Necessity of practical simulation of recent developments in soaking pit, reheating and heat treatment refractory practices

K. P. Jhunjhunwala, M. M. Sahoo, R. Mishra and G. C. Banerjee
Orissa Industries Limited

Reheating, soaking and heat treatment furnaces are primarily responsible for shaping and treating of steel for its ultimate usage. Though, consumption of refractories per tonne of steel may not be as high, but use of appropriate combination of different quality refractories for different zones of furnaces goes a long way to achieve economy and better result.

In reheating furnaces, operating conditions differ from zone to zone and is the severest in hearth area. Based on practical experience and simulative trials, combinations of semi silica/super duty fireclay/high alumina light weight/high alumina insulating have been suggested for side walls and roof depending on operating conditions of furnaces and of dense fireclay / sillimanite / superdense high alumina / dense chromite bricks for hearth area. Present practices in the country as well as abroad have heen discussed ,supplemented by result data. Reactions with different indigenous products have also been reported based on simulative laboratory trials.

The group of furnaces used for "Reheating" and "Heat treatment" covers wide field in the processing of both ferrous and non-ferous metals. Reheating or heating furnaces are used for heating metals to the required temperature for changing their shapes or form by stamping, pressing, rolling, extending sheating, forging, moulding or similar process. Heat treatment furnaces are used for stress relieving and for changing the physical p operties of the metal after the product has attained its final shape. The furnaces may generally be classified into two types as follows :

Reheating furnaces

Aluminium, axle heating, bar mill, billet heating, butt & lap, weld pipe, copper, forge, preheating before melting, plate heating, seamless tube, slag heating, structural mill, upsetting, welding. Soaking pits which are also classified as heating furnaces are described later.

Heat treatment furnaces

Aluminium casting, annealing, brazing, carburising, hardening, nitriding, normalizing, stress relieving, tempering, vitreous enameling. In no other group of furnaces, there are such a great differences in size, design and operating conditions. Every gradation in size is found from small rivet heating furnaces to the huge billet heating furnaces and from small box type heat treatment furnaces to several hundred feet long. Heat recovery units may or may not be provided. The furnace may be any one of several types : Hearth, pit, muffle, tunnel or others. It may be stationary, rotating, stationary except for rotating hearth, and in some cases even portable. The material under treatment may be heated in batches in an 'In & out" type of furnace; or it may pass intermitently or in a moving hearth.

Reheating furnace

The modern continuous reheating furnace is a mechanically complex unit which can put considerable stress on refractories being used in it. Pusher type and walking-beam furnaces embodying up to five heating zones may incorporate both under and over firing, batch type furnaces, though often equipped with a wheel-bogie hearth, are basically of box form and hence place relatively light demands on their refractory linings. (They typically employ bricked walls, with upto 42% alumina fireclay bricks backed by insulating bricks. Mouldable or castable refractory with an insulating backing may also be used, its lower conductivity giving lower heat detention).

Recent developments for heat treatment furnaces and suitable economical products have been recommended and discussed

Refractories in soaking pits have been discussed besides economical / suitable recommendations of fireclay/ high alumina/basic refractories.

The area presenting greatest problem is the hearth of a pusher-type furnace, which demands high strength and abrasion resistance at temperature upto 1400°C. Most effective material for the hearth is either a rammed mix of chrome ore, clay and sodium silicate or dense chrome bricks besides normal magnesite and chrome-magnesite bricks. One means of reducing abrasion of the hearth is the incorporation of raised skids of a dense chrome-alumina solid solution bonded 90% alumina brick or fusion cast refractories. In the notched hearth or walking beam furnace, the hearth condition is less severe than in a pusher-type unit, which is normally formed of 54-60% dense alumina bricks.

Side walls and roof of continuous reheating furnaces employ a wide variety of refractory materials and forms. At the entry end, 40% alumina bricks meet the relatively low temperature conditions and at the hot exit end, bauxite based 60% alumina bricks, backed by insulation fire bricks will serve better than conventional super duty bricks. Thinner wall can be obtained by the use of monolithic facing materials of the similar composition. Roofs may be made of high duty dense fireclay bricks having good spalling resistance property or 60—70% alumina bauxite based bricks can be used with advantages which will require appreciably less maintenance and offer a long working life.

