ASTM INTERNATIONAL

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Standard Practice for
Calibrating Thin Heat Flux Transducers[1]

This standard is issued under the fixed designation C1130; 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, in conjunction with Test Method C177, C518, C1114, or C1363, establishes an experimental procedure for determining the sensitivity of heat flux transducers that are relatively thin.

1.1.1 For the purpose of this standard, the thickness of the heat flux transducer shall be less than 30 % of the narrowest planar dimension of the heat flux transducer.

1.2 This practice discusses a method for determining the sensitivity of a heat flux transducer to one-dimensional heat flow normal to the surface and for determining the sensitivity of a heat flux transducer for an installed application.

1.3 This practice should be used in conjunction with Practice C1046 when performing in-situ measurements of heat flux on opaque building components.

1.4 This practice is not intended to determine the sensitivity of heat flux transducers that are components of heat flow meter apparatus, as in Test Method C518.

1.5 This practice is not intended to determine the sensitivity of heat flux transducers used for in-situ industrial applications that are covered in Practice C1041.

1.6 *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:*[2]
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
C518 Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus
C1041 Practice for In-Situ Measurements of Heat Flux in Industrial Thermal Insulation Using Heat Flux Transducers
C1044 Practice for Using a Guarded-Hot-Plate Apparatus or Thin-Heater Apparatus in the Single-Sided Mode
C1046 Practice for In-Situ Measurement of Heat Flux and Temperature on Building Envelope Components
C1114 Test Method for Steady-State Thermal Transmission Properties by Means of the Thin-Heater Apparatus
C1155 Practice for Determining Thermal Resistance of Building Envelope Components from the In-Situ Data
C1363 Test Method for Thermal Performance of Building Materials and Envelope Assemblies by Means of a Hot Box Apparatus

3. Terminology

3.1 *Definitions*—For definitions of terms relating to thermal insulating materials, see Terminology C168.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *mask*—material (or materials) having the same, or nearly the same, thermal properties and thickness surrounding the heat flux transducer thereby promoting one-dimensional heat flow through the heat flux transducer.

3.2.2 *sensitivity*—the ratio of the electrical output of the heat flux transducer to the heat flux passing through the device when measured under steady-state heat flow.

3.2.3 *test stack*—a layer or a series of layers of material put together to comprise a test sample (for example, a roof system containing a membrane, an insulation, and a roof deck).

3.3 *Symbols:* R = thermal resistance, $m^2 \cdot K/W$ ($h \cdot ft^2 \cdot F /Btu$)
q = heat flux, W/m^2 ($Btu/h \cdot ft^2$)
$Q_{expected}$ = heat flux expected in application, W/m^2 ($Btu/h \cdot ft^2$)
E = measured output voltage, V
S = sensitivity, $V/(W/m^2)$ ($V/(Btu/hr \cdot ft^2)$)
ΔT = temperature difference, K (°F)
R_{layer} = thermal resistance of a layer in the test stack, $m^2 \cdot K/W$ ($h \cdot ft^2 \cdot F /Btu$)
T = temperature, K (°F)
u_c = combined standard uncertainty

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u_1 = standard uncertainty of the regression coefficients
u_2 = standard uncertainty for replicate measurements
u_3 = standard uncertainty for the measurement
ε = error term

4. Significance and Use

4.1 The use of heat flux transducers on building envelope components provides the user with a means for performing in-situ heat flux measurements. Accurate translation of the heat flux transducer output requires a complete understanding of the factors affecting its output, and a standardized method for determining the heat flux transducer sensitivity for the application of interest.

4.2 The sensitivity of the heat flux transducer is determined primarily by the sensor construction and temperature of operation and the details of the application, including geometry, material characteristics, and environmental factors.

NOTE 1—Practice C1046 includes an excellent description of heat flux transducer construction.

4.3 The presence of a heat flux transducer is likely to alter the heat flux that is being measured. To determine the heat flow that would occur in the absence of the transducer, it is necessary to either:

4.3.1 Ensure that the installation is adequately guarded (1).[3]

4.3.2 Adjust the results based on a detailed model or numerical analysis. Such analysis is beyond the scope of this practice, but details can be found in (2-6).

4.3.3 Use the empirically measured heat flux transducer sensitivity measured under conditions that adequately simulate the conditions of use in the final application.

4.4 There are several methods for determining the sensitivity of heat flux transducers, including Test Methods C177, C518, C1114, and C1363. The selection of the appropriate procedure will depend on the required accuracy and the physical limitations of available equipment.

