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Standard Practice for
Using a Guarded-Hot-Plate Apparatus or Thin-Heater Apparatus in the Single-Sided Mode[1]

This standard is issued under the fixed designation C1044; 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 practice covers the determination of the steady-state heat flow through the meter section of a specimen when a guarded-hot-plate apparatus or thin-heater apparatus is used in the single-sided mode of operation.

1.2 This practice provides a supplemental procedure for use in conjunction with either Test Method C177 or C1114 for testing a single specimen. This practice is limited to only the single-sided mode of operation, and, in all other particulars, the requirements of either Test Method C177 or C1114 apply.

NOTE 1—Test Methods C177 and C1114 describe the use of the guarded-hot-plate and thin-heater apparatus, respectively, for determining steady-state heat flux and thermal transmission properties of flat-slab specimens. In principle, these methods cover both the double- and single-sided mode of operation, and at present, do not distinguish between the accuracies for the two modes of operation. When appropriate, thermal transmission properties shall be calculated in accordance with Practice C1045.

1.3 This practice requires that the cold plates of the apparatus have independent temperature controls. For the single-sided mode of operation, a (single) specimen is placed between the hot plate and the cold plate. Auxiliary thermal insulation, if needed, is placed between the hot plate and the auxiliary cold plate. The auxiliary cold plate and the hot plate are maintained at essentially the same temperature. Ideally, the heat flow from the meter plate is assumed to flow only through the specimen, so that the thermal transmission properties correspond only to the specimen.

NOTE 2—The double-sided mode of operation requires similar specimens placed on either side of the hot plate. The cold plates that contact the outer surfaces of these specimens are maintained at essentially the same temperature. The electric power supplied to the meter plate is assumed to result in equal heat flow through the meter section of each specimen, so that the thermal transmission properties correspond to an average for the two specimens.

1.4 This practice does not preclude the use of a guarded-hot-plate apparatus in which the auxiliary cold plate may be either larger or smaller in lateral dimensions than either the test specimen or the cold plate.

NOTE 3—Most guarded-hot-plate apparatus are designed for the double-sided mode of operation (**1**).[2] Consequently, the cold plate and the auxiliary cold plate are the same size and the specimen and the auxiliary insulation will have the same lateral dimensions, although the thickness may be different. Some guarded-hot-plate apparatus, however, are designed specifically for testing only a single specimen that may be either larger or smaller in lateral dimensions than that auxiliary insulation or the auxiliary cold plate.

1.5 This practice can be used for both low- and high-temperature conditions.

1.6 This practice shall not be used when operating an apparatus in a double-sided mode of operation with a known and unknown specimen, that is, with the two cold plates at similar temperatures so that the temperature differences across the known and unknown specimens are similar.

1.7 *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:* [3]
C168 Terminology Relating to Thermal Insulation [3]
C177 Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot-Plate Apparatus [3]
C518 Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus [3]
C1045 Practice for Calculating Thermal Transmission Properties Under Steady-State Conditions [3]

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[1] This practice 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 standard.

[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.

1

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

3. Terminology

3.1 *Definitions*—For definitions of terms used in this practice, refer to Terminology C168. For definitions of terms relating to the guarded-hot-plate apparatus or thin-heater apparatus refer to Test Methods C177 or C1114, respectively,

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *auxiliary cold plate*, *n*—the plate that provides an isothermal boundary at the outside surface of the auxiliary insulation.

3.2.2 *auxiliary insulation*, *n*—thermal insulation used in place of a second test specimen, when the single-sided mode of operation is used (syn. dummy specimen).

3.2.3 *cold plate*, *n*—the plate that provides an isothermal boundary at the cold surface of the specimen.

3.2.4 *double-sided mode*, *n*—operation of the apparatus, such that the heat input to the meter plate flows equally through two specimens, each specimen placed on either side of the hot plate (see also **single-sided mode**).

3.2.5 *gap*, *n*—separation between the meter plate and guard plate, usually filled with a gas or thermal insulation.

3.2.6 *guard plate*, *n*—the outer (rectangular or circular) ring of the guarded hot plate, that encompasses the meter plate and promotes one-dimensional heat flow normal to the meter plate.

3.2.7 *guarded hot plate*, *n*—an assembly, consisting of a meter plate and a co-planar, concentric guard plate, that provides the heat input to the specimen(s).

3.2.8 *meter plate*, *n*—the inner (rectangular or circular) plate of the guarded hot plate, that provides the heat input to the meter section of the specimen(s).

3.2.9 *meter section*, *n*—the portion of the specimen (or auxiliary insulation) through which the heat input to the meter plate flows under ideal guarding conditions.

