$$U = \frac{1}{\frac{1}{f_i} + \frac{1}{f_o} + \frac{x}{k} + \frac{1}{a_1} + \frac{1}{a_2} + \frac{1}{a_3} + etc.} \tag{8}$$

With certain special forms of materials which have irregular air spaces (such as hollow tile) or are otherwise non-homogeneous, it is necessary to use the conductance (C) for the unit construction, in which case $\frac{x}{k}$ is replaced by $\frac{1}{C}$.

Air Spaces and Surface Coefficients: The following from Bulletin No. 102 of the Engineering Experiment Station of the University of Illinois, is pertinent:

In making calculations for heat transmission coefficients of compound walls, an air space may be treated in either of the following ways: the air space may be regarded as a solid insulating material through which the heat passes according to the so-called conductivity theory or considering the transfer by the three methods, radiation, convection, and conduction, the radiation and convection action may be combined into a single surface coefficient and the true conductivity of the air neglected. For every air space two surface coefficients, accordingly, would be considered. If different surfaces enclosed the air space, different surface coefficients would be used for the two walls.

Because reliable air-space conductance values have not been available until recently, it has been the practice in the past, when calculating the heat transmission through constructions containing air spaces, to assign still-air surface values to the surfaces enclosing the air spaces, rather than to consider the air spaces as solid insulating materials. In the 1928 and 1929 editions of THE GUIDE the heat transmission tables were based on the average value of 1.34 for surfaces in still air taken from Table 4, which is equivalent to an air-space conductance of 0.67 B.t.u. per hour per square foot per degree fahrenheit difference in temperature between the two sides.

According to tests conducted at the University of Minnesota, under the direction of Prof. F. B. Rowley, conductances of air spaces for various widths and mean temperatures average somewhat higher than 0.67 (Table 6). These tests indicate that there is practically no increase in the conductance of an air space beyond about 1 in. in width, and that the average conductance of air spaces of this width or greater at a mean temperature of 40 deg. fahr. is about 1.10 B.t.u. per hour per square foot per degree fahrenheit difference in temperature, although this value is probably sufficiently accurate for all air spaces of ½ in. or more in width.

Surface coefficients increase with the velocity of air passing over the surface. Factors for determining conductances of outside surfaces under moving-air conditions are given in Table 5. It is the practice to increase the still-air surface coefficient by the factor 3 to allow for moving-air conditions, which is approximately equivalent to a wind exposure of 15 miles per hour. Thus, the conductance of the average surface for still air is 1.34, based on the values given in Table 4, and when increased by the factor 3 to allow for moving air, the outside surface coefficient is 3 × 1.34 or 4.02 B.t.u. per hour per square foot per degree fahrenheit difference between the surface and the air in contact with it.

The overall transmission of any wall for a wind exposure other than 15 miles per hour, can be computed by assigning the proper outside surface coefficient, but in most cases the accuracy involved does not warrant this degree of refinement, and it is sufficiently accurate to base all calculations on the one wind exposure. For example: If the heat transmission coefficient of a certain wall is 0.20 based on the outside surface coefficient of 4.02 for a 15-mile wind velocity, this coefficient would not vary more than 1 per cent, plus or minus, for a variation in the wind velocity of 5 miles per hour, plus or minus, based on data contained in Table 5. Computed coefficients are not accurate to this degree of variation in most cases, particularly when it is considered that overall coefficients will often vary to a much greater extent with the density of the materials used in the construction, the moisture content, the mean temperature, the quality of workmanship, and other factors.

TABLE 5. FACTORS TO BE USED IN DETERMINING VALUES OF OUTSIDE SURFACE COEFFICIENTS (f_o) UNDER MOVING AIR CONDITIONS

IN EACH CASE, THE MOVING AIR FACTOR IS BASED ON STILL AIR COEFFICIENT f_i FOR *same* MATERIAL. FOR CONDITIONS WHERE WIND VELOCITY IS NOT KNOWN USE THE FACTOR (3) OR TAKE f_o AS $3 f_i$ FOR SAME MATERIAL.

WIND VELOCITY IN MILES PER HOUR	BRICKWORK	MULTIPLIERS OF f_i[a] WOOD	AVERAGE
5	2.38	2.19	2.28
10	3.20	2.71	2.96
15	3.76	2.95	3.36[b]
20	4.22	3.02	3.62
Additional Values—Smooth Surface			
10	....	2.20	....
20	....	2.60	....
Above 20	....	3.00	....

[a]Taken from Engineering Experiment Station Bulletin No. 102, of the University of Illinois. Additional values from Engineering Experiment Station, Pennsylvania State College, reported by Professor Wood. Tests at Pennsylvania State College indicate character of surface, rough or smooth, more important than material of surface.

[b]This is usually taken as 3 even.

Conductivities and Conductances: The majority of the conductivities and conductances of the building materials and insulations given in Tables 7, 8, 9, 10 and 11, were determined by the hot-plate method of testing. (See Standard Test Code for Heat Transmission Through Walls, JOURNAL OF THE AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, January, 1928, p. 63.) Attention is called to the fact that conductivities per inch of thickness of materials or insulations do not afford a true basis for comparison, although they are frequently used for that purpose. Correct comparisons should take into consideration many different factors, including conductivities or conductances, thicknesses installed, manner of installation, etc., while the selection of an insulation should also give consideration to structural qualities, as well as material and application costs. At present there is no universally recognized method of rating insulations. Conductivities and conductances of building materials and insulations are useful to the heating engineer in deter-