Single-Phase Natural Circulation Loop Flow

Steady natural circulation flow and temperature rise of a single-phase water loop from heat input, elevation between thermal centres and loop resistance.

Method: Steady single-phase natural circulation (Boussinesq loop balance)

Input parameters

Unit system: SI

Parameter	Value	Unit
Heat input	1,000.0	kW
Elevation of cooler thermal centre above heater thermal centre	5.0000	m
Reference flow area	100.00	cm²
Total loss coefficient referred to that area	20.000	
Loop pressure	7.0000	MPa
Mean loop temperature	246.85	°C

Calculated results

Parameter	Value	Unit
Natural circulation flow	4.9811	kg/s
Temperature rise across the heater	41.892	K
Velocity at the reference area	0.61713	m/s
Volumetric expansion coefficient	1,854.1	µm/(m·K)
Density at the mean temperature	807.13	kg/m³
Specific heat	4.7923	kJ/(kg·K)

Notes for this case

• Buoyancy ρβΔT gΔz balances friction ΣK ṁ²/(2ρA²), with ΔT = Q/(ṁc_p): ṁ = [2ρ²A²βgΔzQ/(ΣK c_p)]^(1/3). Boussinesq, point heat source and sink; β by a 1 K central difference of IAPWS-IF97 density.

Formula and method

$$\dot{m} = \left(\frac{2\rho^2 A^2 \beta g \Delta z Q}{c_p \Sigma K} \right)^{1/3}, \quad \Delta T = \frac{Q}{\dot{m} c_p}$$

Variables

Q	Heat input	W
Δz	Elevation of cooler thermal centre above heater thermal centre	m
A	Reference flow area	m²
ΣK	Total loss coefficient referred to that area	-
p	Loop pressure	Pa
$\bar{T}$	Mean loop temperature	K
$\dot{m}$	Natural circulation flow	kg/s
ΔT	Temperature rise across the heater	K
v	Velocity at the reference area	m/s
β	Volumetric expansion coefficient	1/K
ρ	Density at the mean temperature	kg/m³
c_p	Specific heat	J/(kg·K)

Method and standards

Natural circulation momentum and energy balance.

Assumptions and limits

- Single phase; steady; Boussinesq; friction as form losses.

References

Steady single-phase natural circulation (Boussinesq loop balance)

Report details

Report reference	FCC-AAB7-65QE (the same inputs always give the same reference)
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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/nuclear-power/natural-circulation-loop-flow

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.