Condensation Inside Tubes: Shah, Boyko–Kruzhilin, Breber, Stratified

Local condensing coefficient inside a tube by Shah, Boyko–Kruzhilin and Breber et al. (shear-controlled) and the stratified-flow Nusselt form, with j* and X_tt.

Input parameters

Unit system: SI

Parameter	Value	Unit
Total mass flux	100.00	kg/(m²·s)
Tube inside diameter	20.000	mm
Vapour quality	50.000	%
Saturation minus wall temperature	10.000	K
Pressure	101.33	kPa
Critical pressure	22,064	kPa
Liquid density	958.40	kg/m³
Vapour density	0.59800	kg/m³
Liquid viscosity (at saturation for Shah)	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)
Latent heat	2,257.0	kJ/kg

Calculated results

Parameter	Value	Unit
Reynolds number, total flow as liquid	7,092.2	
Liquid Prandtl number	1.7510	
All-liquid coefficient (Dittus–Boelter)	1,176.3	W/(m²·K)
Dimensionless vapour velocity (regime map)	4.7174	
Lockhart–Martinelli parameter	0.034167	
Shah coefficient	20,532	W/(m²·K)
Boyko–Kruzhilin coefficient	33,308	W/(m²·K)
Two-phase multiplier (Müller-Steinhagen–Heck)	655.20	
Breber et al. coefficient, exponent 0.45	21,771	W/(m²·K)
Void fraction (Chisholm slip)	99.607	%
Stratified-flow coefficient	13,301	W/(m²·K)

Notes for this case

• Shah (1979) with the Dittus–Boelter h_LO at saturation properties; Breber et al. use h_LO (φ_LO²)^0.45 (exponent 0.5 removes their ~15 % margin). j* above 1.5 with X_tt below 1 indicates annular (shear-controlled) flow; j* below 0.5 stratified (gravity-controlled).

Formula and method

$$h_{Shah} = h_{LO}\left[(1-x)^{0.8} + \frac{3.8x^{0.76}(1-x)^{0.04}}{P_r^{0.38}}\right], \quad h_{BK} = h_{LO}\left[1 + x\frac{\rho_L - \rho_V}{\rho_V}\right]^{1/2}$$

$$h_{Breber} = h_{LO}(\phi_{LO}^2)^{0.45}, \quad h_{strat} = 0.728\varepsilon_V^{0.75}\left[\frac{k_L^3\rho_L(\rho_L-\rho_V)g\lambda}{\mu_L(T_{sat}-T_w)D_i}\right]^{1/4}, \quad j^* = \frac{xG}{[D_i g\rho_V(\rho_L-\rho_V)]^{1/2}}$$

Variables

G	Total mass flux	kg/(m²·s)
D_i	Tube inside diameter	m
x	Vapour quality	-
$T_{sat} - T_w$	Saturation minus wall temperature	K
P	Pressure	Pa
P_c	Critical pressure	Pa
ρ_L	Liquid density	kg/m³
ρ_V	Vapour density	kg/m³
μ_L	Liquid viscosity (at saturation for Shah)	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)
λ	Latent heat	J/kg
Re_{LO}	Reynolds number, total flow as liquid	-
Pr_L	Liquid Prandtl number	-
h_{LO}	All-liquid coefficient (Dittus–Boelter)	W/(m²·K)
j^*	Dimensionless vapour velocity (regime map)	-
X_{tt}	Lockhart–Martinelli parameter	-
h_{Shah}	Shah coefficient	W/(m²·K)
h_{BK}	Boyko–Kruzhilin coefficient	W/(m²·K)
ϕ_{LO}^2	Two-phase multiplier (Müller-Steinhagen–Heck)	-
h_{Breber}	Breber et al. coefficient, exponent 0.45	W/(m²·K)
ε_V	Void fraction (Chisholm slip)	-
h_{strat}	Stratified-flow coefficient	W/(m²·K)

Method and standards

Two-phase multiplier and Nusselt-type correlations for condensation inside tubes.

Assumptions and limits

- Local coefficient at one quality; integrate over the condensing range for the mean.

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/chemical/process-heat-exchangers/in-tube-condensation-shah

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Reopens the calculator with the inputs of this report.