

Methods of test for

Inorganic thermal insulating materials

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- British Gas plc
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- Combustion Engineering Association
- Cranfield Institute of Technology
- Department of Health and Social Security
- Department of the Environment (Building Research Establishment)
- Department of Trade and Industry (National Engineering Laboratory)
- Department of Trade and Industry (National Physical Laboratory)
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- Eurisol (UK Mineral Wool Association)
- Gypsum Products Development Association
- Phenolic Foam Manufacturers' Association
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- Royal Institute of British Architects
- Thermal Insulation Manufacturers' and Suppliers' Association (TIMSA)
- Thermal Insulations Contractors' Association
- Water Tube Boiler Group, Power Plant Contractors' Association

The following bodies were also represented in the drafting of the standard, through subcommittees and panels:

- British Rubber Manufacturers' Association
- Calcium Silicate Brick Association Limited
- Institute of Refrigeration
- Institution of Mechanical Engineers
- Yarsley Technical Centre Ltd

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Foreword

This revision of BS 2972 was prepared under the direction of the Refrigeration, Heating and Air Conditioning Standards Policy Committee. It supersedes BS 2972:1975, which is withdrawn.

All the test methods of the 1975 edition have been reviewed. A few remain in their original form, with some minor amendments. The sections on odour, and emissivity of metal foil (sections 13 and 15 in the 1975 edition) have been deleted. The new section 8 gives a test for interlaminar strength. The new section 22 gives a method of test for pH value of a water extract.

Significant modifications have been made to the following sections:

Section 2. Dimensions. Measurement of the deviation from squareness of a board has been added.

Section 3. Bulk density. This now includes a method of test for blown materials.

Section 6. Heat stability. This has been re-written to clarify and improve the test equipment and method.

Section 9. Vibration settlement. Requirements for testing the settlement of blown materials have been added to the high frequency/small amplitude test.

The test for jolting at low frequency/high amplitude has been deleted because it was rarely, if ever, used.

The test for stability under heat and vibration has been deleted pending the development of a more suitable method.

Section 12. Water absorption. A new test method has been added for resistance to capillary absorption.

Section 14. Coarse shot content. A new dry method has been introduced in place of the former wet method, which used a special glass elutriator.

Section 19. Fibre diameter. The method has been revised to facilitate the identification and measurement of fibre diameters.

Section 21. Trace quantities of water-soluble chlorides. The potentiometric titration method, introduced by amendment in 1982, has been deleted and replaced by a polarographic titration method.

It is very important that claims for technical quality of materials should be related to well established methods of test which are based on sound fundamental principles, and the purpose of this standard is to provide details of basic tests for the assessment of a range of properties which are likely to be of value to a potential user. Some of these tests may not be suitable for quick routine control checking; essentially, they should be regarded as the basis for reference purposes in the event of dispute or of doubt concerning the accuracy of such more rapid methods as may be used as a matter of convenience. It is strongly recommended that, where any dispute arises, the methods of this standard only be used.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 56, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

Section 1. General

1 Scope

This British Standard specifies methods of test for inorganic thermal insulating materials, including preformed, plastic composition, flexible and loose-fill materials.

The following methods of test are given.

- Section 2. Dimensions
- Section 3. Bulk density
- Section 4. Thermal properties
- Section 5. Assessment of fire hazard
- Section 6. Heat stability
- Section 7. Resistance to compression
- Section 8. Interlaminar strength
- Section 9. Vibration settlement
- Section 10. Covering capacity
- Section 11. Moisture content
- Section 12. Water absorption
- Section 13. Water vapour permeance
- Section 14. Coarse shot content
- Section 15. Oil content
- Section 16. Organic matter
- Section 17. Air permeability
- Section 18. Flexural strength
- Section 19. Fibre diameter
- Section 20. Electrical conductivity of aqueous extract
- Section 21. Determination of trace quantities of water-soluble chlorides
- Section 22. pH value of water extract

NOTE The titles of publications referred to in this standard are listed on the inside back cover.

2 Definitions

For the purposes of this British Standard the definitions given in BS 874 and BS 3533 apply together with the following.

2.1

wet covering capacity

the wet covering capacity of a plastic composition material is defined as the area covered to a thickness of 25 mm by unit mass of dry composition when the material is mixed with the quantity of water recommended by the manufacturer and applied in accordance with the method given in section 10 (usually expressed as m²/1 000 kg)

2.2

sample

a portion of material or group of units, taken from a large mass or aggregation, which is used to give information as to the quality of the larger quantity. The sample may be "random" or "representative"

generally, samples of preformed and flexible insulation will, of necessity, be random samples while those of insulating aggregates and powders will be representative ones

2.3

random sample

a sample taken without bias, i.e. so that every item has an equal chance of inclusion

2.4

representative sample

a sample in the selection of which planned action is taken to ensure that a specified proportion of its contents is drawn from a different subportion, e.g. case or package, of the whole aggregation. The sampling from within each subportion may, however, be random

2.5

specimen

a suitably sized portion of a sample which is used for a specific test

2.6

coarse shot

non-fibrous material retained on a 250 µm nominal aperture test sieve complying with BS 410

3 Sampling

3.1 General

Although there are well established procedures for the selection of samples for quality control purposes where the units are of similar type, size and shape, such as insulating bricks, it is not practicable to apply such methods to many consignments of insulating materials owing to the very wide variety of types and shapes which may be involved. It is therefore necessary to adapt the method of sampling to the type of product in question.

Sampling becomes difficult when the consignment consists of relatively small quantities of insulating materials of different types and physical properties, and it may be necessary to restrict the size of the samples in such cases to avoid the destructive testing of too large a proportion of each subportion of the consignment.

As a general rule, it is desirable to select the samples from material at the manufacturer's works, but this procedure may not always be appropriate owing to the possibility that the properties of the material can be modified prior to or during application at site.

