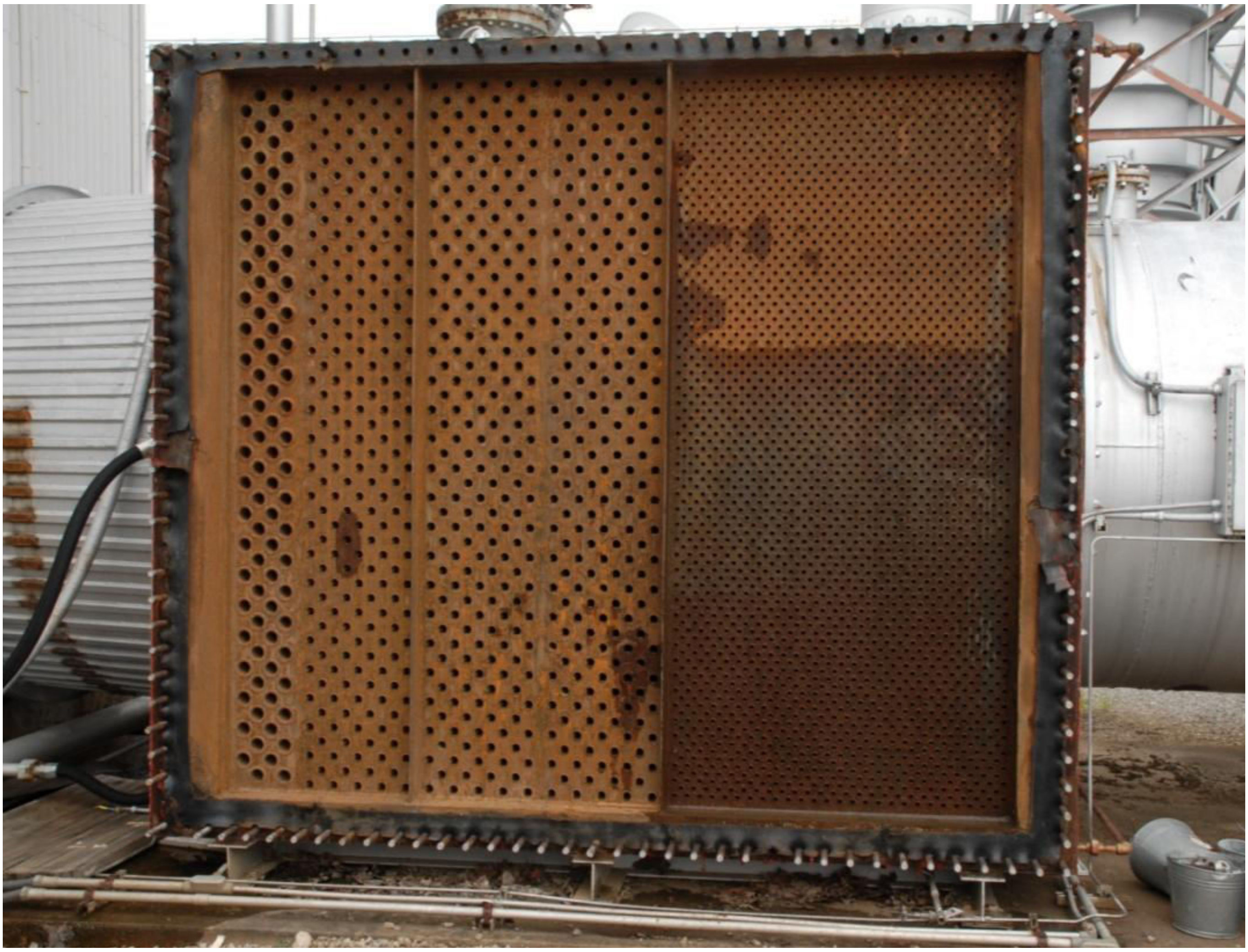
