Critical Heat Flux in Tubes: Palen, Katto–Ohno and Merilo

Critical heat flux for boiling in a uniformly heated tube: Palen's thermosyphon formula, Katto–Ohno for vertical flow and Merilo for horizontal tubes.

Input parameters

Unit system: SI

Parameter	Value	Unit
Mass flux	1,500.0	kg/(m²·s)
Tube inside diameter	12.000	mm
Heated length	2.0000	m
Inlet subcooling enthalpy	50.000	kJ/kg
Pressure	7,000.0	kPa
Critical pressure	22,064	kPa
Liquid density	739.70	kg/m³
Vapour density	36.500	kg/m³
Liquid viscosity	0.091000	mPa·s
Vapour viscosity	0.018900	mPa·s
Surface tension	17.700	mN/m
Latent heat	1,505.0	kJ/kg

Calculated results

Parameter	Value	Unit
Reduced pressure	0.31726	
Palen (vertical thermosyphon)	192.02	kW/m²
Length-to-diameter ratio	166.67	
Katto–Ohno q_oA	2,662.0	kW/m²
Katto–Ohno q_oB	1,424.1	kW/m²
Basic critical heat flux	1,424.1	kW/m²
Inlet subcooling parameter	1.6026	
Katto–Ohno (vertical)	1,499.9	kW/m²
Merilo property group	2.1606e+19	
Merilo (horizontal)	1,145.9	kW/m²

Notes for this case

• Palen ignores flow rate and subcooling. Katto–Ohno is for uniformly heated vertical tubes; Merilo for horizontal tubes (fitted for water and R-12, D 5–19 mm, G 700–8100 kg/(m²·s)). Horizontal tubes dry out at much lower fluxes than vertical ones.

Formula and method

$$\widehat{q_{c,Palen}} = 23\,660\left(\frac{D^2}{L}\right)^{0.35} P_c^{0.61} P_r^{0.25}(1-P_r)$$

$$\widehat{q_c} = \widehat{q_o}\left(1+\psi\frac{\Delta H_{in}}{\lambda}\right), \quad \frac{\widehat{q_{oA}}}{G\lambda} = \frac{C_2(\sigma\rho_L/G^2L)^{0.043}}{L/D}$$

$$\frac{\widehat{q_c}}{G\lambda} = 575 H^{-0.34} \left(\frac{L}{D}\right)^{-0.511} \left(\frac{\rho_L - \rho_V}{\rho_V}\right)^{1.27} \left(1 + \frac{\Delta H_{in}}{\lambda}\right)^{1.64}$$

Variables

G	Mass flux	kg/(m²·s)
D	Tube inside diameter	m
L	Heated length	m
ΔH_{in}	Inlet subcooling enthalpy	J/kg
P	Pressure	Pa
P_c	Critical pressure	Pa
ρ_L	Liquid density	kg/m³
ρ_V	Vapour density	kg/m³
μ_L	Liquid viscosity	Pa·s
μ_V	Vapour viscosity	Pa·s
σ	Surface tension	N/m
λ	Latent heat	J/kg
P_r	Reduced pressure	-
$\widehat{q_{c,Palen}}$	Palen (vertical thermosyphon)	W/m²
L/D	Length-to-diameter ratio	-
$\widehat{q_{oA}}$	Katto–Ohno q_oA	W/m²
$\widehat{q_{oB}}$	Katto–Ohno q_oB	W/m²
$\widehat{q_o}$	Basic critical heat flux	W/m²
ψ	Inlet subcooling parameter	-
$\widehat{q_{c,KO}}$	Katto–Ohno (vertical)	W/m²
H	Merilo property group	-
$\widehat{q_{c,Merilo}}$	Merilo (horizontal)	W/m²

Method and standards

Empirical critical heat flux correlations for flow boiling in tubes (P_c in kPa).

Assumptions and limits

- Uniformly heated round tubes; pure fluids.

Report details

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Results are for engineering estimation. Verify critical designs against the referenced standards and your own data.

This calculator online

https://calc.firecad.com/mechanical/heat-transfer/flow-boiling-critical-heat-flux

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Reopens the calculator with the inputs of this report.