5.11.2.3.2 Friction coefficient consideration

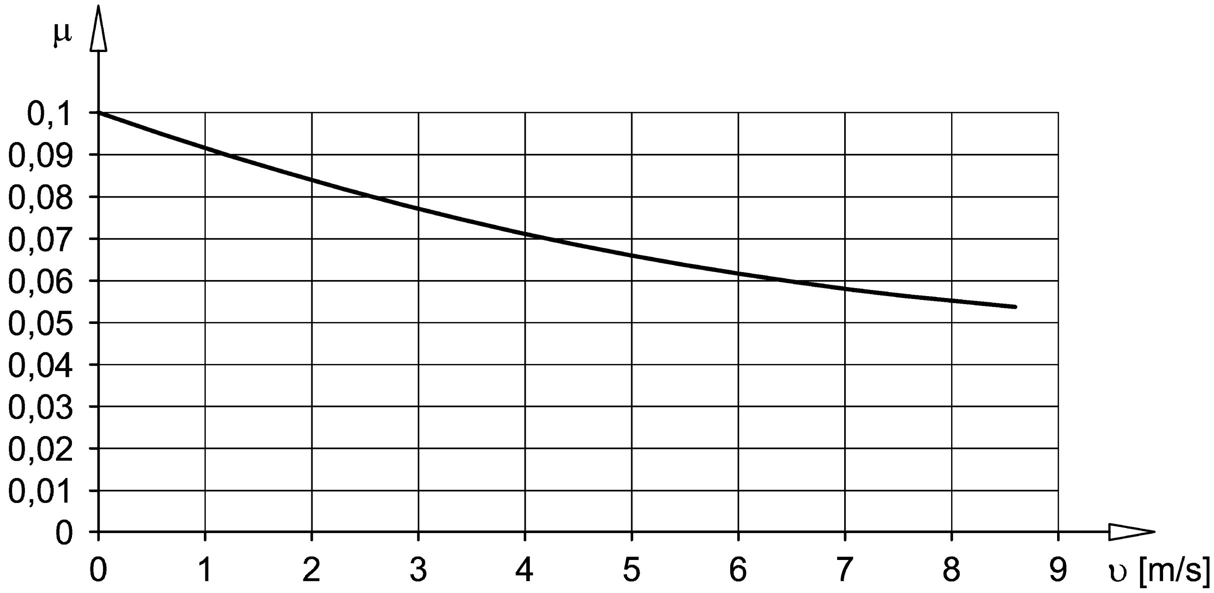


Figure 8 — Minimum friction coefficient

The following values apply:

— Loading conditions $\mu = 0{,}1$;

— Emergency braking conditions $\mu = \frac{0{,}1}{1 + \frac{v}{10}}$;

