Designation: C 1033 – 85 (Reapproved 2000)

Standard Test Method for Steady-State Heat Transfer Properties of Pipe Insulation Installed Vertically[1]

This standard is issued under the fixed designation C 1033; 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 the steady-state heat transfer properties of pipe insulations for pipes operating at temperatures above the ambient environment from approximately 40°C to the maximum insulation design temperature. Specimens may be rigid, flexible, or loose-fill, may be homogeneous or nonhomogeneous, isotropic or nonisotropic, and of circular or noncircular cross section. Measurement of metallic reflective insulations is included in this test method; however, additional precautions must be taken when these materials are being evaluated.

1.2 When appropriate, or as required by specifications or other test methods, the following thermal transfer properties for the specimen can be calculated from the measured data (see 3.2):

1.2.1 The thermal resistance and conductance,

1.2.2 The thermal transference,

1.2.3 The surface resistance and heat transfer coefficient, and

1.2.4 The apparent thermal resistivity and conductivity.

1.3 This test method applies only for testing of insulations on vertical pipes, and the results will only apply for insulations installed vertically (see Note 1).

1.4 The test pipe may be of any size or shape provided that it matches the specimens to be tested. Normally the test method is used with circular pipes, however, its use is permitted with pipes or ducts of noncircular cross section (square, rectangular, hexagonal, etc.). One common size used for interlaboratory comparison is a pipe with an 88.9-mm outside diameter (standard nominal 80-mm, 3-in. pipe size).

1.5 This test method covers only the guarded-end type of pipe apparatus. No experience has been gathered with the calibrated or calculated-end pipe apparatus; therefore, this type of tester is not included as part of this specification.

1.6 The values stated in SI units are to be regarded as the standard. Conversion factors to other units are given in Table 1. The units used must accompany all numerical values.

NOTE 1—Measurement of insulations installed horizontally is covered in Test Method C 335 and Test Method C 691.

NOTE 2—Discussions of the appropriateness of these properties to particular specimens or materials may be found in Test Method C 177, Test Method C 518, and in the literature.[2]

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:*

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 302 Test Method for Density and Dimensions of Preformed Pipe-Covering-Type Thermal Insulation[3]

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

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

C 680 Practice for Determination of Heat Gain or Loss and the Surface Temperatures of Insulated Pipe and Equipment Systems by the Use of a Computer Program[3]

C 691 Test Method for Steady-State Thermal Transmission Properties of Nonhomogeneous Pipe Insulation Installed Horizontally[4]

C 870 Practice for Conditioning of Thermal Insulating Materials[3]

E 230 Temperature Electromotive Force (EMF) Tables for Standardized Thermocouples[5]

3. Terminology

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

3.2 *Definitions of Terms Specific to This Standard:*

[1] This test method 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] ASTM Subcommittee C16.30, "What Property Do We Measure," *Heat Transmission Measurements in Thermal Insulations, ASTM STP 544*, ASTM, 1974, pp. 5–12.

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

[4] Discontinued—See 1986 *Annual Book of ASTM Standards*, Vol 04.06.

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

TABLE 1 Conversion Factors (International Table)

NOTE 1—For thermal conductance per unit length or thermal transference per unit length, use the inverse of the table for thermal resistance per unit length. For thermal resistivity, use the inverse of the table for thermal conductivity. For thermal conductance (per unit area) or thermal transference (per unit area), use the inverse of the table for thermal resistance (per unit area).

Thermal Resistance per Unit Length[A]					
	$K \cdot m \cdot W^{-1}$ (B)	$K \cdot cm \cdot W^{-1}$	$K \cdot cm \cdot s \cdot cal^{-1}$	$K \cdot m \cdot h \cdot kg\text{-}cal^{-1}$	$°F \cdot ft \cdot h \cdot Btu^{-1}$
1 $K \cdot m \cdot W^{-1}$ =	1.000	100.0	418.7	1.163	1.731
1 $K \cdot cm \cdot W^{-1}$ =	1.000×10^{-2}	1.000	4.187	1.163×10^{-2}	1.731×10^{-2}
1 $K \cdot cm \cdot s \cdot cal^{-1}$ =	2.388×10^{-3}	0.2388	1.000	2.778×10^{-3}	4.134×10^{-3}
1 $K \cdot m \cdot h \cdot kg\text{-}cal^{-1}$ =	0.8598	85.98	360.0	1.000	1.488
1$°F \cdot ft \cdot h \cdot Btu^{-1}$ =	0.5778	57.78	241.9	0.6720	1.000

