INTERNATIONAL STANDARD ISO 2581

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION • МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ • ORGANISATION INTERNATIONALE DE NORMALISATION

Plastics — Rigid cellular materials — Determination of "apparent" thermal conductivity by means of a heat-flow meter

Matières plastiques — Matériaux alvéolaires rigides — Détermination de la conductivité thermique «apparente» au moyen d'un fluxmètre thermique

First edition — 1975-11-15

UDC 678.5/.8-496 : 536.21 Ref. No. ISO 2581-1975 (E)

Descriptors : plastics, cellular materials, cellular plastics, thermal conductivity, tests, thermal tests, thermal measurement.

Price based on 7 pages

ISO 2581-1975 (E)

FOREWORD

ISO (the International Organization for Standardization) is a worldwide federation of national standards institutes (ISO Member Bodies). The work of developing International Standards is carried out through ISO Technical Committees. Every Member Body interested in a subject for which a Technical Committee has been set up has the right to be represented on that Committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work.

Draft International Standards adopted by the Technical Committees are circulated to the Member Bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 2581 was drawn up by Technical Committee ISO/TC 61, *Plastics*, and circulated to the Member Bodies in February 1974.

It has been approved by the Member Bodies of the following countries :

Belgium	Germany	Romania
Brazil	Hungary	Spain
Bulgaria	India	Sweden
Canada	Israel	Switzerland
Chile	Italy	Turkey
Czechoslovakia	Japan	United Kingdom
Egypt, Arab Rep. of	Mexico	U.S.A.
Finland	Netherlands	
France	New Zealand	

The Member Body of the following country expressed disapproval of the document on technical grounds :

South Africa, Rep. of

Printed in Switzerland

INTERNATIONAL STANDARD ISO 2581-1975 (E)/ERRATUM

Published 1981-12-15

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION • МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ • ORGANISATION INTERNATIONALE DE NORMALISATION

Plastics — Rigid cellular materials — Determination of "apparent" thermal conductivity by means of a heat-flow meter

ERRATUM

Cover page

Replace the title by the following :

"Rigid cellular plastics — Determination of apparent thermal conductivity by means of a heat-flow meter"

and the sub-title by the following :

"Plastiques alvéolaires rigides — Détermination de la conductivité thermique apparente au moyen d'un fluxmètre thermique"

Page 1

Replace the title by the following :

"Rigid cellular plastics — Determination of apparent thermal conductivity by means of a heat-flow meter"

Plastics – Rigid cellular materials – Determination of "apparent" thermal conductivity by means of a heat-flow meter

1 SCOPE AND FIELD OF APPLICATION

1.1 This International Standard specifies a method for the determination of the "apparent" thermal conductivity of rigid cellular plastic materials.

NOTE – In cellular plastics an important part of the heat transfer is due to passage of heat radiation through their structure. This results in values of thermal conductivity being measured which are not independent of the thickness of specimen tested. Therefore the term "apparent" thermal conductivity should be used.

The method, which is comparatively rapid, is based on preliminary and routine calibration of the apparatus by the use of test specimens the "apparent" thermal conductivity of which has been determined in a standard apparatus of the guarded hot-plate type.

Two arrangements of the apparatus are given both of which have been widely used with satisfactory results :

a) the arrangement shown in figure 1 (symmetrical arrangement – method S), in which the heat-flow meter is placed centrally between two identical test specimens;

b) the arrangement shown in figure 2 (asymmetrical arrangement – method AS), in which the heat-flow meter is placed alongside the single test specimen.

NOTE – Test results obtained using this International Standard are not comparable internationally between countries where different types of guarded hot-plate are used as calibration standards.

1.2 For practical purposes, this International Standard applies to specimens having a thermal conductance of not more than 2,5 W/(m²·K) (method S) or 5 W/(m²·K) (method AS).

