Heat transmission coefficients of building materials

The American Society of Heating, Refrigerating and Air-Conditioning Engineers

Publisher's version / Version de l'éditeur:
https://doi.org/10.4224/20338358
Technical Paper (National Research Council of Canada. Division of Building Research), 1960-04-01

NATIONAL RESEARCH COUNCIL

DIVISION OF BUILDING RESEARCH

CANADA

HEAT TRANSMISSION COEFFICIENTS

OF

BUILDING MATERIALS

REPRINT OF CHAPTER 9

HEATING VENTILATING AIR CONDITIONING GUIDE 1960

OF THE

AMERICAN SOCIETY OF

HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS

TECHNICAL PAPER NO. 7

OF THE

DIVISION OF BUILDING RESEARCH

OTTAWA

APRIL 1960

PRICE 50 CENTS

CHAPTER 9

HEAT TRANSMISSION COEFFICIENTS OF BUILDING MATERIALS

Heat Transfer Symbols; Calculating Overall Coefficients; Conductivity of Homogeneous Materials; Soil Conductivity and Specific Heat; Surface and Air Space Conductance; Overall Coefficients and Their Practical Use; Computed Coefficients of Walls, Roofs, Ceilings, and Floors; Effect of Insulation; Combined Ceiling, Roof, and Floor Coefficients; Glass Coefficients; Calculating Surface Temperatures

THE design of air-conditioning or heating systems for buildings requires a knowledge of the thermal properties of the walls enclosing the space. (The term *walls* in this case, includes windows, doors, ceilings, floors, roofs, and skylights.) The rate of heat flow through the walls under steady-state conditions at design temperatures is usually the basis for calculating the heat required. For a given wall under standard conditions the rate is a specific value designated as U, the *overall coefficient of heat transmission* or thermal transmittance. It may be determined by test in a guarded hot box apparatus, or it may be computed from known values of the thermal conductance of the various components. Because it is impracticable to test all combinations of building materials, the procedure and necessary data for calculation of the value of U are given in this chapter, together with convenient tables of computed values for a large number of the more common constructions.

HEAT TRANSFER SYMBOLS

U = overall coefficient of heat transmission or thermal transmittance (air-to-air); the time rate of heat flow expressed in Btu per (hour) (square foot) (Fahrenheit degree temperature difference between air on the inside and air on the outside of a wall, floor, roof, or ceiling). The term is applied to the usual combinations of materials, and also to single materials, such as window glass, and includes the surface conductance on both sides. This term is frequently called the U value.

k = thermal conductivity; the time rate of heat flow through a homogeneous material under steady conditions per unit temperature gradient through unit area perpendicular to the temperature gradient. Its value is expressed in Btu per (hour) (square foot) (Fahrenheit degree per inch of thickness). Materials are considered homogeneous when the value of k is not affected by variation in thickness or size of sample within the range normally used in construction.

C = thermal conductance; the time rate of heat flow through a unit area of a material from one of its surfaces to the other per unit temperature difference *between the two surfaces*. Its value is expressed in Btu per (hour) (square foot) (Fahrenheit degree). The term is applied to specific materials as used, either homogeneous or heterogeneous, for the thickness or construction stated, not per inch of thickness.

f = film or surface conductance; the time rate of heat exchange by ***radiation conduction and convection*** of a unit area of a surface with ***the surroundings*** and the surrounding air or other fluid. Its value is expressed in Btu per (hour) (square foot of surface) (Fahrenheit degree temperature difference). Subscripts i and o are usually used to denote inside and outside surface conductances, respectively.

a = thermal conductance of an air space; the time rate of heat flow through a unit area of an air space per unit temperature difference *between the boundary surfaces*. Its value is expressed in Btu per (hour) (square foot of area) (Fahrenheit degree). The conductance of an air space is dependent on the temperature difference, the height, the depth, the position, character, and temperature of the boundary surfaces. Since the relationships are not linear, accurate values must be obtained by test and not by computation.

ϵ = emissivity; the ratio of the total radiant flux emitted by a surface to that emitted by an ideal black body at the same temperature.

E = effective emissivity; the combined effect of the surface emissivities ϵ of the boundary surfaces of an air space; the boundaries assumed to be parallel and of large dimensions as compared to the distance between them.

r = surface reflectivity; the ratio of the radiant flux reflected by an opaque surface to that falling upon it.

R = thermal resistance. Its value is obtained from the reciprocal of heat transfer as expressed by U, C, f, or a. It may be expressed in (Fahrenheit degrees per Btu)/(hour) (square foot). For example, a wall with a U value of 0.25 would have a resistance value of $R = 1/0.25 = 4.0$ *ru*. The word *ru* has been suggested as an abbreviation for resistance unit.

CALCULATING OVERALL COEFFICIENTS

From Chapter 5, Equation 7, the total resistance to heat flow through a wall is equal numerically to the sum of the resistances in series.

$$R_T = R_1 + R_2 + R_3 + R_4 + \cdots + R_n \qquad (1)$$

where R_1, R_2, etc., are the individual resistances of the wall components, and R_T is total resistance.

For a wall of a single homogeneous material of conductivity k and thickness x with surface coefficients f_i and f_o,

$$R_T = \frac{1}{f_i} + \frac{x}{k} + \frac{1}{f_o} \qquad (2)$$

Then by definition, $U = 1/R_T$

For a wall with air space construction and consisting of two homogeneous materials of conductivities k_1 and k_2, thicknesses x_1 and x_2, respectively, and separated by an air space of conductance a,

$$R_T = \frac{1}{f_i} + \frac{x_1}{k_1} + \frac{1}{a} + \frac{x_2}{k_2} + \frac{1}{f_o} \qquad (3)$$

and $U = 1/R_T$

For types of building materials having non-uniform or irregular sections such as hollow clay tile or concrete blocks, it is necessary to use the conductance C of the section unit as manufactured instead of a conductivity k. The resistance of the section $1/C$ is therefore substituted for x/k in Equations 2 and 3.

It will be noted that in order to compute the U value of a construction it is first necessary to know the conductivity and thickness of the homogeneous material, the conductance of non-homogeneous materials (such as concrete blocks), the surface conductances of both sides of the construction, and the conductances of any contained air spaces. These items are discussed in the pages that follow.

Conductivities and Conductances

The method of calculating the overall coefficient of heat transmission for a given construction is comparatively simple, but accurate values of conductivities and conductances must be used to obtain satisfactory results. In addition, there are sometimes parallel heat-flow paths of different resistances in the same wall, and these may necessitate modification of the formula. In such cases calculated results should be checked by test.

The determination of the fundamental conductivities and conductances requires considerable skill and experience to obtain accurate results. It is recommended that thermal conductivities of homogeneous materials be determined by means of the Guarded Hot Plate.[1] For determination of conductances, a Guarded Hot Box method[2] is generally used.

Conductivity of Homogeneous Materials

Thermal conductivity is a property of a homogeneous material and of types of building materials such as lumber, brick, and stone, which may be considered homogeneous. Most insulating materials, except reflective types, are of a porous nature and consist of combinations of solid matter with small voids. Such materials including fibrous, cellular, or granular matter are generally known as mass or bulk insulations. The thermal conductivity of these materials will vary with density; mean temperature; size of voids, fibers, or particles; degree and extent of bond between particles; moisture present; and the arrangement of fibers or particles within the material.

The effect of density upon conductivity (at constant mean temperature) is illustrated for two fibrous materials in Fig. 1. Typical variation of conductivity with mean temperature is shown in Fig. 2.

Thermal Conductivity of Soil

The following statements are based largely on results of a study[3] made in the Engineering Experiment Station, University of Minnesota, and published in *Bulletin* No. 28. Tests were made on nineteen different soils which represented a wide textural variety, including gravel, sand, sandy loam, silt loam, and clay, as well as some crushed rocks and a fibrous peat. Moisture contents in tests varied from air-dried values

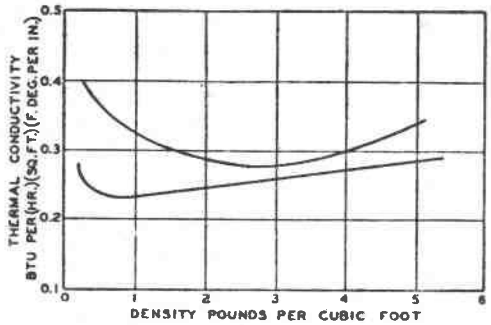


Fig. 1 . . . . Typical Variation of Thermal Conductivity with Density—for Fibrous Material

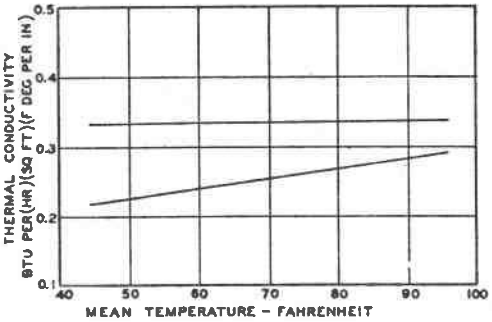


Fig. 2 . . . . Typical Variation of Thermal Conductivity with Mean Temperature

to those greater than the optimum moisture content; densities varied from a loosely-poured condition to the maximum density obtainable by heavy ramming. The general findings of the investigation are as follows:

Effect of Temperature. Soils were tested at several mean temperatures. The degree of influence of temperature depends upon whether it is above or below freezing. For increases of moisture content exceeding about 6 to 12 percent, the conductivity of frozen soil becomes progressively greater than that of the unfrozen soil.

Effect of Density. Density affects the thermal conductivity of a soil in about the same manner for all soils, at any moisture content, and for either the frozen or unfrozen condition. On the average, each one pound per cubic foot increase in dry density increases the thermal conductivity by about 3 percent.

Effect of Moisture. An increase in moisture content, up to the point of saturation, causes an increase in thermal conductivity. The rate of increase in typical soils was as follows: average conductivities, in Btu per (square foot) (hour) (Fahrenheit degree per inch), of four sands at a density of 110 lb per cu ft were: 6.8 at 2.5 percent moisture, 8.9 at 5 percent moisture, 11.2 at 10 percent moisture. Five soils of a fine texture at a density of 100 lb per cu ft, gave average conductivities of 6.7 at 10 percent moisture, and 9.5 at 20 percent. Thus, the doubling of moisture content within the ranges cited increases the conductivity by approximately 30 or 40 percent. At higher moisture contents the percentage increase would be less.

Effect of Soil Characteristics. The thermal conductivity of the soil, at a given density and moisture content, varies in general with the texture of a soil, being relatively high for coarse-textured soils and relatively low for fine-textured soils. The mineral composition of the soils also affects the conductivity. Quartz tends to give high values, whereas minerals such as plagioclase-feldspar and pyroxene, which are constituents of basic rocks tend to give low values of thermal conductivity. These points are illustrated by the values in Table 1 which lists seventeen soils in approximate order of their magnitude of thermal conductivity from greatest to least for seven different density-moisture content conditions. Some of the values in this table have been determined by extrapolation and are consequently approximate. Blank spaces in the table indicate that the density or moisture content, or both, are such that no tests were possible for that condition or that no tests were sufficiently close to permit a reasonable extrapolation of the data. Granular soils, particularly those with high quartz contents, head the tabulation or have the greatest conductivity

Table 1 . . . . Thermal Conductivity (k) Values of Soils in Approximate Order of Decreasing Values[a]

Mean Temperature—40 F

Soil Designation	Mechanical Analysis % by Weight				Moisture Content—%						
	Gravel	Sand	Silt	Clay	4			10		20	
					Dry Density-lb per cu ft						
	Over 2.0 mm	0.5 to 2.00 mm	0.005 to 0.05 mm	Under 0.005 mm	100	110	120	90	110	90	100
Fine Crushed Quartz	0.0	100.0	0.0	0.0	12.0	16.0					
Crushed Quartz	15.5	79.0	5.5		11.5	16.0	22.0				
Graded Ottawa Sand	0.0	99.9	0.1		10.0	14.0					
Fairbanks Sand	27.5	70.0	2.5		8.5±	10.5	13.5		15.0		
Lowell Sand	0.0	100.0	0.0	0.0	8.5	11.0			13.5		
Chena River Gravel	80.0	19.4	0.6			9.0±	13.0				
Crushed Feldspar	25.5	70.3	4.2		6.0	7.5	9.5				
Crushed Granite	16.2	77.0	6.8		5.5	7.5	10.0				
Dakota Sandy Loam	10.9	57.9	21.2	10.0		6.5	9.5		13±		
Crushed Trap Rock	27.0	63.0	10.0		5.0	6.0	7.0				
Ramsey Sandy Loam	0.4	53.6	27.5	18.5	4.5	6.5			10.0		
Northway Fine Sand	0.0	97.0	3.0	0.0	4.5	5.5			8.5		
Northway Sand	3.0	97.0	0.0	0.0	4.5	6.0			7.5±		
Healy Clay	0.0	1.9	20.1	78.0	4.0±			5.5	9.0±	8.0	10.0
Fairbanks Silt Loam	0.0	7.6	80.9	11.5				5.0	9.0±	7.5	10.0
Fairbanks Silty Clay Loam	0.0	9.2	63.8	27.0				5.0	9.0±	7.5	9.5
Northway Silt Loam	1.0	21.0	64.4	13.6				4.0±	7.0±	6.0±	7.0±

[a] k = Btu per (square foot) (hour) (Fahrenheit degree per inch).

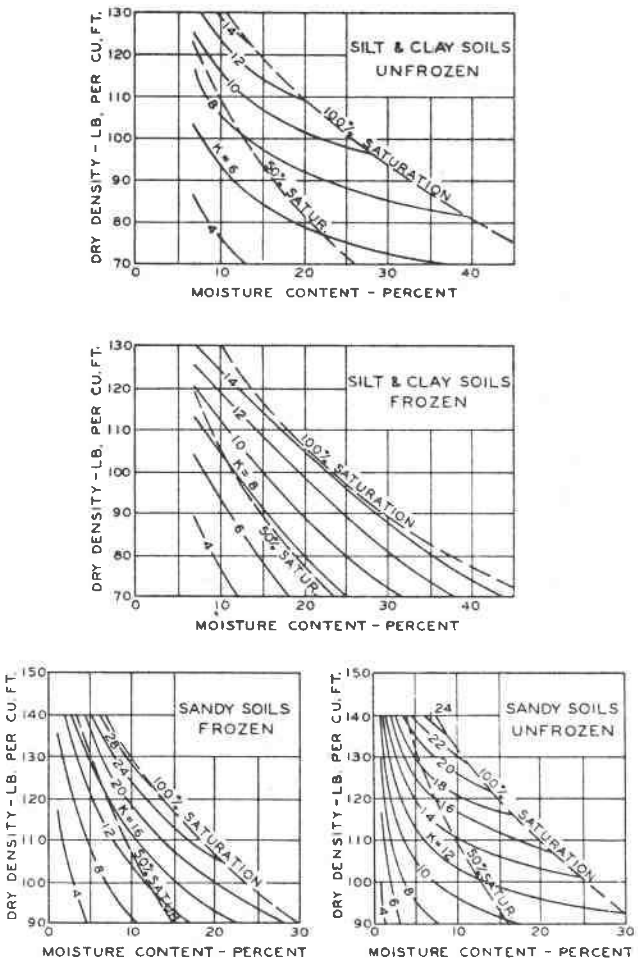


Fig. 3 . . . . Determining Thermal Conductivity of Soils from Density and Moisture Content

at a given condition. Sandy loam soils are midway in the table and fine grained soils such as clay and silt loam are last.

Estimating Thermal Conductivity. The four diagrams of Fig. 3 are presented to aid in the estimate of the thermal conductivity of any soil. Two of the charts are for sands or sandy soils, and two for silt and clay soils. One of the diagrams for each type of soils is for the frozen, and the other for the unfrozen condition. It is expected that these charts will give conductivity values with a precision of 25 percent. The effect of such factors as density, moisture content, freezing, or texture may be easily approximated by use of these graphs.

Specific Heat of Soils

Tests to determine specific heat were run on twelve soils. On five of the soils, tests were made at three or four mean temperatures varying from about 10 to 140 F. The specific heat values of all twelve soils varied by only a small amount (about 0.01), and averaged 0.19 at 140 F. The specific heat values of the soils decreased with a decrease in temperature. The average value at zero F would be about 0.16. Values at temperatures between zero and 140 F can be estimated by considering a straight-line relationship between the two values given.

Surface Conductance

The surface conductance of a wall is the combined heat transfer to or from the wall by radiation, convection, and conduction. Each of the three portions making up the total may vary, independently of the others, thus affecting the total conductance. The heat transfer by radiation between two surfaces is controlled by the character of the surfaces (emissivity), the temperature difference between them, and the solid angle through which they *see* each other. The heat transfer by convection and conduction is controlled by the roughness of the surface, by air movement, and temperature difference between the air and the surface.

The importance of the effect of temperature of *surrounding surfaces* on the surface conductance, due to the effect on radia-

Table 2 . . . . Variation in Surface Conductance Coefficient for Vertical Surfaces with Different Temperatures of Surrounding Surface

Surrounding Surface Temperature	*75 F*	*70 F*	*69 F*	*60 F*	*50 F*
Convection—Btu per (hr) (sq ft)	6.6	6.6	6.6	6.6	6.6
Radiation—Btu per (hr) (sq ft)	4.4	8.6	9.6	17.0	24.9
Total—Btu per (hr) (sq ft)	11.0	15.2	16.2	23.6	31.5

tion, is illustrated in Table 2, which applies to a vertical surface at 80 F, with ambient air at 70 F and with radiation exchange corresponding to an effective emissivity of 0.83.[4]

In many cases, because the heat resistance of the internal parts of the wall is high compared with the surface resistance, the surface factors are of minor importance. In other cases, e.g., single glass windows, the surface resistances constitute almost the entire resistance and are therefore very important. An analysis of various factors affecting surface conductance and the difference between surface and air temperatures will be found in Reference 5. (See also Chapter 30.)

The convection part of the surface conductance is affected markedly by air movement. This is illustrated by Fig. 4, which shows the results of tests[6] made on 12-in. square samples of different materials at a mean temperature of 20 F, and for wind velocities up to 40 mph. These conductances include the radiation portion of the coefficient which, for the conditions of the tests, was about 0.7 Btu per (hr) (sq ft) (F deg). More recent tests[7] on smooth surfaces show that surface length also affects significantly the convection part of conductance; the average value decreases as the surface length increases. Moreover, observations[8] of the magnitude of low temperature radiant energy received from outdoor surroundings show that only under certain conditions may the out-of-doors be treated as a black body radiating at air temperature.

Because of these factors, the selection of surface conductance coefficients for a practical building becomes a matter of judgment. Surface conductances are shown in Tables 3 and 4. *In calculating the overall heat transmission coefficients for the walls, etc., of Tables 5 through 15, the appropriate indoor and outdoor surface coefficients given in Table 4 for Air Surfaces have been used.* Both values combine the effects of convection and radiation, and are applicable to ordinary building materials. They should not be used for low emissivity surfaces such as bright metal. For exposed reflective surfaces refer to Table 3, Section A, and to footnotes under Table 16.

In special cases, where surface conductances become important factors in the overall rates of heat transfer, more selective coefficients may be required. Principles and data given in Chapter 5, Heat Transfer, may be applied in such cases.

Air Space Conductance

The transfer of heat across an air space involves the boundary surfaces as well as the intervening air, and depends markedly on the orientation of the air space and the direction of heat flow. The coefficients given for air space conductance represent the total conductance from one surface bounding the air space to the other. The total conductance is the sum of a component due to radiation and a component due to convection and conduction combined. These components may vary independently of each other.

The radiation portion of the coefficient is affected by the temperature of the two boundary surfaces, and by their respective surface emissivities ϵ, the combined effect of which is expressed by means of the *effective emissivity* E of the air space. The radiation component is not affected by the thickness of the space or by its orientation or direction of heat flow. The heat transfer by convection and conduction combined, however, is markedly affected by the orientation of the air space and the direction of heat flow, is significantly affected by the temperature difference across the space and in some cases by the thickness of the space, and is affected to only a small extent by the mean temperature of its surfaces. For air spaces usually employed in building construction, the radiation and convection-conduction components may vary independently of each other.

Table 3, Section C, gives the thermal conductances and resistances of air spaces of uniform thickness and moderately

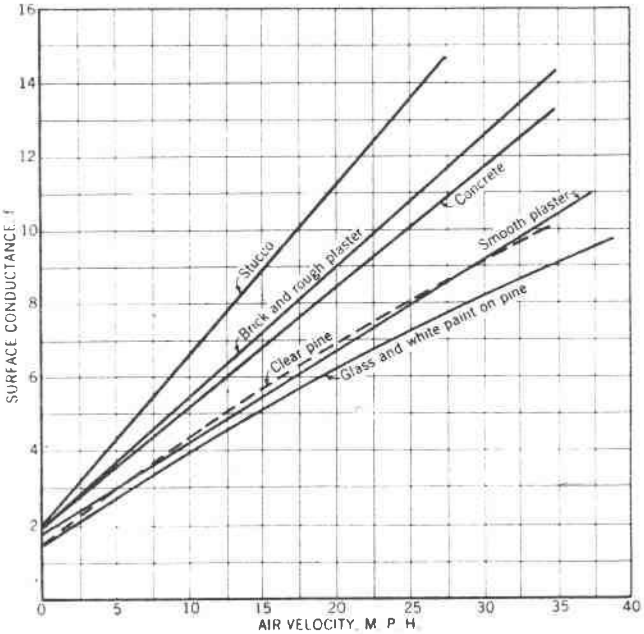


Fig. 4 . . . . Curves Showing Relation Between Surface Conductance for Different Surfaces at 20 F Mean Temperature

smooth surfaces, based on experimental measurements conducted at the National Bureau of Standards.[9] Although the conductances of air spaces vary to some extent with thickness in the range over ¾ in., average values are tabulated for the range from ¾ in. to 4 in., for all except horizontal spaces with heat flow downward. The error involved by averaging is less than 10 percent in the extreme case and less than 5 percent in most. For more exact values Reference 9 may be consulted.

For narrow air spaces, which may be defined as those for which the product of the cube of the thickness of the space in inches times the temperature difference (Fahrenheit degrees) across the space is less than 3 for heat flow horizontally or downward, or less than 1 for heat flow upward, the conductance is the sum of the radiative heat transfer coefficient and that for conduction alone through air, since convection is practically suppressed. The radiation component can be computed by means of Equation 4 and Table 4 of Chapter 5; the conduction component can be computed using the conductivity of air at the appropriate mean temperature (see Table 1, Chapter 5).

The effects of different mean temperatures, temperature differences, and effective emissivities are indicated in Table 3 of this chapter, Section C. As indicated, use may be made of interpolation and moderate extrapolation of conductance values in the table to obtain conductances for conditions moderately different from those given. Interpolation of resistance values is not recommended, especially in relation to emissivity values.

Table 3, Section B, gives values for the surface reflectivities and emissivities of materials used as boundaries of air spaces in building construction, for total radiation at ordinary building temperatures. Effective emissivities for various combinations of these materials, for use in conjunction with Section C of Table 3, are given in the last two columns of Section B.

When considering heat transfer across air spaces in building construction, the emissivities of the boundary surfaces must be known. The possibility of change in emissivity of highly reflective surfaces due to exposure to conditions promoting chemical action, deposition of dust, soiling of the surface, or the application of coatings, even though transparent to the eye, must be considered in selecting a material for use.[10] Surface emissivity values should be obtained by tests.

OVERALL COEFFICIENTS AND THEIR PRACTICAL USE

The values in Tables 3 and 4 for component elements and materials were selected by the ASHAE Technical Advisory Committee on Insulation as representative for dry materials at 75 F mean temperature. They are based on available published data obtained by the guarded hot plate method (*ASTM* C177-45) or by the guarded hot box method (*ASTM* C236-54T). Because there are variations in commercially available materials of the same type, not all of these selected representative values will be in exact agreement with data for individual products. The exact value for a certain manufacturer's material can be secured from unbiased tests or from guaranteed data of the manufacturer.

The most exact method of determining the heat transmission coefficient for a given combination of building materials assembled as a building section is to test a representative section in a guarded hot box. However, it is not practicable to test all the combinations which may be of interest in building construction. Experience has indicated that U values for many constructions, when calculated by the methods given in this chapter, using accurate values for the component materials, are in good agreement with values determined by guarded hot box measurements.

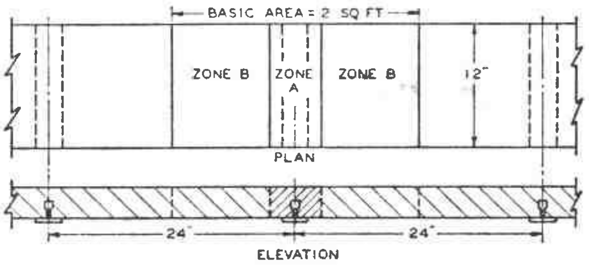
Caution

Although the validity of calculating U values for all of the types of constructions in Tables 5 through 16 has not been fully demonstrated, calculated values are given because measured values are not available. It is emphasized that the calculated values in Tables 5 through 16 are given for the convenience of the user.

In calculating U values, exemplary conditions of components and installations are assumed, i.e., that insulating materials are uniformly of the nominal thickness and conductivity, that air spaces are of uniform thickness and surface temperatures, that effects due to moisture are not involved, and that installation details are in accordance with design. Some evidence of departures of measured values from calculated values for certain insulated constructions is given in *Building Materials and Structures Report* BMS 151, National Bureau of Standards. In order to provide a reasonable factor of safety to account for departures of constructions from exemplary conditions, in part due to field construction requirements and practices, some may wish, before making corrections for framing (as indicated in Fig. 6), to increase moderately the calculated U values of the insulated walls, floors and ceiling sections obtained from Table 16. Where reflective air spaces are involved, increases of U values up to 10 percent for applications where heat flow is horizontal or upward, and up to 20 percent where heat flow is downward, appear reasonable on the basis of present information.