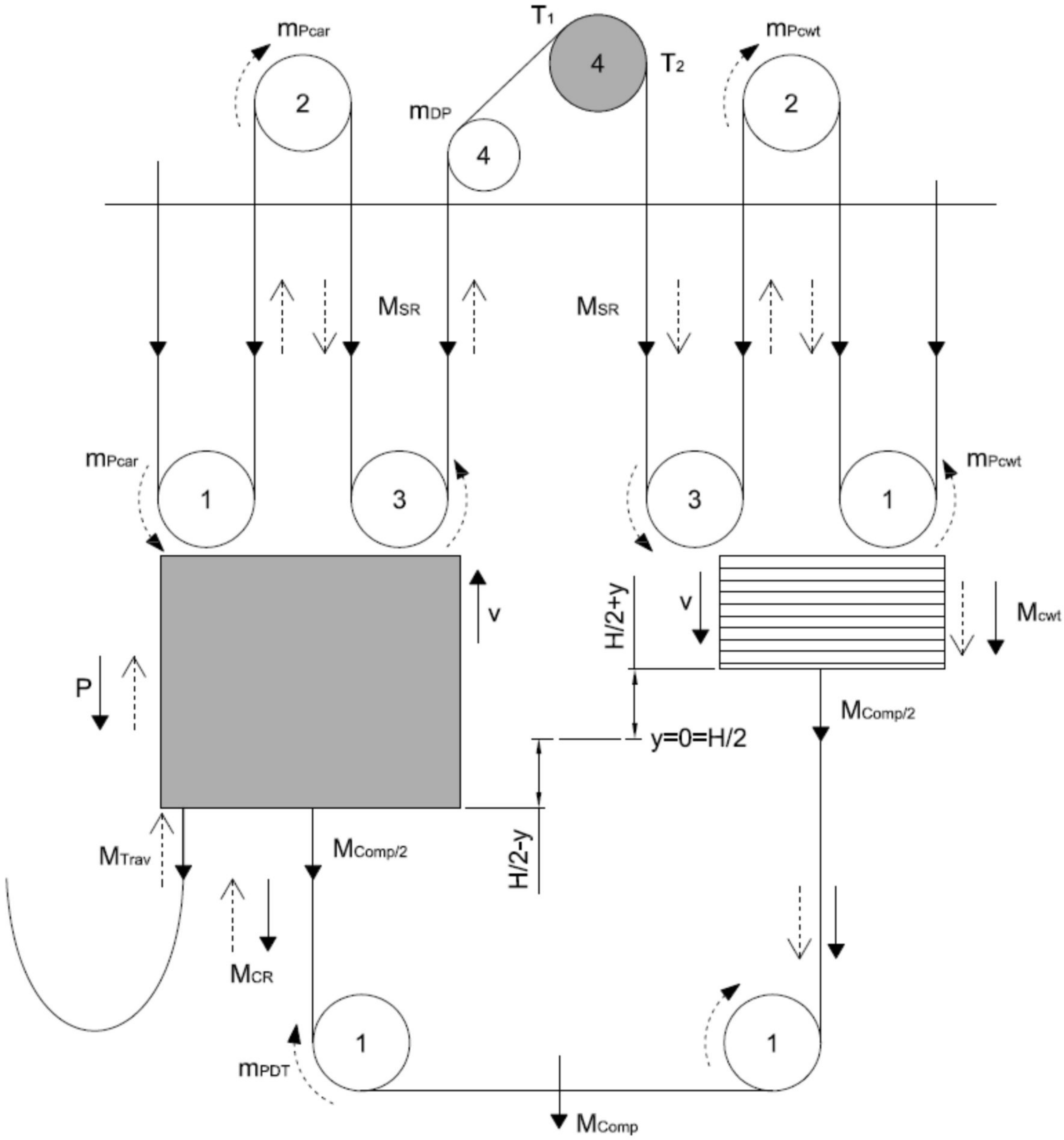
— Counterweight stalled conditions $\mu = 0{,}2$

where:

μ is the friction coefficient;

v is the rope speed at rated speed of the car.

5.11.3 Fomulae for a general case



Key

1, 2, 3, 4 is the speed factor of pulleys (example: $2 = 2 \cdot v_{car}$).

Figure 9 — General case

The following formulae apply:

a) For machinery located above:

$$T_1 = \frac{(P+Q+M_{CRcar}+M_{Trav})}{r}\cdot(g_n \pm a)+\frac{M_{Comp}}{2\cdot r} g_n + M_{SRcar}\left(g_n \pm a\cdot\frac{r^2+2}{3}\right)\pm\left(\frac{i_{PTD}\cdot m_{PTD}}{2\cdot r}\cdot a\right)$$

$$\pm\frac{(m_{DP}\cdot a)^{I}}{r}\pm\left[\frac{\left[\sum_{i=1}^{r-1}(m_{Pcar}\cdot i_{Pcar}\cdot a)\right]}{r}\right]^{III}\mp\frac{FR_{car}}{r}$$

$$T_2 = \frac{M_{cwt}+M_{CRcwt}}{r}\cdot(g_n \mp a)+\frac{M_{Comp}}{2\cdot r}\cdot g_n + M_{SRcwt}\left(g_n \mp a\cdot\frac{r^2+2}{3}\right)\mp\left(\frac{i_{PTD}\cdot m_{PTD}}{2\cdot r}\cdot a\right)$$

$$\mp\left[\frac{(m_{DP}\cdot a)}{r}\right]^{II}\mp\left[\frac{\sum_{i=1}^{r-1}(M_{Pcwt}\cdot i_{Pcwt}\cdot a)}{r}\right]^{III}\pm\frac{FR_{cwt}}{r}$$

