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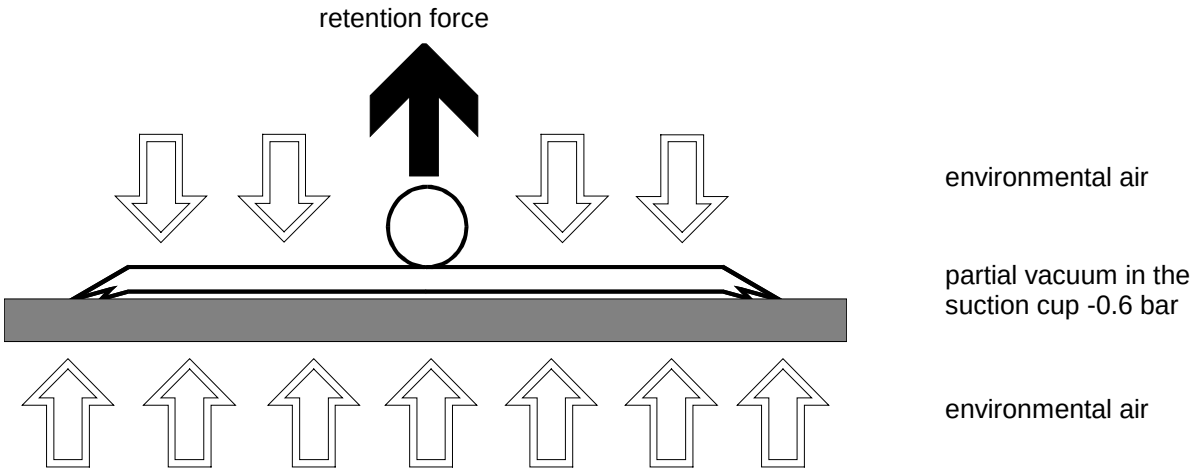
Carrying Capacity of Suction Cups

Why can a Suction Cup hold something?

The carrying capacity of the suction cups is only generated by the pressure difference between the environmental air pressure and the partial vacuum in the suction cup. If there is no pressure difference the suction cup has no holding power.



The larger the difference, the higher the load capacity of the suction cup.

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Dependence on the ambient air pressure

At the same time it means that at low environmental air pressure the carrying capacity of the suction cup is reduced. This is important because when the device is used at higher elevations the holding power decreases. The reason is, that the environmental air pressure decreases with altitude and therefore also the power which presses on a surface.

At sea level the air pressure is 1013 mbar. Each 100 m height difference causes a reduction of approx. 12.5 mbar. To express this more clearly, if a suction cup can carry 100 kg at sea level the same suction cup could carry only 90 kg at a height of 1000 m.

Dependence on the air pressure at various altitudes (Norm atmosphere)	
Altitude in meters	air pressure in mbar
0	1013.25
100	1001.3
200	989.5
400	966.1
600	943.2
800	920.8
1000	898.8
1200	877.2
1400	856.0
1600	835.3
1800	814.9
2000	795.0

Dependence on the Surface of the Suction Cup

The holding power of the suction cup depends not only on the pressure difference between environmental air pressure and partial vacuum in the suction cup, but also on the surface of the suction cup. The pressure power of the environmental air pressure influences the surface, and the result is: The larger the actual surface, the larger the entire pressure power.

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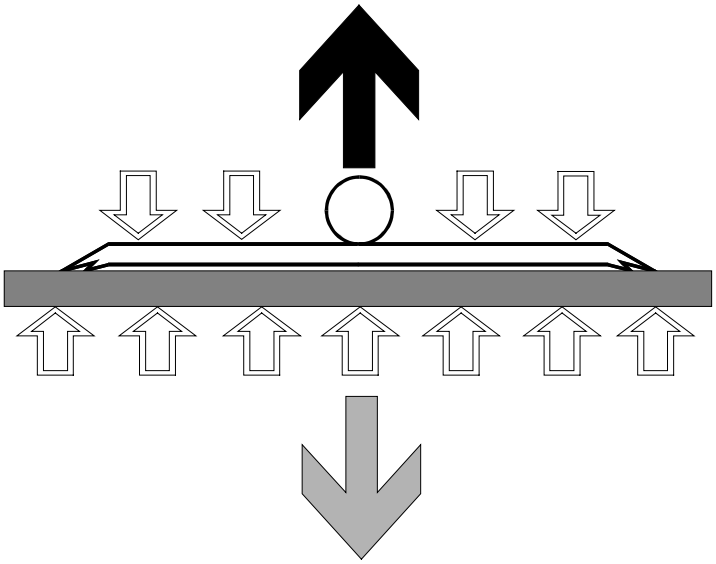
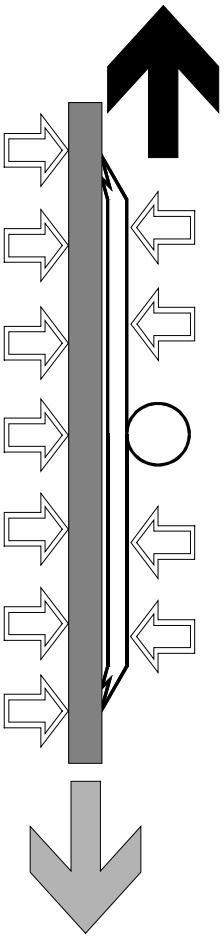
Dependence on the load direction



