INTERNATIONAL

Designation: C 518 – 02

Standard Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus[1]

This standard is issued under the fixed designation C 518; 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 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 C 1045. 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 C 236 or C 976 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 $m^2 \cdot K/W$ 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 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.

1.11 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.

1.12 *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.*

2. Referenced Documents

2.1 *ASTM Standards:*

C 167 Test Methods for Thickness and Density of Blanket or Batt Thermal Insulations[3]

C 168 Terminology Relating to Thermal Insulation[3]

C 177 Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of

[1] This test method is under the jurisdiction of ASTM Committee C16 on Thermal Insulation and is the direct responsibility of Subcommittee C 16.30 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.

[3] *Annual Book of ASTM Standards*, Vol 04.06.

the Guarded Hot Plate Apparatus[3]

C 236 Test Method for Steady-State Thermal Performance of Building Assemblies by Means of a Guarded Hot Box[3]

C 687 Practice for Determination of the Thermal Resistance of Loose-Fill Building Insulation[3]

C 976 Test Method for Thermal Performance of Building Assemblies by Means of a Calibrated Hot Box[3]

C 1045 Practice for Calculating Thermal Transmission Properties Under Steady-State Conditions[3]

C 1046 Practice for In-Situ Measurement of Heat Flux and Temperature on Building Envelope Components[3]

C 1058 Practice for Selecting Temperatures for Evaluating and Reporting Thermal Properties of Thermal Insulation[3]

C 1114 Test Method for Steady-State Thermal Transmission Properties by Means of the Thin-Heater Apparatus[3]

C 1132 Practice for Calibration of the Heat Flow Meter Apparatus[3]

E 230 Specification and Temperature-Electromotive Force (EMF) Tables for Standardized Thermocouples[4]

E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method[5]

2.2 *ISO Standard:*

ISO 8301:1991 Thermal Insulation—Determination of Steady-State Thermal Resistance and Related Properties—Heat Flow Meter Apparatus[6]

3. Terminology

3.1 *Definitions*—For definitions of terms and symbols used in this test method, refer to Terminology C 168 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.

3.2.3 *cold surface assembly*, *n*—the plate that provides as 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.

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 C 168.

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.

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 C 177, or C 1114.

[4] *Annual Book of ASTM Standards*. Vol. 14.03.

[5] *Annual Book of ASTM Standards*, Vol. 1402.

[6] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

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 C 1045). 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 ± 2 % of those determined by Test Method C 177 when the ambient temperature is near the mean temperature of the test (T (ambient) = T (mean)± 1°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 5.8 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 redetermined 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 ± 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 the equipment is built as specified. Serious errors of measurement may result from this oversight.

5.2 *General*:

5.2.1 The general features of a heat flow meter apparatus with the specimen or the specimens installed are described in Section 6 and shown in Figs. 1-3. A heat flow meter apparatus consists of two isothermal plate assemblies, one or more heat flux transducers and equipment to control the environmental conditions when needed. Each configuration will yield equivalent results if used within the limitations stated in this test method. There are distinct advantages for each configuration in practice and these are discussed in Appendix X2.

NOTE 2—Further information can be found in ISO 8301:1991, which is the equivalent ISO standard for the Heat Flow Meter Apparatus.

5.2.2 The exposed surfaces of the plates and the heat flux transducer, that is, the surfaces making contact with the specimens, shall be painted or otherwise treated to have a total hemispherical emittance of greater than 0.8 at their operating temperatures (see Note 3).

NOTE 3—Hard anodizing of aluminum produces a surface with a total hemispherical emittance of approximately 0.85. Several paints are available, which when applied as directed, produce a total hemispherical emittance of approximately 0.86.