b) For machinery located below:

$$T_1 = \frac{(P+Q+M_{CRcar}+M_{Trav})}{r}\cdot(g_n \pm a)+\frac{M_{Comp}}{2\cdot r}\cdot g_n + M_{SR1car}\cdot(-g_n \pm a)+M_{SR2car}\cdot\left(g_n \pm a\cdot\frac{r^2+2}{3}\right)$$

$$\pm\left(\frac{i_{PTD}\cdot m_{PTD}}{2\cdot r}\cdot a\right)\pm\left(\frac{m_{DP}\cdot a}{r}\right)^{I}\pm\left[\frac{\sum_{i=1}^{r-1}(m_{Pcar}\cdot i_{Pcar}\cdot a)}{r}\right]^{III}\mp\frac{FR_{car}}{r}$$

$$T_2 = \frac{M_{cwt}+M_{CRcwt}}{r}\cdot(g_n \mp a)+\frac{M_{Comp}}{2\cdot r}\cdot g_n + M_{SR1cwt}\cdot(-g_n \mp a)+M_{SR2cwt}\cdot\left(g_n \mp a\cdot\frac{r^2+2}{3}\right)$$

$$\mp\left(\frac{i_{PTD}\cdot m_{PTD}}{2\cdot r}\cdot a\right)\mp\left(\frac{m_{DP}\cdot a}{r}\right)^{II}\mp\left[\frac{\sum_{i=1}^{r-1}(m_{Pcwt}\cdot i_{Pcwt}\cdot a)}{r}\right]^{III}\pm\frac{FR_{cwt}}{r}$$

NOTE 1 The above formulas may be also used for the empty car by deleting Q. In this case T_1 becomes T_2 and T_2 becomes T_1.

In the above formulas the symbols ± and ∓ shall be used in such a way that the upper operation is applicable in case the car with its rated load is retarding in the down direction and the lower operation in case the empty car is retarding in the up direction. For the cases car loading and stalled condition $a = 0$.

For the car loading case Q shall be replaced by *1,25 Q* plus the weight of handling devices where used in case of goods passenger lifts.

The friction forces FR_{car} and FR_{cwt} should be deleted in all conditions if a minimum friction force cannot be ensured.

NOTE 2 For calculation example, see Annex D.

Conditions:

I is for any deflection pulley on car side;

II is for any deflection pulley on counterweight side;

III is only for reeving > 1;

where:

a	is the braking retardation (positive value) of the car in metres per square second;
FR_{car}	is the frictional force in the well (efficiency of bearings car side and friction on guide rails, etc.) in newtons;
FR_{cwt}	is the frictional force in the well (efficiency of bearings counterweight side and friction on guide rails, etc.) in newtons;
g_n	is the standard acceleration of free fall in metres per square second;
H	is the travel height in metres;
i_{Pcar}	is the number of pulleys on car side with same rotation speed v_{pulley} (without deflection pulleys);
i_{Pcwt}	is the number of pulleys on counterweight side with same rotation speed v_{pulley} (without deflection pulleys);
i_{PTD}	is the number of pulleys for tensioning device;
m_{DP}	is the reduced mass (related to the car/counterweight) of deflection pulleys on car and/or counterweight side $J_{DP} \cdot (v_{pulley}/v)^2/R^2$ in kilograms;
m_{Pcar}	is the reduced mass (related to the car) of pulleys on car side $J_{Pcar} \cdot (v_{pulley}/v)^2/R^2$ in kilograms;
m_{Pcwt}	is the reduced mass (related to the counterweight) of pulleys on counterweight side $J_{Pcwt} \cdot (v_{pulley}/v)^2/R^2$ in kilograms;
m_{PTD}	is the reduced mass (related to car/counterweight) of one pulley on tensioning device J_{PTD}/R^2 in kilograms;
M_{Comp}	is the mass of tension device including mass of pulleys in kilograms;
M_{CR}	is the actual mass of compensation ropes/chains $([0{,}5 \cdot H \pm y] \cdot n_c \cdot \text{rope weight per unit length})$ in kilograms;
M_{CRcar}	is the mass M_{CR} on car side;
M_{CRcwt}	is the mass M_{CR} on counterweight side;
M_{cwt}	is the mass of counterweight including mass of pulleys in kilograms;
M_{SR}	is the actual mass of suspension ropes $([0{,}5 \cdot H \pm y] \cdot n_s \cdot \text{rope weight per unit length})$ in kilograms;
M_{SRcar}	is the mass M_{SR} on car side.

