DRAFT TANZANIA STANDARD

High Heat Duty Fireclay Refractories- Specification

TANZANIA BUREAU OF STANDARDS

1st Edition

0 National Foreword

The Tanzania Bureau of standards is the statutory national standards body for Tanzania, established under the act.No.3 of 1975, amended by act.No.2 of 2009.

This draft Tanzania Standard is being prepared by BCDC 2 Masonry Technical Committee under the supervision of the Building and Construction Divisional Standards committee (BCDC).

In the preparation of this draft Tanzania Standard, reference was made to ***IS 8:1994 (Reaffirmed 2001) High heat duty fireclay refractories-specification (fifth revision), published by Bureau of Indian Standard.***

1 Scope

This draft Tanzania Standard covers the requirements and test methods for two types of high heat duty burnt fireclay refractories for general purposes.

2 Supply of materials

3.1 General requirements relating to the supply of high heat duty fireclay refractories shall be as laid down in IS 1387: 1993.

3.2 The refractories shall be compact, of homogeneous texture and free from cracks, voids and other flaws. They shall be burnt evenly throughout, shall have no soft corners and have sufficient mechanical strength.

3 Types

High heat duty fireclay refractories shall be of the following two types:

Type 1 - Suitable for general applications, and

Type 2 - Suitable for more critical applications.

4 Chemical composition

5.1 The alumina content of both Type 1 and Type 2 refractories when determined in accordance with the methods given in IS 1527: 1972 or 1335: 1979 shall be not less than 38 percent.

5.2 Provided that such of the physical properties like refractoriness under load and linear changes after reheating which are considered essential for the particular service conditions are satisfactory, the stipulation regarding alumina content may be waived subject to the agreement between the purchaser and the manufacturer for both Type 1 and Type 2 refractories.

5 Physical test requirements

High heat duty fireclay refractories shall conform to the requirements given in Table 1 when tested in accordance with the test methods specified in **Annex A to F**.

Table-1 Physical test requirements

SI No.	Characteristics	Requirements		Test Methods
		Type 1	Type 2	
i)	Apparent porosity percent, Max	25 27 (for hand moulded shapes)	23 25 (for hand moulded shapes)	ANNEX A
ii)	Cold crushing strength, MPa, Min	20 15 (for hand moulded shapes)	25 20 (for hand moulded shapes	ANNEX B
iii)	Pyrometric cone equivalent standard cone (ASTM) No., Min	32	32	ANNEX C
iv)	Refractoriness under load temperature ^{o}C, Min	1400	1425	ANNEX D
v)	Permanent linear change after heating fat 1450 ^{o}C for 2 h, percent, Max	±1.5	±1.0	ANNEX E
vi)	Spalling resistance	Subject to mutual agreement	Subject to mutual agreement	ANNEX F

6 Tolerance on size

7.1 Variation from specified dimensions, covering both warpage and shrinkage, shall be allowed to the extent of ±2 percent or ±1 mm whichever is greater for Type 1 refractories and ±1 percent or ±1 mm whichever is greater for Type 2 refractories.

7.2 The size tolerance for hand moulded shape shall be subject to mutual agreement between the purchaser and the manufacturer.

7 Sampling

Representative samples shall be drawn according to the scheme of sampling given IS 1528 (Part 7): 1974 for carrying out test specified in standard.

8 Marking

Each refractory brick or shape shall be indelibly marked manufacturer's name or trade mark.

ANNEX A

METHOD FOR DETERMINATION OF APPARENT POROSITY

A.1 Principle

A.1.1 The following are determined by weighing:

- The mass of a dry test piece;
- Its apparent mass when immersed in a liquid with which it has been impregnated under vacuum
- Its mass in air while still soaked with the liquid.

A.1.2 the precision of the results does not require any correction to be made for the fact weighing are carried out in air, not in a vacuum.

A.2 Apparatus and materials

A.2.1 Drying oven, capable of being controlled at 110 ^{O}C ± 5 ^{O}C.

NOTE—A fan-assisted oven with ventilation would assist in attaining an even temperature distribution and efficient drying of the test pieces

A.2.2 Balance, with an accuracy of ±0.01g that can be arranged so that test pieces can be suspended in the immersion liquid (see Figure A.1)

A.2.3 Beakers, of a suitable size for containing the samples during soaking (see **C.3.2**) and when determining the apparent immersed mass (see **C.3.3**).

A.2.4 Evacuating equipment, capable of reducing the absolute pressure to a value not greater than 2500Pa (0.025 bar) and a means of measuring the pressure used (see Figure 1).

A.2.5 Thermometer, accurate to ±1 ^{O}C.

A.2.6 Immersion liquid: For materials that do not react with water, the immersion liquid may be cold distilled water. For materials that are sensitive to contact with water, a suitable organic liquid shall be used. The immersion liquid shall not fractionate at a pressure above the absolute pressure attained in the test.

NOTE-Distilled may be used for hydratable materials.

A.2.7 Desiccator

A.2.8 Number and shape of test pieces

A.2.9 The number of items (for example, bricks, shapes, nozzles) to be tested shall be determined by agreement between the interested parties.

A.2.10 The number of test pieces to be tested per item shall be agreed between the parties; it shall be stated in the test report. If the test pieces are cut out of bricks or blocks, the same number shall be cut from each one, in order to facilitate statistical analysis,

A.2.11 Test pieces shall be cutting the form of prisms or cylinders, the bulk volume of a test piece shall be not less than 50cm^3, and shall be not more than 200cm^3. The ratio of the longest to the shortest dimension of a test piece shall not exceed 2:1.

NOTES

1 Where it is not possible to obtain the given size and volume from the item, test piece so for the other dimensions and volume may be used by agreement between parties, and are to be reported.

2 If test pieces are to be cut from an item in which variations in density could occur, the position of the test pieces should be agreed between parties and stated in the report.

A.2.12 Any test piece showing cracks shall be eliminated, since these might falsify the determination of the bulk volume.

A.3 Procedure

A.3.1 Determination of mass of dry test piece (m_1)

See Figure 2.