Soaking pit

Basically, soaking pit can be considered as flame fired or electrically heated refractory lined boxes in which ingots, slabs and blooms are placed. In both cases, temperature rarely exceed 1500°C. Many arrangements of soaking pits are in use in modern steel making plant. The prime objective is to heat all the ingots to an equal degree and at the same time avoid impingement damage to the roof and sidewall refractories. Even heating can be achieved by correctly placing the ingot within the furnace, and controlling flame length by proportioning direct and secondary air stream. The idea is to ensure the correct heating pattern; the system must also prevent flame impingement on the opposite wall. Electrically heated soaking pits have traditionally been used in Scandinavia and certain other countries where low cost hydro-electric power is readily available. In India, A. S. P. Durgapur is also having electric pits. In these, heating is by radiation from electrical resistors running along each side of the pit; heat distribution is even throughout the pits length and temperature control more readily carried out than in the gas or oil fired furnaces. From the refractory aspect too, the problems are much less severe, and relatively little maintenance is required.

Various refractory materials are used for different parts of soaking pits. The principal criteria effecting their choice include the form of heating cycle, maximum operating temperatures, extent of flame impingement and degree of contact between the refractory and the ingots forming the charge. Three areas of the soaking pit structure must be considered—the hearth, sidewalls and roof. The pit hearths are lined with chrome-magnesite bricks having holes in order to clean out the molten slags generated during the operation. Over the chrome-magnesite lining, a bed of coke breeze is provided. The molten scale falls into a layer of coke breeze, this in turn rests on refractory brick hearth backed beneath by insulating bricks. The top layer of bricks is commonly magnesite, chrome-magnesite or high alumina bricks. Dense chrome bricks can be used with advantage as they have very high mechanical strength combined with higher refractoriness under load and good spalling resistance. Lower sidewalls, to avoid under-cutting by slags often employ bricks of the same material backed by fireclay and solid insulation. Mouldable or castable refractories are finding increasing use in both soaking pits and reheating furnaces. They offer a thermal conductivity about half that of brick, making possible the use of thinner stock, and considerably reduce the maintenance required during each campaign. One area of the soaking pit demanding particular attention is the seal between the roof or cover and the top of the sidewall. The traditional sand seal can be superseded by a sealing layer of low density alumina-sillicate fibrewool which readily compresses to form a seal under the roof.

Heat treatment furnace

Heat treatment furnaces generally operate in the temperature range of 400 °C to 950 °C and are seldom designed for temperature above 1150°C. The various heat treatments are accomplished in furnaces capable of heating the product to a specified moderately high temperature for a sufficient time to permit the occurance of phase and surface changes, followed by a cooling cycle which determines the final physical properties. This final phase may be achieved by controlled rates of cooling or by various quenching procedures. Many heat treating process also employ prepared gaseous atmospheres of various compositions. These atmospheres may be used only to prevent oxidation or scaling of the surface, or they may be used to change the chemical compositon of the product by addition of carbon, nitrogen or other elements or by removing carbon as in decarburizing. If controlled atmospheres, containing appreciable quantities of carbon monooxide or hydrogen, come into contact with the refractory lining, care must be taken to select refractories which have unusually low contents of reducible oxides. This can be accomplished—

i) By selecting refractories containing absolute minimum of free iron oxide or other oxides which are reducible in their free state, Or

ii) By selecting refractories which have been so processed that these oxides have been rendered inert by chemically combining them into stable compounds.

Combustion chambers or baffles are usually built of high duty fireclay bricks, supper duty fireclay bricks or high alumina material depending on the fuel, temperature and degree of flame impingement and heat shock.

In furnaces by electrical resistance, the rate of temperature change is very moderate. Very dense and strong high duty fireclay shapes for some furnace designs are used to support the resistors.

