Innovation in lining practice for reheat furnace of indian steel mill*

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Mr. Chairman and Fellow Delegates :-

Permit me to convey my sincerest thanks, to the organisers for their kind invitation to, what in effect, set the tone for, this seminar on a very topical theme, which has a relevance of far reaching character, not only for our Iron and Steel industry, but also for our entire industrial set-up. It is an honour, I greatly value.

Thanks to you also, Mr. Swaminathan, for your generous words of introduction.

After informing Dr. M.R.K. Rao, our Executive Secretary that I would be here this morning, for the assignment given, I wondered if it has not been an act of temerity on my part, verging perhaps on rashness, to agree to be the occupant of this floor, I had intended to and still propose, to do some thinking aloud, and share my thoughts with you. In the process, I would suggest some unconventional if not daring steps —Daring certainly these are not, by international standard, but may appear to be so by ours, where timidity pervades even our Iron and Steel industry which in other countries is a pace setter ; and hesitancy tends to retard every step of our other industries.

New technology

A new technology takes at least two decades to even draw the attention of industrial India and easily another one before a decision is taken to, haltingly try it out. The theme to which I want to turn your attention to, this morning furnishes an example of how slow is the pace of our industries.

Energy crisis

Innovation in lining practice for Reheat Furnace of Indian Steel Mill, which has very recently introduced in the country, let me state, at the very outset, is no novelty for such furnaces abroad. There it has been in vogue for nearly thirty years.

Overwhelming economic factors that have suddenly engulfed us, along with the rest of the world, demand its wide and immediate acceptance; but it appears, we are not yet even cognisant that energy crisis is a stark reality for us.

Indian practice

Reheat Furnaces of Indian Steel Plants have so far been generally lined with dense refractories—conventional firebricks of various grades with or without backing insulation bricks.

The impact of energy crisis which is faced by the world is also severe on India, because bulk of our liquid fuel is imported. The need has thus arisen of having a fresh look at our lining practice of our industrial furnaces with the immediate objective of conserving heat.

Practice abroad

It has been known that many types of reheat furnaces abroad had been entirely lined with light weight insulation, instead of dense bricks. Indeed even this practice abroad, is undergoing modification because of availability of new type of insulating refractory material there e. g. insulating ceramic blankets of comparatively small thickness. These are also capable of direct exposure to temperature and other service conditions prevalent in these and others with similar severe parameters.

In a recent (1976) review of refractory practice in U. S. A. Brown (1) mentions one of the best places for fuel saving is, the reheat furnace where steel slabs are brought to rolling temperature, particularly the skid pipe system, furnace roof and walls. Insulation firebrick used at first is giving place to ceramic fibre blanket for temperature upto 1260°C. Nearly 40% of such furnaces have been so converted in U. S A. It has also been used for higher temperatures. An interesting observation of this reviewer is : fastest growing section of the refractories industry there, is in ceramic fibres at present.

Leeway to make up

It had been assumed so far that refractory insulating brick capable of direct exposure to temperature of reheat furnace was not available in our country. The further assumption was that raw material required for their manufacture was not also indigenously available. Either the raw material or the brick will have to be imported if any such reheat furnace was to be built. It is not necessary to stress that building furnaces with imported material, brick, fibre or raw material, is not a practical proposition. It should be readily available in the country.

A furnace designer and builder of Calcutta determined to strike a new path, with fuel economy in view, made a simple theoretical calculation of amount of fuel consumed in about 40 hours time for an average size reheat furnace, conventionally built with dense firebrick. He made a similar calculation for one of same size, but built entirely with insulating firebrick, capable of direct exposure to furnace operating temperature as has been the practice abroad for over 30 years.

The comparative figures arrived at were startling. BTU consumed in the first case with dense brick construction was over 400 million. With insulation construction it was a little over 200 million.

These revealing data were enough, for decision making of the furnace designer; very appropriately, it was to go ahead with "all insulation" construction, using Indian material. Data on insulation brick of an Indian manufacturer seemed to meet requirement.

"All-Insulation" Construction

Many critical assessment was received and also made by itself of the aforesaid decision. As a result, the brand of insulation brick intended to be used was subjected to many tests. A major flaw was indeed, found in a critical property. Still the decision remained unaltered, with the provision that only brick of correct specification would be used for the proposed "all-insulation" furnaces.