4.5 This practice describes techniques to establish uniform heat flow normal to the heat flux transducer for the determination of the heat flux transducer sensitivity.

4.6 The method of heat flux transducer application must be adequately simulated or duplicated when experimentally determining the heat flux transducer sensitivity. The two most widely used application techniques are to surface-mount the heat flux transducer or to embed the heat flux transducer in the insulation system.

NOTE 2—The difference between the sensitivity under uniform normal heat flow versus that for the surface-mounted or embedded configurations has been demonstrated using multiple mathematical techniques (7-9).

5. Specimen Preparation

5.1 *Specimen Preparation for All Cases:*

5.1.1 Check the electrical continuity of the heat flux transducer. Connect the heat flux transducer voltage leads to the auxiliary measurement equipment (for example, voltmeter) having a resolution of $\pm$ 2 μV or better.

5.1.2 When bringing the heat flux transducer voltage leads out of the test instrument, take care to avoid air gaps in the mask or between the sample stack and the test instrument. Fill air gaps with a conformable material, such as toothpaste, caulk, or putty, or cover with tape.

NOTE 3—The heat flux transducers do not need to be physically adhered to the mask or embedding material but should fit well enough to assure good thermal contact. If needed, apply thermally conductive gel to one or both faces of the heat flux transducer to improve the thermal contact. Material compatibility must be considered in the selection of any such gel.

5.1.3 Place a temperature sensor on or near the heat flux transducer. Connect temperature sensor(s) applied to the heat flux transducer to a readout device.

5.1.4 When compressible insulation is included in the test stack, manually control the distance between the hot and cold apparatus surfaces.

5.1.5 The heat flux transducer(s) must be located within the metered area of the apparatus. In a hot box apparatus, mount the heat flux transducers in the central portion of the metered area of the test panel.

5.2 Three separate test stack preparations are discussed to determine appropriately: the one-dimensional sensitivity, the sensitivity for embedded configurations, and the sensitivity for surface-mounted configurations.

5.3 *One-Dimensional Sensitivity*—The heat flux transducer shall be embedded in a test stack and surrounded with a mask, as shown in Fig. 1.

5.3.1 The test stack shall consist of a sandwich of the heat flux transducer/masking layer between two layers of a compressible homogeneous material, such as high-density fibrous glass insulation board, to assure good thermal contact between the plates of the tester and the heat flux transducer/masking layer.

5.3.2 The mask must have the same thickness and thermal resistance as the heat flux transducer.

5.3.3 The mask or embedding material should be significantly larger than the metering area of the test equipment and ideally be the same size as the plates of the apparatus.

5.3.4 To measure the sensitivity of multiple small heat flux transducers, the heat flux transducer/mask layer shown in Fig. 1 is replaced with a layer containing an arrangement of transducers located within the metered area of the apparatus as illustrated in Fig. 2.

5.4 *Sensitivity, Embedded Configuration*—Place the heat flux transducer, in a fashion identical to its end use application, in a test stack duplicating the building construction to be evaluated. An example of a test stack, for the case where the heat flux transducer is to be embedded in gypsum wallboard facing an insulated wall cavity, is shown in Fig. 3.

5.5 *Sensitivity, Surface-Mounted Configuration*—Apply the heat flux transducer in a manner identical to that of actual use as specified in Practice C1046. Important considerations for surface mounting include thermal contact between the heat flux transducer and the surface and matching of the emittance of the heat flux transducer and test construction. An example of a test arrangement, for the case where the heat flux transducer is to be surface-mounted, is shown in Fig. 4.

