Compressor study: Hydrotreater recycle compressor

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Results are thermodynamic and curve-based estimates from the inputs and data you supply. They are not a manufacturer guarantee. Surge, choke and performance curves must come from the machine maker or from tests; nothing is invented here.

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Centrifugal compressor rating

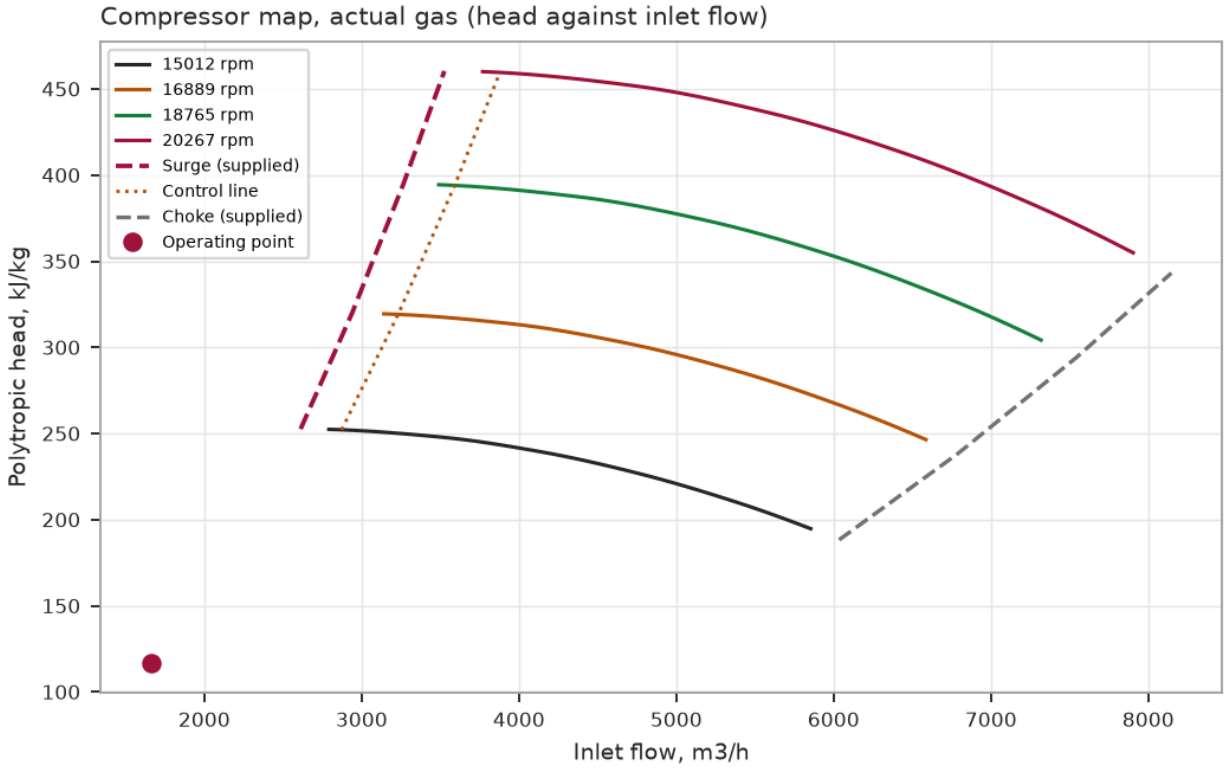
Curves are the data you supplied for the reference gas, converted to the actual gas by the equivalent-speed (Mach similarity) method. This is an approximation that ignores Reynolds number and isentropic-exponent differences. Surge and choke appear only where supplied.

Result	Value
Speed rpm	10,223
Inlet flow m3/h	1,662.9
Polytropic head kJ/kg	117.01
Polytropic efficiency	0.6071
Discharge pressure kPa(a)	4,400.0
Discharge temperature C	78.8
Shaft power kW	655.6
Surge margin	-6.5 %
Choke margin	59.5 %

Note: Operating flow is below the supplied surge flow: the compressor would be in surge. Recycle is required.

Note: Equivalent speed 5448 rpm is outside the tested speeds 8000 to 10800 rpm: the curve is extrapolated by the affinity laws and is not validated.

Note: Flow 1663 m3/h is outside the supplied curve range (1901 to 3987 m3/h at this speed): extrapolated, unvalidated.



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Surge analysis

Surge flows are the maker points you supplied; none are estimated. Control line = surge flow x (1 + control margin).