Heat Flow Through Panels Containing Metal

The transmittance of a panel which includes metal or other highly conductive material extending wholly or partly through insulation should, if possible, be determined by test in the guarded hot box. When a calculation is required, a good ap-



For enlarged section of Zone A, see Fg. 6

Fig. 5 . . . . Gypsum Roof Deck on Bulb Tees

proximation can be made by a *Zone Method.* This involves two separate computations—one for a chosen limited portion, *Zone A*, containing the highly conductive element, and the other for the remaining portion of simpler construction, called *Zone B*. The two computations are then combined, and the average transmittance per unit of overall area is calculated. The basic laws of heat transfer are applied, i.e., adding area conductances $C \cdot A$ of elements in parallel, and adding area resistances $1/C \cdot A$ of elements in series.

The surface shape of *Zone A* is determined by the metal element. For a metal beam (Fig. 5) the *Zone A* surface is a strip of width W, centered on the beam. For a rod perpendicular to panel surfaces it is a circle of diameter W. The value of W is calculated from Equation 4, which is empirical.

$$W = m + 2d \quad (4)$$

where

m = width or diameter of the metal heat path terminal, inches.

d = distance from panel surface to metal, inches. The value of d should not be taken less than 0.5 in. (for still air).

In general, the value of W should be calculated by Equation 4 for each end of the metal heat path, and the larger value, within the limits of the *basic area*, used as illustrated in *Example 1*.

Example 1: Calculate the transmittance of the roof deck shown in Figs. 5 and 6. Tee-bars on 24 in. centers support glass fiber form boards, gypsum concrete and built-up roofing. The conductivities of components are: steel 312; gypsum concrete 1.66; glass fiber 0.25. The conductance of built-up roofing is 3.0.

(Continued on p. 113)

Table 3 . . . . Surface Conductances and Resistances for Still Air

All conductance values expressed in Btu per (hr) (sq ft) (F deg temp diff)

SECTION A. Surface Conductances for Still Air[a, b]

Position of Surface	Direction of Heat Flow	Surface Emissivity: Non-reflective ε = 0.90		Reflective ε = 0.20		Reflective ε = 0.05	
		C	R	C	R	C	R
Horizontal	Upward	1.63	0.61	0.91	1.10	0.76	1.32
Sloping—45 deg	Upward	1.60	0.62	0.88	1.14	0.73	1.37
Vertical	Horizontal	1.46	0.68	0.74	1.35	0.59	1.70
Sloping—45 deg	Downward	1.32	0.76	0.60	1.67	0.45	2.22
Horizontal	Downward	1.08	0.92	0.37	2.70	0.22	4.55

SECTION B. Reflectivity and Emissivity Values of Various Surfaces[c] and Effective Emissivities of Air Spaces

Surface	Reflectivity in percent	Average Emissivity ε	Effective Emissivity E of Air Space: With one surface having emissivity ε and other 0.90	Effective Emissivity E of Air Space: With both surfaces of emissivity ε
Aluminum foil, bright	92 to 97	0.05	0.05	0.03
Aluminum sheet	80 to 95	0.12	0.12	0.06
Aluminum coated paper, polished	75 to 84	0.20	0.20	0.11
Steel, galvanized, bright	70 to 80	0.25	0.24	0.15
Aluminum paint	30 to 70	0.50	0.47	0.35
Building materials: wood, paper, glass, masonry, nonmetallic paints	5 to 15	0.90	0.82	0.82

[a] For ventilated attics or spaces above ceilings under summer conditions (heat flow down) see Table 17.

[b] Conductances are for surfaces of the stated emissivity facing surroundings having an emissivity equal to 0.9 and at the same temperature as the ambient air. Values are based on a surface-air temperature difference of 10 deg and for surface temperature of 70 F. (See Table 4 for surface conductances for moving air.)

[c] See also Chapter 5, Table 3.

SECTION C. Thermal Conductances and Resistances of a Plane[d, e] Air Space*

Position of Air Space	Heat Flow	Air Space: Thickness,[e] inches	Air Space: Mean temp,[f] F	Air Space: Temp diff[f] deg	Thermal Conductance-C Value of E[f, g]: 0.05	0.2	0.5	0.82	Thermal Resistance-R Value of E[g]: 0.05	0.2	0.5	0.82
Horiz.	Up	¾ to 4	50	10	0.41	0.55	0.82	1.11	2.44	1.83	1.22	0.90
			50	30	0.54	0.68	0.95	1.24	1.84	1.47	1.05	0.80
			90	10	0.41	0.58	0.92	1 28	2.47	1.73	1.09	0.78
45° Slope	Up	¾ to 4	50	10	0.35	0.49	0.76	1.05	2.84	2.05	1.31	0.95
			50	30	0.48	0.62	0.89	1.18	2.08	1.62	1.13	0.85
			90	10	0.35	0.52	0.86	1.23	2.85	1.92	1 16	0.81
Vert.	Horiz.	¾ to 4	50	10	0.28	0.42	0.69	0.99	3.52	2.37	1.44	1.02
			50	30	0.38	0.52	0.79	1.08	2.64	1.94	1.27	0.92
			90	10	0.29	0.46	0.80	1.16	3.49	2.19	1.25	0.86
45° Slope	Down	¾ to 4	50	10	0.24	0.38	0.65	0.94	4.14	2.65	1.54	1.06
			50	30	0.30	0.43	0.71	1.00	3.36	2.30	1.41	1.00
			90	10	0.25	0.42	0.76	1.12	4.07	2.40	1.32	0.89
Horiz.	Down[h]	¾	50	20	0.28	0.42	0.69	0.98	3.57	2.38	1.45	1.02
		1½	50	20	0.18	0.31	0.58	0.87	5.56	3.23	1.73	1.15
		4	50	20	0.11	0.25	0.52	0.81	8.94	4.03	1.92	1.23
		¾	90	20	0.31	0.48	0.82	1.18	3.23	2.08	1.22	0.85
		1½	90	20	0.20	0.37	0.71	1.07	5.00	2.70	1.41	0.93
		4	90	20	0.13	0.30	0.64	1.01	7.82	3.35	1.56	0.99

Notes: [d] Spaces of uniform thickness, bounded by moderately smooth surfaces.

[e] Where a range of thickness is given, the given conductance is the average over the range; extreme values within the range differ therefrom by less than 10 percent.

[f] Interpolation, and moderate extrapolation, of conductance values are permissible for other values of mean temperature, temperature difference and effective emissivity E.

[g] Effective emissivity of space, E, is given by $\frac{1}{E} = \frac{1}{\epsilon_1} + \frac{1}{\epsilon_2} - 1$ where ϵ_1 and ϵ_2 are the emissivities of the surfaces of the air space. (See Section B, above.)

[h] The conductances of horizontal spaces with heat flow downward are substantially independent of temperature difference.

* Based on National Bureau of Standards data presented in *Housing Research Paper* No. 32, Housing and Home Finance Agency, 1954 (U. S. Government Printing Office, Washington, D. C.).

Table 4 . . . . Conductivities (*k*), Conductances (*C*), and Resistances (*R*) of Building and Insulating Materials (Design Values)[a]

These constants are expressed in Btu per (hour) (square foot) (Fahrenheit degree temperature difference). Conductivities (k) are per inch thickness and, conductances (C) are for thickness or construction stated, not per inch thickness

Material	Description	Density (Lb per Cu Ft)	Conductivity or Conductance (*k*)	Conductivity or Conductance (*C*)	Resistance[h] (*R*) Per inch thickness $\left(\frac{1}{k}\right)$	Resistance[h] (*R*) For thickness listed $\left(\frac{1}{C}\right)$
AIR SPACES[b]	See Table 3—Section B					
	POSITION — HEAT FLOW — THICKNESS					
	Horizontal....... Up (winter) .... 3/4–4 in.	—	—	1.18	—	0.85
	Horizontal....... Up (summer) .... 3/4–4 in.	—	—	1.28	—	0.78
	Horizontal....... Down (winter) .... 3/4 in.	—	—	0.98	—	1.02
	Horizontal....... Down (winter) .... 1½ in.	—	—	0.87	—	1.15
	Horizontal....... Down (winter) .... 4 in.	—	—	0.81	—	1.23
	Horizontal....... Down (winter) .... 8 in.	—	—	0.80	—	1.25
	Horizontal....... Down (summer) .... 3/4 in.	—	—	1.18	—	0.85
	Horizontal....... Down (summer) .... 1½ in.	—	—	1.07	—	0.93
	Horizontal....... Down (summer) .... 4 in.	—	—	1.01	—	0.99
	Sloping, 45°..... Up (winter) .... 3/4–4 in.	—	—	1.11	—	0.90
	Sloping, 45°..... Down (summer) .... 3/4–4 in.	—	—	1.12	—	0.89
	Vertical......... Horiz. (winter) .... 3/4–4 in.	—	—	1.03	—	0.97
	Vertical......... Horiz. (summer) .... 3/4–4 in.	—	—	1.16	—	0.86
AIR SURFACES[c]	See Table 3—Section A					
STILL AIR	POSITION — HEAT FLOW					
	Horizontal.......... Up	—	—	1.63	—	0.61
	Up Sloping (45°).......... Up	—	—	1.60	—	0.62
	Vertical.......... Horizontal	—	—	1.46	—	0.68
	Sloping(45°).......... Down	—	—	1.32	—	0.76
	Horizontal.......... Down	—	—	1.08	—	0.92
15 MPH WIND	Any position—any direction (for winter)..........	—	—	6.00	—	0.17
7½ MPH WIND	Any position—any direction (for summer)..........	—	—	4.00	—	0.25
BUILDING BOARD[d] BOARDS, PANELS, SHEATHING, ETC.	Asbestos-cement board..........	120	4.0	—	0.25	—
	Asbestos-cement board .... 1/8 in.			33.		0.03
	Gypsum or plaster board .... 3/8 in.	50	—	3.10	—	0.32
	Gypsum or plaster board .... 1/2 in.	50	—	2.25	—	0.45
	Plywood..........	34	0.80	—	1.25	—
	Plywood .... 1/4 in.	34	—	3.20	—	0.31
	Plywood .... 3/8 in.	34	—	2.12	—	0.47
	Plywood .... 1/2 in.	34	—	1.60	—	0.63
	Plywood or wood panels .... 3/4 in.	—	—	1.07	—	0.94
	Wood fiber board, laminated or homogeneous..........	26	0.42	—	2.38	—
		31	0.50	—	2.00	—
	Wood fiber—hardboard type..........	65	1.40	—	0.72	—
	Wood fiber—hardboard type .... 1/4 in.	65	—	5.60	—	0.18
	Wood—fir or pine sheathing .... 25/32 in.	—	—	1.02	—	0.98
	Wood—fir or pine .... 1 5/8 in.	—	—	0.49	—	2.03
BUILDING PAPER	Vapor—permeable felt..........	—	—	16.70	—	0.06
	Vapor—seal, 2 layers of mopped 15 lb felt..........	—	—	8.35	—	0.12
	Vapor—seal, plastic film..........	—	—	—	—	Negl
FLOORING MATERIALS	Asphalt tile .... 1/8 in.	120	—	24.80	—	0.04
	Carpet and fibrous pad..........	—	—	0.48	—	2.08
	Carpet and rubber pad..........	—	—	0.81	—	1.23
	Ceramic tile .... 1 in.	—	—	12.50	—	0.08
	Cork tile..........	25	0.45	—	2.22	—
	Cork tile .... 1/8 in.	—	—	3.60	—	0.28
	Felt, flooring..........	—	—	16.70	—	0.06
	Floor tile or linoleum—av. value .... 1/8 in.	—	—	20.00	—	0.05
	Linoleum .... 1/8 in.	80	—	12.00	—	0.08
	Plywood subfloor .... 5/8 in.	—	—	1.28	—	0.78
	Rubber or plastic tile .... 1/8 in.	110	—	42.40	—	0.02
	Terrazzo .... 1 in.	—	—	12.50	—	0.08
	Wood subfloor .... 25/32 in.	—	—	1.02	—	0.98
	Wood, hardwood finish .... 3/4 in.	—	—	1.47	—	0.68
INSULATING MATERIALS BLANKET AND BATT	Cotton fiber[e]..........	0.8–2.0	0.26	—	3.85	—
	Mineral wool, fibrous form, processed from rock, slag, or glass[e]..........	1.5–4.0	0.27	—	3.70	—
	Wood fiber[e]..........	3.2–3.6	0.25	—	4.00	—
	Wood fiber, multilayer, stitched expanding[e]..........	1.5–2.0	0.27	—	3.70	—

Table 4 . . . . Conductivities (*k*), Conductances (C), and Resistances (*R*) of Building and Insulating Materials (*Continued*)
(*Design Values*)[a]

Material	*Description*	*Density (Lb per Cu Ft)*	Conductivity or Conductance (k)	Conductivity or Conductance (C)	Resistance[h] (R) Per inch thickness $\left(\frac{1}{k}\right)$	Resistance[h] (R) For thickness listed $\left(\frac{1}{C}\right)$
BOARD	Glass fiber	9.5	0.25	—	4.00	—
	Wood or cane fiber					
	Acoustical tile[f] ... ½ in.	—	—	0.84	—	1.19
	Acoustical tile[f] ... ¾ in.	—	—	0.56	—	1.78
	Interior finish (plank, tile, lath)	15.0	0.35	—	2.86	—
	Interior finish (plank, tile, lath) ... ½ in.	15.0	—	0.70	—	1.43
	Roof deck slab					
	Approx. ... 1½ in.	—	—	0.24	—	4.17
	Approx. ... 2 in.	—	—	0.18	—	5.56
	Approx. ... 3 in.	—	—	0.12	—	8.33
	Sheathing (impreg. or coated)	20.0	0.38	—	2.63	—
	Sheathing (impreg. or coated) ... ½ in.	20.0	—	0.76	—	1.32
	Sheathing (impreg. or coated) ... 25/32 in.	20.0	—	0.49	—	2.06
BOARD AND SLABS	Cellular glass	9.0	0.40	—	2.50	—
	Corkboard (without added binder)	6.5–8.0	0.27	—	3.70	—
	Hog hair (with asphalt binder)	8.5	0.33	—	3.00	—
	Plastic (foamed)	1.62	0.29	—	3.45	—
	Wood shredded (cemented in preformed slabs)	22.0	0.55	—	1.82	—
LOOSE FILL	Macerated paper or pulp products	2.5–3.5	0.28	—	3.57	—
	Mineral wool (glass, slag, or rock)	2.0–5.0	0.30	—	3.33	—
	Sawdust or shavings	8.0–15.0	0.45	—	2.22	—
	Vermiculite (expanded)	7.0	0.48	—	2.08	—
	Wood fiber: redwood, hemlock, or fir	2.0–3.5	0.30	—	3.33	—
ROOF INSULATION	All types[g]					
	Preformed, for use above deck					
	Approx. ... ½ in.	—	—	0.72	—	1.39
	Approx. ... 1 in.	—	—	0.36	—	2.78
	Approx. ... 1½ in.	—	—	0.24	—	4.17
	Approx. ... 2 in.	—	—	0.19	—	5.26
	Approx. ... 2½ in.	—	—	0.15	—	6.67
	Approx. ... 3 in.	—	—	0.12	—	8.33
MASONRY MATERIALS Concretes	Cement mortar	116	5.0	—	0.20	—
	Gypsum-fiber concrete 87½% gypsum, 12½% wood chips	51	1.66	—	0.60	—
	Lightweight aggregates including expanded shale, clay or slate; expanded slags; cinders; pumice; perlite; vermiculite; also cellular concretes	120	5.2	—	0.19	—
		100	3.6	—	0.28	—
		80	2.5	—	0.40	—
		60	1.7	—	0.59	—
		40	1.15	—	0.86	—
		30	0.90	—	1.11	—
		20	0.70	—	1.43	—
	Sand and gravel or stone aggregate (oven dried)	140	9.0	—	0.11	—
	Sand and gravel or stone aggregate (not dried)	140	12.0	—	0.08	—
	Stucco	116	5.0	—	0.20	—
MASONRY UNITS	Brick, common	120	5.0	—	0.20	—
	Brick, face	130	9.0	—	0.11	—
	Clay tile, hollow:					
	1 cell deep ... 3 in.	—	—	1.25	—	0.80
	1 cell deep ... 4 in.	—	—	0.90	—	1.11
	2 cells deep ... 6 in.	—	—	0.66	—	1.52
	2 cells deep ... 8 in.	—	—	0.54	—	1.85
	2 cells deep ... 10 in.	—	—	0.45	—	2.22
	3 cells deep ... 12 in.	—	—	0.40	—	2.50
	Concrete blocks, three oval core:					
	Sand and gravel aggregate ... 4 in.	—	—	1.40	—	0.71
	... 8 in.	—	—	0.90	—	1.11
	... 12 in.	—	—	0.78	—	1.28
	Cinder aggregate ... 3 in.	—	—	1.16	—	0.86
	... 4 in.	—	—	0.90	—	1.11
	... 8 in.	—	—	0.58	—	1.72
	... 12 in.	—	—	0.53	—	1.89
	Gypsum partition tile:					
	3 x 12 x 30 in. solid	—	—	0.79	—	1.26
	3 x 12 x 30 in. 4-cell	—	—	0.74	—	1.35
	4 x 12 x 30 in. 3-cell	—	—	0.60	—	1.67

Table 4 . . . . Conductivities (*k*), Conductances (C), and Resistances (*R*) of Building and Insulating Materials (*Concluded*)
(*Design Values*)[a]

Material	Description	Density (Lb per Cu Ft)	Conductivity or Conductance (*k*)	Conductivity or Conductance (C)	Resistance[b] (*R*) Per inch thickness $\left(\frac{1}{k}\right)$	Resistance[b] (*R*) For thickness listed $\left(\frac{1}{C}\right)$
MASONRY UNITS (*Continued*)	Lightweight aggregate (expanded shale, clay, slate or slag; pumice) . . . 3 in.	—	—	0.79	—	1.27
	4 in.	—	—	0.67	—	1.50
	8 in.	—	—	0.50	—	2.00
	12 in.	—	—	0.44	—	2.27
	Stone, lime or sand	—	12.50	—	0.08	—
METALS	(See Chapter 5, Table 1)					
PLASTERING MATERIALS	Cement plaster, sand aggregate	116	5.0	—	0.20	—
	Sand aggregate . . . ½ in.	—	—	10.00	—	0.10
	Sand aggregate . . . ¾ in.	—	—	6.66	—	0.15
	Gypsum plaster:					
	Lightweight aggregate . . . ½ in.	45	—	3.12	—	0.32
	Lightweight aggregate . . . ⅝ in.	45	—	2.67	—	0.39
	Lightweight agg. on metal lath . . . ¾ in.	—	—	2.13	—	0.47
	Perlite aggregate	45	1.5	—	0.67	—
	Sand aggregate	105	5.6	—	0.18	—
	Sand aggregate . . . ½ in.	105	—	11.10	—	0.09
	Sand aggregate . . . ⅝ in.	105	—	9.10	—	0.11
	Sand aggregate on metal lath . . . ¾ in.	—	—	7.70	—	0.13
	Sand aggregate on wood lath	—	—	2.50	—	0.40
	Vermiculate aggregate	45	1.7	—	0.59	—
ROOFING	Asbestos-cement shingles	120	—	4.76	—	0.21
	Asphalt roll roofing	70	—	6.50	—	0.15
	Asphalt shingles	70	—	2.27	—	0.44
	Built-up roofing . . . ⅜ in.	70	—	3.00	—	0.33
	Slate . . . ½ in.	—	—	20.00	—	0.05
	Sheet metal	—	400+	—	Negl	
	Wood shingles	—	—	1.06	—	0.94
SIDING MATERIALS (ON FLAT SURFACE)	Shingles					
	Wood, 16-in. 7½-in. exposure	—	—	1.15	—	0.87
	Wood, double, 16-in., 12-in. exposure	—	—	0.84	—	1.19
	Wood, plus insul. backer board . . . 5/16 in.	—	—	0.71	—	1.40
	Siding					
	Asbestos-cement, ¼ in., lapped	—	—	4.76	—	0.21
	Asphalt roll siding	—	—	6.50	—	0.15
	Asphalt insulating siding (½ in. bd.)	—	—	0.69	—	1.45
	Wood, drop, 1 x 8 in.	—	—	1.27	—	0.79
	Wood, bevel, ½ x 8 in., lapped	—	—	1.23	—	0.81
	Wood, bevel, ¾ x 10 in., lapped	—	—	0.95	—	1.05
	Wood, plywood, ⅜ in., lapped	—	—	1.59	—	0.59
	Structural glass	—	—	10.00		0.10
WOODS	Maple, oak, and similar hardwoods	45	1.10	—	0.91	—
	Fir, pine, and similar softwoods	32	0.80	—	1.25	—

[a] Representative values for dry materials at 75 F mean temperature, selected by the ASHAE Technical Advisory Committee on Insulation. They are intended as design (not specification) values for materials of building construction in normal use. For conductivity of a particular product, the user may obtain the value supplied by the manufacturer or secure the results of unbiased tests.

[b] Air space resistance values shown here are for spaces faced both sides with ordinary *nonreflective* materials (ϵ = 0.90 and E = 0.82) and are based on following conditions: Winter—50 F mean temperature and 20 deg temperature difference, Summer—90 F mean temperature and 10 deg temperature difference except for horizontal air space with heat flow downward which is based on 20 deg temperature difference.

[c] Surface resistance values shown here are for ordinary *nonreflective* materials (ϵ = 0.90).

[d] See also Insulating Materials, Board.

[e] Includes paper backing and facing if any. In cases where the insulation forms a boundary (highly reflective or otherwise) of an air space, refer to Table 3, Sections B and C, to obtain the insulating value of the air space for the appropriate effective emissivity and temperature conditions of the space.

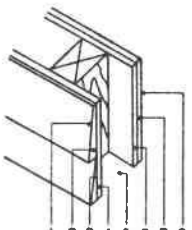
[f] Insulating values of acoustical tile vary depending on density of the board and on the type, size, and depth of the perforations. An average conductivity *k* value is 0.42.

[g] The U. S. Department of Commerce, *Simplified Practice Recommendation for Thermal Conductance Factors for Preformed Above-Deck Roof Insulation*, No. R 257-55, recognizes the specification of roof insulation on the basis of the *C* values shown. Roof insulation is made in thicknesses to meet these values. Therefore, thickness supplied by different manufacturers may vary depending on the conductivity *k* value of the particular material.

[h] Resistance values are the reciprocals of *C* before rounding *C* off to two decimal places.

Table 5 . . . . Coefficients of Transmission (*U*) of Frame Walls[a]

These coefficients are expressed in Btu per (hour) (square foot) (Fahrenheit degree difference in temperature between the air on the two sides), and are based on an outside wind velocity of 15 mph



Example—Wall D 4

Resistances used are given below in this table or in Table 3 or 4

Construction	Resistance (*R*)
1. Outside surface (15 mph wind)	*0.17*
2. Siding, wood, ½ in. x 8 in. lapped (av. *R*)	*0.85*
3. Building paper	*0.06*
4. Wood sheathing (25/32 in.)	*0.98*
5. Air space[b]	*0.97*
6. Gypsum lath (⅜ in.)	*0.32*
7. Plaster (sand agg.) (½ in)	*0.09*
8. Inside surface (still air)	*0.68*
Total resistance	*4.12*
U = 1/*R* = 1/*4.12* =	0.24

See value 0.24 in boldface type in table below.

Example of Substitution

Resistances used are given below in this table or in Table 3 or 4

Replace items 3 and 4 with insul. bd. sheathing (25/32 in.) and items 6 and 7 with gypsum wall board (½ in.)

Total resistance		*4.12*
Deduct 3. Building Paper	*0.06*	
4. Wood sheathing (25/32 in.)	*0.98*	
6. Gypsum lath (⅜ in.)	*0.32*	
7. Plaster (sand agg.) (½ in)	*0.09*	*1.45*
Difference		*2.67*
Add 4. Insul. bd. sheathing (25/32 in.)	*2.06*	
6.-7. Gypsum bd. (½ in.)	*0.45*	*2.51*
Total resistance		*5.18*
U = 1/*R* = 1/*5.18* =		0.19

To Adjust U Values for Construction with Added Insulation between Framing Members, See Table 16.

