Compressor study: CO2 compression for transport

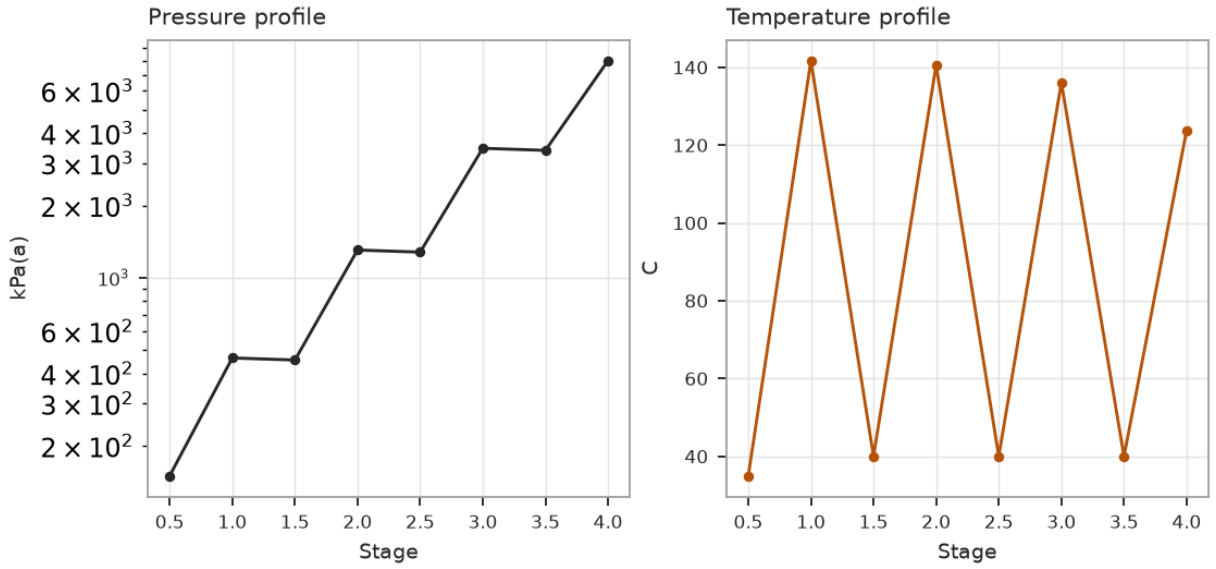
Tag K-301. Generated 2026-11-19 10:12 UTC.

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.

Multistage compression with intercooling

Stage	Ps kPa	Ts C	Pd kPa	Td C	Ratio	Head kJ/kg	eta_p	Power kW	Cooler Tout C	Duty kW
1	150	35.0	464	141.7	3.093	76.76	0.780	1,366.9	40.0	1,343.5
2	455	40.0	1,304	140.6	2.869	71.02	0.780	1,264.6	40.0	1,369.3
3	1,278	40.0	3,458	136.1	2.705	63.94	0.780	1,138.6	40.0	1,438.9
4	3,388	40.0	8,000	123.9	2.361	48.43	0.780	862.4	-	0.0

Mode optimum. Total gas power 4,632.4 kW against 7,062.6 kW in a single stage (saving 34.4 %). Cooling duty 4,151.6 kW. Equal-ratio reference 2.744.



© 2026 HB Process. All rights reserved.

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

© 2026 HB Process. All rights reserved.

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.

[huntington] Huntington, R.A. (1985). Evaluation of polytropic calculation methods for turbomachinery performance. J. Eng. Gas Turbines Power 107, 872.

[pr] Peng, D.-Y. and Robinson, D.B. (1976). A new two-constant equation of state. Ind. Eng. Chem. Fundam. 15, 59.

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

[coolprop] Bell, I.H. et al. (2014). Pure and pseudo-pure fluid thermophysical property evaluation and the open-source library CoolProp. Ind. Eng. Chem. Res. 53, 2498 (used as an independent reference in the benchmarks).

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

© 2026 HB Process. All rights reserved.

Calculation trace: multistage

Id	Quantity	Equation	Value	Unit	Ref
r_eq	Equal stage pressure ratio	r = ((Pd / Ps) / prod(1 - dP_cooler))^(1/N)	2.7437	-	gpsa
s1.head_s	Isentropic head	H_s = h(T2s, P2) - h(T1, P1), s(T2s, P2) = s(T1, P1)	74,193.5000	J/kg	ptc10
s1.head_p	Polytropic head	H_p = eta_p (h2 - h1) = int v dP along dh = v dP / eta_p	76,763.9000	J/kg	ptc10
s1.T2	Discharge temperature	h(T2, P2) = h1 + (1 - f_loss) w	414.8690	K	ptc10
s1.eta_s	Isentropic efficiency	eta_s = H_s / w	0.7539	-	ptc10
s2.head_s	Isentropic head	H_s = h(T2s, P2) - h(T1, P1), s(T2s, P2) = s(T1, P1)	68,762.2000	J/kg	ptc10
s2.head_p	Polytropic head	H_p = eta_p (h2 - h1) = int v dP along dh = v dP / eta_p	71,017.2000	J/kg	ptc10
s2.T2	Discharge temperature	h(T2, P2) = h1 + (1 - f_loss) w	413.7210	K	ptc10
s2.eta_s	Isentropic efficiency	eta_s = H_s / w	0.7552	-	ptc10
s3.head_s	Isentropic head	H_s = h(T2s, P2) - h(T1, P1), s(T2s, P2) = s(T1, P1)	61,931.2000	J/kg	ptc10
s3.head_p	Polytropic head	H_p = eta_p (h2 - h1) = int v dP along dh = v dP / eta_p	63,943.4000	J/kg	ptc10
s3.T2	Discharge temperature	h(T2, P2) = h1 + (1 - f_loss) w	409.2530	K	ptc10
s3.eta_s	Isentropic efficiency	eta_s = H_s / w	0.7555	-	ptc10

© 2026 HB Process. All rights reserved.