

Australian/New Zealand Standard™

**Method of test for heat and smoke
release rates for materials and products
using an oxygen consumption
calorimeter**



AS/NZS 3837:1998

This Joint Australian/New Zealand Standard was prepared by Joint Technical Committee FP-018, Fire Safety. It was approved on behalf of the Council of Standards Australia on 24 July 1998 and on behalf of the Council of Standards New Zealand on 17 July 1998.

This Standard was published on 5 November 1998.

The following are represented on Committee FP-018:

Australasian Fire and Emergency Service Authorities Council
Australian Building Codes Board
Australian Industry Group
AWTA Textile Testing
BRANZ
Bureau of Steel Manufacturers of Australia
CSIRO Manufacturing & Materials Technology
Department of Building and Housing (New Zealand)
Engineers Australia
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This Standard was issued in draft form for comment as DR 94340.

Australian/New Zealand Standard™

Method of test for heat and smoke release rates for materials and products using an oxygen consumption calorimeter

First published as AS/NZS 3837:1998.
Reissued incorporating Amendment No. 1 (June 2012).

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Jointly published by SAI Global Limited under licence from Standards Australia Limited, GPO Box 476, Sydney, NSW 2001 and by Standards New Zealand, Private Bag 2439, Wellington 6140.

ISBN 0 7337 2177 X

PREFACE

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee BD/18, Fire Safety.

This Standard incorporates Amendment No. 1 (June 2012). The changes required by the Amendment are indicated in the text by a marginal bar and amendment number against the clause, note, table, figure or part thereof affected.

A1 | Amendment No. 1 was raised to address significant differences observed between group number achieved by applying empirical correlations to predict the time to flashover using AS 3837 test results and measured results achieved in AS ISO 9705.

This Standard is based on ISO 5660-1:1993, *Fire tests—Reaction to fire—Rate of heat release from building products*, except that the ISO test method excludes smoke measurement, and the test method and test apparatus are based on ASTM E 1354, *Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter*.

It is envisaged that in the future, applications Standards for specific materials will be prepared by appropriate committees. These applications Standards will call up this test method and will set parameters such as irradiance levels and specimen construction or any other relevant parameters.

Specifications for particular materials and products will need to state the irradiance level and specimen construction for each acceptance level.

The terms ‘normative’ and ‘informative’ have been used in this Standard to define the application of the appendix to which they apply. A ‘normative’ appendix is an integral part of a Standard, whereas an ‘informative’ appendix is only for information and guidance.

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FOREWORD

Fire is a complex phenomenon. Its behaviour and effects depend upon a variety of factors which are inter-related in an intricate way. The behaviour of materials and products in a fire will depend on the characteristics of the particular fire, the way the materials are used and the environment in which they are exposed.

A test such as the one described in this Standard deals only with a simple representation of a particular aspect of the potential fire typified by a radiant heat source and a spark. It cannot, by itself, provide direct guidance on the behaviour or safety of a material in a fire. A test of this type may, however, be used for comparative purposes or to ensure a certain level of performance. The test basically measures heat release rates which have a bearing on fire performance generally.

The term heat release rate is defined in AS 2484.1, *Fire—Glossary of terms*, Part 1: *Fire tests*, as the amount of calorific energy released per unit time by a material during combustion under specified test conditions. It is one of the fundamental properties of fire and should almost always be taken into account in any assessment of fire hazard since it significantly affects the development of the fire.

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Australian/New Zealand Standard**Method of test for heat and smoke release rates for materials and products using an oxygen consumption calorimeter**

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE**1.1.1 General**

This Standard specifies a test method for measuring the response of materials exposed to controlled levels of radiant heating with or without an external igniter. The test method is used to determine the ignitability, heat release rates, mass loss rates, effective heat of combustion, and smoke release of materials and products.

Properties are determined as follows:

- (a) Rate of heat release, by measurement of the oxygen consumption, as determined by the oxygen concentration and the flow rate in the exhaust product stream.
- (b) Effective heat of combustion from a concomitant measurement of specimen mass loss rate, in combination with the heat release rate.
- (c) Smoke release, by obscuration of light by the combustion product stream.
- (d) Ignitability, as a measurement of time from initial exposure to time of sustained flaming.

1.1.2 Objectives

The purpose of this Standard is to establish a test method for material and product evaluations, mathematical modelling, design purposes or development and research. The material may comprise specimens from an end-use product or the various components used in the end-use product.

