Film Condensation of Steam on a Vertical Surface (Nusselt)

Average condensing heat transfer coefficient and condensation rate of saturated steam on a vertical wall or tube by Nusselt's film theory with IF97 properties.

Method: W. Nusselt (1916) film condensation; Incropera; DeWitt; ...

Input parameters

Unit system: SI

Parameter	Value	Unit
Steam pressure (absolute)	1.0132	bar
Saturation minus wall temperature	10.000	K
Height of the surface	1.0000	m
Width or tube circumference	0.10000	m

Calculated results

Parameter	Value	Unit
Saturation temperature	99.974	°C
Modified latent heat h_fg + 0.68 c_p ΔT	2,285.2	kJ/kg
Average condensing coefficient	6,418.4	W/(m²·K)
Heat transferred	6.4184	kW
Condensate formed	10.111	kg/h

Notes for this case

- Film Reynolds number about 378 at the bottom, above 30: the film is wavy-laminar (or turbulent above about 1 800), where Incropera uses other correlations that give a higher coefficient; this wave-free result is conservative.
- Laminar, wave-free film (Nusselt); real films ripple and give somewhat more. Non-condensable gas lowers the coefficient sharply.

Formula and method

$$\bar{h} = 0.943 \left[\frac{\rho_l (\rho_l - \rho_v) g \, {h'}_{fg} \, k_l^3}{\mu_l L (T_{sat} - T_w)} \right]^{1/4}, \quad {h'}_{fg} = h_{fg} + 0.68 c_{p,l} \Delta T$$

Variables

p	Steam pressure (absolute)	Pa
ΔT	Saturation minus wall temperature	K
L	Height of the surface	m
W	Width or tube circumference	m
T_{sat}	Saturation temperature	K
${h'}_{fg}$	Modified latent heat h_fg + 0.68 c_p ΔT	J/kg
$\bar{h}$	Average condensing coefficient	W/(m²·K)
$\dot{Q}$	Heat transferred	W
$\dot{m}$	Condensate formed	kg/s

Method and standards

Nusselt's laminar film analysis.

Assumptions and limits

- Pure saturated steam, laminar wave-free film. The film Reynolds number Re_δ = 4ṁ/(μ_l b) is checked: above 30 (wavy-laminar) the result is conservative and a note appears.

References

- W. Nusselt (1916) film condensation; Incropera
- DeWitt
- Bergman and Lavine
- Fundamentals of Heat and Mass Transfer
- ch. 10 (0.943 coefficient, h'fg = h_fg + 0.68 c_p ΔT)
- IAPWS-IF97 (water and steam)

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/film-condensation-vertical

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Reopens the calculator with the inputs of this report.