CRD-C 45-65

METHOD OF TEST FOR THERMAL CONDUCTIVITY OF LIGHTWEIGHT INSULATING CONCRETE[1]

Scope

1. This method of test covers a procedure for measuring the thermal conductivity of lightweight concrete of the type used for roof insulating fill.

Note.- The apparatus as described below is suitable for measuring all semirigid to rigid materials with conductivities in the range 0.6 to 5.0 Btu per sq ft per hr per degree F for a thickness of 1 in. For an alternate test method applicable to a wider range of materials and conductivity values, see ASTM Designation: C 177, "Method of Test for Thermal Conductivity of Materials by Means of the Guarded Hot Plate."

Apparatus

2. The apparatus used in this test shall consist of

(a) Guarded Hot Plate Assembly Shown in Figs. 1 and 3.- The hot plate assembly consists of an evaporator, hot plate, and guard, all assembled in an insulated container as shown in Fig. 1. The evaporator containing n-pentane (C_5H_{12}) constitutes the cold plate. The temperature of its base remains constant at approximately 97 F after the pentane has reached its boiling point. The hot plate itself is heated by an electric heating element which is wound at 1/2-in. intervals on both sides of a Bakelite sheet. The heating coil is made from No. 30 gage bare constantan wire with total length of approximately 255 in. and total resistance of approximately 65 ohms. The guard is heated by an electric heating coil which is glued to its outer and bottom surfaces by means of "Glyptal" red cement. This heating coil consists of approximately 133 in. of No. 30 gage enameled constantan wire with total resistance of approximately 34 ohms. The guard winding is spaced at 1-5/8-in. intervals. Construction details of the evaporator, hot plate, and guard are shown in Fig. 3. The evaporator and guard are made up of brass or copper sheet stock, soldered together as shown. The hot plate consists of layers of copper, asbestos, and Bakelite sheets fastened together with brass flat head screws. After assembly, the upper face of the hot plate and the lower face of the evaporator are machined to a flat surface. (Variations over 90 percent of the surface should not exceed 0.001 in. with maximum variation at any point of the surface not exceeding 0.003 in.) Four thermocouples of No. 30 gage wire are located at center points of guard, hot plate, and evaporator as shown in Fig. 1 (Note 1). The thermocouples on the guard and bottom face of the hot plate are soldered in place. The thermocouples on the evaporator and upper face of the hot plate are set in grooves (Note 2). A thermometer reading up to 100 F is desirable for use in the evaporator as shown in Fig. 1.

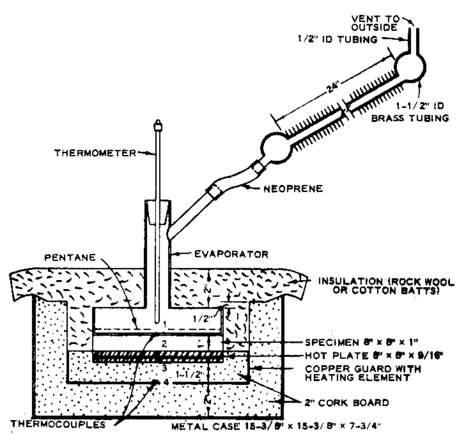

Fig. 1. Thermal conductivity apparatus-general layout

(b) Condenser Assembly Shown in Figs. 1 and 2.-The condenser is air-cooled and consists of three finned tubes connected in parallel between

[1] Based on apparatus developed by National Bureau of Standards.

