Designation: C 1041 – 85 (Reapproved 1995)ε1

Standard Practice for In-Situ Measurements of Heat Flux in Industrial Thermal Insulation Using Heat Flux Transducers[1]

This standard is issued under the fixed designation C 1041; 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.

ε1 NOTE—Safety Caveat was updated and keywords were added editorially in October 1995.

1. Scope

1.1 This practice covers the in-situ measurement of heat flux through industrial thermal insulation using a heat flux transducer (HFT).

1.2 This practice estimates the thermal transport properties of thermal insulation materials in-situ in field applications under pseudo steady-state conditions. It is not intended that this practice should be used as a substitute for more precise laboratory procedures such as Test Methods C 177, C 335, or C 518.

1.3 This practice is limited by the relatively small area that can be covered by an HFT and by the transient effects of environmental conditions.

1.4 Temperature limitations shall be as specified by the manufacturer of the HFT.

1.5 While accurate values of heat flux are highly depend-ent upon proper calibrations under the conditions of use, manufacturer's calibrations may be used with confidence for comparative work between similar materials, aging, or other conditions of use.

NOTE 1—Further information may be found in the literature **(1-6)**.[2]

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:*

C 168 Terminology Relating to Thermal Insulating Materials[3]

C 177 Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot-Plate Apparatus[3]

C 335 Test Method for Steady-State Heat Transfer Properties of Horizontal Pipe Insulation[3]

C 518 Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus[3]

E 220 Method for Calibration of Thermocouples by Comparison Techniques[4]

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

2.2 *Other Standards:*

ASHRAE Standard 101-1981; Application of Infrared Sensing Devices to the Assessment of Building Heat Loss Characteristics[5]

ISO/TC 163/SC 1WG N31E Thermal Insulation—Qualitative Detection of Thermal Irregularities in Building Envelopes—Infrared Method[6]

3. Terminology

3.1 *Definitions:*

3.1.1 *heat flux transducer (HFT)*—a rigid or flexible transducer in a durable housing comprised of a thermopile or equivalent for sensing the temperature drop across a thin thermal resistance layer which gives a voltage output proportional to the heat flux through the transducer.

3.1.1.1 *belt HFT*—a heat flux transducer having a belt-like configuration such that the unit can be wrapped helically around a section of pipe insulation (see Fig. 1).

3.1.1.2 *spot HFT*—a small heat flux transducer having a round, square, rectangular or other configuration for the sensitive area (see Fig. 1).

3.1.2 *pseudo steady state of HFT*—the criterion for pseudo steady-state condition is that the average HFT reading over two consecutive 5-min periods does not differ by more than 2 %. Since the time constant of an HFT is typically less than or of the order of 1 min, using a time interval of 5 min ensures that the transient effects in the HFT are averaged.

3.2 *Symbols:Symbols:*

3.2.1 Q—heat flow, W (Btu/h).

[1] This practice is under the jurisdiction of ASTM Committee C-16 on Thermal Insulation and is the direct responsibility of Subcommittee C16.30 on Thermal Measurement.

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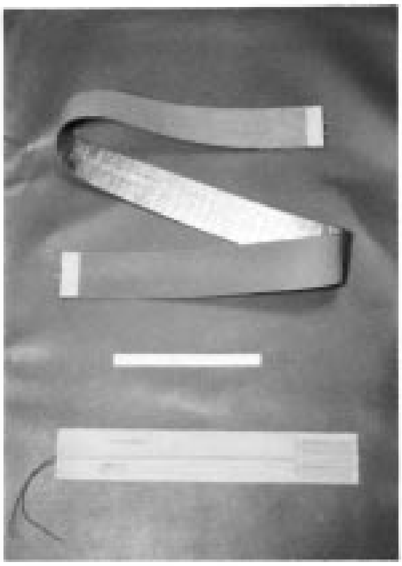
[2] The boldface numbers in parentheses refer to the list of references at the end of this standard.

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

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

[5] Available from ASHRAE, Inc., 1791 Tullie Circle NE, Atlanta, GA 30329.

[6] Available from International Standards Organization, 1 Rue de Varembe, Case Postale 56, CH-1211, Geneva 20, Switzerland.



NOTE 1—Belt wraps around exterior; shim slips under jacketing (spot HFT).