Dry the test piece at 11O°C ± 15 ^{O}C to constant mass, i.e., until two successive weighing made before and after at least 2h in the oven (5.1) do not differ by more than 0.1%. Before each weighing, place the test piece in a desiccator (**A.2.7**) until it has cooled to room temperature. Weigh each test piece to the nearest 0.01g. The mass determined is the mass of the dry test piece (m_1).

A.3.2 Soaking of test piece

Carry out a check test to ensure that the apparatus will hold a vacuum. Place the cooled and dried test piece in an air-tight vessel. After sealing the vessel, evacuate it until a pressure of not more than 2500Pa is attained; maintain this vacuum for at least 15min. In order to ensure that all the air has been removed from the open pores, isolate or disconnect the vessel from the vacuum pump (**A.2.4**) and check that pressure does not rise through any de-gassing of the test piece. Re-connect the vessel to the vacuum pump and progressively introduce the immersion liquid (**A.2.6**) so that, after 3 min, the test piece is covered by about 20 mm of liquid. Maintain this reduced pressure for 30 min, then switch off the pump and open the vessel. Wait a further 30 min to ensure that the liquid penetrates into all the open pores. The test piece or test pieces shall remain covered by the immersion liquid throughout the impregnation and until removed for subsequent weighing (see **A.3.3** and **A.3.4**).

NOTE – certain fine porosity materials such as refractories containing carbon and some clay products may require longer periods of evacuation and soaking. If a different soaking time is used this time should be stated in the report.

A.3.3 Determination of apparent mass of immersed test piece (m_2)

See Figure 2.

Suspend the test piece by a thin thread from the load-pan suspension point of a balance (**A.2.2**) and weight while completely immersed in a quantity of the immersion liquid, contained in a beaker (**A.2.3**) standing on the bridge, if used. In this way, the apparent mass of the immersed test piece is obtained (m_2). The weighing shall be made to the nearest 0.01g Determine the temperature of the immersion liquid to an accuracy of ±1 ^{O}C.

A.3.4 Determination of mass of soaked test piece (m_3)

Remove the test piece from the liquid and immediately sponge it quickly and carefully with a damp sponge or cloth to remove droplets and the surface film of liquid. Be sure not to draw liquid out of any of the pores.

NOTE—Consistent results have been obtained by keeping- for this purpose alone-linen cloth which, having been washed two or three times when new to remove the dressing, is immersed in the immersion liquid and lightly wrung out by hand before each use.

Immediately weigh the test piece in air to the nearest 0.01g. Take care to ensure that evaporation of the immersion liquid does not lead to any appreciable loss in mass during the weighing operation. In this way, the mass of the soaked test piece is obtained (m_3).

A.4 Expression of results.

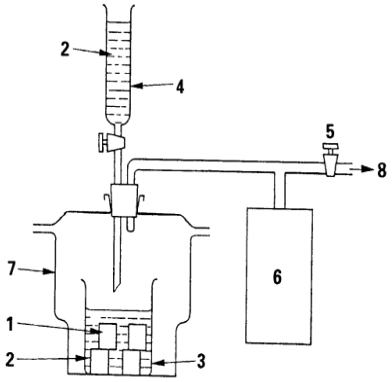
A.4.1 The apparent porosity π_a expressed as a percentage by volume, is given by equation.

$$\pi_a = \frac{M3-M1}{M3-M2} X\ 100$$

A.4.2 Test report

The test report shall include the following information:

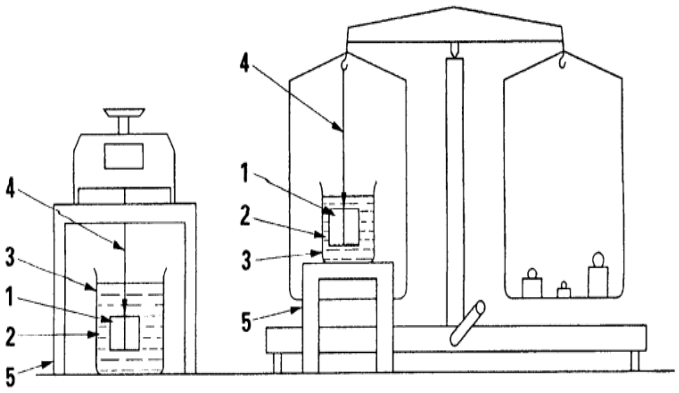
a) The name of testing establishment;
b) The date of the test;
c) The reference to this international standard, i.e., determined in accordance with ISO 5017:1998;
d) The description of the test material (manufacturer, type, batch number);
e) The number of items tested;
f) The number of test pieces per item and if relevant their position;
g) The pressure to which the vacuum chamber was reduced;
h) The immersion liquid used;
i) The individual value and the mean value of the apparent porosity for each item



Key

1 Test pieces
2 Immersion liquid
3 Beaker
4 Tap funnels
5 Pump isolation
6 Pump isolation valves
7 Pressure measuring device (e.g, manometer)
8 Desiccator Air outlet (to vacuum pump)

Figure 1 — Example of a vacuum system for soaking test pieces



Key
1 Test piece
2 Immersion liquid
3 Beaker
4 Suspension thread
5 Bridge

Figure 2 — Arrangement for the determination of apparent mass of immersed test piece using single- and double-pan balances

ANNEX B
(Informative)

DETERMINATION OF COLD CRUSHING STRENGTH

B.1 Principle
At ambient temperature, a test piece of specified dimensions is subjected, in a compression test machine, to an increasing load until either the test piece collapses or its height is reduced to 90% of its original value. During testing, the load is increased at a specified rate. The cold crushing strength is calculated from the maximum force recorded and the dimensions of the test piece.

B.2 Apparatus

B.2.1 Mechanical or hydraulic crushing strength machine, that will enable the load to be increased progressively and smoothly, and with a system of measurement that will enable the force exerted on the test piece to be known to within 2%. The range of the machine shall be such that the maximum force exerted in the test is greater than 10% of the maximum force of which the machine is capable. One of the platens of the machine shall be mounted on a spherical seating that will compensate for any small error of parallelism between the load-bearing faces of the test pieces. The platens of the machine shall be ground and the lower one shall be marked so as to facilitate placing the test piece at its centre. (See Figure 3.)

