Designation: C 1130 – 90 (Reapproved 2001)

Standard Practice for Calibrating Thin Heat Flux Transducers[1]

This standard is issued under the fixed designation C 1130; 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 establishes an experimental procedure for determining the sensitivity of heat flux transducers (HFTs) that are relatively thin. The term *sensitivity* in this practice refers to the ratio of HFT electrical output to heat flux through the HFT.

1.1.1 For the purpose of this standard, the thickness of the HFT shall be less than 15 % of the narrowest planar dimension of the HFT.

1.2 This practice discusses two methods for determining HFT sensitivity. The first method is the calibration of the HFT in unperturbed heat flow normal to the surface of the HFT, while the second method is the sensitivity of the HFT in actual use, or the HFT conversion factor.

1.3 This practice should be used in conjunction with Practice C 1041 when measuring in-situ heat flux and temperature on industrial insulation systems, and with Practice C 1046 when performing in-situ measurements of heat flux on opaque building components.

1.4 This practice is not intended to determine the sensitivity of HFTs that are components of heat flow meter apparatus, as in Test Method C 518. Refer to Practice C 1132 for this purpose.

1.5 The following safety caveat pertains only to the Specimen Preparation and Procedure portions, Sections 5 and 6, of this practice: *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 168 Terminology Relating to Thermal Insulating [2]

C 177 Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot-Plate Apparatus[2]

C 236 Test Method for Steady-State Thermal Performance of Building Assemblies by Means of a Guarded Hot Box[2]

C 335 Test Method for Steady-State Heat Transfer Properties of Horizontal Pipe Insulation[2]

C 518 Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus[2]

C 976 Test Method for Thermal Performance of Building Assemblies by Means of a Calibrated Hot Box[2]

C 1041 Practice for In-Situ Measurements of Heat Flux in Industrial Thermal Insulation Using Heat Flux Transducers[2]

C 1044 Practice for Using the Guarded-Hot-Plate Apparatus or Thin-Heater Apparatus in the Single-Sided Mode[2]

C 1046 Practice for In-Situ Measurement of Heat Flux and Temperature on Building Envelope Components[2]

C 1114 Test Method for Steady-State Thermal Transmission Properties by Means of the Thin-Heater Apparatus[2]

C 1132 Practice for Calibration of the Heat Flow Meter Apparatus[2]

3. Terminology

3.1 *Definitions*—For definitions of terms relating to thermal insulating materials, see Definitions C 168.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *heat flux transducer*—a device containing a thermopile (or equivalent) that produces an output which is a function of the heat flux passing through the HFT.

3.2.2 *sensitivity*—the ratio of the electrical output of the heat flux transducer to the heat flux passing through the HFT. The sensitivity of the HFT will be a function of the HFT temperature, the HFT construction, its curvature, and the method with which it is applied to the building component.

3.2.3 *heat flux transducer calibration factor*—the sensitivity of the heat flux transducer when measured in an undisturbed one-dimensional temperature field.

3.2.4 *heat flux transducer conversion factor*—the sensitivity of the heat flux transducer for the thermal conditions surrounding the HFT in actual use.

3.2.4.1 The relationship between the heat flux transducer calibration and conversion factors is indicative of the magnitude of the heat flux distortion created by the application of the HFT.

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

3.2.5 *temperature field*—a set of temperatures, where each temperature is associated with a point or small domain of space in a region of interest. An example is the distribution of temperatures within a slab of insulation.

3.2.6 *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*:

q = heat flux, W/m^2 [Btu/h·ft^2].
V = measured output voltage of the HFT, V[3].
S = sensitivity of the HFT, V/(W/m^2) [V/(Btu/hr·ft^2)].

4. Significance and Use

4.1 The use of heat flux transducers on industrial equipment or building envelope components provides the user with a relatively simple 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 HFT sensitivity for the application of interest.

4.2 The placement of an HFT in a temperature field (see 3.2.5) will probably disturb that field. If a disturbance in the temperature field occurs when the HFT is applied, the user must account for that disturbance when determining the sensitivity of an HFT.

