



Designation: C 653 – 97

Standard Guide for Determination of the Thermal Resistance of Low-Density Blanket-Type Mineral Fiber Insulation¹

This standard is issued under the fixed designation C 653; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide describes the calculation and interpolation of a thermal resistance value for low-density blanket-type insulation material at a particular density and thickness having been selected as representative of the product. It requires measured values of this average density and thickness, as well as apparent thermal conductivity values determined by either Test Method C 177, C 518, or C 1114.

1.2 This guide applies to a density range for mineral-fiber material of roughly 6.4 to 48 kg/m³ (0.4 to 3.0 lb/ft³). It is primarily intended to apply to low-density, mineral-fiber mass insulation batts and blankets, exclusive of any membrane facings. Apparent thermal conductivity data for these products are commonly reported at a mean temperature of 23.9°C (75°F) and a hot-to-cold plate temperature difference of 27.8°C (50°F) or 22.2°C (40°F).

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 ASTM Standards:

- C 167 Test Methods for Thickness and Density of Blanket or Batt Thermal Insulations²
- C 168 Terminology Relating to Thermal Insulating Materials²
- C 177 Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot-Plate Apparatus²
- C 518 Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus²
- C 1045 Practice for Calculating Thermal Transmission Properties from Steady-State Heat Flux Measurements²
- C 1114 Test Method for Steady-State Thermal Transmission Properties by Means of the Thin-Heater Apparatus²

3. Terminology

3.1 *Definitions*—For definitions used in this guide, refer to Terminology C 168.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *apparent thermal conductivity*, λ —the ratio of the specimen thickness to thermal resistance of the specimen. It is calculated as follows:

$$\lambda = L/R \text{ (W/m} \cdot \text{K) or (Btu} \cdot \text{in./ft}^2 \cdot \text{h} \cdot \text{F)} \quad (1)$$

3.2.1.1 *Discussion*—For this type of material an expression for the apparent thermal conductivity as a function of density is:

$$\lambda = a + bD + c/D \quad (2)$$

where a , b , c = parameters characteristic of a product, and related to the conductivity of the gas, the conductivity of the solid and the conductivity due to radiation.³

3.3 *Symbols*:*Symbols*—The symbols used in this guide have the following significance:

- R = thermal resistance, (m² K/W) or (h·ft² F/Btu)
- λ = apparent thermal conductivity, (W/m·K) or (Btu·in./h·ft²F)
- Q/A = heat flow per unit area, (W/m²) or (Btu/h·ft²)
- D = bulk density of a specimen, (kg/m³) or (lb/ft³)
- L = measured specimen thickness, (m) or (in.)
- T = apparatus plate temperature, (K) or (F)
- L' = specimen thickness if the sample from which the specimen is selected does not recover to label thickness, (m) or (in.)
- s = estimate of the standard deviation for a set of data points
- Δ = apparatus systematic error
- Ψ = overall uncertainty in a measured R -value

3.3.1 Subscripts:

- av = signifies average of a lot
- H = refers to hot surface
- C = refers to cold surface

¹ This guide is under the jurisdiction of ASTM Committee C-16 on Thermal Insulation and is the direct responsibility of Subcommittee C16.30 on Thermal Measurement.

Current edition approved Feb. 10, 1997. Published June 1997. Originally published as C 653 – 70. Last previous edition C 653 – 92.

² Annual Book of ASTM Standards, Vol 04.06.

³ Rennex, Brian G., "Thermal Parameters as a Function of Thickness for Combined Radiation and Conduction for Low-Density Insulation," *Journal of Thermal Insulation*, July 1979.

- T = refers to test specimen
 N = refers to nominal property for the product, as shown on the product label
 i = refers to a set of data points
 s = refers to a particular specimen

4. Significance and Use

4.1 This guide provides a method to determine the thermal performance of low-density blanket-type insulation. It may be used for the purposes of quality assurance, certification, or research.

4.2 The thermal resistance of low-density insulation depends significantly on the density, the thickness, and thermal conductivity. Typical low-density, mineral-fiber insulation for buildings may vary in density from one specimen to the next.

4.3 Thermal tests are time-consuming in comparison with density and thickness measurements. Low-density insulation material is produced in large quantities. A typical lot would be a truckload or the amount necessary to insulate a house.

4.4 The relatively low unit cost of this product and the relatively high cost of thermal resistance testing makes it cost-effective to test only a small percentage of the product area. It is recommended that there be a determination of the density that is representative of a lot by the measurement of the average density of a statistically representative sampling.

