IS : 10607 - 1983
(Reaffirmed 1997)

Indian Standard

SPECIFICATION FOR REFRACTORIES FOR CEMENT ROTARY KILNS

UDC 666·76 : 666·94·043'13

INDIAN STANDARDS INSTITUTION
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

Gr 6

August 1984

Indian Standard

SPECIFICATION FOR REFRACTORIES FOR CEMENT ROTARY KILNS

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(*Continued on page* 18)

Indian Standard

SPECIFICATION FOR REFRACTORIES FOR CEMENT ROTARY KILNS

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 21 April 1983, after the draft finalized by the Refractories Sectional Committee had been approved by the Structural and Metals Division Council.

0.2 This standard has been prepared for rationalizing the requirements of refractory bricks and refractory castables used for lining of cement rotary kilns. In the preparation of this standard, data collected from the cement manufacturers as well as the refractory manufacturers regarding the type of bricks and other refractory materials presently being used in the country, were analysed, and after deliberations, it was decided to restrict the requirements to three types of alumino-silicate and high alumina bricks, three types of refractory castables and one type of insulating castable for use in the cement rotary kilns.

0.3 The use of basic bricks is not prevalent to a very great extent in our country at present, and therefore basic bricks have not been covered in the standard.

0.4 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*. 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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1. SCOPE

1.1 This standard describes the service conditions in the different zones of cement rotary kilns, makes recommendations for the types of refractories to be used in the different zones and specifies the requirements for the different types of refractories.

2. TERMINOLOGY

2.0 For the purpose of this standard, the following definitions shall apply.

*Rules for rounding off numerical values (*revised*).

2.1 Cement Manufacturing Process — Ordinary portland cement is obtained from a clinker which is produced by burning a finely ground thoroughly homogenized mixture of raw materials, generally consisting of limestone and clay in requisite proportions with or without other corrective materials, at 1 400-1 500°C in a kiln. The manufacturing process is designated as dry, semidry and wet, depending on whether the raw mix, fed to the kiln, is in the form of a dry powder, green nodules or an aqueous slurry.

2.2 Rotary Kiln — Rotary kilns are steel tubes having an inner refractory lining, with a slope of 3-4 percent to the horizontal, and rotating on its long axis usually with a speed of 1 to 2 rpm. The tubes generally have a diameter in the range of 2·5 to 5 m (maximum up to 7 m as presently known). The length of the tubes vary from 14-17 to 32-35 times the diameter. The tube is mounted on a number of roller supports.

2.3 Zonation in Cement Rotary Kiln — Depending on the function of a rotary kiln and the transformation that takes place during the passage of a raw mix through it, a rotary kiln is divided from the feed end to the discharge end in the following zones; drying, preheating, transition or intermediate, burning, cooling or discharge. The zonation is conceptual but the operating conditions in each zone are different. Typical illustrations for dry and wet process kilns are given in Fig. 1 and 2.

2.4 Suspension Preheater — It is a preheater used in the dry process of manufacture and consists of a system of cyclones (generally 2 or 4) with connecting pipes, through which the exist gases of a rotary kiln are passed by means of a fan. The raw mix which passes through the system in the opposite direction to the gases (counterflow) is separated from the gas stream in each cyclone and is reintroduced into the stream, in the next stage. The raw meal is conveyed through the pipes by the hot gases (uniflow). In the suspension preheater the raw mix is partially calcined (40 to 50 percent) before it reaches the rotary kiln.

2.5 Precalcinator — It is a calcining system introduced in a dry-process suspension preheater kiln between the suspension preheater and the rotary kiln for precalcination of raw mixes to an extent of 85 to 90 percent.

2.6 Concentrator — A concentrator (also called a calcinator) is a heat exchanger made of a slow rotating drum with built-in heat-transfer elements and installed before the rotary kiln. The hot gases from the kiln are passed through the drum for effective heat transfer between the raw mix and hot kiln gases.

2.7 Grate Preheater — It is a travelling grate carrying a bed of nodulized raw meal through which the hot kiln gases are passed for heat transfer. The grates can have a double-pass system in which the kiln gases are passed twice through the bed of nodules.

