Disclosure to Promote the Right To Information

Whereas the Parliament of India has set out to provide a practical regime of right to information for citizens to secure access to information under the control of public authorities, in order to promote transparency and accountability in the working of every public authority, and whereas the attached publication of the Bureau of Indian Standards is of particular interest to the public, particularly disadvantaged communities and those engaged in the pursuit of education and knowledge, the attached public safety standard is made available to promote the timely dissemination of this information in an accurate manner to the public.

Indian Standard
METHODS OF SAMPLING AND PHYSICAL TESTS
FOR REFRACTORY MATERIALS
PART 16 DETERMINATION OF THERMAL CONDUCTIVITY ACCORDING TO
HOT-WIRE METHOD (PARALLEL)
( First Revision )

© BIS 2007
BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002
NATIONAL FOREWORD

This Indian Standard (Part 16) (First Revision) which is identical with ISO 8894-2 : 1990 'Refractory materials — Determination of thermal conductivity — Part 2: Hot-wire method (parallel)' issued by the International Organization for Standardization (ISO) was adopted by the Bureau of Indian Standards on the recommendation of the Refractories Sectional Committee and approval of the Metallurgical Engineering Division Council.

This standard was originally published in 1991. This revision of the standard has been taken up to align it with ISO 8894-2 : 1990 by adoption, under dual numbering system.

The text of ISO Standard has been approved as suitable for publication as an Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.

b) Comma (,) has been used as a decimal marker, while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

In this adopted standard, reference appears to certain International Standards for which Indian Standards also exist. The corresponding Indian Standards, which are to be substituted in their places, are listed below along with their degree of equivalence for the editions indicated:

<table>
<thead>
<tr>
<th>International Standard</th>
<th>Corresponding Indian Standard</th>
<th>Degree of Equivalence</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISO 5022 : 1979 Shaped refractory products — Sampling and</td>
<td>IS 1528 (Part 7) : 1974 Methods of sampling and physical tests for refractory materials:</td>
<td>Technically Equivalent</td>
</tr>
<tr>
<td>acceptance testing</td>
<td>Part 7 Methods of sampling and criteria for conformity (first revision)</td>
<td></td>
</tr>
<tr>
<td>thermal conductivity</td>
<td>Part 21 Determination of thermal conductivity according to hot-wire method (cross-array)</td>
<td></td>
</tr>
</tbody>
</table>

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (revised)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.
Indian Standard
METHODS OF SAMPLING AND PHYSICAL TESTS
FOR REFRATORY MATERIALS

PART 16 DETERMINATION OF THERMAL CONDUCTIVITY ACCORDING TO
HOT-WIRE METHOD (PARALLEL)
( First Revision )

1 Scope

1.1 This part of ISO 8894 specifies a hot-wire method for the
determination of the thermal conductivity of refractory prod-
ucts and materials.

1.2 The method is applicable at temperatures up to and in-
cluding 1250 °C and to materials whose thermal conductivity
is less than 25 W/(m·K). Electrically conducting materials are
excluded.

1.3 Subject to the limits in 1.2 the method is applicable to
powdered or granular materials (see 7.2).

NOTES

1 The thermal conductivity of bonded bricks and of prepared un-
shaped (monolithic) refractories may be affected by the appreciable
amount of water that is retained after hardening or setting and is
released on firing. These materials may therefore require pre-
treatment; the nature and extent of such pre-treatment and the period
for which the test piece is held at the measurement temperature, as a
preliminary to carrying out the test, are details that are outside the
scope of this part of ISO 8894 and should be agreed between the
parties concerned.

2 In general it is difficult to make measurements on anisotropic
materials, particularly those containing fibres, and the use of this
method for such materials should also be agreed between the parties
concerned.

1.4 The determination of thermal conductivity by the hot-
wire method (cross-array) is the subject of ISO 8894-1.

ISO 5022: 1979, Shaped refractory products — Sampling and
acceptance testing.

ISO 8894-1: 1987, Refractory materials — Determination of

3 Definitions

For the purposes of this part of ISO 8894, the following defi-
nitions apply.

3.1 thermal conductivity, \( \lambda \): Density of heat flow rate
divided by temperature gradient.

The unit of thermal conductivity is the watt per metre-kelvin.

3.2 thermal diffusivity, \( \alpha \): Thermal conductivity divided by
heat capacity per unit volume.

