IS 14406 (1996): Refractories for forge and heat treatment furnaces _ Recommendations [MTD 15: Refractories]

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(Reaffirmed 2001)

भारतीय मानक

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Indian Standard

REFRACTORIES FOR FORGE AND HEAT TREATMENT FURNACES — RECOMMENDATIONS

ICS 81.080

BUREAU OF INDIAN STANDARDS
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NEW DELHI 110002

October 1996 **Price Group 4**

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Refractories Sectional Committee had been approved by the Metallurgical Engineering Division Council.

Refractories are the primary materials used in the construction of all furnaces in the ferrous and non-ferrous industries. These are used in the lining of ladles, hot metal mixers, metal retaining vessels and the flues and stackes through which hot gasses pass. Refractories are used for lining of boilers, pressure vessels, kilns, and vessels using hot fluids at various temperatures. In short, refractories can be termed as the materials of construction exposed to high temperatures and corroding atmospheres and they retain their shapes and characteristics without reacting with the molten material or the corroding atmospheres.

Refractory materials are costly and a sudden failure of any refractory may result in great loss of time, product and equipment. Therefore, the selection of refractories suitable for a particular application is of paramount importance. Cost-benefit-analysis is often the basis of selection of such refractories. A refractory best suited for an application may not necessarily have the longest life. In selecting the proper refractories, a balance is struck between the initial installed cost and in service performance.

Steel industry uses over 70 percent of the refractories consumed in the country. However, integrated steel plants employ a team of refractory engineers and specialists for selection and use of refractories. On the other hand, non-ferrous sector, the glass industry and the other high temperature and corrosion intensive industries do not always employ refractory specialists. The application of refractories in such industries is never the less very critical and any premature failure may lead to long down times and loss of production.

With the above problems of unrecognized sector in mind, the Refractories Sectional Committee, MTD 15 decided to bring out a Handbook for Refractories which could be used as a reference book by the unrecognized sector. The Refractories Sectional Committee, MTD 15 allotted this work to a specially constituted panel, MTD 15/P-1, panel for the Handbook for Refractories, consisting of experts from various fields of activities which the handbook will eventually cover. It is hoped that the work of this panel would lead to improvement of refractory engineering practices and overall conservation of materials and energy.

The handbook will first be published separately as recommendations: each recommendation dealing with particular industry/process. Later on, when all recommendations are published,these would be combined to form a handbook. It is intended to cover the refractories used in the following industries in the handbook for refractories:

1. Refractories for cement kiln systems (large plants);
2. Refractories for mini-cement plants;
3. Refractories for petroleum and petro-chemical industry;
4. Refractories for pulp and paper industry;
5. Refractories for lime kilns-rotary type and shaft type;
6. Refractories used in the primary processing of non-ferrous materials such as aluminium, copper, zinc, lead, etc;
7. Refractories used in the manufacture of ferro-alloys;
8. Refractories used in the pouring practices for ferrous and non-ferrous materials;
9. Refractories for incinerators;
10. Refractories used by the ceramic and refractory industry;
11. Refractories for the nuclear fuel plants;
12. Refractories for the glass industry;
13. Refractories for the glass fibre industry; and
14. Refractories for the iron and steel industry.

(*Continued on third cover page*)

Indian Standard

REFRACTORIES FOR FORGE AND HEAT TREATMENT FURNACES — RECOMMENDATIONS

1 SCOPE

This standard covers the recommendations for refractories generally used for forge and heat treatment furnaces.

2 REFERENCES

The Indian Standards listed below are necessary adjuncts to this standard :

IS No.	*Title*
8 : 1994	High duty fireclay refractories (*fifth revision*)
3305 : 1965	Burnt chrome-magnesite refractories for general purposes
4041 : 1987	Glossary of terms relating to refractory materials

3 TERMINOLOGY

For the purpose of this standard, the definitions given in IS 4041 : 1987 shall apply.

4 INTRODUCTION

For processing steel and its alloys, billets, rounds, squares, etc, for production of finished products; forging method plays a very vital role. In forging industry the heating furnaces are used to raise the temperature of steel to pyroplastic stage working or shaping, such as cutting, rolling or forging. Temperature of these furnaces are usally as follows:

Cutting — around 400°C
Forging — above 1 100°C

However, heat treatment furnaces which are also the most important units in the forging industry, operate at lower temperature generally from 450 to 1 050°C. The heat treatment operations carried out are generally as follows:

a) Hardening,
b) Annealing,
c) Normalizing,
d) Carburising, and
e) Tempering.

