Forced Convection over a Flat Plate (Laminar and Turbulent)

Average convection coefficient over a flat plate in parallel flow of air or water, with laminar, mixed and turbulent boundary layers, from velocity and length.

Method: Incropera; DeWitt; ...

Input parameters

Unit system: SI

Parameter	Value	Unit
Fluid	Air (dry)	
Free-stream velocity	10.000	m/s
Plate length in the flow direction	1.0000	m
Surface temperature	60.000	°C
Fluid temperature	20.000	°C
Pressure (absolute)	1.0132	bar
Boundary layer	Laminar from the leading edge, transition at Re 5 × 10^5	

Calculated results

Parameter	Value	Unit
Reynolds number	591,470	
Average Nusselt number	598.64	
Average convection coefficient	15.566	W/(m²·K)
Heat flux	622.65	W/m²

Notes for this case

- Mixed boundary layer: laminar to Re 5 × 10^5, then turbulent.

Formula and method

$$\overline{Nu}_L = 0.664 Re_L^{1/2} Pr^{1/3} \text{ (laminar)}, \quad \overline{Nu}_L = (0.037 Re_L^{4/5} - 871) Pr^{1/3} \text{ (mixed)}, \quad \overline{Nu}_L = 0.037 Re_L^{4/5} Pr^{1/3} \text{ (turbulent from the leading edge)}$$

$$Re_L = \frac{u_\infty L}{\nu}, \quad \bar{h} = \frac{\overline{Nu}_L k}{L}, \quad q = \bar{h}(T_s - T_\infty)$$

Variables

fluid	Fluid	-
u_∞	Free-stream velocity	m/s
L	Plate length in the flow direction	m
T_s	Surface temperature	K
T_∞	Fluid temperature	K
p	Pressure (absolute)	Pa
$\mathrm{boundary\ layer}$	Boundary layer (laminar with transition, or tripped turbulent)	-
Re_L	Reynolds number	-
Nu_L	Average Nusselt number	-
$\bar{h}$	Average convection coefficient	W/(m²·K)
q''	Heat flux	W/m²

Method and standards

Boundary layer correlations.

Assumptions and limits

- Smooth isothermal plate, Pr 0.6–60 (flagged outside), Re up to about 10^8 (flagged above).
- Properties at the film temperature $(T_s + T_\infty)/2$.
- Choose a tripped (fully turbulent) boundary layer when a leading-edge disturbance makes the flow turbulent from the start.
- Single-phase: a water surface at or above saturation (boiling) is flagged.

References

- Incropera
- DeWitt
- Bergman and Lavine
- Fundamentals of Heat and Mass Transfer
- ch. 7 (Nu = 0.664 Re^½ Pr^⅓ laminar; (0.037 Re^0.8 − 871) Pr^⅓ mixed, $Re_c = 5 \times 10^5$)
- 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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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/forced-convection-flat-plate

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Reopens the calculator with the inputs of this report.