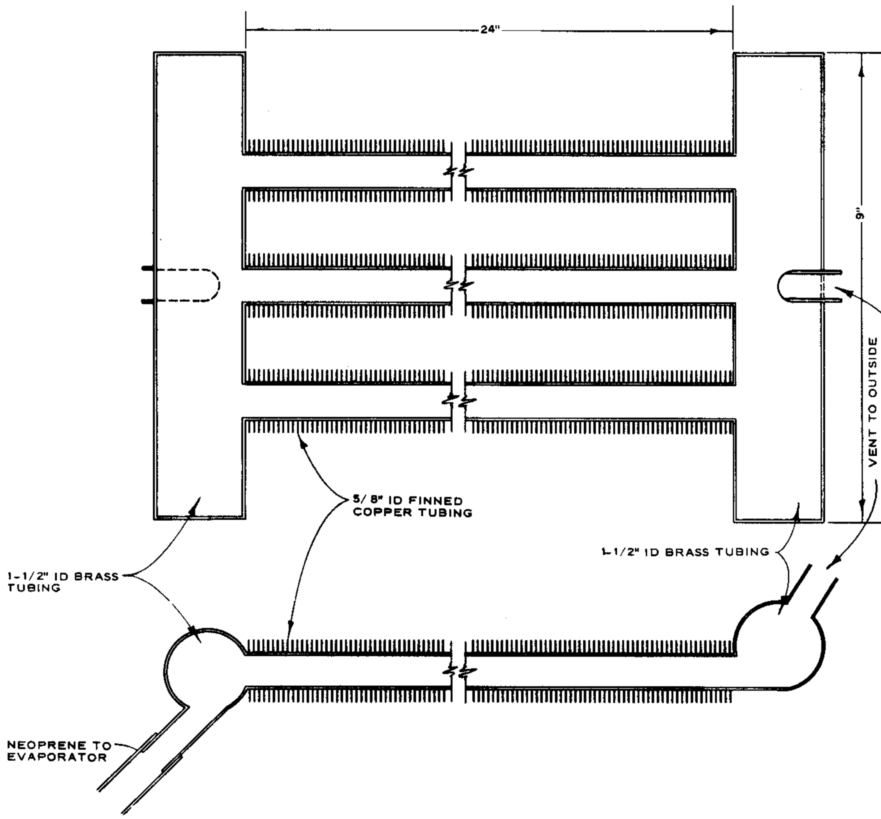

Fig. 2. Thermal conductivity apparatus-condenser details

an upper and lower reservoir. Connection between evaporator and condenser is made by flexible tubing of a material that will not be damaged by the pentant.

(c) Power Supply.- An electrical power supply of constant voltage, either alternating or direct current, is required for the heating coils of the hot plate and guard. Separate means of varying voltage or current must be provided for each heating coil (guard and hot plate). For testing of the materials described in Par. 1, the maximum voltage required will be approximately 50 volts. The power or energy input to the hot plate shall be measured with an accuracy of ±2%. Any of the following type instruments can be used for this measurement provided the above described accuracy limitation is met: wattmeter, voltmeter-ammeter combination, or recordingwatt-hour meter and timer. Measurement of power input to the guard heating coil is not required for computing thermal conductivity, but measurement of the voltage and/or current, used for the guard coil is helpful in controlling guard temperature. A satisfactory circuit for use with alternating current is shown in Fig. 4. If the voltmeter-ammeter combination is used for measuring power input to the hot plate, the range and calibration of the instruments should meet certain requirements for testing the materials described in Par. 1. The voltmeter should be capable of measuring up to 50 volts and the ammeter up to 1 amp-preferably in two or more ranges. The