5 FORGING PROCESS AND FURNACES USED

5.1 The basic unit operation involved in a modern forging process is as stated in the flow diagram given in Fig. 1.

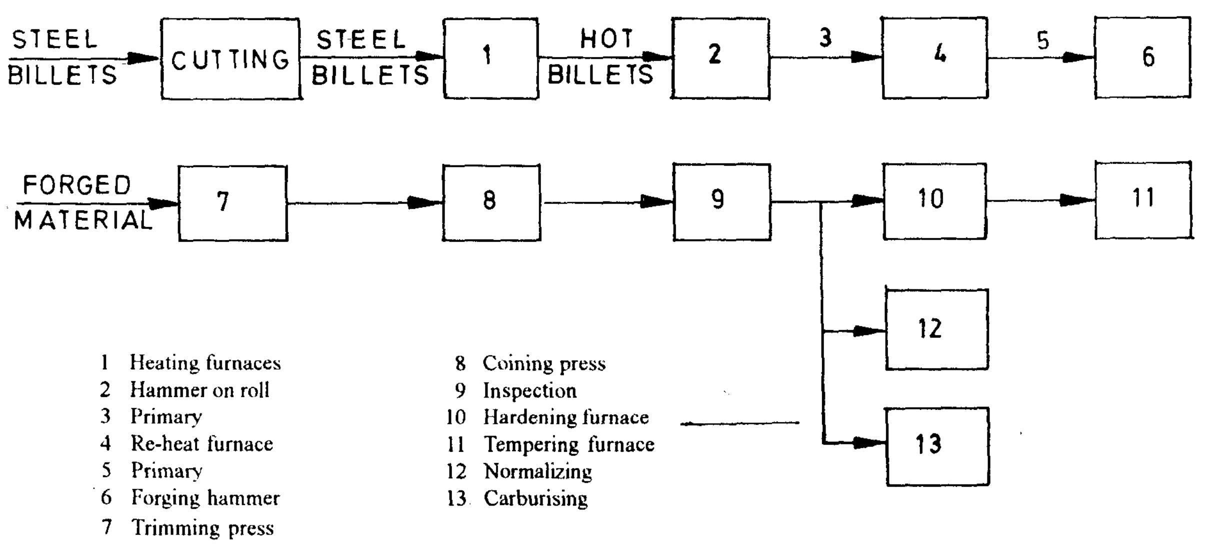


FIG. 1 FLOW DIAGRAM OF A FORGING PROCESS

5.2 In a forging process, furnaces are required at the following stages:

a) Heating billets (1 100 – 1 250°C)
b) Re-heating primaries/rolled billets (1 200 – 1 325°C)
c) Hardening (800 – 750°C)
d) Tempering (450 – 750°C)
e) Normalizing (800 – 900°C)

5.2.1 In a few processes one heating furnace (300 to 400°C) just before billets (hot cropping) and one re-heating furnace (1 200 to 1 250°C) just before coining press is also practised.

6 FURNACE STRUCTURAL DESIGN

Different structural elements common to all categories of furnaces are as follows:

a) Furnace hearth,
b) Furnace walls,
c) Furnace roof,
d) Flue off-takes and stacks,
e) Recuperators, and
f) Burner ports.

7 CLASSIFICATIONS AND TYPES OF FURNACES USED IN FORGING INDUSTRY

7.1 Depending on the types of fuel used, furnace are classified as follows:

Type	*Example*
Solid fuel fired	Coal fired furnaces
Liquid fuel fired	Oil fired furnaces
Gas fired	Gas fired furnaces
Electrically heated	Electric furnaces
Dual fired	Soild-liquid/ liquid-gas/ soild-gas

7.2 These furnaces can be of three different types:

Type	*Characteristic*
Batch type	Low production rate and low fuel efficiency
Semi batch type	Improved production low fuel efficiency
Continuous	Desired production rate and low fuel efficiency

7.2.1 These furnaces can be with or without muffle. These furnaces can be with under firing system or top firing system or combination of both the systems.