Exterior[c] Material	*R*	Av. *R*	Interior Finish Material	*R*	None, Building Paper (Resistance 0.06) *U* A	Gypsum Board ½ in. (0.45) *U* B	Plywood 5/16 in. (0.39) *U* C	Wood, 25/32 in. and Building Paper (1.04) *U* D	Insulation Board Sheathing ½ in. (1.32) *U* E	Insulation Board Sheathing 25/32 in. (2.06) *U* F	Number
Wood siding			None	—	0.57	0.47	0.48	0.36	0.33	0.27	**1**
			Gypsum bd. (⅜ in.)	*0.32*	0.33	0.29	0.30	0.25	0.23	0.20	**2**
			Gypsum lath (⅜ in.) and ½ in. plas. (lt. wt. agg.)	*0.64*	0.30	0.27	0.27	0.23	0.22	0.19	**3**
Drop—(1 in. x 8 in.)	*0.79*		Gypsum lath (⅜ in.) and ½ in. plas. (sand agg.)	*0.41*	0.32	0.28	0.29	**0.24**	0.23	0.19	**4**
Bevel (½ in. x 8 in.)	*0.81*		Metal lath and ¾ in. plas. (lt. wt. agg.)	*0.47*	0.31	0.28	0.28	0.24	0.22	0.19	**5**
Wood shingles		*0.85*[d]	Metal lath and ¾ in. plas. (sand agg.)	*0.13*	0.35	0.31	0.31	0.26	0.24	0.21	**6**
7½ in. exposure	*0.87*		Insul. bd. (½ in.)	*1.43*	0.24	0.22	0.22	0.19	0.18	0.16	**7**
Wood panels (¾ in.)	*0.94*		Insul. bd. lath (½ in.) and ½ in. plas. (sand agg.)	*1.52*	0.24	0.22	0.22	0.19	0.18	0.16	**8**
			Plywood (¼ in.)	*0.31*	0.33	0.29	0.30	0.25	0.23	0.20	**9**
			Wood panels (¾ in.)	*0.94*	0.27	0.25	0.25	0.22	0.20	0.18	**10**
			Wood lath and ½ in. plas. (sand agg.)	*0.40*	0.32	0.28	0.29	0.24	0.23	0.19	**11**
			None	—	0.73	0.56	0.58	0.42	0.38	0.30	**12**
			Gypsum bd. (⅜ in.)	*0.32*	0.37	0.33	0.33	0.27	0.25	0.21	**13**
			Gypsum lath (⅜ in.) and ½ in. plas. (lt. wt. agg.)	*0.64*	0.33	0.30	0.30	0.25	0.24	0.20	**14**
			Gypsum lath (⅜ in.) and ½ in. plas. (sand agg.)	*0.41*	0.36	0.32	0.32	0.27	0.25	0.21	**15**
Face-brick veneer[f]	*0.44*	*0.45*[d]	Metal lath and ¾ in. plas. (lt. wt. agg.)	*0.47*	0.35	0.31	0.32	0.26	0.25	0.21	**16**
Plywood (⅜ in.)	*0.47*		Metal lath and ¾ in. plas. (sand agg.)	*0.13*	0.40	0.35	0.36	0.29	0.27	0.22	**17**
			Insul. bd. (½ in.)	*1.43*	0.26	0.24	0.24	0.21	0.20	0.17	**18**
			Insul. bd. lath (½ in.) and ½ in. plas. (sand agg.)	*1.52*	0.26	0.23	0.24	0.21	0.19	0.17	**19**
			Plywood (¼ in.)	*0.31*	0.38	0.33	0.33	0.27	0.26	0.21	**20**
			Wood panels (¾ in.)	*0.94*	0.30	0.27	0.28	0.23	0.22	0.19	**21**
			Wood lath and ½ in. plas. (sand agg.)	*0.40*	0.36	0.32	0.32	0.27	0.25	0.21	**22**

Type of Sheathing[e]

Table 5 . . . . Coefficients of Transmission (*U*) of Frame Walls[a] (*Concluded*)

Exterior[e]			Interior Finish		Type of Sheathing[c]: None, Building Paper	Gypsum Board ½ in.	Plywood 5/16 in.	Wood, 25/32 in. and Building Paper	Insulation Board Sheathing ½ in.	Insulation Board Sheathing 25/32 in.	Number
				Resistance →	0.06	0.45	0.39	1.04	1.32	2.06	
Material	*R*	Av. *R*	Material	*R*	*U* A	*U* B	*U* C	*U* D	*U* E	*U* F	
Wood shingles over insul.: backer bd. (5/16 in.)	*1.40*	*1.42*[d]	None	—	0.43	0.37	0.38	0.30	0.28	0.23	**23**
Asphalt insul. siding	*1.45*		Gypsum bd. (3/8 in.)	*0.32*	0.28	0.25	0.25	0.22	0.20	0.18	**24**
			Gypsum lath (3/8 in.) and ½ in. plas. (lt. wt. agg.)	*0.64*	0.25	0.23	0.23	0.20	0.19	0.17	**25**
			Gypsum lath (3/8 in.) and ½ in. plas. (sand agg.)	*0.41*	0.27	0.24	0.25	0.21	0.20	0.18	**26**
			Metal lath and ¾ in. plas. (lt. wt. agg.)	*0.47*	0.27	0.24	0.24	0.21	0.20	0.17	**27**
			Metal lath and ¾ in. plas. (sand agg.)	*0.13*	0.29	0.26	0.27	0.23	0.21	0.18	**28**
			Insul. bd. (½ in.)	*1.43*	0.21	0.20	0.20	0.18	0.17	0.15	**29**
			Insul. bd. lath (½ in.) and ½ in. plas. (sand agg.)	*1.52*	0.21	0.19	0.19	0.17	0.16	0.15	**30**
			Plywood (¼ in.)	*0.31*	0.28	0.25	0.25	0.22	0.20	0.18	**31**
			Wood panels (¾ in.)	*0.94*	0.24	0.22	0.22	0.19	0.18	0.16	**32**
			Wood lath and ½ in. plas. (sand agg.)	*0.40*	0.27	0.24	0.25	0.21	0.20	0.18	**33**
Asbestos-cement siding	*0.21*	*0.19*[d]	None	—	0.91	0.67	0.70	0.48	0.42	0.32	**34**
Stucco[g] 1 in.	*0.20*		Gypsum bd. (3/8 in.)	*0.32*	0.42	0.36	0.37	0.30	0.27	0.23	**35**
Asphalt roll siding	*0.15*		Gypsum lath (3/8 in.) and ½ in. plas. (lt. wt. agg.)	*0.64*	0.37	0.32	0.33	0.27	0.25	0.21	**36**
			Gypsum lath (3/8 in.) and ½ in. plas. (sand agg.)	*0.41*	0.40	0.35	0.36	0.29	0.27	0.22	**37**
			Metal lath and ¾ in. plas. (lt. wt. agg.)	*0.47*	0.39	0.34	0.35	0.28	0.26	0.22	**38**
			Metal lath and ¾ in. plas. (sand agg.)	*0.13*	0.45	0.39	0.40	0.31	0.29	0.24	**39**
			Insul. bd. (½ in.)	*1.43*	0.29	0.26	0.26	0.22	0.21	0.18	**40**
			Insul. bd. lath (½ in.) and ½ in. plas. (sand agg.)	*1.52*	0.28	0.25	0.26	0.22	0.21	0.18	**41**
			Plywood (¼ in.)	*0.31*	0.42	0.36	0.37	0.30	0.27	0.23	**42**
			Wood panels (¾ in.)	*0.94*	0.33	0.29	0.30	0.25	0.23	0.20	**43**
			Wood lath and ½ in. plas. (sand agg.)	*0.40*	0.40	0.35	0.36	0.29	0.27	0.22	**44**

[a] See text section Calculating Overall Coefficients for basis of calculations.
[b] To adjust *U* values for the effect of added insulation between framing members, see Table 16.
[c] Note that although several types of exterior finish may be grouped because they have approximately the same thermal resistance value, it is not implied that all types may be suitable for application over all types of sheathing listed.
[d] Average resistance of items listed. This average was used in computation of *U* values shown.
[e] Building paper is not included except where noted.
[f] Small air space between building paper and brick veneer neglected.
[g] Where stucco is applied over insulating board or gypsum sheathing, building paper is generally required, but the change in *U* value is negligible.

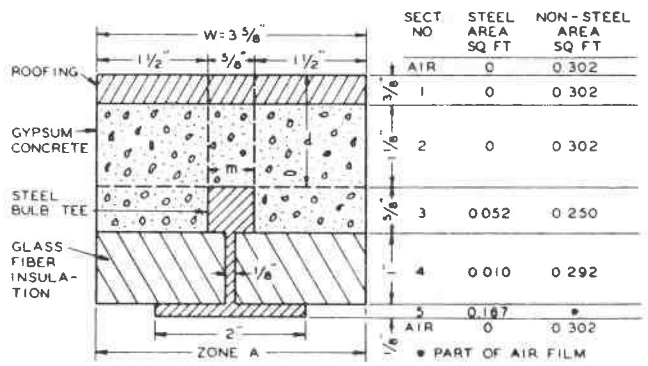


Fig. 6 . . . . Enlarged Section of Zone A of Fig. 5

Solution: The basic area is 2 sq ft (24 in. x 12 in.), with a tee-bar (12 in. long) across the middle. This area is divided into two zones, *A* and *B*.

Zone A is determined from Equation 4 as follows:

$$\text{Top Side } W = m + 2d = 0.625 + 2 \times 1.5 = 3.625 \text{ in.}$$

$$\text{Bottom Side } W = m + 2d = 2.0 + 2 \times 0.5 = 3.0 \text{ in.}$$

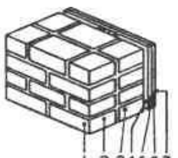
Using the larger value of W, the area of *Zone A* is $(12 \times 3.625)/144 = 0.302$ sq ft. The area of *Zone B* is $2.0 - 0.302 = 1.698$ sq ft.

To determine the area transmittance for *Zone A* the structure within the zone is divided into five sections parallel to the top and bottom surfaces as shown in Fig. 6. The area conductance $C \cdot A$ of each section is calculated by adding the area conductances of its metal and non-metal paths. The area conductances of the sections are converted to area resistances

Table 6 . . . . Coefficients of Transmission (*U*) of Solid Masonry Walls[a]

Coefficients are expressed in Btu per (hour) (square foot) (Fahrenheit degree difference in temperature between the air on the two sides), and are based on an outside wind velocity of 15 mph

Example—Wall G 2



Resistances used are given below in this table or in Table 3 or 4

Construction	Resistance (*R*)
1. Outside surface (15 mph wind)	*0.17*
2. Face brick (4 in.)	*0.44*
3. Common brick (4 in.)	*0.80*
4. Air space[b]	*0.97*
5. Gypsum lath (3/8 in.)	*0.32*
6. Plas. (sand agg.) (1/2 in.)	*0.09*
7. Inside surface (still air)	*0.68*
Total resistance	*3.47*
$U = 1/R = 1/3.47 =$	0.29

See value 0.29 in boldface type in table below.

Example of Substitution

Resistances used are given below in this table or in Table 3 or 4

Assume plain wall—no furring or plaster.

Total resistance		*3.47*
Deduct 4. Air space	*0.97*	
5. Gypsum lath (3/8 in.)	*0.32*	
6. Plas. (sand agg.) (1/2 in)	*0.09*	*1.38*
Total resistance		*2.09*
$U = 1/R = 1/2.09 =$		0.48

To Adjust U Values for Construction with Added Insulation between Furring Strips, See Table 16

Exterior Construction[c]		Interior Finish: None	Plas. 5/8 in. on Wall		Metal Lath and 3/4 in. Plas. on Furring		Gypsum Lath (3/8 in.) and 1/2 in. Plas. on Furring			Insul. Bd. Lath (1/2 in.) and 1/2 in. Plas. on Furring		Wood Lath and 1/2 in. Plas.	Number
			(Sand agg.)	(Lt. wt. agg.)	(Sand agg.)	(Lt. wt. agg.)	No plas.	(Sand agg.)	(Lt. wt. agg.)	No plas.	(Sand agg.)	(Sand agg.)	
Resistance →			*0.11*	*0.39*	*0.13*	*0.47*	*0.32*	*0.41*	*0.64*	*1.43*	*1.52*	*0.40*	
Material	**R**	U	U	U	U	U	U	U	U	U	U	U	
		A	B	C	D	E	F	G	H	I	J	K	
Brick (face and common)[d]													
(6 in.)	*0.61*	0.68	0.64	0.54	0.39	0.34	0.36	0.35	0.33	0.26	0.25	0.35	**1**
(8 in.)	*1.24*	0.48	0.45	0.41	0.31	0.28	0.30	**0.29**	0.27	0.22	0.22	0.29	**2**
(12 in.)	*2.04*	0.35	0.33	0.30	0.25	0.23	0.24	0.23	0.22	0.19	0.19	0.23	**3**
(16 in.)	*2.84*	0.27	0.26	0.25	0.21	0.19	0.20	0.20	0.19	0.16	0.16	0.20	**4**
Brick (common only)													
(8 in.)	*1.60*	0.41	0.39	0.35	0.28	0.26	0.27	0.26	0.25	0.21	0.20	0.26	**5**
(12 in.)	*2.40*	0.31	0.30	0.27	0.23	0.21	0.22	0.22	0.21	0.18	0.17	0.22	**6**
(16 in.)	*3.20*	0.25	0.24	0.23	0.19	0.18	0.19	0.18	0.18	0.16	0.15	0.18	**7**
Stone (lime and sand)													
(8 in.)	*0.64*	0.67	0.63	0.53	0.39	0.34	0.36	0.35	0.32	0.26	0.25	0.35	**8**
(12 in.)	*0.96*	0.55	0.52	0.45	0.34	0.31	0.32	0.31	0.29	0.24	0.23	0.31	**9**
(16 in.)	*1.28*	0.47	0.45	0.40	0.31	0.28	0.29	0.28	0.27	0.22	0.22	0.29	**10**
(24) in.	*1.92*	0.36	0.35	0.32	0.26	0.24	0.25	0.24	0.23	0.19	0.19	0.24	**11**
Hollow clay tile													
(8 in.)	*1.85*	0.36	0.36	0.32	0.26	0.24	0.25	0.25	0.23	0.20	0.19	0.25	**12**
(10 in.)	*2.22*	0.33	0.31	0.29	0.24	0.22	0.23	0.22	0.21	0.18	0.18	0.23	**13**
(12 in.)	*2.50*	0.30	0.29	0.27	0.22	0.21	0.22	0.21	0.20	0.17	0.17	0.21	**14**
Poured concrete													
30 lb per cu ft													
(4 in.)	*4.44*	0.19	0.19	0.18	0.16	0.15	0.15	0.15	0.14	0.13	0.13	0.15	**15**
(6 in.)	*6.66*	0.13	0.13	0.13	0.12	0.11	0.11	0.11	0.11	0.10	0.10	0.11	**16**
(8 in.)	*8.88*	0.10	0.10	0.10	0.09	0.09	0.09	0.09	0.09	0.08	0.08	0.09	**17**
(10 in.)	*11.10*	0.08	0.08	0.08	0.08	0.07	0.08	0.08	0.07	0.07	0.07	0.08	**18**
80 lb per cu ft													
(6 in.)	*2.40*	0.31	0.30	0.27	0.23	0.21	0.22	0.22	0.21	0.18	0.17	0.22	**19**
(8 in.)	*3.20*	0.25	0.24	0.23	0.19	0.18	0.19	0.18	0.18	0.16	0.15	0.18	**20**
(10 in.)	*4.00*	0.21	0.20	0.19	0.17	0.16	0.16	0.16	0.15	0.14	0.14	0.16	**21**
(12 in.)	*4.80*	0.18	0.17	0.17	0.15	0.14	0.14	0.14	0.14	0.12	0.12	0.14	**22**
140 lb per cu ft													
(6 in.)	*0.48*	0.75	0.69	0.58	0.41	0.36	0.38	0.37	0.34	0.27	0.26	0.37	**23**
(8 in.)	*0.64*	0.67	0.63	0.53	0.39	0.34	0.36	0.35	0.32	0.26	0.25	0.35	**24**
(10 in.)	*0.80*	0.61	0.57	0.49	0.36	0.32	0.34	0.33	0.31	0.25	0.24	0.33	**25**
(12 in.)	*0.96*	0.55	0.52	0.45	0.34	0.31	0.32	0.31	0.29	0.24	0.23	0.31	**26**

Table 6 .... Coefficients of Transmission (*U*) of Solid Masonry Walls (*Concluded*)

Exterior Construction[c]		*Interior Finish*											
		None	Plas. 5/8 in. on Wall		Metal Lath and 3/4 in. Plas. on Furring		Gypsum Lath (3/8 in.) and 1/2 in. Plas. on Furring			Insul. Bd. Lath (1/2 in.) and 1/2 in. Plas. on Furring		Wood Lath and 1/2 in. Plas.	Number
			(Sand agg.)	(Lt. wt. agg.)	(Sand agg.)	(Lt. wt. agg.)	No plas.	(Sand agg.)	(Lt. wt. agg.)	No plas.	(Sand agg.)	(Sand agg.)	
Resistance →			*0.11*	0.39	*0.13*	*0.47*	0.32	*0.41*	*0.64*	*1.43*	*1.52*	0.40	
Material	R	U	U	U	U	U	U	U	U	U	U	U	
		A	B	C	D	E	F	G	H	I	J	K	
Concrete block													
(Gravel agg.) (8 in.)	*1.11*	0.52	0.48	0.43	0.33	0.29	0.31	0.30	0.28	0.23	0.22	0.30	**27**
(12 in.)	*1.28*	0.47	0.45	0.40	0.31	0.28	0.29	0.28	0.27	0.22	0.22	0.29	**28**
(Cinder agg.) (8 in.)	*1.72*	0.39	0.37	0.34	0.27	0.25	0.26	0.25	0.24	0.20	0.20	0.25	**29**
(12 in.)	*1.89*	0.36	0.35	0.32	0.26	0.24	0.25	0.24	0.23	0.19	0.19	0.24	**30**
(Lt. wt. agg.) (8 in.)	*2.00*	0.35	0.34	0.31	0.26	0.23	0.24	0.24	0.22	0.19	0.19	0.24	**31**
(12 in.)	*2.27*	0.32	0.31	0.28	0.24	0.22	0.23	0.22	0.21	0.18	0.18	0.22	**32**

[a] See text section Calculating Overall Coefficients for basis of calculations.
[b] To adjust *U* values for the effect of added insulation between framing members, see Table 16.
[c] If stucco or structural glass is applied to the exterior, the additional resistance value of 0.10 would have a negligible effect on the *U* value.
[d] Brick, 6 in. (5½ in. actual) is assumed to have no backing. Walls 8, 12 and 16 in. have 4 in. of face brick and balance of common brick.

$1/(C \cdot A)$ and added to obtain the total resistance of *Zone A*. These calculations are shown in the following tabulation.

Section	Area × Conductance	C·A	1/(C·A) = R/A
Air (outside, 15 mph)	0.302 × 6.0	1.812	0.552
No. 1, Roofing	0.302 × 3.0	0.906	1.105
No. 2, Gypsum concrete	0.302 × 1.66/1.125	0.445	2.250
No. 3, Steel	0.052 × 312.0/0.625	26.0	} 0.038
No. 3, Gypsum concrete	0.250 × 1.66/0.625	0.664	
No. 4, Steel	0.0104 × 312/1.00	3.24	} 0.302
No. 4, Glass fiber	0.292 × 0.25/1.00	0.073	
No. 5, Steel	0.167 × 312/0.125	416.0	0.002
Air, (inside)	0.302 × 1.63	0.493	2.030
		Total *R/A*	= 6.279

Area transmittance of *Zone A* = *A/R* = 1/6.279 = 0.159.

For *Zone B* the unit resistances are added and then converted to area transmittance as shown in the following tabulation.

Section	Resistance, R
Air (outside, 15 mph)	1/6.0 = 0.17
Roofing	1/3.0 = 0.33
Gypsum concrete	1.75/1.66 = 1.05
Glass fiber	1.00/0.25 = 4.00
Air (inside)	1/1.63 = 0.61
Total resistance of a sq ft	= 6.16

Unit transmittance = 1/*R* = 0.162

Area transmittance *U·A*
for *Zone B* = 1.698 × 0.162 = 0.276
for *Zone A* = 0.159

Total area transmittance of *basic area* = 0.435

Transmittance per sq ft = 0.435/2.0 = 0.218

In tests on similar construction, made by the guarded hot box method, one laboratory reported a *U* value of 0.219 Btu per (sq ft) (hr) (F deg) and another laboratory reported a *U* value of 0.206 Btu per (sq ft) (hr) (F deg).

When the steel is a large proportion of the heat path as in *Example 1*, the detailed calculations of resistance in sections 3, 4, and 5 of *Zone A* are not justified. If only the steel were considered, the final result of *Example 1* would be unchanged.

If the steel path is small, such as for a tie rod, the detailed calculations for sections 3, 4, and 5 are necessary.

Caution

A panel with internal metallic structure bonded on one or both sides to a metal skin or covering presents special problems of lateral heat flow not covered in the foregoing *Zone Method*.

Values Used in Calculation of *U* Value Tables

Tables 5 through 15 are based on values given in Table 4. The following conditions have been used:

Equilibrium or steady-state heat transfer, eliminating effects of heat capacity.

Surrounding surfaces at ambient air temperatures.

Exterior wind velocity of 15 mph for winter and 7.5 mph for summer.

Surface emissivity of ordinary building materials ϵ = 0.90.

Stud space in frame construction not insulated. (See Table 16 for method of correcting for added insulation.)

In construction involving air spaces the *U* values shown are calculated for areas between framing. See Fig. 7 in section Correction for Framing if an allowance is to be made for this effect.

Air space resistance values used are those shown in Table 4 under Air Spaces.

Air spaces are ¾ in. or more in width.

Variations of conductivity with mean temperature is neglected.

Corrections for framing to be made on basis of parallel heat

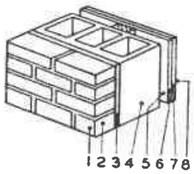
(*Continued on p. 118*)

Table 7 . . . . Coefficients of Transmission (*U*) of Masonry Walls[a]

Coefficients are expressed in Btu per (hour) (square foot) (Fahrenheit degree difference in temperature between the air on the two sides), and are based on an outside wind velocity of 15 mph

Example—Wall G 1

Resistances used are given below in this table or in Table 3 or 4



Construction	Resistance (*R*)
1. Outside surface (15 mph wind)	*0.17*
2. Face brick (4 in.) (av. *R*.)	*0.39*
3. Cement mortar (½ in)	*0.10*
4. Concrete block (cinder agg.) (4 in.)	*1.11*
5. Air space[b]	*0.97*
6. Gypsum lath (⅜ in.)	*0.32*
7. Plas. (sand agg.) (½ in)	*0.09*
8. Inside surface (still air)	*0.68*
Total resistance	*3.83*
$U = 1/R = 1/3.83 =$	0.26

See value 0.26 in boldface type in table below.

Example of Substitution

Resistances used are given below in this table or in Table 3 or 4

Replace items 6 and 7 with wood panels (¾ in.) and vapor barrier applied over furring strips

Total resistance		*3.83*
Deduct 6. Gypsum lath (⅜ in.)	*0.32*	
7. Plas. (sand agg.) (½ in)	*0.09*	*0.41*
Difference		*3.42*
Add 6. Vapor barrier	*0.06*	
7. Wood panel (¾ in.)	*0.94*	*1.00*
Total resistance		*4.42*
$U = 1/R = 1/4.42 =$		0.23

To Adjust U Values for Construction with Added Insulation between Furring Strips, See Table 16

Exterior Facing: Material	*R*	Av. *R*	Backing: Material	*R*	None	Plas. ⅝ in. on Wall (Sand agg.)	Plas. ⅝ in. on Wall (Lt. wt. agg.)	Metal Lath and ¾ in. Plas. on Furring (Sand agg.)	Metal Lath and ¾ in. Plas. on Furring (Lt. wt. agg.)	Gypsum Lath (⅜ in.) and ½ in. Plas. on Furring: No plas.	Gypsum Lath (Sand agg.)	Gypsum Lath (Lt. wt. agg.)	Insul. Bd. Lath (½ in.) and ½ in. Plas. on Furring: No plas.	Insul. Bd. Lath (Sand agg.)	Wood Lath ½ in. Plas. (Sand agg.)	Number
			Resistance →			0.11	0.39	0.13	0.47	0.32	0.41	0.64	1.43	1.52	0.40	
					U A	*U* B	*U* C	*U* D	*U* E	*U* F	*U* G	*U* H	*U* I	*U* J	*U* K	
			Concrete block (Cinder agg.)													
			(4 in.)	*1.11*	0.41	0.39	0.35	0.28	0.26	0.27	**0.26**	0.25	0.21	0.20	0.26	1
			(8 in.)	*1.72*	0.33	0.32	0.29	0.24	0.22	0.23	0.23	0.21	0.18	0.18	0.23	2
			(12 in.)	*1.89*	0.31	0.30	0.28	0.23	0.21	0.22	0.22	0.21	0.18	0.17	0.22	3
			(Lt. wt. agg.)													
Face brick			(4 in.)	*1.50*	0.35	0.34	0.31	0.25	0.23	0.24	0.24	0.22	0.19	0.19	0.24	4
4 in.	*0.44*		(8 in.)	*2.00*	0.30	0.29	0.27	0.23	0.21	0.22	0.21	0.20	0.17	0.17	0.21	5
Stone			(12 in.)	*2.27*	0.28	0.27	0.25	0.21	0.20	0.20	0.20	0.19	0.17	0.16	0.20	6
4 in.	*0.32*		(Sand agg.)													
Precast concrete			(4 in.)	*0.71*	0.49	0.46	0.41	0.32	0.29	0.30	0.29	0.27	0.22	0.22	0.29	7
(sand agg.)		*0.39*	(8 in.)	*1.11*	0.41	0.39	0.35	0.28	0.26	0.27	0.26	0.25	0.21	0.20	0.26	8
4 in.	*0.32*		(12 in.)	*1.28*	0.38	0.37	0.33	0.27	0.25	0.26	0.25	0.24	0.20	0.20	0.25	9
6 in.	*0.48*		Hollow clay tile													
			(4 in.)	*1.11*	0.41	0.39	0.35	0.28	0.26	0.27	0.26	0.25	0.21	0.20	0.26	10
			(8 in.)	*1.85*	0.31	0.30	0.28	0.23	0.22	0.22	0.22	0.21	0.18	0.18	0.22	11
			(12 in.)	*2.50*	0.26	0.25	0.24	0.20	0.19	0.19	0.19	0.18	0.16	0.16	0.19	12
			Concrete (Sand agg.)													
			(4 in.)	*0.32*	0.60	0.56	0.49	0.36	0.32	0.34	0.33	0.31	0.25	0.24	0.33	13
			(6 in.)	*0.48*	0.55	0.52	0.45	0.34	0.31	0.32	0.31	0.29	0.24	0.23	0.31	14
			(8 in.)	*0.64*	0.51	0.48	0.42	0.32	0.29	0.31	0.30	0.28	0.23	0.22	0.30	15
			Concrete block (Cinder agg.)													
			(4 in.)	*1.11*	0.36	0.35	0.32	0.26	0.24	0.25	0.24	0.23	0.19	0.19	0.24	16
			(8 in.)	*1.72*	0.29	0.29	0.26	0.22	0.21	0.21	0.21	0.20	0.17	0.17	0.21	17
			(12 in.)	*1.89*	0.28	0.27	0.25	0.21	0.20	0.21	0.20	0.19	0.17	0.17	0.20	18
			(Lt. wt. agg.)													
			(4 in.)	*1.50*	0.32	0.30	0.28	0.23	0.22	0.22	0.22	0.21	0.18	0.18	0.22	19
			(8 in.)	*2.00*	0.27	0.26	0.25	0.21	0.20	0.20	0.20	0.19	0.16	0.16	0.20	20
Common brick			(12 in.)	*2.27*	0.25	0.25	0.23	0.20	0.19	0.19	0.19	0.18	0.16	0.16	0.19	21
4 in.	*0.80*		(Sand agg.)													
Precast concrete			(4 in.)	*0.71*	0.42	0.40	0.36	0.29	0.26	0.27	0.27	0.25	0.21	0.21	0.27	22
(sand agg.)		*0.72*	(8 in.)	*1.11*	0.36	0.35	0.32	0.26	0.24	0.25	0.24	0.23	0.19	0.19	0.24	23
8 in.	*0.64*		(12 in.)	*1.28*	0.34	0.33	0.30	0.25	0.23	0.24	0.23	0.22	0.19	0.18	0.23	24
			Hollow clay tile													
			(4 in.)	*1.11*	0.36	0.35	0.32	0.26	0.24	0.25	0.24	0.23	0.19	0.19	0.24	25
			(8 in.)	*1.85*	0.28	0.28	0.26	0.22	0.20	0.21	0.20	0.19	0.17	0.17	0.20	26
			(12 in.)	*2.50*	0.24	0.23	0.22	0.19	0.18	0.18	0.18	0.17	0.15	0.15	0.18	27
			Concrete (Sand agg.)													
			(4 in.)	*0.32*	0.50	0.48	0.42	0.32	0.29	0.30	0.30	0.28	0.23	0.22	0.30	28
			(6 in.)	*0.48*	0.47	0.44	0.39	0.31	0.28	0.29	0.28	0.27	0.22	0.22	0.28	29
			(8 in.)	*0.64*	0.43	0.41	0.37	0.29	0.27	0.28	0.27	0.26	0.21	0.21	0.27	30

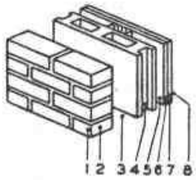
[a] See text section Calculating Overall Coefficients for basis of calculations.