1.1.3 Test parameters

Specimens may be exposed to heating fluxes ranging from 0 to 100 kW/m². External ignition, when used, is by electric spark. The value of the heating flux and the use of external ignition are to be as specified in the relevant material or performance standard. The normal specimen testing orientation is horizontal, independent of whether the end-use application involves a horizontal or a vertical orientation. Provisions are also made for vertical orientation testing; this is intended for exploratory or diagnostic studies only.

NOTES:

- 1 The test method does not prescribe the irradiance levels nor whether external ignition is to be used. For an insight into the development of the test method, the features of the apparatus and the use of the data, see Appendix A.
- 2 See Appendix B for a list of papers that provide additional technical background.

1.2 PRINCIPLE OF TEST METHOD

1.2.1 General

This test method is based on the observation (Ref. 1) that, generally, the net heat of combustion is directly related to the amount of oxygen required for combustion. The relationship is that approximately 13.1×10^3 kJ of heat are released per 1 kg of oxygen consumed. Specimens in the test are burned in ambient air conditions, while being subjected to a predetermined external heat flux, which can be set from 0 to 100 kW/m². Burning may be either with or without a spark ignition. The primary measurements are oxygen concentrations and exhaust gas flow rate. Additional measurements include the mass-loss rate of the specimen, the time to sustained flaming and smoke obscuration, or as required by the relevant material or performance Standard.

1.2.2 Significance and use

This test method is used primarily to determine the heat released from a fire involving products of the test material. Also included is a determination of the effective heat of combustion, mass loss rate, the time to sustained flaming and smoke released. These properties are determined on small size specimens that are representative of those in the intended end use.

This test method is applicable to various categories of products and is not limited to representing a single fire scenario.

NOTE: Additional guidance for testing is given in Appendix A.

This test method is not applicable to end-use products that do not have planar, or nearly planar, external surfaces.

1.3 REFERENCED DOCUMENTS

The following documents are referred to in this Standard:

AS

2484 Fire—Glossary of terms

2484.1 Part 1: Fire tests

AS ISO

9705 Fire tests—Full-scale room test for surface products

ISO

5657 Fire tests—Reaction to fire—Ignitability of building products

5725

Precision of test methods—Determination of repeatability and reproducibility for a standard test method by inter-laboratory tests

ASTM

E 177 Practice for use of the Terms Precision and Bias in ASTM Test Methods

E 662

Test Method for Specific Optical Density of Smoke Generated by Solid

Materials

E 691

Practice for Conducting an Interlaboratory Test Program to Determine the Precision of Test Methods

E 906

Test Method for Heat and Visible Smoke Release Rates for Materials and Products

Other documents

ABCB Australian Building Codes Board

NCC National Construction Code (Volume 1, Building Code of Australia)

FCRC

Fire Performance of Wall and Ceiling Linings, Final Report, Project 2, Stage A,

1998

FCRC PR 98-02, Fire Code Reform Centre Ltd., Sydney

1.4 DEFINITIONS

A1 | For the purpose of this Standard, the definitions in AS 2484.1 and those below apply.

1.4.1 Effective heat of combustion

The measured heat release divided by the mass loss for a specified time period.

1.4.2 Heating flux

The incident flux imposed externally from the heater on the specimen at the initiation of the test.

NOTE: The specimen, once ignited, is also heated by its own flame.

1.4.3 Net heat of combustion

The oxygen bomb (see ASTM D 3286) value for the heat of combustion, corrected for the gaseous state of product water.

1.4.4 Orientation

The plane in which the exposed face of the specimen is located during testing, either vertical or horizontal, facing up.

1.4.5 Oxygen consumption principle

The expression of the relationship between the mass of oxygen consumed during combustion and the heat released.

1.4.6 Sustained flaming

Existence of flame on or over most of the specimen surface for periods of at least 4 s.

NOTE: Flaming of less than 4 s duration is identified as 'flashing' or 'transitory flaming'.

1.5 APPLICATION TO FIRE HAZARD ASSESSMENT

This Standard should be used to measure and describe the properties of materials, products, or assemblies in response to heat and flame under controlled laboratory conditions and should not be used to describe or appraise the fire hazard of materials, products, or assemblies under actual fire conditions. However, results of this test may be used as elements of a fire hazard assessment which takes into account all of the factors that are pertinent to an assessment of the fire hazard of a particular end use.