The unit of thermal diffusivity is the metre squared per second.

3.3 power, \( P \): Product of current and potential difference.

The unit of power is the watt (volt-amperes).

4 Principle

The hot-wire method (parallel) is a dynamic measuring pro-
dure based on the measurement of the temperature increase
at a certain location and at a specified distance from a linear
heat source embedded between two test pieces.

The test pieces are heated in a furnace to a specified
temperature and maintained at that temperature. Further local
heating is provided by a linear electrical conductor (the hot
wire) that is embedded in the test piece and carries an electrical
current of known power that is constant in time and along the
length of the test piece.

A thermocouple is fitted at a specified distance from the hot
wire, the thermocouple leads running parallel to the wire (see
figure 1). The increase in temperature as a function of time,
measured from the moment the heating current is switched on, is a measure of the thermal conductivity of the material of which the test pieces are made.

5 Apparatus

5.1 Furnace, electrically heated, capable of taking one or more test assemblies (see 6.2) up to a maximum temperature of 1 250 °C. The temperature at any two points in the region occupied by the test pieces shall not differ by more than 10 °C. The temperature measured on the outside of the test assembly during a test (of duration about 15 min) shall not vary by more than ±0,5 °C, and shall be known with an accuracy of ± 5 °C.

5.2 Hot wire, preferably of platinum or platinum/rhodium, about 200 mm in length and not exceeding 0,5 mm in diameter, the actual length being known to within ±0,5 mm. One end of the wire is attached to the lead for supply of the heating current. This may also be a continuation of the wire itself, and shall in any case be of the same diameter as the wire when within the assembly. The other end is attached to a lead for measurement of voltage drop, which shall be of diameter not greater than that of the hot wire when within the assembly. Leads outside the assembly shall consist of two or more tightly twisted 0,5 mm diameter wires. External to the furnace the current lead connections shall be made with heavy-gauge cable (20 A/2,5 mm²). The thermocouple wires shall be the same as that of the hot wire and the thermocouple wires shall be long enough to extend outside the furnace where connections to the measuring apparatus shall be made by wire of a different type. The external connections of the thermocouple shall be isothermal.

NOTES
1 Base metal thermocouples are also permitted for use at temperatures below 1 000 °C.
2 An insulating layer between the cover and the upper test piece is allowed.

5.3 Power supply to the hot wire, stabilized a.c., not varying in power by more than 2 % during the period of measurement. A supply to the hot wire of at least 80 W is required (equivalent to 250 W/m for a 200 mm long wire). A constant power supply, if available, is to be preferred.

5.4 Differential platinum/platinum-rhodium thermocouple (Type R or S), formed from a measurement thermocouple and a reference thermocouple connected in opposition (see figure 1). The leads of the measurement thermocouple shall run parallel to the hot wire at a distance of 15 mm ± 1 mm (see figure 2). The output of the reference thermocouple shall be kept stable by placing it between the top outer face of the upper test piece and a cover of the same material as the test piece (see figure 1). The diameter of the thermocouple wires shall be the same as that of the hot wire and the thermocouple wires shall be long enough to extend outside the furnace where connections to the measuring apparatus shall be made by wire of a different type. The external connections of the thermocouple shall be isothermal.

5.5 Digital multimeter, for measuring the current in the hot wire and the voltage drop across it, and capable of measuring both to an accuracy of at least ±0,5 %.

NOTE — An instrument of class 0,2 or better (see IEC 51-2 : 1984, Direct acting indicating analogue electrical measuring instruments and their accessories — Part 2: Special requirements for ammeters and voltmeters) is suitable.

5.6 Data acquisition system.

A temperature-time registration device with a sensitivity of at least 2 µV/cm or 0,05 µV/Digit, with a time resolution better than 0,5 s, and a temperature measurement to 0,05 K.

5.7 Containers (for use if the test is performed on powdered or granular material), having internal dimensions equal to those of the solid test assembly specified in clause 6, so that the test assembly shall consist of two sections as specified in 6.2. The bottom container shall have four sides and a base, and the top container shall have four sides only, plus a detachable cover (see figure 3).

6 Test pieces

6.1 Sampling

The number of items of the material to be tested shall be determined in accordance with ISO 6022 or another standard sampling plan.

6.2 Dimensions

Each test assembly shall consist of two identical test pieces, not less than 200 mm x 100 mm x 50 mm in size.