Plastic composition materials are particularly vulnerable to such modification, if only through the method of application, so that tests at the source of supply may not be a reliable guide to the behaviour of the material during service on the plant.

3.2 Selection of samples

Samples shall be taken only from unbroken packages or from undamaged units and, as far as possible, they are to be representative of each material in the consignment.

Where the consignment comprises more than one type of insulating material and/or more than one thickness or density, each type, each thickness and each density shall be treated as a separate consignment for the purposes of sampling, unless other arrangement is made between the purchaser and the vendor.

Samples of materials consisting of relatively small and similar units, e.g. insulating bricks, shall be obtained by random selection, preferably while the consignment is being unloaded, as it is not practicable to ensure correct sampling from a stock-pile of the units.

Samples of granular, powdered and plastic composition materials shall be prepared by withdrawing material from each container selected for sampling: the material shall be taken after emptying and thoroughly mixing the contents of the container. All the samples of one type (preferably not less than 2 kg total) shall be thoroughly mixed together and gathered into a conical heap which shall then be divided into quarters by vertical cuts. Any two diametrically opposite quarters shall be discarded and the two remaining quarters mixed together and quartered as before. The process of mixing, quartering, discarding and remixing shall be repeated until a sample of size requisite for the tests remains.

When samples are to be drawn from material which has already been applied to a portion of plant, e.g. for bulk density determination on plastic composition or loose-fill insulating materials, care shall be taken to ensure that the portion of material selected is representative of all the material on the plant.

3.3 Size of sample

The sample will vary in size according to the number of tests that are to be carried out, but it should contain a sufficient number of units to permit random selection of specimens for each test.

Although, statistically, the minimum size of sample required is not dependent on the size of the batch being sampled, it is usually convenient to base a sampling schedule to some extent on the size of the consignment. Subject to there being a sufficient number of specimens or bulk of material selected for the tests required, recommendations for sampling are detailed in Table 1.

3.4 Specimens

Specimens which are cut from larger units shall be taken from an inner area of the unit, avoiding the outer edges as far as possible. Unless otherwise specified both original faces of the unit shall be retained in each specimen and not more than one specimen for a given test shall be taken from each unit of the sample.

Table 2 is a guide to the number and size of specimens required for the tests which are described in this standard. Each test is normally carried out three times, and the individual results quoted.

Table 1 — Sample sizes and rates of additional sampling

Material	Minimum size of sample	Rate of additional sampling
Small similar types of units, e.g. insulating bricks and small blocks	10 units	1 unit per 3 000 units above first 30 000 units
Plastic composition, loose-fill granular and powdered materials	2 kg ^a	0.5 kg per 1 000 kg above first 5 000 kg
Other materials	5 units	1 unit per 200 units

^a Taken from a minimum of five containers, where possible.

Table 2 — Size and number of specimens

Section	Test	Material	Size of specimen	Number of specimens
3	Bulk density	Preformed slabs	0.05 m ²	3
		Preformed sections	250 mm long	3
		Plastic composition	0.1 m ² before application	3
			0.013 m ² after application	3
		Flexible	0.1 m ²	3
		Loose-fill	Over 850 µm, 0.007 m ³ Under 850 µm, 0.002 m ³	3 3
		Loose-fill: packing test blown material	0.03 m ³ 0.02 m ³	3 3
4	Thermal conductivity		As required by BS 874	
5	Fire hazard tests to BS 476		As required by BS 476	
	Self heating hazard: hot plate test		Square with sides 300 mm up to 100 mm thick	2
	Self heating hazard: hot bolt test		Square with sides 450 mm over 100 mm thick Square with sides 300 mm and thickness 150 mm	2 4
6	Heat stability		Square with sides 100 mm min.	5
7	Resistance to compression		Square with sides 100 mm min. and not less than twice the thickness of the specimen	5
8	Interlaminar strength		Square with sides 200 mm	5
9	Vibration settlement		900 mm × 600 mm piece or 0.2 m ³ loose-fill	3
10	Covering capacity	Plastic composition	0.004 m ³	3
11	Moisture content		5 g or sufficient to permit determination of 0.5 %	3 (at each required humidity level)
12	Water absorption		150 mm ² × 25 mm (immersion test) 150 mm ² × 50 mm (capillary test)	6 or 9 6
13	Water vapour permeance		See BS 3177	3
14	Coarse shot content		10 g	1
15	Oil content		15 g or multiple thereof	3
16	Organic matter		10 g	3
17	Air permeability	Loose-fill	Approximately 0.004 m ³	3
18	Flexural strength	Preformed	300 mm × 150 mm (not less than 75 mm)	5
19	Fibre diameter		10 g	3 (min.)
20	Electrical conductivity of aqueous extract		5 g	3
21	Trace quantities of water-soluble chlorides		5 g or 20 g according to method	6
22	pH value		2 g	2

Section 2. Dimensions

4 General

Measurements of length, breadth, thickness, squareness and volume are required to check the dimensions of insulating materials supplied both before and after application and also for certain of the test methods specified in this standard.

These dimensions shall be determined as far as possible by the methods specified in this section but where these methods are impracticable, owing to size and nature of the insulating material and other difficulties, other methods may be agreed between the manufacturer and the purchaser.

This section does not attempt to lay down tolerances of manufacture of application; the tolerances quoted are essentially those of measurement only.

5 Measurement before application

5.1 Length and breadth of flat surfaces

5.1.1 Apparatus

5.1.1.1 Steel rule, graduated in millimetres.

5.1.1.2 Tee square

5.1.1.3 Template for cutting test sample, the size of which is dependent on the test for which the sample is to be used.

5.1.1.4 Container of constant cross section throughout its height, to determine the volume of loose-fill materials, the dimensions of which being dependent on the test for which the sample is to be used (see 12.3).