B.2.2 Micrometer, or other suitable instrument, to measure the deformation of the test piece during the test.
B.2.3 Measuring equipment, accurate to 0.1 mm, to measure the size of each test piece and to verify its geometrical form.
B.2.4 Drying oven, capable of being controlled at 110 ^{O}C ±5 ^{O}C

B.2.5 Steel rule.

B.2.6 0.5mm feeler gauge.

B.3 Test pieces

B.3.1 The number of items (e.g., bricks or blocks) to be tested shall be determined in accordance with ISO 5022 or with an alternative sampling plan agreed between the parties concerned.

B.3.2 One test piece shall be taken from each brick of standard size.

NOTE. The number to be taken from larger items is a matter for agreement between the parties concerned. To facilitate further statistical evaluation, the same number of test pieces should be taken from each item.

B.3.3 Each test piece shall be nominally the size of half a standard brick, i.e.; 114mm x 114 mm x 76 mm or 114 mm x 114 mm x 64 mm

B.3.4 In the case of special shapes, the test pieces shall be dry cut to one of the sizes specified in B.3.3.

NOTE. If possible, the test report should indicate the relationship of the direction of loading to the direction of pressing or extrusion during manufacture.

B.3.5 The load-bearing faces of each test piece shall be flat within a tolerance of 0.5 mm. This condition shall be checked across both diagonals of each load-bearing face with a steel rule (B.2.5) and a feeler gauge **(B.2.6).**
B.3.6 The load-bearing faces of each test piece shall be parallel within a tolerance of 1 mm. This condition shall be checked by making four measurements of the height of the test piece, one at the centre of each of its four sides; the measurements shall not differ among themselves by more than 1 mm.

B.3.7 The perpendicular of each of the four sides of the test piece, with respect to the base, shall be within a tolerance of 1 mm. This condition shall be checked by placing the test piece on a flat, smooth surface and presenting a set square to the centre of a horizontal edge of the side; any gap between the set square and the side of the test piece shall not exceed 1 mm.

B.4 Procedure

B.4.1 Measure the length and breadth of each load-bearing face of the test piece, and its height at the mid-point of each of its four sides, in each case to the nearest 0.5 mm.

B.4.2 Dry the test piece to constant mass in the drying oven (B.2.4), controlled at 110 ^{o}C ±5 ^{o}C , cooling it each time in a dry atmosphere.

B.4.3 Place the test piece on one of its larger faces (114 mm x 114mm) in the centre of the lower platen of the testing machine (B.2.1). No packing material shall be used between the test piece and the platens. Mount the measuring instrument (B.2.2) on the lower platen to measure the deformation occurring in the test piece.

B.4.4 Gradually and continuously increase the load at such a rate that

a) If the expected cold crushing strength is less than 10MPa, the rate of increase of stress in the test piece is 0.05MPa/s ± 0.005MPa/s or
b) If the expected cold crushing strength is equal to or greater than 10 MPa, the rate of increase of stress in the test piece is 0.2 MPa ± 0.002MPa

B.4.5 Continue increasing the load at the rate given in B.4.4 until either the test piece collapses (fails to support the load) or its height is reduced to 90% ± 1% of its original height. Record the maximum load indicated during the test.

B.5 Expression of results

Calculate the cold crushing strength, S, in megapascals, using the equation:

$$S = \frac{\mathrm{Fmax}}{\mathrm{l\ x\ b}}$$

Where

F_{max} is the maximum load, in newtons, indicated during the test;
l is the mean of the four measurements of the length, in millimetres, of the test piece;
b is the mean of the four measurements of the breadth, in millimetres, of the test piece.

Report the cold crushing strength to the nearest.

B.6 Test report

The test report shall include the following information:

a) all information necessary for identification of the sample tested including the designation of the material tested (manufacturer, type, batch number);

b) reference to this Tanzania Standard:

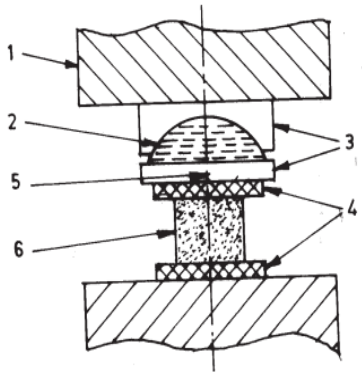
c) the sampling procedure, including:

1) the number of items tested (see B.3.1);
2) the number of test pieces cut from each item, if more than one (see B.3.2);
3) the dimensions of the test pieces (see B.3.3); their positions in the brick (see B.3.2) and the presence and location of any fired surface;

4) where possible, the relationship between the direction of loading and the direction of pressing or extrusion during manufacture (see Note to 6.4);

d) the results of the test, including:

1) the rate of stress increase (see B.4.4);
2) whether the test was terminated by the collapse of the test piece or by the height being reduced to of the original (see B.4.5);
3) the individual values of the cold crushing strength for each test piece, calculated as specified in Clause B.5 and, if appropriate (see B.3.2), the mean value for each item tested;
e) The name of the testing establishment;
f) Any information which might help in the interpretation of the test;
g) Any deviations from the procedure specified.



key

1 Platern of testing machine
2 Spherical seat
3 Spherical bearing block
4 Cellulose fibre board (optional)
5 Centre of spherical surface
6 Test specimen

Figure 3- Hydraulic crushing strength machine

Annex C

(Informative)

DETERMINATION OF PYROMETRIC CONE EQUIVALENT (PCE) OR SOFTENING POINT

C.1 Object of Test
The object of this test is to determine the softening point of refractory materials by comparing the test cones prepared from the refractory material under test with standard pyrometric cones.

C.2 Heating Furnace
A furnace of the type in which a neutral or oxidizing atmosphere may be maintained shall be preferred.

C.3 Preparation of Samples

C.3.1 Raw Materials.
Test pieces prepared from raw materials that are subject to considerable modification during reheating shall then be stabilized by heating before their refractoriness is determined. In particular, clays should be calcined at approximately 1 000ºC; after calcination, the test pieces shall comply with the requirements of **C.4.2**.

