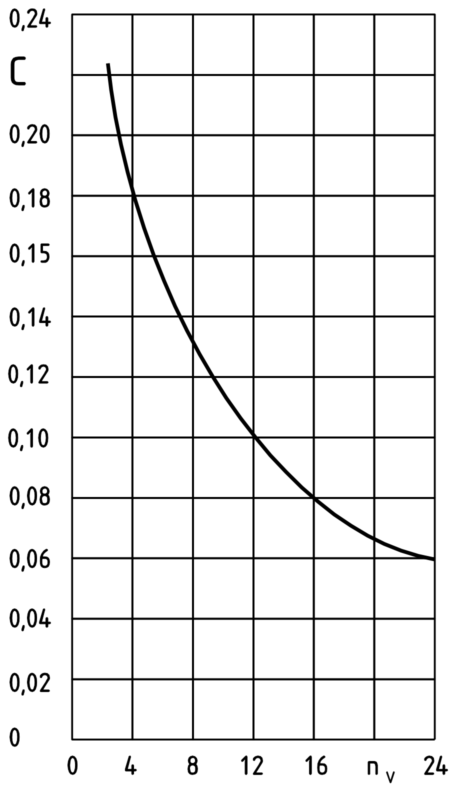


Figure 21.4-1 — Factor C for end without peripheral bending moment

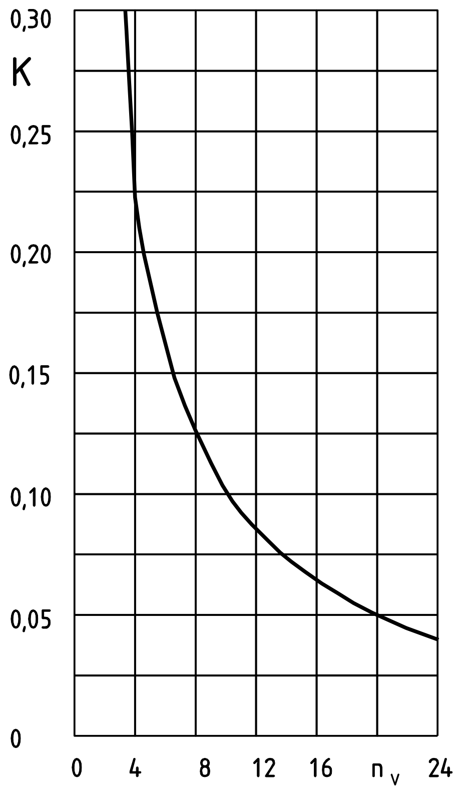


Figure 21.4-2 — Factor K for ends without peripheral bending moment

21.4.2 Minimum Dimensions

The minimum end thickness *e* and the minimum height *h* of the ribs shall be calculated with the following formulae:

$$e = C\, d_2 \sqrt{\frac{P}{f}} \tag{21.4-4}$$

$$h = 0{,}5\, d_2 \sqrt{Z \frac{Z+u}{Z+1}} \tag{21.4-5}$$

where *Z* is given by:

$$Z = \frac{2\, K\, d_2\, P}{f_R\, e_R} \tag{21.4-6}$$

in the above formulae *C*, *K* and *u* shall be determined according to 21.4.1.