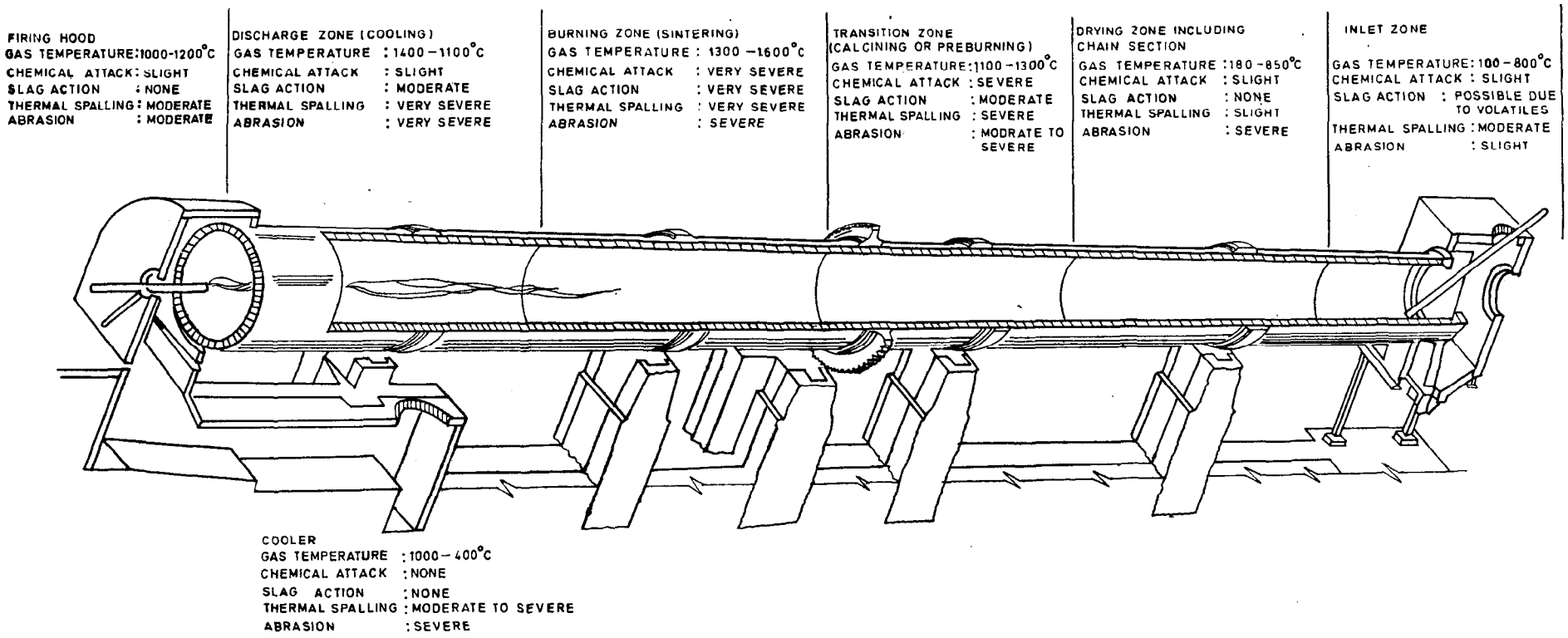

FIG. 1 ZONATION IN TYPICAL WET PROCESS ROTARY KILN SYSTEM

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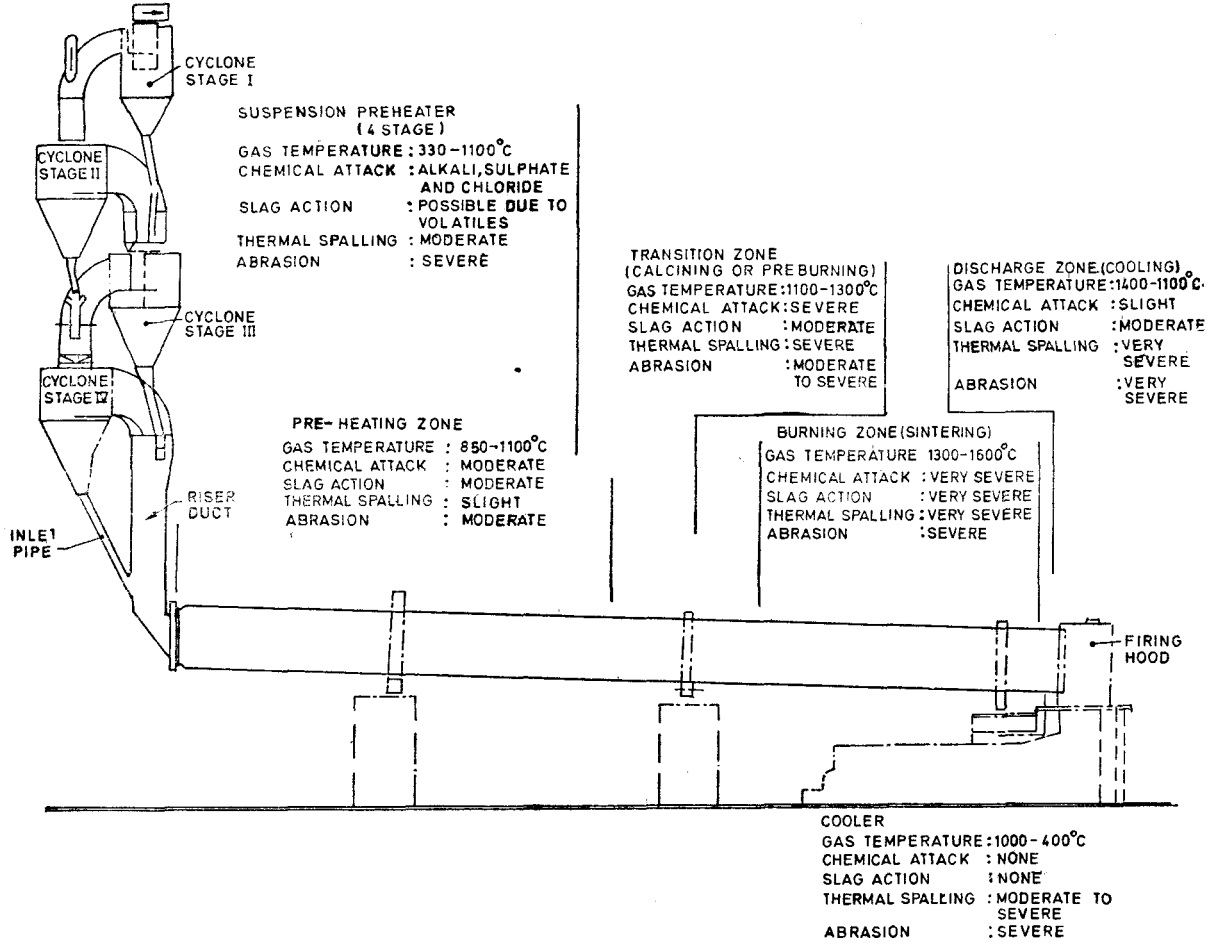

FIG. 2 ZONATION IN TYPICAL DRY-PROCESS ROTARY KILN SYSTEM

2.8 Smoke Chamber — A refractory lined chamber housing the kiln feed pipe and provides an air seal at the inlet end of the kiln.

2.9 Chain Section — In the wet process of manufacture the colder section of a kiln from the inlet side is provided with hanging metallic chains of various configuration for effective heat transfer between the raw mix and hot kiln gases.

2.10 Trefoil — A trefoil is a heat-exchanger built inside the kiln with specially shaped refractory blocks. It is generally of Y configuration in the kiln cross-section.

2.11 Tumbler — Tumblers (or tumbling ledges or lifters) are heat exchangers built inside a rotary kiln with refractory materials particularly in the pre-heating zone or cooling zone. The tumblers are designed to cascade the charge for better heat-exchange.

2.12 Dam Ring — It is a refractory obstacle built inside rotary kiln to increase the residence time of the charge or to divert the material flow. Kilns with planetary coolers often have a refractory dam ring which regulates the flow of clinker into the cooler spouts.

2.13 Nose Ring — The nose ring is the end section of a kiln through which the hot clinker passes over the tip casting to the cooler system as in end discharge kilns.

2.14 Firing Hood — It refers to the firing (mobile or fixed) hood of a rotary cement kiln where the fuel (coal, oil, or gas) is fed at the firing end of a kiln which generally forms the junction with coolers and carries the burner equipment, observation posts and access doors and also provide air seal at the discharge end of the kiln.

