

$T_{air\_4}$	$\alpha_{air}$	$K_{air}$	$P_{r\_air}$	$T_{air\_2}$	$C_{p\_air}$	$k_{air}$
(K)	$\left(\frac{m^2}{s}\right)$	$\left(\frac{W}{m \cdot K} \cdot 10^{-3}\right)$		(°F)	$\left(\frac{Btu}{lbm \cdot R}\right)$	
100	$2.54 \cdot 10^{-6}$	9.34	0.786	40	.240	1.401
150	$5.84 \cdot 10^{-6}$	13.8	0.758	100	.240	1.400
200	$10.3 \cdot 10^{-6}$	18.1	0.737	200	.241	1.397
250	$15.9 \cdot 10^{-6}$	22.3	0.720	300	.243	1.394
300	$22.5 \cdot 10^{-6}$	26.3	0.707	400	.245	1.389
350	$29.9 \cdot 10^{-6}$	30	0.700	500	.248	1.383
400	$38.3 \cdot 10^{-6}$	33.8	0.690	600	.250	1.377
450	$47.2 \cdot 10^{-6}$	37.3	0.686	700	.254	1.371
500	$56.7 \cdot 10^{-6}$	40.7	0.684	800	.257	1.365
550	$66.7 \cdot 10^{-6}$	43.9	0.683	900	.259	1.358
600	$76.9 \cdot 10^{-6}$	46.9	0.685	1000	.263	1.353
650	$87.3 \cdot 10^{-6}$	49.7	0.690	1500	.276	1.330
				2000	.286	1.312

  

$T_{air\_3}$	$\mu_{air}$	$\nu_{air}$	$T_{air\_1}$	$h_{air}$	$T_{ss}$	$K_{ss}$	$C_{pss}$
(°F)	$\left(\frac{lb_f \cdot s}{ft^2}\right)$	$\left(\frac{ft^2}{s}\right)$	(R)	$\left(\frac{Btu}{lbm}\right)$	(K)	$\left(\frac{W}{m \cdot K}\right)$	$\left(\frac{J}{kg \cdot K}\right)$
-40	$3.29 \cdot 10^{-7}$	$1.12 \cdot 10^{-4}$	540	129.06	100	9.2	272
-20	$3.34 \cdot 10^{-7}$	$1.19 \cdot 10^{-4}$	560	133.86	200	12.6	402
0	$3.38 \cdot 10^{-7}$	$1.26 \cdot 10^{-4}$	580	138.66	300	14.9	477
10	$3.44 \cdot 10^{-7}$	$1.31 \cdot 10^{-4}$	600	143.47	400	16.6	515
20	$3.50 \cdot 10^{-7}$	$1.36 \cdot 10^{-4}$	620	148.28	600	19.8	557
30	$3.58 \cdot 10^{-7}$	$1.42 \cdot 10^{-4}$	640	153.09	800	22.6	582
40	$3.60 \cdot 10^{-7}$	$1.46 \cdot 10^{-4}$	660	157.92			
50	$3.68 \cdot 10^{-7}$	$1.52 \cdot 10^{-4}$	680	162.73			
60	$3.75 \cdot 10^{-7}$	$1.58 \cdot 10^{-4}$	700	167.56			
70	$3.82 \cdot 10^{-7}$	$1.64 \cdot 10^{-4}$	720	172.39			

70	$3.82 \cdot 10^{-7}$	$1.64 \cdot 10^{-4}$	740	177.23
80	$3.86 \cdot 10^{-7}$	$1.69 \cdot 10^{-4}$	760	182.08
90	$3.90 \cdot 10^{-7}$	$1.74 \cdot 10^{-4}$	780	186.94
100	$3.94 \cdot 10^{-7}$	$1.79 \cdot 10^{-4}$	800	191.69
120	$4.02 \cdot 10^{-7}$	$1.89 \cdot 10^{-4}$	820	196.69
140	$4.13 \cdot 10^{-7}$	$2.01 \cdot 10^{-4}$	840	201.56
160	$4.22 \cdot 10^{-7}$	$2.12 \cdot 10^{-4}$	860	206.46
180	$4.34 \cdot 10^{-7}$	$2.25 \cdot 10^{-4}$	880	211.35
200	$4.49 \cdot 10^{-7}$	$2.4 \cdot 10^{-4}$	900	216.26
300	$4.97 \cdot 10^{-7}$	$3.06 \cdot 10^{-4}$	920	221.18
400	$5.24 \cdot 10^{-7}$	$3.65 \cdot 10^{-4}$	940	226.11
500	$5.8 \cdot 10^{-7}$	$4.51 \cdot 10^{-4}$	960	231.06
750	$6.81 \cdot 10^{-7}$	$6.68 \cdot 10^{-4}$	980	236.02
1000	$7.85 \cdot 10^{-7}$	$9.3 \cdot 10^{-4}$	1000	240.98
1500	$9.5 \cdot 10^{-7}$	$15.1 \cdot 10^{-4}$	1040	250.95
			1080	260.97
			1120	271.03
			1160	281.14
			1200	291.3

