Vacuum Line Conductance and Effective Pumping Speed

Conductance of a round vacuum line in viscous and molecular flow, the Knudsen number, and the effective pumping speed at the chamber.

Method: Poiseuille and Knudsen conductance of a long round tube; kinetic-theory mean free path

Input parameters

Unit system: SI

Parameter	Value	Unit
Pump speed at its inlet	100.00	L/s
Line inside diameter	40.000	mm
Line length	2.0000	m
Mean pressure in the line	1.0000e-04	bar
Gas temperature	20.000	°C
Molar mass of the gas	28.960	kg/kmol
Gas viscosity	1.8100e-05	Pa·s

Calculated results

Parameter	Value	Unit
Mean free path	0.65811	mm
Knudsen number λ/d	0.016453	
Viscous-flow conductance	17.357	L/s
Molecular-flow conductance	3.8784	L/s
Conductance used (sum)	21.235	L/s
Effective pumping speed at the chamber	17.516	L/s
Speed lost in the line	82.484	%

Notes for this case

• In viscous (laminar) flow the conductance of a long round tube is π d⁴ p̄ /(128 μ L), proportional to pressure; in molecular flow it is (π/12) v̄ d³/L, independent of pressure. The Knudsen number λ/d shows the regime: below about 0.01 viscous, above about 0.5 molecular; between them the sum of the two is a fair estimate. The line and pump act like resistances in series: 1/S_eff = 1/S + 1/C, so a thin, long line wastes a large pump.

Formula and method

$$C_v = \frac{\pi d^4 \bar{p}}{128 \mu L}, \quad C_m = \frac{\pi}{12} \bar{v} \frac{d^3}{L}, \quad \frac{1}{S_{eff}} = \frac{1}{S} + \frac{1}{C}, \quad \lambda = \frac{\mu}{p} \sqrt{\frac{\pi R T}{2M}}$$

Variables

S	Pump speed at its inlet	m³/s
d	Line inside diameter	m
L	Line length	m
$\bar{p}$	Mean pressure in the line	Pa
T	Gas temperature	K
M	Molar mass of the gas	kg/kmol
μ	Gas viscosity	Pa·s
λ	Mean free path	m
Kn	Knudsen number λ/d	-

C_v	Viscous-flow conductance	m³/s
C_m	Molecular-flow conductance	m³/s
C	Conductance used (sum)	m³/s
S_{eff}	Effective pumping speed at the chamber	m³/s
$1 - S_{eff}/S$	Speed lost in the line	-

Method and standards

Vacuum conductance.

Assumptions and limits

- Long round tube; isothermal; transitional flow as a sum.

References

Poiseuille and Knudsen conductance of a long round tube; kinetic-theory mean free path

Report details

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

This calculator online

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