Thermal Conductivity(A)						
	$W \cdot m^{-1} \cdot K^{-1}$ (B	$W \cdot cm^{-1} \cdot K^{-1}$	$cal \cdot s^{-1} \cdot cm^{-1} \cdot K^{-1}$	$kg\text{-}cal \cdot h^{-1} \cdot m^{-1} \cdot K^{-1}$	$Btu \cdot h^{-1} \cdot ft^{-1} \cdot °F^{-1}$	$Btu \cdot in. \cdot h^{-1} \cdot ft^{-2} \cdot °F^{-1}$
1 $W \cdot m^{-1} \cdot K^{-1}$=	1.000	1.000×10^{-2}	2.388×10^{3}	0.8598	0.5778	6.933
1 $W \cdot cm^{-1} \cdot K^{-1}$=	100.0	1.000	0.2388	85.98	57.78	693.3
1 $cal \cdot s^{-1} \cdot K^{-1}$=	418.7	4.187	1.000	360.0	241.9	2903.
1 $kg \cdot cal \cdot h^{-1} \cdot K^{-1}$=	1.163	1.163×10^{-2}	2.778×10^{-3}	1.000	0.6720	8.064
1 $Btu \cdot h^{-1} \cdot ft^{-1} \cdot °F^{-1}$=	1.731	1.731×10^{-2}	4.134×10^{-3}	1.488	1.000	12.00
1 $Btu \cdot in. \cdot h^{-1} \cdot ft^{-2} \cdot °F^{-1}$=	0.1442	1.442×10^{-3}	3.445×10^{-4}	0.1240	8.333×10^{-2}	1.000

Thermal Resistance per Unit Area[A]					
	$K \cdot m^2 \cdot W^{-1}$ (B)	$K \cdot cm^2 \cdot W^{-1}$	$K \cdot cm^2 \cdot s \cdot cal^{-1}$	$K \cdot m^2 \cdot h \cdot kg\text{-}cal^{-1}$	$°F \cdot ft^2 \cdot h \cdot Btu^{-1}$
1 $K \cdot m^2 \cdot W^{-1}$ =	1.000	1.000×10^{4}	4.187×10^{4}	1.163	5.678
1 $K \cdot cm^2 \cdot W^{-1}$ =	1.000×10^{-4}	1.000	4.187	1.163×10^{-4}	5.678×10^{-4}
1 $K \cdot cm^2 \cdot s \cdot cal^{-1}$ =	2.388×10^{-5}	0.2388	1.000	2.778×10^{-5}	1.356×10^{-4}
1 $K \cdot m^2 \cdot h \cdot kg\text{-}cal^{-1}$ =	0.8598	8.594×10^{3}	3.600×10^{4}	1.000	4.882
1$°F \cdot ft^2 \cdot h \cdot Btu^{-1}$ =	0.1761	1.761×10^{3}	7.373×10^{3}	0.2048	1.000

[A] Units are given in terms of (*1*) the absolute joule per second or watt, (*2*) the calorie (International Table) = 4.1868 J, or the British thermal unit (International Table) = 1055.06 J.

[B] This is the SI (International System of Units) unit.

3.2.1 *pipe insulation thermal conductance, C*—the steady-state time rate of heat flow per unit pipe area divided by the difference between the average pipe surface temperature and the average insulation outer surface temperature. It is the reciprocal of the pipe insulation thermal resistance, *R*.

$$C = \frac{Q}{A_o(t_o - t_2)} = \frac{1}{R} \quad (1)$$

3.2.2 *pipe insulation thermal resistance, R*—the average temperature difference between the pipe surface and the insulation outer surface required to produce a steady-state unit time rate of heat flow per unit of pipe area. It is the reciprocal of the pipe insulation thermal conductance, *C*.

$$R = \frac{A_o(t_o - t_2)}{Q} = \frac{1}{C} \quad (2)$$

3.2.3 *pipe insulation thermal transference, T_r*—the steady-state time rate of heat flow per unit pipe area divided by the difference between the average pipe surface temperature and the average air ambient temperature. It is a measure of the heat transferred through the insulation to the ambient environment.

$$T_r = \frac{Q}{A_o(t_o - t_a)} \quad (3)$$

3.2.4 *surface heat transfer coefficient, h_2*—the ratio of the steady-state time rate of heat flow per unit surface area to the average temperature difference between the surface and the ambient surroundings. The inverse of the surface heat transfer coefficient is the surface resistance. For circular cross sections:

$$h_2 = \frac{Q}{A_2(t_2 - t_a)} \quad (4)$$

3.2.5 *pipe insulation apparent thermal conductivity, λ—of homogeneous material*, the ratio of the steady-state time rate of heat flow per unit area to the average temperature gradient (temperature difference per unit distance of heat flow path). It includes the effect of the fit upon the test pipe and is the reciprocal of the pipe insulation apparent thermal resistivity, *r*. For pipe insulation of circular cross section, the pipe insulation apparent thermal conductivity is:

$$\lambda = \frac{Q 1n(r_2/r_o)}{L 2\pi(t_o - t_2)} = \frac{1}{r} \quad (5)$$

3.2.6 *pipe insulation apparent thermal resistivity, r—of homogeneous material*, the ratio of the average temperature gradient (temperature difference per unit distance of heat flow path) to the steady-state time rate of heat flow per unit area. It includes the rate of heat flow per unit area. It includes the effect of the fit upon the test pipe and is the reciprocal of the pipe insulation apparent thermal conductivity, λ. For pipe insulation of circular cross section, the pipe insulation apparent thermal resistivity is:

$$r = \frac{2\pi L(t_o - t_2)}{Q 1n(r_2/ r_o)} = \frac{1}{\lambda} \quad (6)$$