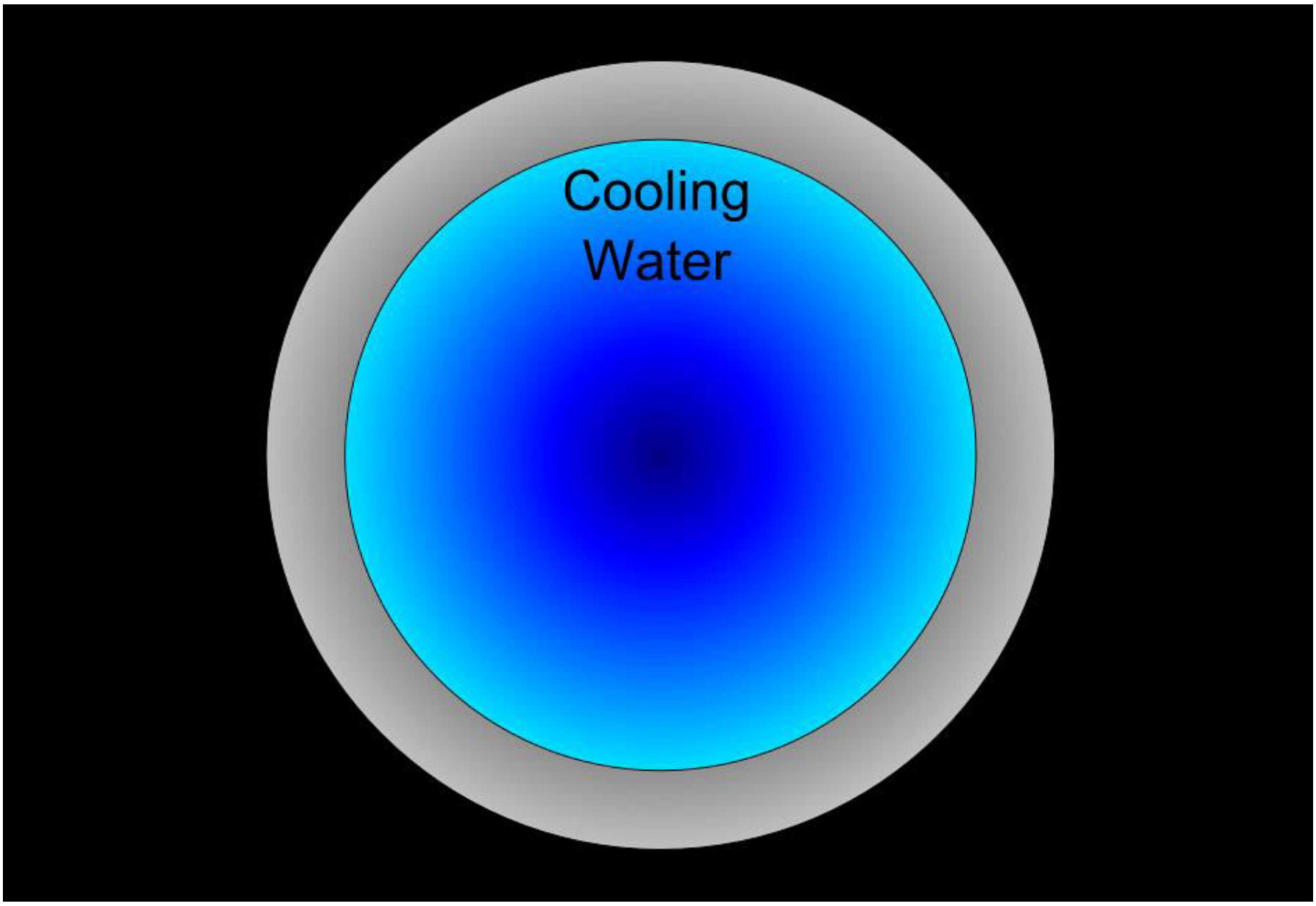
Practical examples