7.3 Furnaces Classified by Application

7.3.1 *Forging Furnaces*

Batch Type	*Semi Continuous*	*Continuous*
Box type	Box type with discharge	Purchase type
Slot type (for spring flats)	Unit fork	Walking beam type
Pit type	Pit type	Rotary hearth

7.3.2 *Heat Treatment Furnace*

Batch Type	*Semi Continuous*	*Continuous*
Box type	Bogey hearth	Pusher type
Pit type	Pit type	Walking beam type Roller hearth Cast link conveyorised Slat conveyorised Slat conveyorised with wire mesh Shaker hearth

7.3.3 Typical examples of furnace type are given in Fig. 2 and Fig. 3.

7.4 Zone Concept and Discharge

7.4.1 Batch type forging and heat treatment furnaces have one zone only and are called furnaces horizontal.

7.4.2 Continuous furnaces are mostly multizonal, having 2, 3 or more zones. The zone distribution in the furnaces can be any one of the following depending on the requirement:

a) Lowest temperature zone at charge end and highest temperature in soaking zone at discharge end.

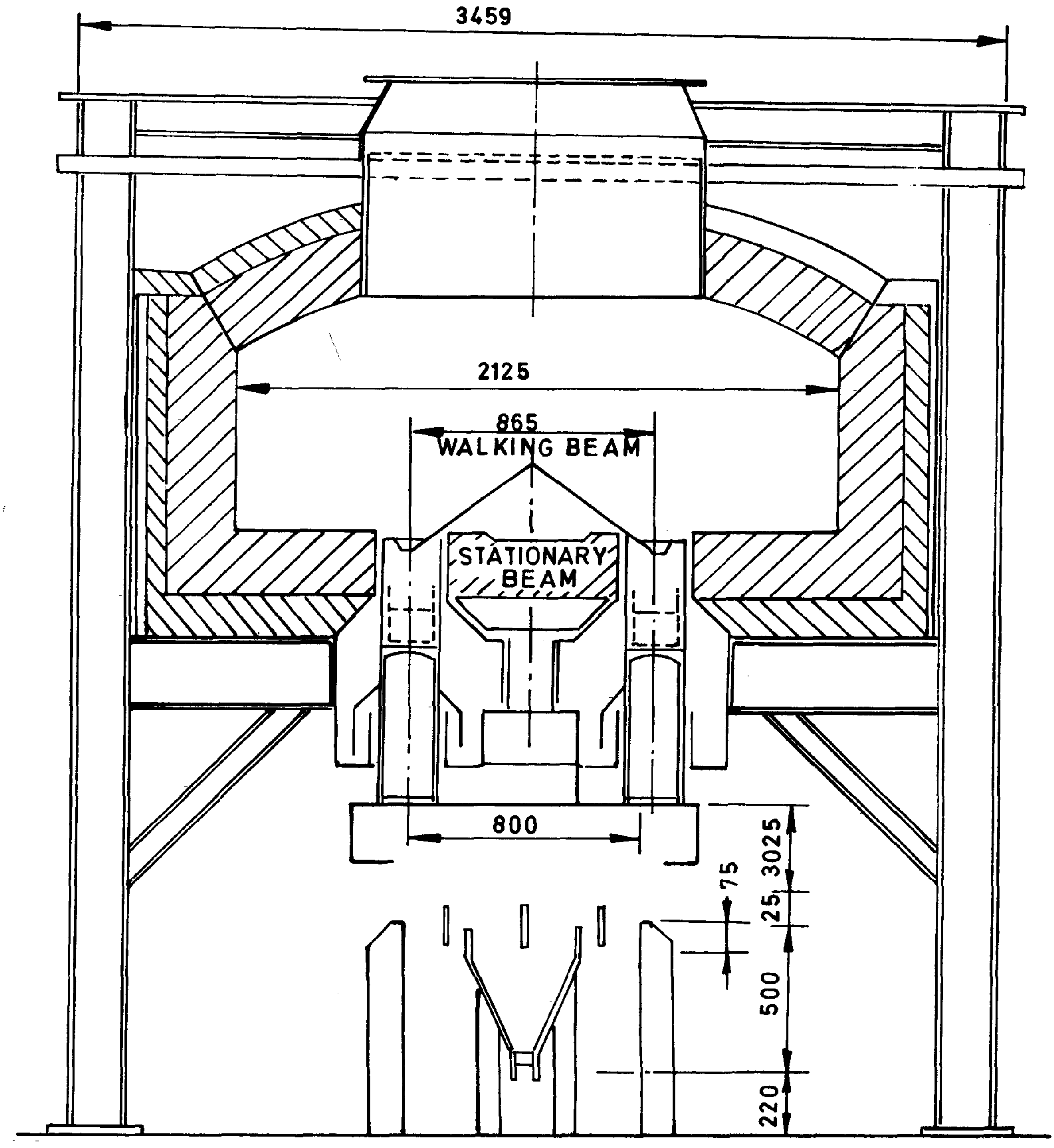
b) Highest temperature at charge end and soaking zone at just required forging temperature but lower than charge end temperature at discharge end.

