Flow Boiling in Tubes: Chen and Liu–Winterton Coefficients

Convective boiling coefficient in a vertical tube by Chen (Forster–Zuber or Mostinski nucleate term) and by Liu–Winterton with Cooper's nucleate term.

Input parameters

Unit system: SI

Parameter	Value	Unit
Mass flux	500.00	kg/(m²·s)
Tube inside diameter	25.000	mm
Vapour mass fraction (quality)	5.0000	%
Wall superheat T_w − T_sat	8.0000	K
P_sat(T_w) − P_sat(T_sat)	46.600	kPa
Pressure	101.33	kPa
Critical pressure	22,064	kPa
Molar mass	18.015	kg/kmol
Liquid density	958.40	kg/m³
Vapour density	0.59800	kg/m³
Liquid viscosity	0.28200	mPa·s
Vapour viscosity	0.012300	mPa·s
Liquid thermal conductivity	0.67900	W/(m·K)
Liquid specific heat	4.2160	kJ/(kg·K)
Surface tension	58.900	mN/m
Latent heat	2,257.0	kJ/kg

Calculated results

Parameter	Value	Unit
Liquid-alone Reynolds number	42,110	
Liquid Prandtl number	1.7510	
Liquid-alone coefficient (Dittus–Boelter)	3,912.7	W/(m²·K)
Lockhart–Martinelli parameter	0.48360	
Chen enhancement factor	4.3114	
Chen suppression factor	0.15342	
Forster–Zuber nucleate coefficient	8,646.6	W/(m²·K)
Chen coefficient (Forster–Zuber)	18,196	W/(m²·K)
Chen coefficient with Mostinski–Palen nucleate term	18,151	W/(m²·K)
Heat flux, Chen–Mostinski	145.21	kW/m²
Liu–Winterton enhancement factor	5.6555	
Liu–Winterton suppression factor	0.73565	
Liu–Winterton coefficient	24,747	W/(m²·K)
Heat flux, Liu–Winterton	197.98	kW/m²

Notes for this case

• Vertical upflow. Chen: Dittus–Boelter liquid coefficient times F, plus the suppressed nucleate term. Liu–Winterton: asymptotic sum with Cooper's nucleate term; for horizontal tubes with Fr_LO < 0.05 apply the Froude corrections.

Formula and method

$$h_b = S_{CH} h_{nb} + F(X_{tt}) h_L, \quad F = 2.35\left(X_{tt}^{-1} + 0.213\right)^{0.736}, \quad S_{CH} = \left[1 + 2.53 \times 10^{-6} (Re_L F^{1.25})^{1.17}\right]^{-1}$$

$$h_{b,LW} = \left[(S_{LW} h_{nb})^2 + (E_{LW} h_L)^2\right]^{1/2}, \quad E_{LW} = \left[1 + x Pr_L \frac{\rho_L - \rho_V}{\rho_V}\right]^{0.35}, \quad S_{LW} = (1 + 0.055 E_{LW}^{0.1} Re_L^{0.16})^{-1}$$

Variables

G	Mass flux	kg/(m²·s)
D_i	Tube inside diameter	m
x	Vapour mass fraction (quality)	-
ΔT_e	Wall superheat T_w − T_sat	K
ΔP_{sat}	P_sat(T_w) − P_sat(T_sat)	Pa
P	Pressure	Pa
P_c	Critical pressure	Pa
M	Molar mass	kg/kmol
ρ_L	Liquid density	kg/m³
ρ_V	Vapour density	kg/m³
μ_L	Liquid viscosity	Pa·s
μ_V	Vapour viscosity	Pa·s
k_L	Liquid thermal conductivity	W/(m·K)
$c_{p,L}$	Liquid specific heat	J/(kg·K)
σ	Surface tension	N/m
λ	Latent heat	J/kg
Re_L	Liquid-alone Reynolds number	-
Pr_L	Liquid Prandtl number	-
h_L	Liquid-alone coefficient (Dittus–Boelter)	W/(m²·K)
X_{tt}	Lockhart–Martinelli parameter	-
$F(X_{tt})$	Chen enhancement factor	-
S_{CH}	Chen suppression factor	-
$h_{nb,FZ}$	Forster–Zuber nucleate coefficient	W/(m²·K)
h_b	Chen coefficient (Forster–Zuber)	W/(m²·K)
h_b'	Chen coefficient with Mostinski–Palen nucleate term	W/(m²·K)
$\widehat{q'}$	Heat flux, Chen–Mostinski	W/m²
E_{LW}	Liu–Winterton enhancement factor	-
S_{LW}	Liu–Winterton suppression factor	-
$h_{b,LW}$	Liu–Winterton coefficient	W/(m²·K)
$\widehat{q_{LW}}$	Heat flux, Liu–Winterton	W/m²

Method and standards

Superposition and asymptotic models of convective plus nucleate boiling in tubes.

Assumptions and limits

- Saturated boiling below dryout; vertical tubes.

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

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