5.1.2 Procedure for materials with clearly defined edges. For rectangular surfaces, lay the material on a flat plane and measure length and breadth by laying a steel rule across the surface parallel to one edge and at right angles to an adjacent edge. Take measurements at three positions on one face for both length and breadth, namely at about 10 mm inwards from each edge and across the centre. Turn the material over and repeat the measurements for the opposite face, in all cases taking measurements to the nearest millimetre.

Record the mean of the six representative measurements as the length and breadth of the material.

For surfaces which are not rectangular, measurements shall be taken as appropriate.

Cut test samples required for other tests in this standard to the specified rectangular size, with square edges, preferably using a template.

5.1.3 Procedure for materials with indeterminate edges. Unpack and unroll materials which are compressed or tightly rolled during transit and allow them to expand freely for 4 h before measuring.

Measure full size material as specified in 5.1.2 as accurately as possible consistent with the nature of the edges. A tee square erected perpendicular to the plane surface and in reasonable contact with the edge of the material may be of assistance in determining the point of reading on the rule. Record the mean of the six respective measurements as the length and breadth of the material.

In the case of long rolls of material, additional measurements of width may be called for and turning the material may be omitted.

Cut test samples under a template and check the bottom face against the template for accuracy of square cut edges. When cutting round the template take care to avoid any extrusion of the material from the edges due to excessive pressure on the template.

Take measurements of length and breadth of the template as in 5.1.2, but on one face only, and consider these measurements to be those of the sample.

5.1.4 Procedure for loose-fill materials.

Measurements of material as delivered are not relevant. In the case of test samples, the length and breadth of the material correspond to the internal dimensions of the container used in the test. Measure the internal length and breadth of the container and record the measurements taken. Measure the position where the insulating material is levelled off and record the depth of material in the container.

5.2 Thickness of flat surfaces

5.2.1 Methods of measurement. Four methods are available for use in determining thickness. These are detailed in 5.2.3 to 5.2.6 and their applicability with respect to different types of material is given in Table 3.

NOTE These methods may be varied by agreement between the user and the supplier in such details as the mass of the plate in 5.2.3 or the load on the plate in 5.2.6.

5.2.2 Apparatus

5.2.2.1 Steel rule, graduated in millimetres.

5.2.2.2 Thickness gauge, as shown in Figure 1 (for use with the method given in 5.2.3). The apparatus comprises three parts: a probe, a collar and a 200 mm × 200 mm plate. The mass of the plate and the collar together shall be such as to exert a pressure of 30 N/m², i.e. 122 ± 1 g.

NOTE This can be achieved by making the plate from 3 mm acrylic sheet and the collar of aluminium, as detailed in Figure 1. The plate may be made from other materials provided that it is rigid and presents a flat, smooth, continuous surface to the insulation.

5.2.2.3 Straightedge (for use with methods given in 5.2.4 and 5.2.6).

5.2.2.4 Callipers (for use with the methods given in 5.2.5 and 5.2.6).

Table 3 — Methods of thickness measurement

BS number	Type of material	Method to be used	Notes
BS 3958-1	Magnesia: flat slabs curved surfaces	5.2.4 or 5.2.5 5.2.5	Facing materials shall not be disturbed. Sample size to be the same as plate
BS 3958-2	Calcium silicate: flat slabs curved surfaces	5.2.4 or 5.2.5 5.2.5	
BS 3958-3	Metal mesh faced man-made mineral fibre mattresses	5.2.6	
BS 3958-4	Bonded preformed man-made mineral fibre pipe sections	5.2.3	
BS 3958-5	Bonded man-made mineral fibre slabs	5.2.3, 5.2.4 or 5.2.5	
BS 5803-1	Man-made mineral fibre mats Compressible sheet materials	5.2.3 5.2.3	Material shall be allowed to expand freely for 4 h after unpacking or unrolling. Test area shall be not less than 400 mm × 400 mm
	Enclosed loose-fill materials	5.2.6	Enclosing material shall not be disturbed
	All materials after application in even layers, including unenclosed loose-fill materials	5.2.3	