c) Lowest at charge end highest at middle and higher discharge end.

7.4.3 These furnaces may have end discharge or side discharge.

7.4.4 Selection of refractories is very much dependent on the zone distribution.

7.5 Selection or adoption of the forging and heat treatment furnaces depends on the following



All dimensions in millimetres.

FIG. 2 TYPICAL WALKING BEAM FURNACE

factors:

a) Billet's shape and size, and their suitability for handling inside the furnace;

b) Availability of the type of fuel;

c) Maintenance facility available with the organization;

d) Captial investment capability of the organization;

e) Economy of the process desired including recurring operation cost and maintenance cost;

f) Production rate desired; and

g) Amount of the involvement of the human elements desired with the process that is the extent of automation.

8 SELECTION OF REFRACTORIES

8.1 The choice of refractories in forging and heat treatment furnaces relates to the following major

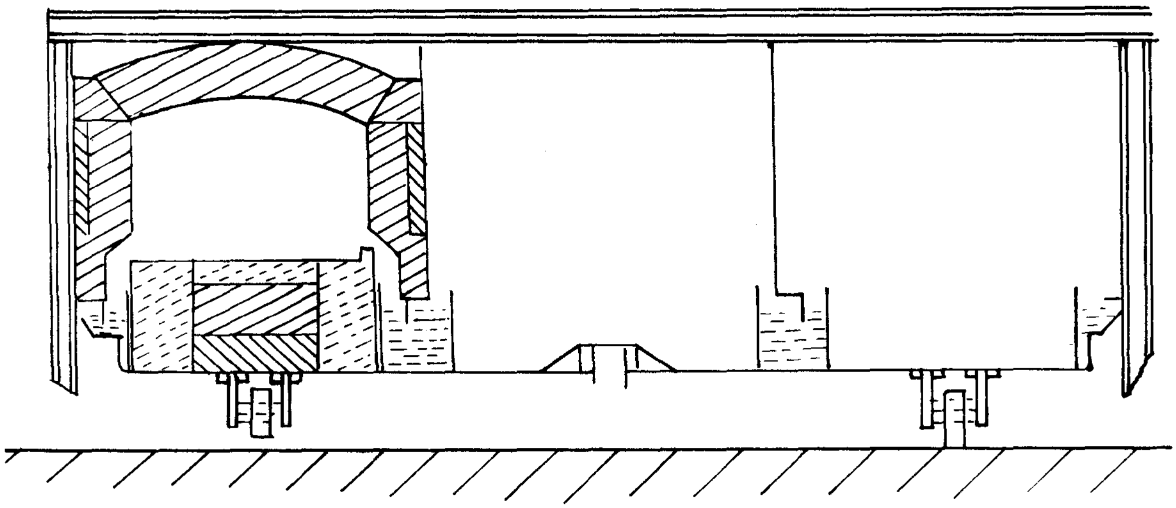


FIG. 3 TYPICAL ROTARY HEARTH FURNACE

aspects:

a) Selection of right type of refractories from available range of products to achieve desired performance;
b) Design of the lining and special shapes;
c) Conservation of energy; and
d) Cost.