C.3.2 Fired Shapes.
Take 1 kg of the material. In the case of bricks or shapes, obtain a composite sample from bricks or portions of a number of test pieces taken for other tests, and reduce these fragments in size by means of rolls or jaw crusher adjusted to pass lumps no greater than 5 mm in diameter; take precautions to prevent contamination of the sample with steel particles during crushing or grinding. Reduce the quantity through quartering by different stages of grinding to about 50 g as test sample. Grind the full quantity of the material to pass through 212 microns IS Sieve by suitable grinder or agate mortar. Magnet should be used to separate the iron particles introduced during grinding and crushing operations except in the case of materials, which are themselves magnetic. In order to avoid excessive reduction of the fines, remove them frequently during the process of reduction by throwing the sample on the sieve and continue grinding of coarser particles until all the sample passes through the sieve. Subsequently make specimen as specified in C.4.1.

C.3.3 For Dry Monolithic Materials.
Samples of unshaped materials, such as, plastic refractories, ramming materials and refractory cement shall be shaped and fired in a manner appropriate to the material and its condition of use; the firing temperature shall be stated in the test report.

C.3.4 For Mortar make specimen as per dry monolithic materials and add the liquid component, if any, in appropriate proportion. Subsequently make specimen as specified in C.4.1.

NOTE — At all states, crushing and grinding should be carried out so as to avoid the introduction of extraneous material. At all stages, mixing should be carefully carried out so that the contents of the test pieces are truly representative of the samples.

C.4 Preparation of Test Cone

C.4.1 Moulding.
Mix thoroughly the sample prepared under C.3.2 and after adding sufficient alkali free dextrin or glue and water, form into test cones in a metal mould, preferably of brass, in the shape of tetrahedron measuring 8 mm on the sides of the base, and 25 mm high (*see* Figure 4).

C.4.2 Sintering.
When dry, subject the test cones, if necessary, to a preliminary burn at a temperature not exceeding 1000°C for the purpose of sintering them into a firm condition to permit handling.

C.5 Procedure

C.5.1 Mount the test cones and the standard pyrometric cones, the feature of typical standard cones used are reported in Table 1, on a plaque with the help of bonding material. Both the plaque and the bonding material should be of such composition, which will not affect the fusibility of the cones.

C.5.2 Mount the cones with the base embedded approximately 3 mm deep in the plaque, and one of the faces inclined towards the centre of plaque and at an angle of 82° with the horizontal. Arrange the test cones around the outer edge of the plaque with standard cones in between them in the anticipated range, as far as practicable (see Figure 5).

C.5.3 Place the test plaque with the test pieces and the pyrometric reference cones attached to it in the uniform temperature zone of the furnace. Avoid reducing conditions in the furnace during heating. Take care that the flame does not strike directly against the cones or the cone plaque. Check the furnace at intervals for uniformity of distribution of heat.

C.5.4 Over a period of 1.5 to 2 h, raise the temperature of the furnace to 200°C below the estimated refractoriness temperature of the test material.

C.5.5 Raise the temperature at the rate of 2.5°C/min or at the rate specified by the manufacturer of the cones. Maintain the heating so that at any moment the deviation from the specified temperature rise curve is less than 10°C.

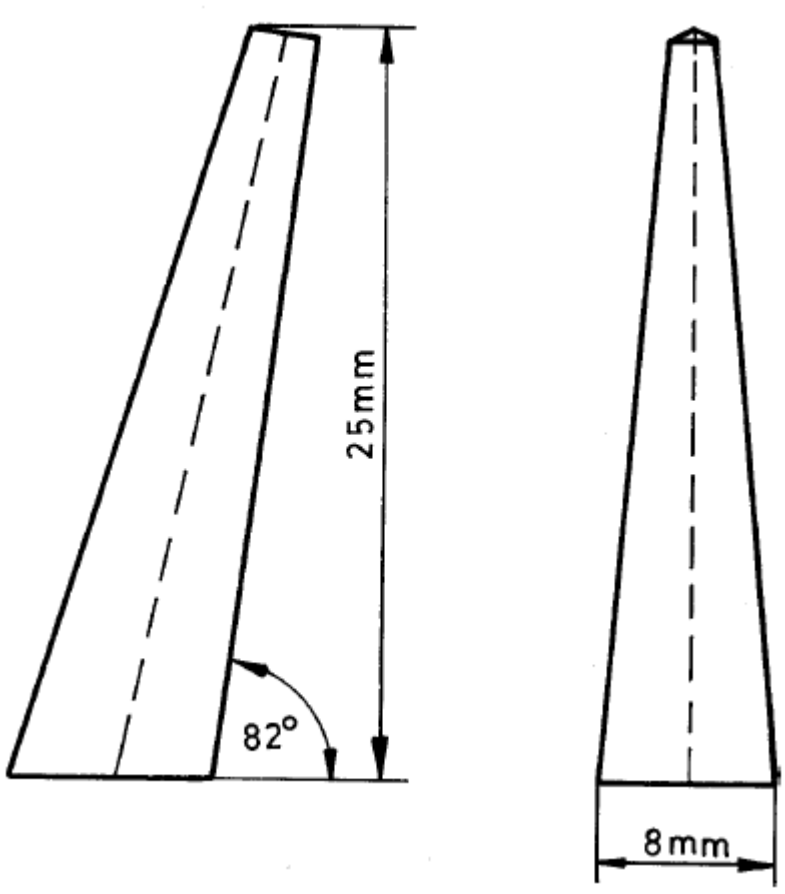


Figure 4-Standard Pyrometric Test Cone

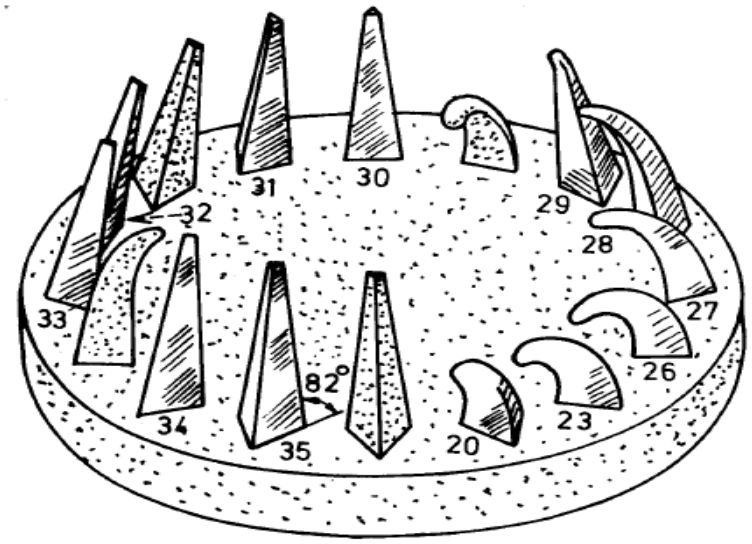


Figure 5-Method of Mounting Test Cone and Appearance After Testing.