4.5 A fewer number of thermal measurements are then made to determine the apparent thermal conductivity at the previously determined representative density. The essential significance of this guide is that a large lot of variable material is best characterized by: (a) determining the representative density, and by (b) determining the thermal property at this representative density with a small number of thermal measurements.

4.6 Building insulation products are commonly manufactured in thicknesses ranging from 19 to 330 mm (0.75 to 13 in.) inclusive. Experimental work has verified that there is a dependence of λ_{app} on thickness for some low density materials.

4.7 The upper limit of test thickness for specimens evaluated using Test Methods C 177, C 518, and C 1114 is established based upon the apparatus design, overall dimensions, expected thermal resistivity level and desired target accuracy. The testing organization is responsible for applying these restrictions when evaluating a product to ensure that the results meet applicable product labels and any existing regulatory requirements.⁴

4.8 Extrapolation of the apparent thermal conductivity or the thermal resistance beyond the ranges of thickness or density of products tested is not valid.

5. Sampling

5.1 For low-density mineral-fiber insulation, a lot sample size of 75 to 150 ft² is recommended to determine the average density, D_{av} . Density is determined by using Test Method C 167; take care to avoid the use of damaged material.

5.2 In order to account for the variation in λ -value due to product density variability, measure a minimum of three “ λ versus D ” data points on three different samples. This represents nine data points for the “ λ versus D ” curve. Again, this “ λ versus D ” curve is developed to determine the λ -value at a particular representative density characteristic of a lot of material.

5.3 The size of a lot of material to be characterized, the amount of material measured for the representative values of density and thickness, and the frequency of tests all depend on the user’s needs, which could be related to quality assurance by a manufacturer, certification, or research.

6. Procedure

6.1 This procedure uses nine $\{\lambda_i; D_i\}$ data points all measured at the same hot and cold plate temperatures, to establish an interpolation equation for the determination of the λ -value at the average density, D_{av} . That is, the subscript i refers to the i^{th} test point. The D_i is the average density of the specimen within the apparatus meter-area. The thermal resistance at L_{av} and D_{av} is as follows:

$$R_{av} = L_{av}/\lambda_{av} \quad (3)$$

6.2 Before the set of “apparent thermal conductivity versus test density (λ_i versus D_i)” data points can be measured on an apparatus, it is necessary to choose the test densities and thicknesses. Three procedures for this choice are described in Annex A1.

6.2.1 *Procedure A*—A single test specimen is compressed to obtain different densities (A1.2). This procedure offers the advantage of less test time to obtain three test points.

6.2.2 *Procedure B*—A different specimen is used for each test point (A1.3). This method has the advantage of a better statistical sampling with regard to material variability.

6.2.3 *Procedure C*—Test at D_{av} thereby eliminating the need for an interpolation (A1.4).

6.3 Obtain a test value for λ at each of the three densities. These three sets of test values result in three equations of the form of Eq 2 in 3.2.2. These are solved simultaneously to determine the values of a_s , b_s , and c_s corresponding to specimen s (see A2.1.2).

NOTE 1—Small errors in the measured values of λ will result in large variations in the values of a , b , and c . Even so, the uncertainty of the interpolated value of λ will be comparable to the measured error in λ .

6.4 Whenever possible, calculate running averages for the specific product lot based on a number N equal to 20 or more sets of product curve parameters (a_s ; b_s ; c_s). Remember from 6.3 that each of these sets requires three test points (see A2.1.3).

6.4.1 A larger number N results in more consistent values for a , b , and c ; a smaller N represents a more current data base.

6.5 In 6.3 a set of parameter values was calculated, and in 6.4 a running average was calculated. This section describes how to obtain an interpolation curve (or equivalently a set of interpolation curve parameters) for the next sample, s , when it has been possible to previously obtain a running average set, ($\bar{a}$; $\bar{b}$; $\bar{c}$). The given values are the set $\{\bar{a}; \bar{b}; \bar{c}\}$ and the measured values of λ_i at three densities, D_i .

⁴ Albers, M. A., and Pelanne, C. M., “An Experimental and Mathematical Study of the Effect of Thickness in Low-Density Glass-Fiber Insulation,” *Proceedings, Seventeenth International Thermal Conductivity Conference*, J. G. Hust, Ed., Plenum Press, 1983, pp. 471–482.