STANDARDS ASSOCIATION OF AUSTRALIA

Australian Standard

METHODS OF TESTING THERMAL INSULATION

AS 2464.6
STEADY–STATE THERMAL TRANSMISSION PROPERTIES BY MEANS OF THE GUARDED HOTPLATE*

CONTENTS

* Based on ANSI/ASTM C1

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METHOD

1 SCOPE. This standard sets out the method for determining the steady-state thermal transmission properties of thermal insulating specimens using a guarded hotplate, within the limits set by Clauses 2.1, 2.2 and 2.3. For purposes of certification, this method is limited to specimens with thermal resistances greater than 0.017 m^2.K/W in all directions (see Note 1).

NOTES:

1. Special techniques may be required for measuring surface temperatures with specimens having thermal resistances less than 0.1 m^2.K/W.
2. The accuracy of measurement on specimens of low-density thermal insulation by this standard may be difficult to verify and may require an extensive analysis of the equipment and/or a performance check using calibration standards having heat transmission characteristics and thickness similar to the test specimens.

This standard is a primary method for measuring the thermal transmission properties of specimens, as only measurements of length, electrical power, and temperature difference are required.

2 APPLICATION.

2.1 Measurement of Thermal Resistance and Thermal Conductance. The specimen(s) shall comply with the following requirements if the thermal resistance and thermal conductance of the specimen(s) are to be determined by this standard:

(a) The portion of the specimen over the test area shall be typical of the whole specimen in every aspect.

(b) The remainder of the specimen shall not, on average, distort the heat flow in that part of the specimen adjacent to the metering area.

(c) The specimen shall be free of low thermal resistance paths that create thermal short-circuits between the test surfaces.

(d) The heat-flux density through the specimens shall be directly proportional to the temperature differences across the specimens.

NOTE: Appendix C describes tests that can help ascertain whether the specimen complies with Clause 2.1. For the purposes of this standard, differences in the measurements of less than 2 percent may be considered insignificant, and the requirements consequently complied with.

2.2 Measurement of Average Thermal Resistivity and Average Thermal Conductivity. The specimen(s) shall comply with *one* of the following requirements in addition to the requirements of Clause 2.1 if the average thermal resistivity and average thermal conductivity of the specimen(s) are to be determined by this method:

(a) The specimen shall be homogeneous.

(b) The specimen shall not be layered, and the net direction of heat flow shall not be altered by any inhomogeneities.

NOTE: Appendix C gives one test for checking the condition described in (b) above.

2.3 Applicability of Test Results to a Material. The following requirements, in addition to the requirements of Clauses 2.1 and 2.2, shall apply if the values of thermal resistivity and thermal conductivity measured for the specimen are to be considered valid for the material:

(a) The material shall be homogeneous.

(b) The thickness of the specimen shall be greater than that for which the apparent thermal resistivity of the material does not change by more than 2 percent with further increases in thickness.

NOTE: Appendix C gives one test for checking the condition described in (b) above.

(c) Adequate sampling shall be performed to ensure that the measurements are representative of the whole material.

NOTE: The material standard normally specifies the sampling procedure required for the material.

3 REFERENCED DOCUMENTS. The following documents are referred to in this standard:

AS 2352	Glossary of Terms for Thermal Insulation of Buildings
AS 2464	Methods of Testing Thermal Insulation 2464.5— Steady-state Thermal Transmission Properties by Means of the Heat Flow Meter*
ANSI/ASTM E230-77	Temperature-electromotive Force (EMF) Tables for Thermocouples

* In course of preparation.

4 DEFINITIONS. For the purpose of this standard, the definitions given in AS 2352 apply together with the following:

4.1 Layered specimen — a specimen that, if sliced parallel to the faces, has one or more slices with a significantly different apparent thermal conductivity than have the other slices.

4.2 Homogeneous specimen — a specimen in which every geometrically identical portion has the same apparent thermal conductivity.

5 SYMBOLS. The symbols used in this standard shall have the following significance:

k = thermal conductivity. Unit: watt per metre kelvin (W/m.K)

$\frac{1}{k}$ = thermal resistivity. Unit: metre kelvin per watt (m.K/W)

C = thermal conductance. Unit: watt per square metre kelvin ($W/m^2.K$)

R = thermal resistance, the reciprocal of C. Unit: square metre kelvin per watt ($m^2.K/W$)

Q = heat flow rate. Unit: watt (W)

q = heat flux density, i.e. time rate of heat flow per unit area. Unit: watt per square metre (W/m^2)

A = area measured on a selected isothermal surface. Unit: square metre (m^2)

D = thickness of specimen measured along a path normal to isothermal surfaces. Unit: metre (m)

T_1 = temperature of warm surface of specimens. Unit: degree Celsius (°C)

T_2 = temperature of cold surface of specimens. Unit: degree Celsius (°C)

6 APPARATUS.

6.1 General Features. The general features of a metal-surfaced guarded hotplate apparatus with specimens installed are shown in Fig. 1, the assembly consisting essentially of a heating unit, two specimens and two cooling units. The heating and cooling units may be either round or square. The heating unit consists of a central metering section and a guard section. The metering section consists of a metering area heater and metering area surface plates. The guard section consists of one or more guard heaters and the guard surface plates. The working surfaces of the heating unit and cooling plates shall be smoothly finished to conform to a true plane, the maximum departure from which shall not exceed 0.025 percent.