5.3 *Plate Assemblies, Hot and Cold*—The two plate assemblies should provide isothermal surfaces in contact with either side of the test specimen. The assemblies consist of heat source or sink, a high conductivity surface, means to measure surface

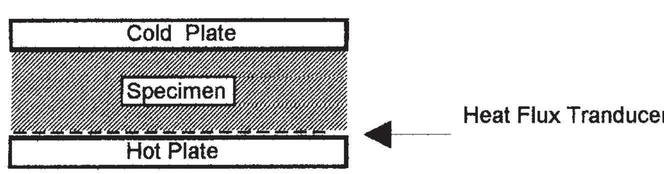

FIG. 1 Apparatus with One Heat Flux Transducer and One Specimen

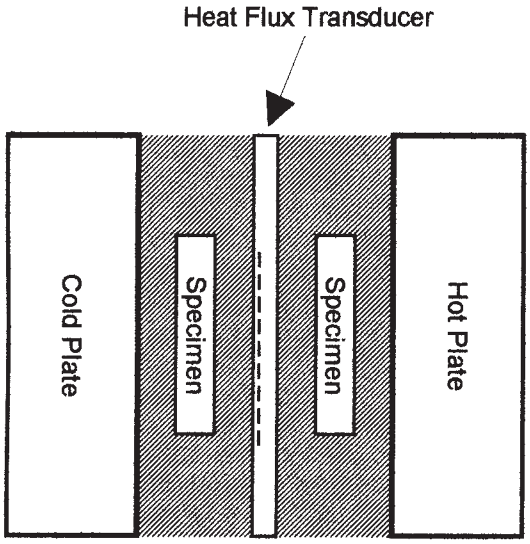

FIG. 2 Apparatus with One Heat Flux Transducer and Two Specimens

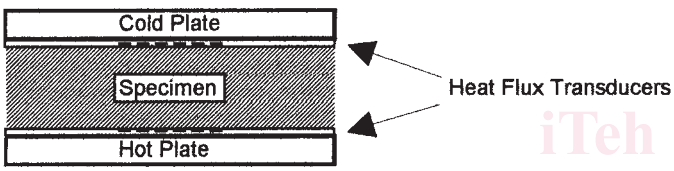

FIG. 3 Apparatus with Two Heat Flux Transducers and One Specimen

temperature, and means of support. A heat flux transducer may be attached to one, both, or neither plate assembly, depending upon the design, (see Section 6). In all cases, the area defined by the sensor of the heat flux transducer is called the metering area and the remainder of the plate is the guard area.

5.3.1 The portion of each plate assembly in contact with the heat flux transducer, or if a heat flux transducer is not mounted on the plate assembly, the portion in contact with the specimen, shall consist of a high conductivity material, known as the isothermal plate. The isothermal plate shall be supported so as to minimize temperature gradients across its surface. Deviations from isothermal conditions over the plate surface of no more than ± 0.3 *K* shall be allowed.

5.3.2 A means shall be provided to maintain the temperature of the plate assemblies at the desired level. Examples are fluid baths, electrical heaters, or thermoelectric coolers, or a combination thereof **(7-9)**.

5.3.3 If a heat flux transducer is located at the midplane of the specimens (see Fig. 2), then means shall be provided to determine the average temperature of the transducer in order to apply temperature corrections to the calibration, except when the test temperatures are equal to those used in calibration, in which case no correction is required. If a matched pair of specimens is tested, the temperature of the transducer can be computed from the temperatures of the plate assemblies.

5.3.4 The plate assemblies shall be sufficiently rigid to maintain flatness and parallelism. For an apparatus designed to be used over wide ranges of conductivity and thickness (thermal resistances) the flatness and parallelism of the plates should be 0.02 % of the maximum linear dimensions of the plates (see Note 4). One way to check this is to use standard gauge blocks to generate a map over the metering area **(10)**. For instruments designed to be used solely for testing nonrigid materials with a small range of resistances it has been shown that a flatness of 0.2 % of the maximum linear dimension is sufficient, but these instruments should be calibrated with standards having a thermal resistance between 0.5 and 1.0 times the resistance of the tested specimens.

NOTE 4—The planeness of the surface can be checked with a straightedge, of a length greater than the width or diameter of the unit, held against the surface and viewed with a light behind the straightedge. Departures as small as 25µm are readily visible, and larger departures can be measured using shimstock or thin paper.

5.3.4.1 It is important to maintain the parallelism of the plates for several reasons. In most cases it is the plate separation, which is measured in order to determine specimen thickness. Furthermore, the plate parallelism is important in maintaining consistent surface contact with specimens in repeat testing, such as calibration, and is required to maintain a uniform temperature difference across the specimen(s). If the plate temperatures are cycled continuously during testing, the flatness needs to be checked periodically.