Since the operating themperatures are relatively low and the service conditions such as corrosion and abrasion are relatively mild in heat tresting operating, insulating firebricks are widely used in building the furnaces. In the case of continuously operated furnaces, the use of insulating firebrick is specially advantageous, because of the low rate of heat loss through such refractory linings. For intermittent or batch type operations, insulation fire bricks provide a lining with a low heat storage capacity. Thus the minimum amount of fuel is wasted in heating up and cooling down the furnaces. More-over, use of insulating firebrick enables the operator to keep very close temperature control during all phases of the heat treating cycle. Except where load bearing or resistance to abrasion must be high, or high porosity is undesirable, insulating firebricks should find increasing use in heat treating furnace.

Discussions

The conditions prevailing in various parts of the furnaces mentioned above have been discussed in detail in Tables I to IV along with the suitable refractories. The general recommendations of ORIND Products for the various furnaces based on present practices are given in Annexure—I. The datailed specifications of the products discussed are given in Annexure –II. The result of the simulative tests carried out in the laboratory for the reacaion against molten scale have been given in Annexure III and the photograph of the cut specimens are shown in figs. I to 3.

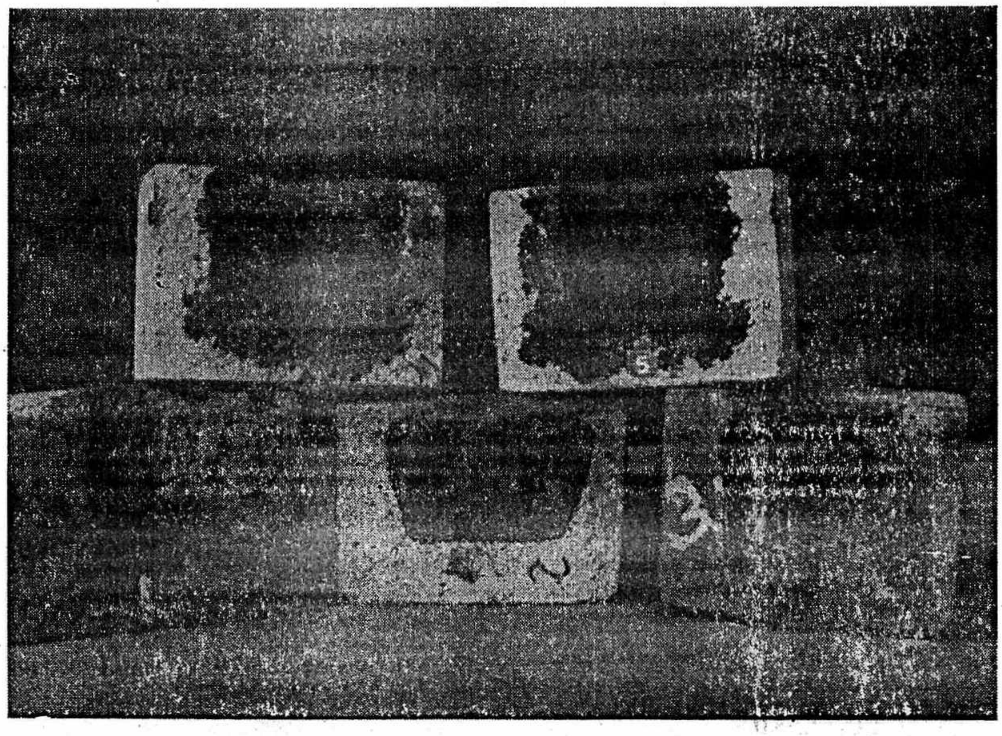

Fig. 1—Bricks after iron oxide scale resistance test. 1 Corod—SD; 2 Corod—D1; 3 Corod—D2; 4 Corod—L2 ; 5 Corod—L1.