C.6 Softening Point
Softening of the cone will be indicated by the top bending over and the tip of the cone touching the plaque surface.

C.7 Standard Cone Data

The standard pyrometric cone equivalents of standard cones are given in Table 1.

C.8 Report of Results

C.8.1 Report the softening point in terms of the standard pyrometric cone, it being that cone which most nearly corresponds in time of softening with the test cone.

C.8.2 If the test cone softens later than one cone but earlier than the next cone and approximately midway between, report the softening point, for example, Cone Number 31-32.

C.8.3 If the test cone starts bending at an early cone but it is not down until a later cone, report the fact.

Table 1 Reference Temperature and Cone Designations

Sl No.	Cone Designation	Temperature ^{O}C
i).	ISO 150	1500
ii).	ISO 152	1520
iii).	ISO154	1540
iv).	ISO 156	1560
v).	ISO 158	1580
vi).	ISO 160	1600
vii).	ISO 162	1620
viii).	ISO 164	1640
ix).	ISO 166	1660
x).	ISO 168	1680
xi).	ISO 170	1700
xii).	ISO 172	1720
xiii).	ISO 174	1740
xiv).	ISO 176	1760
xv).	ISO 178	1780
xvi).	ISO 180	1800

NOTES
1 The end point temperatures reported in the table have been obtained from the respective manufacturers' catalogue.
2 Any standard cone is acceptable.

ANNEX D

(Informative)

DETERMINATION OF REFRACTORINESS UNDER LOAD

D.1 Object of Test This test determines the softening temperature of refractories under load indicated either by complete sloughing down or breaking of the test specimen.

D.2 Apparatus.

D.2.1 Electrical Furnace — The furnace shall be electrically heated and shall consist of a heating tube of 100 to 120 mm inside diameter and about 500 mm length with a wall thickness of 10 to 15 mm. Heating tubes of corundum, magnesite or mullite shall be used. The surface surrounding and limiting the narrowed space shall be rounded off at the corners. The zone of approximately uniform temperature shall have a minimum length of 100 to 120 mm.

D.2.2 The essential features of the furnace are shown in Figure 6 and the loading arrangement in Figure 7. Thermocouple may be placed in the temperature sighting tube for the measurement of temperature, otherwise optical pyrometers may be used for the same purpose. The thermocouple shall be made from platinum and/or platinum-rhodium wire, and shall be compatible with the final test temperature. The thermocouple shall be calibrated on a regular basis.

D.2.3 The loading arrangement shall be such that a constant load of 0.2 N/mm^2 or 0.05 N/mm^2 can be applied vertically to the test piece. Provision shall be made for recording changes in the height of the test specimen and to permit it to be compressed by at least 20 mm.

D.2.3 Preparation of Test Specimens A cylinder of 50 ± 0.5 mm diameter and 50 ± 0.5 mm height obtained after boring or cutting and grinding out of the central portion of the brick to be tested shall be used as a test specimen. Measurements of the height at any two points, using Vernier calipers, shall not differ by more than 0.2 mm. The original surface of the brick should form one of the end faces of the finished test specimen. The top and bottom faces of the test piece shall be made plane and parallel by sawing (and grinding, if necessary), and shall be perpendicular to the axis of the cylinder. When one face of the test piece is placed on a plane surface and a set square also in contact with the surface is brought into contact with any part of the periphery of the test piece, the gap between the side of the test piece and the set square shall not exceed 0.5 mm. To ensure that the top and bottom ends of the test piece are flat over their entire surface, each end shall in turn be pressed onto a levelling plate which is lined with carbon paper and hard filter paper (0.15 mm in thickness). As an alternative to carbon paper, the ends of the test piece may be inked using a stamp pad. Test pieces that do not show two complete clearly visible coloured impressions shall be re-ground. Specimens with cracks or other visible defects shall not be used, and the surface of the cylinder shall be free from visible defects.

D.3 Procedure

D.3.1 Apply an actual load to the loading column of such magnitude that the preferred stress caused in the test piece (including that due to the mass of the loading column) is as follows.

a) For dense shaped products: 0.2 N/mm^2 , and

b) For shaped insulating products: 0.05 N/mm^2 .

NOTES

1 All stresses being ± 2 percent. The total load used shall be rounded to the nearest 1 N.
2 However, if such tests are carried out for unshaped products using the method described, the recommended loads are:
    (a) N/mm2 for dense unshaped products, and
    (b) 0.05 N/mm2 for unshaped insulating products.

D.3.2 Raise the temperature of the furnace at the rate of 15°C/min up to 1 000°C and at a rate of 8°C/min above 1 000°C. The difference between the actual temperature-rise and the scheduled rise of temperature should not be more than 20°C at any time. The temperature in the horizontal plane may also vary widely, but should not be greater than 30°C.

D.3.3 Plot the change in the height of the specimen during heating against time on rectangular coordinates beginning at least at 1 000°C, on 10: 1 scale for change in height and a convenient scale for time. As the temperature is raised at an approximately constant rate and the change in height with respect to time is plotted, this chart will give the temperature-deformation curve.

D.3.4 Measure temperature with an optical pyrometer, refractory tube closed at its bottom and suspended in the furnace at the beginning of the test. The other option may be to measure the temperature by using a well calibrated suitable thermocouple.

D.3.5 In control investigations for manufacturing purposes, apply the following methods for measuring temperatures, which give values that agree sufficiently closely with those secured by methods described under D.3.4. Sighting upon the surface of the test specimen, either,

a) obliquely from above or;
b) and b) from the side through a radial tube of 20 mm maximum inside diameter, inserted in the furnace.