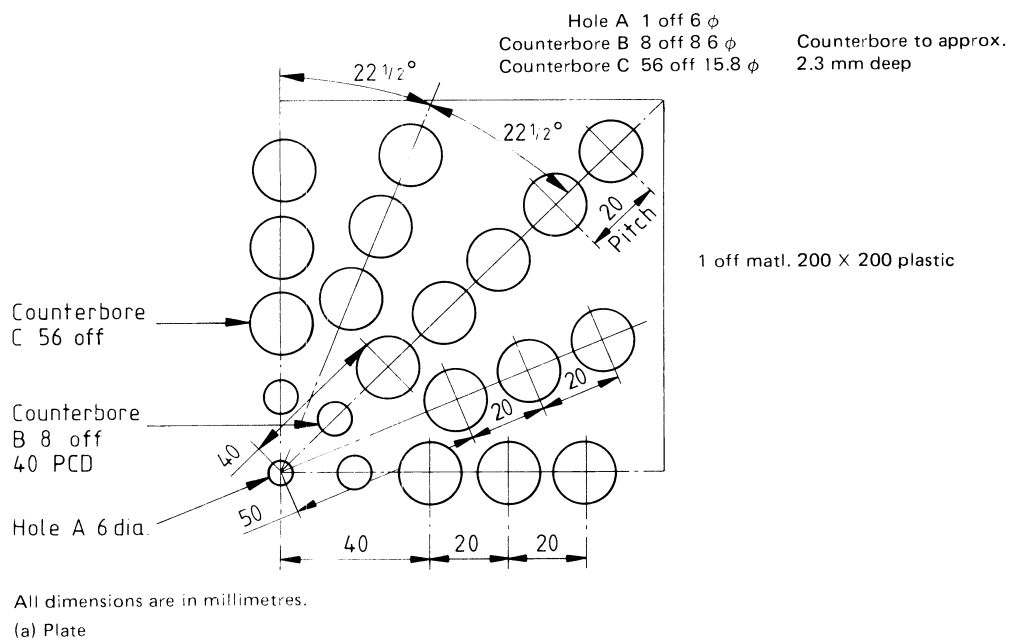
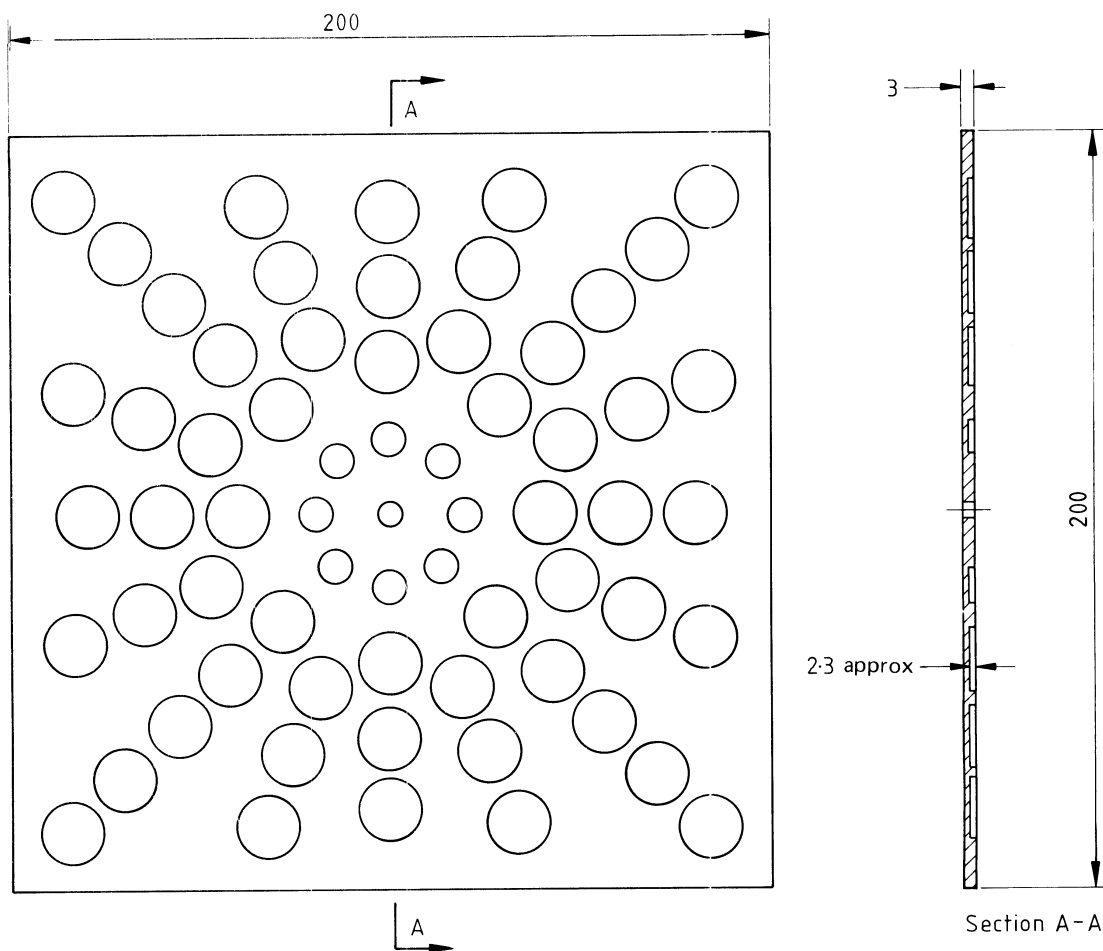
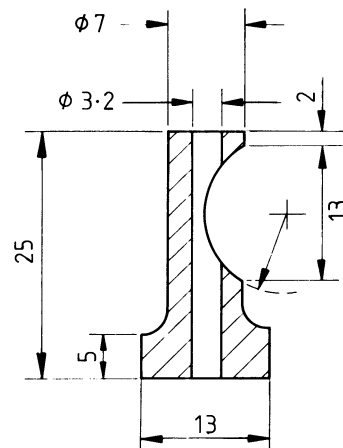
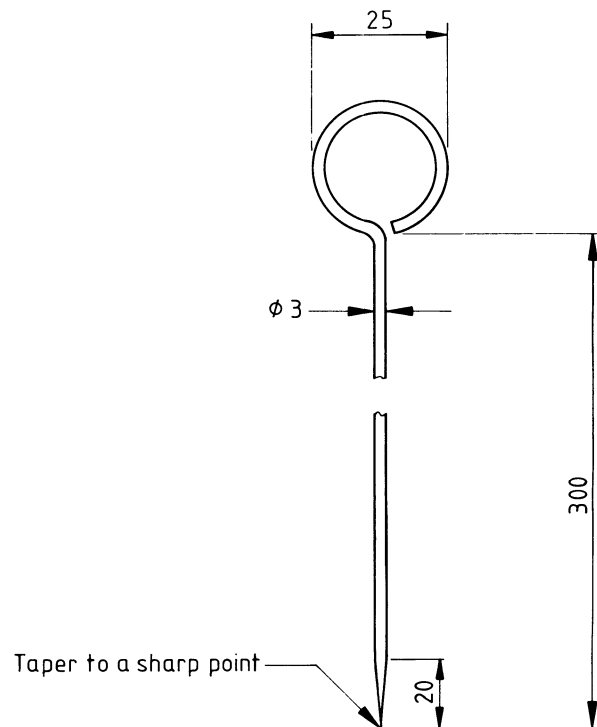


Figure 1 — Thickness gauge (continued)



NOTE. Radius for thumb-hold should extend to centre line of hole.