The Inlet of H2's Cross Flow, Staggered Tube Heat Exchanger



Cross Sectional View of the H2 Cooler



Single Tube Control Volume

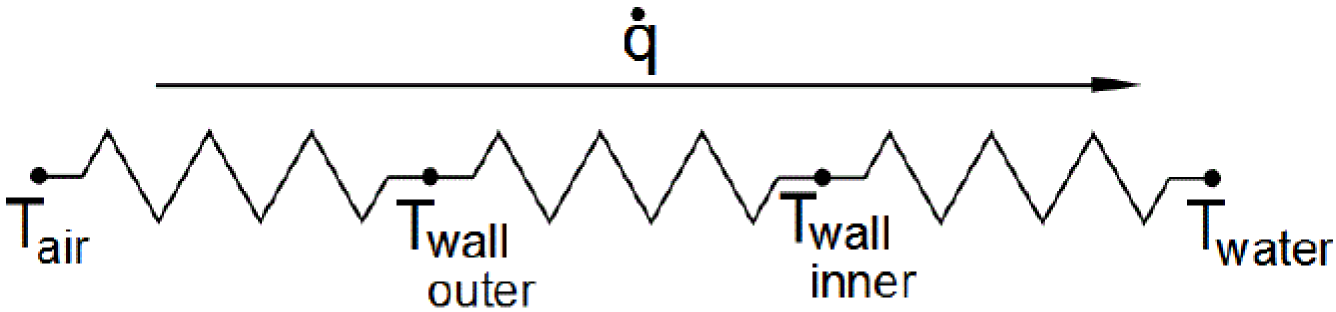


Figure 10 - Equivalent Resistance Circuit Analogy