3.2.10 *single-sided mode*, *n*—operation of the apparatus such that essentially all of the heat input to the meter plate flows through a specimen placed on one side of the hot plate (see also **double-sided mode**).

3.2.11 *thin heater*, *n*—an assembly, consisting of a unpartitioned thin-screen heater or thin-foil, that provides the heat input to the specimen(s).

3.3 *Symbols*—The symbols used in this practice have the following significance. The prime ($'$) denotes quantities associated with the auxiliary insulation used to control heat from the other side of the hot plate.

3.3.1 A—metre area of hot plate, m^2.

3.3.2 C'—thermal conductance of auxiliary insulation, $W/(m^2 \cdot K)$.

3.3.3 Q—heat flow through meter section of specimen, W.

3.3.4 Q'—heat flow through meter section of auxiliary insulation, W.

3.3.5 Q_m—power input to meter plate, W.

3.3.6 T_c—surface temperature of cold plate, K.

3.3.7 T'_c—surface temperature of auxiliary cold plate, K.

3.3.8 T_h—surface temperature of hot plate in contact with specimen, K.

3.3.9 T'_h—surface temperature of hot plate in contact with auxiliary insulation, K.

4. Significance and Use

4.1 This practice provides a procedure for operating the apparatus so that the heat flow, Q', through the meter section of the auxiliary insulation is small; determining Q'; and, calculating the heat flow, Q, through the meter section of the specimen.

4.2 This practice requires that the apparatus have independent temperature controls in order to operate the cold plate and auxiliary cold plate at different temperatures. In the single-sides mode, the apparatus is operated with the temperature of the auxiliary cold plate maintained, as close as possible, to the temperature of the side of the hot plate adjacent to the auxiliary insulation.

NOTE 4—Ideally, if the temperature difference across the auxiliary insulation is zero and there are no edge heat losses or gains, all of the power input to the meter plate will flow through the specimen. In practice, a small correction is made for heat flow, Q', through the auxiliary insulation.

4.3 The thermal conductance, C', of the auxiliary insulation must be determined from one or more separate tests using either Test Method C177, C1114, or as indicated in 5.4. The values of C' should be checked periodically, particularly if during regular testing it is not possible to keep the temperature drop across the auxiliary insulation less than 1 % of the temperature drop across the test specimen.

4.4 This practice can be used when it is desirable to determine the thermal properties of a single specimen. For example, the thermal properties of a single specimen are used to calibrate a heat-flow-meter apparatus for Test Method C518. In other cases, there may be only one specimen available.

5. Procedure for Single-Sided Mode of Operation

5.1 Refer to Fig. 1 for a schematic diagram of the single-sided mode of operation of the guarded-hot-plate apparatus.

NOTE 5—The schematic diagram for a thin-heater apparatus (not shown) is similar, except the hot plate is much thinner and is not partitioned by a gap.

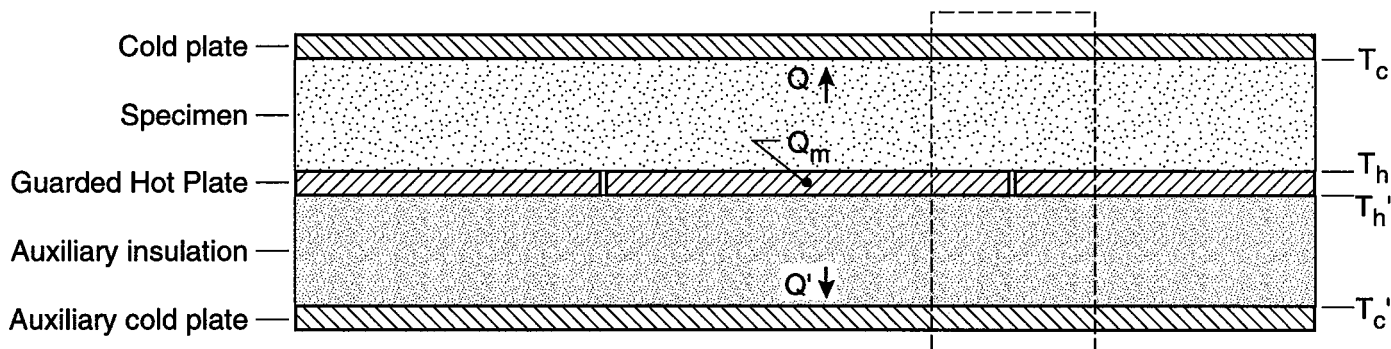5.2 Follow the procedure of either Test Method C177 or C1114 with the following modifications.