All dimensions are in millimetres.

(b) Collar and probe

Figure 1 — Thickness gauge (concluded)

5.2.2.5 Weighted plate (for use with the method given in 5.2.6).

5.2.3 30 N/m² method. Place the sample (not less than 400 mm × 400 mm) on a plane, hard surface and lay the plate centrally on the upper surface of the insulating material. Insert the probe with the sliding collar through the hole in the centre of the plate and push through the insulating material, normal to the principle surface, until its point touches but does not penetrate the underlying plane surface. Hold the collar firmly to the probe by pressure of the thumb in the position where it just touches the upper surface of the plate and, after withdrawal, measure the distance between the point of the probe and the underside of the collar to the nearest millimetre by means of a suitable rule. Record the thickness of the material as this measurement minus the thickness of the plate.

5.2.4 Straightedge method. Place the sample on a plane surface and lay a straightedge across the face of the material in three positions parallel to one edge of the material and at distances from the edge of one-sixth, half and five-sixths of the length of the adjacent edge. Determine the thickness by measuring with a steel rule the distance between the plane surface and the straightedge at both edges of the slab. Repeat measurements for the three positions of the straightedge at right angles to the initial set. Read measurements to the nearest millimetre and record the thickness as the mean of the 12 measurements.

5.2.5 Calliper method. Rule the sample of material into nine rectangles of equal area. Apply callipers at the centre of each area, taking care not to penetrate the surfaces. Take measurements to the nearest millimetre and record the thickness as the mean of nine measurements.

5.2.6 Weighted plate method. Place the specimen on a plane surface and subject it to a pressure of 725 N/m². A flat, stiff plate measuring at least 200 mm × 200 mm may be used for this. The specimen size is to be the same as the plate size. Determine the combined thickness of the specimen and plate by the use of a straightedge (see 5.2.4). Determine the thickness of the plate by callipers (see 5.2.5) and record the thickness as the difference between these two measurements.

NOTE A plate measuring 200 mm × 200 mm and weighing or loaded to weigh 2.96 kg exerts a pressure of 725 N/m². The methods appropriate to the different types of material are listed in Table 3.

When the thickness of an insulating material after application in an uneven layer (e.g. plastic compositions “finger-marked”) is to be determined and it cannot be measured by any of the methods described in 5.2 the methods described in 6.2.2 and 6.5.2 shall be used.

5.3 Volume of a flat shape

Calculate and record the volume from the significant length, breadth and thickness measurements obtained as in 5.1 and 5.2.

5.4 Deviation from square of a board

5.4.1 General. Methods are given for the determination of the deviation from square for the thickness, width and length of boards that are nominally square.

5.4.2 Apparatus

5.4.2.1 Steel square, with limbs of at least 500 mm in length.

5.4.2.2 Steel tape or ruler, graduated in millimetres.

5.4.3 Specimen. The specimen under test shall be a full board laid on a flat surface.

5.4.4 Thickness deviation. Place steel square with limbs longer than the board thickness on the flat surface against one end of the board as shown in Figure 2(a). Using a steel tape or ruler, take measurements to the nearest millimetre around the edge corners of the board.

The deviation from square is the distance between the edge corner of the board and the edge of the steel square at the point of greatest deviation (A).

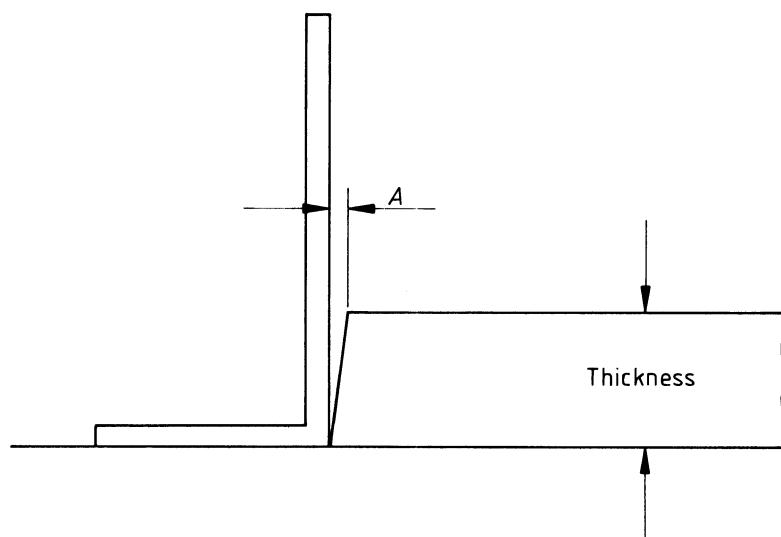
Report the deviation in millimetres.

5.4.5 Width or length deviation. Place a steel square along one of the parallel sides of the insulation with the right angle of the square aligned against the adjoining edge as in Figure 2(b). Using a steel tape or ruler measure the distance (C) between the edge of the board and the edge of the square at each corner and determine the greatest deviation (C). B is the distance over which the deviation is measured [see Figure 2(b)].

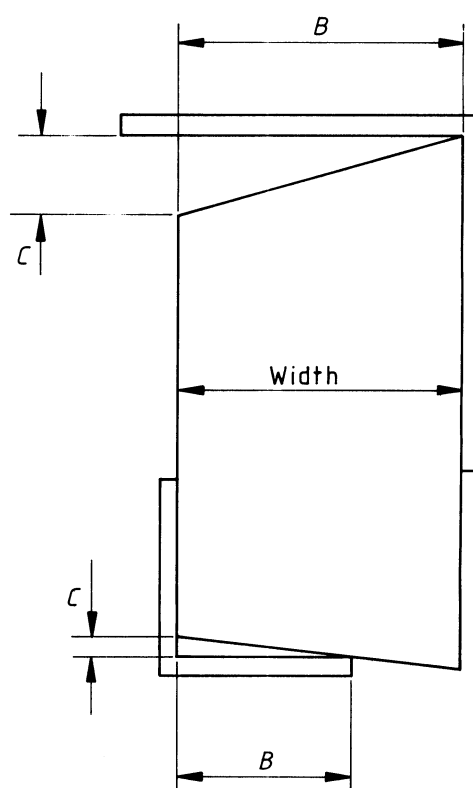
Calculate and report the deviation from square as millimetres gap per 100 mm of width or length.