Current Development

This brought two immediate problems viz. (a) Hot face insulation brick for 1500°C service had to be developed anew from Indian raw material, to meet international standard for such brick (b) The thus developed material was to be commercially manufactured within two to three months time, to meet the commitments of the furnace builder.

Surveying the overall situation, it was felt that immediate and simultaneous attention needed to be paid to

a) Testing facility

b) Raw material

c) Prevailing manufacturing process

A brief indication of what needed to be done for the above three items were :

a) Testing facility—By and large the manufacturer had the required testing facilities excepting for the one that is regarded as the most critical one for such insulating brick. From procurement of (i) drawing for the high temperature test furnace and (ii) firing equipment, through their installation to first trial test, was done in remarkably short time.

b) Raw material—It is only necessary to stress that, there was no option but to use easily available indigenous material. It is well to emphasise that Indian raw materials are eminently suitable for manufacturing any grade of insulation brick for direct exposure to 1500°C and even to 1600°C service whether required for service under oxidising or reducing e. g. carbon monoxide gas atmosphere prevalent in heat treatment furnace for ball bearing steel. The last named grade has been available in the country for over a decade.

It would not be out of place to mention that there seems to be a prevalent notion that without 'bubble alumina' a commodity currently not available in India, we would never be able to make such high temperature insulation brick. The results that I will shortly present do not support this assumption.

c) Manufacturing Process—Unfortunately, but perhaps fortunately for the furnace builder, mentioned above, many anti-dated practices still prevail in the manufacture of insulation and other refractory products in India. Coming specifically to insulating brick, a part of the manufacturing process, involved a 3 week period. This could be reduced to 3 days and in our assessment, could be reduced still further. This reduction, in manufacturing time helped to make up greatly the threatened extended delivery time of the brick and helped the furnace builder in a great measure, to stick to his scheduled time, set for lining the furnaces.

The test data that would be presented are on insulating brick made according to revised—shortened process of manufacture using Indian raw materials.

Design of furnaces of all-insulation construction

Before presenting data on insulating brick, attention would be drawn to the basic features of design of these furnaces. So far seven bogie hearth furnaces (7 to 10M) for reheating alloy steels for forging and operating at 1300°C, and also a Rotary Hearth Furnace (10 M diameter) for reheating alloy steel and operating at 1300°C have been commissioned.

A few pictures and diagrams of the furnaces commissioned are presented below to bring out their design features—

Figure (I) Inside view: "All Insulation" lining of Bogie Heath Furnace.—Suspended Roof.

Figure (II) Inside view of an All-insulation bogie hearth furnace—sprung Arch Roof.

Figure (IIA) Inside view "All Insulation" Rotary Hearth Furnace under construction.

Figure (III) shows Design feature of side wall of "All Insulation" Furnace.

Figure (IV) Design features of Roof of All-Insulation Furnace.

Figure (V) Top: Time-Temperature and Time-Fuel consumption curves for dense and insulation construction.

Bottom : Down Draft Kiln—before and after conversion.

Figure (VI) A converted down draft kiln.

Figure (VII) Industry-wise Guide for application of instruction.

Figure (VIII) Table I—Data on Indian and American Insulation Brick.

(Note : Figure III to Figure VII are from a foreign manufacturer's catalogue)

N. B.—All figures appear in Annexure at the end of this paper.

Simplicity

The principal feature of the furnaces may be summed up in one word : 'Simplicity'.

It is to be noted, the unit of construction is a standard size brick 230 x 114 x 75 mm. It makes bricklaying easy. In the case of roof, it is of suspended construction and uses standard 230 mm brick - only these are provided with suitable holes, for the suspension rods of alloy steel. Very few shapes are involved.

It would be appreciated that, what is useful for, some Reheat Furnaces of steel plants will be equally, if not more useful for other reheat furnaces in the steel mills, both for their batch type and many areas of continuous furnaces. The commensurate benefits would vary from furnace to furnace but benefit there would be, which could be expressed in terms of substantial rupees and paise.

Advantages

What exactly are the benefits of all insulation brick construction compared to conventional dense brick construction. Briefly these are :-

a) Lighter construction : for a particular temperature gradient e. g. operation temperature inside a furnace to its skin temperature, conventional construction calls for thick lining with comparatively heavy brick with higher bulk density and thermal conductivity. The thickness of lining is thus substantially reduced and so is skin temperature - operation temperature inside remaining same.

b) Less weight of brick work permits use of lighter structurals. The overall reduction in weight reduced cost of foundation

c) Fuel saving—This arises from several factors the obvious one being

i) Saving on unnecessary use of fuel in heating up a dense thick brick lining, which must be done to bring a furnace to its operating temperature, not only at the time of initial heating after construction but after every shut down, e. g. the week end ones.

ii) Low co-efficient of thermal conductivity allows less flow of heat through brick structure to outside atmosphere

iii) Rapid heating to full operating temperature-thus reducing down time—time which can be usefully employed in getting more output per furnace in a given time.

