STANDARDS ASSOCIATION OF AUSTRALIA

**Australian Standard**

**METHODS OF TESTING THERMAL INSULATION**

# AS 2464.5
# STEADY–STATE THERMAL TRANSMISSION PROPERTIES BY MEANS OF THE HEAT FLOW METER*

## CONTENTS



* Based on ASTM C 518, Steady–state Thermal Transmission Properties by Means of the Heat Flow Meter.

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# METHOD

**1 SCOPE.** This standard sets out a method for determining the steady-state thermal transmission properties of thermal insulation materials within the limits set by Clause 5, by means of a heat flow meter.

NOTES:

1. This is a secondary or comparative method for measuring the thermal transmission properties of specimen(s), since only the ratio of the thermal resistance of the specimen(s) to that of a standard specimen(s) is measured. The thermal resistances of the standard specimens must be determined in accordance with AS 2464.6.
2. For purposes of certification, this method is limited to specimens with thermal resistances greater than 0.10 $m^2$.K/W in any direction.

**2 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
- 2464.4—Length, Width and Thickness of Batt and Blanket Type Thermal Insulation
- 2464.6—Steady-state Thermal Transmission Properties by Means of the Guarded Hotplate
- 2464.7—Determination of the Average Thermal Resistance of Low-density Mineral Wool Batt and Blanket Type Thermal Insulation*

**3 DEFINITIONS.** For the purpose of this standard, the definitions given in AS 2352 and the following apply:

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

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

**4 SYMBOLS.** The symbols used in this standard have the following significance:

- $k$ = thermal conductivity. Unit: watt per metre kelvin (W/m.K)
- r = 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. Unit: square metre kelvin per watt ($m^2$.K/W)
- Q = time rate of heat flow. Unit: watt (W)
- q = heat flux, or 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 hot surface of specimen. Unit: degree Celsius (°C)
- $T_2$ = temperature of cold surface of specimen. Unit: degree Celsius (°C)

**5 GENERAL REQUIREMENTS FOR SPECIMENS.**

**5.1 For determination of thermal resistance and thermal conductance.** Specimens for the determination of thermal resistance and thermal conductance shall comply with the following requirements:

(a) The portion of the specimen over the metering 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 through the specimen(s) shall be directly proportional to the temperature difference across the specimens.

NOTES:

1. Appendix B describes tests that can help ascertain whether the specimens comply with these requirements. For the purposes of this standard, differences in the measurements of less than 2 percent may be considered insignificant, and the requirements fulfilled.
2. When low density batt or blanket type thermal insulation is being evaluated, recourse should be made to AS 2464.7, wherein reference is made to the testing of materials exhibiting non-linear relationships between thermal resistance and thickness and also showing a random variation of resistance with area.

**5.2 For determination of apparent thermal resistivity and apparent thermal conductivity.** Specimens for the determination of the apparent thermal resistivity and

* In course of preparation.

apparent thermal conductivity shall comply with Clause 5.1 and either of the following:

(a) The material 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 B describes methods for checking these requirements.

**5.3 For determination of thermal resistivity and thermal conductivity.** Specimens for the determination of thermal resistivity and thermal conductivity shall comply with Clauses 5.1 and 5.2 and the following:

(a) The specimen shall be homogeneous.

(b) The thickness of the specimen shall be greater than that for which the thermal resistivity of the material does not change by more than 2 percent with further increases in thickness (see Note 1).

NOTES:

1. Appendix B describes methods for checking the requirements of Clause 5.3 (b). Further discussion on the definition of these requirements can be found in Reference 1.
2. This method is capable of determining thermal properties within ± 3 percent of those determined by AS 2464.6 when the ambient temperature is near the mean temperature of the test.

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

## 6 CERTIFICATION OF RESULTS.

**6.1 General.** Where certification of measurement by the use of this standard is required, one of the following procedures shall be followed:

(a) The testing laboratory apparatus shall be calibrated (see Clause 9) within 24 h before or after the certification test using calibration standards that have been issued by a recognized laboratory not more than 5 years prior to the certification test date. The certification test and the apparatus calibration test shall be carried out using approximately the same hot-side and cold-side temperatures as were used in the official calibration of the standards.

(b) Where both short-term and long-term stabilities of the meter have been proven to be better than 1 percent of reading, the meter may be calibrated at less frequent intervals, not exceeding 30 days. The specimens so tested cannot be certified until after the calibration following the test and then only if the change in calibration from the previous test is less than 1 percent.

The average of the two calibrations shall be used as the calibration factor and the specimens certified with this value. When the change in calibration is greater than 1 percent, test results from this interval shall be considered void and the tests repeated in accordance with (a) above.

NOTES:

1. The precision and reproducibility of measurements made by the heat flow meter are normally much better than 1 percent. This precision is required to identify changes in calibration and is desirable in quality control applications.
2. Because of the requirements for test conditions prescribed by this standard, it is to be recognized that the thermal properties obtained will not necessarily apply, without modification, to all service conditions. As an example, this standard provides that the thermal properties are to be obtained on specimens that do not contain any free moisture, although in service such conditions may not be realized. Even more basic is dependence of the thermal properties on variables such as mean temperature and temperature difference. These dependences should be measured or the tests made at conditions typical of use.
3. The thermal transmission properties of many materials depend upon the prior thermal history. Care is to be exercised when testing a single specimen at a number of conditions to perform the tests in a sequence that limits such effects on the results.