2.15 Cooler Chute — The chute connecting the kiln discharge and the cooler inlet.

2.16 Rotary Cooler — It is a rotating inclined cylindrical steel tube below the discharge end of the rotary kiln. Hot clinker is discharged from the rotary kiln into the raised end of the tube, cooled by air drawn through the cooler by the kiln induced-draught system, and discharged from the other end of the tube.

2.17 Planetary (Integral) Cooler — A planetary cooler is made of a number of small-diameter steel tubes (generally 9 to 11) symmetrically mounted on the outer side of a rotary kiln shell near the discharge end. The cooler tubes are connected to the kiln shell through ports to admit hot clinker, which is cooled by a flow of air, and discharged through opening at the other end of the tubes.

2.18 Grate Cooler — It is a type of cooler in which air is blown through a bed of clinker carried on a grate formed of a number of rows of plates, alternate rows being fixed and reciprocating. The grates can either be inclined or horizontal. The cold air is blown by fans into the space below the grate which is divided into chambers, and flows up through perforations in the plates and through the bed of clinker.

2.19 Castable Refractories — A mixture of refractory aggregate and heat-resisting hydraulic cement. These products are generally cast or gunned into place.

2.20 Plastic Refractories — These are monolithic refractories manufactured and packed in mouldable ready-to-use form and are generally rammed into place with a pneumatic hammer. The bond may be chemical or heat-setting.

2.21 Ramming Masses — These are monolithic refractories either supplied in moist ready-to-use form or in dry form for mixing on the job. The bond may be chemical and/or heat setting.

2.22 Air Setting Refractory Mortar — A refractory material containing chemical agents for ensuring hardening at room temperature.

2.23 Anchor — A metallic or ceramic device to hold refractory concrete in stable positions while encountering effects of various types of load, thermal stresses and vibration.

2.24 Clinker Coating — The refractory lining in the burning zone of a rotary kiln acquires a protective coating due to the interaction between the charge and refractory material during the kiln campaign. This is known as clinker coating which is essential for the durability of a burning zone lining.

3. RECOMMENDATIONS FOR TYPES OF REFRACTORIES TO BE USED FOR LINING DIFFERENT ZONES OF ROTARY KILNS

3.1 The service conditions obtained in the various parts of cement rotary kilns and the ancillaries are given in Table 1. The recommended refractory linings for the different zones are given in Table 2.

3.1.1 Three grades of alumino-silicate and high alumina bricks, three grades of refractory castables and one grade of insulating castable are recommended for lining different zones of the rotary kilns.

4. REQUIREMENTS FOR REFRACTORY BRICKS

4.1 Grades of Refractory Bricks — There shall be three grades of refractory bricks for lining of cement rotary kilns, that is 35 percent alumina bricks, 55 percent alumina bricks and 70 percent alumina bricks.

TABLE 1 SERVICE CONDITIONS IN CEMENT ROTARY KILN SYSTEM

(*Clause* 3.1)

KILN ZONE	GAS TEMPERATURE (°C)	MATERIAL TEMPERATURE (°C)	CHEMICAL ATTACK	SLAG ACTION	THERMAL SPALLING	ABRASION
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Grate preheater	100-1 000	Up to 700	Alkali, sulphate and chloride	Possible due to volatiles	Moderate	Slight
*Suspension preheater (4-stage)	330-1 100	Up to 800	Alkali, sulphate and chloride	Possible due to volatiles	Moderate	Severe
Drying zone including chain, etc	180- 850	Up to 250	Slight	None	Slight	Severe
Preheating zone	850-1 100	Up to 550-600	Moderate	Moderate	Slight	Moderate
Transition zone (calcining or preburning)	1 100-1 300	Up to 1 100	Severe	Moderate	Severe	Moderate to severe
Burning zone (sintering)	1 300-1 600	Up to 1 450	Very severe	Very severe	Very severe	Severe
Discharge zone (cooling)	1 400-1 100	Up to 1 100	Slight	Moderate	Very severe	Very severe
Firing hood	1 000-1 200	—	Slight	—	Moderate	Moderate
Cooler spout	1 000-1 100	900-1 000	None	None	Moderate to severe	Very severe
Coolers	1 000- 400	Up to 80-300	None	None	Moderate to severe	Severe

*With precalcinator, the gas temperature will be 350 to 1 100°C and the material temperature will be up to 900°C.