NOTE — It is recommended that the size of each test piece be 230 mm x 114 mm x 64 mm or 230 mm x 114 mm x 76 mm. Standard-size bricks may then be used as the pieces forming the test assembly, subject to the requirements of 6.3.

6.3 Surface flatness

The surfaces of the two test pieces forming the test assembly which are in contact with each other shall, if necessary, be ground so that the deviation from flatness between two points not less than 100 mm apart is not more than 0,2 mm.

6.4 Groove in dense materials

In dense materials, a groove to accommodate the hot wire and the thermocouple shall be machined in either both the contact faces or in the lower face only of the test assembly (see figure 4). The width and depth of the groove shall permit the arrangement shown in figure 4 to be achieved, where required.

NOTE — Grooves in both faces will be necessary for materials of higher conductivity, e.g. greater than 5 W/(m·K).

7 Procedure

7.1 Arrange the test assembly ready for testing. Place the hot wire (5.2) and differential thermocouple (5.4) between the two test pieces, with the hot wire along the centreline of the brick
faces in contact with each other and cement them into the 
grooves where appropriate, using a cement made from finely 
ground test material mixed with a small amount of a suitable 
binder (e.g. 2 % dextrin and water). Ensure that the wires are 
cemented evenly, to allow equal heat transfer to the two test 
pieces, as shown in figure 4.

7.2 If the test is being performed on powdered or granular 
material, fill the bottom container (5.7) with the test material up 
to its top, and place on it the hot wire and differential thermo-
couple as shown in figure 1. Place the top container (5.7) on 
the bottom one and fill with the test material. Cover the test 
assembly with a slab of the same material as that of the con-
tainers. Determine the apparent bulk density of the test material 
in the poured, untamped state.

NOTE — The container may be filled by vibration or by pressing to give 
a specific bulk density, where a figure has been agreed upon.

7.3 Place the test assembly in the furnace (5.1), resting each 
assembly (to ensure uniform heating) on three supports of a 
material similar to that being tested and having dimensions 
of 125 mm x 10 mm x 20 mm. The supports shall rest on 
a 125 mm x 10 mm face, and be placed parallel to the 
114 mm x 76 mm (or 100 mm x 50 mm) faces of the test 
assembly about 20 mm in from these faces.

7.4 Connect the test assembly to the measuring apparatus 
(5.5). With the hot-wire circuit open, raise the temperature of 
the furnace, at not more than 10 K/min, to the first test 
temperature required.

NOTE — Heating rates should be low enough to ensure that there is no 
risk of thermal shock damage.

7.5 Set the power input to a value that (from preliminary 
tests) is known to produce, for a chosen recorder sensitivity, an 
instrument deflection of at least 60 %, and preferably about 
80 %, of full-scale deflection.

A guide to the choice of power input for a range of thermal 
conductivities and for a range of recorder sensitivities is given 
in table 1. The power levels are based on a recorder deflection 
of 0.8 x full-scale deflection for a given maximum duration of 
the test (t_max), and table 1 also shows the required accuracy for 
the measurement of time (accuracy t).

NOTE — The appropriate level of power input to the hot wire will differ 
from equipment to equipment and needs to be evaluated in preliminary 
tests, but may eventually be based on experience.

7.6 When the furnace reaches the test temperature, verify 
that the temperature in the region occupied by the test 
assembly is uniform and constant. The differential thermo-
couple (5.4) shall not show a variation of more than 0.05 °C 
over a period of 10 min immediately prior to the test.

7.7 When the conditions of 7.6 are met, close the heating cir-
cuit and make a record of the output of the differential ther-
ocouple with time. Mark the exact moment the power input 
to the hot wire was made. If not using an automatically con-
trolled power supply, measure and record the voltage drop 
across the hot wire and the current in it immediately after 
switching on the heating circuit and again at intervals during 
the test period.

7.8 After an appropriate heating time (see table 1), discon-
nect the heating circuit and discontinue recording the output of 
the differential thermocouple.

7.9 Allow time for the hot wire and test assembly to reach 
temperature equilibrium. Verify the uniformity and constancy of 
the temperature as specified in 7.6. Repeat the procedures of 
7.7 and 7.8, so obtaining a further measurement of the rate of 
rise of temperature of the hot wire under the same conditions.

