GUSTAV WOLF

Determining number of trips

$N_{eq(t)}$

Deviating from DIN EN 81-50:2015 Table 2, some additional undercut-U grooves (U-angle β= 70°) and V-grooves (V-angle γ= 55° and 60°) will be used, the corresponding equivalent number of traction sheaves $N_{eq(t)}$ has been determined by graphical extrapolation. The values are presented in table 1.

V-Grooves	γ [°]	35	36	38	40	42	45	50	55	60
	Neq(t)	18,5	16	12	10	8	6,5	5	3,7	3,0
U-Undercut Grooves	β [°]	0	70	75	80	85	90	95	100	105
	Neq(t)	1	2,3	2,5	3	3,8	5	6,7	10	15,2

Table 1 equivalent number of traction sheaves Neq(t)

Decision formula

The rope in this study, Gustav-Wolf PAWO 819W and PAWO F7S d_{Nom}=6,0 mm until 10,0 mm is designed for application in elevators, both inside and outside the requirements of the DIN EN 81-50 and EN 81-20.

Traction elevator

The element from which to start is the fact that in the DIN EN 81-50 the calculation of safety factor is based on a minimum number of trips of $Z=6 \cdot 10^5$. In deviating from the DIN EN 81-50 relative to the safety factor and the bending ratio, the below must be taken into consideration.

Case 1: The safety factor calculated on the basis of DIN EN 81-50 and the number of expected trips is higher than the minimum number of trips $Z=6 \cdot 10^5$.

In this case, there are no additional measures necessary for the operation.

Case 2: The safety factor S_f is outside the requirements of DIN EN 81-50 and/or the number of expected trips is lower than the minimum number of trips $Z=6 \cdot 10^5$.

In this case, the elevator has to be considered as an elevator with a *limited number of trips.*
To handle this condition a trip counter device has to be installed on the system to count the number of starts per direction, as a trip is defined as the sum of all starts in one direction before reversal of direction. A start is considered to be a trip of at least a distance l>100 mm. Setting the limit in that way, will exclude from the count the readjusting procedure that could occur for operational needs. This readjusting/re-leveling procedure will not affect the expected number of trips of the elevator.

The evaluation of the expected number of trips could be performed with the **Formula 1.** The element from which to start is the number of "simple bendings" that the rope could withstand on a sheave with a plain-U groove: such data are reported in the table 2 for different diameter ratios D/d and safety factor S_f.

Intermediate values can be interpolated.

Indirect Hydraulic elevators

In this case, considering that the safety factor is having a fixed value (the requirement is $S_f \geq 12$), the only element that could deviate from the DIN EN 81-20 is the bending ratio of the deflection sheave to rope D/d. The basis of the evaluation is again the fact that in DIN EN 81-50 the calculation of the safety factor is based on a minimum number of trips $Z=6 \cdot 10^5$.

Case 1: Safety factor $S_f \geq 12$, D/d ratio of the steel or cast iron sheave is outside the requirements of DIN EN 81-20, and the number of expected trips is higher than the minimum number of trips $Z=6 \cdot 10^5$.

In this case, there are no additional measures necessary for the operation.

Case 2: The safety factor $S_f \geq 12$, D/d ratio of the steel or cast iron sheave is outside the requirements of DIN EN 81-20 and the number of expected trips is lower than the minimum number of trips $Z=6 \cdot 10^5$.

In this case, the elevator has to be considered as an elevator with a *limited number of trips.*
To handle this condition a trip counter device has to be installed on the system to count the number of starts per direction, as a trip is defined as the sum of all starts in one direction before reversal of direction. A start is considered to be a trip of at least a distance l>100 mm. Setting the limit in that way, will exclude from the count the readjusting procedure that could occur for operational needs. This readjusting/re-leveling procedure will not affect the expected number of trips of the elevator.

The evaluation of the expected number of trips could be performed with the **Formula 1.** The element from which to start is the number of "simple bendings" that the rope could withstand on a sheave with a plain-U groove: such data are reported on the table 2 for different diameter rations D/d and safety factor S_f.

Intermediate values can be interpolated.

In the case in which a **plastic deflection sheave** is used on indirect hydraulic elevators, this will increase the number of trips obtained by the formula by factor $f_N=1,2$.
The use of plastic deflection sheaves in indirect hydraulic lifts in all cases makes a trip counter necessary.

Decision formula: instructions of application and use

What follows is a simplified method of calculation to obtain the number of trips of the elevator in service, in order to be as general as possible and at the same time to be a conservative evaluation.

The table below represents the number of simple bendings N_A that the rope could withstand on a sheave with a plain-U groove. This is the basis for the calculation that will be developed in the following and represents the "basic data" from which to start to complete the calculation of the expected number of trips Z_A.