1.3 For ordinary purposes, the suggested limiting temperatures of the surfaces in contact with the heat-flow meter are $-50\,^\circ C$ and $+100\,^\circ C$. These limits may be extended in both directions, subject to appropriate precautions being taken in relation to the materials of construction, the calibration procedure and the conduct of the test.

1.4 Experience has shown that the results obtained by this method agree satisfactorily with those obtained with a guarded hot-plate apparatus for temperature gradients ranging between $4\,^\circ C/cm$ and $10\,^\circ C/cm$ across the test specimen, subject to a minimum temperature difference between the hot and cold plates of $15\,^\circ C$ (see 8.1).

1.5 The long-term reproducibility of measurements obtained with apparatus constructed and used in accordance with this method can be better than 3 %, as many previous experiments have already shown.

2 REFERENCE

ISO/R 291, *Plastics – Standard atmospheres for conditioning and testing.*

3 DEFINITIONS

3.1 heat flow rate : The quotient of the quantity of heat flowing through a surface and the time.

3.2 density of heat flow rate through a surface : The quotient of the heat flow rate through a surface and the area of that surface.

3.3 thermal conductivity : The quotient of the density of heat flow rate through a surface and the temperature gradient. (This is a fundamental property of a material, independent of the thickness of specimen tested.)

3.4 thermal conductance : The quotient of the density of the heat flow rate and the temperature difference which maintains this heat flow under steady-state conditions.

3.5 apparent thermal conductivity : The quotient of the heat flow rate, inclusive of any heat transmitted through the specimen by radiation, through unit area and the temperature gradient in the direction perpendicular to the surface of the test specimen. (This is not a fundamental property of the material and is dependent on the thickness of the specimen tested which should always be quoted in conjunction with the value.)

4 PRINCIPLE

From two isothermal surfaces at constant upper and lower temperatures, a heat flow is established through a single test specimen (method AS) or through a pair of test specimens (method S) of identical shape and equal thickness and density, cut from the cellular material under test.

A steady state (thermal equilibrium) having been established, the electromotive force generated in a heat-flow meter inserted between the two test specimens (method S) or between the plate at lower temperature and the single specimen (method AS) is measured.

The thermal conductivity of the cellular material is calculated from the value of this electromotive force, the thickness of the test specimen(s) and the calibration constant of the apparatus. This calibration constant depends on the upper and lower temperatures selected for the test and on the sensitivity of the heat-flow meter.

5 APPARATUS

5.1 General

5.1.1 *Method S*

The assembly of apparatus and test specimens shall consist essentially of a cold plate, one of the test specimens, a heat-flow meter, the second test specimen and a hot plate, assembled in that order (see figure 1).

5.1.2 *Method AS*

The assembly of apparatus and test specimen apparatus shall consist essentially of a cold plate, a heat-flow meter, a test specimen and a hot plate, assembled in the same order as that for calibration (for example see figure 2).

5.2 Heat-flow meter (for method S or method AS)

5.2.1 This shall consist of a round or square thermopile of linear dimensions not less than 100 mm, mounted in a round or square support and having flat parallel faces.

The linear dimensions of the thermopile shall be not greater than and preferably equal to half the linear dimensions of the heat-flow meter. The linear dimensions of the heat-flow meter shall be not less than four times the thickness of the (pair of) specimen(s) (see clause 7).

5.2.2 The material of the thermopile support shall be isotropic, non-hygroscopic and thermally stable under the conditions of test.

5.2.3 The faces of the heat-flow meter shall be painted (black mat finish) or otherwise treated to have a total emittance of at least 0,8 at operating temperatures.

5.2.4 Taking into account the requirement of 5.5.1, it is recommended that the calibration constant of the heat-flow meter be such that the electromotive force generated under all test conditions is not less than 0,5 mV.

5.2.5 In the case of method S, the thermal conductance of the heat-flow meter shall be such that the difference in temperature between its faces is not greater than 2 % of that existing between the hot and cold plates, under all test conditions.

5.2.6 In the case of method AS, a suitable device shall be employed for measuring the average temperature of the face of the heat-flow meter nearer the test specimen.