21.5 Ends with additional peripheral bending moment

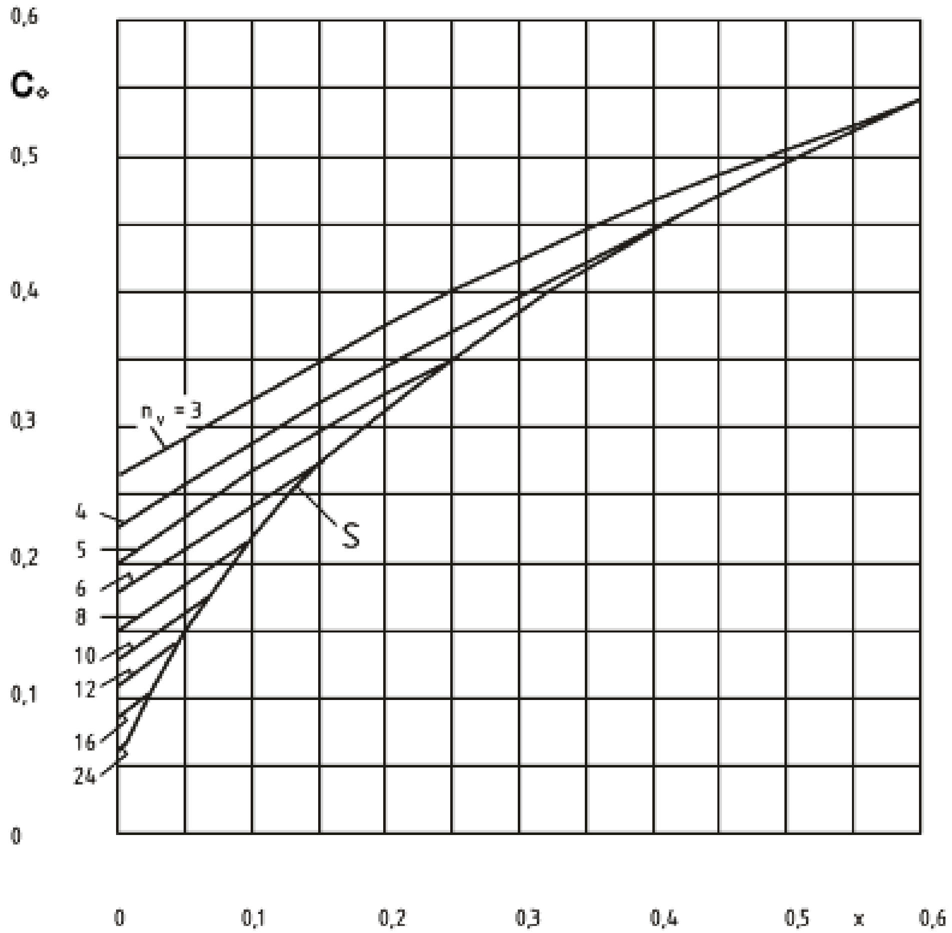


Figure 21.5-1 — Factor C_o for ends with peripheral bending moment

The minimum end thickness *e* and the minimum height *h* of the ribs shall be calculated with the following formulae:

$$e = C_o \ d_2 \sqrt{\frac{P}{f}} \quad (21.5\text{-}1)$$

$$h = 0{,}5 \ d_2 \sqrt{Z_o \frac{Z_o + u}{Z_o + 1}} \quad (21.5\text{-}2)$$

where Z_o is given by:

$$Z_o = \frac{2 K_o d_2 P}{f_R e_R} \quad (21.5\text{-}3)$$

In the above formulae *u* shall be determined with Formula (21.4-3), while C_o and K_o shall be taken from Figures 21.5-1 and 21.5-2 after determining the parameter *x* as follows:

$$x = \frac{4 W}{P \ d_2^2 \ \pi} \left(\frac{d_3 - d_2}{d_2} \right) \quad (21.5\text{-}4)$$