[b] To adjust *U* values for the effect of added insulation between framing members, see Table 16.

Table 8 . . . . Coefficients of Transmission (U) of Masonry Cavity Walls[a]

Coefficients are expressed in Btu per (hour) (square foot) (Fahrenheit degree difference in temperature between the air on the two sides), and are based on an outside wind velocity of 15 mph

Example—Wall H 6



Resistances used are given below in this table or in Table 3 or 4

Construction	Resistance (R)
1. Outside surface (15 mph wind)	*0.17*
2. Common brick (4 in.) (av. R.)	*0.76*
3. Air space[b]	*0.97*
4. Concrete block (gravel agg.) (4 in.)	*0.71*
5. Air space[b]	*0.97*
6. Gypsum lath (⅜ in.)	*0.32*
7. Plas. (lt. wt. agg.) (½ in.)	*0.32*
8. Inside surface (still air)	*0.68*
Total resistance	*4.90*
$U = 1/R = 1/4.90 =$	0.20

See value 0.20 in boldface type in table below.

Example of Substitution

Resistances used are given below in this table or in Table 3 or 4

Replace item 4 with 8 in. concrete block and items 6 and 7 with ⅝ in. plas. (sand agg.) applied directly to concrete block.

Total resistance		*4.90*
Deduct 4. Concrete block (gravel agg.) 4 in.	*0.71*	
5. Air space	*0.97*	
6. Gypsum lath (⅜ in.)	*0.32*	
7. Plas. (lt. wt. agg.) (½ in.)	*0.32*	*2.32*
Difference		*2.58*
Add 4. Concrete block (gravel agg.) 8 in.	*1.11*	
7. Plas. (sand agg.) (⅝ in)	*0.11*	*1.22*
Total resistance =		*3.80*
$U = 1/R = 1/3.80$		0.26

To Adjust U Values for Construction with Added Insulation[c] between Inner and Outer Tiers or between Furring Strips, See Table 16

Exterior Construction: Material	R	Av. R	Inner Section: Material	R	None (A) U	Plas. ⅝ in. on Wall (Sand agg.) 0.11 (B) U	Plas. ⅝ in. on Wall (Lt. wt. agg.) 0.39 (C) U	Metal Lath and ¾ in. Plas. on Furring (Sand agg.) 0.13 (D) U	Metal Lath and ¾ in. Plas. on Furring (Lt. wt. agg.) 0.47 (E) U	Gypsum Lath (⅜ in.) and ½ in. Plas. on Furring (No plas.) 0.32 (F) U	Gypsum Lath (⅜ in.) and ½ in. Plas. on Furring (Sand agg.) 0.41 (G) U	Gypsum Lath (⅜ in.) and ½ in. Plas. on Furring (Lt. wt. agg.) 0.64 (H) U	Insul. Bd. Lath and ½ in. Plas. on Furring (No plas.) 1.43 (I) U	Insul. Bd. Lath and ½ in. Plas. on Furring (Sand agg.) 1.52 (J) U	Wood Lath and ½ in. Plas. (Sand agg.) 0.40 (K) U	Number
Face brick (4 in.)		*0.44*	Concrete block (4 in.) (Gravel agg.)	*0.71*	0.34	0.32	0.30	0.25	0.23	0.23	0.23	0.22	0.19	0.18	0.23	1
			(Cinder agg.)	*1.11*	0.30	0.29	0.27	0.22	0.21	0.21	0.21	0.20	0.17	0.17	0.21	2
			(Lt. wt. agg.)	*1.50*	0.27	0.26	0.24	0.21	0.19	0.20	0.19	0.19	0.16	0.16	0.19	3
			Common brick (4 in.)	*0.80*	0.33	0.32	0.29	0.24	0.22	0.23	0.23	0.21	0.18	0.18	0.23	4
			Clay tile (4 in.)	*1.11*	0.30	0.29	0.27	0.22	0.21	0.21	0.21	0.20	0.17	0.17	0.21	5
Common brick (4 in.)	*0.80*	*0.76*	Concrete block (4 in.) (Gravel agg.)	*0.71*	0.30	0.29	0.27	0.23	0.21	0.22	0.21	**0.20**	0.18	0.17	0.21	6
Concrete block (gravel agg.) (4 in.)	*0.71*		(Cinder agg.)	*1.11*	0.27	0.26	0.25	0.21	0.19	0.20	0.20	0.19	0.16	0.16	0.20	7
			(Lt. wt. agg.)	*1.50*	0.25	0.24	0.22	0.19	0.18	0.19	0.18	0.18	0.15	0.15	0.18	8
			Common brick (4 in.)	*0.80*	0.30	0.29	0.27	0.22	0.21	0.21	0.21	0.20	0.17	0.17	0.21	9
			Clay tile (4 in.)	*1.11*	0.27	0.26	0.25	0.21	0.19	0.20	0.20	0.19	0.16	0.16	0.20	10
Concrete block (cinder agg.) (4 in.)		*1.11*	Concrete block (4 in.) (Gravel agg.)	*0.71*	0.27	0.27	0.25	0.21	0.20	0.20	0.20	0.19	0.17	0.16	0.20	11
			(Cinder agg.)	*1.11*	0.25	0.24	0.23	0.19	0.18	0.19	0.18	0.18	0.16	0.15	0.18	12
			(Lt. wt. agg.)	*1.50*	0.23	0.22	0.21	0.18	0.17	0.17	0.17	0.17	0.15	0.14	0.17	13
			Common brick (4 in.)	*0.80*	0.27	0.26	0.24	0.21	0.19	0.20	0.20	0.19	0.16	0.16	0.20	14
			Clay tile (4 in.)	*1.11*	0.25	0.21	0.23	0.19	0.18	0.19	0.18	0.18	0.16	0.15	0.18	15

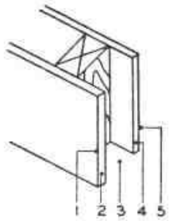
[a] See text section Calculating Overall Coefficients for basis of calculations.

[b] To adjust U values for the effect of added insulation between framing members, see Table 16.

[c] If insulation is to be used in the cavity it should be a water resistant type.

Table 9 . . . . Coefficients of Transmission (*U*) of Frame Partitions or Interior Walls[a]

Coefficients are expressed in Btu per (hour) (square foot) (Fahrenheit degree difference in temperature between the air on the two sides), and are based on still air (no wind) conditions on both sides



Example—Wall B 1

Resistances used are given below in this table or in Table 3 or 4

Construction	Resistance (R)
1. Surface (still air)	*0.68*
2. Gypsum bd. (⅜ in.)	*0.32*
3. Air space[b]	*0.97*
4. Gypsum wall board (⅜ in.)	*0.32*
5. Surface (still air)	*0.68*
Total resistance	*2.97*
$U = 1/R = 1/2.97$	0.34

See value 0.34 in boldface type in table below.

Example of Substitution

Resistances used are given below in this table or in Table 3 or 4

Replace item 2 with wood fiber hardboard (¼ in.).

Total resistance	*2.97*
Deduct 2. Gypsum wall board (⅜ in.)	*0.32*
Difference	*2.65*
Add 2. Hardboard (¼ in.)	*0.18*
Total resistance	*2.83*
$U = 1/R = 1/2.83 =$	0.35

To Adjust U Values for Construction with Added Insulation between Members, See Table 16

Type of Interior Finish — Material	R	Single Partition (Finish on Only One Side of Studs) U — A	Double Partition (Finish on Both Sides of Studs) U — B	Number
Gypsum bd. (⅜ in.)	*0.32*	0.60	**0.34**	**1**
Gypsum lath (⅜ in.) and ½ in. plas. (lt. wt. agg.)	*0.64*	0.50	0.28	**2**
Gypsum lath (⅜ in.) and ½ in. plas. (sand agg.)	*0.41*	0.56	0.32	**3**
Metal lath and ¾ in. plas. (lt. wt. agg.)	*0.47*	0.55	0.31	**4**
Metal lath and ¾ in. plas. (sand agg.)	*0.13*	0.67	0.39	**5**
Insul. bd. (½ in.)	*1.43*	0.36	0.19	**6**
Insul. bd. lath (½ in.) and ½ plas. (sand agg.)	*1.52*	0.35	0.19	**7**
Plywood: (¼ in.)	*0.31*	0.60	0.34	**8**
(⅜ in.)	*0.47*	0.55	0.31	**9**
(½ in.)	*0.63*	0.50	0.28	**10**
Wood panels (¾ in.)	*0.94*	0.43	0.24	**11**
Wood-lath and ½ in. plas. (sand agg.)	*0.40*	0.57	0.32	**12**
Sheet-metal panels	*0*	0.74	0.43	**13**
Glass and glass blocks	See Table 21			

[a] See text section Calculating Overall Coefficients for basis of calculations.
[b] To adjust U values for the effect of added insulation between framing members, see Table 16.

flow through 2 x 4 in. (nominal) studs, 16 in. on centers, the framing covering 15 percent of wall area, as shown in Fig. 7.

Thermal resistance for gypsum board and insulating board apply equally to plain material and to those which may be decorated at the factory or on the job.

In order to condense the tables an average resistance value (Av.R) has been used in some tables for types of materials having approximately the same thermal resistance values. The difference between the average value and the exact value for any given material usually causes no significant change in the resulting U value.

Actual thicknesses of lumber assumed to be as follows:

Nominal	*Actual*	*Nominal*	*Actual*
1 in. (S-2-S)	25⁄32 in.	3 in. (S-2-S)	2⅝ in.
1½ in. (S-2-S)	15⁄16 in.	4 in. (S-2-S)	3⅝ in.
2 in. (S-2-S)	1⅝ in.	Finish flooring,	
2½ in. (S-2-S)	2⅛ in.	(maple or oak)	¾ in.

It should be noted that the effects of poor workmanship in construction and installation have an increasingly greater percentage effect on heat transmission as the coefficient becomes numerically smaller. Failure to meet design estimates may be caused by lack of proper attention to exact compliance with specifications. A factor of safety may be employed as a precaution when it is judged desirable.

Insulating Materials

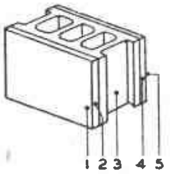
In order to determine the benefit derived from the addition of insulating materials to a given construction, the overall coefficient of heat transmission U_i of the insulated construction may be compared with the corresponding coefficient U without insulation. Table 16 (Part A to Part E) and Fig. 7 may be used for determining the coefficients of transmission of constructions with any combination of fibrous, bulk, or mass insulation and air spaces of various effective emissivities.

Example [illegible]: Find the coefficient of transmission of a frame wall consisting of ½ x 8-in. bevel lap wood siding, building pa-

(*Continued on p. 121*)

Table 10 . . . . Coefficients of Transmission (*U*) of Masonry Partitions[a]

Coefficients are expressed in Btu per (hour) (square foot) (Fahrenheit degree difference in temperature between the air on the two sides), and are based on still air (no wind) conditions on both sides



Example—Wall C 2

Resistances used are given below in this table or in Table 3 or 4

Construction	Resistance (*R*)
1. Inside surface (still air)	*0.68*
2. Plas. (lt. wt. agg.) 5/8 in.	*0.39*
3. Cement block (cinder agg.) (4 in.)	*1.11*
4. Plas. (lt. wt. agg.) 5/8 in.	*0.39*
5. Inside surface (still air)	*0.68*
Total resistance	*3.25*
$U = 1/R = 1/3.25 =$	0.31

See value 0.31 in boldface type in table below.

Example of Substitution

Resistances used are given below in this table or in Table 3 or 4

Replace item 3 with gypsum tile (4 in.)

Total resistance	*3.25*
Deduct 3. Cement block (cinder agg.) (4 in.)	*1.11*
Difference	*2.14*
Add 3. Gypsum tile (4 in.)	*1.67*
Total resistance	*3.81*
$U = 1/R = 1/3.81 =$	0.26

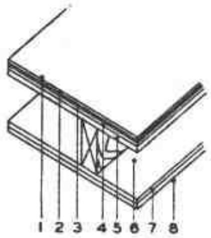
Type of Partition — Material	Resistance *R*	Surface Finish: None *U* (A)	Plas. (lt. wt. agg.) 5/8 in. One side 0.39 *U* (B)	Plas. (lt. wt. agg.) 5/8 in. Two sides 0.78 *U* (C)	Plas. (sand agg.) 5/8 in. One side 0.11 *U* (D)	Plas. (sand agg.) 5/8 in. Two sides 0.22 *U* (E)	Number
Hollow concrete block							
(Cinder agg.)							
(3 in.)	*0.86*	0.45	0.38	0.33	0.43	0.41	**1**
(4 in.)	*1.11*	0.40	0.35	**0.31**	0.39	0.37	**2**
(8 in.)	*1.72*	0.32	0.29	0.26	0.31	0.30	**3**
(12 in.)	*1.89*	0.31	0.27	0.25	0.30	0.29	**4**
(Lt. wt. agg.)							
(3 in.)	*1.27*	0.38	0.33	0.30	0.36	0.35	**5**
(4 in.)	*1.50*	0.35	0.31	0.27	0.34	0.32	**6**
(8 in.)	*2.00*	0.30	0.27	0.24	0.29	0.28	**7**
(12 in.)	*2.27*	0.28	0.25	0.23	0.27	0.26	**8**
(Gravel agg.)							
(8 in.)	*1.11*	0.40	0.35	0.31	0.39	0.37	**9**
(12 in.)	*1.28*	0.38	0.33	0.29	0.36	0.35	**10**
Hollow clay tile							
(3 in.)	*0.80*	0.46	0.39	0.34	0.44	0.42	**11**
(4 in.)	*1.11*	0.40	0.35	0.31	0.39	0.37	**12**
(6 in.)	*1.52*	0.35	0.31	0.27	0.33	0.32	**13**
(8 in.)	*1.85*	0.31	0.28	0.25	0.30	0.29	**14**
Hollow gypsum tile							
(3 in.)	*1.35*	0.37	0.32	0.29	0.35	0.34	**15**
(4 in.)	*1.67*	0.33	0.29	0.26	0.32	0.31	**16**
Solid plaster walls							
Gypsum lath (1/2 in.) and plas.							
3/4 in. each side							
(Lt. wt. agg.)	*1.39*	0.36	—	—	—	—	**17**
(Sand agg.)	*0.71*	0.48	—	—	—	—	**18**
1 in. each side							
(Lt. wt. agg.)	*1.73*	0.32	—	—	—	—	**19**
(Sand agg.)	*0.81*	0.46	—	—	—	—	**20**
Metal lath and plas.[b]							
2 in. total thickness							
(Lt. wt. agg.)	*1.28*	0.38	—	—	—	—	**21**
(Sand agg.)	*0.36*	0.58	—	—	—	—	**22**
2 1/2 in. total thickness							
(Lt. wt. agg.)	*1.60*	0.34	—	—	—	—	**23**
(Sand agg.)	*0.45*	0.55	—	—	—	—	**24**
Glass and glass blocks	See Table 19						

[a] See text section Calculating Overall Coefficients for basis of calculations.

[b] Metal core and supports disregarded. Plaster troweled smooth both sides.

Table 11 . . . . Coefficients of Transmission (*U*) of Frame Construction Ceilings and Floors[a]

Coefficients are expressed in Btu per (hour) (square foot) (Fahrenheit degree difference between the air on the two sides) and are based on still air (no wind) conditions on both sides



Example—Floor E 5

Resistances used are given below in this table or in Table 3 or 4

Heated room below unheated space

Construction (Heat flow up)	Resistance (*R*)
1. Top surface (still air)	*0.61*
2. Linoleum or tile (av. *R*)	*0.05*
3. Felt	*0.06*
4. Plywood (⅝ in.)	*0.78*
5. Wood subfloor (25/32 in.)	*0.98*
6. Air space[b] (7½ in.)	*0.85*
7. Metal lath and ¾ in. plas. (lt. wt. agg.)	*0.47*
8. Bottom surface (still air)	*0.61*
Total resistance	*4.41*
$U = 1/R = 1/4.41 =$	0.23

See value 0.23 in boldface type in table below.

Example of Substitution

Resistances used are given below in this table or in Table 3 or 4

Assume heated room is above unheated space so heat flow is down

Total resistance		*4.41*
Deduct 1. Top surface (heat flow up)	*0.61*	
6. Air space (heat flow up)	*0.85*	
8. Bottom surface (heat flow up)	*0.61*	*2.07*
Difference		*2.34*
Add 1. Top surface (heat flow down)	*0.92*	
6. Air space (heat flow down)	*1.25*	
8. Bottom surface (heat flow down)	*0.92*	*3.09*
Total resistance		*5.43*
$U = 1/R = 1/5.43 =$		0.18

To Adjust U Values for Construction with Added Insulation between Framing Members, See Table 16

Direction of Heat →		Heat Flow Upward (Winter Conditions)						Heat Flow Downward (Summer Conditions)						
		Type of Floor												
				Wood subfloor (25/32 in.), felt, and—						Wood subfloor (25/32 in.) felt, and—				
Type of Ceiling		None	Wood subfloor (25/32 in.)	Cement (1½ in.) and ceramic tile (½ in.)	Hardwood floor (¾ in.)	Plywood (⅝ in.) and floor tile or linoleum (⅛ in.)	Insul. bd. (⅜ in.) and hard bd. (¼ in.) and floor tile or linoleum (⅛ in.)	None	Wood subfloor (25/32 in.)	Cement (1½ in.) and ceramic tile (½ in.)	Hardwood floor (¾ in.)	Plywood (⅝ in.) and floor tile[c] or linoleum (⅛ in.)	Insul. bd. (⅜ in.) and hard bd. (¼ in.) and floor tile or linoleum (⅛ in.)	Number
Resistance ↓→		—	*0.98*	*1.38*	*1.72*	*1.87*	*2.26*	—	*0.98*	*1.38*	*1.72*	*1.87*	*2.26*	
Material	*R*	*U*	*U*	*U*	*U*	*U*	*U*	*U*	*U*	*U*	*U*	*U*	*U*	
		A	B	C	D	E	F	G	H	I	J	K	L	
None	—	—	0.45	0.38	0.34	0.31	0.28	—	0.35	0.31	0.28	0.26	0.24	1
Gypsum bd. (⅜ in.)	*0.32*	0.65	0.30	0.27	0.24	0.23	0.21	0.46	0.23	0.21	0.20	0.18	0.17	2
Gypsum lath (⅜ in.) and ½ in. plas. (lt. wt. agg.)	*0.64*	0.54	0.27	0.24	0.23	0.21	0.20	0.40	0.21	0.20	0.18	0.17	0.16	3
Gypsum lath (⅜ in.) and ½ in. plas. (sand agg.)	*0.41*	0.61	0.29	0.26	0.24	0.22	0.21	0.44	0.22	0.21	0.19	0.18	0.17	4
Metal lath and ¾ in. plas. (lt. wt. agg.)	*0.47*	0.59	0.28	0.26	**0.23**	0.22	0.20	0.43	0.22	0.20	0.19	0.18	0.17	5
Metal lath and ¾ in. plas. (sand agg.)	*0.13*	0.74	0.31	0.28	0.26	0.24	0.22	0.51	0.24	0.22	0.20	0.19	0.18	6
Insul. bd. (½ in.)	*1.43*	0.38	0.22	0.20	0.19	0.18	0.17	0.31	0.18	0.17	0.16	0.15	0.15	7
Insul. bd. lath (½ in.) and ½ in. plas. (sand agg.)	*1.52*	0.36	0.22	0.20	0.19	0.18	0.17	0.30	0.18	0.17	0.16	0.15	0.14	8
Acoustical tile														
(½ in.) on gypsum bd. (⅜ in.)	*1.51*[d]	0.37	0.22	0.20	0.19	0.18	0.17	0.30	0.18	0.17	0.16	0.15	0.14	9
(½ in.) on furring	*1.19*	0.41	0.24	0.22	0.20	0.19	0.18	0.33	0.19	0.18	0.17	0.16	0.15	10
(¾ in.) on gypsum bd. (⅜ in.)	*2.10*[d]	0.30	0.19	0.18	0.17	0.16	0.15	0.25	0.16	0.15	0.15	0.14	0.13	11
(¾ in.) on furring	*1.78*	0.33	0.21	0.19	0.18	0.17	0.16	0.28	0.17	0.16	0.15	0.15	0.14	12
Wood lath and ½ in. plas. (sand agg.)	*0.40*	0.62	0.29	0.26	0.24	0.22	0.21	0.45	0.22	0.21	0.19	0.18	0.17	13

[a] See text section Calculating Overall Coefficients for basis of calculations.
[b] To adjust *U* values for the effect of added insulation between framing members, see Table 16.
[c] Includes asphalt, rubber, and plastic tile (⅛ in.), ceramic tile, or terrazzo (1 in.).
[d] Includes thermal resistance of ⅜ in. gypsum wall board.

per, $25/32$-in. wood sheathing, studs, gypsum lath, and sand aggregate plaster, with 2-in. fibrous insulation between studs.

Solution: According to the example calculation in Table 5 a wall of this construction with no insulation between studs has a coefficient U of 0.24. Referring to Table 16, Part A, it will be found that a wall of this value with 2-in. fibrous insulation between the studs has a coefficient U of 0.087.

Attention is called to the necessity of applying the insulating material in accordance with the manufacturer's specification. The engineer must evaluate carefully the economic considerations involved in the selection of an insulating material as adapted to various building constructions. Lack of proper evaluation, or improper installation may lead to unsatisfactory results. Special attention must be given to vapor barriers as outlined in Chapter 10. Moisture from condensation or other sources materially reduces the heat-flow resistance of insulation.

INSULATED CONSTRUCTIONS—HOW TO USE TABLE 16

In Tables 5 through 15, U values are given for many common types of building wall, floor, and ceiling constructions. For such of these constructions as contain an air space, the tabulated U value is based on the assumption that the air space is empty, and that its surfaces are of ordinary building materials of low thermal reflectivity, such as wood, masonry, plaster, or paper. Considerable benefit in reducing the heat transmission coefficient of a construction can be effected by the application of thermal insulating materials in the air space.

Table 16 provides a means of determining, without calculation, the U value of the between-framing area of such constructions with the added insulation installed in the air space. Column 1 of Table 16 refers to the U values of uninsulated constructions as taken from Tables 5 through 15. Columns 2 to 14 of the table give corresponding coefficients U_i for the constructions with various insulating applications in the between-framing air space, as indicated by the column headings. Table 16 is in 5 parts, (A, B, C, D, and E) corresponding to the type of building element and the direction of heat flow. Each part is based on temperature conditions considered generally appropriate for the case.