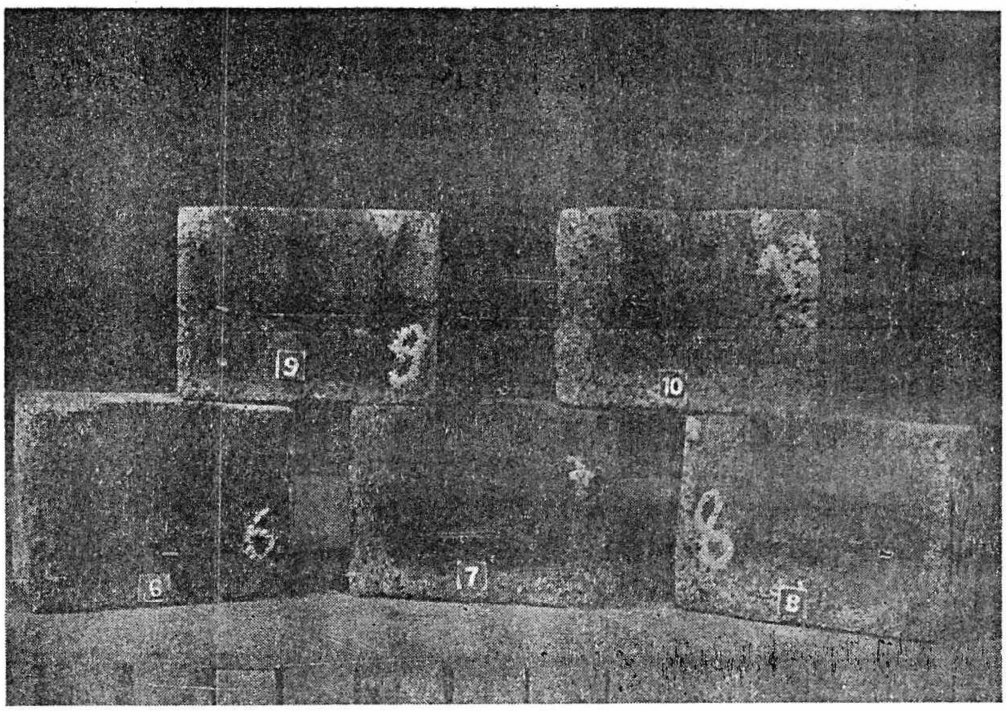

Fig 2—Bricks after iron oxide scale resistance test. 6 Korond—90 D; 7 Orimul; 8 Sillimax—IV; 9 Orind—AL—70; 10 Orind—AL—60.

