



Designation: C518 – 17

Standard Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus¹

This standard is issued under the fixed designation C518; 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 reappraisal. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reappraisal.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope

1.1 This test method covers the measurement of steady state thermal transmission through flat slab specimens using a heat flow meter apparatus.

1.2 The heat flow meter apparatus is used widely because it is relatively simple in concept, rapid, and applicable to a wide range of test specimens. The precision and bias of the heat flow meter apparatus can be excellent provided calibration is carried out within the range of heat flows expected. This means calibration shall be carried out with similar types of materials, of similar thermal conductances, at similar thicknesses, mean temperatures, and temperature gradients, as expected for the test specimens.

1.3 This a comparative, or secondary, method of measurement since specimens of known thermal transmission properties shall be used to calibrate the apparatus. Properties of the calibration specimens must be traceable to an absolute measurement method. The calibration specimens should be obtained from a recognized national standards laboratory.

1.4 The heat flow meter apparatus establishes steady state one-dimensional 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, and thermal resistivity or thermal resistance and thermal conductance.

1.5 This test method shall be used in conjunction with Practice C1045. Many advances have been made in thermal technology, both in measurement techniques and in improved understanding of the principles of heat flow through materials. These advances have prompted revisions in the conceptual

approaches to the measurement of the thermal transmission properties (1-4).² All users of this test method should be aware of these concepts.

1.6 This 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 thicknesses up to approximately 250 mm, and with plate temperatures from -195°C to 540°C at 25-mm thickness (5, 6).

1.7 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 C236 or C976 should be used if needed.

1.8 To meet the requirements of this test method the thermal resistance of the test specimen shall be greater than 0.10 m²·K/W in the direction of the heat flow and edge heat losses shall be controlled, using edge insulation, or a guard heater, or both.

1.9 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.

1.10 The user of this method must be familiar with and understand the Annex. The Annex is critically important in addressing equipment design and error analysis.

1.11 Standardization of this test method is not intended to restrict in any way the future development of improved or new methods or procedures by research workers.

1.12 Since the design of a heat flow meter apparatus is not a simple matter, a procedure for proving the performance of an apparatus is given in Appendix X3.

¹ This test method is under the jurisdiction of ASTM Committee C16 on Thermal Insulation and is the direct responsibility of Subcommittee C16.30 on Thermal Measurement.

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² The boldface numbers in parentheses refer to the list of references at the end of this test method.

1.13 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.14 *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 consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.15 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 ASTM Standards:³

C167 Test Methods for Thickness and Density of Blanket or Batt Thermal Insulations

C168 Terminology Relating to Thermal Insulation

C177 Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot-Plate Apparatus

C236 Test Method for Steady-State Thermal Performance of Building Assemblies by Means of a Guarded Hot Box (Withdrawn 2001)⁴

C687 Practice for Determination of Thermal Resistance of Loose-Fill Building Insulation

C976 Test Method for Thermal Performance of Building Assemblies by Means of a Calibrated Hot Box (Withdrawn 2002)⁴

C1045 Practice for Calculating Thermal Transmission Properties Under Steady-State Conditions

C1046 Practice for In-Situ Measurement of Heat Flux and Temperature on Building Envelope Components

C1058 Practice for Selecting Temperatures for Evaluating and Reporting Thermal Properties of Thermal Insulation

C1114 Test Method for Steady-State Thermal Transmission Properties by Means of the Thin-Heater Apparatus

E230/E230M Specification for Temperature-Electromotive Force (emf) Tables for Standardized Thermocouples

E178 Practice for Dealing With Outlying Observations

E456 Terminology Relating to Quality and Statistics

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

2.2 ISO Standard:

ISO 8301:1991 Thermal Insulation—Determination of Steady-State Thermal Resistance and Related Properties—Heat Flow Meter Apparatus⁵

³ For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

⁴ The last approved version of this historical standard is referenced on www.astm.org.

⁵ Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, <http://www.ansi.org>.

3. Terminology

3.1 *Definitions*—For definitions of terms and symbols used in this test method, refer to Terminology **C168** and to the following subsections.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *calibration, n*—the process of establishing the calibration factor for a particular apparatus using calibration specimens having known thermal transmission properties.

3.2.2 *calibration transfer specimen, n*—(CTS) a thermal calibration specimen that has been measured by a national standards laboratory (7).

3.2.3 *cold surface assembly, n*—the plate that provides an isothermal boundary at the cold surface of the test specimen(s).

3.2.4 *controlled environment, n*—an environment sometimes employed in the apparatus to limit lateral heat flows.

3.2.5 *edge insulation, n*—auxiliary insulation used to limit lateral heat flows, these are sometimes permanently mounted in the apparatus.

3.2.6 *guard, n*—promotes one-dimensional heat flow. Primary guards are planar, additional coplanar guards can be used and secondary or edge guards are axial.

3.2.7 *heat flow meter apparatus, n*—the complete assemblage of the instrument, including hot and cold isothermal surfaces, the heat flux transducer(s), and the controlled environment if used, and instrumentation to indicate hot and cold surface temperatures, specimen thickness, and heat flux.

3.2.8 *hot surface assembly, n*—the plate that provides an isothermal boundary at the hot surface of the test specimen(s).

3.2.9 *heat flux transducer, n*—a device containing a thermopile, or an equivalent, that produces an output which is a function of the heat flux passing through it. The metering area usually consists of a number of differently connected temperature sensors placed on each face of a core and surface sheets to protect the assembly. A properly designed transducer will have a sensitivity that is essentially independent of the thermal properties of the specimen.

3.2.10 *metering area, n*—the area of the specimen(s) in contact with the sensor area of the heat flux transducer.