7.10 Raise the temperature of the furnace to the next higher 
test temperature at not more than 10 K/min. Carry out again 
the procedure described in 7.5 to 7.9.

7.11 Repeat the procedure of 7.10 until at least two 
measurements have been obtained at each of the required test 
temperatures.
Table 1 — Recommended choice of scales and of power level
(based on a deflection of 0,8 x full-scale)

<table>
<thead>
<tr>
<th>Thermal conductivity, $\lambda$, W/(m·K)</th>
<th>Maximum duration of test, $t_{\text{max}}$, s</th>
<th>Accuracy of measurement of $t$, s</th>
<th>Recommended power level (W/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>0 to 20 µV scale</td>
</tr>
<tr>
<td>0.1</td>
<td>2 500</td>
<td>4.0</td>
<td>15</td>
</tr>
<tr>
<td>0.4</td>
<td>1 260</td>
<td>2.0</td>
<td>15</td>
</tr>
<tr>
<td>1.0</td>
<td>900</td>
<td>2.0</td>
<td>15</td>
</tr>
<tr>
<td>2.0</td>
<td>450</td>
<td>1.0</td>
<td>30</td>
</tr>
<tr>
<td>4.0</td>
<td>350</td>
<td>1.0</td>
<td>60</td>
</tr>
<tr>
<td>8.0</td>
<td>190</td>
<td>0.4</td>
<td>120</td>
</tr>
<tr>
<td>16</td>
<td>100</td>
<td>0.2</td>
<td>240</td>
</tr>
<tr>
<td>25</td>
<td>65</td>
<td>0.2</td>
<td>375</td>
</tr>
</tbody>
</table>

NOTE — The figures in table 1 are based on the use of type "S" thermocouples (see 5.4), and should be adjusted if a type "R" thermocouple is used.

8 Expression of results

Calculate the thermal conductivity, $\lambda$, of the material, in watts per metre kelvin, at each test temperature from the equation

$$\lambda = \frac{V \cdot I}{4 \pi l} \times \frac{Ei \left( -\frac{r^2}{4al} \right)}{\Delta \theta(t)}$$

where

- $I$ is the heating current, in amperes;
- $V$ is the voltage, in volts;
- $l$ is the length, in metres, of the hot wire between the voltage taps P and Q in figure 2;
- $\Delta \theta(t)$ is the temperature difference, in kelvins, between the measurement and reference thermocouples at time $t$;
- $t$ is the period of time, in seconds, between switching on and switching off the heating circuit;
- $r$ is the separation, in metres, of the hot wire and the measurement thermocouple;
- $a$ is the thermal diffusivity, in square metres per second;
- $Ei \left( -\frac{r^2}{4al} \right)$ is an exponential integral of the form

$$\int_{s}^{u} e^{-u} du$$

After determining $\frac{\Delta \theta(2t)}{\Delta \theta(t)}$, the expression

$$-Ei \left( -\frac{r^2}{4al} \right)$$

is calculated from table 2.

The values of $\lambda$ which can be considered accurate are those which correspond to values of $\frac{\Delta \theta(2t)}{\Delta \theta(t)}$ between 1,5 and 2,4.

9 Test report

The test report shall include the following information:

a) the testing establishment;
b) the date of the test;
c) reference to this part of ISO 8894;
d) the material tested (manufacturer, product, type, batch number, etc.);
e) any pre-treatment given to the test material (see note 1 to clause 1);
f) in the case of powders or granular materials, the apparent bulk density in the poured, untamped state (see 7.2);
g) the furnace atmosphere;
h) the test temperature or temperatures and, for each of them, the individual and mean values of thermal conductivity.
<table>
<thead>
<tr>
<th>Δh(2)/Δh(0)</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.2</td>
<td>3.419</td>
<td>3.249</td>
<td>3.091</td>
<td>3.046</td>
<td>3.166</td>
<td>3.032</td>
<td>2.972</td>
<td>2.873</td>
<td>2.739</td>
<td>2.583</td>
</tr>
<tr>
<td>1.4</td>
<td>2.028</td>
<td>2.122</td>
<td>2.047</td>
<td>1.976</td>
<td>1.909</td>
<td>1.846</td>
<td>1.786</td>
<td>1.729</td>
<td>1.675</td>
<td>1.624</td>
</tr>
<tr>
<td>1.6</td>
<td>1.575</td>
<td>1.529</td>
<td>1.485</td>
<td>1.443</td>
<td>1.402</td>
<td>1.364</td>
<td>1.327</td>
<td>1.292</td>
<td>1.258</td>
<td>1.227</td>
</tr>
<tr>
<td>1.8</td>
<td>1.194</td>
<td>1.164</td>
<td>1.135</td>
<td>1.108</td>
<td>1.081</td>
<td>1.051</td>
<td>1.031</td>
<td>1.007</td>
<td>0.984</td>
<td>0.961</td>
</tr>
<tr>
<td>2.0</td>
<td>0.940</td>
<td>0.919</td>
<td>0.899</td>
<td>0.883</td>
<td>0.861</td>
<td>0.843</td>
<td>0.829</td>
<td>0.818</td>
<td>0.804</td>
<td>0.792</td>
</tr>
</tbody>
</table>