In the case of machine below, the rope leading from the machine to the pulley(s) in the headroom is M_{SR1car} and rope leading from pulley(s) in the headroom to the car is M_{SR2car} (M_{SR2car} = 0 if car at upmost landing);

M_{SRcwt} is the mass M_{SR} on counterweight side.

In the case of machine below, the rope leading from the machine to the pulley(s) in the headroom is M_{SR1cwt} and rope leading from pulley(s) in the headroom to the counterweight is M_{SR2cwt} (M_{SR2cwt} = 0 if counterweight at upmost landing);

M_{Trav} is the actual mass of travelling cable $\left([0{,}25H \pm 0{,}5y] \cdot n_t \cdot \text{travelling cable weight per unit length}\right)$ in kilograms;

n_C is the number of compensating ropes/chains;

n_S is the number of suspension ropes;

n_t is the number of travelling cables;

P is the masses of the empty car in kilograms;

Q is the rated load in kilograms;

T_1, T_2 is the force exerted on rope in newtons;

r is the reeving factor;

v_{pulley} is the rotation speed of the pulley (rope speed) in metres per second;

y is on the level $0{,}5 \cdot H \rightarrow y = 0$ in metres;

$\rightarrow$ is the static force;

— → is the dynamic force;

5.12 Evaluation of safety factor on suspension ropes for electric lifts

5.12.1 General

With reference to the requirements laid down in the standards calling for the use of this standard (e.g. EN 81-20:2020, 5.5.2.2), this clause describes the method of evaluation of the safety factor "S_f" for the suspension ropes. This evaluation method shall only be used for:

— Steel or cast iron traction sheaves;

— Steel wire ropes according to EN 12385-5:2002.

NOTE This method is based on sufficient life time of the ropes assuming a regular maintenance and inspection.

5.12.2 Equivalent number N_{equiv} of pulleys

5.12.2.1 General

The number of bends and the degree of severity of each bend cause deterioration of the rope. This is influenced by the type of grooves (U- or V- groove) and whether the bend is reversed or not.

The degree of severity of each bend can be equated to a number of simple bends.

A simple bend is defined by the rope travelling over a semi-circular groove where the radius of the groove is not more than 0,53 of the nominal rope diameter.

The number of simple bends corresponds to an equivalent number of pulleys N_{equiv}, which can be derived from:

$$N_{equiv} = N_{equiv(t)} + N_{equiv(p)}$$

where:

$N_{equiv(t)}$ is the equivalent number of traction sheaves;

$N_{equiv(p)}$ is the equivalent number of deflection pulleys.

5.12.2.2 Evaluation of $N_{equiv(t)}$

Values of $N_{equiv(t)}$ can be taken from Table 2.

Table 2 — Evaluation of equivalent number of traction sheaves $N_{equiv(t)}$

V-grooves	V-angle (γ)	35°	36°	38°	40°	42°	45°	50°
	$N_{equiv(t)}$	18,5	16	12	10	8	6,5	5
U-Undercut grooves	U-angle (β)	75°	80°	85°	90°	95°	100°	105°
	$N_{equiv(t)}$	2,5	3,0	3,8	5,0	6,7	10,0	15,2

For U-grooves without undercut: $N_{equiv(t)} = 1$.

Values for angles not in the table may be determined by linear interpolation.

