Curtis (Velocity-compounded) Stage and Number of Stages Needed

Optimum velocity ratio, diagram efficiency, row work split and isentropic drop of a Curtis stage, compared with impulse and reaction stages and stages needed.

Input parameters

Unit system: SI

Parameter	Value	Unit
Mean blade speed	250.00	m/s
Nozzle angle	15.000	°
Rows of moving blades	3 (three-row Curtis)	
Velocity ratio V_b/V_1 (0 for the optimum)	0	
Total isentropic drop to be handled	2,000.0	kJ/kg

Calculated results

Parameter	Value	Unit
Velocity ratio used	0.16099	
Nozzle exit velocity	1,552.9	m/s
Diagram efficiency (frictionless, symmetric)	93.301	%
Diagram work per kg	1,125.0	kJ/kg
Isentropic drop of this stage	1,205.8	kJ/kg
Drop of a simple impulse stage at optimum	133.97	kJ/kg
Drop of a 50 % reaction stage at optimum	66.987	kJ/kg
Stages of this type for the total drop	2.0000	
Share of work on the first row	55.556	%

Notes for this case

- Frictionless, symmetric blades and axial discharge, in the derivation; real Curtis stages lose much more to blade friction, which is why they are used only as a first (control) stage. The work split 3: 1 (two rows) or 5: 3: 1 (three rows) holds at the optimum ratio cos α/2Z.

Formula and method

$$\rho_{opt} = \frac{\cos\alpha}{2Z}, \quad \eta_D = 4Z\rho(\cos\alpha - Z\rho), \quad (\eta_D)_{max} = \cos^2\alpha, \quad \Delta h_s = \frac{V_1^2}{2}$$

$$(\Delta h_s)_{50\%} : (\Delta h_s)_{imp} : (\Delta h_s)_{Curtis,2} = 1 : 2 : 8, \quad n = \left\lceil \frac{(\Delta h_s)_{total}}{\Delta h_s} \right\rceil$$

Variables

V_b	Mean blade speed	m/s
α	Nozzle angle	rad
Z	Rows of moving blades	-
ρ	Velocity ratio V_b/V_1 (0 for the optimum)	-
$(\Delta h_s)_{total}$	Total isentropic drop to be handled	J/kg
V_1	Nozzle exit velocity	m/s

η_D	Diagram efficiency (frictionless, symmetric)	-
W_D	Diagram work per kg	J/kg
Δh_s	Isentropic drop of this stage	J/kg
$(\Delta h_s)_{imp}$	Drop of a simple impulse stage at optimum	J/kg
$(\Delta h_s)_{50\%}$	Drop of a 50 % reaction stage at optimum	J/kg
n	Stages of this type for the total drop	-
W_1/W_D	Share of work on the first row	-

Method and standards

Velocity-compounded impulse stage theory.

Assumptions and limits

- Frictionless symmetric blades; axial discharge.

Report details

Report reference	FCC-VEE6-KJT9 (the same inputs always give the same reference)
Generated	23 November 2026, 17:43 UTC
Calculator	Curtis (Velocity-compounded) Stage and Number of Stages Needed
Method last reviewed	17 November 2026
Software release	FireCAD Calc, release of 22 November 2026
Release checks	3 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/boilers-power-plant/steam-turbines/curtis-stage-velocity-compounded

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Reopens the calculator with the inputs of this report.