The suction cup can only pull-off and not slide-off when overstressed in a horizontal direction. The suction cup can be most heavily loaded in this load direction because a slipping off is not possible. Theoretically, the holding force results from the product surface multiplied by the partial vacuum. If this value is exceeded the suction cup breaks away and this is called the pull-off strength.



In case of overstressing in a vertical direction, the suction cup can slide along the surface before the suction cup releases from the surface. In this situation you get sliding friction between the suction cup and transport load. In general, the holding power is essentially lower in a vertical direction than in a horizontal one. If this retention force is exceeded, the suction cups slip off slowly. This is called the slipping off force.

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Further Influential Factors

- surface properties of the material
- contamination of the material and the suction cup
- air permeability of the material
- ambient temperature
- temperature of the material
- flexural strength of the material

Safety Factor

The safety factor 2 has been set as the new standard by the European Standard DIN EN 13155 for the slipping off force as well as for the pull-off force. For the slide-off power one must consider the coefficient of sliding friction **μ**.

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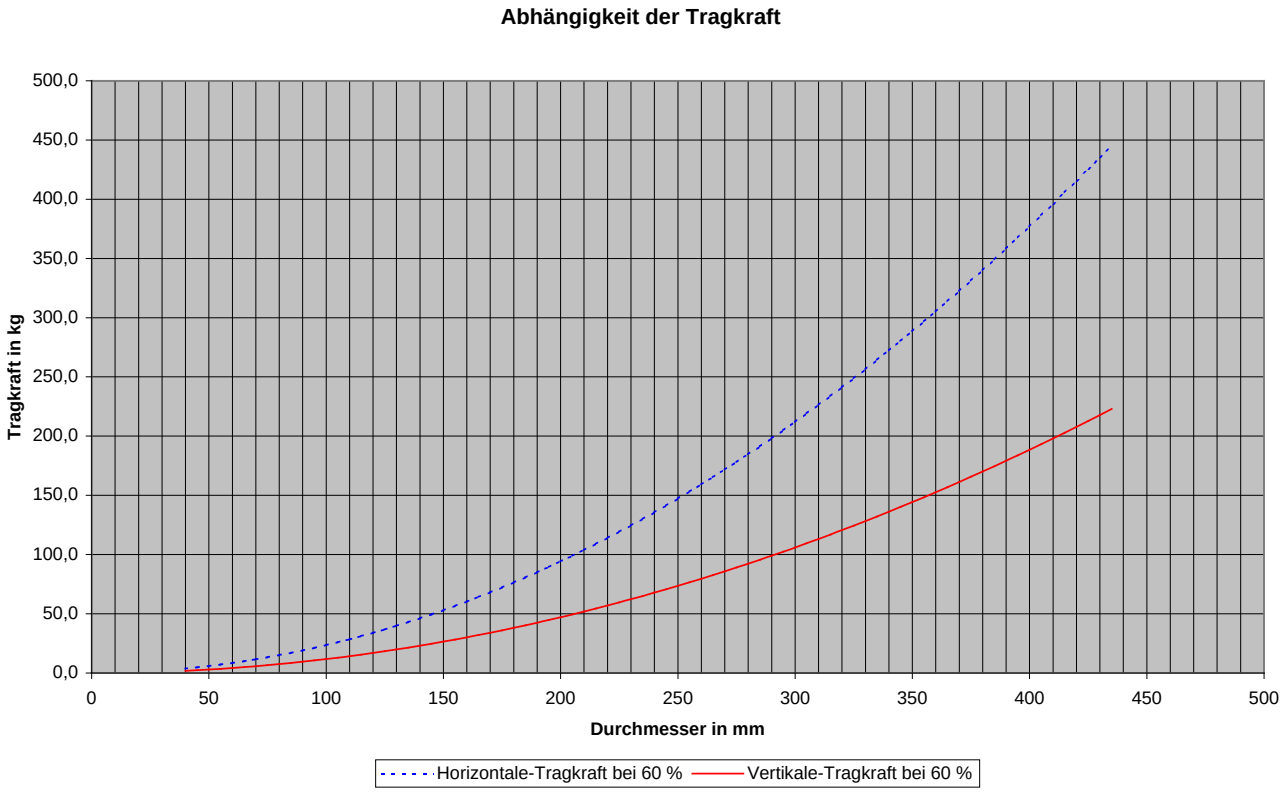
How high is the load capacity of the suction cup?