$$C_{pair}(x) := \text{linterp}(T_{air\_2}, C_{p\_air}, x)$$

$$k_{air}(x) := \text{linterp}(T_{air\_2}, k_{air}, x)$$

$$h_{air}(x) := \text{linterp}(T_{air\_1}, h_{air}, x)$$

$$\mu_{air}(x) := \text{linterp}(T_{air\_3}, \mu_{air}, x)$$

$$\nu_{air}(x) := \text{linterp}(T_{air\_3}, \nu_{air}, x)$$

$$\alpha_{air}(x) := \text{linterp}(T_{air\_4}, \alpha_{air}, x)$$

$$K_{air}(x) := \text{linterp}(T_{air\_4}, K_{air}, x)$$

$$K_{ss}(x) := \text{linterp}(T_{ss}, K_{ss}, x)$$

$$P_{r\_air}(x) := \text{linterp}(T_{air\_4}, P_{r\_air}, x)$$

$$Re_V(\text{Velocity}, D_h, T_{air}) := \frac{(\text{Velocity} \cdot D_h)}{\nu_{air}(T_{air})}$$

$$Re_m(\text{Mdot}, D_h, T_{air}) := \frac{4 \cdot \text{Mdot}}{\pi \cdot \mu_{air}(T_{air}) \cdot D_h}$$

$$\rho_{air}(\text{Temperature}, \text{Pressure}) := \frac{\text{Pressure} \cdot M_{bar\_air}}{\text{Temperature} \cdot R_u}$$

$$M_{bar\_air} \equiv 28.97 \frac{\text{lb}}{\text{mol}}$$

$$R_u \equiv (1.545 \cdot 10^3) \frac{(\text{ft} \cdot \text{lb}_f)}{\text{R} \cdot \text{mol}}$$

$$K_{air\_p}(T, P) := \rho_{air}(T, P) \cdot C_{pair}(T) \cdot \alpha_{air}(T)$$

Below are the heat transfer calculations for a circular pipe

$$Nu_{Di}(f, Re_D, P_r) := \frac{\left(\frac{f}{8}\right) \cdot (Re_D - 1000) \cdot P_r}{1 + 12.7 \cdot \left(\frac{f}{8}\right)^{\frac{1}{2}} \cdot \left(P_r^{\frac{2}{3}} - 1\right)} \quad \begin{array}{l} 0.5 < P_r < 2000 \\ 3000 < Re_D < 5 \cdot 10^6 \end{array}$$

$$Nu_{Di}(Re_D, P_r, n) := 0.023 \cdot Re_D^{\frac{4}{5}} \cdot P_r^n \quad \begin{array}{l} n = 0.3 \text{ for cooling} \\ n = 0.4 \text{ for heating} \end{array}$$

$$Nu_{Do}(Re_D, Pr) := 0.3 + \frac{0.62 \cdot Re_D^{\frac{1}{2}} \cdot Pr^{\frac{1}{3}}}{\left(1 + \left(\frac{0.4}{Pr}\right)^{\frac{2}{3}}\right)^{\frac{1}{4}}} \cdot \left(1 + \left(\frac{Re_D}{282000}\right)^{\frac{5}{8}}\right)^{\frac{5}{5}} \quad \begin{array}{l} \text{All } Re_D \\ Pr > 0.2 \end{array}$$

$$Nu_{Di}(T_{fi}, T_{fo}, m_{rate}, D_i, n) := Nu_{Di}\left(Re_m\left(m_{rate}, D_i, \frac{T_{fo} + T_{fi}}{2}\right), Pr_{air}\left(\frac{T_{fi} + T_{fo}}{2}\right), n\right)$$

