Designation: C 236 – 89 (Reapproved 1993)$^{\epsilon 1}$

Standard Test Method for Steady-State Thermal Performance of Building Assemblies by Means of a Guarded Hot Box[1]

This standard is issued under the fixed designation C 236; 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.

This standard has been approved for use by agencies of the Department of Defense.

ϵ^1 NOTE—Section 12 was added editorially in September 1993.

1. Scope

1.1 This test method, known as the guarded hot box method, covers the measurement of the steady-state thermal transfer properties of panels. In distinction to Test Method C 177, which is primarily applicable to homogeneous samples, the guarded hot box method provides for the evaluation of thermal performance of building assemblies. This test method is suitable for building construction assemblies, building panels, and other applications of nonohomogeneous specimens at similar temperature ranges. It may also be used for homogeneous specimens.

1.2 This test method may be applied to any building construction for which it is possible to build a reasonably representative specimen of size appropriate for the apparatus.

NOTE 1—A calibrated hot box, Test Method C 976, may also be used for the described measurements and may prove more satisfactory for testing assemblies under dynamic conditions (nonsteady-state) and to evaluate the effects of water migration and air infiltration. The choice between the calibrated or the guarded hot box should be made only after careful consideration of the contemplated use.

1.3 In applying this test method, the general principles outlined must be followed; however, the details of the apparatus and procedures may be varied as needed.

1.3.1 The intent of this test method is to give the essential principles and the general arrangement of the apparatus. Any test using this apparatus must follow those principles. The details of the apparatus and the suggested procedures that follow are given not as mandatory requirements but as examples of this test method and precautions that have been found useful to satisfy the essential principles.

1.3.2 Persons applying this test method shall be trained in the methods of temperature measurement, shall possess a knowledge of the theory of heat flow, and shall understand the general requirements of testing practice.

1.4 *This standard does not purport to address all of the safety problems, 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.*

NOTE 2—While various units may be found for thermal properties, the International System of units is used exclusively in this test method. For conversion factors to inch-pound and kilogram-calorie systems, see Table 1.

2. Referenced Documents

2.1 *ASTM Standards:*

C 168 Terminology Relating to Thermal Insulating Materials[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 518 Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus[2]
C 578 Specification for Preformed Cellular Polystyrene Thermal Insulation[2]
C 976 Test Method for Thermal Performance of Building Assemblies by Means of a Calibrated Hot Box[2]
C 1045 Practice for Calculating Thermal Transmission Properties from Steady-State Heat Flux Measurements[2]
E 178 Practice for Dealing With Outlying Observations[3]
E 230 Temperature-Electromotive Force (EMF) Tables for Standardized Thermocouples[4]
E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method[3]

3. Terminology

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

3.2 *Symbols:*Symbols:

3.2.1 The symbols used in this test method have the following significance:

[1] This test method 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] *Annual Book of ASTM Standards*, Vol 04.06.
[3] *Annual Book of ASTM Standards*, Vol 14.02.
[4] *Annual Book of ASTM Standards*, Vol 14.03.

TABLE 1 Conversion Factors for Thermal Conductivity[A]

	W/(m·K)[B]	W/(cm·K)	cal/(s·cm·K)	kg-cal/(h-m·K)	Btu/(h·ft·°F)	Btu·in./(h·ft^2°F)
1 W·m^{-1}·K^{-1} =	1.000	1.000 × 10^{-2}	2.388 × 10^{-3}	0.8598	0.5778	6.933
1 W·cm^{-1}·K^{-1} =	100.0	1.000	0.2388	85.98	57.78	693.3
1 cal·s^{-1}·cm^{-1}·K^{-1} =	418.7	4.187	1.000	360.0	241.9	2903.00
1 kg-cal·h^{-1}·h^{-1}·K^{-1} =	1.163	1.163 × 10^{-2}	2.778 × 10^{-3}	1.000	0.6720	8.064
1 Btu·h^{-1}·ft^{-1}·°F^{-1} =	1.731	1.731 × 10^{-2}	4.134 × 10^{-3}	1.488	1.000	12.00
1 Btu·in.·h^{-1}·ft^{-2}·°F^{-1} =	0.1442	1.442 × 10^{-3}	3.445 × 10^{-4}	0.1240	8.333 × 10^{-2}	1.000
	Thermal Conductance[A]					
	W/(m^2·K)[B]	W/(cm^2·K)	cal/(s·cm^2·K)	kg-cal/(h·m^2·K)	Btu/h·ft^2·°F)	
1 W·m^{-2}·K^{-1} =	1.000	1.000 × 10^{-4}	2.388 × 10^{-5}	0.8598	0.1761	
1 W·cm^{-2}·K^{-1} =	1.000 × 104	1.000	0.2388	8598	1761	
1 cal·s^{-1}·cm^{-2}·K^{-1} =	4.187 × 10^4	4.187	1.000	3.600 × 10^4	7373	
1 kg-cal·h^{-1}·m^{-2}·K^{-1} =	1.163	1.163 × 10^{-4}	2.778 × 10^{-3}	1.000	0.2048	
1 Btu·h^{-1}·ft^{-2}·°F^{-1} =	5.678	5.678 × 10^{-4}	1.356 × 10^{-4}	4.882	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 unit.