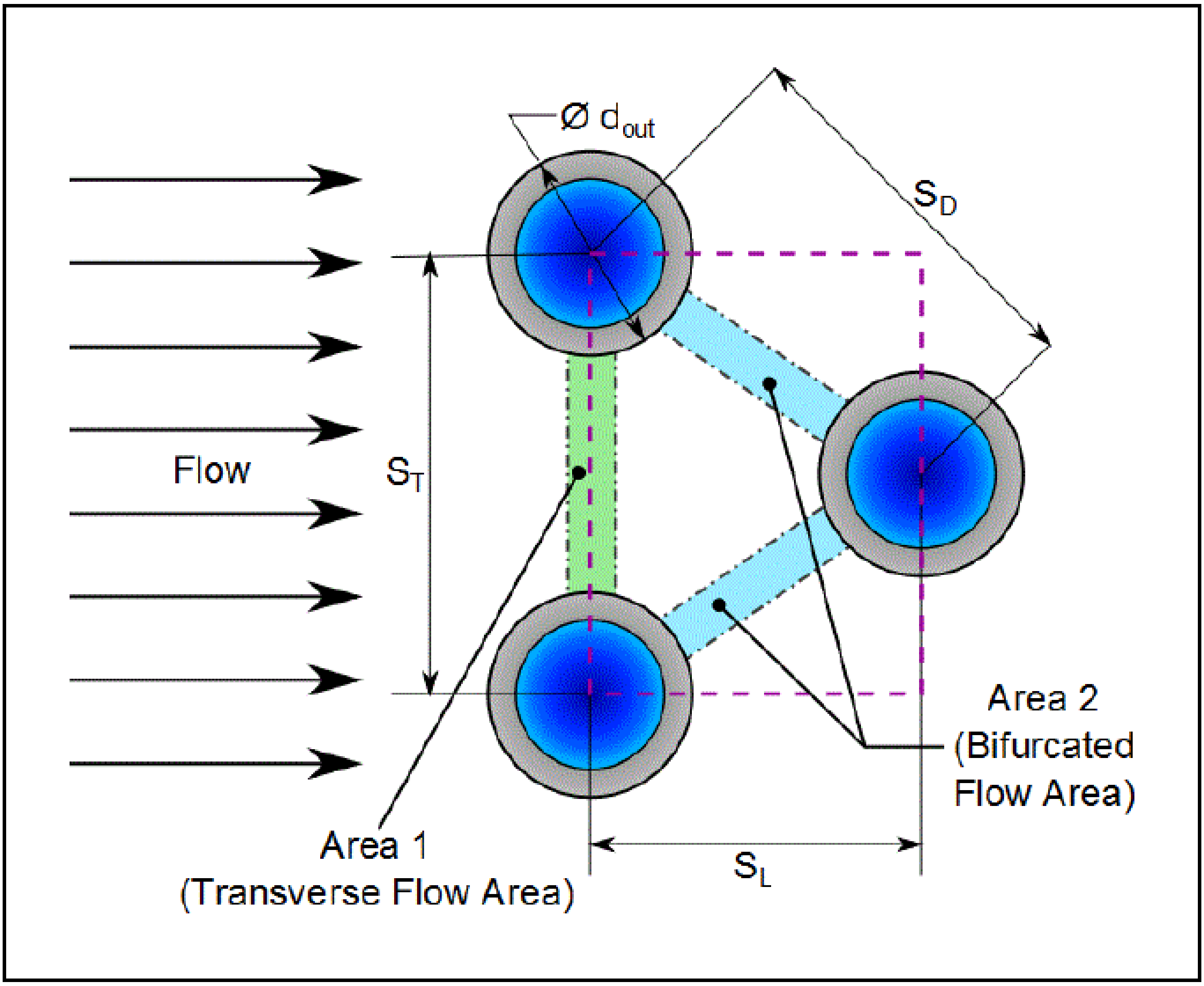


Figure 11 - Staggered Tube Free Body Diagram

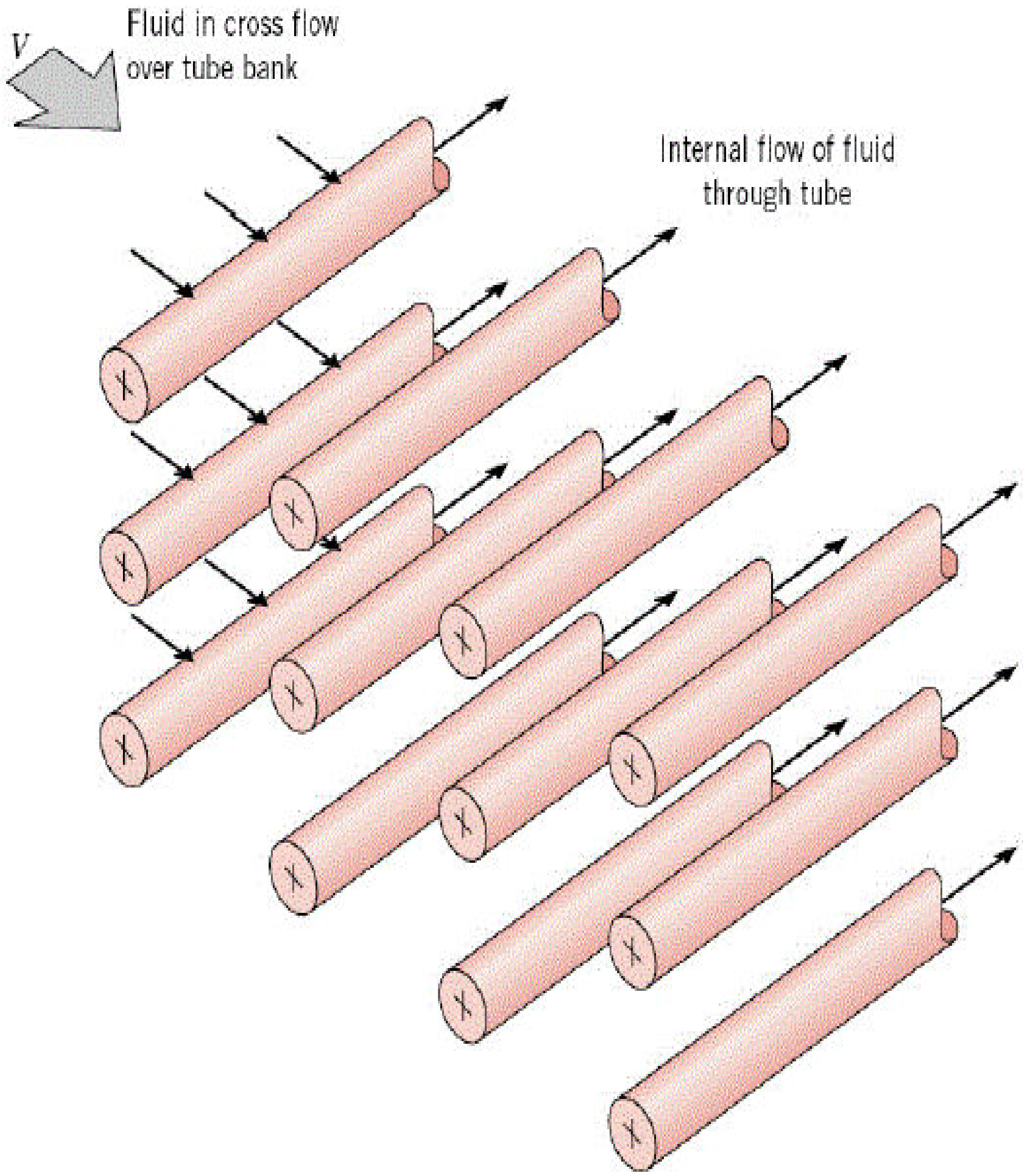


Figure 7.10 Schematic of a tube bank in cross flow.