5.3.5 Plate flatness may become critical when measuring specimens with less thermal resistance than the calibration standards, irrespective of the thickness or rigidity of the calibration standard. For rigid thin specimens the criteria given in 5.3.4 may not be sufficient.

5.3.6 The rigidity, flatness, and parallelism of the plates may impede the testing of rigid specimens where it is not possible to obtain good surface contact. In such cases, the use of a thin sheet of suitable homogeneous material may be interposed between the specimen and the plates surfaces. This thin sheet should have a low thermal resistance relative to the specimen. The resistance of the thin sheet should be determined using a Test Method C 177 apparatus. The resistance of the composite sandwich (sheet-rigid specimen-sheet) then is determined and the value of the sheet resistance subtracted from the total resistance.

5.4 *Temperature Measuring and Control Systems*:

5.4.1 The surfaces of the plate assemblies in contact with the specimen(s) shall be instrumented with precision temperature sensors such as thermocouples, platinum resistance thermometers (RTD), and thermistors. Temperature sensors shall be mounted in grooves so as to be flush with the surface in contact with the specimen(s).

5.4.2 No strict specification is given as the number of temperature sensors that shall be used for each surface; however, the user shall report the uncertainty of the temperature measurement, including the component due to temperature nonuniformity across the surface. In some cases where temperature mapping of the plate surfaces has indicated high uniformity under all conditions of use, one thermal sensor per surface has been used satisfactorily.

5.4.2.1 Special precautions should be taken to ensure that the temperature sensors are anchored thermally to the surface to be measured and that the temperature gradients along the wires leading to the sensors are minimized. If thermocouples on opposing surfaces are connected differentially, they shall be electrically insulated from the plates with a resistance of 1 megohm or greater **(5, 6)**.

5.4.2.2 Thermocouples mounted in the surfaces of the plates or set into the surfaces of specimens should be made of wire no longer than 0.25 mm in diameter (No. 30 B and S gage). For highest accuracy only" special limit" thermocouples should be used. In addition, even these "special limit" thermocouples should be checked for nonhomogeneities in the wire. For information concerning voltage output and accuracy of thermocouples in the cryogenic temperature range, and installation see references **(7, 8)**.

5.4.2.3 Temperature sensors should be calibrated to an accuracy equivalent to that for thermocouples conforming to Tables E 230. The precision of the temperature measuring system may need to be better than this to detect the effect of drift on the results discussed in Appendix X3. The accuracy required by a heat flow meter apparatus can best be determined by carrying out an error analysis (see Section 8), and then calibrating the temperature sensors to the degree required.

5.4.2.4 In the special case where the heat flow meter apparatus is used only for repetitive tests on one material and the same plate temperatures are used for calibration (and where the standards are tested at the same temperatures), the accuracy of the calibration of the temperature sensors will not be as critical since any errors will remain constant and be included in the calibration.

5.5 *Heat Flux Transducer*:

5.5.1 *Types of Heat Flux Transducer*—The types of heat flux transducers are described in Practice C 1046. The gradient type, often used in the heat flow meter apparatus, consists of a slab of material, the "core," across which the temperature gradient is measured, normally with a thermopile. The main transducer surfaces are assumed to be isothermal, so the heat flow will be normal to them. Precautions shall be taken to limit the effect of heat flow through the leads on the output of the thermopile. Often the heat flux transducer also is instrumented to measure one of the surface temperatures of the specimen(s).

5.5.2 *Surface Sheets*—Both surfaces of the transducer should be covered with a layer of material as thin as is compatible with protection from thermal shunting of the thermopile. The exposed surfaces of the heat flux transducer shall be finished smoothly to conform to the desired geometric shape to within the limits of 5.3.5.

5.6 *Plate Separation, Specimen Thickness*—A means shall be provided to determine the average separation between the heating and cooling plate surfaces during operation. Rigid specimens generally act as the spacers themselves, and plate separation is determined by their thickness at operating temperature. In this case, a small constant force generally is applied to hold the plates against the specimen. It is unlikely that a pressure greater than 2.5 kPa will be required. For easily compressible specimens, small stops interposed between the corners of the hot and cold plates, or some other positive means shall be used to limit the compression of the specimens (see Note 5). Provision shall be made for checking the linearity of any thickness measuring system.