Fuel saving of the order of 25 to 30 percent is not uncommon abroad. Brown (1) mentions an instance, when using Ceramic Fibre Blanket of annual saving of 230,000 dollars on one furnace alone.

d) Intimately connected with fuel saving, and what is stated under c(iii) above is increassed output from a furnace with all-insulation construction.

a) Another consequential advantage is better working atmosphere around the furnace—less heat is thrown outside the furnace of new design.

f) Better temperature control permits corresponding improvement in quality of products heat-treated in the furnace of new design.

g) All these simplify construction of such furnaces as pointed out earlier.

h) The same is true of maintenance of these furnaces. Roofs are generally the most vulnerable section of a furnace, location of the burners are such that there is very little possibility of flame impingement of the roof. Further, being of suspended construction, a section of the roof which may be occasionally damaged can be expeditiously repaired.

i) Benefits for the converted Furnace —Converted from dense to all-insulation construction, with existing structural retained. Apart from most of all those enumerated above, there would be increased output. This is because of the larger area inside the furnace made available for processing, in the converted furnace.

Some of the advantages enumerated above would be further evident from the above mentioned diagrams. Fig. (V) top half shows (i) Time-Temperature relation and (ii) Time-Fuel consumption relation.

The solid lines are of insulation firebrick construction and dotted line for heavy brick construction.

To reach 1000°C, for example, it takes insulation construction about $1\frac{3}{4}$ hours against heavy brick's 5 hours. Similarly in 5 hours time-gas consumption is about 16 cubic metre for insulation and 32.7 cubic metre for heavy construction. The bottom half shows plan of down draft kiln with dense brick construction on left and a converted kiln with all insulation on right. Outside diameter of both is 10.3 M. inside diameter changes from 9.2 M to 9.8 M, with consequent increase, in setting area from 66 sq. M to 75 sq. M.

Figure (VI) is a picture of a converted down draft kiln for firebrick manufacture. The foreground shows another down draft kiln in the process of conversion, using insulation brick.

Properties of Insulating brick used

In Fig. (VIII) Table (I) are given relevant A. S. T. M. and Indian

Standard specifications, properties of two grades of brick from two different Indian raw materials.

It may be mentioned that in the quick development work for the brick the quality target set, was what is called for, by A. S. T. M. Standard. It was logical to depend on a yardstick which has enabled furnaces in an industrially advanced country to make their rated output. Also A. S. T. M. test procedure is more rational e. g. in measuring length, before and after P. L. C. test, direct measurement by a slide calliper is called for. Actual measurement is made by holding machined steel plates of known thickness against the ends of bricks to be measured. This procedure ensures that no specks of insulation brick, which is inherently fragile, come off during testing, to vitiate test data.

The rationale of Indian specification permitting P. L. C. data to be deduced from change in volume, by immersion and boiling method is not understood. The bricks are liable to be damaged owing to their fragility and thus give unreliable data.

In Fig. (VIII) (Table (I) Column (I) gives properties of brick, actually called for, by various specifications; Column (2) gives A. S. T. M. specification for insulating brick for 1510°C & 1650°C service; Column (3) and (4) give properties of bricks developed from one raw material; Column 3) represents properties attained during development work and Column (4) - those for brick actually used. Column (5) gives properties obtained with another raw material; Column (6) gives the properties of an equivalent American brick; Column (7) gives Indian Standard Specification 2047-72, for insulation brick.

Indian specification

It would not be out of place to refer to Indian specification for insulation firebrick - indeed for several other Indian specifications. The properties of the American bricks are from the catalogue of one of the manufacturers. These are superior to what are called for by A. S. T. M. Specification. A footnote in the catalogue says these are typical properties and should not be used for specification purpose. This however is exactly what appears to be done in our country by many end users. If supplier (X) has properties superior to those of supplier (Y) and both more than meet relevant standard specification, an Indian user very often stipulates properties of (X) for his purchase. If no such supplier is available, the prospective user or even our Indian Standard Institute would not hestiate to shift limit prescribed by a foreign standard. With what object this is done is not clear. A case in point is P L C stipulation at 1500°C for Insulation Brick. Without a single such brick being laid in any Indian furnace for service at 1500°C and without any supporting service data, PLC requirement for Indian Standard is 1.5% against 2% of A. S. T. M.