1.6 HAZARD WARNINGS

1.6.1 General

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.

1.6.2 Temperatures

The test procedures involve high temperatures and combustion processes. Therefore, hazards may exist for burns, ignition of extraneous objects or clothing, and for inhalation of combustion products. The operator should use protective gloves for insertion and removal of test specimens. Neither the cone heater nor the associated fixtures should be touched while hot except with the use of protective gloves.

1.6.3 Eye protection

The possibility of violent ejection of molten hot material or sharp fragments from some kinds of specimens when irradiated cannot be totally discounted and eye protection should be worn.

1.6.4 Ventilation

The exhaust system should be checked for proper operation before testing and should discharge into a building exhaust system with adequate capacity. Provision should be made for collecting and venting any combustion products that should for whatever reason fail to be collected by the normal exhaust system of the apparatus.

1.7 MATHEMATICAL SYMBOLS

The following symbols are used in this Standard:

A_s	=	nominal specimen exposed surface area, 0.01 m^2
C	=	calibration constant for oxygen consumption analysis, $\text{m}^{1/2}.\text{kg}^{1/2}.\text{K}^{1/2}$
Δh_c	=	net heat of combustion, kJ/kg
$\Delta h_{c,\text{eff}}$	=	effective heat of combustion, kJ/kg
I	=	actual beam intensity
I_o	=	beam intensity with no smoke
k	=	smoke extinction coefficient, m^{-1}
L	=	extinction beam path length, m
m	=	specimen mass, kg
m_f	=	final specimen mass, kg
m_i	=	initial specimen mass, kg
$\dot{m}$	=	specimen mass loss rate, kg/s
ΔP	=	orifice meter pressure differential, Pa
$\dot{q}$	=	heat release rate, kW
$\dot{q}_m$	=	heat release rate of methane, kW
$\dot{q}''$	=	heat release rate per unit area, kW/m^2
$\dot{q}_{\text{tot}}''$	=	total heat released, kJ/m^2 (Note that $\text{kJ} \equiv \text{kW.s}$)
$\dot{q}_{\text{max}}''$	=	maximum heat release rate per unit area, kW/m^2
$\dot{q}_{180}''$	=	average heat release rate, per unit area, over the time period starting at t_{ig} and ending 180 s later, kW/m^2
r	=	repeatability (the units are the same as for the variable being characterized)
R	=	reproducibility (the units are the same as for the variable being characterized)
r_o	=	stoichiometric oxygen/fuel mass ratio
s_r	=	sample-based standard deviation estimate for repeatability (same units as r)
s_R	=	sample-based standard deviation estimate for reproducibility (same units as R)
t	=	time, s
t_d	=	oxygen analyser delay time, s
t_{ig}	=	time to sustained flaming, s
Δt	=	sampling time interval, s
T_e	=	absolute temperature of gas at the orifice meter, K

$\dot{V}$	=	volume exhaust flow rate, measured at the location of the laser photometer, m^3/s
X_{O_2}	=	oxygen analyser reading, mole fraction O_2
$X_{\text{O}_2}^0$	=	initial value of oxygen analyser reading
$X_{\text{O}_2}^1$	=	oxygen analyser reading, before delay time correction
ρ	=	density (kg/m^3)
σ_f	=	specific extinction area, for smoke, m^2/kg
σ_r	=	repeatability standard deviation (same units as r)
σ_R	=	reproducibility standard deviation (same units as R)

SECTION 2 APPARATUS, SPECIMENS AND TEST PROCEDURES

2.1 TEST APPARATUS

2.1.1 General

2.1.1.1 Dimensions

Where explicitly stated in the description below, dimensions are mandatory and should be followed within nominal tolerances of ± 1 mm, unless otherwise specified. These critical dimensions are followed by an asterisk in Figures 1 through 12. All other dimensions are recommended values and should be followed closely.

2.1.1.2 Components

The test apparatus* shall consist essentially of the following:

- (a) A conical-shaped radiant electric heater, capable of horizontal or vertical orientation.
- (b) Specimen holders, different for the two orientations.
- (c) An exhaust gas system with oxygen monitoring and flow measuring instrumentation.
- (d) An electric ignition spark-plug.
- (e) A data collection and analysis system.
- (f) A load cell for measuring specimen mass loss.

