TABLE 2. APPROXIMATE UNIT CONDUCTANCES FOR THERMAL CONVECTION FOR SEVERAL FLOW SYSTEMS[a]

Expressed in Convenient Empirical Form

CASE	SYSTEM	UNIT CONDUCTANCE EQUATION[b]
	FORCED CONVECTION	
1.	Longitudinal flow in cylinders, turbulent region. Fluid being heated[c].	$\frac{h_c D}{k} = 0.0225 \left(\frac{DG}{\mu}\right)^{0.8} \left(\frac{c_p \mu}{k}\right)^{0.4}$ For $\left(\frac{DG}{\mu}\right) > 3000$
2.	For longitudinal air flow in cylinders case 1 reduces to[c].	$h_c = 0.0036\, G^{0.8}/D^{0.2}$ For $\left(\frac{DG}{\mu}\right) > 3000$
3.	For longitudinal water flow in cylinders case 1 reduces to[c].	$h_c = 0.00486\ (1 + 0.01t)\ \frac{G^{0.8}}{D^{0.2}}$ For $\left(\frac{DG}{\mu}\right) > 3000$
4.	Air flow normal to a single right circular cylinder.	$h_c = 0.45 \left(\frac{k}{D}\right) + 0.178\, G^{0.66} \left(\frac{k}{D}\right)^{0.44}$
5.	Air flow over staggered pipe banks.	$h_c = 0.061 \left(\frac{k}{D}\right)^{0.31} G^{0.62}$
6.	Air flow over single spheres.	$h_c = 0.040\ \frac{G^{0.62}}{D^{0.38}}$ $0 < t < 250$ F
7.	Air flow over plane surfaces.	$h_c = 1 + 0.22\, V_s$ For $V_s < 16$ fps or $h_c = 0.53\, V_s^{0.8}$ 16 fps $< V_s <$ 100 fps
8.	Air flow normal to finned cylinders.	$h_c = 6.2 \left(\frac{G}{3600}\right)^{0.6} \frac{s^{0.22}}{D^{0.62}}$ $0 < t < 250$ F
	FREE CONVECTION[d]	
9.	Single horizontal right circular cylinder in air.	$h_c = 0.23 \left(\frac{t_1 - t_2}{D}\right)^{0.25}$
10.	Vertical surfaces in air.	$h_c = 0.3\ (t_1 - t_2)^{0.25}$
11.	Top surface of horizontal plates to air.	$h_c = 0.4\ (t_1 - t_2)^{0.25}$
12.	Bottom surface of horizontal plates to air.	$h_c = 0.2\ (t_1 - t_2)^{0.25}$

[a] Heat Transmission, by W. H. McAdams.

[b] Fluid properties should be evaluated at the arithmetic mean fluid temperature, $t_f = (t_{surface} + t_{fluid})$ divided by 2.

[c] These expressions are applicable to longitudinal flow in other than right circular cylinders provided the hydraulic radius is employed as the conduit dimension parameter. For non-circular cross-sections $D = 4\, R_H$.

[d] For low rates of heat transfer by free convection the exponent decreases towards zero, and for higher rates increases towards 0.33. The following equations employing an exponent equal to 0.25 are applicable in the intermediate range.

The heat transmission by free or natural convection for objects surrounded by air can be conveniently expressed as in Equation 2a:

$$q_c = C \left(\frac{1}{D}\right)^{0.2} \left(\frac{1}{T_{av}}\right)^{0.181} (t_s - t_t)^{1.27} \qquad (2a)$$

where

q_c = heat transmission by convection, Btu per (square foot) (hour).
C = a constant depending upon the shape of the surface.
D = diameter of pipe or circular duct or height of vertical wall, inches. (Effect of diameter or height becomes constant at 24 in.)
T_{av} = average of wall surface and surrounding air temperature, Fahrenheit degrees absolute.
$t_s - t_t$ = temperature excess between wall surface and surrounding air, Fahrenheit degrees.

For horizontal cylinders, the value of $C = 1.016$ has been well established by various investigations. For vertical plates, the value of $C = 1.394$ has been fairly well established. Suggested values[2] of C for horizontal plates warmer than the surrounding air are 1.79 when facing upward, and 0.89 when facing downward.

Problems in either forced convection or natural convection may be solved by the simple first-power equation if the convection coefficient is expressed as a unit conductance:

$$q_c = h_c\, A\, (t_1 - t_2) \qquad (2b)$$

where

q_c = heat transmission by convection, Btu per hour.
A = surface area, square feet.
$t_1 - t_2$ = temperature difference between the surface and the fluid, Fahrenheit degrees.
h_c = unit conductance, from Table 2, Btu per (square foot) (hour) (Fahrenheit degree temperature difference.)

Thermal Radiation Equation

The relation shown in Equation 3 is usually applicable to systems in

NOMENCLATURE AND DIMENSIONS FOR TABLE 2

c_p = fluid unit heat capacity at constant pressure, Btu per (pound) (Fahrenheit degree).
D = cylinder diameter, feet.
G = 3600 $V_s \rho$ = fluid mass velocity, pounds per (hour) (square foot of flow cross-section).
ρ = density, pounds per cubic foot.
h_c = unit conductance for thermal convection, Btu per (hour) (square foot) (Fahrenheit degree).
k = unit thermal conductivity of the fluid, Btu per (hour) (square foot) (Fahrenheit degree per one foot thickness).
R_H = hydraulic radius of the flow cross-section = flow cross-section area per wetted perimeter, feet.
s = fin spacing, feet.
t = average fluid film temperature, Fahrenheit degree.
$t_1 - t_2$ = temperature difference surface to main fluid, Fahrenheit degree.
V_s = fluid velocity, feet per second.
μ = fluid viscosity, pounds per (hour) (foot) = viscosity in centipoises × 2.42.