D.4 Report of Results

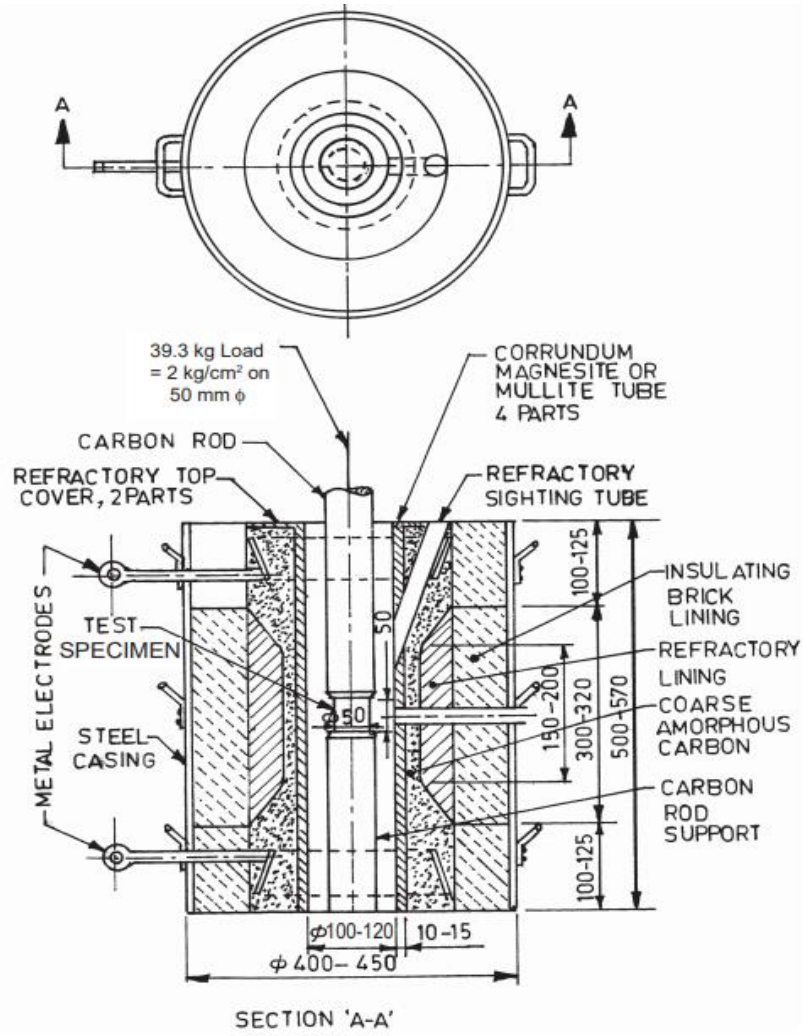
D.4.1 Report the following results of the test in figures, in addition to the plotted curves:

a) The temperature (t_e) denoting the point at which the curve has dropped 3 mm below its highest point. (The highest point is the point of curve at which it bends downward from the horizontal tangent).
b) The temperature (t_e) at which the height of the specimen has dropped by 20 mm below its highest height.

D.4.2 If, in consequence of premature breaking of the test specimen before (t_e), report the actual softening temperature (t_b) denoting the breaking point.

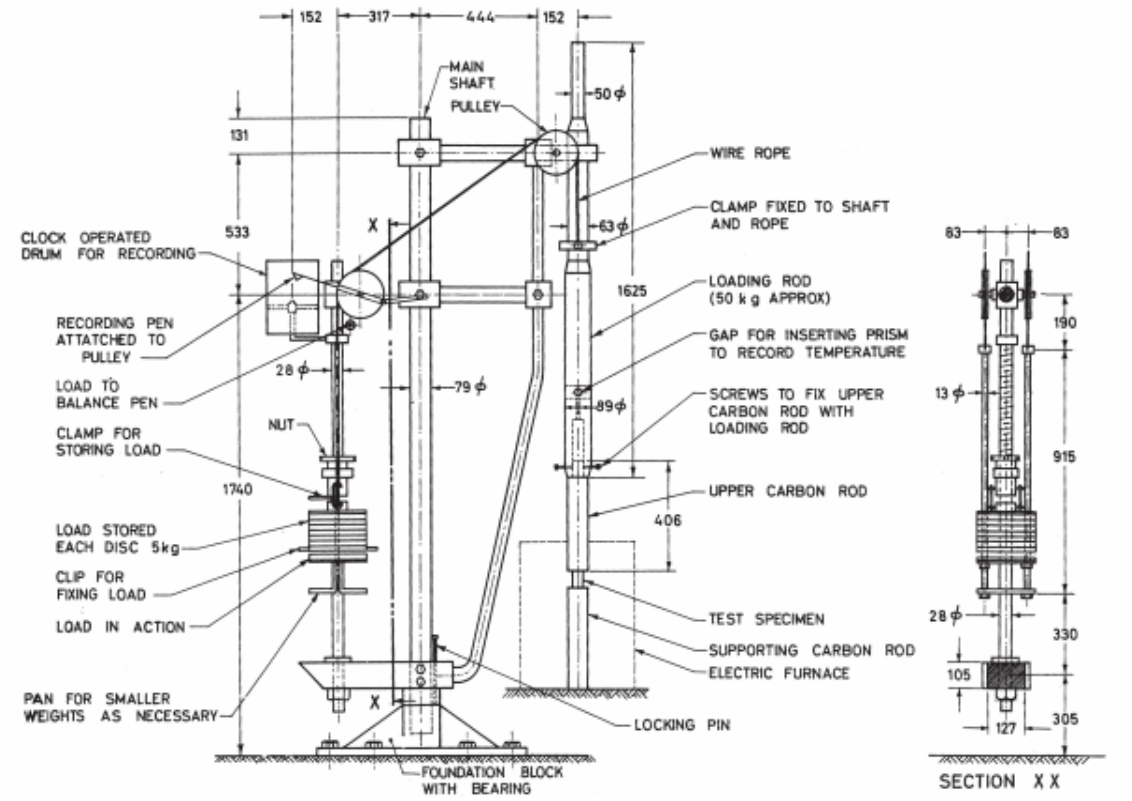
D.4.3 Report the temperature corrects to the nearest 10°C.