Tube Bank Geometry

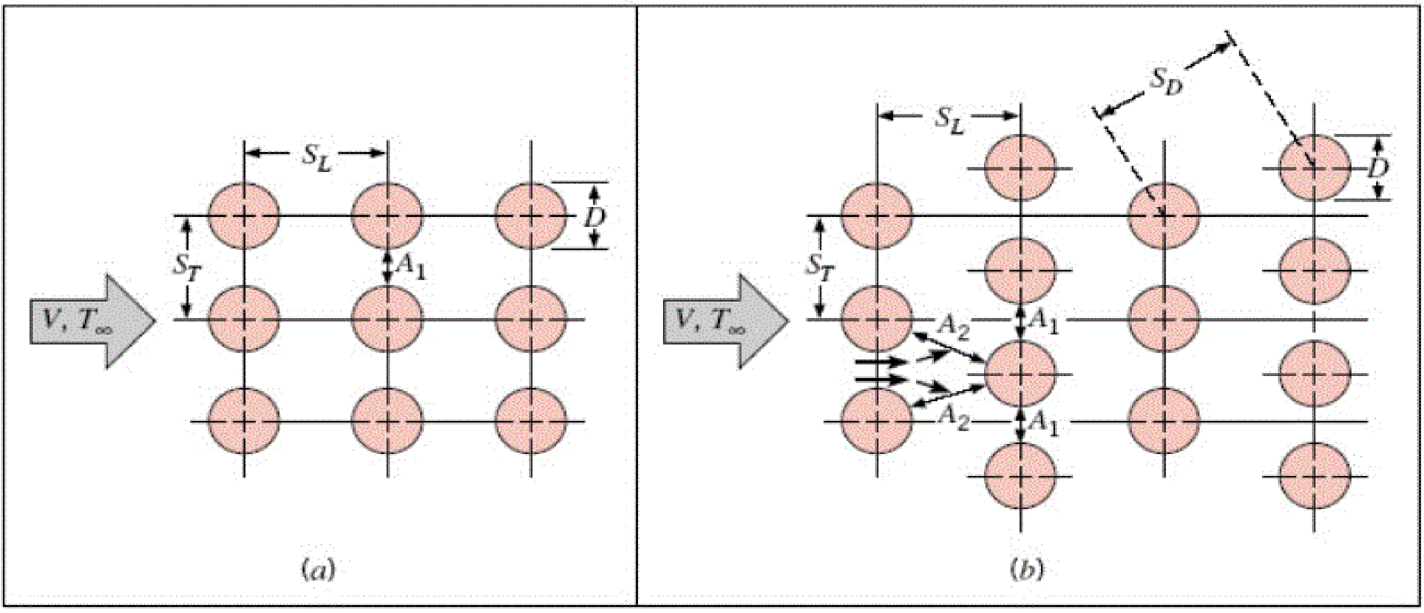


Figure 7.11 Tube arrangements in a bank. (a) Aligned. (b) Staggered.

Tube Bank Calculations

$$Re_{D,max} = \frac{\rho V_{max} D}{\mu} = \frac{V_{max} D}{\nu}$$

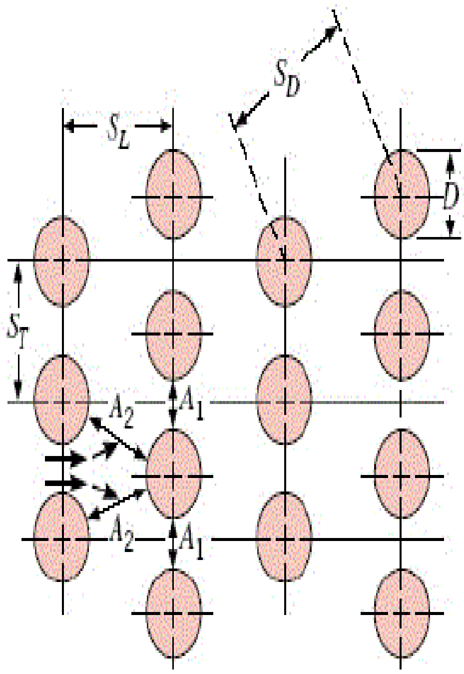
→ V_{max} depends on tube bank geometry…

→ If tubes are aligned or if they're staggered with $2A_2 > A_1$ then

$$V_{max} = \frac{S_T}{S_T - D} V$$

→ Otherwise, if staggered and $2A_2 < A_1$

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



Heat Transfer Correlations for Tube Banks

Zukauskas

$$\overline{\mathrm{Nu}}_D = C\,\mathrm{Re}_{D,\max}^{m}\,\mathrm{Pr}^{0.36}\left(\frac{\mathrm{Pr}}{\mathrm{Pr}_s}\right)^{1/4}$$

(Eq. 7.58)
(7.64 in 6th Ed.)