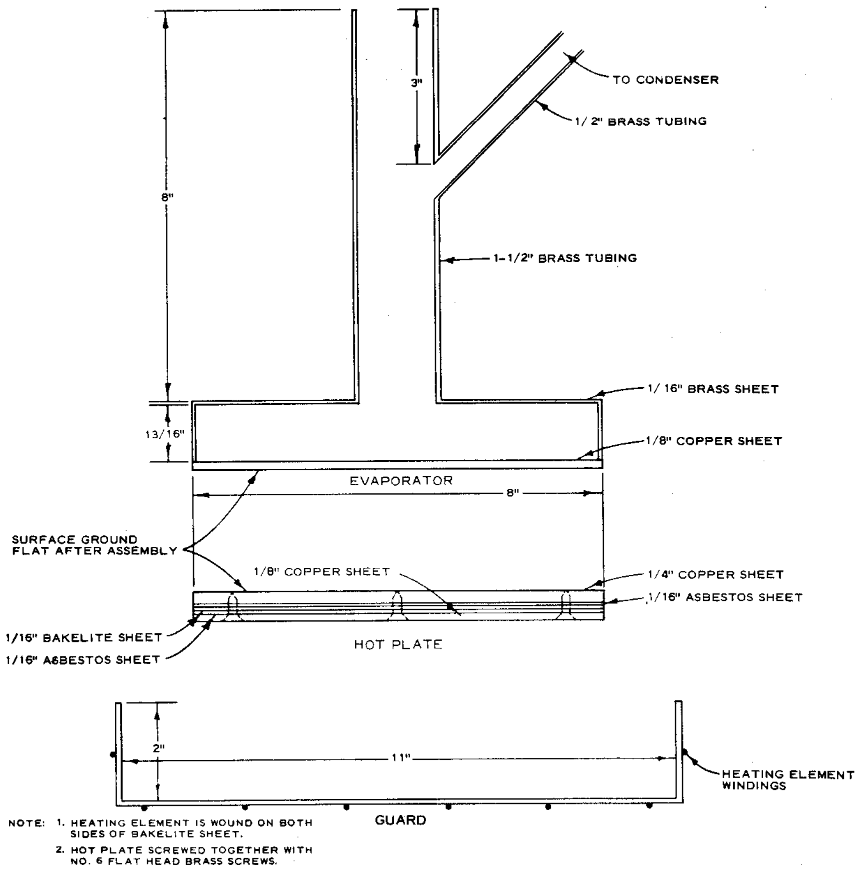

Fig. 3. Thermal conductivity apparatus-evaporator, hot plate, and guard details

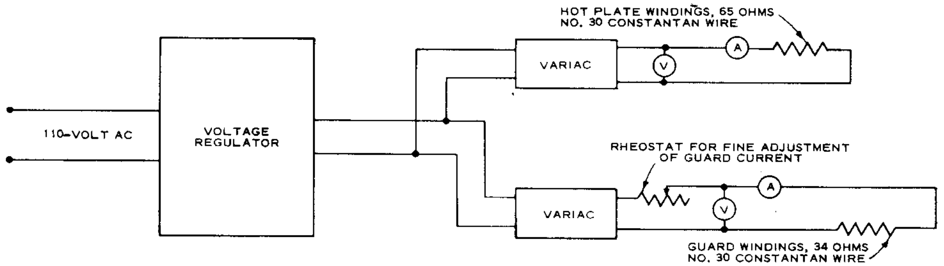

Fig. 4. Thermal conductivity apparatus-typical circuit for use with alternating current

accuracy of the instruments and the spacing of the scale divisions should be such that both the ammeter and the voltmeter readings can be made to an accuracy of l 1% in the range being used (Note 3).

Note 1.- Copper-constantan thermocouples are believed to be more satisfactory for this use than iron-constantan couples because of the rusting which occurs with the latter type.

Note 2.- In the case of rigid materials with k value greater than 2.0, accuracy of the temperature readings of the specimen can be increased by placing a sheet of resilient rubber 8 by 8 by 1/8 in. on each face of the specimen with one or more thermocouples between rubber and specimen.

Note 3.- When the ammeter-voltmeter combination is used to measure power, a correction may be necessary for the effect of meter resistance. For example, in the circuit shown in Fig. 4 the voltmeter reading should be corrected by an amount equal to the voltage drop across the ammeter. If a direct current power supply is used, the current can be obtained by measuring the potential drop in a standard 0.01-ohm resistor, and the voltage can be obtained by using a precision voltage divider, both potentials being measured by the same potentiometer which is used for the thermocouple emf.

(d) A potentiometer for measuring the electromotive force of the various thermocouples is required as auxiliary equipment. The potentiometer should be of sufficient accuracy to enable temperatures to be determined with an accuracy of ±1% of the temperature difference between the two faces of the sample under test.

Preparation of Test Specimen

3. The specimen to be tested shall be exactly 8 by 8 in. in cross section. The thickness of the specimen shall be approximately 1 in. and shall be measured to an accuracy of l 1%. In the case of rigid material the 8- by 8-in. faces shall be ground flat and parallel. Flatness shall be such that variations over 90 percent of the surface shall not exceed 0.001 in., with maximum variation at any point of the surface not exceeding 0.003 in. Before the test, the specimen shall be dried to constant weight at a temperature not exceeding 220 F.

Test Procedure

4. The thermal conductivity apparatus shall be assembled as shown in Fig. 1. (CAUTION: Pentane is a highly inflammable liquid.) The evaporator and condenser units should be carefully checked for leaks and all electrical circuits tested for groundings or shorts before the apparatus is put into use. The power input to the hot plate shall be adjusted to produce a final hot plate temperature of approximately 140 F after the pentane has reached its boiling point. The power input to the guard shall be adjusted to hold the guard temperature at the same value as that of the lower surface of the hot plate (Note). Regulation of guard temperature shall be such that the average difference between it and the lower face of the hot plate during the final test observation period shall be not greater than 0.1 F and the maximum difference shall be not greater than 0.3 F. After the steady state has been obtained, the test shall be continued for a final observation of 2 hr. During the 2-hr observation period, temperature and power input determinations shall be made for use in the calculations. The readings shall be taken at intervals of not greater than 15 min.

