Centrifugal Compressor Sizing: Head, Stages, Tip Speed and Power

Polytropic head, number of stages for a head per stage, impeller tip speed from a head coefficient, shaft speed, flow coefficients, discharge temperature and power.

Input parameters

Unit system: SI

Parameter	Value	Unit
Inlet volume flow	12,000	ft^3/min
Mass flow	120,000	lb/h
Molar mass	44.100	kg/kmol
Inlet temperature	20.000	°F
Inlet pressure	20.000	psi
Discharge pressure	200.00	psi
Isentropic exponent	1.1300	
Polytropic efficiency	78.000	%
Average compressibility	0.92000	
Maximum head per stage	29.891	kJ/kg
Polytropic head coefficient	0.48000	
Impeller diameter	30.000	in
Mechanical losses	1.5000	%

Calculated results

Parameter	Value	Unit
Pressure ratio	10.000	
Polytropic exponent	1.1730	
Polytropic head	126.74	kJ/kg
Number of stages	5.0000	
Head per stage	25.347	kJ/kg
Impeller tip speed	753.93	ft/s
Shaft speed	5,759.6	rpm
Inlet volume of the last stage	2,495.6	ft^3/min
First-stage flow coefficient	0.054042	
Last-stage flow coefficient	0.011239	
Discharge temperature	213.98	°F
Shaft power	3,343.9	hp

Notes for this case

• The rules: about 10,000 ft·lbf/lbm (29.9 kJ/kg) of head per stage, head coefficient 0.48, at most eight stages per casing and a discharge temperature below about 475 °F. Flow coefficients of 0.01-0.10 (2-D impellers) or up to 0.15 (3-D) give good efficiency; read the efficiency from the maker's curve and repeat.

Formula and method

$$\frac{n-1}{n}=\frac{k-1}{k\eta_p},\quad H_p=Z\frac{R}{M}T_1\frac{n}{n-1}\left(r_p^{\frac{n-1}{n}}-1\right),\quad z=\left\lceil\frac{H_p}{H_{stage}}\right\rceil$$

$$u_2=\sqrt{\frac{H_p/z}{\mu_p}},\quad N=\frac{u_2}{\pi d_2},\quad Q_{ls}=Q_1/\left(r_p^{(z-1)/z}\right)^{1/n},\quad \delta=\frac{Q}{(\pi/4)d_2^2u_2}$$

Variables

Q_1	Inlet volume flow	m³/s
w	Mass flow	kg/s
M	Molar mass	kg/kmol
T_1	Inlet temperature	K
P_1	Inlet pressure	Pa
P_2	Discharge pressure	Pa
k	Isentropic exponent	-
η_p	Polytropic efficiency	-
Z_{avg}	Average compressibility	-
H_{stage}	Maximum head per stage	J/kg
μ_p	Polytropic head coefficient	-
d_2	Impeller diameter	m
f_m	Mechanical losses	-
r_p	Pressure ratio	-
n	Polytropic exponent	-
H_p	Polytropic head	J/kg
z	Number of stages	-
H_p/z	Head per stage	J/kg
u_2	Impeller tip speed	m/s
N	Shaft speed	rad/s
Q_{ls}	Inlet volume of the last stage	m³/s
δ_1	First-stage flow coefficient	-
δ_z	Last-stage flow coefficient	-
T_2	Discharge temperature	K
W	Shaft power	W

Method and standards

The centrifugal compressor sizing procedure.

Assumptions and limits

- Single uncooled section; ideal-gas head with average Z.

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

https://calc.firecad.com/mechanical/compressors/centrifugal-compressor-stage-sizing

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Reopens the calculator with the inputs of this report.