5.5 Length and circumference of curved shapes

5.5.1 General. This sub-clause applies to materials of regular curvature in one direction only, this curvature being built into the material so that before application it conforms without change of shape to the surface it is intended to fit, e.g. circular, semi-circular and segmental pipe sections, radiused and bevelled lags. It does not apply to flexible shapes which when not applied will lie flat, or to special shapes such as hemispheres, domes or dished shapes etc.



(a) Thickness deviation



(b) Width or length deviation

Figure 2 — Determination of deviation from square of a board

5.5.2 Length. Take length measurements along the straight dimension by laying a steel rule along this direction at four positions equally spaced around the outside circumference in the case of completely circular sections, and at two positions for each semi-circular or segmental section or lag, or similar. Repeat the measurements for the inner surface, i.e. inside the bore of the section or on the other face of the lag. Read measurements to the nearest millimetre and record the length as the mean of the measurements taken.

5.5.2 Circumference or breadth. Measure the circumference, part circumference or breadth by laying a flexible steel rule in close contact with the surface. Take measurements at three positions on the external face and three positions on the internal face, namely, at about 10 mm inwards from each end and in the centre. In the case of completely circular sections the internal centre measurement may be omitted. Read measurements to the nearest millimetre. Record the mean of the external measurements as the breadth or circumference over the external curved surface and the mean of the internal measurements as the breadth or circumference over the internal curved surface.

5.6 Thickness of a curved shape

Thickness should preferably be measured by means of a probe and collar, (see 5.2.2.2 and Figure 1). Fit the material over a hard surface of radius equal to or less than the internal radius of the material and push the probe radially through the insulation from the external surface until the point is in contact with the hard surface lining held in close contact with the internal surface of the insulation. Measure the thickness from the probe setting as in 5.2.3.

Divide the material along its length into three equal distances and take thickness measurements to the nearest millimetre at the centre of each division at three positions equidistant around the circumference or part circumference.

Record the thickness as the mean of the measurements taken.

Thickness shall not, unless required otherwise, include the thickness of any external covering.

Alternatively, take thickness measurements by means of suitable callipers at positions outlined above. Where measurements at the centre are not possible due to the length of the calliper arms other positions may be chosen.

5.7 Volume of a curved shape

Calculate and record the volume as the product of the mean length, the mean of the breadth of the internal and external curved surfaces, and the thickness, as measured in 5.5 and 5.6.

6 Measurement after application

6.1 Length and breadth on flat surfaces

Measurement of length and breadth after application is not normally required in situ (except as indicated below). If specimens can be removed, the length and breadth can be measured by any of the methods outlined in 5.1.

The process of removal may result in a break-up of the specimen, preventing length and breadth measurement after removal. In this case, mark off the applied material into an area not less than 0.1 m² before removal, the developed area being as far as possible rectangular and of sides as far as possible dimensionally similar. Measure the length and breadth between the markings by means of a steel rule as in 5.1.2, but on one face (i.e. exposed insulation face) only. Record the length and breadth as the mean of these three respective measurements.

If it is not found possible to remove the marked area accurately trim the sides until an approximately rectangular hole is obtained and the length and breadth of the hole measured as above.

6.2 Thickness on flat surfaces

6.2.1 Even layers. Where the surface is sufficiently uniform, thickness shall be measured by means of a probe and collar as specified in 5.2.2.2. Insert the probe from the outer face only and record the thickness as the mean of the nine measurements.

6.2.2 Uneven layers. When the applied insulating material has an uneven surface, its thickness cannot be satisfactorily measured by the methods already described. The most usual example of this is when plastic composition is left "finger-marked" ready for the addition of a layer of some different material. In such cases determine the average thickness by measuring in situ the length and breadth of a marked off area of minimum 0.1 m², then carefully remove all the material in this area and weigh the material removed. The bulk density of the material is determined as in section 3 and the average thickness calculated from the following equation:

$$L = \frac{1000 m}{\rho A}$$

where

- L is the average insulation thickness (in mm);
- m is the mass of insulation removed (in kg);
- ρ is the bulk density of insulation (in kg/m³);
- A is the area of insulation removed (in m²).

6.3 Volume applied on flat surfaces

The volume shall be recorded as the product of the mean length, breadth and thickness as measured in 6.1 and 6.2 above.

6.4 Length and circumference on curved surfaces

Measurement of length and circumference after application is not normally required in situ (except for plastic composition). Test specimens can be removed and length and circumference measured by the methods outlined in 5.5.

For materials of uneven surface an area shall be marked off in situ and measured as in 6.1.

6.5 Thickness on curved surfaces

6.5.1 Even layers. Where the surface is sufficiently uniform, thickness shall be measured by means of a probe and collar as detailed in 5.2.2.2.

6.5.2 Uneven layers. For materials of uneven surface, the method given in 6.2.2 shall be adopted. The formula to be used for evaluation of thickness will depend on the degree of curvature and the thickness.

If the external circumference of the insulation in relation to the nominal thickness exceeds the values shown in column 1, Table 4, the surface may be regarded as flat and the formula in 6.2.2 used.

If the circumference is less than the value given in column 1 of Table 4, but exceeds the values in column 2, the appropriate equation is:

$$L = L_1 + \frac{\pi L_1^2}{C_2 - 2\pi L_1}$$

where

L is the average insulation thickness (in mm);

L_1 is $\frac{1000 m}{\rho A}$ (see 6.2.2);

C_2 is the circumference over insulation (in mm).