Irrationality of test method for volume change as also for porosity determination by Indian Standards has already been dealt with earlier.

Another such instance is stipulation of higher C. C. S value for an insulation brick to be used on sprung arch of a furnace. The lurking belief here is—higher the C.C.S. greater will be its load bearing capacity at elevated temperature. The opposite is however the case in general.

Norton and Duplin (2) studied deformation of insulating firebrick under load at high temperature vis-a-vis dense brick. They mention "It might be concluded that a dense strong brick usually would carry more load when heated than the lighter and more fragile brands. This is not the case however inasmuch as some of the brands with the best load bearing capacity are also among the lightest brands tested. The bulk density and cold strength, in general, do not indicate whether or not the brick structure is capable of withstanding hot load conditions.

One point of considerable interest is that some brands of insulating firebrick can actually carry more load at the same test temperature than the two samples of dense firebrick tested. It is surprising that a refractory structure which consists of 80% solids will not stand as much actual loading as another refractory structure containing only 20% solids."

Finally, it needs to be stressed that our Indian Standards need to be pruned off, many of their stipulations. Can we not judge the likely performance of an insulation brick if we are supplied with data on its bulk density and PLC at service temperature for 24 hours. Perhaps C. C. S. or Modulus of rupture would be of added benefit to assess likely handling damage. Why must we insist on P. C. E. porosity, unnecessarily.

Significant pointer

Having described the properties of Indian insulation brick for direct exposure to 1500°C and the design of the furnaces which have been recently commissioned and in which such bricks have been used, the question is: of what import are these to existing furnaces.

Massive conversion programme

If we are genuinely concerned about energy crisis, the answer is: Conversion—Conversion of every single intermittent reheating and heat treatment furnace and many areas of continuous ones, to insulation design, not only in steel plants but in every industry where such furnaces operate. In steel plants also there are many furnaces which calls for such conversion.

It is surprising that our furnaces which do not require 1500°C insulation brick are still continuing with dense construction. Insulation brick for their conversion has long been in the market.

Fig. (VII) shows industry - wise, where all insulation or partial insulation has been resorted to with advantage.

From refractory manufacturers kilns to furnaces of every end user of refractories, there is a formidable list of firing units, which calls for conversion to "All-insulation" or a judicious bland of dense and insulation construction. A massive conversion programme needs to be undertaken, in almost every industry, if energy conservation is to be a reality

Both material and expertise for such construction or conversion are available in the country.

Follow-up

Immediate follow-up action for this Seminar is "Good-bye" to dense brick, for new furnaces and a massive conversion programme, to "all insulation" design, for existing ones.

Summary

1 "All-Insulation" furnaces with refractory insulation brick, capable of direct exposure to 1500°C and possibly above, have been installed for the first time, in the country. Several such Bogie Hearth and Rotary Hearth Furnaces have been recently commissioned and others are on immediate programme.

2 This has been possible because for the first time such brick became available, using indigenous raw materials. Data presented herein indicate that these meet International Standards.

3 It would not be unreasonable to expect substantial fuel saving in these furnaces as also other benefits, such as quicker heating cycle, increased output improvement in quality of product etc.

4 Availability of requisite insulation bricks and design expertise paves the way for construction of such new furnaces and conversion of existing ones to all-insulation construction.

5 Energy crisis demands that

a) Dense brick construction for new furnaces be discarded and

b) A massive conversion programme is taken on hand without delay.

Acknowledgement

Grateful acknowledgement is made of the help received in compiling data for this address. First to M/s. Wesman Engg. Co. Pvt. Ltd., Calcutta, whose decision to switch over to all insulation construction of reheat furnaces inspite of odds, was responsible for the production of insulation brick for 1500°C service, meeting International Standards and that in record time; and secondly to Maithan Ceramic Pvt. Ltd. Chirkunda, Bihar who starting from virtual scratch in some areas of their manufacturing and testing facilities, produced the required quality brick in time discarding some long followed practice without hesitation as the need arose.

The pictures of installed furnaces are by the courtesy of M/s. Wesman. The data on bricks used therein are by M/s. Maithan Ceramic Pvt. Ltd.