A general view of the apparatus is shown in Figure 1; a cross-section through the heater in Figure 2, and exploded views of horizontal and vertical orientations in Figures 3 and 4.

NOTES:

- 1 Additional details describing features and operation of the test apparatus are given in Ref. 2.
- 2 A schematic diagram of a cone calorimeter assembly is shown in Appendix C.

2.1.2 Conical heater

2.1.2.1 Heating element

The active element of the heater shall consist of an electrical heater rod, rated at 5000 W at 240 V, tightly wound into the shape of a truncated cone (see Figures 2 and 4). The heater shall be encased on the outside with a double-wall stainless steel cone, packed with a refractory fibre material of approximately 100 kg/m^3 density.

2.1.2.2 Heat flux

The heater shall be hinged so that it can be swung into either a horizontal or a vertical orientation. The heater shall be capable of producing irradiances on the surface of the specimen of up to 100 kW/m^2 . The irradiance shall be uniform within the central $50 \times 50 \text{ mm}$ area of the specimen, to within $\pm 2\%$ in the horizontal orientation and to within $\pm 10\%$ in the vertical orientation. As the geometry of the heater is critical, the dimensions in Figure 2 are mandatory.

* A complete set of construction drawings is available from the National Institute of Standards and Technology, Center for Fire Research, Building 224, Room A345, Gaithersburg, Maryland 20899, USA.

2.1.2.3 Thermocouples

The irradiance from the heater shall be capable of being held at a preset level by means of a temperature controller and three type K stainless-steel-sheathed thermocouples, symmetrically disposed and in contact with, but not welded to, the heater element (see Figure 2). The thermocouples shall be of equal length and wired in parallel to the temperature controller. The standard thermocouples are sheathed, 1.5 mm to 1.6 mm outside diameter, with an unexposed hot junction. Alternatively, either 3 mm outside diameter sheathed thermocouples with an exposed hot junction, or 1 mm outside diameter sheathed thermocouples with an unexposed hot junction can be used.

2.1.3 Temperature controller

2.1.3.1 General

The temperature controller for the heater shall be capable of holding the element temperature steady to within $\pm 2^{\circ}\text{C}$. A suitable system is a '3-term' controller (proportional, integral and derivative) and a thyristor unit capable of switching currents up to 25 A at 240 V.

2.1.3.2 Features

The controller should have a temperature input range of 0 to 1000°C ; a set scale capable of being read to 2°C , or better, and automatic cold junction compensation. The controller shall be equipped with a safety feature such that, in the event of an open circuit in the thermocouple line, it will cause the temperature to fall to near the bottom of its range.

2.1.3.3 Thyristor

The thyristor unit shall be of the 'zero crossing' and not of the 'phase angle' type.

2.1.3.4 Meter

The heater temperature shall be monitored by a meter capable of being read to $\pm 2^{\circ}\text{C}$, or better. It may be incorporated into the temperature controller or be separate.

2.1.4 Exhaust system

2.1.4.1 General

The exhaust-gas system shall consist of a high temperature centrifugal exhaust fan, a hood, intake and exhaust ducts for the fan, and an orifice plate flowmeter (see Figure 5). The exhaust system shall be capable of developing flows from $0.012\text{ m}^3/\text{s}$ to $0.035\text{ m}^3/\text{s}$.

2.1.4.2 Orifice

A restrictive orifice (57 mm inside diameter) shall be located between the hood and the duct to promote mixing.

2.1.4.3 Ring sampler

A ring sampler shall be located in the fan intake duct for gas sampling, 685 mm from the hood (see Figure 1). The ring sampler shall contain 12 holes to average the stream composition, with the holes facing away from the flow to avoid soot clogging.

2.1.4.4 Thermocouples

The temperature of the gas stream shall be measured using a 1.0 mm to 1.6 mm outside diameter sheathed-junction thermocouple or a 3 mm outer diameter exposed junction thermocouple positioned in the exhaust stack on the centre-line and 100 mm upstream from the measuring orifice plate.

2.1.4.5 Flow rate

The flow rate shall be determined by measuring the differential pressure across a sharp-edged orifice (57 mm inside diameter) in the exhaust stack, at least 350 mm downstream from the fan if the latter is located as shown in Figure 5.