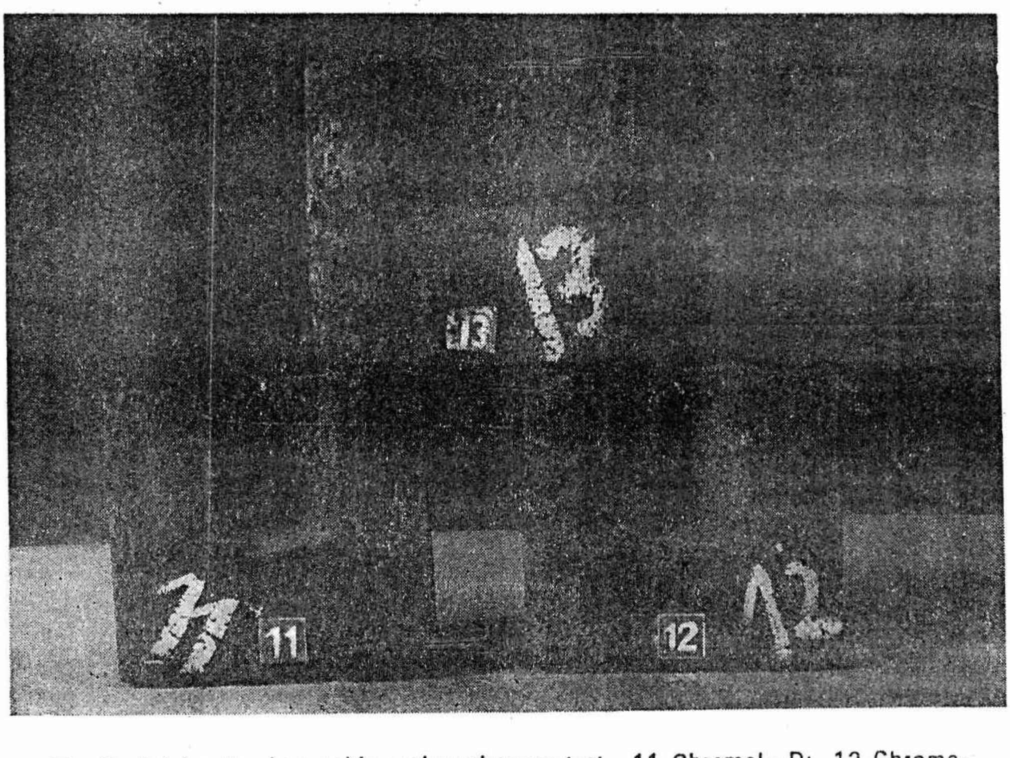

Fig. 3—Bricks after iron oxide scale resistance test. 11 Chromel—D; 12 Chrome-Magne B; 13 Magne—B.

Table—I Service conditions and types of refractories used in hearth of reheating furnaces.

Description of vagaries in the furnace.	Refractory properties required to withstand the furnace vagaries.	Types of refractories which have the required properties	ORIND refractories which withstand the vagaries and have reqd. properties	Laboratory test and application datas
Extremely severe condition a) Extremely high abrasive action of sliding stock. b) Heavy load at moderately high temperature. c) Corrosive action of molten scale. d) Temperature fluctuation because of charging, drawing and slagging out.	High chemical resistance towards molten scale, high CCS, low AP, high bulk density, high RUL, high spalling resistance and volume stability.	a) For extremely severe molten scale action Dense chromite bricks having low porosity, high mechanical strength, highly refractory combined with capability of absorbing large quantity of iron oxide with little change in rigidity.	CHROMEL—D—Having AP less than 18%, CCS above 600 kg/cm2, BD about 3.2 gm/cc, RUL Ta. 1550°C, high abradibility.	Dense texture, consisting of chromite grains bonded with magnesio ferrite, tested for molten scale at 1550°for 4 hr alongwith conventional magnesite chrome magnesite bricks. **Result**—Chromel—D showed excellent resistance in comparison to other two(evidence from photographs). Proved successful and economical in smaller furnaces.
		b) For unusually high temp. and severe abrasion condition. Bricks having extremely dense (Low AP and high BD very high CCS, high PCE and RUL, high purity and volume stability at high temp. Good spalling resistance, high resistance to scale reaction, or fusion cast refractories.	KOROND 90D—having AP less than 18%, BD—3.0 gm/cc, CCS—above 800 kg/cm2. PCE over orton 40, RUL over 1700°C, Fe_2O_3 less than 0.3%, very high abradibility.	Super dense texture unique Cr_2O_3—Al_2O_3 solid solution bond high resistance towards molten scale. Panel trial was conducted in one of the integrated steel plants and the bricks showed extremely good results.
Severe condition Abrasion by sliding stock at high temperature, corrosion by molten scale and temp. fluctuation.	Resistance to molten scale, high CCS, low AP, high RUL and spalling resistance.	Super duty & dense high alumina (mullite base)	ORIMUL—AP—12/15% CCS —above 800 kg/cm2, RUL—1700°C, PCE Orton 37, extremely high spalling resistance.	Having interlocking texture of well developed mullite crystal with few corundum grains. Showing comparatively high resistance towards molten scale in the high alumina—range bricks successfully tried out and found highly satisfactory.
Mild temp. condition a) Less scale formation and little melting of scale. b) High abrasion c) Normal temperature fluctuation.	Good spalling and abrasion resistance. Normal resistance towards corrosion of scale	Super duty fire bricks having low AP, high CCS and good spalling resistance, or high alumina refractories of 60% Al_2O_3	COROD DL or SILLIMAX—IV or ORIND AL—60	—

Table—II Service conditions and types of refractories used in sidewalls and roof of reheating furnaces.

