Intertek ETL SEMKO

ASTM C 518–04
STEADY-STATE HEAT FLUX MEASUREMENTS AND THERMAL TRANSMISSION PROPERTIES BY MEANS OF THE HEAT FLOW METER APPARATUS

HEATLOK SOY

Project No. 3147434SAT-002

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Prepared for:

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ABSTRACT

Specimens submitted for testing by Demilec USA, LLC and identified as "HEATLOK SOY" were tested in triplicate in accordance with ASTM C 518–04. The foam was allowed to age for more than 180 days before testing at 73 ± 5°F.

TEST NO.	HOT & COLD PLATE SEPARATION (mm)	HEAT FLOW $(\frac{W}{m^2})$	HOT PLATE TEMPERA-TURE (°C)	COLD PLATE TEMPERA-TURE (°C)	THERMAL TRANSMIS-SION $(\frac{W}{m\cdot K})$	COLD /HOT PLATE DELTA T (°F)
1	49.28	12.32	38.7	10.5	0.0215	50.8
2	49.28	12.43	39.1	10.6	0.0215	51.3
3	49.28	12.36	39.0	10.6	0.0215	51.1
Average	49.28	12.37	38.9	10.6	0.0215	51.1

NOTE: See Conclusions Section for expression of thermal transmission and thermal conductivity in English units and for various material thickness.

This report contains a total of ten pages.

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October 3, 2008

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I. INTRODUCTION[1]

This test method covers the measurement of steady state thermal transmission through flat slab specimens using a heat flow meter apparatus. This is a comparative (or secondary) method of measurement since specimens of known thermal transmission properties must be used to calibrate the apparatus. Properties of the calibration specimens must be traceable to an absolute measurement method, and should be obtained from or traceable to a recognized national standards laboratory.

The test method is applicable to the measurement of thermal transmission through a wide range of specimen properties and environmental conditions. The method has been used at ambient conditions of 10 to 40°C with thickness up to approximately 250 mm, and with plate temperatures from –195°C to 540°C at 25 mm thickness.

This test method may be used to characterize material properties which may or may not be representative of actual conditions of use. Other test methods such as Test Methods C 236 or C 976 should be used if needed.

To meet the requirements of this test method, the thermal resistance of the sample must be greater than 0.10 K•m^2/W in all directions. It is not practical in a test method of this type to try to establish details of construction and procedures to cover all contingencies that might offer difficulties to a person without pertinent technical knowledge. Thus users of this test method shall have sufficient knowledge to satisfactorily fulfill their needs. For example, knowledge of heat transfer principles, low level electrical measurements, and general test procedures is required."

1 *ASTM C518-04 Standard Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus*, Annual Book of ASTM Standards, 04.06, American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA.

Summary of Test Method

"The heat flow meter apparatus establishes steady state unidirectional heat flux through a test specimen between two parallel plates at constant but different temperatures. By appropriate calibration of the heat flux transducer(s) with calibration standards and by measurement of the plate temperatures and plate separation, Fourier's law of heat conduction is used to calculate thermal conductivity, thermal resistance, or resistivity.

The accurate use of the test method is limited by the capability of the apparatus to reproduce unidirectional constant heat flux density in the specimens, and by the precision in the measurement of temperature, thickness, EMF produced by the heat flux transducer, etc.

The apparatus shall not be used at temperatures, thickness or resistances, other than those within the range of the calibration, unless it can be shown that there is no difference in accuracy.
The apparatus must be capable of maintaining at least a 10°C temperature difference across the specimen for the duration of the test, unless a smaller LT is a requirement of a particular test. The specimens under test may also limit the use of the test method and these limitations are outlined in Practice C1045.

This evaluation was accomplished using a Model Rapid-k Heat Flow Meter Thermal Conductivity Instrument, manufactured by Dynatech R/D Company. "The Rapid-k determines thermal conductivity in accordance with ASTM C 518 . . .