Scenario	Status	Flow m3/h	Speed rpm	Surge margin	Recycle %	Mixed suction C	Extra power %
Base case	SURGE (flow below surge)	1,663	10,223	-6.5 %	17.4	45.0	3.2
Flow 9,000 kg/h	SURGE (flow below surge)	173	12,995	-92.3 %	1,026.6	45.0	454.7
Flow 16,000 kg/h	SURGE (flow below surge)	305	12,459	-85.9 %	540.1	45.0	205.6

Minimum process flow without recycle at the base duty: 14,083 kg/h (117 % of the base flow).

Recycle at the base duty: 2,083 kg/h; mixed suction 45.0 C; converged in 1 iteration(s).

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Validation status

32 of 32 benchmark checks pass. Closed-form ideal-gas equations, CoolProp pure-gas properties, interpolation and clearance equations. No manufacturer or field test data are included, so centrifugal and reciprocating machine models are not validated against real machines.

Case	Reference	Quantity	Reference value	Result	Deviation %	Tolerance %	Status
Ideal gas isentropic	closed form T2 = T1 r^((k-1)/k)	Discharge temperature	445.7983	445.7983	-0.000	0.01	pass
Ideal gas isentropic	closed form H = k/(k-1) R T1 (r^((k-1)/k) - 1)	Isentropic head	146,455.6582	146,455.6582	-0.000	0.01	pass
Ideal gas polytropic	closed form Hp = R T1/e (r^e - 1), e = (k-1)/(k eta_p)	Polytropic head	157,244.5943	157,253.6188	0.006	0.05	pass
Ideal gas polytropic	closed form T2 = T1 r^((k-1)/(k eta_p))	Discharge temperature	508.7184	508.7304	0.002	0.05	pass
Ideal gas polytropic	closed form Hp = R T1/e (r^e - 1), e = (k-1)/(k eta_p)	Polytropic head	152,044.6427	152,053.9894	0.006	0.05	pass
Ideal gas polytropic	closed form T2 = T1 r^((k-1)/(k eta_p))	Discharge temperature	478.0732	478.0841	0.002	0.05	pass
Ideal gas isothermal	closed form w = R T ln(r)	Isothermal work	119,360.9870	119,360.9870	0.000	0.01	pass
Multistage optimum, 2 stages	theory: equal ratio is optimal for equal efficiencies and equal intercooling	Power, optimiser vs equal ratio	386,279.3652	386,279.3652	0.000	0.20	pass
Multistage ratio, 2 stages	closed form r = (Pd/Ps)^(1/N)	Stage ratio	4.0000	4.0000	0.000	0.00	pass
Multistage optimum, 3 stages	theory: equal ratio is optimal for equal efficiencies and equal intercooling	Power, optimiser vs equal ratio	353,600.1328	353,600.1328	0.000	0.20	pass
Multistage ratio, 3 stages	closed form r = (Pd/Ps)^(1/N)	Stage ratio	2.5198	2.5198	0.000	0.00	pass
Real gas isentropic: Methane	CoolProp (Helmholtz EOS)	Isentropic discharge temperature (cubic EOS accuracy, about 1 K)	386.9876	386.9320	-0.014	0.50	pass
Real gas isentropic: Methane	CoolProp (Helmholtz EOS)	Isentropic head	188,634.4101	186,726.5816	-1.011	2.50	pass
Compressibility: Methane	CoolProp (Helmholtz EOS)	Z at suction	0.9667	0.9580	-0.897	4.00	pass
Real gas isentropic: Nitrogen	CoolProp (Helmholtz EOS)	Isentropic discharge temperature (cubic EOS accuracy, about 1 K)	411.3257	410.7898	-0.130	0.50	pass
Real gas isentropic: Nitrogen	CoolProp (Helmholtz EOS)	Isentropic head	115,416.9963	115,011.9002	-0.351	2.50	pass
Compressibility: Nitrogen	CoolProp (Helmholtz EOS)	Z at suction	0.9984	0.9960	-0.241	4.00	pass
Real gas isentropic: CarbonDioxide	CoolProp (Helmholtz EOS)	Isentropic discharge temperature (cubic EOS accuracy, about 1 K)	421.2920	420.6195	-0.160	0.50	pass
Real gas isentropic: CarbonDioxide	CoolProp (Helmholtz EOS)	Isentropic head	71,271.4761	70,521.4914	-1.052	4.00	pass
Compressibility: CarbonDioxide	CoolProp (Helmholtz EOS)	Z at suction	0.9261	0.9179	-0.885	4.00	pass
Real gas isentropic: Hydrogen	CoolProp (Helmholtz EOS)	Isentropic discharge temperature (cubic EOS accuracy, about 1 K)	410.8019	412.3353	0.373	0.50	pass
Real gas isentropic: Hydrogen	CoolProp (Helmholtz EOS)	Isentropic head	1,628,559.3119	1,618,520.4855	-0.616	3.00	pass
Compressibility: Hydrogen	CoolProp (Helmholtz EOS)	Z at suction	1.0117	1.0059	-0.579	4.00	pass
Curve interpolation: linear	analytic quadratic y = 3 + 2x - 0.1x^2	y at x = 4.4	9.8640	9.8000	-0.649	1.50	pass
Curve interpolation: pchip	analytic quadratic y = 3 + 2x - 0.1x^2	y at x = 4.4	9.8640	9.8587	-0.054	1.50	pass
Curve interpolation: spline	analytic quadratic y = 3 + 2x - 0.1x^2	y at x = 4.4	9.8640	9.8606	-0.034	1.50	pass
Curve interpolation: polynomial	analytic quadratic y = 3 + 2x - 0.1x^2	y at x = 4.4	9.8640	9.8640	0.000	0.00	pass

