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 No.	Soil Designation	Moisture Content—%						
		4	4	4	10	10	20	20
		Dry Density-lb per cu ft						
		100	110	120	90	110	90	100
P4714	Fine Crushed Quartz	12.0	16.0					
P4703	Crushed Quartz	11.5	16.0	22.0				
P4701	Graded Ottawa Sand	10.0	14.0					
P4709	Fairbanks Sand	8.5±	10.5	13.5		15.0		
P4604	Lowell Sand	8.5	11.0			13.5		
P4601	Chena River Gravel		9.0±	13.0				
P4705	Crushed Feldspar	6.0	7.5	9.5				
P4706	Crushed Granite	5.5	7.5	10.0				
P4711	Dakota Sandy Loam		6.5	9.5		13±		
P4704	Crushed Trap Rock	5.0	6.0	7.0				
P4713	Ramsey Sandy Loam	4.5	6.5			10.0		
P4502	Northway Fine Sand	4.5	5.5			8.5		
P4503	Northway Sand	4.5	6.0			7.5±		
P4708	Healy Clay	4.0±			5.5	9.0±	8.0	10.0
P4602	Fairbanks Silt Loam				5.0	9.0±	7.5	10.0
P4710	Fairbanks Silty Clay Loam				5.0	9.0±	7.5	9.5
P4505	Northway Silt Loam				4.0±	7.0±	6.0±	7.0±

[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 140F. 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

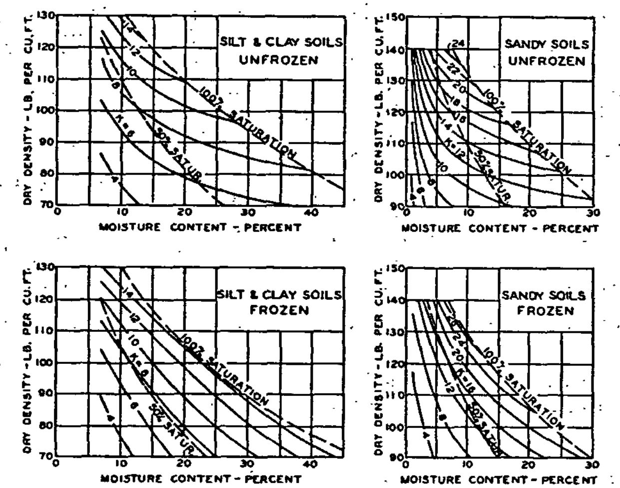

FIG. 3. DETERMINING THERMAL CONDUCTIVITY OF SOILS FROM DENSITY AND MOISTURE CONTENT

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 radiation, is illustrated in Table 4, which applies to a vertical surface at 80 F, with ambient air at 70 F and effective emissivity equal to 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 23.)

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