TABLE 2 REFRACTORIES FOR THE IMPORTANT ZONES OF CEMENT ROTARY KILN SYSTEM

KILN ZONE	REFRACTORIES	
	Bricks	Castables
Grate preheater	35 percent alumina bricks	Medium purity high strength alumino-silicate castables (Grade 300)
Suspension preheater	*Hot face* — 35 percent alumina bricks	*Hot face* — High purity alumino-silicate castable of high strength (Grade 400)
	Backing — Insulating bricks conforming to Type 1 of IS : 2042-1972*	*Backing* — Insulating castable of 1 100-1 200 kg/m³ density for backing (insulating grade)
		Sealing areas in roof ducts — High strength medium purity alumino-silicate castable (Grade 400)
Drying zone including chain section	35 percent alumina bricks	Medium purity high strength alumino-silicate castables (Grade 300)
Pre-heating zone	35 percent alumina bricks	High purity high strength coarse (up to 10 mm) castables (Grade 400)
Transition zone	55 percent alumina bricks	Castables not used
Burning zone	70 percent alumina bricks	
Discharge zone including cooler spouts	70 percent alumina bricks	Extra high strength +90 percent alumina wear-resistant castable (Grade 500) *see* Note 3
Grate coolers and cooler tubes	35 percent alumina bricks	*See* Note 1 and Fig. 3

NOTE 1 — Depending upon the location (*see* Fig. 3), for instance, target wall *A*, side wall *B* and its extension *C* and roof *D* of grate coolers, different grades of castables as given below are used:

Position *A*	Grade 500 castable
Position *B*	Grade 400 castable
Position *C*	Grade 300 castable
Position *D*	Grade 300 castable

NOTE 2 — For precalcinator vessels, kiln inlets, tumbling ledges in preheating zone, tip casting, firing hood, etc, castables are preferred to bricks and the general recommendations are given below:

a) Precalcinator	
1) Bottom, roof, gas duct, damper	Grade 400 castable
2) Precalciner back-up	Insulating castable
b) Dam ring, cooler inlet, tip'casting kiln outlet	Grade 500 castable
c) Tumbler ledges	Grade 400 castable
d) Kiln firing hood	Grade 300 castable

NOTE 3 — At certain locations, ramming mass can also be used, for example, in planetary cooler spouts and discharge zones. Requirements of ramming mass should be a matter of mutual agreement between the purchaser and the supplier.

NOTE 4 — For suspension preheaters, 35 percent alumina bricks may be used for the hot face, with a backing consisting of insulating castables.

*Specification for insulating bricks (*first revision*).

4.2 Chemical Composition and Physical Properties — The chemical composition and the physical properties of the three grades of bricks shall be as given in Table 3. The physical properties shall be determined in accordance with the relevant test methods specified in the different parts of IS : 1528*.

4.3 Size and Shape of Refractory Bricks — The size and shape of the wedge-shaped high alumina bricks for use in cement rotary kilns shall be as given in Table 4.

4.3.1 *Tolerances* — The dimensional tolerance for 35 percent alumina bricks shall be ±2 percent or ±2 mm, whichever is higher. The tolerances for 50 percent alumina bricks and 70 percent alumina bricks shall be ±1·5 percent or ±2 mm, whichever is higher.

4.3.2 Circular bricks may be used subject to mutual agreement between the manufacturer and the purchaser and the sizes and tolerances shall also be mutually agreed in such cases.

4.3.2.1 Although both circular as well as wedge shaped bricks are presently used in the cement industry, the trend is gradually changing over from circular bricks to wedge bricks due to the following advantages in wedge brick linings:

a) Wedge bricks can be laid in any diameter of kiln choosing correct ratio of two sizes,

b) Bricks fit the undulated shell properly by choice of combination of bricks,

c) Chipping and dressing of bricks is minimized, and

d) Installation is faster and inventories are reduced in the case of wedge bricks.

4.4 General requirements for the supply of refractory bricks shall be in accordance with IS : 1387-1967†.

4.5 Sampling — The sampling for determining the characteristics of refractory bricks shall be done in accordance with IS : 1528 (Part 7)-1974‡.

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*Methods of sampling and physical tests for refractory materials (*issued in several parts*).