References

1 DARWYN I BROWN. "Refractories for the Steel Industry," Iron & Steel Engineer, R1—R24, Jan. (1976).

2 C. L. NORTON (Jr.) & V. J. DUPLIN Jr. "Deformation of Insulating Brick Under Load", J. Am. Cer. Soc. Vol. 21, No. 1 Jan. (1940)

ANNEXURE

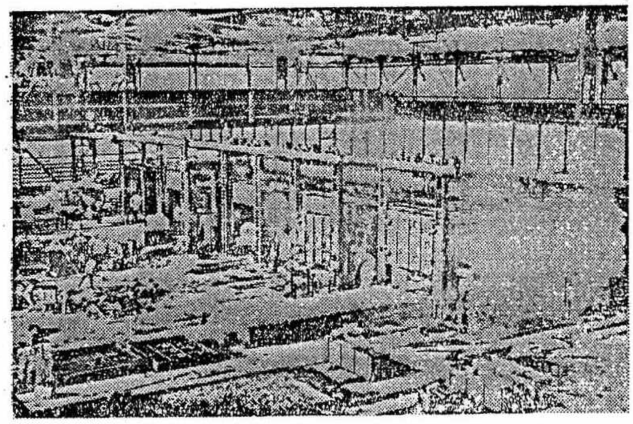


Fig. I—Birds Eye View of 5 Nos. Double Ended Bogie Furnaces in various stages of completion.

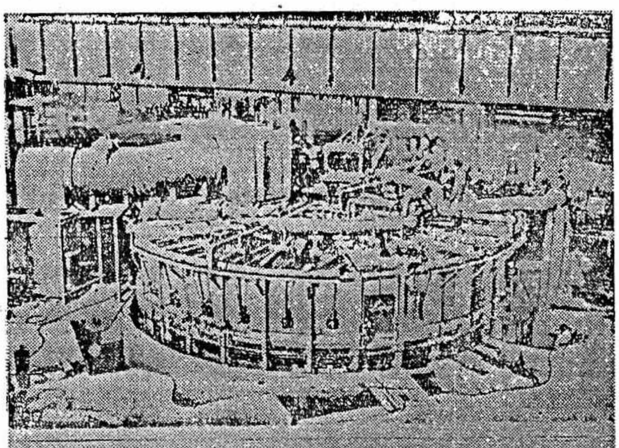


Fig II—Birds eye view of a Rotary Hearth Furnace

Fig. II-A—Lining under progress of a Rotary Hearth Furnace.

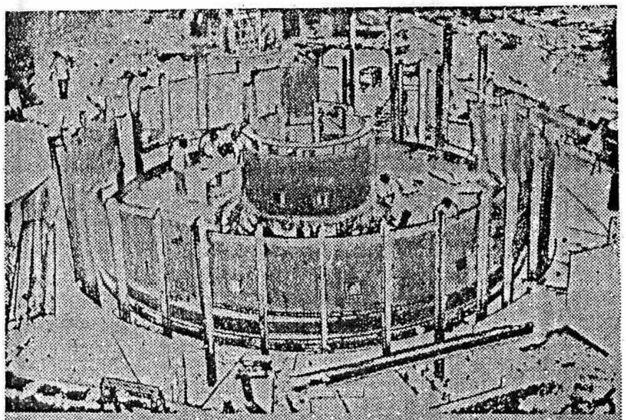


Fig. II-B—Inside View of a Rotary Hearth Furnace under construction.

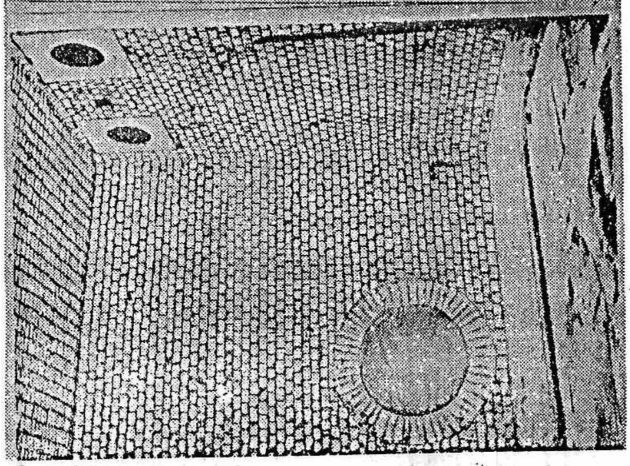


Fig. II-C—Refractory Lining: Side Wall Back Wall and Roof—Bogie Hearth Furnace.