5.12.2.3 Evaluation of $N_{equiv(p)}$

A bend is only considered to be a reverse bend if the distance from the rope contacts on two consecutive pulleys, which have a fixed distance between their axles, is less than 200 times the rope diameter and the bending planes are rotated through more than 120°.

$$N_{equiv(p)} = K_p \cdot (N_{ps} + 4 \cdot N_{pr})$$

where:

N_{ps} is the number of pulleys with simple bends;

N_{pr} is the number of pulleys with reversed bends;

K_p is the factor of ratio between sheave and pulley diameters.

with: $K_p = \left(\frac{D_t}{D_p}\right)^4$

where:

D_t is the diameter of the traction sheave;

D_p is the average diameter of all pulleys, traction sheave excluded.

NOTE Examples for evaluation of equivalent number of pulleys are given in Annex E.

5.12.3 Safety factor

For a given design of rope drive the minimum value of safety factor can be selected from Figure 10 taking into account the correct ratio of D_t/d_r and the calculated N_{equiv} for the worst case section of ropes.

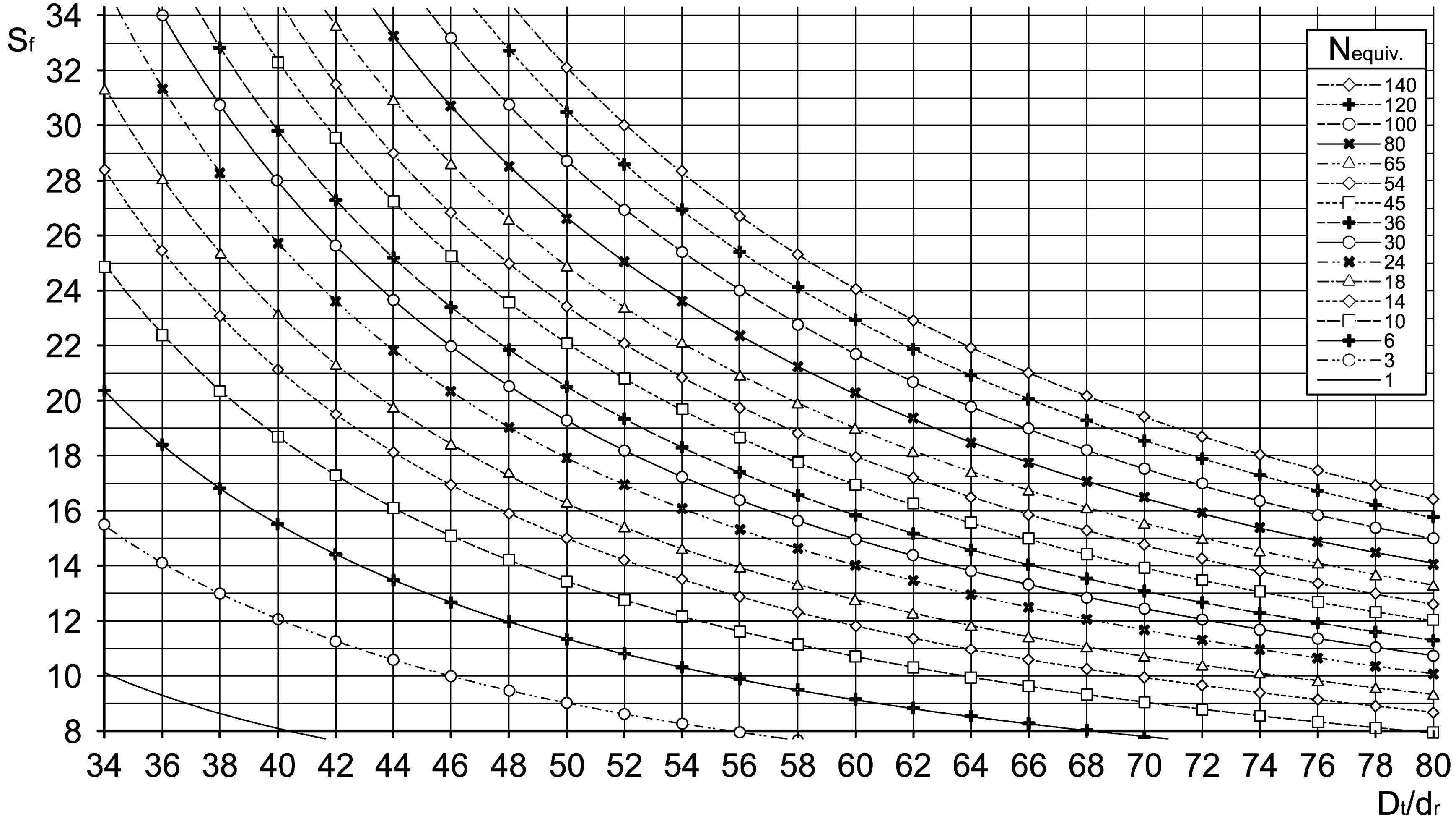


Figure 10 — Evaluation of minimum safety factor

The curves of the Figure 10 are based on the following formula:

