Natural Convection from a Vertical Plate (Churchill–Chu)

Natural convection coefficient and heat loss from a vertical plate or wall in air or water by the Churchill–Chu correlation, with Grashof and Rayleigh numbers.

Method: S.W. Churchill and H.H.S. Chu; Int. J. Heat Mass Transfer 18 (1975) 1323; ...

Input parameters

Unit system: SI

Parameter	Value	Unit
Fluid	Air (dry)	
Surface temperature	70.000	°C
Fluid temperature away from the surface	20.000	°C
Height of the plate	1.0000	m
Width of the plate	1.0000	m
Pressure (absolute)	1.0132	bar

Calculated results

Parameter	Value	Unit
Rayleigh number at the film temperature	3.7579e+09	
Nusselt number	186.39	
Convection coefficient	4.9070	W/(m²·K)
Heat flow from one face of the plate	245.35	W

Notes for this case

• Heat flow from one face; double it for a plate open on both sides. Properties at the film temperature. Radiation from the surface is extra and often as large as convection in air.

Formula and method

$$Ra_L = \frac{g\beta\,\Delta T L^3}{\nu\alpha}, \quad \overline{Nu}_L = \left\{ 0.825 + \frac{0.387 Ra_L^{1/6}}{\left[1 + (0.492/Pr)^{9/16}\right]^{8/27}} \right\}^2, \quad h = \frac{Nu\,k}{L}$$

Variables

fluid	Fluid	-
T_s	Surface temperature	K
T_∞	Fluid temperature away from the surface	K
L	Height of the plate	m
W	Width of the plate	m
p	Pressure (absolute)	Pa
Ra	Rayleigh number at the film temperature	-
Nu	Nusselt number	-
h	Convection coefficient	W/(m²·K)
$\dot{Q}$	Heat flow from one face of the plate	W

Method and standards

Churchill–Chu correlation for all Rayleigh numbers.

Assumptions and limits

- Isothermal vertical surface, quiescent fluid; heat flow from one face of area L × W.

- Water at or above its boiling point is rejected (boiling is not covered).

References

- S.W. Churchill and H.H.S. Chu
- Int. J. Heat Mass Transfer 18 (1975) 1323
- Incropera
- DeWitt
- Bergman and Lavine
- Fundamentals of Heat and Mass Transfer
- ch. 9
- Air from NIST Shomate
- Sutherland and Eucken (engine); water from IAPWS-IF97 and the IAPWS 2008/2011 transport releases

Report details

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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/mechanical/heat-transfer/natural-convection-vertical-plate

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.