FIG. 1 Flexible Heat Flux Transducers for Pipes

3.2.2 *q*—heat flux, W/m^2 (Btu/h·ft^2).

3.2.3 *C*—overall conductance of the insulated section, W/m^2·K (Btu/h·ft^2 · °F).

3.2.4 t_0—process surface temperature,° C(°F).

3.2.5 t_1—insulation inside surface temperature. For purposes of this standard, t_0 and t_1 shall be considered to be identical.

3.2.6 t_2—insulation outside surface temperature,° C (°F).

3.2.7 *R*—areal resistance of the insulating section,

$$\frac{m^2 \cdot K}{W}\left(\frac{h \cdot ft^2 \cdot °F}{Btu}\right) \quad (1)$$

3.2.8 λ (*k*)—apparent thermal conductivity, W/m·K (Btu·in·h·ft^2·°F).

3.2.9 *D*—thickness of test section, m (in.).

3.2.10 r_2—outer radius of pipe insulation, m (in.).

3.2.11 r_1—inner radius of pipe insulation, m (in.).

3.2.12 r_0—outer radius of pipe, m (in.).

3.2.13 *V*—HFT output in millivolts or other chosen unit.

4. Summary of Practice

4.1 This practice is a guide to the proper use of heat flux transducers for estimating the thermal transport properties of thermal insulation in-situ in field applications under pseudo steady-state conditions.

5. Significance and Use

5.1 The major contribution of this practice is that it enables a measurement of the real-time energy loss or gain through a chosen surface of an existing process insulation with minimal disturbance to the heat flux through the insulating body.

5.2 The primary use of this practice will be for the in-situ estimation of thermal transport properties of industrial insulation such as used on pipes, tanks, ovens, and boilers, operating under normal process conditions.

5.3 Errors attributable to heat flow measurements over a small area or short term testing can be misleading and this practice is intended to minimize such errors.

5.4 Insulation processes with large temperature differences across the insulation are best suited to HFT measurements because modest changes in ambient conditions have but minimal effects on HFT output.

5.5 While it would be ideal for the HFT and attachment system to have zero thermal resistance, this factor is insignificant to the measured result if kept to 5 % or less of the resistance of the insulating section being tested.

6. Apparatus

6.1 *Heat Flux Transducer*, as described in 3.1.1.

6.2 *Voltmeter/Recorder*—A voltage-measuring recording instrument accurate to within 0.5 % of the lowest HFT output anticipated during the test. An integrating voltmeter is even more appropriate for reading the output of the HFT.

6.3 *Temperature Sensor*—A thermocouple or other device of a type suitable for the temperatures being measured.

6.3.1 For measuring the temperature of an insulated surface, such as a pipe under insulation, a 1.5-mm diameter or smaller, flexible ungrounded thermocouple probe 500 mm long is recommended.

6.3.2 For measuring the temperature of surfaces that can be easily accessed, 24 gage or smaller, bare bead thermocouples or equivalent shall be used.

6.4 *Attachment Materials*—Pressure-sensitive adhesive tape, elastic bands, straps, mastic, grease, or other means may be used to hold the HFT in place on the test surface.

6.5 *Thermal Contact Materials*—Patching cement, silicone grease, heat sink grease, silicone sealant, room temperature vulcanizing elastomer, thermally conducting epoxy, or conformable pads may be used to provide maximum contact between the test surface and the HFT where applicable. The thermal coupler should not add to or reduce the resistance of the system such that the temperature patterns of heat flows are significantly changed. This could be measured by surface temperature probes or infrared measurement devices.

6.6 *Surfacing Materials*—Coating, films, or foils to adjust the surface emittance of the HFT to match the radiant characteristics of the test surface.

7. Calibrations

7.1 HFT must be calibrated under the conditions of use; for example, a calibration under aluminum jacketing on a test setup in accordance with Test Method C 335, would be proper for calibration of an HFT for subsequent testing under similar conditions.

7.2 Calibrate HFT to national reference standards in accordance with Test Methods C 177, C 335, or C 518. A calibration curve showing *q/V* versus insulation surface temperature (expected to be the HFT temperature) shall be developed covering the intended range of operating temperatures and heat fluxes.

7.2.1 The following is an example of calibration under use conditions (pipe insulated with preformed insulation and jacketed with aluminum):

7.2.1.1 Set up the apparatus in accordance with Test Method C 335 with preformed insulation, jacketed with aluminum