In the following diagram you can read the load capacity according to the diameter, considering the following points.

- The load capacity according to calculations use a safety factor of 2 for the horizontal pull-off force as well as for the vertical slipping off force.
- The coefficient of sliding friction **μ** was assumed with 0.5. This is a normal value for flat surfaces as they are given for glass and sheet metals. Under certain conditions another value could be set for other materials.
- Use at a height of 100 meters.
- Achieved vacuum in the suction cup of -0.6 bar.



calculated as follows:

$$\text{horizontal carrying capacity} = \frac{\text{effective surface} \times \text{effective vacuum}}{\text{safety factor}}$$

$$\text{vertical load capacity} = \frac{\text{effective surface} \times \text{effective vacuum} \times \text{coefficient of friction}}{\text{safety factor}}$$

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The values for the arithmetical carrying capacity are stated in the following table.

Depending on the diameter resp. the available active surface of the suction cup, the arithmetical carrying capacity is stated at diverse vacuum values. Other influencing factors have not been taken into consideration for the calculation of the carrying capacity.

diameter in mm	surface in cm²	carrying capacity in kg					
		Horizontal			Vertical		
		0.6	0.7	0.8	**0.6**	0.7	0.8
40	13	**3.8**	4.4	5.0	**1.9**	2.2	2.5
45	16	**4.8**	5.6	6.4	**2.4**	2.8	3.2
50	20	**5.9**	6.9	7.9	**2.9**	3.4	3.9
55	24	**7.1**	8.3	9.5	**3.6**	4.2	4.8
60	28	**8.5**	9.9	11.3	**4.2**	4.9	5.7
65	33	**10.0**	11.6	13.3	**5.0**	5.8	6.6
70	38	**11.5**	13.5	15.4	**5.8**	6.7	7.7
75	44	**13.3**	15.5	17.7	**6.6**	7.7	8.8
80	50	**15.1**	17.6	20.1	**7.5**	8.8	10.1
85	57	**17.0**	19.9	22.7	**8.5**	9.9	11.3
90	64	**19.1**	22.3	25.4	**9.5**	11.1	12.7
95	71	**21.3**	24.8	28.4	**10.6**	12.4	14.2
100	79	**23.6**	27.5	31.4	**11.8**	13.7	15.7
105	87	**26.0**	30.3	34.6	**13.0**	15.2	17.3
110	95	**28.5**	33.3	38.0	**14.3**	16.6	19.0
115	104	**31.2**	36.4	41.5	**15.6**	18.2	20.8
120	113	**33.9**	39.6	45.2	**17.0**	19.8	22.6
125	123	**36.8**	43.0	49.1	**18.4**	21.5	24.5
130	133	**39.8**	46.5	53.1	**19.9**	23.2	26.5
135	143	**42.9**	50.1	57.3	**21.5**	25.0	28.6
140	154	**46.2**	53.9	61.6	**23.1**	26.9	30.8
145	165	**49.5**	57.8	66.1	**24.8**	28.9	33.0
150	177	**53.0**	61.9	70.7	**26.5**	30.9	35.3
155	189	**56.6**	66.0	75.5	**28.3**	33.0	37.7
160	201	**60.3**	70.4	80.4	**30.2**	35.2	40.2
165	214	**64.1**	74.8	85.5	**32.1**	37.4	42.8
170	227	**68.1**	79.4	90.8	**34.0**	39.7	45.4
175	241	**72.2**	84.2	96.2	**36.1**	42.1	48.1
180	254	**76.3**	89.1	101.8	**38.2**	44.5	50.9
185	269	**80.6**	94.1	107.5	**40.3**	47.0	53.8
190	284	**85.1**	99.2	113.4	**42.5**	49.6	56.7