$$S_f = 10^{\left(2{,}6834 - \frac{\log\left(\frac{695{,}85.10^6 \cdot N_{equiv}}{\left(\frac{D_t}{d_r}\right)^{8{,}567}}\right)}{\log\left(77{,}09\left(\frac{D_t}{d_r}\right)^{-2{,}894}\right)}\right)}.$$

where:

D_t	is the diameter of traction sheave;
d_r	is the diameter of the ropes;
N_{equiv}	is the equivalent number of pulleys;
S_f	is the safety factor.

5.13 Calculations of rams, cylinders, rigid pipes and fittings

5.13.1 Calculation against over pressure

5.13.1.1 Calculation of wall thickness of rams, cylinders, rigid pipes and fittings

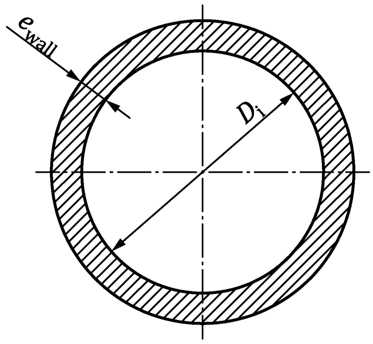


Figure 11 — Wall thickness calculation

$$e_{wall} \geq \frac{2{,}3 \cdot 1{,}7 \cdot p}{R_{p0,2}} \cdot \frac{D_i}{2} + e_0$$

e_o = 1,0 mm for wall and base of cylinders and rigid pipes between the cylinder and the rupture valve, if any;

e_o = 0,5 mm for rams and other rigid pipes;

2,3 is the factor for friction losses (1,15) and pressure peaks (2);

1,7 is the safety factor referred to the proof stress.

5.13.1.2 Calculation of the base thickness of cylinders (examples)

5.13.1.2.1 General

The examples shown do not exclude other possible constructions.

5.13.1.2.2 Flat bases with relieving groove

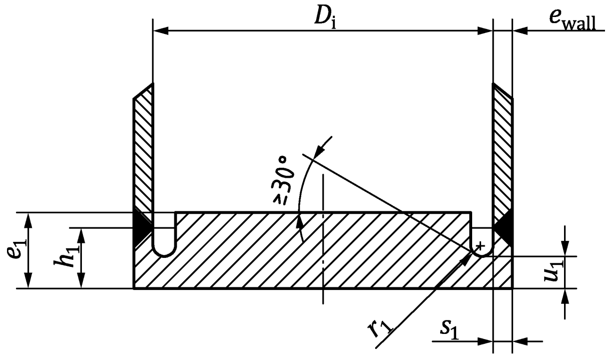


Figure 12 — Flat bases with relieving groove

Conditions for the stress relief of the welding seam:

$r_1 \geq 0{,}2 \cdot e_1$ and $r_1 \geq 5$ mm

$u_1 \leq 1{,}5 \cdot s_1$

$h_1 \geq u_1 + r_1$

$$e_1 \geq 0{,}4 \cdot D_i \sqrt{\frac{2{,}3 \cdot 1{,}7 \cdot p}{R_{P0,2}}} + e_0$$

$$u_1 \geq 1{,}3 \cdot \left(\frac{D_i}{2} - r_1\right) \cdot \frac{2{,}3 \cdot 1{,}7 \cdot p}{R_{P0,2}} + e_0$$