2.1.4.6 Variations

In other details, the geometry of the exhaust system is not critical. Where necessary, small deviations from the recommended dimensions given in Figure 5 are allowed; e.g. the inner diameter of the duct and the orifice plates can be slightly different. Also, the fan does not need to be at the exact location indicated in Figure 5, but can be further downstream, allowing for a more common type of fan to be used. In this case, undisturbed inflow distances to the gas sampling probe and the measuring orifice shall be sufficient for the flow to be uniformly mixed.

2.1.5 Load cell

The general arrangement of the specimen holders on the load cell is indicated in Figures 3 and 4. The load cell shall have an accuracy of 0.1 g, and preferably shall have a measuring range of 500 g and a mechanical tare adjustment range of 3.5 kg.

2.1.6 Specimen mounting

2.1.6.1 Horizontal

The horizontal specimen holder is shown in Figure 6. The bottom of the horizontal specimen holder shall be lined with a layer of low density (nominal density 65 kg/m³) refractory fibre blanket with a thickness of at least 13 mm. The distance between the bottom surface of the cone heater and the top of the specimen shall be adjusted to be 25 mm by using the sliding cone height adjustment (see Figure 2).

2.1.6.2 Vertical

The vertical specimen holder is shown in Figure 7 and includes a small drip tray for containing a limited amount of molten material. A specimen shall be installed in the vertical specimen holder by backing it with a layer of refractory fibre blanket (nominal density 65 kg/m³), the thickness of which depends on specimen thickness, but shall be at least 13 mm. A layer of rigid, ceramic fibre millboard shall be placed behind the fibre blanket layer. The millboard thickness shall be such that the entire assembly is rigidly bound together once the retaining spring clip is inserted behind the millboard. In the vertical orientation, the cone heater height is set so the centre lines up with the specimen centre.

2.1.6.3 Retainer frame

A retainer frame (see Figure 12) is required for some specimens tested in the horizontal orientation (see Clause 2.2.3.3).

2.1.6.4 Wire grid

A wire grid (Figure 8), to be used in conjunction with the retainer frame, is required for some specimens in the horizontal orientations. The wire grid shown in Figure 8 is also suitable for the vertical orientation (see Clause 2.2.3.3).

2.1.7 Radiation shield

The cone bearer shall be provided with a removable radiation shield to protect the specimen from the heat flux prior to the start of a test. The shield shall be made of non-combustible material with a total thickness not to exceed 12 mm. The shield shall be one of the following:

- (a) Water cooled and coated with a durable matte black finish of surface emissivity $e = 0.95 \pm 0.05$.
- (b) Not water cooled with a reflective top surface to minimize radiation transfer.

The shield shall be equipped with a handle or other suitable means for quick insertion and removal. The cone heater base plate shall be equipped with the means for holding the shield in position and allowing its easy and quick removal.

2.1.8 Ignition circuit

External ignition is accomplished by a spark plug powered from a 10 kV transformer. The spark plug shall have a gap of 3 mm. The transformer shall be of a type specifically designed for spark ignition use. The transformer shall have an isolated (ungrounded) secondary winding to minimize interference with the data transmission lines. The electrode length and location of the spark plug shall be such that the spark gap is located 13 mm above the centre of the specimen in the horizontal orientation; in the vertical orientation the gap shall be located in the specimen face plane and 5 mm above the top of the holder. In either position the spark plug shall be removed when sustained flaming is achieved.

2.1.9 Ignition timer

The timing device for measuring time to sustained flaming shall be capable of recording elapsed time to the nearest second and shall be accurate to within 1 s in 1 h.

2.1.10 Gas sampling

Gas sampling arrangements are shown in Figure 9. They shall incorporate a pump, a filter to prevent entry of soot, a cold trap to remove most of the moisture, a bypass system set to divert all flow except that required for the oxygen analyser, a further moisture trap and a trap for carbon dioxide (CO₂) removal, the latter if CO₂ is not measured.

NOTE: If an optional CO₂ analyser is used instead of removing CO₂ from the oxygen analyser stream, the equations to calculate the rate of heat release will be different from those for the standard case (see Clause 3.1) and are, instead, given in Appendix C.