Description of vagaries in the furnace.	Refractory properties required to withstand the furnace vagaries.	Types of refractories which have the required properties	ORIND refractories which withstand the vagaries and have reqd. properties	Laboratory test and application datas
Sidewall				
a) Temperature fluctuation b) Reaction by alkalies and vanadium oxide in the ash of fuel oil. c) Elevated temperature d) Scale reaction at the lower part	Spalling resistance, resistance towards the alkalies vanadium oxide, resistance to slag & scale attack, high refractoriness underload	Dense superduty firebricks and high alumina bricks of 60–70% Al_2O_3 range having good resistance to slag attack	COROD D—1 ORIND AL—60 ORIND AL—70	For the furnace wall having normal condition For severe conditions
Roof (Generally flat suspended type due to long span and uniform radiation required)				
Same as above besides, direct flame impingement, more temperature fluctuation and prolonged exposure to high temperature	Same as above having high spalling resistance and volume stability	Super duty firebricks of 38–42% Al_2O_3 range having 18–23% AP and good spalling resistance, or high alumina 60–70% Al_2O_3 range with good spalling properties	ORIND SUPER—IH or ORIND AL—60 ORIND AL—70	— —

Table—III Service conditions and types of refractories used in soaking pits of reheating furnaces.

Description of vagaries in the furnace.	Refractory properties required to withstand the furnace vagaries.	Types of refractories which have the required properties	ORIND refractories which withstand the vagaries and have reqd. properties	Laboratory test and application datas
Bottom				
a) Elevated temperature b) High load at high temperature c) Chemical attack by slag and molten scale.	Adequate refractoriness, good hot strength, good thermal shock resistance, volume stability at high temperature, good resistance to slag attack	Magnesite, chrome-magnesite and chromite refractories	CHROMEL—D. Dense chromite bricks having having AP less than 18%, CCS above 600 kg/cm2, BD 3.2 gm/cc, RUL Ta 1550 °C, high abradibility with capability of absorbing iron oxide with little change in rigidity	Dense texture, chromite grains bonded with magnesio ferrite. Tested for molten scale at 1550 °C for 4 hrs. **Result** : Chromel—D showed excellent resistance in comparison to other two. (see photographs)
Sidewall				
a) Chemical attack by slag & scale b) Hot load at high temperature c) Physical damage because of leaning ingots d) Stripping due to fins in the ingots	Excellent resistance to slag and scale attack, good hot strength, good abradibility & high mechanical strength, besides volume stability	Magnesite, chrome magnesite and chromite refractories	— As above —	— As above —
Sidewall above slagline				
a) Elevated temperature b) Load of high temp. c) Severe temperature fluctuation	Excellent thermal spalling resistance, high retractoriness hot load strength, volume stability, resistance to attack	Silica or semi-silica or high alumina bricks having 60—70% Al_2O_3 range	ORIND AL—60 or ORIND AL—70 or	1) H A bricks have much superior spalling resistance, compared to silica bricks 2) H A bricks have better
d) Mechanical abuses	of alkali and iron oxide, me-		SEMISIL — II	abrasion and impact resis-

fluctuation	stability, resistance to attack		or	2) H A bricks have better
d) Mechanical abuses e) Flame impingement and alkali attack. f) Scale reaction at ingot setting level	of alkali and iron oxide, mechanical strength to resist abrasion and impact		SEMISIL — II	abrasion and impact resistance 3) Better resistance towards molten scale 4) Pits lined with H A bricks can be cooled or heated rapidly reducing the down time besides easy maintainance 5) A panel of ORIND AL—70 bricks was tried in a steel plant soaking pit wall and have given good life in comparison to silica walls
Cover				
a) Severe temperature fluctuation during charging and drawing operation b) Mechanical abuses which takes place each time when cover is moved.	Excellent thermal spalling resistance, good physical strength volume stability	Super duty firebricks having high CCS, AP 18—23%, good spalling resistance and lower PLC, or high alumina bricks 60—70% Al_2O_3 range and having good mechanical strength, high RUL and good spalling resistance. Or Plastic ramming mass of superduty of high alumina type supported by high alumina 30% Al_2O_3 quality anchor bricks	ORIND SUPER—IH (20/22% AP, & CCS above 300 kg/cm2) ORIND AL—60 or ORIND AL—70 ORIND AL—60 anchor brick + Orind H. A. plastic ramming mass	Being manufactured from pure raw materials these bricks have less glassy phase and good spalling resistance and high mechanical strength, volume stability and high hot strength. Shows no continuous shrin kage to prolonged use. Monolithic covers can be used with advantages in respect of good spalling resistance, rapidly repairable, besides easy installation

Table—IV Service conditions and types of refractories used in heat treatment furnaces.