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[3] The boldface numbers in parentheses refer to the references at the end of this standard.
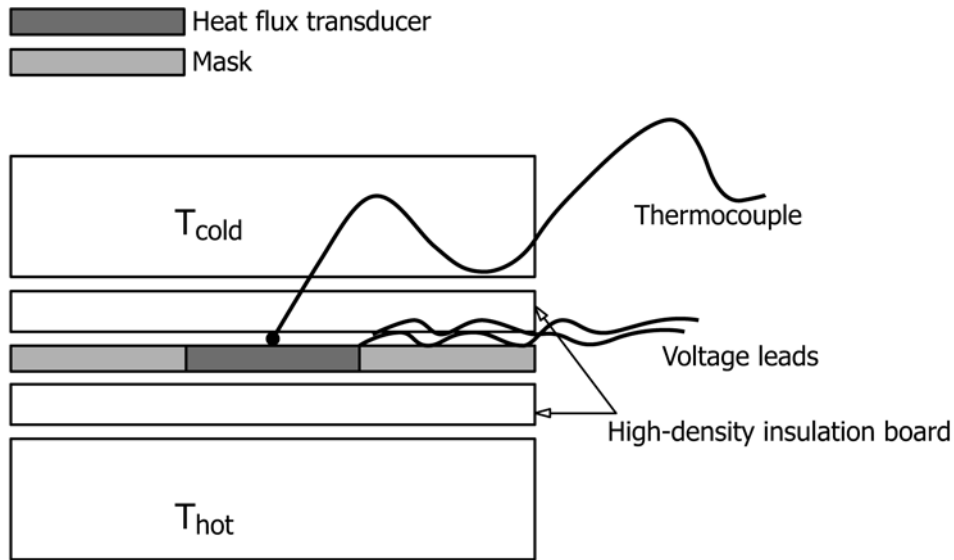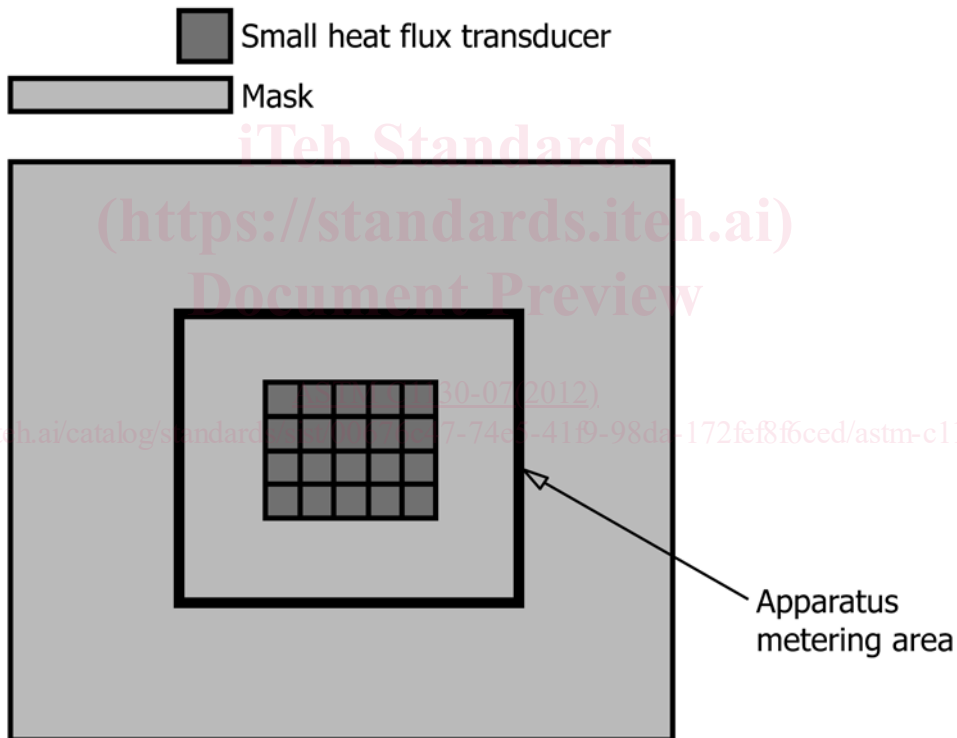
FIG. 1 Example of a Test Stack Used to Measure Heat Flux Transducer Sensitivity, Side View

NOTE 1—Some apparatus metering areas are round.

FIG. 2 Top View of the Heat Flux Transducer/Mask Layer Within the Test Stack for the Case Where Multiple Small Heat Flux Transducers are Evaluated Simultaneously

NOTE 4—In many cases, several surface-mounted heat flux transducers will be used at one time and can be analyzed for sensitivity simultaneously.

6. Procedure

6.1 Use a guarded-hot-plate, heat flow meter, hot box, or thin-heater apparatus. Follow Test Method C177, C518, C1363, or C1114, including test stack conditioning, to measure the heat flux through the heat flux transducer. Apparatuses that typically require two samples should be operated in the single-sided mode in conformance with Practice C1044.