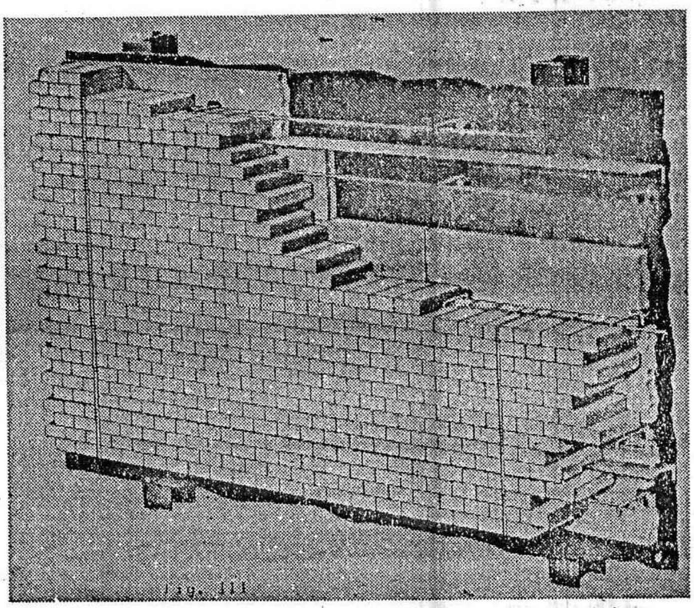


Fig. III—Design Features of Side Wall of "All-Insulating" Bogie Hearth Furnace.

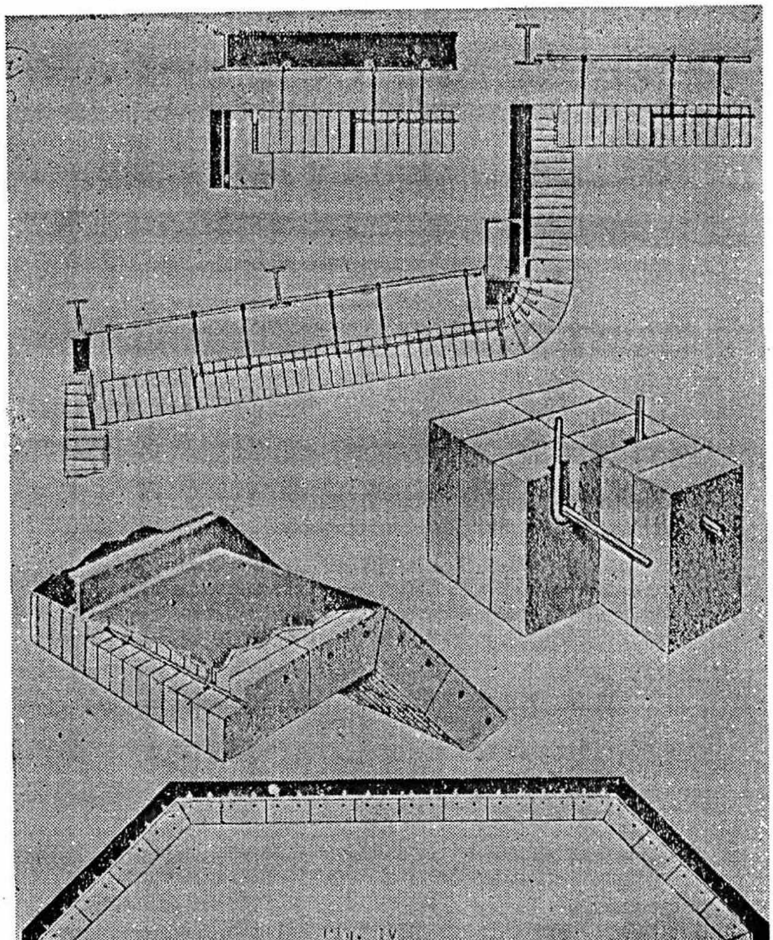
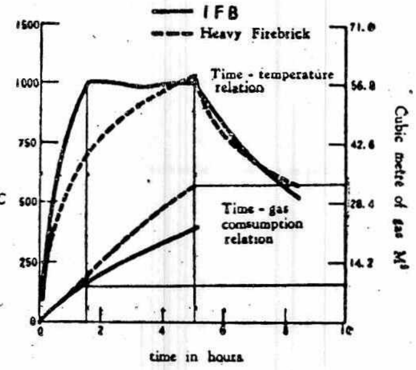