4.3 There are several methods for determining the sensitivity of HFTs (see 6.1). The selection of the best procedure will depend on the required accuracy and the physical limitations of available equipment.

4.4 The presence of a heat flux transducer is likely to alter the heat flux that is being measured. This disturbance is difficult to predict without sufficient knowledge of the construction of the HFT and the thermal conductivities of both the HFT components and its surroundings. With such knowledge, analytical **(1, 2)**[4] and numerical **(3, 4, 5)** methods have been used to account for the disturbance in heat flux caused by the presence of an HFT.

4.5 If an HFT calibration factor is sought, the user of this standard must assure that parallel heat flow, normal to the HFT, is achieved. If the user wishes to obtain a conversion factor, then the user must account for the end-use conditions of the HFT, either by using an acceptable and verifiable mathematical technique to correct the calibration factor, or by performing a series of experiments that adequately simulates the conditions of use to obtain the conversion factor empirically **(6, 7, 8)**.

4.6 This practice describes techniques to establish uniform heat flow normal to the heat flux transducer for the determination of the HFT calibration factor, or how to establish conditions that simulate those that the HFT will encounter when in use.

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

5. Specimen Preparation

5.1 Preparation of the HFT depends on which type of sensitivity is desired and the method of HFT application to be employed.

5.1.1 Three separate cases are discussed: the determination of the calibration factor and the measurement of the conversion factor for embedded and surface-mounted HFTs.

5.2 The HFT for which sensitivity is determined will measure the heat flux at the position of the HFT in the test stack. It is recommended that the HFT be installed near the metering side of the test instrument and in a relatively thin stack assembly to reduce the impact of edge effects. The thickness and thermal resistance of the test stack should be selected after considering its impact on the accuracy of the chosen test method.

5.3 *Calibration factor*—The HFT shall be embedded in a stack of materials and surrounded with a framing material or mask. Guarded-hot-plate and heat flow meter apparatuses (Test Method C 177 and C 518, respectively) have been successfully used for this purpose.

5.3.1 The sample stack used to determine the calibration factor of HFTs shall consist of a sandwich of the HFT/masking layer between two layers of a compressible homogeneous material, such as high-density fiberglass insulation board, to assure good thermal contact between the plates of the tester and the HFT/masking layer. The use of a thermally conductive gel is another technique to improve good thermal contact.

5.3.2 The mask used in determining the HFT calibration factor must have the same thickness and thermal resistance as the HFT. The matching of the mask and HFT is sensitive to the HFT size and on whether the HFT incorporates an intrinsic mask surrounding its active sensing area. An effective masking technique that has been employed for small sensors is to utilize other identical sensors as a mask.

5.4 *Conversion factor, embedded*—The HFT shall be placed, in a fashion identical to its end use application, in a stack of materials duplicating the building construction to be evaluated. The instruments listed in 5.3 along with the thin-heater apparatus (see Test Method C 1114) have been used for this analysis.

5.5 *Conversion factor, surface mounted*—The HFT shall be applied in a manner identical to that of actual use to a homogeneous test panel or pipe insulation of similar thermal resistance, surface-layer thermal conductance, and orientation. Pipe tester (Test Method C 335), guarded-hot-box (Test Method C 236), and calibrated-hot-box (Test Method C 976) apparatuses have been used to perform these procedures.

5.5.1 The sample stack for use in determining HFT conversion factors shall comprise a sandwich of the same materials to be found in the construction to be analyzed. The HFT shall be placed in the same exact location as that in end use. For embedded applications, the HFT shall be placed between the same layers within the sample stack. For surface-mounted applications, the HFT shall be mounted as specified in either Practices C 1041 or C 1046. Important considerations for

[3] For the purpose of this practice, the HFT output shall be assumed to be a voltage, although other outputs, such as current, may exist.

[4] The boldface numbers in parentheses refer to the references at the end of this practice.