Any and all U values are based on a series of assumptions as to nominal characteristics. Common variations in conditions, materials, workmanship, etc., can introduce much greater variations in U values than the variations resulting from the assumed mean temperatures and temperature differences described. From this it is also clear that the use of more than two significant figures in stating a U value is assuming more precision than can possibly exist. Three significant figures are used in Table 16 merely as a means of reducing cumulative errors when the table is used several times to obtain a single result. It should not be assumed that the figures are accurate, overall, to three significant figures. Also, a result taken from Table 16 should always be rounded off to two significant figures.

To use Table 16:

1. Find in Column 1 of the appropriate table the value for U obtained from Tables 5 through 15 for the construction without added insulation.

2. If there is a column which exactly corresponds to the condition for which you desire the U value, read the answer in this column, opposite the Column 1 value. Interpolate if necessary.

3. If there is no column which fully corresponds to the condition for which you desire the U value, then obtain the answer by means of two or more steps—each time using the value obtained in one step to reenter the same table through Column 1. In this way U values may be obtained for combinations of insulation in the framing space.

For combinations of fibrous insulations and air spaces, take account of the fibrous component first and the air space second as illustrated in Example 6. This is necessary to assure the approximately correct temperature difference across the air space.

Examples of the Use of Table 16

Example 3: Find the coefficient of transmission U_i of the frame wall shown as an example at the top of Table 5 when (*a*) a 2-inch blanket fibrous insulation is added between the studs and in contact with the gypsum lath and when (*b*) aluminum-foil-backed gypsum lath is added.

Solution: According to Table 5, the U value for this construction with no insulation in the air space is 0.24. Referring to Table 16, Part A, for walls, it is found that corresponding to the value 0.24 in Column 1, the coefficient for conditions (*a*) and (*b*) are:

(*a*) In Column 4, find $U_i = 0.087$. Use 0.09.

(*b*) From Table 3, Section C, the effective emissivity **E** of aluminum foil is 0.05.

In Column 8 find $U_i = 0.173$. Use 0.17.

Example 4: Consider the floor-ceiling construction shown in the example at the top of Table 11, insulated with a sheet of aluminum foil, or paper faced on both sides with foil, (effective emissivity **E** of air space = 0.05) placed between the joists and dividing the air space into two equal spaces. From Table 11, the U value for the uninsulated construction is 0.18 for heat flow down for summer, and 0.22 for heat flow up for winter. Determine the coefficient U_i for:

(*a*) Heat flowing downward from uncooled room above to cooled space below (a summer condition) and,

(*b*) Heat flowing upward from heated room below to unheated space above (a winter condition).

Solution:

(*a*) Use Table 16, Part D, and corresponding to $U = 0.18$ in Column 1 find, in Column 11, $U_i = 0.049$. Use 0.05.

(*b*) Use Table 16, Part C, and corresponding to $U = 0.22$ in Column 1 find, in Column 11, $U_i = 0.12$.

Special Uses of Table 16

Values of U_i for insulating applications or combinations other than those indicated by the headings of Columns 2 to 14 of Table 16 can be ascertained if the table is used appropriately. For instance, going horizontally in the table from Column 2 to Column 3 is equivalent to adding $\frac{1}{2}$ in. of fibrous insulation to the construction. Similarly, going from Column 2 to Column 4 adds $1\frac{1}{2}$ in. of fibrous insulation to the construction. In the same way, going horizontally from Column 8 to Column 11 is equivalent to adding to a construction the insulating value of one additional highly reflective (E = 0.05) air space, and going from Column 6 to Column 12 in effect adds two non-reflective (E = 0.82) air spaces to the construction, etc.

Examples 5 and 6 show the combinational use of Table 16.

Example 5: Determine the coefficient U_i for the wall of *Example 3*, with $1\frac{1}{2}$ in. of fibrous insulation added on one side of the air space.

Solution: U_i can be determined in several ways, by using Table 16, Part A, for example;

(*a*) By going from Column 1 to Column 2 three times, for a total of $1\frac{1}{2}$ inches of insulation, as follows; enter Column 1 at 0.24 and find $U_i = 0.166$ in Column 2; enter Column 1 at 0.166 and find $U_i = 0.126$ in Column 2; enter Column 1 at 0.126 and find $U_i = 0.102$ in Column 2. Therefore, for a total of $1\frac{1}{2}$ in. of insulation, use 0.10.

(*b*) More simply, by going from 0.24 in Column 2 to 0.103 in Column 4. Use 0.10.

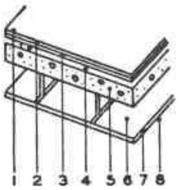
Example 6: Considering again the wall of *Example 3*, assume that one-inch blanket insulation is to be installed in mid-space,

(*Continued on p. 123*)

Table 12A . . . . Coefficients of Transmission (*U*) of Concrete Floor-Ceiling Constructions[a] (Winter Conditions, Upward Flow)

Coefficients are expressed in Btu per (hour) (square foot) Fahrenheit degree difference in temperature between the air on the two sides), and are based on still air (no wind) conditions on both sides

Example—Floor J 4



Resistances used are given below in this table or in Table 3 or 4

Heated room below unheated space

Construction (heat flow up)	Resistance (*R*)
1. Top surface (still air)	*0.61*
2. Asphalt tile and felt	*0.11*
3. Plywood (5/8 in.)	*0.78*
4. Air space[c]	*0.85*
5. Concrete slab 4 in. (av. *R*)	*0.40*
6. Air space[b] (8 in.)	*0.85*
7. Metal lath and 3/4 plas. (sand agg.)	*0.13*
8. Bottom surface (still air)	*0.61*
Total resistance	*4.34*
$U = 1/R = 1/4.34 =$	0.23

See value 0.23 in bold face type in table below.

Example of Substitution

Resistances used are given below in this table or in Table 3 or 4

Replace items 2, 3, and 4 with hard wood block (13/16 in.) on slab

Total resistance		*4.34*
Deduct 2. Asphalt tile and felt	*0.11*	
3. Plywood (5/8 in.)	*0.78*	
4. Air space	*0.85*	*1.74*
Difference		*2.60*
Add 2. Wood block (13/16 in.)		*0.74*
Total resistance		*3.34*
$U = 1/R = 1/3.34 =$		0.30

To Adjust U Values for Construction with Added Insulation in Air Space above Suspended Ceiling, See Table 16

Type of Deck: Material	R	Av. R	Type of Finish Floor: Material	Av. R	None	Ceiling Applied Directly to Slab: Plas. (Lt. wt. agg.) 1/8 in.	Plas. (Sand agg.) 1/8 in.	Acoustical tile—glued 1/2 in.	Acoustical tile—glued 3/4 in.	Suspended Ceiling: Gypsum bd. (3/8 in.) and Plas.: No plas.	Gypsum bd. (Lt. wt. agg.) 1/2 in.	Gypsum bd. (Sand agg.) 3/4 in.	Metal lath and plas. (Lt. wt. agg.) 1/2 in.	Metal lath and plas. (Sand agg.) 3/4 in.	Acoustical tile On furring or channels 1/2 in.	On furring or channels 3/4 in.	On gypsum bd. (3/8 in.) 1/2 in.	On gypsum bd. (3/8 in.) 3/4 in.	Number
			Resistance →		—	0.08	0.02	1.19	1.78	0.32	0.64	0.41	0.47	0.13	1.19	1.78	1.51	2.10	
					U A	U B	U C	U D	U E	U F	U G	U H	U I	U J	U K	U L	U M	U N	
Concrete[d] (sand agg.) (4 in.) / (6 in.)	*0.32* / *0.48*	*0.40*	None	—	0.62	0.59	0.61	0.36	0.29	0.36	0.32	0.35	0.34	0.38	0.27	0.24	0.25	0.22	1
			Floor tile[e] or linoleum (1/8 in.)	*0.05*	0.60	0.57	0.59	0.35	0.29	0.35	0.32	0.34	0.33	0.38	0.27	0.23	0.25	0.22	2
			Wood block (13/16 in.) on slab	*0.74*	0.42	0.41	0.42	0.28	0.24	0.28	0.26	0.28	0.27	0.30	0.23	0.20	0.21	0.19	3
			Floor on sleepers: Plywood subfloor (5/8 in.), felt and floor tile[e] or linoleum (1/8 in.)	*0.89*	0.30	0.29	0.30	0.22	0.19	0.22	0.21	0.22	0.21	**0.23**	0.19	0.17	0.17	0.16	4
			Wood subfloor (25/32 in.), felt and hardwood (3/4 in.)	*1.72*	0.24	0.24	0.24	0.19	0.17	0.19	0.18	0.18	0.18	0.19	0.16	0.15	0.15	0.14	5
Concrete[d] (sand agg.) (8 in.) / (10 in.)	*0.64* / *0.80*	*0.72*	None	—	0.52	0.50	0.51	0.32	0.27	0.32	0.29	0.31	0.31	0.34	0.25	0.22	0.23	0.20	6
			Floor tile[e] or linoleum (1/8 in.)	*0.05*	0.50	0.48	0.50	0.31	0.26	0.32	0.29	0.31	0.30	0.34	0.25	0.22	0.23	0.20	7
			Wood block (13/16 in.) on slab	*0.74*	0.37	0.36	0.37	0.26	0.22	0.26	0.24	0.25	0.25	0.27	0.21	0.19	0.20	0.18	8
			Floor on sleepers: Plywood subfloor (5/8 in.), felt and floor tile[e] or linoleum (1/8 in.)	*0.89*	0.27	0.27	0.27	0.21	0.18	0.21	0.19	0.20	0.20	0.21	0.17	0.16	0.17	0.15	9
			Wood subfloor (25/32 in.), felt and hardwood (3/4 in.)	*1.72*	0.22	0.22	0.22	0.18	0.16	0.18	0.17	0.17	0.17	0.18	0.16	0.14	0.15	0.13	10

[a] See text section Calculating Overall Coefficients for basis of calculations.
[b] To adjust *U* values for the effect of added insulation between framing members, see Table 16.
[c] Table 16 can be used only if sleeper space is non-reflective. The sleeper air space is not to be counted in using Table 16.
[d] Concrete is assumed to have a thermal conductivity *k* of 12.0 as given in Table 4.
[e] Includes asphalt, rubber, and plastic tile (1/8 in.), ceramic tile on terrazzo (1 in.).

Table 12B . . . . Coefficients of Transmission (*U*) of Concrete Floor-Ceiling Constructions[a] (Summer Conditions, Downward Flow)

Coefficients are expressed in Btu per (hour) (square foot) (Fahrenheit degree difference in temperature between the air on the two sides), and are based on still air (no wind) conditions on both sides

Type of Deck: Material	R	Av. R	Type of Finish Floor: Material	Av. R	TYPE OF CEILING: None	Ceiling Applied Directly to Slab: Plas. (Lt. wt. agg.) ⅛ in.	Ceiling Applied Directly to Slab: Plas. (Sand agg.) ⅛ in.	Ceiling Applied Directly to Slab: Acoustical tile—glued ½ in.	Ceiling Applied Directly to Slab: Acoustical tile—glued ¾ in.	Suspended Ceiling: Gypsum bd. (⅜ in.) and Plas.: No plas.	Suspended Ceiling: Gypsum bd. (⅜ in.) and Plas.: (Lt. wt. agg.) ½ in.	Suspended Ceiling: Gypsum bd. (⅜ in.) and Plas.: (Sand agg.) ½ in.	Suspended Ceiling: Metal lath and plas.: (Lt. wt. agg.) ¾ in.	Suspended Ceiling: Metal lath and plas.: (Sand agg.) ¾ in.	Suspended Ceiling: Acoustical tile: On furring or channels ½ in.	Suspended Ceiling: Acoustical tile: On furring or channels ¾ in.	Suspended Ceiling: Acoustical tile: On gypsum bd. (⅜ in.) ½ in.	Suspended Ceiling: Acoustical tile: On gypsum bd. (⅜ in.) ¾ in.	Number
			Resistance →		—	0.08	0.02	1.19	1.78	0.32	0.64	0.41	0.47	0.13	1.19	1.78	1.51	2.10	
					U	U	U	U	U	U	U	U	U	U	U	U	U	U	
					O	P	Q	R	S	T	U	V	W	X	Y	Z	Z′	Z″	
Concrete[d] (sand agg.)			None	—	0.45	0.43	0.44	0.29	0.25	0.26	0.24	0.26	0.25	0.28	0.21	0.19	0.20	0.18	1
(4 in.)	*0.32*	*0.40*	Floor tile[e] or linoleum (⅛ in.)	*0.05*	0.44	0.42	0.43	0.29	0.25	0.26	0.24	0.25	0.25	0.27	0.21	0.19	0.20	0.18	2
(6 in.)	*0.48*		Wood block (13/16 in.) on slab	*0.74*	0.34	0.33	0.33	0.24	0.21	0.22	0.21	0.22	0.21	0.23	0.19	0.17	0.17	0.16	3
			Floor on sleepers: Plywood subfloor (⅝ in.), felt and floor tile[e] or linoleum (⅛ in.)	*0.89*	0.23	0.23	0.23	0.18	0.17	0.17	0.16	0.17	0.17	0.18	0.15	0.14	0.14	0.13	4
			Floor on sleepers: Wood subfloor (25/32 in.), felt and hardwood (¾ in.)	*1.72*	0.20	0.19	0.20	0.16	0.15	0.15	0.14	0.15	0.15	0.16	0.13	0.12	0.13	0.12	5
Concrete[d] (sand agg.)			None	—	0.39	0.38	0.39	0.27	0.23	0.24	0.23	0.24	0.23	0.26	0.20	0.18	0.19	0.17	6
(8 in.)	*0.64*	*0.72*	Floor tile[e] or linoleum (⅛ in.)	*0.05*	0.38	0.37	0.38	0.26	0.23	0.24	0.22	0.24	0.23	0.25	0.20	0.18	0.19	0.17	7
(10 in.)	*0.80*		Wood block (13/16 in.) on slab	*0.74*	0.30	0.30	0.30	0.22	0.20	0.21	0.19	0.20	0.20	0.21	0.17	0.16	0.17	0.15	8
			Floor on sleepers: Plywood subfloor (⅝ in.), felt and floor tile[e] or linoleum (⅛ in.)	*0.89*	0.22	0.21	0.22	0.17	0.16	0.16	0.15	0.16	0.16	0.17	0.14	0.13	0.14	0.13	9
			Floor on sleepers: Wood subfloor (25/32 in.), felt and hardwood (¾ in.)	*1.72*	0.19	0.18	0.18	0.15	0.14	0.14	0.14	0.14	0.14	0.15	0.13	0.12	0.12	0.11	10

[a] See text section Calculating Overall Coefficients for basis of calculations.
[b] To adjust *U* values for the effect of added insulation between framing members, see Table 16.
[c] Table 16 can be used only if sleeper space is nonreflective. The sleeper air space is not to be counted in using Table 16.
[d] Concrete is assumed to have a thermal conductivity *k* of 12.0 as given in Table 4.
[e] Includes asphalt, rubber, and plastic tile (⅛ in.), ceramic tile on terrazzo (1 in.).

leaving equal air spaces on the two sides. The coefficient U_i is desired for two cases in which

(*a*) the blanket has non-reflective surfaces on both sides, so that both air spaces are non-reflective (E = 0.82) and,

(*b*) the blanket has one highly reflective surface, so that one of the air spaces is highly reflective (E = 0.05).

Solution:

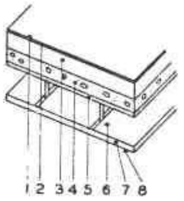
(*a*) In Table 16, Part A, when *U* without added insulation is 0.24, U_i for one inch of fibrous insulation and one non-reflective air space, is 0.127 in Column 3. To add the second non-reflective air space, enter Column 6 at 0.127, and by interpolating find U_i = 0.112 in Column 9. Use 0.11.

(*b*) U_i for one inch of fibrous insulation and one non-reflective air space is 0.127 as in (*a*). To add one E = 0.05 air space, enter Column 8 at 0.127 and by interpolating find U_i = 0.092 in Column 11. Use 0.09.

(*Continued on p. 131*)

Table 13A . . . . Coefficients of Transmission (*U*) of Flat Masonry Roofs with Built-up Roofing, with and without Suspended Ceilings[a] (Winter Conditions, Upward Flow)

These Coefficients are expressed in Btu per (hour) (square foot) (Fahrenheit degree difference in temperature between the air on the two sides), and are based on an outside wind velocity of 15 mph



Example—K 4

Resistances used are given below in this table or in Table 3 or 4

Construction (heat flow up)	Resistance (*R*)
1. Outside surface (15 mph wind)	*0.17*
2. Built-up roofing—3/8 in.	*0.33*
3. Roof insulation (none)	—
4. Concrete slab (lt. wt. agg.) (2 in.)	*2.22*
5. Corrugated metal	*0*
6. Air space[b]	*0.85*
7. Metal lath and 3/4 in. plas. (lt. wt. agg.)	*0.47*
8. Inside surface (still air)	*0.61*
Total resistance	*4.65*
$U = 1/R = 1/4.65 =$	0.22

See value 0.22 in boldface type in table below.

Example of Substitution

Resistances used are given below in this table or in Table 3 or 4

Replace item 4 with 4 in. concrete slab (gravel agg.) and roof insulation ($C = 0.36$) on top of slab.

Total resistance		*4.65*
Deduct 4. Concrete slab (lt. wt. agg.) (2 in.)		*2.22*
Difference		*2.43*
Add 3. Roof insulation ($C = 0.36$)	*2.78*	
4. Concrete slab (gravel agg.) 4 in.	*0.44*	*3.22*
Total resistance		*5.65*
$U = 1/R = 1/5.65 =$		0.18

To Adjust U Values for Construction with Added Insulation in Air Space, See Table 16

Type of Deck		Type of Form		Type of Ceiling: Roof Insulation No Ceiling — C value of roof insulation							Suspended Ceiling[h]: Gypsum bd. (3/8 in.) and plas.			Metal lath and plas.		Acoustical tile: On furring or channels		On gyp-sum bd. (3/8 in.)		Number
				None	0.72	0.36	0.24	0.19	0.15	0.12	No plas.	Lt. wt. agg. 1/2 in.	Sand agg. 1/2 in.	Lt. wt. agg. 3/4 in.	Sand agg. 3/4 in.	1/2 in.	3/4 in.	1/2 in.	3/4 in.	
		Resistance		—	1.39	2.78	4.17	5.26	6.67	8.33	0.32	0.64	0.41	0.47	0.13	1.19	1.75	1.51	2.10	
Material	R	Material	R	U A	U B	U C	U D	U E	U F	U G	U H	U I	U J	U K	U L	U M	U N	U O	U P	
Concrete slab[d] Gravel agg. (4 in.)	*0.32*	Temporary	—	0.70	0.35	0.24	0.18	0.15	0.12	0.10	0.38	0.34	0.37	0.36	0.41	0.29	0.25	0.26	0.23	**1**
(6 in.)	*0.48*	Temporary	—	0.63	0.34	0.23	0.17	0.15	0.12	0.10	0.36	0.32	0.35	0.34	0.39	0.27	0.24	0.25	0.22	**2**
(8 in.)	*0.64*	Temporary	—	0.57	0.32	0.22	0.17	0.14	0.12	0.10	0.34	0.31	0.33	0.33	0.37	0.26	0.23	0.24	0.21	**3**
Lt. wt. agg.[e] (2 in.)	*2.22*	Corrugated metal[c]	*0*	0.30	0.21	0.16	0.13	0.12	0.10	0.09	0.22	0.21	0.22	**0.22**	0.23	0.19	0.17	0.18	0.16	**4**
		Insulation bd. (1 in.)	*2.78*	0.16	0.13	0.11	0.10	0.09	0.08	0.07	0.14	0.13	0.14	0.13	0.14	0.12	0.11	0.12	0.11	**5**
		Insulation bd. (1½ in.)	*4.17*	0.13	0.11	0.10	0.09	0.08	0.07	0.06	0.12	0.11	0.11	0.11	0.12	0.10	0.10	0.10	0.10	**6**
		Glass fiber bd. (1 in.)	*4.00*	0.14	0.11	0.10	0.09	0.08	0.07	0.06	0.12	0.11	0.12	0.12	0.12	0.11	0.10	0.10	0.10	**7**
(3 in.)	*3.33*	Corrugated metal[c]	*0*	0.23	0.17	0.14	0.12	0.10	0.09	0.08	0.18	0.17	0.18	0.17	0.18	0.15	0.14	0.15	0.14	**8**
		Insulation bd. (1 in.)	*2.78*	0.14	0.12	0.10	0.09	0.08	0.07	0.06	0.12	0.11	0.12	0.12	0.12	0.11	0.10	0.10	0.10	**9**
		Insulation bd. (1½ in.)	*4.17*	0.12	0.10	0.09	0.08	0.07	0.07	0.06	0.10	0.10	0.10	0.10	0.10	0.09	0.09	0.09	0.09	**10**
		Glass fiber bd. (1 in.)	*4.00*	0.12	0.10	0.09	0.08	0.07	0.07	0.06	0.10	0.10	0.10	0.10	0.11	0.10	0.09	0.09	0.09	**11**
(4 in.)	*4.44*	Corrugated metal[c]	*0*	0.18	0.14	0.12	0.10	0.09	0.08	0.07	0.15	0.14	0.15	0.15	0.15	0.13	0.12	0.13	0.12	**12**
		Insulation bd. (1 in.)	*2.78*	0.12	0.10	0.09	0.08	0.07	0.07	0.06	0.11	0.10	0.10	0.10	0.11	0.10	0.09	0.09	0.09	**13**
		Insulation bd. (1½ in.)	*4.17*	0.10	0.09	0.08	0.07	0.07	0.06	0.06	0.09	0.09	0.09	0.09	0.09	0.09	0.08	0.08	0.08	**14**
		Glass fiber bd. (1 in.)	*4.00*	0.10	0.09	0.08	0.07	0.07	0.06	0.06	0.09	0.09	0.09	0.09	0.09	0.09	0.08	0.08	0.08	**15**
Gypsum slab[g] (2 in.)	*1.20*	Gypsum bd. (½ in.)	*0.45*	0.36	0.24	0.18	0.14	0.12	0.11	0.09	0.25	0.24	0.25	0.25	0.27	0.21	0.19	0.20	0.18	**16**
		Insulation bd. (1 in.)	*2.78*	0.20	0.15	0.13	0.11	0.10	0.09	0.07	0.16	0.15	0.16	0.16	0.16	0.14	0.13	0.13	0.12	**17**
		Insulation bd. (1½ in.)	*4.17*	0.15	0.13	0.11	0.09	0.09	0.08	0.07	0.13	0.13	0.13	0.13	0.13	0.12	0.11	0.11	0.11	**18**
		Asbestos-cement bd.[f] (¼ in.)	*0.06*	0.40	0.26	0.19	0.15	0.13	0.11	0.09	0.27	0.25	0.26	0.26	0.29	0.22	0.19	0.20	0.18	**19**
		Glass fiber bd. (1 in.)	*4.00*	0.16	0.13	0.11	0.10	0.09	0.08	0.07	0.13	0.13	0.13	0.13	0.14	0.12	0.11	0.12	0.11	**20**
(3 in.)	*1.80*	Gypsum bd. (½ in.)	*0.45*	0.30	0.21	0.16	0.13	0.12	0.10	0.09	0.22	0.21	0.22	0.21	0.23	0.19	0.17	0.17	0.16	**21**
		Insulation bd. (1 in.)	*2.78*	0.18	0.14	0.12	0.10	0.09	0.08	0.07	0.15	0.14	0.14	0.14	0.15	0.13	0.12	0.12	0.12	**22**
		Insulation bd. (1½ in.)	*4.17*	0.14	0.12	0.10	0.09	0.08	0.07	0.06	0.12	0.12	0.12	0.12	0.12	0.11	0.10	0.11	0.10	**23**
		Asbestos-cement bd. (¼in.)	*0.06*	0.34	0.23	0.17	0.14	0.12	0.10	0.09	0.24	0.22	0.24	0.23	0.25	0.20	0.18	0.19	0.17	**24**
		Glass fiber bd. (1 in.)	*4.00*	0.14	0.12	0.10	0.09	0.08	0.07	0.07	0.12	0.12	0.12	0.12	0.13	0.11	0.10	0.11	0.10	**25**
(4 in.)	*2.40*	Gypsum bd. (½ in.)	*0.45*	0.25	0.19	0.15	0.12	0.11	0.09	0.08	0.19	0.18	0.19	0.19	0.20	0.17	0.15	0.16	0.14	**26**
		Insulation bd. (1 in.)	*2.78*	0.16	0.13	0.11	0.10	0.09	0.08	0.07	0.13	0.13	0.13	0.13	0.14	0.12	0.11	0.12	0.11	**27**
		Insulation bd. (1½ in.)	*4.17*	0.13	0.11	0.10	0.08	0.08	0.07	0.06	0.11	0.11	0.11	0.11	0.12	0.10	0.10	0.10	0.09	**28**
		Asbestos-cement bd. (¼ in.)	*0.06*	0.28	0.20	0.16	0.13	0.11	0.10	0.08	0.21	0.20	0.21	0.20	0.22	0.18	0.16	0.17	0.15	**29**
		Glass fiber bd. (1 in.)	*4.00*	0.13	0.11	0.10	0.09	0.08	0.07	0.06	0.12	0.11	0.11	0.11	0.12	0.10	0.10	0.10	0.10	**30**

[a] See text section Calculating Overall Coefficients for basis of calculations.

