Vacuum Cup Holding Force and Number of Cups

Holding force of a vacuum cup from vacuum and diameter, and the number of cups to lift a load horizontally or vertically with acceleration and safety factor.

Method: Pressure × area and friction statics (definitions)

Input parameters

Unit system: SI

Parameter	Value	Unit
Load mass	50.000	kg
Vacuum (below atmospheric)	60.000	kPa
Cup diameter	80.000	mm
Acceleration of the handling motion g is added for the vertical component.	5.0000	m/s²
Lift orientation	Horizontal surface, vertical lift	
Cup–load friction coefficient	0.50000	
Safety factor	2.0000	

Calculated results

Parameter	Value	Unit
Theoretical force per cup	301.59	N
Required total force	1,480.7	N
Cups needed (rounded up)	5.0000	

Notes for this case

• Theoretical cup force; makers' rated forces are lower for porous or curved surfaces. On a vertical surface the cups hold by friction, so far more force is needed.

Formula and method

$$F_c = \Delta p \frac{\pi d^2}{4}, \quad F_{req} = m(g+a)S \ \text{(horizontal)}, \ \frac{m(g+a)S}{\mu} \ \text{(vertical)}$$

Variables

m	Load mass	kg
Δp	Vacuum (below atmospheric)	Pa
d	Cup diameter	m
a	Acceleration of the handling motion	m/s²
$\mathrm{orientation}$	Lift orientation	-
g	Standard gravity, 9.80665	m/s²
μ	Cup–load friction coefficient	-
S	Safety factor	-
F_c	Theoretical force per cup	N
F_{req}	Required total force	N
n	Cups needed (rounded up)	-

Method and standards

Statics.

Assumptions and limits

- Sealed cups; rigid load.

References

- Pressure × area and friction statics (definitions)

Report details

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Release checks	2 reference cases of this calculator, computed independently, are checked on every release

Results are for engineering estimation. Verify critical designs against the referenced standards and your own data.

This calculator online

https://calc.firecad.com/mechanical/hydraulics-pneumatics/vacuum-cup-holding-force

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.