8.1.1 However, service conditions dictate the essential features of the design and selection of refractories. Objective evaluation of the conditions, proper assessment and correlation of the refractory property to performance are the essential criteria. For setting up minimum requirement to meet any particular set conditions so that desired end result can be achieved with available range of materials.

8.2 The important condition to be considered in the selection of refractories for forging and heat treatment furnaces are as follows:

a) Area of application,
b) Service temperature,
c) Abrasion encountered in the process,
d) Structural load due to charge,
e) Temperature fluctuation,
f) Vibration limit,
g) Chemical compatibility to furnace environment,
h) Contact with scale and slags, and
j) Conservation of fuel.

8.3 Recommended Refractories for Forging Furnaces

Furnace	*Area*	*Refractories*
Batch type and semi-continuous type	Walls	Dense firebricks conforming to IS 8 : 1994 backed by cold face insulation
	Roof	Dense firebricks conforming to IS 8 : 1994 backed by cold face insulation
	Hearth	Sillimanite, high alumina of chrome magnesite
Continuous type (soaking zone is most critical and hearth requires special attention)	Walls	Dense firebricks conforming to IS 8 : 1994 backed by cold face insulation
	Roof	Dense firebricks conforming to IS 8 : 1994 backed by cold face insulation

Furnace	*Area*	*Refractories*
	Hearth	a) Chorme-magnesite where chances of contact of the hearth with moisture is not there b) Sillimanite or high alumina (60 percent) quality with no silica c) High alumina (85 percent) d) Fusion cast refractories e) Silicon carbide shape

8.4 Over the last 10 years, ceramic fibres in various forms have been increasingly in use for lining both forging and heat treatment furnaces. Lower portion of the walls attached to the hearth is lined with conventional refractory bricks in order to avoid the chance of damage of the ceramic wool due to mechanical collision. Roof and upper portion of the walls are lined with ceramic blanket or its '*z*' block modules.

8.5 These ceramic fibres are made of various base materials, such as silica, alumino-silicates, pure alumina, zirconia, chrome, etc. Ceramic fibres are available in various forms such as, felts, blanket, rope, tape, block, etc. Typical properties of ceramic fibres for use in forging and heat-treatment furnaces are given in Annex A.

8.6 Typical specifications for electrocast corrundum blocks and electrocast refractories for solid hearth are also given in Annex A.

8.7 Monlithics in the form of castable, mouldables and plastics are extensively used in the construction and maintenance of forging and heat treatment furnaces. Castables are of hydraulic setting type and mouldables and plastic are of chemical or air setting type.

8.8 It is of paramount importance to stress the necessity of suitable mortars and good workmanship in laying bricks in achieving superior result. This involves proper bondings with proper expansion joints. Design of the refractory shapes are also quite relevant to the performance. Improper design of furnaces or faults in manufacturing process may give rise to premature failure of furnaces during service. Some of the examples of bad design and manufacturing processes are:

a) overhang in hearth shapes,

b) sharp edges and corners in certain refractory shapes,

c) improper selection of the raw materials and given size control, and

d) existence of residual stresses during the manufacturing process.

8.9 Burner Quarls or Burner Blocks

Sillimanite or high alumina refractories with 60 percent alumina may be used for the burner quarls or burner block with advantage.

9 REFRACTORY CONSUMPTION TREND

Refractory consumption in forging industry is very low. It is about 1 to 2 percent of the total expenditure. In fact loss of production due to non-availability of the plants during the repair time is costlier than the refractoriy repair cost. Therefore, costlier refractory materials having much better technical properties may be selected for use for getting longer life with less number of shut-downs to achieve lower overall cost of refractories per tonne of product. Ultimate performance of refractories is judged by the overall cost, that is cost of refractories and the cost due to breakdown.