If the circumference is less than the values given in column 2, the insulation shall be completely removed from a 250 mm straight length of pipe (in this case ignoring the minimum 0.1 m² area earlier specified) and the following equation used:

$$L = \sqrt{\frac{(C_1^2 + (16 \times 10^6 \pi m/\rho)) - C_1}{2\pi}}$$

where C_1 is the external circumference of the pipe (in mm).

For curved surfaces in those cases where it is not possible to measure the internal circumference of the material, it shall be permissible to estimate this dimension from knowledge of the dimensions of the apparatus on which the insulation is applied.

6.6 Volume applied on curved surfaces

The volume shall be recorded as the product of the mean length, the mean of the breadth of the internal and external curved surfaces, and the thickness.

7 Weighing

Weighing shall be done on scales of sufficient capacity and sensitivity to weigh the test specimens to an accuracy of $\pm 0.5\%$. Unless specified otherwise, the result shall be recorded in kilograms.

Table 4 — Calculation of insulation thickness

Nominal thickness	External circumference of insulation	
	Column 1	Column 2
mm	m	m
up to 25	1.2	0.3
over 25 up to and including 50	5	0.75
over 50 up to and including 75	12	1.2
over 75 up to and including 100	20	1.7
over 100 up to and including 125	32	2.1
over 125 up to and including 150	45	2.7

Section 3. Bulk density

8 General

Methods are given for determining the bulk density of:

- a) preformed materials;
- b) plastic composition materials;
- c) flexible materials;
- d) loose-fill materials;
- e) blown materials.

Some insulating materials may be provided in composite form with a surface finish or protective covering which is substantially different in composition from that of the insulating material itself. Thus, it is common practice for flexible materials to be enclosed in galvanized wire netting, expanded metal, cloth etc., while flexible or preformed insulating materials may have a surface finish of man-made mineral fibre tissue, board or sheet material to facilitate handling or to provide an abrasion resisting surface. Normally, the contribution of this surface sheet to the thermal characteristics of the insulating material is negligible. Its mass shall therefore be omitted from bulk density figures referring to the insulating material.

Alternatively it may be desirable to know the total mass of the complete assembly of insulating material together with the surface finish; this shall be given in terms of mass per square metre or, for pipe insulation, mass per linear metre, as a supplementary figure to the bulk density of the insulating material alone and such a figure shall be accompanied by the corresponding total thickness of the composite insulation.

The test for bulk density shall be carried out on the material as ready for application in the case of preformed and flexible materials. It is recommended that the packing density of loose-fill materials be determined after application and bulk density of blown materials determined after the material has been blown through a suitable blowing unit. In the case of plastic composition materials, the test shall be carried out on the material after mixing the water, applying either to a test plate or to a portion of the plant, and drying. The amount of water used for mixing shall be noted as a percentage of the weight of the material.

Where required by the purchaser or supplier, the moisture content at the time of test shall be stated (see section 11).

In every case, three specimens shall be tested and the result expressed as the average of three tests.

The test for bulk density involves two types of measurement:

- a) measurement of volume, as determined by direct measurement of length, width and thickness;
- b) determination of mass.

9 Preformed materials

9.1 Specimens

Flat specimens should be not less than 0.05 m² in area or, failing this, the largest size available. Pipe sections shall be not less than 250 mm in length.

9.2 Determination of dimensions

Each sample shall be measured by the methods specified in section 2.

9.3 Calculation of results

The bulk density (ρ) in kg/m³ shall be calculated from the equation.

- a) For flat specimens

$$\rho = \frac{m}{a b L}$$

where

- m is the mass of test specimen (in kg);
- a is the length of specimen (in m);
- b is the width of specimen (in m);
- L is the thickness of specimen (in m).

- b) For pipe sections (complete cylinder):

$$\rho = \frac{2 m}{\pi a L (d_1 + d_2)}$$

where

- m is the mass of specimen (in kg);
- a is the length of specimen (in m);
- L is the thickness = $\frac{1}{2} (d_2 - d_1)$, (in m);
- d_1 is the internal diameter (in m);
- d_2 is the external diameter (in m).

9.4 Expression of results

The results of the test shall be expressed in kg/m³. If required, the moisture content shall be given as a percentage of the dry mass.

10 Plastic composition materials

10.1 Determination for manufacturer's declared value

For the purposes of determining bulk density in connection with the manufacturer's declared value, the specimens shall be prepared as given in section 10. The bulk density shall be determined substantially as given in clause 9, the linear dimensions of the dried sample being measured as in section 2, and the result shall be given to the nearest 10 kg/m³.

10.2 Determination after application

For the purposes of determining the bulk density of material which has been applied to portions of a plant and dried in situ, one of the following methods shall be adopted.

- a) Where the material is conveniently removable in sufficiently large specimens, remove a piece and determine its mass and volume after smoothing such faces as may be necessary to permit measurement of volume. The size of the specimen shall be not less than 0.01 m².
- b) Where the material cannot be removed in pieces which are sufficiently large for measurement of volume, determine the linear dimensions in situ.

First, smooth at least 0.05 m² of the outer surface of the material on the plant (or 250 mm lengths in the case of pipes) as necessary to remove any irregularities such as finger marks. Measure the thickness of insulating material either by means of a probe or, in the case of cylindrical surfaces, by circumferential measurement. Remove the insulating material entirely from the surface of the plant, taking care to avoid loss, and weigh. Determine the appropriate volume by measuring the area of the surface of the plant from which the insulation has been removed, in relation to the previously determined thickness of insulating material.

10.3 Expression of results

The results of the test shall be expressed in kg/m³. If required, the moisture content shall be given as a percentage of the dry mass.