	Sf = 12	Sf = 14	Sf = 16	Sf = 18	Sf = 20	Sf = 22	Sf = 24	Sf = 26	Sf = 28	Sf = 30
Bending Ratio D/d	N_a	N_a	N_a	N_a	N_a	N_a	N_a	N_a	N_a	N_a
18,5	25.000	35.500	45.000	55.000	65.000	82.500	99.500	114.500	130.000	148.500
20	141.000	201.000	255.000	311.000	368.000	467.000	564.000	649.000	737.000	842.000
21	219.000	311.000	396.000	485.000	577.000	729.000	880.000	1.014.000	1.152.000	1.317.000
22	295.000	422.000	541.000	668.000	816.000	1.009.000	1.226.000	1.416.000	1.614.000	1.848.000
23	377.000	544.000	702.000	872.000	1.086.000	1.332.000	1.628.000	1.887.000	2.161.000	2.481.000
24	461.000	669.000	867.000	1.082.000	1.363.000	1.665.000	2.043.000	2.376.000	2.729.000	3.140.000
25	529.000	753.000	960.000	1.178.000	1.413.000	1.773.000	2.146.000	2.473.000	2.812.000	3.216.000
26	614.000	882.000	1.134.000	1.403.000	1.725.000	2.136.000	2.604.000	3.015.000	3.447.000	3.955.000
27	700.000	1.015.000	1.312.000	1.634.000	2.043.000	2.510.000	3.076.000	3.575.000	4.102.000	4.719.000
28	766.000	1.106.000	1.447.000	1.811.000	2.316.000	2.779.000	3.417.000	3.970.000	4.556.000	5.241.000
29	893.000	1.300.000	1.717.000	2.167.000	2.797.000	3.378.000	4.185.000	4.892.000	5.641.000	6.524.000
30	952.000	1.398.000	1.830.000	2.303.000	2.973.000	3.589.000	4.439.000	5.186.000	5.986.000	6.912.000
31	1.085.000	1.603.000	2.112.000	2.671.000	3.465.000	4.209.000	5.236.000	6.139.000	7.107.000	8.242.000
32	1.120.000	1.655.000	2.181.000	2.758.000	3.577.000	4.345.000	5.405.000	6.337.000	7.336.000	8.508.000
33	1.236.000	1.839.000	2.421.000	3.065.000	3.984.000	4.852.000	6.048.000	7.100.000	8.234.000	9.562.000
34	1.273.000	1.894.000	2.494.000	3.157.000	4.105.000	5.000.000	6.231.000	7.315.000	8.484.000	9.852.000
35	1.615.000	2.413.000	3.247.000	4.172.000	5.495.000	6.738.000	8.485.000	10.042.000	11.705.000	13.680.000
36	1.734.000	2.636.000	3.526.000	4.575.000	6.052.000	7.453.000	9.421.000	11.180.000	13.092.000	15.321.000
37	1.885.000	2.822.000	3.831.000	4.950.000	6.553.000	8.055.000	10.182.000	12.088.000	14.114.000	16.534.000
38	1.936.000	2.899.000	3.934.000	5.083.000	6.730.000	8.273.000	10.457.000	12.414.000	14.495.000	16.980.000
39	1.987.000	2.975.000	4.038.000	5.217.000	6.907.000	8.490.000	10.732.000	12.741.000	14.877.000	17.427.000
40	2.400.000	3.700.000	5.000.000	6.590.000	8.810.000	10.920.000	13.920.000	16.620.000	19.570.000	23.000.000

Table 2 Number of bendings over a plain-U groove sheave

The above basic data/number of simple bendings, have to be corrected in the case in which a formed (e.g. undercut-U or V-groove) traction sheave is to be used. To correct the number of bendings, this number has to be multiplied by a coefficient that is reported in the following table.

U-Undercut grooves		V-Grooves	
β	f_{N3}	γ	f_{N3}
70°	0,43	35°	0,054
75°	0,4	36°	0,066
80°	0,33	38°	0,095
85°	0,26	40°	0,14
90°	0,2	42°	0,18
95°	0,15	45°	0,25
100°	0,1	50°	0,33
105°	0,066	55°	0,4
		60°	0,45

Table 3 Correction coefficient to obtain the number of bendings over a formed traction groove

To evaluate the number of trips Z_A that the elevator could withstand, it is necessary to take into consideration the complete roping arrangement and so to take into consideration the number of sheaves that are included in the system. What has to be considered is the most stressed rope section that passes over the sheaves.

If, according to DIN EN81-50:2015, the distance between two subsequently fixed rope sheaves is not higher than 200times the rope diameter, **reverse bending** has to be considered during calculation.

The number of reverse bendings is to be determined by means of **formula 6** from the number of simple bendings.

The evaluation is a simplified one and could be summarized into the following equation.