5.13.1.2.3 Cambered based

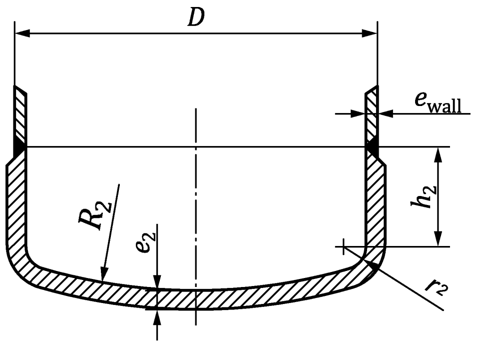


Figure 13 — Cambered based

Conditions:

$h_2 \geq 3{,}0 \cdot e_2$

$r_2 \geq 0{,}15 \cdot D$

$R_2 = 0{,}8 \cdot D$

$$e_2 \geq \frac{2{,}3 \cdot 1{,}7 \cdot p}{R_{P0,2}} \cdot \frac{D}{2} + e_0$$

5.13.1.2.4 Flat bases with welded flange

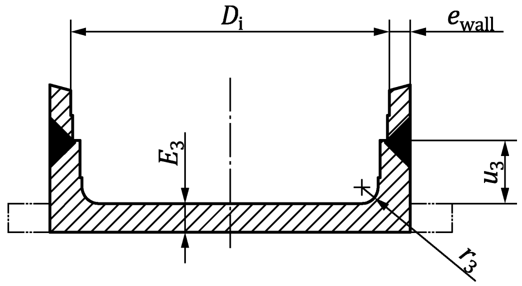


Figure 14 — Flat bases with welded flange

Conditions:

$u_3 \geq e_3 + r_3$

$r_3 \geq \frac{e_{wall}}{3}$ and $r_3 \geq 8$ mm

$$e_3 \geq 0{,}4 \cdot D_i \sqrt{\frac{2{,}3 \cdot 1{,}7 \cdot p}{R_{P0,2}}} + e_0$$

5.13.2 Calculations of the jacks against buckling

5.13.2.1 General

The buckling calculation shall be made on the part with least buckling resistance.

5.13.2.2 Single acting jacks

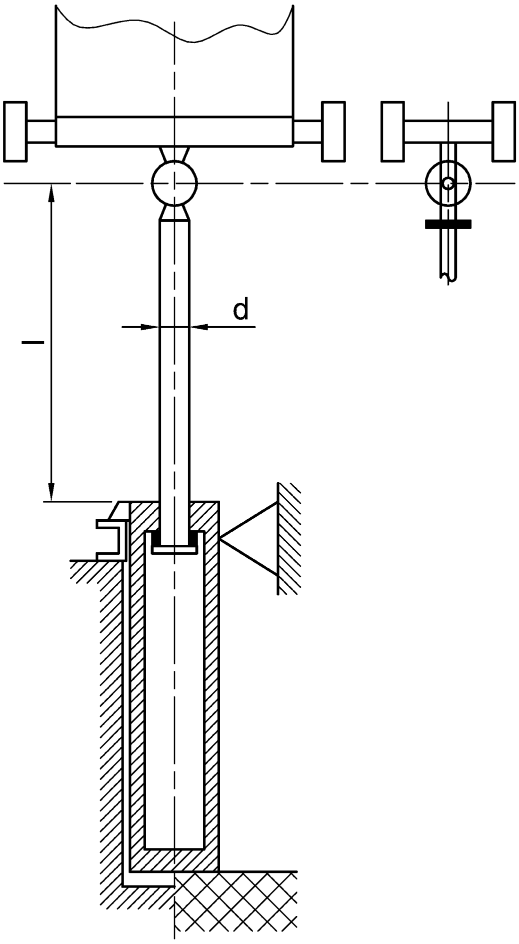


Figure 15 — Single acting jacks

For $\lambda_n \geq 100$: $F_s \leq \frac{\pi^2 \cdot E \cdot J_n}{2 \cdot l^2}$	For $\lambda_n < 100$: $F_s \leq \frac{A_n}{2}\left[R_m - (R_m - 210) \cdot \left(\frac{\lambda_n}{100}\right)^2\right]$

$F_s = 1,4 \cdot g_n \cdot [c_m \cdot (P + Q) + 0,64 \cdot P_r + P_{rh}]$ [3)]

3) Valid for rams extending in upward direction.