2.1.11 Oxygen analyser

The analyser shall be of the paramagnetic type with a range from 0% to 25% oxygen. The analyser shall exhibit a linear response and drift of not more than ± 50 ppm oxygen (root-mean-square value) over a period of $\frac{1}{2}$ h. Since oxygen analysers are sensitive to stream pressures, the stream pressure shall be regulated (upstream of the analyser) to allow for flow fluctuations, and the readings from the analyser compensated with an absolute pressure regulator to allow for atmospheric pressure variations. The analyser and the absolute pressure regulator shall be located in a constant-temperature environment. The oxygen analyser shall have a 10% to 90% response time of less than 12 s.

2.1.12 Smoke measuring system

The smoke measuring system (see Figure 10) comprises a helium-neon laser, silicon photodiodes as main beam and reference detectors, and appropriate electronics to derive the extinction coefficient and to set the zero reading. The system is designed for split yoke mounting in two pieces, which are rigidly screwed together but resiliently attached to the exhaust duct by means of refractory gasketing, at the location shown in Figure 5. The meter is located in place by means of two small-diameter tubes welded onto each side of the exhaust duct. These serve as part of the light baffling for the air purging and also allow for any smoke that may enter despite the purge flow to be deposited on tube walls before reaching the optical elements.

2.1.13 Heat flux meter

2.1.13.1 General

The total heat flux meter shall be of the Gardon (foil) or Schmidt-Boelter (thermopile) type, with a design range of about 100 kW/m². The target receiving radiation, and possibly to a small extent convection, shall be flat, circular, approximately 12.5 mm in diameter and coated with a durable matt black finish. The target shall be water cooled. Radiation shall not pass through any window before reaching the target. The instrument shall be robust, simple to set up and use, and stable in calibration. The instrument shall have an accuracy of within $\pm 3\%$ and a repeatability within 0.5%.

2.1.13.2 Calibration

The calibration of the heat flux meter shall be checked whenever a recalibration of the apparatus is carried out by comparison with an instrument (of the same type as the working heat flux meter and of similar range) held as a reference standard and not used for any other purpose. The reference standard shall be fully calibrated at a standardizing laboratory at yearly intervals.

This meter shall be used to calibrate the heater temperature controller (see Figures 3 and 4). It shall be positioned at a location equivalent to the centre of the specimen face in either orientation during this calibration.

2.1.13.3 Calibration burner

To calibrate the rate of heat release apparatus, a burner is used (see Figures 3 and 4). The burner is constructed from a square-section brass tube with a square orifice covered with wire gauze through which the methane diffuses (see Figure 11). The tube is packed with ceramic fibre to improve uniformity of flow. The calibration burner is suitably connected to a metered supply of methane of at least 99.5% purity.

2.1.13.4 Optical calibration filters

Glass neutral density filters, of at least two different values, accurately calibrated at the laser wavelength of 0.6328 μm are required.

2.1.13.5 Digital data collection

The data collection system used shall have facilities for the recording of the output from the oxygen analyser, the orifice meter, the thermocouples, the load cell, and the smoke measuring system. The data collection system shall have an accuracy corresponding to at least 50 ppm oxygen for the oxygen channel, 0.5°C for the temperature measuring channels, and 0.01% of full-scale instrument output for all other instrument channels. The system shall be capable of recording data for at least 1 h, at intervals not exceeding 5 s.

2.2 TEST SPECIMENS

2.2.1 Product suitability

2.2.1.1 Surface characteristics

A product having one of the following surface characteristics is suitable for testing—

- (a) an essentially flat exposed surface; or
- (b) a surface irregularity which is evenly distributed over the exposed surface provided that—
 - (i) at least 50% of the surface of a representative 100 mm square area lies within a depth of 10 mm from a plane taken across the highest points on the exposed surface; or
 - (ii) for surfaces containing cracks, fissures, or holes not exceeding 8 mm in width or 10 mm in depth, the total area of such cracks, fissures or holes at the surface does not exceed 30% of a representative 100 mm square area of the exposed surface.

NOTE: When the exposed surface does not meet the requirements of either Items (i) or (ii) above, the product may, if practicable, be tested in a modified form complying as nearly as possible with the requirements given in Clause 2.2.1.1. The test report shall state that the product has been tested in a modified form and clearly describe the modification.

2.2.1.2 Asymmetrical products

A product submitted for this test could have faces which differ or could contain laminations of different materials arranged in a different order in relation to the two faces. If either of the faces can be exposed in use, then both faces shall be tested.