NOTES:
1) Table 2 has been made up of statements in the literature (see annex B, [11], [21] and [3]).
2) The expressions \( \Delta h(2)/\Delta h(0) \) and \( -Ei(\frac{-r^2}{4\alpha t}) \) are quoted in the literature as \( -Ei(\frac{-r}{\alpha t}) \) and \( -Ei(-r) \) respectively.
Figure 1 – Diagram showing location of heating circuit and measurement circuit (differential thermocouple circuit)

Figure 2 – Diagram showing measurement arrangement
Figure 3 — Container with hot wire and thermocouple laid on it

Figure 4 — Symmetrical embedding of hot wire and thermocouple in test pieces (where required)
Annex A
(informative)

Example of the determination of thermal conductivity

Table A.1 — Example of an evaluation of the measurements for the determination of the thermal conductivity by the parallel hot-wire method

<table>
<thead>
<tr>
<th>Time, t</th>
<th>( \Delta \theta(t) )</th>
<th>( \Delta \theta(2t) )</th>
<th>( - \left( -\frac{r^2}{4t} \right) )</th>
<th>Thermal conductivity, ( \lambda )</th>
<th>( \lambda ) mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>s</td>
<td>( \mu V )</td>
<td>K</td>
<td>( \Delta \theta(t) )</td>
<td>W/(m K)</td>
<td>W/(m K)</td>
</tr>
<tr>
<td>6</td>
<td>0.55</td>
<td>0.054</td>
<td>4.46</td>
<td>0.0496</td>
<td>13.2</td>
</tr>
<tr>
<td>12</td>
<td>2.47</td>
<td>0.241</td>
<td>4.46</td>
<td>0.2434</td>
<td>14.5</td>
</tr>
<tr>
<td>18</td>
<td>4.45</td>
<td>0.434</td>
<td>1.96</td>
<td>0.4785</td>
<td>15.8</td>
</tr>
<tr>
<td>24</td>
<td>6.08</td>
<td>0.593</td>
<td>1.78</td>
<td>0.6521</td>
<td>15.7</td>
</tr>
<tr>
<td>30</td>
<td>7.47</td>
<td>0.729</td>
<td>1.69</td>
<td>0.7764</td>
<td>15.3</td>
</tr>
<tr>
<td>36</td>
<td>8.72</td>
<td>0.861</td>
<td>1.61</td>
<td>0.9197</td>
<td>15.5</td>
</tr>
<tr>
<td>48</td>
<td>10.82</td>
<td>1.056</td>
<td>1.52</td>
<td>1.1358</td>
<td>15.4</td>
</tr>
<tr>
<td>60</td>
<td>12.60</td>
<td>1.229</td>
<td>1.46</td>
<td>1.3274</td>
<td>15.5</td>
</tr>
<tr>
<td>72</td>
<td>14.05</td>
<td>1.371</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>96</td>
<td>16.47</td>
<td>1.607</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>120</td>
<td>18.40</td>
<td>1.795</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[
\frac{V.t}{4\pi l} = 14.32 \text{ W/m}
\]

In column 2 of table A.1, the differential thermocouple emf, in microvolts, is given at the various times \( t \).

In column 3 of table A.1, this emf is converted to kelvins (K).

It is essential that the correct thermo-emf is used in the conversion of temperature. Thermo-emf values for a range of thermocouple types can be obtained from US National Bureau of Standards Monograph 125.

In column 4 of table A.1, the expression \( -\left(-\frac{r^2}{4at}\right) \) is stated.