D.4.4 The outward appearance of the test specimen after completion of the test, for example, form of the softened body, such as, barrel shape or mushroom shape, location of enlarged sectional view of cracks, spall, etc, shall also be reported



All dimension in mm

Figure 6- Essential Features of The Electrical Heating Furnace.



All dimensions in millimeters

Figure 7-The loading arrangement

ANNEX E

(Informative)

Determination of Permanent Linear Change After Reheating

E.1 PRINCIPLE

Test pieces prepared out of the bricks are dried. Initial dimension with respect to length in case of Insulating product and initial volume in case of dense shaped product are determined. The test pieces are heated in a furnace at a prescribed rate to a specified temperature, which is maintained for a specified time. After cooling to ambient temperature, test pieces are measured again for final length or final volume and permanent linear change is calculated.

E.2 APPARATUS

E.2.1 Furnace — Either electric or gas fired, capable of firing the test pieces at the specified rate and of maintaining the test temperature for the required time. The furnace should be equipped with temperature controlling system which shall be able to comply the heating schedule mentioned in **E 8**.

NOTE — Use of electric furnace is recommended.

E.2.2 Thermocouple — Thermocouple(s) to measure the temperature.

E.2.3 Length Measuring Device — Vernier callipers or a dial gauge comparator with an accuracy of 0.1mm.

E.2.4 Drying Oven — Oven shall be fan assisted and shall have openings, which permit efficient ventilation

E.2.5 Drying Oven — Oven shall be fan assisted and shall have openings, which permit efficient ventilation.

E.3 TEST PIECES

E.3.1 Size of Test Pieces

D.3.1 *For Insulation Bricks* 114 mm × 114 mm × 64 mm or 76 mm, that is, half of standard brick.

E.4 PROCEDURE

E.4.1 Dry the test specimen in a drying oven at 110 ± 5°C to constant mass.

E.4.2 Measurement of Test Pieces

E.4.3 For Insulating Refractory Shaped Product

Calibrated length measuring device shall be used for measurement of dimensions. Make measurements on each test piece to the nearest 0.2 mm of the distance *L*o between the opposite faces nominally 114 mm apart. Make two of these measurements parallel to the centrelines (EF and *GH* in Figure 8) of the top and bottom faces of the test pieces, 15 mm from the edges of those faces, and two parallel to the centrelines (*AB* and *CD*) of the front and rear faces of the test pieces 15 mm from the edges of those faces. Mark the position of the measurements with refractory paint.

E.5 Mounting of Test Pieces in The Furnace

E.5.1 Furnace

Place the test pieces in the furnace as given below:

a) For Insulation Bricks — Place each sample on a 114 mm × 76 mm or 114 mm × 64 mm face.

The samples shall be protected from direct radiation in an electrically heated furnace or from the flame of the gas burner in a gas fired furnace. Do not superimpose test pieces one on another. To allow free circulation of the hot gases, the test pieces shall be separated from each other by a distance of not less than 20 mm and shall be not nearer than 50 mm to the wall of the furnace to avoid direct heat impingement. The test pieces shall be placed in the furnace on bricks of 30 to 65 mm thick preferably of same quality.

E.6 Test Temperature

Unless otherwise agreed, the test temperature shall be 800°C or a higher temperature in multiples of 50°C.

E.7 Temperature Measurement

Thermocouple shall be placed away from the walls of the furnace, away from the heaters so as not to be in contact with any flames or direct heating from elements.

E.8 Heating

Raise the temperature in the furnace at one of the following rates:

a) For test temperatures up to 1250°C:
   - From ambient temperature up to 50°C below the test temperature: between 5 to 10°C/min
   - For the last 50°C: between 1 to 5°C/min.

b) For test temperatures above 1250°C:
   - From ambient temperature up to 1200°C: between 5 to 10°C/min.
   - From 1200°C up to 50°C below the test temperature: between 2 to 5°C/min.
   - For the last 50°C: between 1 to 5°C /min.

E.9 Cooling

Switch off the furnace after reaching and holding at the test temperature. Allow it to cool at its natural rate, the test pieces being allowed to cool in the furnace.

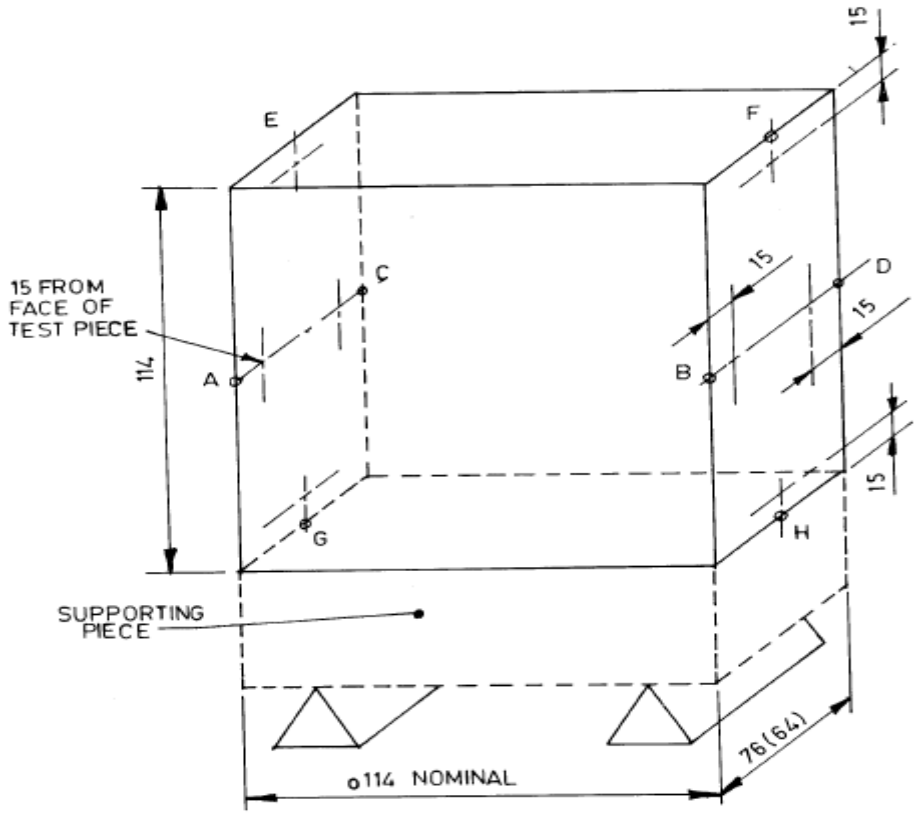


FIGURE 8- Position of Measurements and Mounting of the Test Pieces in The Furnace

E.10 Measurement of Test Pieces After Firing

First examine the test pieces, noting particularly any blisters or accretions produced during firing.