NOTE: The term 'guarded hotplate' is applied to the entire assembled apparatus, including the heating unit, the cooling units, and the edge insulation.

6.2 Heating Unit. The heating unit shall be designed and constructed so that, when in operation, the two faces of the metering section, and of the guard section, are within 0.2°C of the same uniform temperature, and so that the heating unit does not warp or depart from planeness at the operating temperatures.

6.3 Gap and Surfaces. The heating unit shall have a definite separation or gap not greater than 4 mm between the surface plates of the metering area and the guard. In addition, the area of the gap in the plane of the surface plate shall be not greater than 8 percent of the metering section area. The separation between the heater windings and the gap between the metering section and the adjacent guard section shall be designed so as to distribute heat to the surface plates uniformly, and a check shall be made to ensure that this is accomplished under worst-case conditions. The dimensions of the test area shall be determined by measurements to the centres of the separations that surround this area unless calculations or tests are used to define the area more precisely.

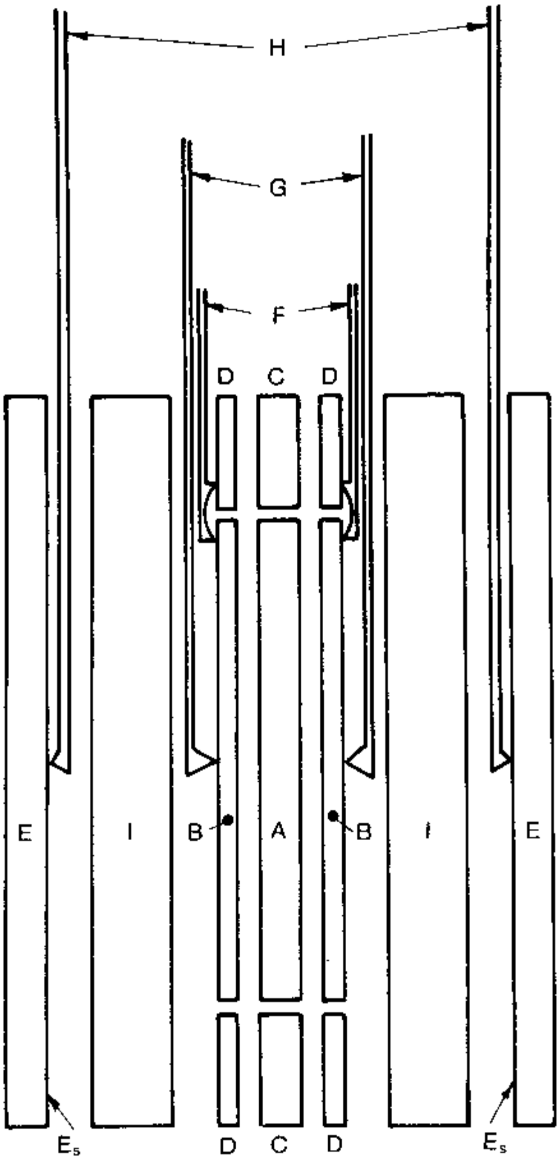
NOTE: A proven design should be used where no checks can be made.

6.4 Imbalance Detectors. A suitable means shall be provided to detect the average temperature imbalance between surface plates of the metering area and guard. Temperature-sensing elements shall be positioned so as to register correctly the average temperature balance existing along the length of the gap (see Note). The detection system shall be sufficiently sensitive to assure that variation in measured properties due to gap temperature imbalance shall be restricted to not more than 0.5 percent as determined experimentally or analytically.

NOTE: For information on determining this requirement, see References (1) to (5) and (23).

The temperature-sensing elements may be read individually and the temperature difference calculated or they may be connected differentially to indicate such temperature difference directly. Fine-gauge thermocouples connected as thermopiles are generally used for this purpose. Copper wire should be avoided where possible.

6.5 Cooling Units. The cooling units shall have surface dimensions at least as large as those of the heating unit, including the guard heaters(s). They shall consist of metal plates maintained at a uniform temperature lower than that of the heating unit by a constant-temperature fluid, by electrical means, or by thermal insulation of uniform conductance applied on the outermost surfaces, as appropriate for the cooling unit temperature desired.