This expression is calculated by dividing the temperature difference after a period \( 2t \) by the temperature difference after a period \( t \).

This expression can be calculated from the data measured (see column 2 of table A.1).

**EXAMPLES**

\[
\frac{\Delta \theta(2t)}{\Delta \theta(t)} = \frac{\Delta \theta(60)}{\Delta \theta(30)} = \frac{1.229 \text{ K}}{0.729 \text{ K}} = 1.69
\]

\[
\frac{\Delta \theta(2t)}{\Delta \theta(t)} = \frac{\Delta \theta(96)}{\Delta \theta(48)} = \frac{1.607 \text{ K}}{1.056 \text{ K}} = 1.52
\]

The \( -\left(-\frac{r^2}{4at}\right) \) values associated with the individual \( \frac{\Delta \theta(2t)}{\Delta \theta(t)} \) values are taken from table 2, interpolated where necessary, and entered in column 5 of table A.1.

By substituting the expressions \( -\left(-\frac{r^2}{4at}\right) \), \( \Delta \theta(t) \), power input and length of the hot wire in the equation in clause 8, \( \lambda \) is calculated and entered in column 6 of table A.1.

The time from which \( \lambda \) becomes almost constant depends on the material.

The actual value of \( \lambda \) for the test is the mean value of the accurate values in column 6 of table A.1.

The mean value of two tests at any one temperature shall be reported. The individual value of \( \lambda \) as determined in each test shall not deviate by more than 5 % from their mean value.
Annex B
(informative)

Bibliography

3. GROSSKOPF, B. and KILIAN, B., *Table book with Ei (−x) and \( \frac{\Delta V(2i)}{\Delta V(i)} \) values*, 1980, Kübel-Druck, Wiesbaden, FRG.
Bureau of Indian Standards

BIS is a statutory institution established under the Bureau of Indian Standards Act, 1986 to promote harmonious development of the activities of standardization, marking and quality certification of goods and attending to connected matters in the country.

Copyright

BIS has the copyright of all its publications. No part of these publications may be reproduced in any form without the prior permission in writing of BIS. This does not preclude the free use, in course of implementing the standard, of necessary details, such as symbols and sizes, type or grade designations. Enquiries relating to copyright be addressed to the Director (Publications), BIS.

Review of Indian Standards

Amendments are issued to standards as the need arises on the basis of comments. Standards are also reviewed periodically; a standard along with amendments is reaffirmed when such review indicates that no changes are needed; if the review indicates that changes are needed, it is taken up for revision. Users of Indian Standards should ascertain that they are in possession of the latest amendments or edition by referring to the latest issue of ‘BIS Catalogue’ and ‘Standards: Monthly Additions’.

This Indian Standard has been developed from Doc: No. MTD 15 (4704).

Amendments Issued Since Publication

<table>
<thead>
<tr>
<th>Amendment No.</th>
<th>Date of Issue</th>
<th>Text Affected</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

BUREAU OF INDIAN STANDARDS

Headquarters:
Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi 110 002
Telephone: 2323 0131, 2323 3375, 2329 9402 Website: www.bis.org.in

Regional Offices:

Central : Manak Bhavan, 9 Bahadur Shah Zafar Marg
NEW DELHI 110 002
{ 2323 7617
{ 2323 3841

Eastern : 1/14, C.I.T. Scheme VII M, V.I.P. Road, Kankurgachi
KOLKATA 700 054
{ 2337 8499, 2337 8561
{ 2337 8526, 2337 9120

Northern : SCO 335-336, Sector 34-A, CHANDIGARH 160 022
{ 260 3843
{ 260 9285

Southern : C.I.T. Campus, IV Cross Road, CHENNAI 600 113
{ 2254 1216, 2254 1442
{ 2254 2519, 2254 2315

Western : Manakalaya, E9 MIDC, Marol, Andheri (East)
MUMBAI 400 093
{ 2832 9295, 2832 7858
{ 2832 7891, 2832 7892

Branches: AHMEDABAD, BANGALORE, BHOPAL, BHUBANESHWAR, COIMBATORE, FARIDABAD, GHAZIABAD, GUWAHATI, HYDERABAD, JAIPUR, KANPUR, LUCKNOW, NAGPUR, PARWANO, PATNA, PUNE, RAJKOT, THIRUVANANTHAPURAM, VISAKHAPATNAM.

Printed at Prabhat Offset Press, New Delhi-2