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		Horizontal			Vertical		
		0.6	0.7	0.8	**0.6**	0.7	0.8
195	299	**89.6**	104.5	119.5	**44.8**	52.3	59.7
200	314	**94.2**	110.0	125.7	**47.1**	55.0	62.8
205	330	**99.0**	115.5	132.0	**49.5**	57.8	66.0
210	346	**103.9**	121.2	138.5	**52.0**	60.6	69.3
215	363	**108.9**	127.1	145.2	**54.5**	63.5	72.6
220	380	**114.0**	133.0	152.1	**57.0**	66.5	76.0
225	398	**119.3**	139.2	159.0	**59.6**	69.6	79.5
230	415	**124.6**	145.4	166.2	**62.3**	72.7	83.1
235	434	**130.1**	151.8	173.5	**65.1**	75.9	86.7
240	452	**135.7**	158.3	181.0	**67.9**	79.2	90.5
245	471	**141.4**	165.0	188.6	**70.7**	82.5	94.3
250	491	**147.3**	171.8	196.3	**73.6**	85.9	98.2
255	511	**153.2**	178.7	204.3	**76.6**	89.4	102.1
260	531	**159.3**	185.8	212.4	**79.6**	92.9	106.2
265	552	**165.5**	193.0	220.6	**82.7**	96.5	110.3
270	573	**171.8**	200.4	229.0	**85.9**	100.2	114.5
275	594	**178.2**	207.9	237.6	**89.1**	103.9	118.8
280	616	**184.7**	215.5	246.3	**92.4**	107.8	123.2
285	638	**191.4**	223.3	255.2	**95.7**	111.6	127.6
290	661	**198.2**	231.2	264.2	**99.1**	115.6	132.1
295	683	**205.0**	239.2	273.4	**102.5**	119.6	136.7
300	707	**212.1**	247.4	282.7	**106.0**	123.7	141.4
305	731	**219.2**	255.7	292.2	**109.6**	127.9	146.1
310	755	**226.4**	264.2	301.9	**113.2**	132.1	151.0
315	779	**233.8**	272.8	311.7	**116.9**	136.4	155.9
320	804	**241.3**	281.5	321.7	**120.6**	140.7	160.8
325	830	**248.9**	290.4	331.8	**124.4**	145.2	165.9
330	855	**256.6**	299.4	342.1	**128.3**	149.7	171.1
335	881	**264.4**	308.5	352.6	**132.2**	154.2	176.3
340	908	**272.4**	317.8	363.2	**136.2**	158.9	181.6
345	935	**280.4**	327.2	373.9	**140.2**	163.6	187.0
350	962	**288.6**	336.7	384.8	**144.3**	168.4	192.4
355	990	**296.9**	346.4	395.9	**148.5**	173.2	198.0
360	1018	**305.4**	356.3	407.2	**152.7**	178.1	203.6
365	1046	**313.9**	366.2	418.5	**157.0**	183.1	209.3

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		Horizontal			Vertical		
		0.6	0.7	0.8	**0.6**	0.7	0.8
370	1075	**322.6**	376.3	430.1	**161.3**	188.2	215.0
375	1104	**331.3**	386.6	441.8	**165.7**	193.3	220.9
380	1134	**340.2**	396.9	453.6	**170.1**	198.5	226.8
385	1164	**349.2**	407.5	465.7	**174.6**	203.7	232.8
390	1195	**358.4**	418.1	477.8	**179.2**	209.1	238.9
395	1225	**367.6**	428.9	490.2	**183.8**	214.4	245.1
400	1257	**377.0**	439.8	502.7	**188.5**	219.9	251.3
405	1288	**386.5**	450.9	515.3	**193.2**	225.4	257.6
410	1320	**396.1**	462.1	528.1	**198.0**	231.0	264.1
415	1353	**405.8**	473.4	541.1	**202.9**	236.7	270.5
420	1385	**415.6**	484.9	554.2	**207.8**	242.5	277.1
425	1419	**425.6**	496.5	567.5	**212.8**	248.3	283.7
430	1452	**435.7**	508.3	580.9	**217.8**	254.1	290.4
435	1486	**445.9**	520.2	594.5	**222.9**	260.1	297.2

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