[b] To adjust *U* values for the effect of added insulation between framing members, see Table 16.

[c] *U* values would also apply if slab were poured on metal lath, paper-backed wire, fabric, or asbestos-cement board (¼ in.).

[d] Concrete assumed to have a thermal conductivity *k* of 12.0 and a density of 140 lb per cu ft.

[e] Concrete assumed to have a thermal conductivity *k* of 0.90 and a density of 30 lb per cu ft.

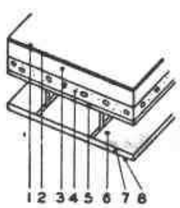
[f] Gypsum slab 2¼ in. thick since this is recommended practice.

[g] Gypsum fiber concrete with 12½ percent wood chips (thermal conductivity $k = 1.66$).

[h] See Table 16 E for *U* value of roof and ceiling construction with roof insulation added to roof deck.

Table 13B . . . . Coefficients of transmission (*U*) of Flat Masonry Roofs with Built-up Roofing with and without Suspended Ceiling[a] (Summer Conditions, Downward Flow)

These coefficients are expressed in Btu per (hour) (square foot) (Fahrenheit degree difference in temperature between the air on the two sides), and are based on an outside wind velocity of 7.5 mph



Example—Roof 1' 2

Resistances used are given below in this table or in Table 3 or 4

Construction (heat flow down) — Resistance (*R*)

1. Outside surface (7.5 mph wind) *0.25*
2. Built-up roofing (3/8 in.) *0.33*
3. Roof insulation (none) *0.00*
4. Concrete slab (gravel agg.) (6 in.) *0.48*
5. Temporary form bd *0.00*
6. Air space[b] (8 in.) *1.25*
7. Gypsum lath (3/8 in.) and 1/2 in. plas. (lt. wt. agg.) *0.64*
8. Inside surface (still air) *0.92*

Total resistance *3.87*

$U = 1/R = 1/3.87 =$ 0.26

See value 0.26 in boldface type in table below.

Example of Substitution

Resistances used are given below in this table or in Table 3 or 4

Replace item 3 with roof insulation ($C = 0.36$) and remove suspended ceiling

Total resistance *3.87*

Deduct 6. Air space *1.25*

7. Gypsum lath (3/8 in.) and 1/2 in. plas. (lt. wt. agg.) *0.64* *1.89*

Difference *1.98*

Add 3. Roof insulation ($C = 0.36$) *2.78*

Total resistance = ... *4.76*

$U = 1/R = 1/4.76 =$ 0.21

To Adjust U Values for Construction with Added Insulation in Air Space, See Table 16

Type of Deck: Material	R	Type of Form: Material	R	Type of Ceiling: Roof Insulation—No Ceiling: None	C value of roof insulation 0.72	0.36	0.24	0.19	0.15	0.12	Suspended Ceiling[h]: Gypsum bd. (3/8 in.) and plas.: No plas.	Lt. wt. agg. (1/2 in.)	Sand agg. (1/2 in.)	Metal lath and plas.: Lt. wt. agg. (3/4 in.)	Sand agg. (3/4 in.)	Acoustical tile: On furring or channels 1/2 in.	3/4 in.	On gypsum bd. (3/8 in.) 1/2 in.	3/4 in.	Number
		Resistance →		—	1.39	2.78	4.17	5.26	6.67	8.33	0.32	0.64	0.41	0.47	0.13	1.19	1.78	1.51	2.10	
				U A'	U B'	U C'	U D'	U E'	U F'	U G'	U H'	U I'	U J'	U K'	U L'	U M'	U N'	U O'	U P'	
Concrete slab[d] (Gravel agg.) (4 in.)	*0.32*	Temporary	—	0.55	0.31	0.22	0.17	0.14	0.12	0.10	0.30	0.27	0.29	0.28	0.31	0.24	0.21	0.22	0.19	**1**
(6 in.)	*0.48*	Temporary	—	0.51	0.30	0.21	0.16	0.14	0.12	0.10	0.28	**0.26**	0.28	0.27	0.30	0.23	0.20	0.21	0.19	**2**
(8 in.)	*0.64*	Temporary	—	0.47	0.28	0.20	0.16	0.14	0.11	0.10	0.27	0.25	0.26	0.26	0.29	0.22	0.19	0.20	0.18	**3**
Lt wt. agg.[e] (2 in.)	*2.22*	Corrugated metal[c]	*0*	0.27	0.20	0.15	0.13	0.11	0.10	0.08	0.19	0.18	0.19	0.18	0.20	0.16	0.15	0.15	0.14	**4**
		Insulation bd. (1 in.)	*2.78*	0.15	0.13	0.11	0.09	0.09	0.08	0.07	0.12	0.12	0.12	0.12	0.13	0.11	0.11	0.11	0.10	**5**
		Insulation bd. (1½ in.)	*4.17*	0.13	0.11	0.09	0.08	0.08	0.07	0.06	0.11	0.10	0.10	0.10	0.11	0.10	0.09	0.09	0.09	**6**
		Glass fiber bd. (1 in.)	*4.00*	0.13	0.11	0.10	0.08	0.08	0.07	0.06	0.11	0.10	0.11	0.11	0.11	0.10	0.09	0.10	0.09	**7**
(3 in.)	*3.33*	Corrugated metal[c]	*0*	0.21	0.16	0.13	0.11	0.10	0.09	0.08	0.16	0.15	0.15	0.15	0.16	0.14	0.13	0.13	0.12	**8**
		Insulation bd. (1 in.)	*2.78*	0.13	0.11	0.10	0.08	0.08	0.07	0.06	0.11	0.11	0.11	0.11	0.11	0.10	0.09	0.10	0.09	**9**
		Insulation bd. (1½ in.)	*4.17*	0.11	0.10	0.08	0.08	0.07	0.06	0.06	0.09	0.09	0.09	0.09	0.10	0.09	0.08	0.09	0.08	**10**
		Glass fiber bd. (1 in.)	*4.00*	0.11	0.10	0.09	0.08	0.07	0.06	0.06	0.10	0.09	0.10	0.09	0.10	0.09	0.08	0.09	0.08	**11**
(4 in.)	*4.44*	Corrugated metal[c]	*0*	0.17	0.14	0.11	0.10	0.09	0.08	0.07	0.13	0.13	0.13	0.13	0.14	0.12	0.11	0.12	0.11	**12**
		Insulation bd. (1 in.)	*2.78*	0.11	0.10	0.09	0.08	0.07	0.06	0.06	0.10	0.09	0.10	0.10	0.10	0.09	0.09	0.09	0.08	**13**
		Insulation bd. (1½ in.)	*4.17*	0.10	0.09	0.08	0.07	0.07	0.06	0.05	0.09	0.08	0.09	0.08	0.09	0.08	0.08	0.08	0.07	**14**
		Glass fiber bd. (1 in.)	*4.00*	0.10	0.09	0.08	0.07	0.07	0.06	0.05	0.09	0.08	0.09	0.09	0.09	0.08	0.08	0.08	0.08	**15**
Gypsum slab[g] (2 in.)	*1.20*	Gypsum bd. (½ in.)	*0.45*	0.32	0.22	0.17	0.14	0.12	0.10	0.09	0.21	0.20	0.21	0.21	0.22	0.18	0.16	0.17	0.15	**16**
		Insulation bd. (1 in.)	*2.78*	0.18	0.15	0.12	0.10	0.09	0.08	0.07	0.14	0.14	0.14	0.14	0.15	0.13	0.12	0.12	0.11	**17**
		Insulation bd. (1½ in.)	*4.17*	0.15	0.12	0.10	0.09	0.08	0.07	0.07	0.12	0.11	0.12	0.12	0.12	0.11	0.10	0.10	0.10	**18**
		Asbestos-cement bd.[f] (¼ in.)	*0.06*	0.34	0.23	0.18	0.14	0.12	0.10	0.09	0.22	0.21	0.22	0.22	0.23	0.19	0.17	0.18	0.16	**19**
		Glass fiber bd. (1 in.)	*4.00*	0.15	0.12	0.11	0.09	0.08	0.07	0.07	0.12	0.12	0.12	0.12	0.12	0.11	0.10	0.11	0.10	**20**
(3 in.)	*1.80*	Gypsum bd. (½ in.)	*0.45*	0.27	0.19	0.15	0.13	0.11	0.10	0.08	0.19	0.18	0.19	0.18	0.20	0.26	0.15	0.15	0.14	**21**
		Insulation bd. (1 in.)	*2.78*	0.16	0.13	0.11	0.10	0.09	0.08	0.07	0.13	0.13	0.13	0.13	0.13	0.12	0.11	0.11	0.11	**22**
		Insulation bd. (1½ in.)	*4.17*	0.13	0.11	0.10	0.09	0.08	0.07	0.06	0.11	0.11	0.11	0.11	0.11	0.10	0.10	0.10	0.09	**23**
		Asbestos-cement bd. (¼ in.)	*0.06*	0.30	0.21	0.16	0.13	0.12	0.10	0.09	0.20	0.19	0.20	0.20	0.21	0.17	0.16	0.16	0.15	**24**
		Glass fiber bd. (1 in.)	*4.00*	0.14	0.12	0.10	0.09	0.08	0.07	0.06	0.11	0.11	0.11	0.11	0.12	0.10	0.10	0.10	0.09	**25**
(4 in.)	*2.40*	Gypsum bd. (½ in.)	*0.45*	0.23	0.17	0.14	0.12	0.10	0.09	0.08	0.17	0.16	0.17	0.17	0.18	0.15	0.14	0.14	0.13	**26**
		Insulation bd. (1 in.)	*2.78*	0.15	0.12	0.11	0.09	0.08	0.07	0.07	0.12	0.12	0.12	0.12	0.12	0.11	0.10	0.11	0.10	**27**
		Insulation bd. (1½ in.)	*4.17*	0.12	0.11	0.09	0.08	0.08	0.07	0.06	0.10	0.10	0.10	0.10	0.11	0.10	0.09	0.09	0.09	**28**
		Asbestos-cement bd.[c] (¼ in.)	*0.06*	0.25	0.19	0.15	0.12	0.11	0.09	0.08	0.18	0.17	0.18	0.18	0.19	0.16	0.14	0.15	0.14	**29**
		Glass fiber bd. (1 in.)	*4.00*	0.13	0.11	0.09	0.08	0.08	0.07	0.06	0.11	0.10	0.10	0.10	0.11	0.10	0.07	0.09	0.09	**30**

[a] See text section Calculating Overall Coefficients for basis of calculations.

[b] To adjust *U* values for the effect of added insulation between framing members, see Table 16.

[c] *U* values would also apply if slab were poured on metal lath, paper-backed wire fabric, or asbestos-cement board (¼ in.).

[d] Concrete assumed to have a thermal conductivity *k* of 12.0 and a density of 140 lb per cu ft.

[e] Concrete assumed to have a thermal conductivity *k* of 0.90 and a density of 30 lb per cu ft.

[f] Gypsum slab 2¼ in. thick since this is recommended practice.

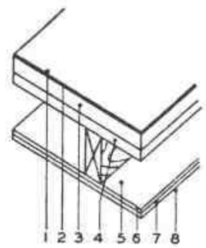
[g] Gypsum fiber concrete with 12½ percent wood chips (thermal conductivity $k = 1.66$).

[h] See Table 16 E for *U* value of roof and ceiling construction with roof insulation added to roof deck.

Table 14A . . . . Coefficients of Transmission (*U*) of Wood or Metal Construction Flat Roofs and Ceilings[a] (Winter Conditions, Upward Flow)

Coefficients are expressed in Btu per (hour) (square foot) (Fahrenheit degree difference in temperature between the air on the two sides), and are based upon an outside wind velocity of 15 mph

Example—Roof J 2



Resistances used are given below in this table or in Table 3 or 4

Construction (Heat flow up)	Resistance (*R*)
1. Outside surface (15 mph wind)	*0.17*
2. Built-up roofing, 3/8 in.	*0.33*
3. Roof insulation (C = 0.72)	*1.39*
4. Wood deck (1 in.)	*0.98*
5. Air space[b]	*0.85*
6. Gypsum wall board (3/8 in.)	*0.32*
7. Acoustical tile (1/2 in.)—glued	*1.19*
8. Inside surface (still air)	*0.61*
Total resistance	*5.84*
$U = 1/R = 1/5.84$	0.17

See value 0.17 in boldface type in table below.

Example of Substitution

Resistances used are given below in this table or in Table 3 or 4

Replace item 4 with 2 in. wood deck (exposed to inside) and omit items 5, 6, and 7.

Total resistance		*5.84*
Deduct 4. Wood deck (1 in.)	*0.98*	
5. Air space	*0.85*	
6. Gypsum wall board (3/8 in.)	*0.32*	
7. Acoustical tile (1/2 in.) glued	*1.19*	*3.34*
Difference		*2.50*
Add 4. Wood deck (2 in.)		*2.03*
Total resistance		*4.53*
$U = 1/R = 1/4.53$ =		0.22

To Adjust U Values for Construction with Added Insulation in Air Space, See Table 16

Type of Deck (Built-up Roof in All Cases) — Material	R	Insulation Added on Top of Deck[d]: Conductance of insul. C	Insulation Added on Top of Deck[d]: Resistance R	TYPE OF CEILING: None — U A	Gypsum Bd. (3/8 in. and Plas.): None 0.32 — U B	Gypsum Bd.: Lt. wt. agg. 1/2 in. 0.64 — U C	Gypsum Bd.: Sand agg. 1/2 in. 0.41 — U D	Metal Lath and Plas.: Lt. wt. agg. 3/4 in. 0.47 — U E	Metal Lath and Plas.: Sand agg. 3/4 in. 0.13 — U F	Insul. Bd. (1/2 in.): Plain (1.43) or 1/2 in. plas. sand agg. (1.52) 1.47 — U G	Acoustical Tile On Furring: 1/2 in. 1.19 — U H	Acoustical Tile On Furring: 3/4 in. 1.78 — U I	Acoustical Tile On Gypsum Bd. (3/8 in.): 1/2 in. 1.51 — U J	Acoustical Tile On Gypsum Bd. (3/8 in.): 3/4 in. 2.10 — U K	Number
Wood[c] 1 in.	*0.98*	None	—	0.48	0.31	0.28	0.30	0.29	0.33	0.23	0.24	0.21	0.22	0.20	1
		0.72	*1.39*	0.29	0.22	0.20	0.21	0.21	0.22	0.17	0.18	0.16	**0.17**	0.16	2
		0.36	*2.78*	0.21	0.17	0.16	0.16	0.16	0.17	0.14	0.14	0.13	0.14	0.13	3
		0.24	*4.17*	0.16	0.13	0.13	0.13	0.13	0.14	0.12	0.12	0.11	0.12	0.11	4
		0.19	*5.26*	0.14	0.12	0.11	0.12	0.12	0.12	0.10	0.11	0.10	0.10	0.10	5
		0.15	*6.67*	0.11	0.10	0.10	0.10	0.10	0.10	0.09	0.09	0.09	0.09	0.09	6
		0.12	*8.33*	0.10	0.09	0.08	0.09	0.09	0.09	0.08	0.08	0.08	0.08	0.07	7
Wood[c] 2 in.	*2.03*	None	—	0.32	0.23	0.22	0.23	0.22	0.24	0.18	0.19	0.17	0.18	0.16	8
		0.72	*1.39*	0.22	0.18	0.17	0.17	0.17	0.18	0.15	0.15	0.14	0.15	0.13	9
		0.36	*2.78*	0.17	0.14	0.13	0.14	0.14	0.14	0.12	0.13	0.12	0.12	0.11	10
		0.24	*4.17*	0.14	0.12	0.11	0.12	0.12	0.12	0.10	0.11	0.10	0.10	0.10	11
		0.19	*5.26*	0.12	0.10	0.10	0.10	0.10	0.11	0.09	0.10	0.09	0.09	0.09	12
		0.15	*6.67*	0.10	0.09	0.09	0.09	0.09	0.09	0.08	0.08	0.08	0.08	0.08	13
		0.12	*8.33*	0.09	0.08	0.08	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.07	14
Wood[c] 3 in.	*3.28*	None	—	0.23	0.18	0.17	0.18	0.18	0.19	0.15	0.16	0.14	0.15	0.14	15
		0.72	*1.39*	0.17	0.14	0.14	0.14	0.14	0.15	0.12	0.13	0.12	0.12	0.11	16
		0.36	*2.78*	0.14	0.12	0.12	0.12	0.12	0.12	0.11	0.11	0.10	0.10	0.10	17
		0.24	*4.17*	0.12	0.10	0.10	0.10	0.10	0.10	0.09	0.09	0.09	0.09	0.09	18
		0.19	*5.26*	0.10	0.09	0.09	0.09	0.09	0.09	0.08	0.09	0.08	0.08	0.08	19
		0.15	*6.67*	0.09	0.08	0.08	0.08	0.08	0.08	0.07	0.08	0.07	0.07	0.07	20
		0.12	*8.33*	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.06	21
Preformed slabs—wood fiber and cement binder															
2 in.	*3.60*	None	—	0.21	0.17	0.16	0.17	0.17	0.18	0.14	0.15	0.14	0.14	0.13	22
3 in.	*5.40*	None	—	0.15	0.13	0.13	0.13	0.13	0.13	0.11	0.12	0.11	0.11	0.11	23
Flat metal roof deck	*0*	None	—	0.90	0.44	0.38	0.42	0.41	0.48	0.29	0.32	0.27	0.29	0.25	24
		0.72	*1.39*	0.40	0.27	0.25	0.27	0.26	0.29	0.21	0.22	0.19	0.21	0.18	25
		0.36	*2.78*	0.26	0.20	0.19	0.19	0.19	0.21	0.16	0.17	0.15	0.16	0.15	26
		0.24	*4.17*	0.19	0.16	0.15	0.15	0.15	0.16	0.13	0.14	0.13	0.13	0.12	27
		0.19	*5.26*	0.16	0.13	0.13	0.13	0.13	0.14	0.12	0.12	0.11	0.11	0.11	28
		0.15	*6.67*	0.13	0.11	0.11	0.11	0.11	0.11	0.10	0.10	0.10	0.10	0.09	29
		0.12	*8.33*	0.11	0.09	0.09	0.09	0.09	0.10	0.09	0.09	0.08	0.08	0.08	30

[a] See text section Calculating Overall Coefficients for basis of calculations.

[b] To adjust U values for the effect of added insulation between framing members, see Table 16.

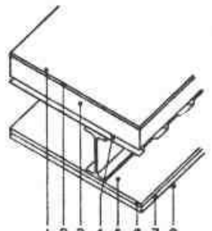
[c] Wood deck 1, 2, and 3 in. is assumed to be 25/32, 1 5/8, and 2 5/8 in. thick, respectively. The thermal conductivity k is assumed to be 0.80.

[d] If a vapor barrier is used beneath roof insulation it will have a negligible effect on the U value. For information on vapor barrier requirements see Chapter 10, Moisture in Building Construction.

Table 14B . . . . Coefficients of Transmission (*U*) of Wood or Metal Construction Flat Roofs and Ceilings[a] (Summer Conditions, Downward Flow)

Coefficients are expressed in Btu per (hour) (square foot) (Fahrenheit degree difference in temperature between the air on the two sides), and are based upon an outside wind velocity of 7.5 mph

Example—Roof F′ 27



Resistances used are given below in this table or in Tables 3 or 4

Construction	Resistance (*R*)
1. Outside surface (7.5 mph wind)	*0.25*
2. Built-up roofing (3/8 in.)	*0.33*
3. Roof insulation (C = 0.24)[d]	*4.17*
4. Metal deck	*0.00*
5. Air space[b]	*1.23*
6. Metal lath and 7. 3/4 in. plas. (sand agg.)	*0.13*
8. Inside surface (still air)	*0.92*
Total resistance	*7.03*
$U = 1/R = 1/7.03$ =	0.14

See value 0.14 in boldface type in table below.

Example of Substitution

Resistances used are given below in this table or in Tables 3 or 4

Replace item 3 with roof insulation (C = 0.36) and items 6 and 7 with metal lath and 3/4 in. plas. (lt. wt. agg.)		
Total resistance		*7.03*
Deduct 3. Roof insulation (C = 0.24)	*4.17*	
6. Metal lath and 7. 3/4 in. plas. (sand agg.)	*0.13*	*4.30*
Difference		*2.73*
Add 3. Roof insulation (C = 0.36)	*2.78*	
6. Metal lath and 7. 3/4 in. plas. (lt. wt. agg.)	*0.47*	*3.25*
Total resistance		*5.98*
$U = 1/R = 1/5.98$ =		0.17

To Adjust U Values for Construction with Added Insulation in Air Space See Table 16

Type of Deck (Built-up Roof in All Cases)		Insulation Added on Top of Deck[d]		Type of Ceiling											
				None	Gypsum Bd. (3/8 in.) and Plas.			Metal Lath and Plas.		Insul. Bd. (1/2 in.)	Acoustical Tile				
											On Furring		On Gypsum Bd. (1/2 in.)		
		Con-duct-ance of Insul.	Resis-tance		None	Lt. wt. agg. 1/2 in.	Sand agg. 1/2 in.	Lt. wt. agg. 3/4 in.	Sand agg. 3/4 in.	Plain (1.43) or 1/2 in. plas. sand agg. 1.52	1/2 in.	3/4 in.	1/2 in.	3/4 in.	Number
Resistance ——			↓	→	0.32	0.64	0.41	0.47	0.13	1.47	1.19	1.78	1.51	2.10	
Material	R	C	R	U A′	U B′	U C′	U D′	U E′	U F′	U G′	U H′	U I′	U J′	U K′	
Wood[c] 1 in.	*0.98*	None	—	0.40	0.25	0.23	0.24	0.24	0.26	0.19	0.20	0.18	0.19	0.17	**1**
		0.72	*1.39*	0.26	0.18	0.17	0.18	0.18	0.19	0.15	0.16	0.15	0.15	0.14	**2**
		0.36	*2.78*	0.19	0.15	0.14	0.14	0.14	0.15	0.13	0.13	0.12	0.13	0.12	**3**
		0.24	*4.17*	0.15	0.12	0.12	0.12	0.12	0.12	0.11	0.11	0.10	0.11	0.10	**4**
		0.19	*5.26*	0.13	0.11	0.10	0.11	0.11	0.11	0.10	0.10	0.09	0.10	0.09	**5**
		0.15	*6.67*	0.11	0.09	0.09	0.09	0.09	0.10	0.08	0.09	0.08	0.08	0.08	**6**
		0.12	*8.33*	0.09	0.08	0.08	0.08	0.08	0.08	0.07	0.08	0.07	0.07	0.07	**7**
Wood[c] 2 in.	*2.03*	None	—	0.28	0.20	0.19	0.19	0.19	0.20	0.16	0.17	0.15	0.16	0.15	**8**
		0.72	*1.39*	0.20	0.15	0.15	0.15	0.15	0.16	0.13	0.14	0.13	0.13	0.12	**9**
		0.36	*2.78*	0.16	0.13	0.12	0.13	0.12	0.13	0.11	0.11	0.11	0.11	0.10	**10**
		0.24	*4.17*	0.13	0.11	0.10	0.11	0.11	0.11	0.10	0.10	0.09	0.10	0.09	**11**
		0.19	*5.26*	0.11	0.10	0.07	0.10	0.10	0.10	0.09	0.09	0.08	0.09	0.08	**12**
		0.15	*6.67*	0.10	0.09	0.08	0.08	0.08	0.09	0.08	0.08	0.08	0.08	0.07	**13**
		0.12	*8.33*	0.08	0.07	0.07	0.07	0.07	0.08	0.07	0.07	0.07	0.07	0.07	**14**
Wood[c] 3 in.	*3.23*	None	—	0.21	0.16	0.15	0.16	0.15	0.16	0.13	0.14	0.13	0.13	0.12	**15**
		0.72	*1.39*	0.16	0.13	0.12	0.13	0.13	0.13	0.11	0.12	0.11	0.11	0.11	**16**
		0.36	*2.78*	0.13	0.11	0.11	0.11	0.11	0.11	0.10	0.10	0.09	0.10	0.09	**17**
		0.24	*4.17*	0.11	0.10	0.09	0.09	0.09	0.10	0.09	0.09	0.08	0.09	0.08	**18**
		0.19	*5.26*	0.10	0.09	0.08	0.09	0.09	0.09	0.08	0.08	0.08	0.08	0.07	**19**
		0.15	*6.67*	0.09	0.08	0.08	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.07	**20**
		0.12	*8.33*	0.08	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06	**21**
Preformed slabs—wood fiber and cement binder															
2 in.	*3.60*	None	—	0.20	0.15	0.14	0.15	0.15	0.15	0.13	0.13	0.12	0.13	0.12	**22**
3 in.	*5.40*	None	—	0.14	0.12	0.11	0.12	0.12	0.12	0.10	0.11	0.10	0.10	0.10	**23**
Flat Metal Roof Deck	*0*	None	—	0.67	0.33	0.30	0.32	0.31	0.35	0.24	0.26	0.22	0.24	0.21	**24**
		0.72	*1.39*	0.35	0.23	0.21	0.22	0.22	0.24	0.18	0.19	0.17	0.18	0.16	**25**
		0.36	*2.78*	0.23	0.17	0.16	0.17	0.17	0.18	0.14	0.15	0.14	0.14	0.13	**26**
		0.24	*4.17*	0.18	0.14	0.13	0.14	0.14	**0.14**	0.12	0.12	0.12	0.12	0.11	**27**
		0.19	*5.26*	0.15	0.12	0.12	0.12	0.12	0.12	0.11	0.11	0.11	0.10	0.10	**28**
		0.15	*6.67*	0.12	0.10	0.10	0.10	0.10	0.10	0.09	0.09	0.09	0.09	0.09	**29**
		0.12	*8.33*	0.10	0.09	0.09	0.09	0.09	0.09	0.08	0.08	0.08	0.08	0.08	**30**

[a] See text section Calculating Overall Coefficients for basis of calculations.