†General requirements for the supply of metallurgical materials (*first revision*).

‡Methods of sampling and physical tests for refractory materials : Part 7 Methods of sampling and criteria for conformity (*first revision*).

TABLE 3 REQUIREMENTS FOR ALUMINO-SILICATE AND HIGH ALUMINA BRICKS

(*Clause* 4.2)

SL NO.	CHARACTERISTIC	REQUIREMENT		
		35 Percent Alumina Bricks	55 Percent Alumina Bricks	70 Percent Alumina Bricks
(1)	(2)	(3)	(4)	(5)
i)	Al_2O_3, percent, *Min*	35	55	70
ii)	Fe_2O_3, percent, *Max*	2·5	2·5	3·5
iii)	Pyrometric cone equivalent (Orton) *Min*	30	34	36
iv)	Permanent linear change	±1 percent at 1 350°C for 5 h	±1 percent at 1 400°C for 2 h	±2·5 percent at 1 500°C for 2 h
v)	Refractoriness under lead (RUL) t_a, *Min*	1 300°C	1 400°C	1 450°C
vi)	Apparent porosity, percent, *Max*	25	25	23
vii)	Cold crushing strength, kgf/cm^2, *Min*	250	300	400

NOTE 1 — The characteristics, specified in this Table, are applicable to machine-moulded refractory bricks only.

NOTE 2 — The requirements of Fe_2O_3 and RUL for 70 percent Al_2O_3 bricks will be reviewed as soon as experience of using such bricks in large diameter kilns are available.

4.6 Marking

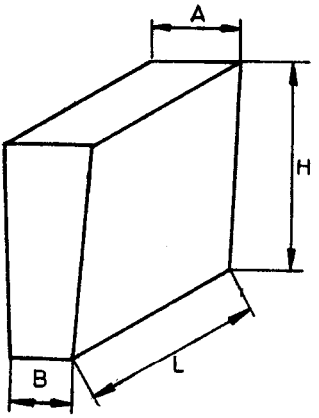
4.6.1 Each refractory brick shall be clearly marked with the manufacturer's name or trade-mark.

4.6.2 The working face of the wedge bricks shall be suitably marked with a paint for easy identification.

4.6.3 The bricks may also be marked with the ISI Certification Mark.

TABLE 4 SIZES OF WEDGE SHAPED HIGH ALUMINA BRICKS

(*Clause* 4.3)



DESIGNATION	DIMENSIONS (mm)			
	A	*B*	*H*	*L*
216		86·0		
316		92·0	160	
416		94·5		
516		96·5		
716		98·3		
218		84·0		
318		90·5	180	
418		93·5		
518		95·5		
618		97·0		
718		97·7		
220		82·0		
320		89·0		
420		92·5		
520	103	94·7	200	198
620		96·2		
720		97·0		
820		97·8		
322		88·0		
422		91·5		
522		94·0		
622		95·5	220	
722		96·5		
822		97·3		
425		90·0		
525		92·7		
625		94·5	250	
725		95·5		
825		96·5		

5. REQUIREMENTS FOR REFRACTORY CASTABLES

5.1 Grades of Refractory Castables — There shall be three grades of refractory castables classified on the basis of the minimum cold crushing strength value obtained after drying at 110°C and shall be classified as Grade 300, 400 and 500.

5.2 The requirements for the three grades of refractory castables are given in Table 5 for information only.

TABLE 5 REQUIREMENTS FOR DENSE REFRACTORY CASTABLES

Sl No.	Characteristics	Requirement		
		Grade 300	Grade 400	Grade 500
(1)	(2)	(3)	(4)	(5)
i)	Al_2O_3, percent, *Min*	50	50	90
ii)	Fe_2O_3, percent, *Max*	6	2	0·5
iii)	Cold crushing strength, kgf/cm^2, *Min*			
	a) after drying at 110°C	300	400	500
	b) after firing at 800-1 000°C	250	300	350
iv)	Grain size	Subject to agreement between the supplier and the purchaser		

NOTE — The refractory castables have been classified into three grades on the basis of minimum CCS value obtainable after drying at 110°C.

5.3 Insulating Castables — The requirements for insulating castables are given in Table 6, for information only.

5.4 Sampling and Test Methods — The properties of refractory castables shall be determined in accordance with the Indian Standard Methods of test for refractory castables (*under preparation*).