A — Metering area heater
B — Metering area surface plates
C — Guard heater
D — Guard surface plates
E — Cooling units
E_s — Cooling unit surface plates
F — Differential thermocouples
G — Heating unit surface thermocouples
H — Cooling unit surface thermocouples
I — Test specimens

Fig. 1. GENERAL FEATURES OF THE METAL-SURFACED HOTPLATE APPARATUS

6.6 Temperature Detectors. A proven method possessing adequate accuracy shall be used for measurement of the temperature in the apparatus. The number of temperature sensors on each side shall be not less than $10\sqrt{A}$ or 2, whichever is the greater, where A is the area in square metres of one face of the metering area plate. There shall be the same number of sensors permanently and similarly installed at corresponding positions in the facing cooling units.

NOTES:

1. The surface temperature is often measured by permanently mounting temperature sensors, such as thermocouples, which are set in grooves or just under the working surface. The hot plate and cold plate sensors on each side are sometimes connected differentially. For thermocouples, this is usual. In such cases, they shall be electrically insulated from the plates, a resistance of greater than 1 MΩ being recommended.
2. One thermocouple per surface has been found adequate on existing plates having surface areas of less than 0.04 m^2, provided that either the thermocouples are changed frequently or the thermocouple calibration is checked regularly. A minimum of two thermocouples is recommended for all new apparatus.

6.7 Clamping Force. A means shall be provided —

(a) either for imposing a reproducible constant clamping force upon the system to promote good thermal contact or for maintaining an accurate spacing between the plates (see Note 1); and

(b) for measuring the effective thickness of the specimen to within 0.5 percent (see Note 2).

NOTES:

1. A steady force, which will thrust the cold plates toward each other, can be imposed by means of constant-force springs, a system of levers and dead weights, or an equivalent method. It is unlikely that a pressure greater than 2.5 kPa on the specimens would be required. Where easily compressible specimens are tested, it may be necessary to use small stops between the corners or edges of the cold plates and the edge of the guard section. Other positive means may be used to limit the compression of the specimens. A constant-pressure arrangement is not needed for such tests.
2. Because of the changes of specimen thickness possible as a result of temperature, or compression by the plates, it is recommended that, where possible, specimen thickness be measured in the apparatus at the existing test temperature and compression conditions. Gauging points, or measuring studs at the outer four corners of the cold plates or along the axis perpendicular to the plates at their centres, will serve for these measurements. The effective combined specimen thickness is determined by the average difference in the distance between the gauging points when the specimen is in place in the apparatus and when it is not in place, and the same force is used to press the cold plates toward each other.

6.8 Temperature Difference Across Specimens. Temperature sensors used for the measurement of the temperature drops across the specimens shall be calibrated within a precision equivalent to that for thermocouples in accordance with the requirements of ANSI/ASTM E 230. The resulting error in temperature differences due to distortion of the heat flow around the sensor, to sensor drift, and other sensor characteristics, shall be less than 1 percent.

NOTES:

1. For non-rigid specimens with flat uniform surfaces that conform well to the flat working surfaces of the plates, the temperature drop in specimens of thermal resistance greater than 0.1 m^2.K/W is normally taken as that indicated by the thermocouples permanently set in the hot and cold surface plates (see Note 2), and the thickness of the specimen may be taken as the mean distance between the working surfaces of the hot and cold plates. For non-rigid specimens having a resistance less than 0.1 m^2.K/W, the operator's judgement should rule in accordance with the circumstances.

   For rigid specimens, i.e. specimens of a material too hard and unyielding to be appreciably altered in shape by the pressure of the heating and cooling units (for example, a slab of glass or hard plastics), the surfaces should be both flat and parallel to within 0.025 percent. Rigid specimens may be installed in the apparatus with a thin sheet of suitable homogeneous material interposed between the specimen and each plate surface. This thin sheet should have a low thermal resistance relative to that of the insulating material being tested. The resistance of the composite sandwich (sheet/rigid specimen/sheet) can be determined using the temperature drop indicated by the permanent thermocouples in the hot and cold surface plates. The resistance of the interposed sheets alone is similarly measured in a separate test made at the same mean temperature and with the same average thickness as when used on the surfaces of the specimens. The resistance of the rigid specimen can then be calculated from the two resistances obtained.

   Another method of determining the resistance of a rigid specimen is to interpose the thin layer of material between the specimen and plates as indicated above and to determine the temperature drop across the rigid specimen by means of separate thermocouples mounted flush with, or interior to, the surface of the rigid specimen. This method of measuring the specimen temperature drop may be subject to uncertainties difficult to evaluate, among them being the effects of —

   (a) distortion of heat flow lines in the immediate vicinity of the thermocouple, due to its presence;

   (b) imprecision in ascertaining the exact position of the effective thermocouple junctions; and

   (c) local inhomogeneities in the surface of the specimen at the thermocouple junction, such as pores, voids or inclusions.

   The number of uniformly distributed thermocouples used on each side of the specimen in the area contiguous to the metering area should be not less than $10\sqrt{A}$ or 2, whichever is the greater, where A is the area in square metres of one side of the metering area. If separate thermocouples are used, the effective thickness of the specimen is taken as the average distance, perpendicular to the face of the specimen, between the centres of the thermocouples on the two sides.