E.10.1 Linear Measurement for Insulating Brick Samples

Measure the distance between the two opposite faces of each test piece as described in **E.4.2**. If any of the measuring points might be affected by such a defect, measure at the nearest point unaffected. If necessary, rotate the test piece to avoid contact between defects.

E.10.2 Volume Measurement

The bulk volume V_b of the test piece is given, in cubic centimetres, by the equation

$V_b = lbd$

Where l, *b* and *d* are the length, breadth and thickness, respectively, in centimetres, of the test piece.

E.11 Expression of Results

For Insulation refractory quality, calculate the change in the relevant length, Δ*L* as a percentage of original value *L*o, that is, 100 × *L* / *L*o. Calculate the change in length for each measuring point.

2

E.12 Test Report

The test report shall include the following:

a). Description of the material tested.
b). Number of items tested.
c). Number of test pieces per item or brick,
d). Type of length measuring device used,
e). Type of furnace used,
f). The heating schedule used,
g). Test temperature,
h). Period of the actual holding time at test temperature, and
i). Appearance of test pieces after firing.

ANNEX F

(Informative)

DETERMINATION OF SPALLING RESISTANCE

F.1 Apparatus

F.1.1 Furnace — The furnace is pre-heated to 950 ± 25 °C. The specimens, which have been brought up to 100 °C in the drier, are then placed in the furnace. The furnace temperature is measured by means of the thermocouple placed at the centre of the floor area of the furnace, some 20 mm above the specimens. The temperature of the furnace shall not fall below 750± 25°C.

The thermal capacity of the furnace must be adequate to bring the temperature back to test temperature within 15 to 30 min of insertion of the first specimen.

F.1.2 Water Tank — A suitable water tank shall be used for cooling the heated specimen with running water.

F.2 Procedure

F.2.1 Water Quenching test

F.2.2 Test Specimen.

The test will be conducted on cylindrical specimens with an original surface 50 ± 0.5 mm in diameter and 50 ± 0.5 mm height. They count as standard specimens. If standard specimens cannot be taken from a sample, cylindrical specimen 36 ± 0.3 mm in diameter and 50 ± 0.5 mm height may be used. Standard specimens are, where possible, to be taken from shaped bricks. Specimens with defects, for example, fissures or shrink holes, must not be tested. Agreement is to be reached on specimens of other shapes.

F.2.3 Drying of Specimens.

Prior to the test, the specimens are dried at 110 ± 5 °C until constant weight is reached. Constant weight is deemed to have been reached when the change in weight between two consecutive weighing made at an interval of at least one hour is not more than 0.1 percent. Pending the test, the specimens must be protected from moisture.

The specimens then remain for a further 15 min in the furnace at 950 ± 25 °C, after which they are plunged into running water at 10 °C to 30 °C and left there for 3 min.

The specimens are then stored for 30 min in the hot cabinet at 110 ± 5 °C before being replaced in the furnace.

The procedure is the same for all further quenching. Should the test have to be broken off, the wet quenched specimens are to be left in the test laboratory in ambient condition and, when the test is resumed (the following morning), the test specimens are to be put in the hot cabinet for 30 min at 110 °C, after which they are immediately placed in the furnace. The test is continued until the specimen splits into two or more large pieces. The test will also be discontinued after the specimen has withstood 30 quenching.

F.3 Air Quenching Test.

F.3.1 Three test pieces shall be cut or ground to the shape of prisms 75 mm high with a square base of 50 mm in the case of standard shapes, and bricks; or rings 50 mm high from sleeves, nozzles or any other type of pouring refractories. The test pieces shall be thoroughly dried before use.

F.3.2 Place the test pieces in the cold furnace. Heat the furnace at a uniform rate so that in 3 h it attains a temperature 1 000°C for firebricks, high alumina bricks or basic bricks. Maintain the testing temperature for

30 min and remove the test pieces from the furnace with a pair of light tongs, which shall have been warmed in the furnace for a short time before use. Place the test pieces on end on a brick floor in a position free from draughts. After they have been cooled in this way for 10 min, replace the test pieces in the furnace (which shall have been maintained at the temperature of the test) for a further 10 min and the cycle is repeated. The furnace shall be maintained at the required constant temperature during testing. Examine the test pieces towards the end of each 10 min cooling period. The test shall be concluded when the specimens can be pulled apart (to be specified for each type of refractory in the material specification depending upon the service condition).

F.4 REPORT

Report the number of complete cycles of heating and cooling required to promote fracture together with a note of the cycle during which cracks first appeared. Three individual results shall be included in the report.

Bibliography

2) **IS 1335: 1979** Methods for direct determination of alumina in refractory materials (first revision)
3) **IS 1387: 1993** General requirements for the supply of metallurgical materials (second revision)
4) **IS 1527:1972** Methods of chemical analysis of high silica refractory materials (first revision)
5) **IS 1528-1:1980** Methods of sampling and physical tests for refractory materials-Part 1: Determination of pyrometric cone equivalent (PCE) or softening point (first revision)
6) **IS 1528-2:1974** Methods of sampling and physical tests for refractory materials-Part 2: toriness under load (first revision)
7) **IS 1528-3:1983** Methods of sampling and physical tests for refractory materials-Part 3: Determination of spalling resistance (second revision)
8) IS 1528-4:1974 Methods of sampling and physical tests for refractory materials-Part 4: Determination of cold crushing strength (first revision)
9) **IS 1528-6:1974** Methods of sampling and physical tests for refractory materials-Part 6: Determination of permanent change after reheating (first revision)
10) **IS 1528-7: 1974** Methods of sampling and physical tests for refractory materials-Part 7: Methods of sampling and criteria for conformity (first revision)
11) **IS 1528-8:1974** Methods of sampling and physical tests for refractory materials-Part 6: Determination of apparent porosity (first revision)