

TABLE 2. CONDUCTIVITIES (*k*) AND CONDUCTANCES (*C*) OF BUILDING AND INSULATING MATERIALS—(Concluded)(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		RESISTANCE	
			(<i>k</i>)	(<i>C</i>)	Per Inch Thick- ness ($\frac{1}{k}$)	For Thick- ness Listed ($\frac{1}{C}$)
ROOFING	Asbestos-cement shingles.....	120	—	2.85	—	0.35
	Asphalt shingles.....	70	—	2.00	—	0.50
	Wood shingles.....	—	—	1.00	—	1.00
	Asphalt roll roofing.....	70	1.1	—	0.91	—
	Built-up roofing..... ^b 1/8 in.	70	—	3.00	—	0.33
	Slate..... ^c 1/2 in.	—	—	20.00	—	0.05
WOODS	Maple, oak, and similar hardwoods.....	45	1.10	—	0.91	—
	Fir, pine, and similar softwoods.....	32	0.80	—	1.25	—
INSULATING MATERIALS BLANKET AND BATT	Wood fiber ^d	3.2-3.6	0.25	—	4.00	—
	Wood fiber, multilayer, stitched expanding ^e	1.5-2.0	0.27	—	3.70	—
	Cotton fiber ^d	0.8-2.0	0.26	—	3.85	—
	Mineral wool, fibrous form, processed from rock, slag, or glass ^d	1.5-4.0	0.27	—	3.70	—
INSULATING MATERIALS BOARD	Wood or cane fiber.....	11.0-12.0	0.30 ^g	—	3.33	—
	Glass fiber.....	13.0	0.33 ^g	—	3.00	—
	Glass fiber.....	20.0	0.39 ^g	—	2.56	—
INSULATING MATERIALS LOOSE FILL TYPE	Macerated paper or pulp products.....	2.5-3.5	0.28	—	3.57	—
	Shredded redwood bark.....	2.5-3.5	0.30	—	3.33	—
	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	—
	Cellular glass.....	9.0	0.40	—	2.50	—
INSULATING MATERIALS BOARDS AND SLABS	Corkboard (without added binder).....	6.5-8.0	0.27	—	3.70	—
	Hog hair (with asphalt binder).....	8.5	0.33	—	3.00	—
	Shredded wood (cemented in preformed slabs).....	22.0	0.55	—	1.82	—

^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 See also Insulating Materials, Board.

^c If no sheathing is used, building paper will gap into the stud space. The air space thus formed adds to the resistance of the combination of siding and paper. For ordinary application of paper, the slight air space adds about 0.40 to the resistance. If paper is deliberately bowed into the stud space, the added resistance approaches that of a plane air space as a limit. The values given include a resistance of 0.06 for the building paper.

^d 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 1, Sections B and C, to obtain the insulating value of the air space for the appropriate effective emissivity and temperature conditions of the space.

^e Tentative values pending completion of testing programs.

ing. 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 con-

tent 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 3 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

TABLE 3. 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	4	4	10	10	20	20	
	Over 2.0 mm	9.5 to 2.00 mm	0.005 to 0.05 mm	Under 0.005 mm	DRY DENSITY—LB PER CU FT							
					100	110	120	90	110	90	100	
Fine Crushed Quarts	0.0	100.0	0.0	0.0	12.0	16.0						
Crushed Quarts	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	8.0	10.0	
Fairbanks Silt Loam	0.0	7.6	80.9	11.5					5.0	9.0±	7.5	
Fairbanks Silty Clay Loam	0.0	9.2	63.8	27.0					5.0	9.0±	7.5	
Northway Silt Loam	1.0	21.0	64.4	13.6					4.0±	7.0±	6.0±	

^a *k* = Btu per (square foot) (hour) (Fahrenheit degree per inch).

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 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