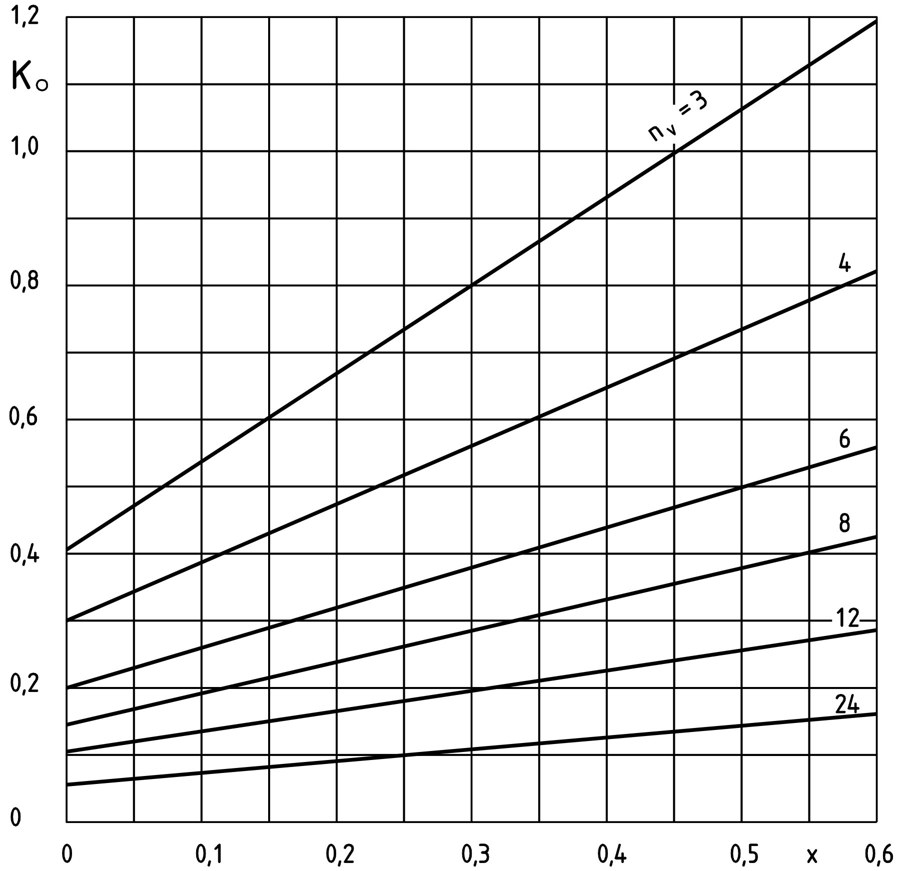


Figure 21.5-2 — Factor K_o for ends with peripheral bending moment

By the graph in Figure 21.5-1 it is possible to check if there is an advantage in increasing the number of ribs: for high values of *x* the coefficient C_o remains constant (it cannot be lower than the minimum values determined by the curve labelled with 'S'); therefore a number of ribs higher than 5 is ineffective if $x \geq 0{,}25$, a number higher than 4 is ineffective if $x \geq 0{,}37$, a number higher than 3 is ineffective if $x \geq 0{,}55$.

NOTE 1 The first term of Formula (21.5-4) is the ratio between the total bolt load and the total pressure load over the end, which is normally higher than 1 in operating and testing conditions (because the bolts shall develop a reaction higher than the pressure load in order to keep the gasket compressed); since the second term is normally much smaller than 1, the resulting values of x in these conditions are generally lower than 0,6; for higher values of x the ribs are not effective, and a normal unstayed flat end would be recommended.

NOTE 2 The above method is not adequate for the bolting-up condition, where the pressure is 0 and the value of x would become infinite; in order to verify the end also in this condition an equivalent plate thickness shall be calculated with the formula:

$$e_{EQ} = \sqrt{\frac{e^3 + \frac{e_R^2 h^4}{t^2 e} + \frac{e_R h}{t}\left(4e^2 + 4h^2 + 6eh\right)}{e + h}} \qquad (21.5\text{-}5)$$

where *t* is given by:

$$t = \frac{\pi d_2}{n_V} \qquad (21.5\text{-}6)$$

in the calculation of e_{EQ} all the negative tolerances for corrosion and fabrication shall be taken into account.

The reinforced end is able to withstand the bolting-up load *W* if:

$$e_{EQ} \geq \sqrt{\frac{3(d_3 - d_2)}{\pi d_2}\left(\frac{W}{f_{MIN}}\right)} \qquad (21.5\text{-}7)$$

In the above formula f_{MIN} is the lower of the nominal design stress of the end and the nominal design stress of the ribs.