Heat Transfer Coefficient Over a Tube Bank (Zukauskas)

Gas-side convective heat transfer coefficient for cross-flow over an in-line or staggered bank of plain tubes, by the Zukauskas correlation, with Re and Nu.

Method: Zukauskas (1972) tube-bank correlation (Incropera Tables 7.5–7.6)

Input parameters

Unit system: SI

Parameter	Value	Unit
Tube arrangement	Staggered	
Tube outer diameter	50.800	mm
Transverse pitch (across the flow)	100.00	mm
Longitudinal pitch (along the flow)	90.000	mm
Gas velocity approaching the bank	8.0000	m/s
Gas density	0.55000	kg/m³
Gas dynamic viscosity	3.2000e-05	Pa·s
Gas thermal conductivity	0.050000	W/(m·K)
Gas specific heat	1.1500	kJ/(kg·K)
Prandtl number at the tube wall (0 = same as the gas)	0	
Correction for fewer than 20 rows (1 for 20 or more) Take it from the Zukauskas row-correction table in a heat transfer text; 1 for deep banks.	1.0000	

Calculated results

Parameter	Value	Unit
Maximum velocity in the bank	16.260	m/s
Reynolds number at maximum velocity	14,197	
Prandtl number of the gas	0.73600	
Nusselt number	99.224	
Heat transfer coefficient	97.661	W/(m²·K)

Formula and method

$$V_{max} = \frac{S_T}{S_T - D} V \quad \text{or} \quad \frac{S_T}{2(S_D - D)} V$$

$$Re_{D,max} = \frac{\rho V_{max} D}{\mu}, \quad Pr = \frac{c_p \mu}{k}$$

$$Nu_D = C_2 C Re_{D,max}^{m} Pr^{n} (Pr/Pr_s)^{1/4}, \quad h = Nu_D k / D$$

Variables

D	tube outer diameter	m
S_T	transverse pitch	m
S_L	longitudinal pitch	m
S_D	diagonal pitch, staggered	m
V	approach velocity	m/s

ρ	gas density	kg/m³
μ	gas dynamic viscosity	Pa·s
k	gas thermal conductivity	W/(m·K)
c_p	gas specific heat	J/(kg·K)
Pr_s	Prandtl number at the wall	-
C_2	row correction for fewer than 20 rows	-
C, m	Zukauskas constants for arrangement and Re	-
n	Prandtl exponent: 0.36 (0.37 for the isolated-cylinder range with Pr up to 10)	-
arr	tube arrangement	-
V_{max}	maximum velocity	m/s
$Re_{D,max}$	Reynolds number	-
Pr	Prandtl number	-
Nu_D	Nusselt number	-
h	heat transfer coefficient	W/(m²·K)

Method and standards

The Zukauskas correlation for banks of 20 or more rows, with constants for Re from 10 to 2 000 000 as tabulated by Incropera (Tables 7.5 and 7.6): from 10 to 100, C = 0.80 in-line and 0.90 staggered with m = 0.40; from 100 to 1 000 the bank is approximated as isolated cylinders (C = 0.51, m = 0.5, Pr exponent 0.37 up to Pr 10); from 1 000, in-line C = 0.27, m = 0.63 up to Re 2×10^5; staggered C = 0.35 (S_T/S_L)^0.2 (or 0.40 when S_T/S_L ≥ 2), m = 0.60; above 2×10^5 C = 0.021 or 0.022, m = 0.84. The maximum velocity is at the narrowest gap, transverse or diagonal.

Assumptions and limits

- Plain tubes in cross-flow; Re 10 to 2 000 000; Pr 0.7 to 500. Below Re 1 000 the constants are less certain and the page says so.
- Gas radiation not included (add it separately at high temperatures).
- Row correction C_2 from the Zukauskas table for shallow banks.

References

• Zukauskas (1972) tube-bank correlation (Incropera Tables 7.5–7.6)

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/tube-bank-gas-side-coefficient

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Reopens the calculator with the inputs of this report.