3.2.11 *secondary transfer standard, n*—a specimen, which has been measured in a heat flow meter apparatus, which has been calibrated with primary standards, used to calibrate additional apparatuses.

3.2.12 *sensitivity, n*—the ratio of the heat flux passing through the transducer to the electrical output of the heat flux transducer.

3.2.13 *standard reference material (SRM), n*—a lot of material that has been characterized by a national standards laboratory (7).

3.2.14 *thermal transmission properties, n*—those properties of a material or system that define the ability of the material or system to transfer heat. Properties, such as thermal resistance, thermal conductance, thermal conductivity, and thermal resistivity would be included, as defined in Terminology **C168**.

3.3 *Symbols and Units*—The symbols used in this test method have the following significance:

- 3.3.1 λ —thermal conductivity, $W/(m \cdot K)$.
- 3.3.2 C —thermal conductance, $W/(m^2 \cdot K)$
- 3.3.3 R —thermal resistance, $(m^2 \cdot K)/W$.
- 3.3.4 q —heat flux (heat flow rate, Q , through area A), W/m^2 .
- 3.3.5 Q —heat flow rate in the metered area, W .
- 3.3.6 A —metering area, m^2 .
- 3.3.7 L —separation between the hot and cold plate assemblies during testing, m .
- 3.3.8 T_m —mean temperature, $(T_h + T_c)/2$, K .
- 3.3.9 ΔT —temperature difference across the specimen, K .
- 3.3.10 ρ —(bulk) density of the material tested, kg/m^3 .
- 3.3.11 S —calibration factor of the heat flux transducer, $(W/m^2)/V$.
- 3.3.12 E —heat flux transducer output, V .
- 3.3.13 T_h —temperature of the hot plate surface, K .
- 3.3.14 T_c —temperature of the cold plate surface, K .
- 3.4 *Subscripts*:
- 3.4.1 h —hot.
- 3.4.2 c —cold
- 3.4.3 a, b —first and second specimen.
- 3.4.4 m —mean.
- 3.4.5 α —statistical term used to define significance level.

4. Significance and Use

4.1 This test method provides a rapid means of determining the steady-state thermal transmission properties of thermal insulations and other materials with a high level of accuracy when the apparatus has been calibrated appropriately.

4.2 Proper calibration of the heat flow meter apparatus requires that it be calibrated using specimen(s) having thermal transmission properties determined previously by Test Methods C177, or C1114.

NOTE 1—Calibration of the apparatus typically requires specimens that are similar to the types of materials, thermal conductances, thicknesses, mean temperatures, and temperature gradients as expected for the test specimens.

4.3 The thermal transmission properties of specimens of a given material or product may vary due to variability of the composition of the material; be affected by moisture or other conditions; change with time; change with mean temperature and temperature difference; and depend upon the prior thermal history. It must be recognized, therefore, that the selection of typical values of thermal transmission properties representative of a material in a particular application should be based on a consideration of these factors and will not apply necessarily without modification to all service conditions.

4.3.1 As an example, this test method provides that the thermal properties shall be obtained on specimens that do not contain any free moisture although in service such conditions may not be realized. Even more basic is the dependence of the thermal properties on variables, such as mean temperature and temperature difference. These dependencies should be measured or the test made at conditions typical of use.

4.4 Special care shall be taken in the measurement procedure for specimens exhibiting appreciable inhomogeneities,

anisotropies, rigidity, or especially high or low resistance to heat flow (see Practice C1045). The use of a heat flow meter apparatus when there are thermal bridges present in the specimen may yield very unreliable results. If the thermal bridge is present and parallel to the heat flow the results obtained may well have no meaning. Special considerations also are necessary when the measurements are conducted at either high or low temperatures, in ambient pressures above or below atmospheric pressure, or in special ambient gases that are inert or hazardous.

4.5 The determination of the accuracy of the method for any given test is a function of the apparatus design, of the related instrumentation, and of the type of specimens under test (see Section 10), but this test method is capable of determining thermal transmission properties within $\pm 2\%$ of those determined by Test Method C177 when the ambient temperature is near the mean temperature of the test ($T(\text{ambient}) = T(\text{mean}) \pm 1^\circ\text{C}$), and in the range of 10 to 40°C . In all cases the accuracy of the heat flow meter apparatus can never be better than the accuracy of the primary standards used to calibrate the apparatus.

4.5.1 When this test method is to be used for certification testing of products, the apparatus shall have the capabilities required in A1.7 and one of the following procedures shall be followed:

4.5.1.1 The apparatus shall have its calibration checked within 24 h before or after a certification test using either secondary transfer standards traceable to, or calibration standards whose values have been established by, a recognized national standards laboratory not more than five years prior to the certification date. The average of two calibrations shall be used as the calibration factor and the specimen(s) certified with this average value. When the change in calibration factor is greater than 1%, the standard specimen shall be retested and a new average calculated. If the change in calibration factor is still greater than 1% the apparatus shall be calibrated using the procedure in Section 6.

4.5.1.2 Where both the short and long term stability of the apparatus have been proven to be better than 1% of the reading (see Section 10), the apparatus may be calibrated at less frequent intervals, not exceeding 30 days. The specimens so tested cannot be certified until after the calibration test following the test and then only if the change in calibration factor from the previous calibration test is less than 1%. When the change in calibration is greater than 1%, test results from this interval shall be considered void and the tests repeated in accordance with 4.5.1.1.

4.5.2 The precision (repeatability) of measurements made by the heat flow meter apparatus calibrated as in Section 6.6 normally are much better than $\pm 1\%$ of the mean value. This precision is required to identify changes in calibration and is desirable in quality control applications.

5. Apparatus

5.1 The construction guidelines given in this section should be understood by the user of this test method. While it is mandatory that these details be followed carefully when constructing an apparatus, it behooves the user to verify that