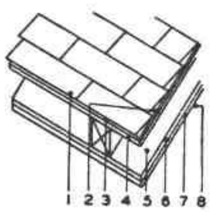
[b] To adjust U values for the effect of added insulation between framing members, see Table 16.

[c] Wood deck 1, 2, and 3 in. is assumed to be 25/32, 1 5/8, and 2 5/8, in. thick, respectively. The thermal conductivity k is assumed to be 0.80.

[d] If a vapor barrier is used beneath roof insulation it will have a negligible effect on the U value. For information on vapor barrier requirements see Chapter 10, Moisture in Building Construction.

Table 15 . . . . Coefficients of Transmission (*U*) of Pitched Roofs[a, b]

Coefficients are expressed in Btu per (hour) (square foot) (Fahrenheit degree difference in temperature between the air on the two sides), and are based on an outside wind velocity of 15 mph for heat flow upward and 7.5 mph for heat flow downward



Example—Roof C 4

Resistances used are given below in this table or in Table 3 or 4

Construction (Heat flow up)	Resistance (*R*)
1. Outside surface (15 mph wind)	*0.17*
2. Slate shingles (½ in.)	*0.05*
3. Building paper	*0.06*
4. Wood sheathing (25/32 in.)	*0.98*
5. Air space[c]	*0.90*
6. Gypsum lath (⅜ in.)	*0.32*
7. Plas. (sand agg.) (½ in.)	*0.09*
8. Inside surface (still air)	*0.62*
Total resistance	*3.19*
$U = 1/R = 1/3.19$	0.31

See value 0.31 in boldface type in table below.

Example of Substitution

Resistances used are given below in this table or in Table 3 or 4

Find *U* value for same construction with heat flow down (summer conditions)

Total resistance		*3.19*
Deduct 1. Outside surface (15 mph wind)	*0.17*	
5. Air space	*0.90*	
8. Inside surface (still air)	*0.62*	*1.69*
Difference		*1.50*
Add 1. Outside surface (7.5 mph wind)	*0.25*	
5. Air space	*0.89*	
8. Inside surface (still air)	*0.76*	*1.90*
Total resistance		*3.40*
$U = 1/R = 1/3.40$		0.29

To Adjust U Values for Construction with Added Insulation between Framing Members, See Table 16

Direction of Heat Flow →		Upward Flow Winter Conditions					Downward Flow Summer Conditions					
		Rafter Space					Rafter Space					
		Unventilated, Not to be Further Insulated				Insulated	Unventilated, Not to be Further Insulated				Insulated	
Type of Ceiling (Applied Directly to Roof Rafters)		Asphalt shingles building paper: On plywood sheathing (5/16 in.)	Asphalt shingles building paper: On wood sheathing (25/32 in.)	Asbestos-cement slate or tile shingles, building paper on wood sheathing (25/32 in.)	Wood shingles on 1 x 4 in. wood strips on 6-in. centers	Roof and sheathing disregarded[d]	Asphalt shingles building paper: On plywood sheathing (5/16 in.)	Asphalt shingles building paper: On wood sheathing (25/32 in.)	Asbestos-cement slate, or tile shingles, building paper on wood sheathing (25/32 in.)	Wood shingles on 1 x 4 in. wood strips on 6 in. centers	Roof and sheathing disregarded[d]	Number
Resistance →		0.95	1.48	1.09	0.87	—	0.95	1.48	1.09	0.87	—	
Material	*R* ↓	*U*	*U*	*U*	*U*	*U*	*U*	*U*	*U*	*U*	*U*	
		A	B	C	D	E	F	G	H	I	J	
None	—	0.57	0.44	0.53	0.60	0.66	0.51	0.40	0.48	0.53	0.56	**1**
Gypsum bd. (⅜ in.)	*0.32*	0.34	0.29	0.32	0.35	0.54	0.30	0.26	0.29	0.31	0.47	**2**
Gypsum lath (⅜ in.) & ½ in. plas. (lt. wt. agg.)	*0.64*	0.30	0.26	0.29	0.31	0.46	0.28	0.24	0.27	0.28	0.41	**3**
Gypsum lath (⅜ in.) and ½ in. plas. (sand agg.)	*0.41*	0.33	0.28	**0.31**	0.34	0.52	0.29	0.25	0.28	0.30	0.45	**4**
Metal lath and ¾ in. plas. (lt. wt. agg.)	*0.47*	0.32	0.27	0.31	0.33	0.50	0.29	0.25	0.28	0.30	0.44	**5**
Metal lath and ¾ in. plas. (sand agg.)	*0.13*	0.36	0.30	0.34	0.37	0.61	0.32	0.27	0.31	0.33	0.52	**6**
Insul. bd. (½ in.)	*1.43*	0.25	0.22	0.24	0.25	0.34	0.23	0.20	0.22	0.23	0.31	**7**
Insul. bd. lath and ½ in. plas. (sand agg.)	*1.52*	0.24	0.21	0.23	0.25	0.33	0.22	0.20	0.22	0.23	0.30	**8**
Acoustical tile												
(½ in.) on gypsum bd. (⅜ in.)	*1.51*	0.24	0.21	0.23	0.25	0.33	0.22	0.20	0.22	0.23	0.30	**9**
(½ in.) on furring	*1.19*	0.26	0.23	0.25	0.27	0.37	0.24	0.21	0.23	0.24	0.34	**10**
(¾ in.) on gypsum bd. (⅜ in.)	*2.10*	0.21	0.19	0.20	0.21	0.26	0.20	0.18	0.19	0.20	0.26	**11**
(¾ in.) on furring	*1.78*	0.23	0.20	0.22	0.23	0.30	0.21	0.19	0.20	0.21	0.28	**12**
Wood lath and ½ in. plas. (sand agg.)	*0.40*	0.33	0.28	0.31	0.34	0.52	0.29	0.26	0.28	0.30	0.46	**13**

[a] See text section Calculating Overall Coefficients for basis of calculations.

[b] Pitch of roof—45 deg.

[c] To adjust *U* values for the effect of added insulation between framing members, see Table 16.

[d] When insulation is installed between rafters, the space above should be ventilated and in this case the roof construction is disregarded in calculation of *U* values. To adjust *U* values for pitched roof construction with added insulation between framing members, use the average of values for horizontal and vertical heat flow in Table 16A and either 16C or 16D depending on direction of heat flow.

Table 16 . . . . Determination of *U* Value Resulting from Addition of Insulation or Air Spaces to Uninsulated Building Sections*

PART A. WALLS[a]

U Value[b] Without Added Insulation	*Fibrous Insulation*[c] *Thickness—Inches*				*One Air Space of Effective Emissivity*[d] E			*Two Air Spaces of Effective Emissivity*[d] E			*Three Air Spaces of Effective Emissivity*[d] E		
	½	1	2	3	0.82[e]	0.20	0.05	0.82	0.20	0.05	0.82	0.20	0.05
Col. 1	2	3	4	5	6	7	8	9	10	11	12	13	14
0.70	0.304	0.194	0.113	0.080	0.752	0.463	0.380	0.437	0.240	0.189	0.298	0.150	0.112
0.60	0.284	0.186	0.110	0.078	0.630	0.412	0.341	0.392	0.225	0.177	0.276	0.144	0.108
0.45	0.246	0.168	0.104	0.075	0.460	0.331	0.280	0.318	0.195	0.158	0.237	0.130	0.098
0.40	0.230	0.161	0.101	0.074	0.409	0.299	0.258	0.291	0.185	0.149	0.222	0.125	0.095
0.35	0.212	0.152	0.097	0.072	0.354	0.267	0.234	0.262	0.172	0.140	0.205	0.119	0.092
0.30	0.192	0.142	0.093	0.069	0.30	0.234	0.207	0.232	0.158	0.130	0.186	0.112	0.087
0.28	0.184	0.138	0.091	0.068	0.28	0.221	0.196	0.220	0.151	0.125	0.178	0.108	0.084
0.26	0.175	0.133	0.089	0.066	0.26	0.208	0.185	0.207	0.144	0.120	0.169	0.104	0.082
0.24	0.166	0.127	0.087	0.065	0.24	0.194	0.173	0.194	0.137	0.115	0.160	0.100	0.079
0.22	0.156	0.121	0.084	0.064	0.22	0.180	0.161	0.180	0.129	0.110	0.150	0.096	0.076
0.20	0.145	0.115	0.081	0.062	0.20	0.165	0.149	0.166	0.120	0.104	0.140	0.091	0.073
0.18	0.134	0.108	0.078	0.060	0.18	0.150	0.137	0.152	0.112	0.098	0.129	0.086	0.069
0.16	0.123	0.100	0.074	0.057	0.16	0.136	0.124	0.137	0.103	0.090	0.118	0.080	0.065
0.14	0.111	0.092	0.069	0.054	0.14	0.120	0.111	0.122	0.094	0.083	0.106	0.075	0.061
0.12	0.098	0.083	0.064	0.051	0.12	0.105	0.098	0.107	0.084	0.075	0.094	0.068	0.056
0.10	0.085	0.073	0.058	0.047	0.10	0.089	0.084	0.091	0.074	0.066	0.082	0.061	0.051
0.08	0.070	0.062	0.050	0.042	0.08	0.073	0.068	0.074	0.062	0.056	0.068	0.053	0.045

* For constructions with air spaces as insulation, coefficients are based on National Bureau of Standards data in *Housing Research Paper* No. 32 (U. S. Government Printing Office, Washington, D. C.).

[a] Based on an indoor-outdoor temperature difference of 70 F deg, and a mean temperature of 50 F. Values are applicable conservatively to winter and summer conditions.

[b] *U* value taken from Tables 5 to 15, based on one nonreflective 3⅝-in. air space between framing members.

[c] Thermal conductivity of fibrous or bulk insulation taken as 0.27 Btu per (hr) (sq ft) (F deg per in.).

[d] For values of effective emissivity E of air space, see Table 3, Section B.

[e] Certain *U* values in Column 6 differ from Column 1 because they are adjusted to the specific temperature drop across the air space in question as affected by the *U* value of the construction.

PART B. FLOORS[f]—HEAT FLOW DOWN

U Value[g] Without Added Insulation	*Fibrous Insulation*[h] *Thickness—Inches*				*One Air Space of Effective Emissivity*[i] E			*Two Air Spaces of Effective Emissivity*[i] E			*Three Air Spaces of Effective Emissivity*[i] E		
	½	1	2	3	0.82	0.20	0.05	0.82	0.20	0.05	0.82	0.20	0.05
Col. 1	2	3	4	5	6	7	8	9	10	11	12	13	14
0.70	0.305	0.195	0.113	0.080	0.70	0.240	0.114	0.377	0.122	0.057	0.262	0.086	0.042
0.60	0.284	0.186	0.110	0.078	0.60	0.236	0.111	0.346	0.118	0.056	0.246	0.084	0.041
0.50	0.260	0.175	0.106	0.076	0.50	0.210	0.106	0.310	0.114	0.055	0.228	0.082	0.041
0.45	0.246	0.168	0.104	0.075	0.45	0.200	0.103	0.290	0.111	0.055	0.217	0.081	0.040
0.40	0.230	0.161	0.101	0.074	0.40	0.189	0.100	0.268	0.107	0.054	0.205	0.079	0.040
0.35	0.212	0.152	0.097	0.072	0.35	0.176	0.096	0.244	0.103	0.052	0.192	0.077	0.040
0.30	0.192	0.142	0.093	0.069	0.30	0.162	0.091	0.219	0.098	0.051	0.175	0.074	0.039
0.28	0.184	0.138	0.091	0.068	0.28	0.156	0.089	0.208	0.096	0.050	0.168	0.073	0.039
0.26	0.175	0.133	0.089	0.066	0.26	0.150	0.087	0.197	0.094	0.049	0.161	0.072	0.038
0.24	0.166	0.127	0.087	0.065	0.24	0.143	0.084	0.185	0.091	0.048	0.153	0.070	0.038
0.22	0.156	0.121	0.084	0.064	0.22	0.136	0.081	0.173	0.088	0.047	0.145	0.068	0.037
0.20	0.145	0.115	0.081	0.062	0.20	0.128	0.078	0.160	0.084	0.046	0.136	0.066	0.036
0.18	0.134	0.108	0.078	0.060	0.18	0.119	0.074	0.148	0.080	0.045	0.126	0.064	0.036
0.16	0.123	0.100	0.074	0.057	0.16	0.109	0.070	0.133	0.076	0.044	0.116	0.061	0.035
0.14	0.111	0.092	0.069	0.054	0.14	0.099	0.065	0.118	0.071	0.042	0.105	0.058	0.034
0.12	0.098	0.083	0.064	0.051	0.12	0.088	0.060	0.103	0.066	0.040	0.094	0.054	0.033
0.10	0.085	0.073	0.058	0.047	0.10	0.076	0.054	0.089	0.058	0.037	0.081	0.049	0.031
0.08	0.070	0.062	0.050	0.042	0.08	0.063	0.047	0.072	0.050	0.033	0.068	0.044	0.028

* For construction with air spaces as insulation, coefficients are based on National Bureau of Standards data in *Housing Research Paper* No. 32 (U. S. Government Printing Office, Washington, D. C.).

[f] Based on a temperature difference of 50 F deg from air to air, and a mean temperature of 50 F.

[g] *U* value taken from Tables 11 and 12, in which it is assumed that the air space between joists or above the suspended ceiling is nonreflective (E = 0.82), and is 8 in. thick.

[h] Thermal conductivity of fibrous or bulk insulation taken as 0.27 Btu per (hr) (sq ft) (F deg per in.).

[i] For values of effective emissivity E of air space, see Table 3, Section B.

Table 16 . . . . Determination of *U* Value Resulting from Addition of Insulation or Air Spaces to Uninsulated Building Sections* (*Continued*)

PART C. CEILINGS—HEAT FLOW UP[j] *(WINTER CONDITION)*

U Value[k] *Without Added Insulation*	*Fibrous Insulation*[l] *Thickness—Inches*				*One Air Space of Effective Emissivity*[m] E			*Two Air Spaces of Effective Emissivity*[m] E			*Three Air Spaces of Effective Emissivity*[m] E		
	½	1	2	3	0.82[n]	0.20	0.05	0.82	0.20	0.05	0.82	0.20	0.05
Col. 1	2	3	4	5	6	7	8	9	10	11	12	13	14
0.70	0.305	0.195	0.113	0.080	0.690	0.472	0.403	0.427	0.262	0.216	0.307	0.180	0.146
0.60	0.284	0.186	0.110	0.078	0.588	0.417	0.362	0.385	0.244	0.204	0.284	0.171	0.139
0.50	0.260	0.175	0.106	0.076	0.488	0.361	0.318	0.339	0.224	0.189	0.258	0.160	0.131
0.45	0.246	0.168	0.104	0.075	0.438	0.331	0.295	0.316	0.212	0.180	0.243	0.154	0.126
0.40	0.230	0.161	0.101	0.074	0.389	0.300	0.270	0.288	0.199	0.170	0.227	0.146	0.121
0.35	0.212	0.152	0.097	0.072	0.340	0.269	0.244	0.260	0.185	0.158	0.209	0.138	0.115
0.30	0.192	0.142	0.093	0.069	0.292	0.237	0.215	0.230	0.168	0.145	0.189	0.129	0.108
0.28	0.184	0.138	0.091	0.068	0.272	0.224	0.203	0.217	0.161	0.140	0.181	0.125	0.104
0.26	0.175	0.133	0.089	0.066	0.253	0.211	0.191	0.204	0.154	0.134	0.172	0.120	0.101
0.24	0.166	0.127	0.087	0.065	0.234	0.199	0.179	0.191	0.146	0.128	0.163	0.115	0.097
0.22	0.156	0.121	0.084	0.064	0.214	0.186	0.166	0.178	0.137	0.120	0.153	0.109	0.093
0.20	0.145	0.115	0.081	0.062	0.195	0.173	0.154	0.164	0.128	0.114	0.143	0.104	0.088
0.18	0.134	0.108	0.078	0.060	0.176	0.159	0.141	0.150	0.119	0.106	0.132	0.097	0.084
0.16	0.123	0.100	0.074	0.057	0.156	0.146	0.128	0.136	0.109	0.098	0.121	0.090	0.079
0.14	0.111	0.092	0.069	0.054	0.137	0.132	0.115	0.120	0.099	0.090	0.109	0.083	0.073
0.12	0.098	0.083	0.064	0.051	0.118	0.118	0.101	0.105	0.088	0.080	0.096	0.075	0.068
0.10	0.085	0.073	0.058	0.047	0.099	0.105	0.088	0.090	0.076	0.071	0.082	0.067	0.062
0.08	0.070	0.062	0.050	0.042	0.079	0.091	0.074	0.073	0.064	0.061	0.067	0.058	0.056

* For construction with air spaces as insulation, coefficients are based on National Bureau of Standards data in *Housing Research Paper* No. 32 (U. S. Government Printing Office, Washington, D. C.).

[j] Based on a temperature difference of 75 deg F from air to air, and a mean temperature of 40 F.

[k] *U* value taken from Tables 11, 12, 13-A, 14-A, and 15, in which it is assumed that the air space between joists or above the suspended ceiling is nonreflective (E = 0.82), and is 8 in. thick.

[l] Thermal conductivity of fibrous or bulk insulation taken as 0.27 Btu per (hr) (sq ft) (F deg per in.).

[m] For values of effective emissivity E of air space, see Table 3, Section B.

[n] Certain *U* values in Column 6 differ from Column 1 because they are adjusted to the specific temperature drop across the air space in question as affected by the *U* value of the construction.

PART D. CEILINGS—HEAT FLOW DOWN[o] *(SUMMER CONDITION)*

U Value[p] *Without Added Insulation*	*Fibrous Insulation*[q] *Thickness— Inches*				*One Air Space of Effective Emissivity*[r] E			*Two Air Spaces of Effective Emissivity*[r] E			*Three Air Spaces of Effective Emissivity*[r] E		
	½	1	2	3	0.82	0.20	0.05	0.82	0.20	0.05	0.82	0.20	0.05
Col. 1	2	3	4	5	6	7	8	9	10	11	12	13	14
0.70	0.305	0.195	0.113	0.080	0.704	0.269	0.119	0.423	0.144	0.061	0.306	0.103	0.046
0.60	0.284	0.186	0.110	0.078	0.602	0.252	0.116	0.384	0.139	0.060	0.284	0.100	0.046
0.50	0.260	0.175	0.106	0.076	0.501	0.231	0.112	0.340	0.133	0.059	0.260	0.097	0.045
0.45	0.246	0.168	0.104	0.075	0.450	0.220	0.108	0.316	0.128	0.058	0.246	0.095	0.044
0.40	0.230	0.161	0.101	0.074	0.400	0.206	0.105	0.291	0.123	0.057	0.230	0.092	0.044
0.35	0.212	0.152	0.097	0.072	0.350	0.192	0.100	0.264	0.118	0.056	0.213	0.090	0.043
0.30	0.192	0.142	0.093	0.069	0.300	0.175	0.095	0.234	0.112	0.055	0.193	0.086	0.042
0.28	0.184	0.138	0.091	0.068	0.280	0.168	0.093	0.222	0.109	0.054	0.185	0.085	0.042
0.26	0.175	0.133	0.089	0.066	0.260	0.160	0.090	0.209	0.105	0.054	0.176	0.083	0.041
0.24	0.166	0.127	0.087	0.065	0.240	0.152	0.087	0.195	0.102	0.053	0.167	0.080	0.040
0.22	0.156	0.121	0.084	0.064	0.220	0.144	0.084	0.182	0.098	0.052	0.157	0.078	0.040
0.20	0.145	0.115	0.081	0.062	0.200	0.135	0.081	0.168	0.094	0.050	0.146	0.075	0.039
0.18	0.134	0.108	0.078	0.060	0.180	0.125	0.077	0.154	0.089	0.049	0.135	0.072	0.038
0.16	0.123	0.100	0.074	0.057	0.160	0.115	0.073	0.139	0.084	0.047	0.124	0.068	0.038
0.14	0.111	0.092	0.069	0.054	0.140	0.104	0.069	0.124	0.078	0.045	0.111	0.064	0.037
0.12	0.098	0.083	0.064	0.051	0.120	0.093	0.063	0.108	0.072	0.042	0.098	0.059	0.035
0.10	0.085	0.073	0.058	0.047	0.099	0.080	0.056	0.091	0.064	0.039	0.084	0.054	0.033
0.08	0.070	0.062	0.050	0.042	0.079	0.068	0.048	0.074	0.054	0.034	0.070	0.046	0.030

[o] Based on a temperature difference of 35 F deg from air to air, and a mean temperature of 100 F.

[p] *U* value taken from Tables 11, 12, 13-B, 14-B, and 15, in which it is assumed that the air space between joists or above the suspended ceiling is nonreflective (E = 0.82), and is 8 in. thick.

[q] Thermal conductivity of fibrous or bulk insulation taken as 0.27 Btu per (hr) (sq ft) (F deg per in.).

[r] For values of effective emissivity E of air space, see Table 3, Section B.

Table 16 . . . . Determination of *U* Value Resulting from Addition of Insulation to Uninsulated Building Sections (Concluded)

(For use with Tables 13A and 13B)

PART E. FLAT ROOFS AND CEILINGS WITH ROOF DECK

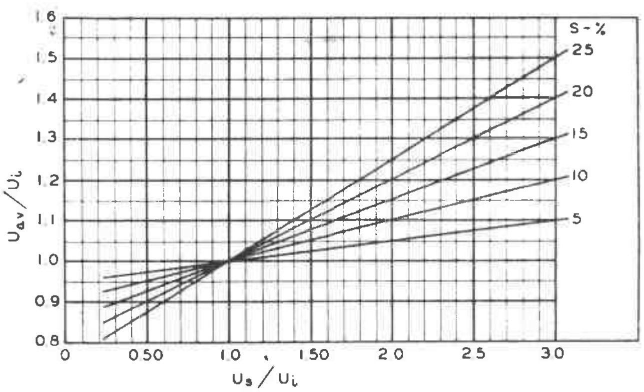
U Value of Roof without Roof-Deck Insulation[a]	*Conductance C of Roof-Deck Insulation*					
	0.12	0.15	0.19	0.24	0.36	0.72
	U	*U*	*U*	*U*	*U*	*U*
0.10	0.05	0.06	0.07	0.07	0.08	0.09
0.15	0.07	0.08	0.08	0.09	0.11	0.12
0.20	0.08	0.09	0.10	0.11	0.13	0.16
0.25	0.08	0.09	0.11	0.12	0.15	0.19
0.30	0.09	0.10	0.12	0.13	0.16	0.21
0.35	0.09	0.10	0.12	0.14	0.18	0.24
0.40	0.09	0.11	0.13	0.15	0.19	0.26
0.50	0.10	0.12	0.14	0.16	0.21	0.29
0.60	0.10	0.12	0.14	0.17	0.22	0.33
0.70	0.10	0.12	0.15	0.18	0.24	0.35

[a] Interpolation or mild extrapolation may be used

CORRECTION FOR FRAMING

Correction for parallel heat flow through framing and insulated areas may be made by use of Fig. 7. Correction for the effect of framing should be applied after final U_i and U_s values have been obtained for a given construction. In many cases this correction may be omitted.

Example 7: Consider a frame wall with 2-in. blanket insulation which has a U_i value of 0.08. By calculation it is found that heat loss from the area backed by framing members (U_s) is 0.13. U_s/U_i is 1.63. From Fig. 7 if 15 percent of wall area is backed by framing, the value U_{ab}/U_i = 1.1. U_{at} is therefore 1.1 × 0.08 = 0.088.



U_{av} = *average U value for building section.*
U_i = *U value for area between framing members.*
U_s = *U value for area backed by framing members.*
S = *percentage of area backed by framing members.*

Fig. 7 . . . . Correction for Effect of Framing in Insulated Building Sections

VENTILATED ATTICS—HOW TO USE TABLE 17

Table 17 is intended to be used with Table 11, Part D of Table 16, and Fig. 7, or when ceiling resistance is known. Its purpose is to determine the resistance to heat flow of the attic space under various conditions of ventilating air temperatures and rates, ceiling resistance, roof or sol-air temperatures, and surface emissivities.[11] Ventilating air temperature is the outdoor design temperature.

The total resistance, $1/U$, obtained by adding the ceiling and attic resistances can be converted to a U value so that the heat gain may be calculated. The applicable temperature difference is that difference between room air and sol-air temperature or between room air and roof temperatures. (See footnote d, Table 17.)

Table 17 may be used for both pitched and flat residential roofs over attic spaces. When there is an attic floor, the ceiling resistance should be that which applies to the complete ceiling-floor construction.

All values in Table 16, Part D, include the resistance of a non-reflective surface facing the attic space. Therefore, if separate calculations are made, include only the value of a non-reflective surface and not the value of a reflective surface in determining ceiling resistance. The use of Table 17, Part B, will account for this reflection surface.

Example 8: Determine the heat gain for a 1000 sq ft ceiling of ⅜-in. gypsum board and ½-in. light weight aggregate plaster, with no flooring above, when insulated with a 2-in. foil-enclosed fibrous blanket. The blanket is installed so as to form a reflective air space between the ceiling and the blanket. The attic has a gable roof which meets the ventilation requirements in Table 3, Chapter 10. (Use ventilation rate of 0.1 cfm per sq ft.)