5.5 Marking — Each container of refractory and insulating castable shall be clearly marked with the manufacturer's name or trade-mark.

5.5.1 The containers may also be marked with the ISI Certification Mark.

NOTE — The use of the ISI Certification Mark is governed by the provisions of the Indian Standards Institution (Certification Marks) Act and the Rules and Regulations made thereunder. The ISI Mark on products covered by an Indian Standard conveys the assurance that they have been produced to comply with the requirements of that standard under a well-defined system of inspection, testing and quality control which is devised and supervised by ISI and operated by the producer. ISI marked products are also continuously checked by ISI for conformity to that standard as a further safeguard. Details of conditions under which a licence for the use of the ISI Certification Mark may be granted to manufacturers or processors, may be obtained from the Indian Standards Institution.

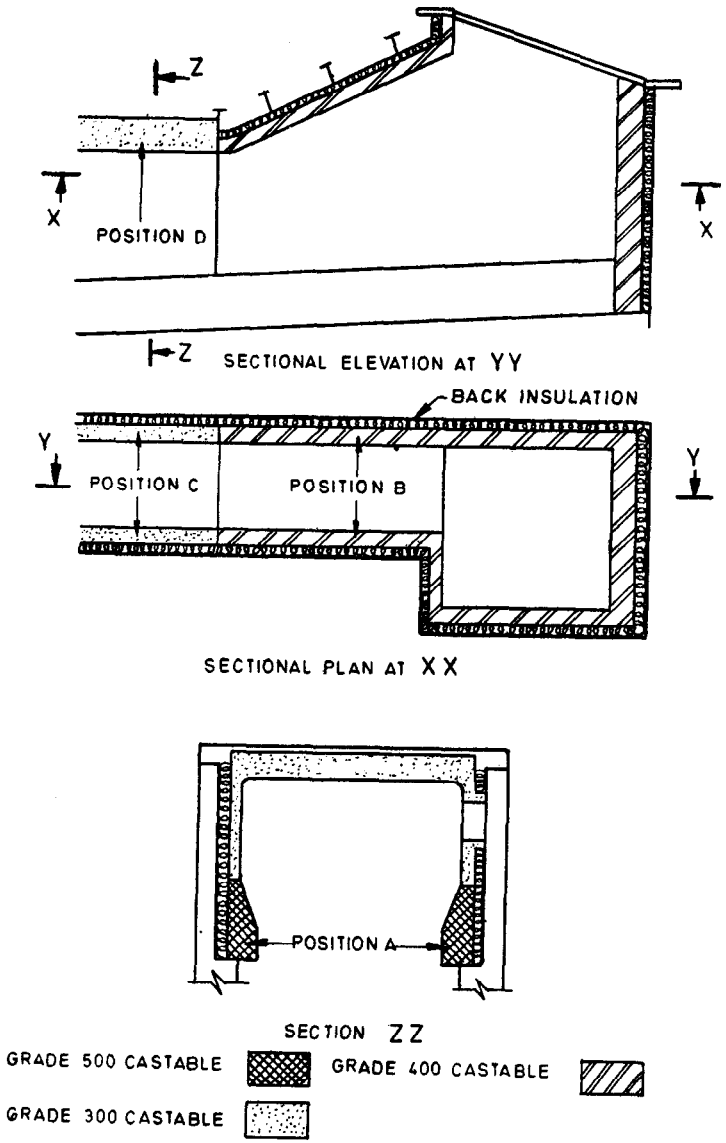


FIG. 3 REFRACTORY LINING FOR GRATE COOLER

TABLE 6 REQUIREMENTS FOR INSULATING CASTABLES

(*Clause* 5.3)

SL NO.	CHARACTERISTIC	REQUIREMENT
(1)	(2)	(3)
i)	Fe_2O_3, percent, *Max*	3·5
ii)	Bulk density, kg/m^3	1 100 to 1 200
iii)	Cold crushing strength after drying at 110°C, kgf/cm^2	30 to 40
iv)	Permanent linear change, after heating for 5 h at 1 300°, percent, *Max*	1·5
v)	Grain size	Subject to agreement between the supplier and the purchaser

(*Continued from page* 2)

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