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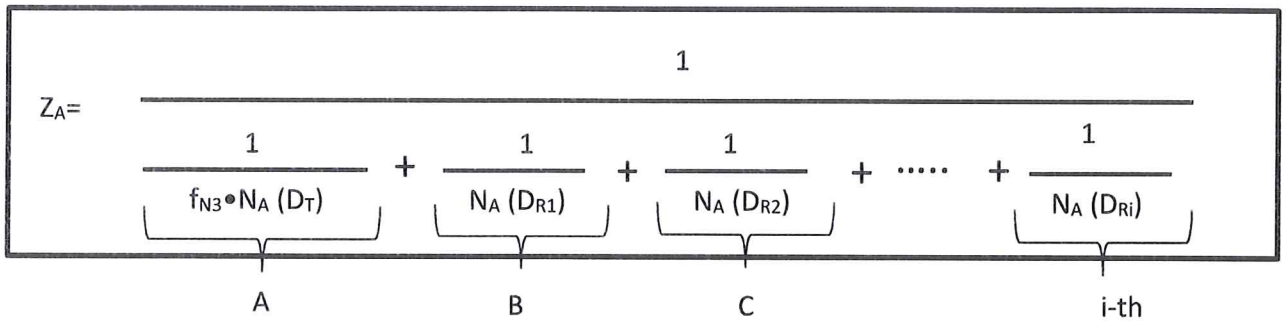
Decision formula for the number of trips:



Formula 1

Where:

Z_A=	Number of trips for the elevator
f_{N3}=	Reduction factor from Table 2
D_T=	Diameter of the traction sheave in [mm]
D_{R1}=	Diameter of the first deflection sheave in [mm]
D_{R2}=	Diameter of the second deflection sheave in [mm]
D_{Ri}=	Diameter of the i-th (additional) deflection sheave in [mm]
$N_A (D_T)$=	Number of simple bending for the sheave diameter D_T, taken from Table 2
$N_A (D_{R1})$=	Number of simple bending for the sheave diameter D_{R1}, taken from Table 2
$N_A (D_{R2})$=	Number of simple bending for the sheave diameter D_{R2}, taken from Table 2
$N_a (D_{...})_{korr}$ =	Number of reverse bendings determined from the number of simple bendings for the corresponding sheave
Sf =	Safety factor 1. Safety factor calculated according to DIN EN 81-50:2015-02 2. Safety factor table 2 determined deviating from DIN EN 81-50:2015-02

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Some simplification could be arranged in the specific cases:

1) Indirect Hydraulic Elevator:

$$Z_A = N_A (D_R)$$ **Formula 2**

In this specific case, the term related to the traction sheave is obviously not present, and there is only one sheave on top of the piston. In this particular case the number of trips Z_A corresponds equally to the number of simple bendings N_A as reported in the Table 2.
In the very seldom case in which there are 2 sheaves on top of the piston, the number of trips Z_A will be halved.

2) Traction Elevator 1:1 without any deflection sheave:

$$Z_A = f_{N3} \bullet N_A (D_T)$$ **Formula 3**

In this case, both terms related to the deflection sheaves are ignored, as only the traction sheave has to be considered.

3) Traction Elevator 1:1 or 2:1 with one deflection sheave:

$$Z_A = \frac{1}{\frac{1}{f_{N3} \bullet N_A (D_T)} + \frac{1}{N_a (D_{R1})}}$$ **Formula 4**

In this case, there are only the terms relative to the traction sheave and the first deflection sheave that have to be considered.

4) Traction Elevator 1:1 or 2:1 with two deflection sheaves of equal diameter:

$$Z_A = \frac{1}{\frac{1}{f_{N3} \bullet N_A (D_T)} + \frac{2}{N_A (D_{R1})}}$$ **Formula 5**

In this case beyond the term of the traction sheave, the term relative to the deflection sheave is considered two times to take into account the fact that there are two sheaves of the same diameter.

5) Traction elevator 1:1 or 2:1 with two or more deflection sheaves of different diameter:

In this case the most generic **Formula 1** has to be applied.

Number of reverse bendings determined from the number of simple bendings:
according to: Feyrer, Klaus; Drahtseile: Bemessung, Betrieb, Sicherheit; 2., revised and extended edition; Springer-Verlag 2000; p.269

$$N_a(D...)_{korr} = 2{,}670 \bullet N_a(D...)^{0{,}671} \bullet (D/d)^{0{,}499}$$ **Formula 6**

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EXAMPLE – Calculation based on a 2:1 roped elevator

Elevator Data:

Elevator suspension:	2:1
Rope diameter:	6,5 mm
Safety Factor:	24
Traction groove:	V-hardened/γ=50°
Traction sheave ϕ:	195 mm (D/d = 30)
Deflection sheave ϕ:	234 mm (D/d = 36) – one sheave on counterweight side

Identification of the most stressed rope part:

The most stressed rope section is normally the section that moves over the sheaves while the car starts from or goes to the main floor (usually the ground floor). In case of suspension 2: 1 the most stressed section moves over the traction sheave and the counterweight sheave. The two bendings per trip from or to the ground floor are simple bendings. One of the bendings moves in a sheave with formed grooves and one with round grooves.

Data from table 2 and table 3:

$N_a (D_T)$ = 4.439.000

$N_a (D_{R1})$= 9.421.000

f_{N3} = 0,33

Number of trips based on formula 4 :

$$Z_A = \frac{1}{\frac{1}{f_{N3} \bullet N_A (D_T)} + \frac{1}{N_A (D_{R1})}}$$

$$Z_A = \frac{1}{\frac{1}{0{,}33 \bullet 4.439.000} + \frac{1}{9.421.000}} = 1.267.748 \text{ Trips}$$