$$Nu_{Do}(T_{so}, T_{inf}, D_o, V_{inf}) := Nu_{Do}\left(Re_V\left(V_{inf}, D_o, \frac{T_{inf} + T_{so}}{2}\right), Pr_{air}\left(\frac{T_{inf} + T_{so}}{2}\right)\right)$$

$$h(Nu_D, K, Diameter) := \frac{Nu_D \cdot K}{Diameter}$$

$$h_i(n, P_{avg}, T_{fi}, T_{fo}, m_{rate}, D_i) := \frac{Nu_{Di}(T_{fi}, T_{fo}, m_{rate}, D_i, n) \cdot K_{air-p}\left(\frac{T_{fi} + T_{fo}}{2}, P_{avg}\right)}{D_i}$$

$$h_o(T_{si}, T_{inf}, m_{rate}, D_o, V_{inf}) := \frac{Nu_{Do}(T_{si}, T_{inf}, D_o, V_{inf}) \cdot K_{air}\left(\frac{T_{inf} + T_{si}}{2}\right)}{D_o}$$

$$\Delta T_{lm}(T_{fi}, T_{fo}, T_{si}) := \frac{T_{fi} - T_{fo}}{\ln\left(\frac{T_{si} - T_{fi}}{T_{si} - T_{fo}}\right)}$$

$$T_{fo} := 10 \text{ } ^\circ\text{C}$$

$$Q_{trans}(T_{fo}) := m_{rate} \cdot (h_{air}(T_{fi}) - h_{air}(T_{fo}))$$

$$h_{int}(T_{fo}) := h_i(n, P_{avg}, T_{fi}, T_{fo}, m_{rate}, D_i)$$

$$T_{si}(T_{fo}) := \frac{T_{fi} - T_{fo} \cdot e^{\frac{(T_{fi} - T_{fo}) \cdot h_{int}(T_{fo}) \cdot \pi \cdot D_i \cdot L}{Q_{trans}(T_{fo})}}}{1 - e^{\frac{(T_{fi} - T_{fo}) \cdot h_{int}(T_{fo}) \cdot \pi \cdot D_i \cdot L}{Q_{trans}(T_{fo})}}}$$

$$T_{so}(T_{fo}) := T_{si}(T_{fo}) - \frac{Q_{trans}(T_{fo}) \cdot \ln\left(\frac{D_o}{D_i}\right)}{2 \cdot \pi \cdot L \cdot K_{ss}(T_{si}(T_{fo}))}$$

$$h_{ext}(T_{fo}) := h_o(T_{so}(T_{fo}), T_{inf}, m_{rate}, D_o, V_{inf})$$

$$Q_{conv\_out}(T_{fo}) := h_{ext}(T_{fo}) \cdot \pi \cdot D_o \cdot L \cdot (T_{so}(T_{fo}) - T_{inf})$$

$$Q_{conv\_out}(T_{fo}) = Q_{trans}(T_{fo})$$

$$Temps(n, P_{avg}, m_{rate}, T_{fi}, T_{inf}, D_i, D_o, L, V_{inf}) := \mathbf{find}(T_{fo})$$

Schätzwerte

Gleichheitsbedingungen

$$Temps\left(0.3, 80 \text{ } \mathbf{psi}, 30 \frac{\mathbf{lbm}}{\mathbf{s}}, 340 \text{ } ^\circ\mathbf{C}, 20 \text{ } ^\circ\mathbf{F}, 10 \text{ } \mathbf{in}, 10.2 \text{ } \mathbf{in}, 100 \text{ } \mathbf{ft}, 20 \text{ } \mathbf{mph}\right) = 598.681 \text{ } \mathbf{K}$$

$$Temps\left(0.3, 20 \text{ } \mathbf{psi}, 5 \frac{\mathbf{lbm}}{\mathbf{s}}, 700 \text{ } \mathbf{K}, 35 \text{ } ^\circ\mathbf{F}, 6.1 \text{ } \mathbf{in}, 6.625 \text{ } \mathbf{in}, 50 \text{ } \mathbf{ft}, 30 \text{ } \mathbf{mph}\right) = 654.932 \text{ } \mathbf{K}$$