NOTE 5—Because of the changes of specimen thickness possible as a result of temperature or compression by the plates, it is recommended that specimen thickness be measured in the apparatus, at the existing test temperature and compression conditions whenever possible.

5.7 *Edge Insulation*—Heat loss from the outer edges of the heat flow meter apparatus and specimens shall be restricted by edge insulation or by governing the surrounding air temperature or by both methods. The three different configuration differ in their susceptibility to edge heat losses as is discussed in Appendix X2 **(2, 4, 9, 10)**.

5.7.1 For all three configurations, the susceptibility to edge heat losses is related strongly to the sensitivity of the transducer to temperature differences along its main surfaces, and therefore, only experimental checks while changing environmental conditions can confirm, for each operating condition, the magnitude of the effect of edge heat losses on measured heat flux. This error should be smaller than 0.5 %.

5.8 *Measuring System Requirements*—The apparatus measuring system shall have the following capabilities:

5.8.1 The uncertainty of the measurement of the temperature difference across the specimens shall be within ± 0.5 % of the actual temperature difference.

5.8.2 A voltage accuracy of better than 0.2 % of the minimum output (from the transducer) to be measured.

5.8.3 Sufficient linearity so that the system contributes less than 0.2 % error at all outputs.

5.8.4 Sufficient input impedance so that the system contributes less than 0.1 % error for all readings. One megohm has been found adequate for many apparatuses.

5.8.5 Sufficient stability so that the system contributes less than 0.2 % error during the period between calibrations, or 30 days, whichever is greater.

5.8.6 Adequate noise immunity so that less than 0.2 % rms noise occurs in the readings.

5.8.7 Where direct readout equipment is used, adequate provision shall be made for calibration of the electronic circuitry, independent of the remainder of the apparatus, and shall contribute no more than 0.2 % error, for each variable.

5.9 *Proven Performance*—The test results obtained by this test method only can be assured if the limitations of the apparatus are known. See Appendix X3 for further details. To establish these limitations, one must prove the performance by comparing the results with materials of similar thermal properties previously tested on a guarded hot plate apparatus as those to be evaluated.

5.9.1 A single point of reference may lead to serious errors. It is best to select a range of transfer standards having known thermal transmission properties, which cover the range of values to be tested, in both resistance and thickness.

5.9.2 If the apparatus is to be used at thicknesses greater than that of the available reference materials, a series of calibration measurements shall be performed to insure that the equipment does not introduce additional errors, which may be due to lateral heat losses or gains brought about by insufficient guarding **(4, 10)**. One means of checking for these errors is to use multiple thicknesses of the calibration standards. If these are stacked with a radiation blocking septum between each of the standards, the first approximation is that the total thermal resistance is the sum of the individual thermal resistances.

5.10 *Environmental Control*—In many applications, it is desirable to control the environment surrounding the test specimen to reduce edge heat losses, and it is especially important when the mean test temperature is below the ambient temperature, in order to avoid condensation on the cold plate. A cabinet or enclosure surrounding the isothermal plates and the specimens to maintain the ambient temperature at the mean temperature of the specimen also may be used as a means to maintain the dew point temperature at least 5 K lower than the temperature on the cold plates, in order to prevent condensation and moisture pickup by the specimen. Any environmental control system employed in conjunction with a heat flow meter apparatus shall be capable of maintaining its set point condition within ± 1°C in temperature.

6. Calibration

6.1 The calibration of a heat flow meter apparatus is a very critical operation. Since lateral heat losses or gains of heat are not controlled or eliminated automatically, but only lessened by increasing the size of the guard area and edge insulation, there is no guarantee that the heat losses or gains are negligible under all testing conditions. To ensure that the equipment is performing properly with specimens of different thermal resistances, the apparatus shall be calibrated with materials having similar thermal characteristics and thicknesses as the materials to be evaluated. The apparatus shall be calibrated with the specimen in the same orientation and the heat flux in the same direction under which the primary, CTS or SRM, or secondary transfer standards were characterized, if known. The material selected for the calibration standard shall have properties that are not affected by convection over the range of calibration parameters (temperature difference, thickness, density, and so forth) of interest. The apparatus shall be calibrated as a unit, with the heat flux transducers(s) installed in the apparatus.