Heat flow through a solid, results from having a temperature gradient in the material. Thermal conductivity is a material property, which determines how much heat flows through a given thickness of the material when there is a temperature difference. The Fourier linear heat flow equation defines thermal conductivity under steady state conditions as:

$$l = \O \frac{DX}{DT}$$

where:

l = thermal conductivity, $\frac{W}{m \cdot K}$

$\O$ = heat flux, $\frac{W}{m^2}$

DT = temperature difference across distance LX, K

DX = distance between hot and cold plates, m

II. PROCEDURE

"In practice, thermal conductivity determinations are made on thermal insulation by placing a sample of the material between two surfaces maintained at a known temperature. Because of the temperature difference, heat flows through the sample from the hot side to the cold side. The quantity of heat flowing through the sample is measured by a heat flow transducer, which is a device having an output proportional to the heat flow passing through it. This transducer is placed between the sample and the cold plate. Because some heat flows through the edges of the sample to or from the surroundings, the heat flow measurement is made in the central 4 inch square area of a 12 inch square sample only. The heat flow through the central area of the sample is one-directional between the hot and the cold face, as the effect of heat flow across the edges is absorbed entirely by the sample material that surrounds the central heat measuring area.

The Rapid-k test apparatus is used for determining the thermal conductivity of fibrous, cellular, particulate, and other thermal insulation. Although the instrument can be used to test almost any solid insulating materials that can be produced in 12-inch square sections, its primary applications are the testing of coarse grain and non-homogeneous materials, where the large sample is necessary in order to obtain test results that are representative of the sample material in bulk form. Examples are foam plastics, fibrous insulation, sand, asbestos, wood, concrete, and other materials.

Description of Test Specimens

The test specimens were submitted by Demilec USA, LLC and identified as follows:

ID Number: HEATLOK SOY

Description: 2 pcf Rigid Spray Polyurethane Foam Insulation

Date Sprayed: March 7, 2008

Date Received: The samples were received in good condition on 3/12/08.

Date Tested: September 18, 2008

This Test Witnessed by: N/A

Environmental Conditions: 70°F and 49% r.h.

Three specimens were tested so that an average result could be reported. The specimens had dimensions of 12 inches by 12 inches by an average thickness of 1.94 inches and consisted of rigid foam insulation. All the specimens were conditioned under standard laboratory conditions (23 ± 3°C and 50% relative humidity) until they were at constant moisture content, as determined by their attaining constant weight.

Prior to each series of three tests, the Rapid-k was calibrated using a sample whose thermal conductivity is known and traceable to national standards.

To perform the test, the specimen was placed in the Rapid-k instrument, the bottom (cold) plate is brought upwards creating contact of both plates with the test specimen, and the instrument was sealed. The hot and cold plates were then allowed to equilibrate to the required temperatures and their exact temperatures were read from the instrument. In addition, a millivolt signal, which is proportional to the heat flow through the transducer, was recorded.

III. TEST RESULTS

The test results from this evaluation are given in the following table, which contains equilibrium data from each test.

TEST NO.	HOT & COLD PLATE SEPARATION (mm)	HEAT FLOW ($\frac{W}{m^2}$)	HOT PLATE TEMPERATURE (°C)	COLD PLATE TEMPERATURE (°C)	THERMAL TRANSMISSION ($\frac{W}{m \cdot K}$)	COLD /HOT PLATE DELTA T (°F)
1	49.28	12.32	38.7	10.5	0.0215	50.8
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TEST NO.	DENSITY OF SPECIMEN (kg/m^3)	DURATION OF EQUILIBRIUM PERIOD (min)	DATE TESTED
1	45.21	135.00	9/18/08
2	44.70	175.00	9/18/08
3	45.21	175.00	9/18/08

IV. CONCLUSIONS

The Thermal Conductivity, l, and Thermal Resistance, R, of the specimens tested were:

THERMAL CONDUCTIVITY		
SAMPLE NO.	Btu-in / °F-ft²-h)	W/(m*K)
1	0.149	0.0215
2	0.149	0.0215
3	0.149	0.0215
Average	0.149	0.0215

Thermal resistance (R, $\frac{K \cdot m^2}{W}$) is a function of thickness, and is determined by dividing the thickness in meters by the thermal conductivity.