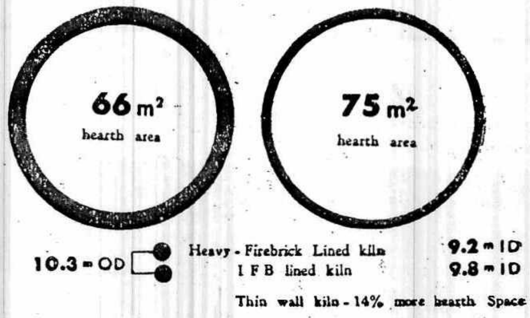
Fig. IV—Design Features of Roof of "All-Insulation" Bogie Hearth Furnace.

Time
temperature
fuel
consumption

Fig. V — Time Temperature and Time-Fuel Consumption, Curves Dense Vs Insulation Construction.



Down Draft Kiln Before and After Conversion.



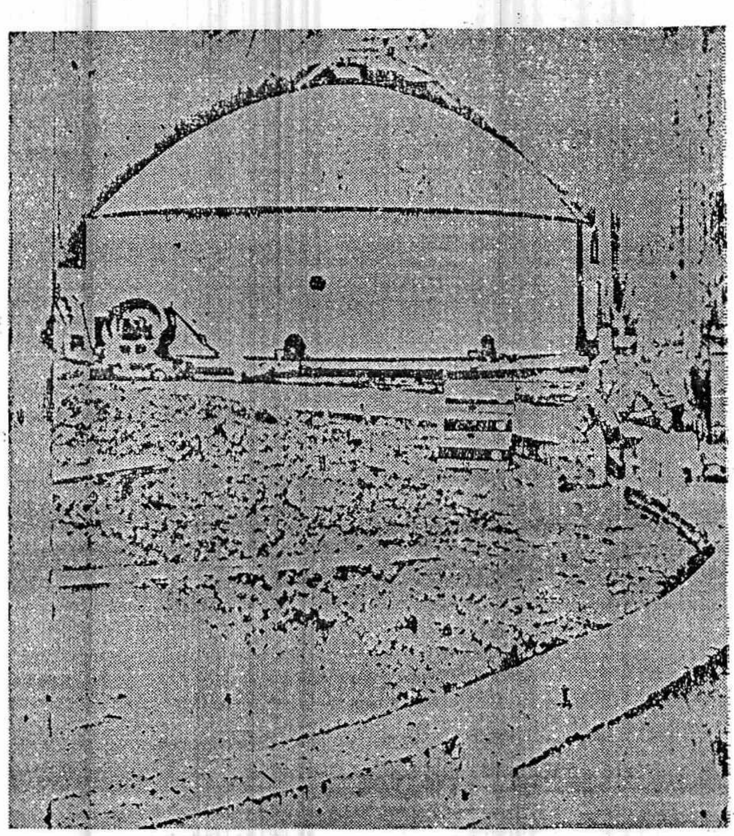


Fig. VI — A Converted All Insulation Down Draft Kiln. Foreground— A Kiln Under Conversion.

Fig. VII - Industrywise Guide for Application of Insulation, Complete or Partial

Ferrous Metals Industry

Service Temp. (x100) °C	11	13	15	16
Sintering Furnaces	B	●		
Blast Furnace Stoves	B	B		
Blast Furnace Ducts	●			
Open Hearth Furnaces	B			
Open Hearth Recuperator	B			
Crucible Type Melting Furnaces	B		●	●
Soaking Pit Walls	B		B	
Soaking Pit Covers			●	●
Soaking Pit Flue Checker Area			●	
Soaking Pit Hot Air Piping	●	●		
Plate Heaters	B		●	●
Slab Heaters	B		●	●
Billet Heaters	B		●	●
Rotary Hearth Furnaces	B	●	●	●
Pusher Furnaces	B		●	●
Car Type Reheat Furnaces	B		●	●
Batch Type Reheat Furnaces	B		●	●
Barrel Furnaces	B			
Forging Furnaces Batch	B		●	●
Forging Furnaces Pusher	B		●	●
Butt Weld Furnaces		B	B	
Walking Beam Furnaces	B			
Annealing Furnaces	●			
Annealing Hoods	●			
Stress Relieving Furnaces	●			
Normalizing Furnaces	●	●		
Spheroidizing Furnaces	●			
Carburizing Furnaces	●	●		
Hardening & Drawing Furnaces	●	●		
Case Hardening Furnaces	●	●		
Tool Hardening Furnaces	●	●	●	
Controlled Atmosphere Furnaces	●	●	●	●
Calorizing Furnaces	●	●	●	
Malleableizing Furnaces		●		
Tempering Furnaces	B	●		
Rabiant Walls				●
Car Tops	B			

