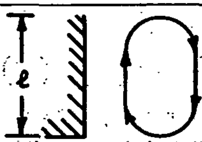
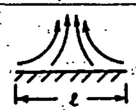
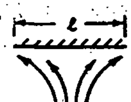
Table 2. Approximate Unit Conductances for Thermal Convection for Several Flow Systems (*Concluded*)

Case	System	Heat Transfer Equation[a] and its Limits of Application	Reference
		Forced Convection	
9	Same as Case 7.	*General Equation* (Laminar Flow) $\frac{h_{cx}x}{k} = 0.332 \left(\frac{xG}{\mu}\right)^{0.5} \left(\frac{c_p\mu}{k}\right)^{0.33}$ For $\left(\frac{xG}{\mu}\right) \le 500{,}000$; $h_{c\ (average)} = 2h_{cx}$	3
10	Same as Case 7.	*Equation for Air* (Laminar Flow) $h_{cx} = 0.0562(Tt)^{0.5} \frac{(u_\infty \rho)^{0.5}}{x^{0.5}}$ For $\left(\frac{xG}{\mu}\right) < 500{,}000$	3
		Free Convection[c]	
11	 Free convection past a heated horizontal cylinder.	*Equation for Air* $h_c = 0.271 \left(\frac{P}{P_o}\right)^{0.5} \left(\frac{\Delta t}{D}\right)^{0.25}$; $10^3 < N_{Gr} < 10^7$	5
12	 Free convection past a single vertical surface.	*Equation for Air* $h_c = 0.354 \left(\frac{P}{P_o}\right)^{0.50} \left(\frac{\Delta t}{l}\right)^{0.25}$; $10^3 < N_{Gr} < 10^7$; $h_c = 0.420 \left(\frac{P}{P_o}\right)^{0.50} \left(\frac{\Delta t}{l}\right)^{0.25}$; $10^3 < N_{Gr} < 10^{10}$	6
13	 Free convection past a heated horizontal surface (face up).	*Equation for Air* $h_c = 0.478 \left(\frac{P}{P_o}\right)^{0.50} \left(\frac{\Delta t}{l}\right)^{0.25}$; $10^3 < N_{Gr} < 10^7$	5
14	 Free convection past a heated horizontal surface (face down).	*Equation for Air* $h_c = 0.239 \left(\frac{P}{P_o}\right)^{0.50} \left(\frac{\Delta t}{l}\right)^{0.25}$; $10^3 < N_{Gr} < 10^7$	5

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

[b] These expressions are suitable approximations to longitudinal flow in other than right circular cylinders, provided the hydraulic diameter is employed as the conduit dimension parameter. For non-circular cross-sections, the hydraulic diameter is equal to four times the cross-sectional area divided by the wetted perimeter.

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

NOMENCLATURE AND DIMENSIONS FOR TABLE 2

c_p = heat capacity at constant pressure, Btu per (pound) (Fahrenheit degree).
D = cylinder diameter, feet.
f = subscript denoting film.

g = body force per unit mass, feet per hour per hour. (For static system on earth, $g = 32.2 \times 3600^2$ feet per hour per hour.)
$G = 3600\, u_m\rho$ = mass flow per unit cross-sectional area normal to flow, pounds per (hour) (square foot of flow cross-section).
N_{Gr} = Grashof modulus, dimensionless ($N_{Gr} = D^3\rho^2\beta\Delta t g/\mu^2$).
h_c = average unit thermal convective conductance from the leading edge of surface to the position x, Btu per (hour) (square foot) (Fahrenheit degree).
h_{cx} = local unit thermal convective conductance, at the position x from the leading edge of surface, Btu per (hour) (square foot) (Fahrenheit degree).
k = thermal conductivity, Btu per (hour) (square foot) (Fahrenheit degree per foot thickness).
l = a dimension of the system, feet.
m = a subscript denoting *mean*.
P = pressure, atmospheres.
P_o = pressure (atmospheric) atmospheres.
t = temperature, Fahrenheit.
T = temperature, Fahrenheit, absolute.
u = fluid velocity, feet per second.
V = volume, cubic feet.
x = a dimension of the system, feet.
β = coefficient of cubical expansion ($\beta = \frac{1}{V}(\frac{dV}{dT})_P$); for perfect gases $\beta = 1/T$.
Δt = difference between wall and fluid temperatures, Fahrenheit degrees.
μ = fluid viscosity, pounds per (hour) (foot).
ρ = density, pounds per cubic foot.
∞ = infinity, referring the quantity to a point not directly affected by the phenomenon in question.

Table 3. Radiation Factors or Emissivities, ϵ*

For the determination of factor F_E in Equation 3

Class	Surfaces	Fraction of Black-Body Radiation		Absorptivity for Solar Radiation
		At 50–100 F	At 1000 F	
1	A small hole in a large box, sphere, furnace, or enclosure	0.97 to 0.99	0.97 to 0.99	0.97 to 0.99
2	Black non-metallic surfaces such as asphalt, carbon, slate, paint, paper	0.90 to 0.98	0.90 to 0.98	0.85 to 0.98
3	Red brick and tile, concrete and stone, rusty steel and iron, dark paints (red, brown, green, etc.)	0.85 to 0.95	0.75 to 0.90	0.65 to 0.80
4	Yellow and buff brick and stone, firebrick, fire clay	0.85 to 0.95	0.70 to 0.85	0.50 to 0.70
5	White or light-cream brick, tile, paint or paper, plaster, whitewash	0.85 to 0.95	0.60 to 0.75	0.30 to 0.50
6	Window glass	0.90 to 0.95	....	Transparent[a]
7	Bright aluminum paint; gilt or bronze paint	0.40 to 0.60	....	0.30 to 0.50
8	Dull brass, copper, or aluminum; galvanized steel; polished iron	0.20 to 0.30	0.30 to 0.50	0.40 to 0.65
9	Polished brass, copper, monel metal	0.02 to 0.05	0.05 to 0.15	0.30 to 0.50
10	Highly polished aluminum, tin plate, nickel, chromium	0.02 to 0.04	0.05 to 0.10	0.10 to 0.40

* Emissivities of other materials may be found in Reference 4. [a] Reflects about 8 percent.

fourth powers of the absolute surface temperatures ($T_1^4 - T_2^4$). The proportionality factor ($\sigma F_A F_E$) may be conveniently separated into three parts (excepting in some problems involving interreflections, where it is not possible to divide the product ($F_A F_E$) into separate terms):

σ = the Stefan-Boltzmann radiation constant = 1730×10^{-12} Btu per (hour) (square foot) (Fahrenheit degree absolute temperature to the fourth power).
F_A = the geometrical factor which is dimensionless and ≤ 1. This factor accounts for the shape and relative position of the two surfaces. The value of $F_A = 1$ may be used in the cases of large parallel planes, long concentric cylinders or smaller bodies in large enclosures.
F_E = the emissivity factor which is also dimensionless and ≤ 1. This factor accounts for the absorption and emission characteristics of the surfaces for the