TABLE 1. APPROXIMATE UNIT THERMAL CONDUCTIVITIES OF MISCELLANEOUS MATERIALS[a]

MATERIAL	CONDUCTIVITY, k BTU PER HOUR PER SQ FT PER DEG F FOR ONE INCH THICKNESS
Air	0.168
Aluminum	1416.0
Brass (70 − 30)	720.0
Cast-Iron	336.0
Copper	2640.0
Glass	3.6—7.32
Lead	240.0
Nickel	330.0
Soil	2.4—12.0
Steel, mild	312.0
Water, liquid	4.08

[a]Thermal conductivities depend to some extent on temperature. The above magnitudes are approximate only. Refer to Heat Transmission, by W. H. McAdams (McGraw-Hill Co., 1942) for additional values.

the temperature difference, $(t_s - t_f)$ which is the temperature of the surface less that of the fluid[3]. The proportionality factor is termed the *unit convection conductance* (sometimes called the film coefficient for convection), h_c, Btu per hour per square foot per degree Fahrenheit. These convection conditions are illustrated in Fig. 1.

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

$$q_c = C\left(\frac{1}{D}\right)^{0.2}\left(\frac{1}{T\,\text{av.}}\right)^{0.181}(t_s - t_f)^{1.27} \qquad (2a)$$

where

q_c = heat transmission by convection, Btu per square foot per hour.
C = a constant depending upon the surface shape.
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 wall surface and surrounding air temperature, degrees Fahrenheit absolute.
$t_s - t_f$ = temperature excess between wall surface and surrounding air, degrees Fahrenheit.

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. A value of $C = 1.79$ for horizontal plates warmer than the surrounding air facing upward and 0.89 for horizontal plates warmer than air facing downward is indicated by recent investigations[4].

The heat transmission by free convection from vertical walls 24 in. or more in height is given in Table 2 as calculated from Equation 2a for ambient air temperature of 80 F. The values in Table 2 will not be changed appreciably by a considerable change in air temperature for a given temperature excess. For instance, a change in air temperature

[3]The particular fluid temperature to use for a given system will be noted under the discussion of that system.

[4]The Transmission of Heat by Radiation and Convection, by Griffith and Davis (*Special Report* No. 9, 1922, *Department of Scientific and Industrial Research*, His Majesty's Stationery Office, London, England).

from 80 to 40 F will increase the heat transmission given in Table 2 by only 1.3 per cent.

Table 2 can also be used for calculating the free convection rate of transmission for various commercial shapes such as pipes and ducts. These calculations are simplified by the use of the factors in Tables 3 and 4. Table 3 gives factors by which the values in Table 2 must be multiplied to obtain the free convective transfer from various shapes whose characteristic dimensions are 24 in. or over, and Table 4 gives the factors to be used in conjunction with the factors in Table 3 for obtaining the free convection from Table 2 for pipes and ducts whose characteristic dimensions are less than 24 in.

For example, the free convection transfer from a 3 in. o.d. horizontal cylinder for a temperature difference for 40 F = 25.0 × 0.73 × 1.52 = 27.7 Btu per square foot per hour.

TABLE 2. HEAT TRANSMISSION BY FREE CONVECTION FOR LARGE VERTICAL SURFACES
Expressed in Btu per square foot per hour

TEMP. DEG F	TEMPERATURE DIFFERENCE BETWEEN BODY AND SURROUNDING STILL AIR AT 80 F													
	0	10	20	30	40	50	60	70	80	90	100	110	120	130
0	0	4.4	10.4	17.4	25.0	33.2	41.8	50.6	59.9	69.4	79.4	89.2	99.4	109.8
1	0.3	4.9	11.1	18.1	25.8	34.1	42.6	51.5	60.8	70.3	80.4	90.2	100.4	110.9
2	0.6	5.5	11.8	18.9	26.7	34.9	43.5	52.4	61.8	71.3	81.4	91.2	101.5	112.0
3	1.0	6.0	12.5	19.7	27.5	35.7	44.3	53.4	62.7	72.3	82.4	92.2	102.6	113.0
4	1.4	6.6	13.2	20.5	28.3	36.6	45.2	54.3	63.7	73.3	83.3	93.3	103.6	114.1
5	1.8	7.3	13.9	21.2	29.2	37.4	46.1	55.2	64.6	74.3	84.2	94.3	104.7	115.2
6	2.3	7.9	14.6	22.0	30.0	38.3	47.0	56.1	65.6	75.3	85.2	95.3	105.7	116.3
7	2.8	8.5	15.3	22.7	30.8	39.1	47.8	57.1	66.5	76.3	86.2	96.3	106.7	117.3
8	3.3	9.1	16.0	23.5	31.6	40.0	48.7	58.0	67.5	77.4	87.2	97.4	107.8	118.4
9	3.8	9.7	16.7	24.3	32.4	40.9	49.7	59.0	68.4	78.4	88.2	98.4	108.8	119.5

TABLE 3. FREE CONVECTION FACTORS FOR VARIOUS SHAPES

SHAPES	FACTOR
Horizontal cylinders 24 in. in diam. or over	0.73
Long vertical cylinders 24 in. in diam. or over	0.88
Vertical plates 24 in. in height or over	1.00
Horizontal plates warmer than air facing upward	1.28
Horizontal plates warmer than air facing downward	0.64
Horizontal plates cooler than air facing upward	0.64
Horizontal plates cooler than air facing downward	1.28

TABLE 4. FREE CONVECTION FACTORS FOR VARIOUS DIAMETER PIPES OR VARIOUS HEIGHT PLATES

Actual o. d., or height, in.	1	2	3	4	5	6	7	8
Factor	1.88	1.64	1.52	1.43	1.37	1.32	1.28	1.25
Actual o. d., or height, in.	9	10	12	14	16	18	20	22
Factor	1.22	1.19	1.15	1.11	1.09	1.06	1.04	1.02