- λ = thermal conductivity, W/(m·K),
- C = thermal conductance, W/(m^2·K),
- h = surface conductance, W/(m^2·K),
- U = thermal transmittance, W/(m^2·K),
- q = heat flux (time rate of heat flow through Area A), W/m^2,
- Q = time rate of heat flow, total input to the metering box, W,
- A = metering area normal to heat flow, m^2,
- L = length of path of heat flow (thickness of specimen), m,
- N = minimum number of thermocouples (see Eq 1, 6.5.1.1),
- r = surface resistance, K·m^2/W,
- R = thermal resistance, K·m^2/W,
- R_u = overall thermal resistance, K·m^2/W,
- t_h = average temperature of air 75 mm or more from the hot surface, K,
- t_1 = area weighted average temperature of hot surface, K,
- t_2 = area weighted average temperature of cold surface, K, and
- t_c = average temperature of air 75 mm or more from cold surface, K.

4. Summary of Test Method

4.1 To determine the conductance, C, the thermal transmittance, U, and the thermal resistance, R, of any specimen, it is necessary to know the area, A, the heat flux, q, and the temperature differences, all of which must be determined under such conditions that the flow of heat is steady. The hot box is an apparatus designed to determine thermal performance for representative test panels and is an arrangement for establishing and maintaining a desired steady temperature difference across a test panel for the period of time necessary to ensure constant heat flux and steady temperature, and for an additional period adequate to measure these quantities to the desired accuracy. The area and the temperatures can be measured directly. The heat flux, q, however, cannot be directly measured, and it is to obtain a measure of q that the hot box has been given its characteristic design. In order to determine q, a five-sided metering box is placed with its open side against the warm face of the test panel. If the average temperature across the walls of the metering box is maintained the same, then the net interchange between the metering box and the surrounding space is zero, and the heat input to the metering box is a measure of the heat flux through a known area of the panel. The portion of the panel outside the meter area, laved by the air of the surrounding guard space, constitutes a guard area to minimize lateral heat flow in the test panel near the metering area. Moisture migration, condensation, and freezing within the specimen can cause variations in heat flow; to avoid this, the dew point temperature on the warm side must be kept below the temperature of the cold side when the warm surface is susceptible to ingress of moisture vapor. It is expected that, in general, tests in the guarded hot box apparatus will be conducted on substantially dry test panels, with no effort made to impose or account for the effect of the vapor flow through or into the panel during the test.

4.2 Since the basic principle of the test method is to maintain a zero temperature difference across the metering box walls, adequate controls and temperature-monitoring capabilities are essential. It is recognized that small temperature gradients could occur due to the limitations of controllers. Since the total wall area of the metering box is often more than twice the metering area of the panel, small temperature gradients through the walls may cause heat flows totaling a significant fraction of the heat input to the metering box. For this reason, the metering box walls may also be equipped to serve as a heat flow meter so that heat flow through them can be estimated and minimized by adjusting conditions during tests, and so that a heat flow correction can be applied in calculating test results.

5. Significance and Use

5.1 When the guarded hot box is constructed to test assemblies in the vertical orientation, it is suited for evaluating walls and other vertical structures. When constructed to test assemblies in the horizontal orientation, it is suited for evaluating roof, ceiling, floor, and other horizontal structures. Other orientations are allowable. The same apparatus may be used for both vertical and horizontal testing if it can be rotated or reassembled in either orientation.

NOTE 3—Horizontal structures that incorporate attic spaces between a ceiling and a sloping roof are highly complex constructions, and testing in the guarded hot box would be extremely difficult. Proper consideration must be given to specimen size, natural air movement, ventilation effects, radiative effect, baffles at the guard-meter demarcation, etc. All of these special conditions must be included in the report (10.1.1). Consideration should be given to the use of the calibrated hot box for such large, complex constructions.

5.2 For vertical specimens with air spaces that significantly affect thermal performance, the metering box height should ideally match the construction height. If this is not possible, horizontal convection barriers must be installed to prevent air exchange between meter and guard areas, unless it can be shown that the omission of such barriers does not significantly affect results.