→ Properties evaluated at arithmetic mean of inlet & outlet temp

→ *C* and *m* from Table 7.5 (Table 7.7 in 6th Ed.)

→ If number of tubes (longitudinal NL) is < 20 use Table 7.6 (7.8 in 6th Ed.)

Table 7.5 Constants of Equation 7.56 for the tube bank in cross flow [15]

Configuration	$Re_{D,max}$	C	m
Aligned	$10–10^2$	0.80	0.40
Staggered	$10–10^2$	0.90	0.40
Aligned	$10^2–10^3$	Approximate as a single (isolated) cylinder	
Staggered	$10^2–10^3$		
Aligned $(S_T/S_L > 0.7)^a$	$10^3–2 \times 10^5$	0.27	0.63
Staggered $(S_T/S_L < 2)$	$10^3–2 \times 10^5$	$0.35(S_T/S_L)^{1/5}$	0.60
Staggered $(S_T/S_L > 2)$	$10^3–2 \times 10^5$	0.40	0.60
Aligned	$2 \times 10^5–2 \times 10^6$	0.021	0.84
Staggered	$2 \times 10^5–2 \times 10^6$	0.022	0.84

[a] For $S_T/S_L < 0.7$, heat transfer is inefficient and aligned tubes should not be used.

Table 7.6 Correction factor C_2 of Equation 7.57 for $N_L < 20$ ($Re_{D,max} \gtrsim 10^3$) [15]

N_L	1	2	3	4	5	7	10	13	16
Aligned	0.70	0.80	0.86	0.90	0.92	0.95	0.97	0.98	0.99
Staggered	0.64	0.76	0.84	0.89	0.92	0.95	0.97	0.98	0.99

Other Correlations for Tube Banks

Grimison (Equation and Table exist only in 6th edition)

$$\overline{Nu}_D = 1.13 C_1 Re_{D,max}^{m} Pr^{1/3} \qquad (Eq.\ 7.60)$$

- → Properties evaluated at T_{film}
- → C_1 and m determined from Table 7.5 in 6th Edition
- → If number of tubes (longitudinal N_L) is < 10 use Table 7.6 (6th Ed)

TABLE 7.5 Constants of Equations 7.50 and 7.52 for airflow over a tube bank of 10 or more rows [19]

	S_T/D							
	1.25		1.5		2.0		3.0	
S_L/D	C_1	m	C_1	m	C_1	m	C_1	m
Aligned								
1.25	0.348	0.592	0.275	0.608	0.100	0.704	0.0633	0.752
1.50	0.367	0.586	0.250	0.620	0.101	0.702	0.0678	0.744
2.00	0.418	0.570	0.299	0.602	0.229	0.632	0.198	0.648
3.00	0.290	0.601	0.357	0.584	0.374	0.581	0.286	0.608
Staggered								
0.600	—	—	—	—	—	—	0.213	0.636
0.900	—	—	—	—	0.446	0.571	0.401	0.581
1.000	—	—	0.497	0.558	—	—	—	—
1.125	—	—	—	—	0.478	0.565	0.518	0.560
1.250	0.518	0.556	0.505	0.554	0.519	0.556	0.522	0.562
1.500	0.451	0.568	0.460	0.562	0.452	0.568	0.488	0.568
2.000	0.404	0.572	0.416	0.568	0.482	0.556	0.449	0.570
3.000	0.310	0.592	0.356	0.580	0.440	0.562	0.428	0.574

TABLE 7.6 Correction factor C_2 of Equation 7.53 for $N_L < 10$ [20]

N_L	1	2	3	4	5	6	7	8	9
Aligned	0.64	0.80	0.87	0.90	0.92	0.94	0.96	0.98	0.99
Staggered	0.68	0.75	0.83	0.89	0.92	0.95	0.97	0.98	0.99