**6.2 Reporting of results.** If results are to be reported as having been obtained by the use of this standard, then all pertinent requirements prescribed by this method shall be complied with. Where such conditions are not complied with, the phrase ‘All requirements of AS 2464.5 have been complied with except for . . .’ shall be added to the test certificate and a complete list of the exceptions included.

## 7 APPARATUS.

**7.1 General.** The heat flow meter apparatus shall consist of a warm plate, a heat flow meter, and a cold plate. The general features of a heat flow meter apparatus with specimens installed are shown in Fig. 1. Where a single specimen is utilized, the apparatus is termed a ‘single specimen configuration’. The specimen may be placed against either plate.

NOTES:

1. Results from the apparatus will sometimes agree more closely with those from the guarded hot plate apparatus (see AS 2464.6) if the heat meter is against the warm plate. The heat is metered on the warm side in both cases so edge losses have the same effects on the measurements; however the operating temperature range of the meter may govern the placement of the heat meter.

   In the two-specimen configuration, the meter is placed between two substantially identical specimens cut from the same sample of material. Each configuration will yield equivalent results if used within the limitations stated in this method. There are distinct advantages for each method in practice. A brief discussion is included in Appendix E.

2. Where more than one heat flow meter apparatus is desired, a double apparatus can be constructed by utilizing the other side of the warm plate and adding another heat flow meter and a cold plate. Examples of both single and double apparatus are described in References 2 to 6.
3. The working surfaces of the plates and the heat meter, i.e. the surfaces making contact with the specimens, are to be painted or otherwise treated to have a total hemispherical emittance of greater than 0.8 at operating temperatures. Hard anodizing of aluminium produces a surface with a total hemispherical emittance of approximately 0.85.

**7.2 Warm plate.** The warm plate shall be constructed so that an isothermal surface is obtained (see Note 1). The working surface of the warm plate shall consist of a metal of high thermal conductivity and shall be smoothly finished to conform to a plane to within 0.025 percent (see Note 2). The temperature of the warm plate, the heater, or the surface of the specimen shall be measured by some suitable means (see Note 3).

NOTES:

1. This can be achieved by placing an electrical winding of uniform watt density between two metal plates, or by circulating a constant-temperature liquid between the plates, or by a combination of both. Where a plate containing a constant-temperature liquid is used, the upper temperature is limited by the liquid properties. One way to overcome this is to place a suitable slab of material of uniform conductance against the surface of the cold plate, then a uniform flux density heater between this slab and the test specimens.
2. The planeness of the surface can be checked with a steel straight-edge, of a length greater than the width or diameter of the unit, held against the surface and viewed with a light behind the straightedge. Departures as small as 25 µm are readily visible, and larger departures can be measured by shims or thin paper.
3. The surface temperature is often measured by permanently mounted 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 are to be electrically insulated from the plates. A resistance of greater than 1 MΩ is recommended. The number of such temperature sensors on each side should be not less than $10\sqrt{A}$, or 2, whichever is the greater, where A is the metering area in square metres. 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. This procedure can lead to errors in the measurements due to the thermal resistance between the sensors and the surfaces. One method for overcoming this problem when high-density materials are tested is given in Reference 7.

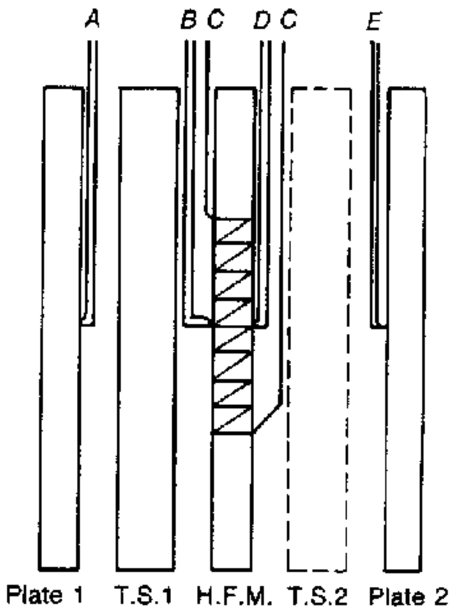


Plate 1 — Controlled temperature plate at $T_1$ (or $T_2$)
T.S. 1 — Test specimen 1
H.F.M. — Heat flow meter (simplified)
T.S. 2 — Test specimen 2 or damping layer
Plate 2 — controlled temperature plate at $T_2$ (or $T_1$)
*A* and *E* — Plate surface thermocouples or transducers
*B* and *D* — Heat meter surface thermocouples
*C* — Heat meter thermopile or temperature-difference detector

NOTE: The direction of heat flow and the use of two specimens is optional; if only one specimen is used, it is necessary to measure the surface temperature of the heat flow meter only on the side contacting the specimen. A thin layer of material may be used, as shown, to dampen temperature fluctuations in the one specimen configuration.