ANNEX A

(*Foreword* and *Clause* 8.5)

PROPERTIES OF REFRACTORIES USED IN FORGING AND HEAT – TREATMENT FURNACES

Table 1 Characteristics of Electrocast Refractories for Soild Hearth

Characteristics	Requirements
(1)	(2)
Al_2O_3, percent, *Min*	90.0
SiO_2, percent, *Max*	2.0
TiO_2, percent, *Max*	1.0
Fe_2O_3, percent, *Max*	2.0
Na_2O, percent, *Max*	1.0
Other oxides, percent, *Max*	2.0
R. U. L., *ta*°C, *Min*	17.0
B.D., g/cm³, *Min*	3.0

Table 2 Characteristics of Alumina Silicate Fibre

Characteristics	Requirements	
	Oxide I	Oxide II
(1)	(2)	(3)
Al_2O_3	32 -36	43-47
ZrO_2	16.5 -19.5	—
SiO_2	44 -48	53-57
Tensile strength, kPa	30- 60	30-60
Specific heat capacity at 980°C (1.5/kg°C)	1.07	1.07
Melting point,°C	More than 1 650	More than 1 760

Table 3 Relative Properties of Ceramic Fibres/Other Refractories

Characteristics	Requirements		
	Ceramic Fibre		Insulation Bricks
	I	II	
(1)	(2)	(3)	(4)
Pyrometric cone equivalent, standard cone (ASTM), *Min*	—	—	27
Bulk density, g/cm³	0.13, *Min*	0.16, *Min*	0.7-0.75
Thermal conductivity at mean temp of 550°C (W/m°K), *Max*	0.11	0.12	0.30

Table 4 Properties of Some Indigenous Refractories in Reheating Furnaces

Characteristics	Requirements				
	Super Duty		Sillimanite Bricks	High Alumina	
	I	II		I	II
(1)	(2)	(3)	(4)	(5)	(6)
Al_2O_3, percent, *Min*	38	40	58	58	78
Fe_2O_3, percent, *Max*	2.0	2.0	1.2, *Min*	3.0	—
PCE (Orton), *Min*	33	34	36	35	38
AP, percent, *Max*	19	22	17, *Min*	23	23
BD, g/cm³, *Min*	2.2	2.4	2.4	2.45	2.45
CCS, kg/cm², *Min*	400	450	400	400	500
Reheat change 1 400 °C/2 h, percent, *Max*	± 0.5	± 0.5	± 0.5	± 1.0	± 1.0 (1 500°C/2 h)
RUL, *ta*°C, *Min*	1 450	1 480	—	—	—

Table 5 Properties of Monolithic Refractories in Reheating Furnaces

Characteristics		Requirement					
		Castables			Plastic Refractories		
		I	II	III	I	II	III
(1)		(2)	(3)	(4)	(5)	(6)	(7)
Al_2O_3		50-55	60-65	88-92	55-60	43-45	79-91
Fe_2O_3		1.0-1.7	0.7-1.5	0.5-0.7	1-2	0.3-1.5	1.5-2.0
PCE (Orton)		28-31	30-32	38-39	35-36	32-33	38, *Min*
BD, g/cm³		2.3, *Min* (110°C)	2.5, *Min* (110°C)	3.1, *Min* (110°C)	2.2-2.3	2.3-2.4	2.8-2.9
MOR, kg/cm²		—	—	—	4-6	20-30	4-6
Service temperature, °C, *Max*		1 500	1 600	1 750	1 650	1 500	1 700
CCS kg/cm², *Min* at	110°C	350	450	500-800	—	—	—
at	1 350°C	300	300	500	—	—	—
at	1 450°C	–	–	600	—	—	—

(*Continued from second cover page*)

Each recommendation will cover the following aspects of the refractory engineering:

a) Process of manufacture used;
b) Type of boiler furnaces systems;
c) Objectives of the refractory lining;
d) Design engineering features of the furnaces;
e) Principal zones and sections of the furnaces;
f) Service conditions in different zones including service temperatures;
g) Details of lining used in various zones and sections;
h) Refractory installation practices used for the boilers/furnaces;
j) Consumption pattern of refractories;
k) Applicable standards, namely, Indian and other standards, designs, codes, stress considerations, etc; and
m) Miscellaneous aspects not covered from (a) to (k).

This standard covers the recommendations for the types of furnaces used in the forging shops and heat treatment shops, their structural design, various temperature zones and the basis of selection of refractories. It further covers the recommendations for refractories for use in various zones of furnaces and heat treatment furnaces. It also recommends the use of ceramic fibres for lining of various zones of the furnaces and compares of the properties of ceramic fibres with those of the conventional insulating materials.

Annex A of the standard gives the typical properties of refractories used in the forging and heat-treatment furnaces.

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.

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