11 Flexible materials

11.1 Specimens

The specimens shall be not less than 0.1 m².

11.2 Determination of dimensions

Each sample shall be measured by the methods specified in section 2.

11.3 Calculation of results

The bulk density shall be calculated in accordance with the appropriate formula as given in 9.3 and, unless measurements of thickness have been made, shall be expressed as the bulk density at the nominal thickness. The nominal thickness shall be that quoted by the manufacturer as relating to the particular material supplied and this figure shall be used for dimension *L* in the appropriate formula given in 9.3.

11.4 Expression of results

The results of the test shall be expressed in kg/m³ (based on the nominal thickness, where applicable). If required, the moisture content shall be given as a percentage of the dry mass.

12 Loose fill materials

12.1 General

For the purposes of this standard, loose-fill insulating materials are divided into two classes: powdered or granular, and fibrous. It should be recognized, however, that this division is not well defined, since the different types of material overlap and can in fact be used when mixed together. Further difficulty arises from the fact that nearly all loose-fill materials may be subjected, intentionally or otherwise, to compression or settlement in use. The practical performance of insulation is more directly linked with the bulk density of the loose-fill material after application, but for some purposes it may be necessary to determine the bulk density before application or to prepare a specimen having some specified bulk density.

Furthermore, the bulk density of many powdered and granular materials is not a uniquely defined property, but will depend on the history of the material. A test for determining the bulk density under specified conditions is given in 12.3 but it should be recognized that the value given by this test will not necessarily represent the bulk density which may be obtained in any particular application.

For methods of measuring bulk density after vibration, see section 9.

12.2 Measurements of bulk density of powdered, granular and fibrous loose-fill materials after application

No satisfactory test exists for measuring the bulk density of loose-fill materials after application. The following observations may give some guidance to suitable methods of approach to the problem.

The average bulk density may be deduced from the total volume of a section of insulation and the mass of insulating material that has been put into it. This may be misleading since it takes no account of possible variations in the degree of compression throughout the section. It is therefore desirable to test at a number of points in a given section of insulation. If this is done after the installation has been completed, as is preferable, it is generally necessary to remove part of the containing structure, such as a panel, so that the insulation from a measurable volume can be removed and weighed.

The procedure for removing the insulation, and the accuracy with which the volume of space from which it is removed can be determined, depend upon the nature of the material and upon the site. A coherent powder can fairly easily be divided from the surrounding material and removed without disturbing the latter. Fibrous materials are not so easily separated and therefore reasonably large amounts should be removed so as to reduce the ratio of edge to area. The controlled removal of freely flowing granules from a vertical cavity is likely to be difficult and their subsequent replacement may be impracticable.

If access can be gained to a horizontal space, however, it may be possible to press into the material a light sheet metal frame from within which the granules can be removed. Variations of the above methods should be devised to suit the particular material and site.

If it is impracticable to test after the insulation is complete, the less desirable course may be adopted of removing samples of material as the work proceeds. The general principles are much the same as those outlined in the preceding paragraph.

12.3 Bulk density of powdered and granular materials before application

12.3.1 Indication of bulk density. An indication of the bulk density of the material may be obtained by using one of the procedures given in 12.3.2, 12.3.3 or 12.3.5.

12.3.2 Material passing an 850 μm nominal aperture BS 410 test sieve

12.3.2.1 Apparatus

12.3.2.1.1 Measuring cylinder of 25 mL capacity.

12.3.2.1.2 Apparatus which can raise the cylinder through a distance of 5 mm by means of a cam (see Figure 3).

12.3.2.1.3 A means of weighing the sample.

12.3.2.2 Procedure. Mount the measuring cylinder on the table of the apparatus, fill to the 25 mL mark, drop ten times at 5 s intervals and determine the level of the powder. Weigh the powder.

12.3.3 Other materials

12.3.3.1 Apparatus

12.3.3.1.1 Box, 200 mm $\times$ 200 mm $\times$ 250 mm high.

12.3.3.1.2 Straightedge

12.3.3.1.3 Means of weighing the sample.

12.3.3.2 Procedure. Fill the box by allowing the material to fall evenly and loosely into it from a height of 150 mm above the upper edge. When the container is full, smooth the surface off with a straightedge and drop the box ten times from a distance of 25 mm onto a hard surface. Determine the level of the upper surface of the material below the edge. Weigh the contents of the box.

12.3.4 Expression of results. The results of the tests carried out in 12.3.2 and 12.3.3 shall be expressed in kg/m^3 . If required, the moisture content shall be given as a percentage of the dry mass.

12.3.5 Determination of the loose bulk density and the bulk density

12.3.5.1 General. The object of the test given in 12.3.5.3 is to determine the loose bulk density of the insulating material and also the bulk density after a specified regime of compaction. It is applicable to powders and granular materials.

12.3.5.2 Apparatus

12.3.5.2.1 500 mL graduated plastics measuring cylinder of known mass.

12.3.5.2.2 The apparatus shown in Figure 4. This is provided with a platform which can be raised 19 mm by a motorized cam and then allowed to fall onto a 6.3 mm thick pad of flexible closed pore expanded PVC (not shown in Figure 4). The cam is driven at 15 ± 1 r/min by a geared induction motor.

12.3.5.2.3 Means of weighing the sample.

12.3.5.3 Procedure. Using a scoop, transfer material from a coned sample, tipped from its packed or other container, into a cylinder held at approximately 45° to the vertical which is slowly rotated. Fill the cylinder to the 500 mL mark, weigh the cylinder and its contents and determine the mass of the specimen, m (in kg) by deducting the weight of the cylinder.

Place the cylinder and contents onto the platform of the apparatus, close the cover plate by means of the wing nuts and run the motor of the apparatus for a specified time, (e.g. for 20 min or until no further settling appears), after which read the new (compacted) volume, V (in litres) of the specimen from the cylinder graduations.