Fig. 1. HEAT FLOW METER APPARATUS

**7.3 Cold plate.** The cold plate shall be constructed so that an isothermal surface is obtained with a surface dimension at least as large as that of the warm plate. It shall consist of a metal plate of high thermal conductivity (see Note 2 to Clause 7.4.2) maintained at a temperature lower than that of the warm plate. The working surface temperature of the plate shall be measured by a proven technique.

**7.4 Heat flow meter.**

**7.4.1** *Core.* The core shall be constructed from a suitable non-hygroscopic material which shall be sufficiently uniform and isotropic, and shall have sufficiently parallel faces, to assure a uniform heat flow normal to the faces. The core material shall not effectively change under the temperature and humidity conditions of use and storage nor from typical handling. It shall be thermally uniform and shall remain stable over a long period of time.

NOTE: The cold plate and warm plate may be identical.

**7.4.2** *Thermopile.* The temperature difference across the core material shall be measured with a sensitive, stable temperature detector (see Appendices D and E).

NOTES:

1. The heat flow meter is an assembly that measures the heat flow through the specimen(s) by generating a temperature difference across a slab of material of known thermal resistance. Several types of heat flow meter are described in Appendix C. Often the heat flow meter also measures one of the surface temperatures of the specimen(s). Most commonly it consists of a homogeneous core, a surface temperature-difference detector, and a surface temperature detector(s). It can also have cover sheets to provide protection and thermal damping. Metal, temperature-levelling plates or foils are sometimes used to improve or simplify the measurements, but these are to be situated so as not to make the temperature difference dependent on specimen thermal properties.

   Precautions are to be taken to limit the effect of heat flow through the leads in the output of the temperature difference detector.

2. When the output from the temperature-difference detector is less than 0.0002 V, special techniques are to be used to prevent extraneous thermal e.m.f.s in leads, the measuring circuits and the meter itself. The latter can be found only by testing the meter at several heat flows, half in one direction, half in the other, and examining the zero intercept of the line joining the points.

   To assure that the heat flow is substantially perpendicular to the faces of the meter, the temperature difference detectors are to be either—

   (a) uniformly distributed within the most central area of meter, which area is to be not greater than 40 percent nor less than 10 percent of the entire surface area; or

   (b) the temperature detectors are to be concentrated in areas of not less than 10 percent of the entire surface area and these areas are to be within the most central 40 percent of the meter.

3. Multijunction thermopiles have been used successfully. The junctions are placed on the surfaces of the core material of the heat meter to measure the temperature difference across the core. To avoid the effects of heat conduction along the elements passing from one face to the other it is recommended that the cross-sectional area of the conductors in the thermopile be smaller than that of a 0.26 mm diameter wire and be parallel to the working faces of the meter except near the edges. It is also recommended that thermoelements such as Type E thermocouples be used. These are described in ASTM E 230. These elements produce a high e.m.f. output and have a low thermal conductivity. Both ribbon and plated thermocouples have proven advantageous in certain designs.

4. The following are some of the materials that can be used for heat flow meters:

   (a) Cork composition.
   (b) Hard rubber plastics.
   (c) Ceramics.
   (d) Asbestos compositions.

**7.4.3** *Surface sheets.* To prevent damage to the temperature-difference detector that will affect its calibration, both surfaces shall be covered with a layer of material as thin as is compatible with protection from thermal shunting of the wires of the temperature-difference detector. The working surfaces of the heat flow meter shall be smoothly finished to conform to the desired geometric shape to within 0.025 percent. (See Note 2 to Clause 7.2 and Clause 7.3.)

NOTE: A properly designed meter will have a sensitivity that is essentially independent of the specimen's thermal properties. The surface sheet may also be chosen to aid in damping of any temperature fluctuation. The surface sheet may be similar to the core material and should be tightly bonded to the core by chemical means such as adhesive films or fusible materials.

**7.4.4** *Surface temperatures.* A suitable device shall be employed for measuring the average temperature of the sample side of the heat flow meter.

NOTE: It has been found that an 80 μm thick piece of copper foil, adhered to the surface sheet, can be used to average the surface temperature of the heat flow meter over the area where the junctions of the thermopile are placed. The foil should extend beyond this area by a distance approximately equal to the thickness of the heat flow meter. The foil is used as a part of a copper-constantan thermocouple circuit. A copper and a constantan wire, 0.26 mm in diameter, are strung through the surface sheet before the surface sheet is attached to the core. The constantan wire is soldered to the centre of the foil while the positive lead is soldered near one of the edges. All of the excess solder should be removed. The surface sheet can be sanded away to eliminate any lumps. The surface of the meter not covered by the metal foil is masked by an applied sheet of non-metal, 80 μm in thickness, to assure a smooth surface.

**7.5 Clamping.** Means shall be provided to apply a reproducible constant pressure to the assembly to assure a good surface contact with the specimen regardless of orientation and