5.3 *Hot and cold plates*

5.3.1 The working surfaces of the hot and cold plates shall consist of a metal of high thermal conductivity, such as copper, aluminium or steel, and shall be smoothly finished to conform to a true plane to within 0,5 mm/m. These working surfaces shall be painted or otherwise treated to have a total emittance of at least 0,8 at operating temperatures.

5.3.1.1 METHOD S

The linear dimensions of the plates shall be at least the same as those of the heat-flow meter.

5.3.1.2 METHOD AS

The linear dimensions of the hot plate shall be at least the same as those of the heat-flow meter, those of the cold plate being at least as large as those of the hot plate.

5.3.2 A groove or grooves shall be machined into the surfaces of the hot and cold plates to allow one or more temperature-sensing devices to be embedded in the surface of each plate.

5.3.3 Each plate shall be provided with a means of maintaining its temperature at the required level by, for example, the circulation of heated or refrigerated fluid, or a combination of refrigeration and direct electrical heating. The degree of control required is such that the temperature T_h or T_c of the surface in contact with the test specimen does not vary by more than 0,2 °C during the period of test. Individual temperature readings of the sensing devices during the test period should not differ by more than 0,4 °C.

5.4 Mounting

5.4.1 A means shall be provided to ensure that throughout the test the hot and cold plates can be maintained parallel to each other and to the heat-flow meter to within 0,5 mm, and remain in intimate contact with the test specimen(s).

5.4.2 A means shall also be provided to enable the heat-flow meter and the pair of test specimens to be centred accurately on the axis of symmetry of the hot and cold plates.

5.4.3 The apparatus may be arranged vertically or horizontally.

5.4.4 Spacers of low conductance may be positioned between the plates and the heat-flow meter along the outer perimeter to prevent any distortion of the test specimen(s) due to compression.