5.3 Select a semi-rigid material for the auxiliary insulation having a low thermal conductance so that heat gains or losses from the face of the meter plate in contact with the auxiliary insulation will be small. The thickness and lateral conductance of the auxiliary insulation should be small enough to avoid significant effects on the heat transfer through the meter section of the auxiliary insulation due to heat transfer at the edge of the auxiliary insulation.

NOTE 6—The influence of edge effects for a particular apparatus and test configuration can be determined experimentally as described in Test Method C177 or by computation using one of the procedures referenced in Test Method C177 or described by Peavy and Rennex (2).

5.4 Determine C' of the auxiliary insulation over the temperature range of interest using one of the following procedures. Either Test Method C177 or C1114 in a separate test setup for a matched pair of similar specimens, or in-situ as described in Annex A1 will be used.

5.4.1 In the first instance using either Test Method C177 or C1114, a match pair of similar specimens is required so that

NOTE 8—The terms, Q_m and Q' in Eq 2 should be different by at least two orders of magnitude, if possible. Thus, a large uncertainty in Q' may result in a small uncertainty in Q. For example, suppose that the ratio Q_m/Q' is 100 and suppose that the ratio $\Delta Q'/Q'$ is 0.1. The percentage uncertainty in Q due to $\Delta Q'$, then, would be 0.1 %.

7.4 Refer to Appendix X2 for a discussion of the gap error.

8. Report

8.1 Report all measurements in accordance with either Test Method C177 or C1114. Perform all calculations in accordance with Practice C1045. The report shall note that the apparatus

was operated in a single-sided mode in accordance with Practice C1044 and, in addition, the report shall include, where applicable, values for quantities associated with the auxiliary insulation, including Q', T'_c and T'_h. The report shall include a description of the apparatus and the procedure for determining C' in 5.4.

9. Keywords

9.1 guarded-hot-plate apparatus; heat flow; single-sided; steady state; thermal insulation; thin-heater apparatus

ANNEX

(Mandatory Information)

A1. IN-SITU DETERMINATION OF THERMAL CONDUCTANCE OF AUXILIARY INSULATION

A1.1 This annex describes an iterative procedure for determining the thermal conductance of the auxiliary insulation from test data acquired with the hot-plate apparatus operated in the single-sided mode.

A1.2 *Procedure*:

A1.2.1 Install the auxiliary insulation and specimen in the apparatus. Conduct the following sequence of tests over the temperature range of interest.

A1.2.2 Following the procedure of Sections 5 and 6, calculate the thermal conductance, C, of the test specimen at a mean temperature corresponding to $(T_h + T_c)/2$. Determine C for at least three values of mean temperature over the temperature range of interest selected in A1.2.1.

NOTE A1.1—For the first iteration, the user must estimate a value for C' based on experience, handbook data, etc.

A1.2.3 Using the same temperature range selected in A1.2.1, establish a small temperature difference, $T_h - T_c$, for example, <2 K across the specimen and a significant temperature difference, $T'_h - T'_c$, for example, 20 K to 30 K across the auxiliary insulation.

A1.2.4 Calculate the heat flow through the specimen as follows:

$$Q = CA(T_h - T_c) \tag{A1.1}$$

where:

C is the thermal conductance of the test specimen at a temperature corresponding to $(T_h + T_c)/2$, as determined in A1.2.2. Interpolation for the value of C may be required.

A1.2.5 Calculate the heat flow through the auxiliary insulation as follows:

$$Q' = Q_m - Q \tag{A1.2}$$

A1.2.6 Using the value of Q', thus obtained, calculate the thermal conductance of the auxiliary insulation, C', corresponding to a mean temperature of $(T'_h + T'_c)/2$. Determine C' for at least three values of mean temperature.

A1.2.7 Repeat A1.2.2 through A1.2.6 until successive values of C' vary be no more than 1 %.

APPENDIXES

(Nonmandatory Information)

X1. THERMAL TRANSMISSION EQUATIONS

X1.1 For reference, equations for calculating thermal transmission properties are provided in X1.2.

X1.2 *Symbols*—The following symbols refer to equations in Appendix X1.

A = metre area of hot plate, m^2.
Q = heat flow through meter section of test specimen, W.

C = thermal conductance of specimen, $W/(m^2 \cdot K)$.
R = thermal resistance of specimen, $(m^2 \cdot K)/W$.
λ = thermal conductivity of specimen, $W/(m \cdot K)$
r = thermal resistivity of specimen, $(m \cdot K)/W$
L = specimen thickness, m.
T_c = surface temperature of cold plate, K.
T_h = surface temperature of hot plate in contact with test specimen, K.

$$C = Q/A(T_h - T_c)) \tag{X1.1}$$