6.2 This procedure applies to the calibration of a heat flow meter apparatus over a wide range of heat flow rates and temperatures, which permits the testing of a wide variety of insulation materials over an extended temperature range.

6.3 The following calibration procedure is used to compute the calibration factor, S (see Practice C 1132) for a heat flow meter apparatus, and must be used by anyone who desires to produce meaningful heat flux measurements from a heat flow apparatus.

6.4 *Calibration Standards*:

6.4.1 Calibration standards may be good for many years if handled carefully but shall be checked periodically to confirm lack of change.

6.4.2 It is recommended that the primary standards obtained from a national standards laboratory should not be used on a daily basis, but secondary or working standards should be produced. Create a record on the secondary standards with the following information.

6.4.2.1 Name of national laboratory to which it is traceable.

6.4.2.2 Date the secondary standard is produced.

6.4.2.3 Date the secondary standard is last tested.

6.4.2.4 Thermal value of the secondary standard.

6.4.2.5 Range of parameters for which it is valid.

6.4.2.6 Estimate of bias of the primary and secondary standards.

6.5 *Calibration Procedure*:

6.5.1 Calibrate the heat flow meter apparatus under the same conditions of plate temperatures, temperature gradient, specimen thickness, heat flow direction, and apparatus orientation as those for which data are available for the standard.

6.5.2 *Single Temperature Point*—If the calibration standard is tested at a single mean temperature, conduct the calibration and subsequent tests near the same mean temperature. Use engineering judgment or an error analysis to determine how closely the mean temperature must be maintained. As assessment of the sensitivity of the calibration standard to test conditions should be determined by the user of the transfer standard to determine its limitations of use.

6.5.3 *Multiple Temperature Points*—If the calibration standard is tested at three or more mean temperatures, calibrate the heat flow meter apparatus at the same temperatures using the same temperature gradients **(11)**. A smooth curve can be fitted to the points such that a calibration factor can be interpolated for any given mean temperature. It is not permissible to extrapolate above or below the mean temperature range of the calibration standard measurements. Changing the plate temperature of a heat flow meter apparatus has the potential of changing apparatus calibration. When changing plate temperatures, take steps to determine if the heat flux transducer calibration factor has changed.

6.5.4 *Single Thickness Point*—If the original calibration standard is tested at only one thickness, the heat flow meter apparatus can be calibrated for that thickness without an exhaustive thickness study. If tests are to be conducted at thicknesses other than the calibrated thickness, make a thorough study of the error of the heat flow meter apparatus at other thicknesses. Several references on this subject are listed at the end of this test method **(4** and **12-15)**.

6.5.5 *Multiple Thickness Points*—If the original standard is tested at three or more thicknesses, the heat flow meter apparatus can be calibrated over the same thickness range. A smooth curve can be fitted to the points such that a calibration factor can be interpolated for any given thickness. If tests are to be conducted at thicknesses above or below the calibrated thicknesses, make a thorough study of the error of the heat flow meter apparatus at these thicknesses.

6.6 *Calibration of Various Designs*:

6.6.1 There are several configurations of heat flow meter apparatuses that use one or two heat flux transducers and one or two specimens in the apparatus. While it is not practical to list all of the possible combinations of apparatus and specimen configurations, this section contains the equations for calculating the calibration factor of three common apparatuses. The calibration and testing configuration should be identical. The calibration factor of a heat flow meter apparatus is determined by running the same standard specimens a number of times, not consecutively, but over a period of time with the standard removed each time.

6.6.2 *One Calibration Standard*—Apparatus with one heat flux transducer and one standard (see Fig. 1).

$$S = C \cdot (Th - Tc)/E \quad (1)$$

6.6.3 *Two Calibration Standards*—Apparatus with one heat flux transducer and one specimen configuration (same as that for 6.6.2).