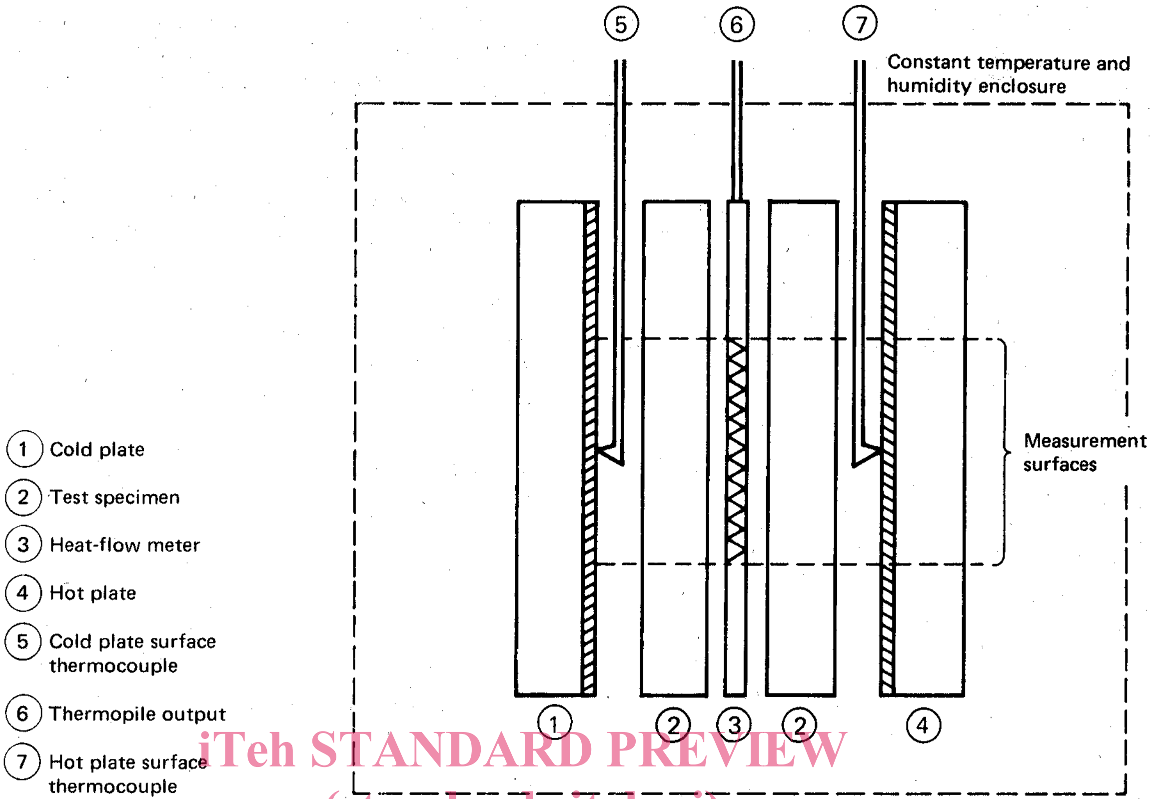

FIGURE 1 — **Heat-flow meter apparatus with two test specimens (method S)**

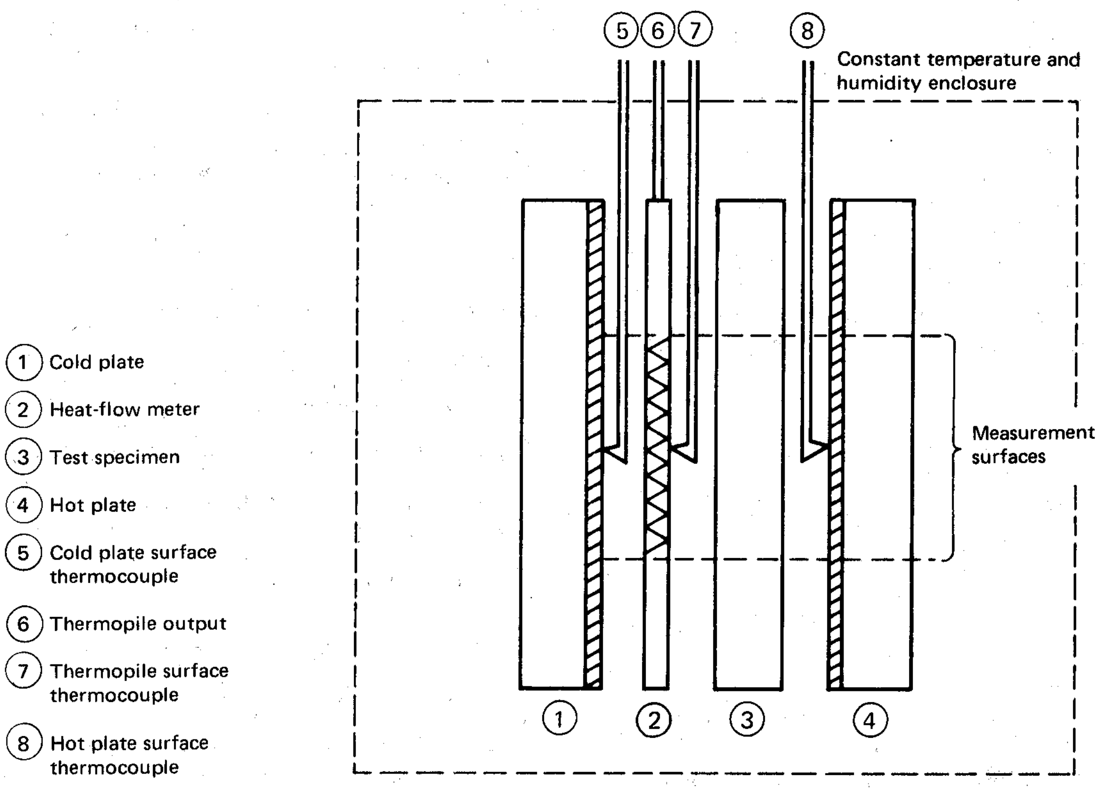

FIGURE 2 — **Heat-flow meter apparatus with single test specimen (method AS)**

5.5 Measuring devices

5.5.1 A potentiometer or other measuring device having a capability of measuring to ± 0,5 % or better shall be used for measurements of all thermocouple and thermopile electromotive forces.