Nonferrous Metals Industry

	11	13	15	16
Roasting Furnace			B	
Aluminum Melting Furnaces		●	●	●
Aluminum Holding Furnaces		●	●	●
Galvanizing Furnaces		●		
Lead Crucible Furnaces	B		●	
Magnesium Crucible Melting Furnaces			●	
Die Casting Machine Furnaces	●	●	●	
Heat Treating & Annealing Furnaces	●	●		
Brazing Furnaces	●			

Chemical Process Industry

	11	13	15	16
Sulphur Towers	●	●	●	
High Temperature Flues	●	●	●	
Rotary Calciners & Dryers	●	●	●	●
Carbon Baking Oven Covers			●	
Carbon Retorts	B			
Carbon Bisulphide Furnaces		●		
Gypsum Kettles	B	●		
Combustion Chambers-General	B	●	●	●
Ammonia Reformers	B			
Muriatic Acid Furnaces	B		●	●

Structural Clay, Ceramic Kilns and Refractory Industry

Circular Down Draft Kilns	●	●	●	●
Rectangular Down Draft Kilns	●	●	●	●
Shuttle Kilns	●	●	●	●
Tunnel Kilns	●	●	●	●
Car Type Periodics	●	●	●	●
Chamber Kilns	●	●	●	●
Hobby & Laboratory Kilns	●	●	●	●

Steam Generators

Industrial Boilers	●	●	●	●
Marine Boilers	B		B	
Fire Tube Boilers	B		●	

Glass Industry

Ports		B	B	
Checker Chamber	B	B	B	
Forehearths	B	B		
Lehrs	●			

Refinery and Petrochemical Industry

Heaters	●	●	●	
Stacks, Ducts, & Breechings	●			
Secondary Catalytic Reformers	B	B		
Carbon Black Furnace	B	B		
Hot Gas Mains	●			

Miscellaneous Applications

Core Drying Ovens	●			
Baking Ovens	●	●	●	
Air Heaters For Drying Processes	B	B	B	●
Gas Generators	B			
Duct Linings	●	●		
Stacks & Breechings	●			
Cooling Pits	●			
Enameling Furnaces	●			
Japanning Ovens	●			
Incinerators	B			

● = Insulation Exposed
B = Back Up

TABLE — 1

Properties of Indian & American Insulating Firebrick & Relevant Indian & American Specifications

1			3	4	5	6	7
PROPERTIES	A. S. T M. C 155-70 & C 434-71		Brick from one raw material		Brick from another raw material	American Brick	IS-2042-1972.
	Moulded	M/c Made	Development	Commercial			
Size tolerance (mm)	Allowed variation ±(mm)						
230	3	$1\frac{1}{2}$	...	Within permissible limits	Within permissible limits	...	(±) 2%or(±) 1mm whichever is greater.
114	$2\frac{1}{2}$	$1\frac{1}{2}$					
76	2	1					
Chemical composition	...		...	...	...	...	Fe_2O_3 1% max. for specific atmosphere
P. C. E. (Orton)	...		(+) 32	(+) 32	(+) 32	...	32 (min.)
Bulk Density (gm/cm²)							
for 1500°C	0.96 (max.)		0.91 - 0.92	0.87	1.00	(0.74-0.8)	1.00 (max.)
for 1650°C	1.09 (max.)		...	...	...	...	...
App. pososity (p. c.)	...		70 - 71	71	60	...	60 (min)
C. C. S. (kg/cm²)	...		17 - 18	18	18	13 - 20	15 (min)
PLC (%) 1500°C - 24 hrs	...		...	...	...	...	1.5 (max)
PLC (%) ASTM-1510°C 24 hrs	2 (max)		(—) 1.98 to (—) 2.32	(—) 1.22	(—) 2 (max)	...	...
PLC (3) 1650°C - 24 hrs	2 (max)		...	....		...	...
Thermal conductivity K. Cal/hr./M2/°C - 600°C	...		0.36	0.291	0.32	0.284	...

Fig. —VIII