6.2 Vary the hot- and cold-surface plates of the test instrument to produce the range of heat fluxes and mean temperatures according to the guidance found in Appendix X1 and Appendix X2.
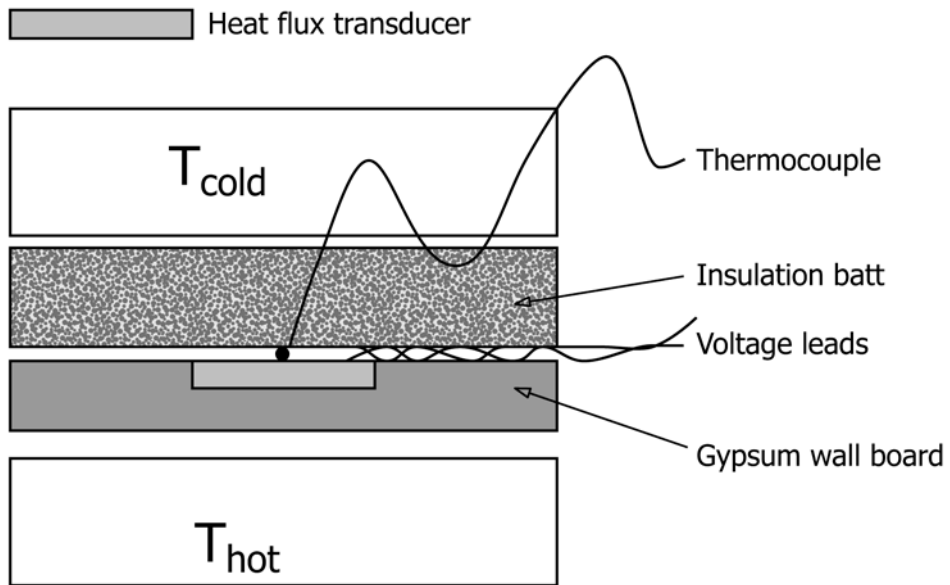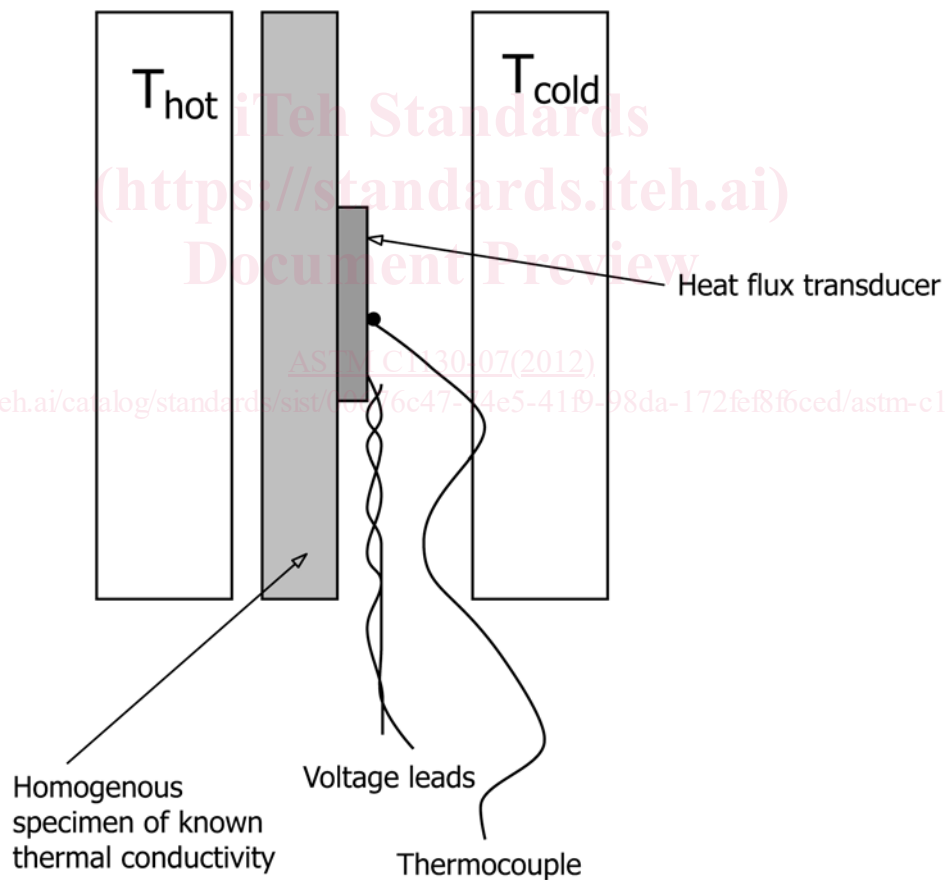
FIG. 3 Example of Test Stack Emulating an Embedded Position Within an Insulated Wall Cavity, Side View

NOTE 1—Drawing not to scale, heat flux transducer size exaggerated relative to hot box dimensions.
FIG. 4 Example of a Test Stack for a Surface-Mounted Heat Flux Transducer