NOTE — Thermocouples, if used, shall be constructed from calibrated thermocouple wire of diameter about 0,2 mm or preferably less.

5.5.2 Means shall be provided to measure the thickness of the test specimen in position for the test to the nearest 0,1 mm.

5.6 Constant-temperature enclosure

5.6.1 The assembled apparatus shall be contained in an enclosure, maintained during the test at a temperature T, to within ± 0,5 °C, such that :

$$T = \frac{T_h + T_c}{2}$$

5.6.1.1 METHOD S

In this case the enclosure at constant temperature is an essential requirement. If it is not satisfied, the results may not be free of error, especially at a mean temperature of test differing considerably from the room temperature.

5.6.1.2 METHOD AS

In the case of method AS it is possible to substitute for this enclosure an adequate edge insulation after checking that edge losses are adequately minimized by this alternative means and do not affect the result of the measurements.

5.6.2 Means shall be provided to maintain the air in contact with the cold plate at a relative humidity such that no condensation of moisture on the cold plate or the heat-flow meter occurs in the course of the test. It is recommended that the dew point temperature be maintained at least 5 °C lower than the temperature of the cold plate.

6 TEST SPECIMENS

6.1 Shape and dimensions

6.1.1 Each test specimen shall have flat parallel faces similar in shape to the heat-flow meter. The linear dimensions shall be preferably equal to and not less than those of the heat-flow meter.

6.1.2 The thickness L of the pair of specimens (method S) or specimen (method AS) shall be no greater than 25 % of the linear dimension of the heat-flow meter.

The minimum thickness L_{min} of the pair of specimens (method S) or specimen (method AS) depends on the maximum thermal conductance permitted (see 1.2).

Method S	Method AS
$L_{min} = \frac{10^3 \lambda}{2,5}$ mm	$L_{min} = \frac{10^3 \lambda}{5}$ mm

It also depends on the maximum temperature gradient and the minimum temperature difference between the hot and cold plates (see 1.4); thus, the minimum thickness of specimen or pair of specimens is 15 mm.

Any difference of thickness between the test specimens (method S) shall not exceed 1 mm.

6.1.3 The faces of the test specimens shall be flat to within 0,5 mm/m and parallel to within 0,5 mm.

6.2 Preparation

6.2.1 The test specimens shall be cut by an appropriate method and machined if necessary without alteration to the structure of the material. Where required by the relevant material specification, moulding skins shall be removed.

6.2.2 In the case of method S, a sufficient number of test specimens shall be cut from the sample under test to permit selection of several pairs of specimens so that the density of each specimen in a pair is as similar as possible. The maximum permissible difference in density between the two specimens of the test pair shall be 5 %.

6.3 Conditioning

The test specimens shall be conditioned for a minimum of 24 h in accordance with ISO/R 291, or preferably the relevant material specification if available.

7 SUMMARY OF DIMENSIONS

Linear dimension of thermopile = x

Linear dimension of heat-flow meter = $A \geqslant 2x$

Linear dimension of hot and cold plates $\geqslant A$

Linear dimension of test specimen or pair of test specimens $\geqslant A$

Thickness of test specimen :

Method S	Minimum	15 mm or $\frac{10^3 \lambda}{2,5}$
	Maximum	0,25 A
Method AS	Minimum	15 mm or $\frac{10^3 \lambda}{5}$
	Maximum	0,25 A

Examples of dimensions (mm)

Dimension of thermopile		100	150	200
Linear dimension of plates, heat-flow meter and test specimen(s)		200	300	400
Maximum specimen(s) thickness		50	75	100
Minimum specimen(s) thickness corresponding to :				
$\lambda = 0{,}025$ W/(m·K)*	Method S	15	15	15
	Method AS	15	15	15
$\lambda = 0{,}050$ W/(m·K)	Method S	20	20	20
	Method AS	15	15	15
$\lambda = 0{,}075$ W/(m·K)	Method S	30	30	30
	Method AS	15	15	15

* 1 W/(m·K) = 6,933 Btu·in/(h·ft^2·°F) = 0,859 8 kcal/(m·h·°C).