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Case	Reference	Quantity	Reference value	Result	Deviation %	Tolerance %	Status
Recycle mixing temperature	closed form T = (m1 T1 + m2 T2) / (m1 + m2), constant cp	Mixed temperature	330.0000	330.0000	0.000	0.01	pass
Axial stage: Euler work	dh0 = lambda U^2	Stage enthalpy rise	34,543.6154	34,543.6154	0.000	0.00	pass
Axial stage: ideal-gas temperature rise	dT = lambda U^2 / cp, cp = 3.5 R	Temperature rise	34.3886	34.3849	-0.011	0.30	pass
Screw compressor: matched built-in ratio	no under- or over-compression when P2/P1 = Vi^k	Mismatch loss, %	0.0000	0.0000	0.000	0.50	pass
Reciprocating volumetric efficiency	closed form eta = 1 - C (r^(1/k) - 1)	eta_v	0.8672	0.8672	0.000	0.00	pass

Methods and limitations

Method	Status	Validity	Validation
Gas properties	implemented	gas phase, away from the critical region and the dew point	benchmarked against CoolProp for pure gases (see Validation)
Isentropic compression	implemented	gas phase	benchmarked: ideal-gas closed form and CoolProp
Polytropic compression	implemented	gas phase; constant eta_p along the path	benchmarked: ideal-gas closed form
Isothermal compression	implemented	reference process, also used for large reciprocating cylinders	benchmarked: ideal-gas closed form
Multistage compression with intercooling	implemented	equal-flow stages; no liquid condensation	benchmarked: ideal-gas equal-ratio optimum
Performance curve scaling (equivalent speed)	approximate	same machine, similar Reynolds number and isentropic exponent; speed within the tested range	affinity-law consistency tested; no manufacturer data used. Treat as an approximation, not as a real-gas validated scaling.
Surge and control lines	data-driven	only the supplied points; never extrapolated silently	none: manufacturer data governs
Reciprocating volumetric efficiency	implemented	clearance model with lumped valve loss and leakage factors you supply	benchmarked: closed-form clearance equation

References

[ptc10] ASME PTC 10 Performance Test Code on Compressors and Exhausters (definitions of head, polytropic and isentropic efficiency, equivalent-speed test conversion). Check the edition you work to.

[api617] API Standard 617 Axial and Centrifugal Compressors and Expander-compressors (data sheets, surge margin, operating range definitions). Check the edition before using any criterion.

[api618] API Standard 618 Reciprocating Compressors for Petroleum, Chemical and Gas Industry Services (cylinder and valve definitions, rod load).

[api619] API Standard 619 Rotary-type Positive-displacement Compressors.

[gpsa] GPSA Engineering Data Book, section on compressors (volumetric efficiency with clearance, multistage ratio, intercooling).

[perry] Perry's Chemical Engineers' Handbook, compressors and thermodynamics chapters (isothermal, isentropic and polytropic work).

[schultz] Schultz, J.M. (1962). The polytropic analysis of centrifugal compressors. J. Eng. Power 84(1), 69.

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[srk] Soave, G. (1972). Equilibrium constants from a modified Redlich-Kwong equation of state. Chem. Eng. Sci. 27, 1197.

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[lapina] Lapina, R.P. (1982). Estimating Centrifugal Compressor Performance. Gulf Publishing (similarity and gas-correction methods).

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