The table below gives the average thermal resistance for a range of practical thicknesses, in both SI and English units:

R-VALUE			
THICKNESS (in.)	THICKNESS (mm)	R (K•M²/W)	R (°F•ft²•h/Btu)
1.00	25.4	1.182	6.71
1.94*	49.3	2.293	13.02
2.00	50.8	2.364	13.42
3.00	76.2	3.546	20.13
3.50	88.9	4.137	23.49
4.00	101.6	4.728	26.85

Note: These results are based on the average thermal transmission of all three samples.
* This is the average tested thickness of 3 samples.

COLD & HOT PLATE MEAN TEMPERATURES		
SAMPLE NO.	MEAN TEMP. °F	MEAN TEMP. °C
1	76.3	24.6
2	76.7	24.9
3	76.6	24.8
Average	76.6	24.8

The tables below illustrate the constants to convert from standard SI units to any of the other commonly used units. To convert from any set of units in the left-most column to any of the sets of units along the top row, multiply by the constant in the intersecting square:

THERMAL CONDUCTIVITY, l (SI Units = $\frac{W}{m \cdot K}$)

	$\frac{W}{m \cdot K}$	$\frac{W}{cm \cdot K}$	$\frac{cal}{s \cdot cm \cdot K}$	$\frac{kg\text{-}cal}{h \cdot m \cdot K}$	$\frac{Btu}{h \cdot ft \cdot {}^\circ F}$	$\frac{Btu \cdot in}{h \cdot ft^2 \cdot {}^\circ F}$
$\frac{W}{m \cdot K}$	1	1×10^{-2}	2.388×10^{-3}	0.8598	0.5778	6.933
$\frac{W}{cm \cdot K}$	100	1	0.2388	85.98	57.78	693.3
$\frac{cal}{s \cdot cm \cdot K}$	418.7	4.187	1	360	241.9	2903
$\frac{kg\text{-}cal}{h \cdot m \cdot K}$	1.163	1.163×10^{-2}	2.778×10^{-3}	1	0.672	8.064
$\frac{Btu}{h \cdot ft \cdot {}^\circ F}$	1.731	1.731×10^{-2}	4.134×10^{-3}	1.488	1	12
$\frac{Btu \cdot in}{h \cdot ft^2 \cdot {}^\circ F}$	0.1442	1.442×10^{-3}	3.445×10^{-4}	0.124	8.333×10^{-2}	1

THERMAL RESISTANCE, R (SI UNITS = $\frac{K \cdot m^2}{W}$)

	$\frac{K \cdot m^2}{W}$	$\frac{K \cdot cm^2}{W}$	$\frac{K \cdot cm^2 \cdot s}{cal}$	$\frac{K \cdot m^2 \cdot h}{kg\text{-}cal}$	$\frac{°F \cdot ft^2 \cdot h}{Btu}$
$\frac{K \cdot m^2}{W}$	1	1×10^4	4.187×10^4	1.163	5.678
$\frac{K \cdot cm^2}{W}$	1×10^{-4}	1	4.187	1.163×10^{-4}	5.678×10^{-4}
$\frac{K \cdot cm^2 \cdot s}{cal}$	2.388×10^{-5}	0.2388	1	2.778×10^{-5}	1.356×10^{-4}
$\frac{K \cdot m^2 \cdot h}{kg\text{-}cal}$	0.8598	8.598×10^3	3.6×10^4	1	4.882
$\frac{°F \cdot ft_2 \cdot h}{Btu}$	0.1761	1.761×10^3	7.373×10^3	0.2048	1

V. UNCERTAINTY OF METHOD

The uncertainty of the Rapid-k apparatus is estimated to be 4% at the two standard deviation level.