Note.- After steady state is obtained, the upper surface of the hot plate will be at a slightly higher temperature than the bottom surface of the hot plate. This condition is to be expected and does not indicate improper adjustment.

Calculations

5. The thermal conductivity of the test sample shall be computed as follows:

$$k = \frac{qL}{A(t_1 - t_2)}$$

where:

k = thermal conductivity, Btu per sq ft per hr per degree F for a thickness of 1 in.,

L = thickness of specimen at test temperature, in.,

A = area of specimen, sq ft,

t_1 = temperature of hot plate face in contact with specimen, degree F,

t_2 = temperature of cold plate face in contact with specimen, degree F, and

q = rate of heat flow through the sample, Btu per hr (q is assumed to be the same as the rate of heat output from the hot plate and is computed as 3.41 times rate of electrical energy input to hot plate expressed in watts).

Typical data and sample calculations are shown below.

THERMAL CONDUCTIVITY TEST DATA-"PEROLITE" CONCRETE

	TC-1 Cold Plate		TC-2 Hot Plate (Top)		TC-3 Hot Plate (Bottom)		TC-4 Guard		Hot Plate		Guard
Time	emf (μv)	°F	emf (μv)	°F	emf (μv)	°F	emf (μv)	°F	E (Volts)	I (Amps)	E (Volts)
0800									45.0		30.0
1000			3898	163.1	3953	165.0	3359	145.0	45.0/21.4		30.0/25.0
1030					3538	151.0	3614	153.6	21.4		24.8/16.0
1055			3301	143.0	3352	144.8	3500	149.7	21.4/26.0		16.0
1115					3339	144.3	3427	147.3	26.1		16.0
1135					3320	143.7	3392	146.1	26.2		16.0
1150					3313	143.4	3359	145.0	26.2		16.0
1225					3294	142.8	3308	143.3	26.2/27.0		16.0
1240					3290	142.7	3302	143.1	26.9		16.0
1320					3309	143.3	3256	141.5	26.9/25.7		16.0/17.0
1330					3295	142.8	3267	141.9	25.7/26.3		17.0
1338					3289	142.6	3275	142.2	26.3		17.0
1342					3287	142.6	3279	142.3	26.2		17.0
1400					3280	142.3	3291	142.7	26.2/26.8		17.0/16.5
1412	1819	93.1	3220	140.3	3284	142.5	3290	142.7	26.8	0.374	16.4
1428	1819	93.1	3220	140.3	3289	142.6	3285	142.5	26.8/26.6	0.374/0.372	16.4/16.7
1446	1817	93.1	3222	140.4	3289	142.6	3289	142.6	26.6	0.371	16.7
1508	1819	93.1	3221	140.4	3290	142.7	3293	142.8	26.6	0.370	16.7/16.3
1528	1818	93.1	3220	140.3	3287	142.6	3285	142.5	26.5	0.370	16.1/16.7
1545	1819	93.1	3218	140.3	3286	142.5	3290	142.7	26.5	0.370	16.7/16.4
1600	1818	93.1	3218	140.3	3284	142.5	3284	142.5	26.5	0.370	16.1/16.5
1615	1820	93.2	3217	140.2	3284	142.5	3287	142.6	26.5	0.370	16.6
1622	1818	93.1	3218	140.3	3285	142.5	3289	142.6	26.5	0.370	16.6

Computation of k

$$k = \frac{q L}{A(t_1 - t_2)}$$

$$= \frac{33.4 \times 0.875}{0.444 \times 47.2}$$

= 1.39 Btu per sq ft per hr per degree F for thickness of 1 in.

$q = 3.41 \times E \times I$

E = hot plate voltage = 26.5 volts

I = hot plate current = 0.370 amp

$q = 3.41 \times 26.5 \times 0.370$

q = 33.4 Btu per hr

L = 0.875 in.

A = 0.444 sq ft

t_1 = 140.3 F

t_2 = 93.1 F