5.3 For all specimens it is necessary to maintain a near zero lateral heat flow between the guard area and the meter area of the specimen. This can be achieved by maintaining a near zero temperature difference on the specimen surface between the metered and guard areas. In specimens incorporating an element of high lateral conductance (such as a metal sheet), it may be necessary to separate the metered and the guard areas of the highly conductive element by a narrow gap such as a saw cut.

5.4 Since this test method determines the total flow of heat through the test area demarcated by the metering box, it is possible to determine the heat flow through a building element smaller than the test area, such as a window or representative area of a panel unit, if the parallel heat flow through the remaining surrounding area or mask is determined (see Annex A1).

6. Apparatus

6.1 *Arrangement*—Fig. 1 (*a*) shows a schematic arrangement of the test panel and of various major elements of the apparatus; Fig. 1(*b*) and (*c*) show alternative arrangements. Still other arrangements, accomplishing the same purpose, may be preferred for reasons of convenience or ease of installing panels. In general, the size of the metering box determines the minimum size of the other elements.

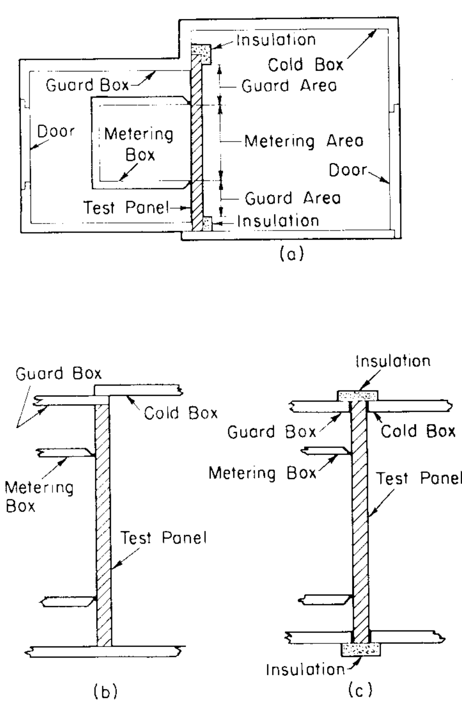

FIG. 1 General Arrangements of Test Box, Guard Box, Test Panel, and Cold Box

6.2 *Metering Box*:

6.2.1 *Size*—The size of the metering box is largely governed by the metering area required to obtain a representative test area of panel. For example, for panels incorporating air spaces or stud spaces, the metering area, preferably, should exactly span an integral number of spaces. The height of the metering box should be not less than the width and is subject to the limitations as described in 5.2. The depth of the metering box should be not greater than that required to accommodate its necessary equipment.

6.2.2 *Thermal Resistance*—The metering box walls shall have a thermal resistance of not less than 0.83 m^2 K/W. In order that the resistance of the box wall shall be uniform over the entire box area, a construction without internal ribs shall be used, for example, a glued balsa wood or a sandwich construction with aged urethane foam core. The edge in contact with the panel shall, if necessary, be narrowed on the outside only, to hold a gasket not more than 13 mm wide. If necessary, a wood nosepiece can be used to carry the gasket. The metering area of the panel shall be taken as the area included between the center lines of the gaskets. All surfaces that can exchange radiation with the specimen must have a total hemispherical emittance greater than 0.8.

6.2.3 *Heat Supply and Air Circulation*—Fig. 2 shows a possible arrangement of equipment in the metering box to assure an even, gentle movement of air over the metering area of the panel. The electric heaters are mounted in a housing with walls of resistance not less than 0.83 m^2 K/W, and with a low emittance outside surfacing to minimize radiation heat transfer to the metering box walls. In this arrangement air is continuously circulated by a small fan upward through the cylindrical housing and downward between the baffle and the panel in accordance with the motion that would result from natural convection forces. A slat-type baffle is placed some distance above the outlet of the cylindrical housing to prevent impingement of a jet of heated air against the top inner surface of the metering box. For large meter boxes the cylindrical housing may cause concentrations of air flow. To direct the air properly across the specimen, other fan arrangements may be preferable. A curved vane is mounted at the top of the baffle to smooth the entrance of air into the baffle space. In a hot box apparatus used for testing panels in a vertical position only, the moderate circulation of air resulting from natural convection may be sufficient without the use of a fan. The change in temperature of the air as it moves along the surface of the panel will, in general, be greater with natural circulation than with a fan. If a fan is used, its motor should be within the metering box, its electrical input should be as small as feasible, and the input should be carefully measured. If it is necessary to locate the motor outside the metering box, the heat equivalent of the shaft power must be accurately measured, and air leakage into or out of the metering box around the shaft must be zero.