Design temperatures are: indoor air = 75 F, outdoor air = 95 F, and sol-air = 160 F.

Solution: From Table 11, for heat flow down, the U value for this ceiling G3 without insulation is 0.40. Referring to Table 16, Part D, with the value 0.40 in Column 1, find U_i = 0.101 in Column 4; enter Column 1 at 0.101 and find U_i = 0.056 in Column 8. Correct for framing (8 in. joists on 16 in. centers) from Fig. 7 and find corrected ceiling coefficient U_c = 0.059; R_c = 17.0.

By interpolation in Table 17, Part B, using 95 F ventilation air and 160 F sol-air temperatures, the effective attic resistance R_a is 8.2.

The overall coefficient for the combined ceiling and attic is:

$$U_o = \frac{1}{R_c + R_a} = \frac{1}{17.0 + 8.2} = 0.04$$

Heat gain = $U_o\, A\, (t_s - t_i)$ = 0.04 × 1000 × (160–75) = 3400 Btuh

COMBINED CEILING AND ROOF COEFFICIENTS

If the attic space between the ceiling and roof is unheated and *not ventilated*, the combined coefficient from room air below the ceiling to exterior air can be calculated from the following formula:

$$R_T = \frac{1}{U_{ce}} + \frac{1}{nU_r} \qquad (5)$$

The combined coefficient U is the reciprocal of R_T, or

$$U = 1/R_T \qquad (6)$$

where

U = combined coefficient to be used with ceiling area.
R_T = total resistance of ceiling and roof.
U_{ce} = coefficient of transmission of ceiling.
U_r = coefficient of transmission of roof.
n = ratio of roof area to ceiling area.

It should be noted that the overall coefficient U should be multiplied by the ceiling area to determine heat loss, and not

Table 17 . . . . Effective Resistance of Ventilated Attics[a]—(Summer Condition)[11]

PART A. NON-REFLECTIVE SURFACES

Ventilation Air temp., F	Sol-air[d] temp., F	No Ventilation		Natural Ventilation		Power Ventilation[e]					
		Ventilation rate, cfm/ sq ft									
		0		0.1[b]		0.5		1.0		1.5	
		1/U Ceiling resistance, ru[c]									
		10	20	10	20	10	20	10	20	10	20
80	120	1.9	1.9	2.8	3.4	6.3	9.3	9.6	16	11	20
	140	1.9	1.9	2.8	3.5	6.5	10	9.8	17	12	21
	160	1.9	1.9	2.8	3.6	6.7	11	10	18	13	22
90	120	1.9	1.9	2.5	2.8	4.6	6.7	6.1	10	6.9	13
	140	1.9	1.9	2.6	3.1	5.2	7.9	7.6	12	8.6	15
	160	1.9	1.9	2.7	3.4	5.8	9.0	8.5	14	10	17
100	120	1.9	1.9	2.2	2.3	3.3	4.4	4.0	6.0	4.1	6.9
	140	1.9	1.9	2.4	2.7	4.2	6.1	5.8	8.7	6.5	10
	160	1.9	1.9	2.6	3.2	5.0	7.6	7.2	11	8.3	13
PART B. REFLECTIVE SURFACES[f]											
80	120	6.5	6.5	8.1	8.8	13	17	17	25	19	30
	140	6.5	6.5	8.2	9.0	14	18	18	26	20	31
	160	6.5	6.5	8.3	9.2	15	18	19	27	21	32
90	120	6.5	6.5	7.5	8.0	10	13	12	17	13	19
	140	6.5	6.5	7.7	8.3	12	15	14	20	16	22
	160	6.5	6.5	7.9	8.6	13	16	16	22	18	25
100	120	6.5	6.5	7.0	7.4	8.0	10	8.5	12	8.8	12
	140	6.5	6.5	7.3	7.8	10	12	11	15	12	16
	160	6.5	6.5	7.6	8.2	11	14	13	18	15	20

[a] The term *effective resistance* is used when there is attic ventilation. A value for no ventilation is also included. The effective resistance of the attic may be added to the resistance (1/U) of the ceiling (Table 16, Part D) to obtain the effective resistance of the combination based on sol-air (Chapter 13) and room temperature. These values apply to wood frame construction with a roof deck and roofing having a conductance of 1.0 Btu/(sq ft) (hr) (F deg).

[b] When attic ventilation meets the requirements of Table 3 in Chapter 10, 0.1 cfm/sq ft may be assumed as the natural summer ventilation rate for design purposes.

[c] *Resistance Unit*, abbreviated *ru* is one (hr) (sq ft) (F deg) per Btu. Determine ceiling resistance from Tables 11 and 16, and correct for framing by Figure 7. Do not add the effect of a reflective surface facing the attic to the ceiling resistance from Table 16, Part D, as it is accounted for in Table 17, Part B.

[d] Roof surface temperature rather than sol-air temperature (see Chapter 13) may be used if 0.25 is subtracted from the attic resistance shown.

[e] Based on air discharging outward from attic.

[f] Surfaces with effective emissivity E of 0.05 between ceiling joists facing the attic space.

by the roof area. Values of U_r and U_{ce} should be calculated using a value of 2.5 (the reciprocal of one-half the air space resistance, 0.80) rather than the conductances of surfaces facing the attic, since the attic is assumed to be equivalent to an air space.

If the attic contains windows, dormers, and vertical wall spaces, and if their area is small compared to that of the roof, they may be considered part of the roof area. For accuracy, the sum of the coefficients of each individual section, multiplied by its percentage of the total area, should be used as U_r. Where attic wall areas are large or where louvers or vents are used, it is preferable to estimate the attic temperature as illustrated in Chapter 12, and calculate the heat loss through the ceiling by multiplying the value of U_{ce} for the ceiling by the difference in temperature above and below the ceiling.

BASEMENT FLOOR, BASEMENT WALL, AND CONCRETE SLAB FLOOR COEFFICIENTS

The heat transfer through basement walls and floors to the ground is dependent on the temperature difference between the air within and that of the ground, on the material constituting the wall or floor, and on the conductivity of the surrounding earth. The conductivity of the earth will vary with local conditions, and is usually unknown. Tests[12] at the ASHAE Research Laboratory indicate a heat flow of approximately 2.0 Btu per (hr) (sq ft) through an uninsulated concrete basement floor, with a temperature difference of 20 deg between ground temperature and the air temperature 6 in. above the floor (see Table 18).

For basement walls below grade only, the temperature difference for winter design conditions will be greater than for the floor. The test results indicate a unit area heat loss, at mid-height of the basement wall portion below grade approximately twice that of the same floor area.

For concrete slab floors laid in contact with the ground at grade level, tests[13] indicate that for *small floor areas* (equal to

Table 18 . . . . Coefficients of Transmission (*U*) of Concrete Basement Floors on Ground with Various Types of Finish Flooring

U = 0.10[a] Btu per (hr) (sq ft) (Fahrenheit degree temperature difference between the ground and the air over the floor).

[a] Since authentic data are not available, this coefficient is sometimes used for concrete floors on ground. For more recent procedures[13] refer to *National Bureau of Standards Report* BMS-103.

that of a house 25 feet square) the heat loss may be calculated as proportional to the length of exposed edge rather than total area. This amounts to 0.81 Btu per (hr) (linear foot of exposed edge) (Fahrenheit degree difference between the indoor air temperature and the average outdoor air temperature). It should be noted that this may be appreciably reduced by insulating under the ground slab, and also along the edges between the floor and the abutting walls. See also sections on Basement Temperatures and Heat Loss, and on Floor Heat Loss in Basementless Houses, in Chapter 12. In most calculations if the perimeter loss is calculated accurately, no other floor loss need be considered.

GLASS AND DOOR COEFFICIENTS

The U values for glass sheets and hollow glass block, given in Sections A, B, and C of Table 19, have been computed by methods ind data given in an ASHVE Research Paper.[8] It is assumed that the surface conductance for convection loss to the air is 4.0 Btu per (hr) (sq ft) (F deg). It is also assumed that the glass loses heat by radiation to the ground and to the clear sky, which together have an effective radiating temperature *below* the air temperature. It is therefore necessary to determine, by trial and error, the temperature of the outdoor glass surface such that the sum of the radiation and convection losses equals the heat conducted through the glass section, and equals the heat delivered to the glass from the heated space. This heat flow, divided by the air-to-air temperature difference, results in a U value that is used in the usual manner. The equivalent surface conductance for radiation and convection combined, based on *air-to-surface* temperature difference, therefore varies from about 5.5 for single glass to about 6.6 for double glass for exactly the same environmental design conditions. Curtains, draperies, Venetian blinds, etc., will result in lower glass surface temperatures than when the windows are not covered.

It is assumed that the room air temperature equals the average temperature of the room surfaces *seen* by the glass. Special consideration should be given to those cases where the glass *sees* interior surfaces at temperatures differing greatly from the room air temperature, i.e., such cases as in sun rooms, greenhouses, and some panel heated rooms, or where there is an unusual amount of air motion in the vicinity of the glass. Although based on zero outdoor air, the values change only slightly with different design temperatures, being about 5 percent greater for a 30 F outdoor design temperature.

In computing the Table 19 values, consideration of the dependence of the indoor surface conductances upon temperature and direction of heat flow leads to surface conductances averaging about 1.50 for block and vertical glass, and about 1.80 for horizontal glass, as compared to the value of 1.46 used in computing U values given in other tables in this chapter. *These values should therefore be used in estimating the temperature at which condensation on glass surfaces will occur.*

The application factors given in Section D of Table 19 are based upon hot box tests summarized in a research bulletin,[14] and are approximate only. In practice, some variation in heat flow through windows having the same ratio of glass to sash area, may be expected because of difference in construction details and in air-space edge effects. The high conductance of aluminum and steel sash must be taken into consideration where excessive amounts of metal sash and frames are involved. This is particularly important when they are in close proximity to radiation heat sources and are consequently subjected to high differential temperatures.

Table 19 . . . . Coefficients of Transmission (U) of Windows, Skylights and Glass Block Walls

Coefficients are expressed in Btu per (hour) (square foot) (Fahrenheit degree difference in temperature between the air on the two sides). Those for outdoor exposures are based upon the following outdoor conditions: 0 F air temperature, clear skies, no solar radiation, and 15 mph outdoor wind velocity

SECTION A—VERTICAL GLASS SHEETS

Number of Sheets	One	Two			Three		
Air space, inches	None	¼	½	1[a]	¼	½	1[a]
Outdoor exposure	1.13	0.61	0.55	0.53	0.41	0.36	0.34
Indoor exposure	0.75	0.50	0.46	0.45	0.38	0.33	0.32

SECTION B—HORIZONTAL GLASS SHEETS

	Heat Flow Up				Heat Flow Down			
Number of Sheets	One	Two			One	Two		
Air space, inches	None	¼	½	1[a]	None	¼	½	1[a]
Outdoor exposure	1.40	0.70	0.66	0.63	[b]	[c]	—	—
Indoor exposure	0.96	0.59	0.56	0.56	0.60	0.43	0.39	0.38

SECTION C—WALLS OF HOLLOW GLASS BLOCK

Description	Outdoor Exposure	Indoor Partition
5¾ x 5¾ x 3⅞ in. thick	0.60	0.46
7¾ x 7¾ x 3⅞ in. thick	0.56	0.44
11¾ x 11¾ x 3⅞ in. thick	0.52[d]	0.40
7¾ x 7¾ x 3⅞ in. thick with glass fiber dividing the cavity	0.48	0.38
11¾ x 11¾ x 3⅞ in. thick with glass fiber dividing the cavity	0.44	0.36

SECTION D—APPROXIMATE APPLICATION FACTORS FOR WINDOWS—MULTIPLY FLAT GLASS U VALUES BY THESE FACTORS

Window Description	Single Glass		Double Glass[e]		Windows with Storm Sash[f]	
	Percent Glass[g]	Factor	Percent Glass[g]	Factor	Percent Glass[g]	Factor
Sheets	100	1.00	100	1.00		
Wood sash	80	0.90	80	0.95	80	0.90
Wood sash	60	0.80	60	0.85	60	0.80
Steel sash	80	1.00	80	1.20	80	1.00[h]
Aluminum	80	1.10	80	1.30	80	1.10

[a] For 1 in. or greater.

[b] See Chapter 13, Tables 14 and 15, for summer load.

[c] See Chapter 13, Tables 14, 15, and 16, for summer load.

[d] From unpublished data recommended by ASHAE Tech. Adv. Comm. on Heat Flow Through Fenestration.

[e] Unit type double glazing (two lights or panes in same opening).

[f] Use with U values for two sheets with 1 in. air space.

[g] Based on area of exposed portion of sash; does not include frame or portions of sash concealed by frame.

[h] For metal storm sash or metal sash with attached storm pane.

Heat transmission coefficients for wood doors, with and without glass storm doors are given in Table 20.

WIND VELOCITY EFFECT ON *U* VALUES

Tables 5 through 8, 13-A, 14-A, 15, parts of Table 19, and Table 20 show values of U for winter calculations, for an outdoor wind velocity of 15 mph. Tables 13-B and 14-B show values of U for summer calculations and an outdoor wind velocity of 7.5 mph. Tables 11, 12, and 15 show values of U for both winter and summer. Tables 9 through 12 are for indoor U values and are based upon still air. All roof coefficient tables also take into account the direction of heat flow. Care must be exercised in selecting the table which applies to the design conditions. Table 21 shows comparative values of U for other wind velocities. When this table is used for summer U values, it is necessary to enter the table at 7.5 mph which can be interpolated between 5 and 10 mph. Any value taken from this table should be rounded to two significant figures.

Table 20 .... Coefficients of Transmission (*U*) of Solid Wood Doors

Coefficients are expressed in Btu per (hour) (square foot) (Fahrenheit degree difference in temperature between the air on the two sides), and are based upon an outside wind velocity of 15 mph.

Nominal Thickness Inches	Actual Thickness Inches	$U^{a,b}$ Exposed Door	$U^{a,b}$ With Glass Storm Door[c]
1	25/32	0.64	0.37
1¼	1 1/16	0.55	0.34
1½	1 5/16	0.49	0.32
1¾	1 3/8	0.48	0.31
2	1 5/8	0.43	0.28
2½	2 1/8	0.36	0.26
3	2 5/8	0.31	0.23

[a] Computed using k = 1.10 for wood, f_i = 1.46, f_c = 6.0, and 1.03 for air space.
[b] A U value of 0.85 may be used for single exposed doors containing thin wood panels or single panes of glass, and 0.39 for the same with glass storm doors.
[c] 50 per cent glass and thin wood panels.

Example 8: Find the coefficient of transmission U of a frame wall consisting of stucco, 25/32-in. insulation board sheathing, 2 x 4-in. studs, gypsum lath and plaster, and with 2-in. blanket insulation between studs, for 25 mph wind velocity.

Solution: From Table 5, this wall, F37, with no insulation between studs has a value of U = 0.22. From Table 16, Part A, Col. 4, this wall with 2-in. insulation added has a value of U = 0.084. Entering Table 21 in the 15 mph column, interpolate between 0.080 and 0.090 in 15 mph column and proceed horizontally to the 25 mph column where the U value is found by interpolation to be 0.085.

Table 21 .... Conversion Table for Wall Coefficient *U* for Various Wind Velocities

U for 15 mph[a]	*U* for 0 to 30 mph Wind Velocities					
	0	5	10	20	25	30
0.050	0.049	0.050	0.050	0.050	0.050	0.050
0.060	0.059	0.059	0.060	0.060	0.060	0.060
0.070	0.068	0.069	0.070	0.070	0.070	0.070
0.080	0.078	0.079	0.080	0.080	0.080	0.080
0.090	0.087	0.089	0.090	0.090	0.091	0.091
0.100	0.096	0.099	0.100	0.100	0.101	0.101
0.110	0.105	0.108	0.109	0.110	0.111	0.111
0.130	0.123	0.127	0.129	0.131	0.131	0.131
0.150	0.141	0.147	0.149	0.151	0.151	0.152
0.170	0.158	0.166	0.169	0.171	0.172	0.172
0.190	0.175	0.184	0.188	0.191	0.192	0.193
0.210	0.192	0.203	0.208	0.212	0.213	0.213
0.230	0.209	0.222	0.227	0.232	0.233	0.234
0.250	0.226	0.241	0.247	0.252	0.253	0.254
0.270	0.241	0.259	0.266	0.273	0.274	0.275
0.290	0.257	0.278	0.286	0.293	0.295	0.296
0.310	0.273	0.296	0.305	0.313	0.315	0.317
0.330	0.288	0.314	0.324	0.333	0.336	0.338
0.350	0.303	0.332	0.344	0.354	0.357	0.359
0.370	0.318	0.350	0.363	0.375	0.378	0.380
0.390	0.333	0.368	0.382	0.395	0.399	0.401
0.410	0.347	0.385	0.402	0.416	0.420	0.422
0.430	0.362	0.403	0.421	0.436	0.441	0.444
0.450	0.376	0.420	0.439	0.457	0.462	0.465
0.500	0.410	0.464	0.487	0.509	0.514	0.518
0.600	0.474	0.548	0.581	0.612	0.620	0.626
0.700	0.535	0.631	0.675	0.716	0.728	0.736
0.800	0.592	0.711	0.766	0.821	0.836	0.847
0.900	0.645	0.789	0.858	0.927	0.946	0.960
1.000	0.695	0.865	0.949	1.034	1.058	1.075
1.100	0.742	0.939	1.039	1.142	1.170	1.192
1.200	0.786	1.010	1.129	1.250	1.285	1.318
1.300	0.828	1.080	1.217	1.359	1.400	1.430

[a] U in first column is from previous tables or as calculated for 15 mph wind velocity.

CALCULATING SURFACE TEMPERATURES

In many heating and cooling load calculations it is necessary to determine the inside surface temperature or the temperature of the surfaces within the structure. As the resistance of any path of heat flow is expressed in Fahrenheit degrees per (Btu)/(hour) (square foot), the resistances through any two paths of heat flow would be proportional to the temperature drop through these paths, and can be expressed as follows:

$$\frac{R_1}{R_2} = \frac{(t_i - t_x)}{(t_i - t_o)} \qquad (7)$$

where

R_1 = the resistance from the indoor air to any point in the structure at which the temperature is to be determined.

R_2 = the overall resistance of the wall from indoor air to outdoor air.

t_i = indoor air temperature.

t_x = temperature to be determined.

t_o = outdoor air temperature.

Example 9: Determine the inside surface temperature for a wall having an overall coefficient of heat transmission U =

0.25, indoor air temperature 70 F, and outdoor air temperature −20 F.

Solution:

$$R = 1/f_i = 1/1.46 = 0.684$$

$$R_2 = 1/U = 1/0.25 = 4.00$$

Then, by Equation 7

$$\frac{0.684}{4.00} = \frac{70 - t_x}{70 - (-20)}$$

$$t_x = 54.6 \text{ F}$$

Exaple 10: Determine the temperature of the bottom of a 4-in. insulated concrete roof slab to which has been glued ½-in. acoustical tile (C = 0.84) as the interior finish. The roof-ceiling overall coefficient of heat transmission U is 0.14 for heat flow up. The indoor air temperature is assumed to be 70 F and the outdoor air temperature −20 F.

Solution:

$$R_1 = \frac{1}{f_i} + \frac{1}{C} = \frac{1}{1.63} + \frac{1}{0.84} = 1.80$$

$$R_2 = \frac{1}{U} = \frac{1}{0.14} = 7.14$$

Then, by Equation 7

$$\frac{1.80}{7.14} = \frac{70 - t_x}{70 - (-20)}$$

$$t_x = 47.3 \text{ F}$$

The concrete surface temperature is of interest since reference to a psychrometric chart or table will show that moisture condensation could occur on this surface under the above conditions (47.3 F) if the relative humidity in the room exceeds 44 percent. Additional roof insulation should be considered above the slab to avoid condensation at this point if higher relative humidities in the room are anticipated.

The same procedure can be used for determining the temperature it any point within the structure.

A chart for determining inside wall surface temperature is given in Fig. 13 of Chapter 30, Panel Heating.

REFERENCES

[1] *Standard Method of Test for Thermal Conductivity by Means of the Guarded Hot Plate*, sponsored by ASHVE, ASTM, ASRE, and NRC, and approved as a tentative code by ASHVE and ASTM in 1942 (ASTM designation C-177-45, Approved, 1945).

[2] F. B. Rowley and A. B. Algren: *Heat Transmission Through Building Materials* (University of Minnesota, *Engineering Experiment Station Bulletin* No. 8, p. 11).

[3] M. S. Kersten: *Thermal Properties of Soils* (University of Minnesota, *Engineering Experiment Station Bulletin* No. 28, June 1949).

[4] G. B. Wilkes and C. M. F. Peterson: Radiation and convection from surfaces in various positions (ASHVE Transactions, Vol. 44, 1938, p. 513).

[5] B. F. Raber and F. W. Hutchinson: Radiation corrections for basic constants used in the design of all types of heating systems (ASHVE Transactions, Vol. 51, 1945, p. 213).

[6] F. B. Rowley, A. B. Algren, and J. L. Blackshaw: ASHVE Research Report No. 869—Surface conductances as affected by air velocity, temperature and character of surface (ASHVE Transactions, Vol. 36, 1930, p. 444).

[7] G. V. Parmelee and R. G. Huebscher: *Forced Convection Heat Transfer from Flat Surfaces* (ASHVE Research Bulletin No. 3, p. 40, also published in ASHVE Transactions, Vol. 53, 1947, p. 245).

[8] G. V. Parmelee and W. W. Aubele; ASHVE Research Report No. 1399—Heat flow through unshaded glass: Design data for load calculations (ASHVE Transactions, Vol. 56, 1950, p. 371).

[9] H. E. Robinson, F. J. Powlitch, and R. S. Dill: *The Thermal Insulating Value of Airspaces* (Housing and Home Finance Agency, *Housing Research Paper* No. 32, U. S. Government Printing Office, 1954).

[10] G. B. Wilkes, F. G. Hechler, and E. R. Queer: Thermal test coefficients of aluminum insulation for buildings (ASHAE Transactions, Vol. 46, 1940, p. 109).

[11] F. A. Joy: Improving attic space insulating values (ASHAE Transactions, Vol. 64, 1958, p. 251).

[12] F. C. Houghten, S. I. Taimuty, Carl Gutberlet, and C. J. Brown: ASHVE Research Report No. 1213—Heat loss through basement walls and floors (ASHVE Transactions, Vol. 48, 1942, p. 369).

[13] R. S. Dill, W. C. Robinson, and H. E. Robinson: *Measurements of Heat Losses from Slab Floors* (National Bureau of Standards, *Building Materials and Structures Report BMS* 103).

[14] G. V. Parmelee: *Heat Transmission through Glass* (ASHVE Research Bulletin No. 1, July 1947).

BIBLIOGRAPHY

ASHVE Research Reports:

No. 852—F. B. Rowley, A. B. Algren, and J. L. Blackshaw: Effects of air velocities on surface coefficients (ASHVE Transactions, Vol. 36, 1930, p. 123).

No. 895—F. C. Houghten and Paul McDermott: Wind velocities gradients near a surface and their effect on film conductance (ASHVE Transactions, Vol. 37, 1931, p. 301).

No. 914—F. B. Rowley and W. A. Eckley: Surface coefficients as affected by direction of wind (ASHVE Transactions, Vol. 38, 1932, p. 33).

No. 915—F. C. Houghten and Carl Gutberlet: Conductivity of concrete (ASHVE Transactions, Vol. 38, 1932, p. 47).

No. 964—F. B. Rowley: The heat conductivity of wood at climatic temperature differences (ASHVE Transactions, Vol. 39, 1933, p. 329).

No. 966—F. B. Rowley: Insulating value of bright metallic surfaces (ASHVE Transactions, Vol. 40, 1934, p. 413).

No. 1026—F. B. Rowley, A. B. Algren, and Clifford Carlson: Thermal properties of concrete construction (ASHVE Transactions, Vol. 42, 1936, p. 33).

No. 1048—F. B. Rowley, A. B. Algren, and Robert Lander: Thermal properties of concrete construction (ASHVE Transactions, Vol. 43, 1937, p. 33).

No. 1351—G. V. Parmelee and W. W. Aubele: Overall coefficients for flat glass determined under natural weather conditions (ASHVE Transactions, Vol. 55, 1949, p. 39).

G. B. Wilkes and C. M. F. Peterson: Radiation and convection across air spaces in frame construction (ASHVE Transactions, Vol. 43, 1937, p. 351).

L. W. Schad: Insulating effect of successive air space bounded by bright metallic surfaces (ASHVE Transactions, Vol. 37, 1931, p. 285).

J. D. MacLean: Thermal conductivity of wood (ASHVE Transactions, Vol. 47, 1941, p. 323).

G. B. Wilkes and C. O. Wood: The specific heat of thermal insulating materials (ASHVE Transactions, Vol. 48, 1942, p. 493).

D. B. Anderson: Heat loss studies in four identical buildings to determine the effect of insulation (ASHVE Transactions, Vol. 48, 1942, p. 471).

T. D. Phillips: *Effect of Ceiling Insulation upon Summer Comfort* (*National Bureau of Standards Report* BMS52, July 1, 1940).

L. V. Teesdale: *Thermal Insulation Made of Wood-Base Materials, Its Application and Use in Houses* (*U. S. Forest Products Laboratory Report* No. R1740, October 1949).

F. B. Rowley and A. B. Algren: *Heat Transmission through Building Materials* (University of Minnesota, *Engineering Experiment Station Bulletin* No. 8).

Paul D. Close: *Building Insulation* (American Technical Society, Chicago, 1951, 4th ed.).