8 PROCEDURE

8.1 Ensure that the hot and cold plates are at the desired temperatures and that the difference between these temperatures is not less than 15 °C.

NOTE – To reduce the time required for the tests, it is recommended that test programmes be arranged to keep the same temperatures T_h and T_c over as long a run as possible. It is assumed here that these temperatures have already been stabilized (to within 1 % of their mean value) at the required level and that a calibration check as indicated in clause 9 has been carried out.

8.2 Weigh the conditioned specimen(s) to ± 0,5 %.

8.3 Arrange the pair of specimens between the hot and cold plates on either side of the heat-flow meter (method S, figure 1) or the single specimen between the heat-flow meter and the opposite plate (method AS, see figure 2).

8.4 Move the hot and cold plates carefully towards each other until good contact is obtained between the plates, the test specimen(s) and the heat-flow meter without significantly compressing the specimens. (This can be checked by trying to move by hand, without noticeable effort, the test specimen(s). Such movement must not be possible.)

8.5 Measure and record the thickness of the test specimen (method AS) or the total thickness of the pair of test specimens (method S) to the nearest 0,1 mm as indicated in 5.5.2.

8.6 Record (method S) the temperatures T_h and T_c of the hot and cold plate faces or (method AS) that of the hot plate face (T_h) and that of the heat-flow meter face in contact with specimen (T_m). For either method, measure and record the electromotive force E generated by the heat-flow meter, until a steady-state condition has been established. The criterion of a steady state shall be that for three successive readings, taken at intervals of not less than 10 min, the values of the temperature differences $T_h - T_c$ (method S) or $T_h - T_m$ (method AS) and of the electromotive force E agree within 1 % of their respective means. Record the mean value of these three sets of readings.

NOTE – If this method is used for quality assurance purposes, it may be possible to reduce the time between readings.

8.7 Remove the specimen(s) and immediately reweigh it (them) to ± 0,5 %.

Record the value(s).

8.8 Measure the linear dimensions (length of sides or several diameters) of the specimen(s) to ± 1 % and calculate the apparent density of the test specimen (or of test specimen pair) from these dimensions, the test thickness (see 8.5), and the test mass (see 8.7).

9 CALIBRATION

9.1 Standard test specimens

This test method requires that the heat-flow meter apparatus be calibrated with standard test specimens, the apparent thermal conductivity of which has been determined by a standard guarded hot-plate procedure.

Such standard specimens must have stable physical characteristics and be accompanied by a calibration curve relating apparent thermal conductivity to mean temperature of test over the appropriate range. If this is not practical, the date of validity of the calibration must be indicated. If tests are to be carried out over a wide range of apparent thermal conductivity, more than one standard test specimen shall be available. The thickness and apparent thermal conductivity of the calibration specimens shall be consistent with the mean characteristics of the material to be tested.

9.2 Calibration procedure (method S)

9.2.1 *Primary calibration*

The method is identical with that detailed in clause 8, special care being taken not to alter the test thickness of the standard test specimen pair from that stated in the calibration sheet.

Under steady-state conditions, the calibration constant C_T of the apparatus at mean temperature T is given, in watts per square metre microvolt [W/(m²·µV)], by the formula :

$$C_T = \frac{\lambda_T \times \Delta T}{L \times E_T}$$

where

λ_T is the apparent thermal conductivity, in watts per metre kelvin [W/(m·K)], of the standard test specimen pair at mean temperature T;