Steam Flow through a Vent, Orifice or Leak

Steam flow through a start-up vent, restriction orifice or leak from the upstream pressure and the opening size, with the choked-flow check.

Method: Isentropic nozzle flow (Shapiro; Perry's Chemical Engineers' Handbook); IAPWS R7-97(2012) IF97

Input parameters

Unit system: SI

Parameter	Value	Unit
Upstream pressure (absolute)	66.000	bar
Steam condition	Superheated at the temperature below	
Steam temperature (superheated only)	485.00	°C
Diameter of the opening	40.000	mm
Discharge coefficient About 0.6–0.65 for a sharp-edged orifice or hole, 0.8–0.9 for a short pipe or valve, 0.95–0.98 for a rounded nozzle.	0.85000	
Downstream pressure (absolute)	1.0132	bar
Isentropic exponent of steam 1.3 for superheated steam; 1.135 for dry saturated steam (Zeuner).	1.3000	

Calculated results

Parameter	Value	Unit
Steam flow	29,472	kg/h
Choked (1 = yes)	1.0000	
Critical (choking) downstream pressure	36.018	bar
Critical pressure ratio	0.54573	
Specific volume upstream	0.050026	m³/kg
Area of the opening	1,256.6	mm²

Formula and method

$$r_c = \left(\frac{2}{k+1}\right)^{\frac{k}{k-1}} \qquad p_c = r_c\, p_0 \qquad A = \frac{\pi d^2}{4}$$

$$\dot{m} = C_d\, A \sqrt{\frac{k\, p_0}{v_0}} \left(\frac{2}{k+1}\right)^{\frac{k+1}{2(k-1)}}$$

$$\dot{m} = C_d\, A \sqrt{\frac{2\, p_0}{v_0} \cdot \frac{k}{k-1} \left(r^{2/k} - r^{(k+1)/k}\right)}$$

Variables

p_0	upstream pressure, absolute	Pa
state	dry saturated or superheated steam	–
T_s	steam temperature (superheated)	K
d	diameter of the opening	m
C_d	discharge coefficient	–

p_b	downstream pressure, absolute	Pa
k	isentropic exponent of steam	–
$\dot{m}$	steam flow	kg/s
choked	1 when the flow is choked	–
p_c	critical downstream pressure	Pa
r_c	critical pressure ratio	–
v_0	specific volume upstream	m³/kg
A	area of the opening	m²

Method and standards

Isentropic flow of a gas with constant exponent k through a nozzle, with the upstream specific volume from FireCAD's IAPWS-IF97. k = 1.3 for superheated and 1.135 for dry saturated steam are the classical values (Zeuner).

Assumptions and limits

- Steam treated as a gas with a constant isentropic exponent. This is an approximation; it is not compared here with a homogeneous-equilibrium calculation. Dry saturated steam turns wet as it expands, and Zeuner's 1.135 is an empirical exponent for that wet expansion.
- k should match the steam state; a mismatch is flagged.
- Upstream velocity neglected (opening small against the pipe).
- Not a safety-valve calculation: relieving capacities are certified to the pressure-vessel code.

References

• Isentropic nozzle flow (Shapiro; Perry's Chemical Engineers' Handbook)
• IAPWS R7-97(2012) IF97

Report details

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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/steam-vent-flow

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.