Description of vagaries in the furnace.	Refractory properties required to withstand the furnace vagaries.	Types of refractories which have the required properties	ORIND refractories which withstand the vagaries and have reqd. properties	Laboratory test and application datas
Moderate temperature, fluctuation, reducing atmosphere and gaseous reaction (CO, H_2 etc) in some cases.	Mechanically strong spall resistance, purity (low content of reducible oxides) besides low thermal conductivity.	Insulating type bricks having considerable strength and purity	HITEMLITE—100 HITEMLITE—130	Having considerable CCS of 60—80 kg/cm and insulating properties
Abrasion (in case of continuous and rotary furnaces)	Dense & abrasion resistance	Dense fire bricks having good spalling with low iron and low reducible oxide contents	SUPER—IIH or COROD D—1	Bricks made of purer raw material having low iron content.

Conclusion

To sum it up briefly, one needs the following classes of refractories to resolve the problems of most application areas :—

a) Dense chromite bricks for the areas where the molten slag and scale reaction is very severe, besides other severe conditions in reheating furnace soaking zone, hearths, soaking pit, bottom and sidewalls upto slag line.

b) Dense solid solution bonded 90% Al_2O_3 bricks, where abrasion is most severe at unusually high temperature as in case of pusher-type roller hearth and in ejector axis area where presently fusion cast bricks are used.

c) High alumina bricks of 60—70% Al_2O_3 range for sidewalls and roofs under critical operating conditions specially in soaking pit which faces severe spalling conditions and needs longer down time for maintenance and repairs as required by the conventional practice of using silica.

d) Semi silica brick for building upper wall of soaking pit, which in service tend to acquire a glaze contribute to fairly long life. This brick withstand the rapid temperature changes and possess the desirable properties of volume stability and rigidity at the working temperature.

ORIND has already carried out some panel trials in integrated and mini-steel plants which has shown encouraging performances. More constructive response from manufacturers and users are needed to introduce modern practices (internationally accepted) for higher economy.

ANNEXURE—I

(ORIND's Recommendations)

	HEARTH	SIDEWALLS	ROOF
1. REHEATING FURNACES :			
I. Pre heating & heating zone	High heat duty & super duty fire-clay bricks—COROD L1 & COROD —D1 backed by light fire bricks and insulating bricks i. e. ORIND-LMH, HITEMLITE—100 & HITE-MLITE—130	High heat duty & super duty bricks —COROD L1, COROD L2 & COROD D1, backed by insulating bricks—INSUL PA—9	High heat duty & super heat duty bricks with good spalling resistance properties such as—ORIND SUPER—IIH & ORIND SUPER—IH. Top of the roof is covered by insulating material
II. Soaking zone	**For very high temperature & abrasion** Super dense high alumina bricks such as ALUMITE—72, ORIMUL & KOROND—90 D	High heat duty & super duty fire-bricks COROD L1, COROD L2, & COROD D1	Spalling resistant super duty bricks SUPER—IIH and SUPER—IH
		For lower sidewalls facing severe condition, ORIND AL—60 ORIND AL—70 & SILLIMAX—IV	For outstanding performance ORIND AL—60 & ORIND AL—70
	Where corrosive action of molten scale is severe Dense chromite bricks—CHROMEL—D for outstanding & economical performance, besides conventional MAGNE — B & CHROME MAGNE—B		

ANNEXURE—I (*Contd.*)
(ORIND's Recommendations)

	HEARTH	SIDEWALLS	ROOF
III. Monolithics			
For forming hearth contours	:—ORICHROME A—II, & A—III, ORIMAG & ORIND MULLITE RAMMING MASS		
For hearth subject to severe scale attack	:—Dressed with chrome mass or D.B.Magnesite (which absorbs iron scale and periodically replaced with fresh material).		
2. SOAKING PITS	Dense chrome bricks i. e. CHROMEL—D for outstanding and economic performance dressed with a bed of coke breeze at the top of conventional MAGNE — B or CHROME MAGNE—B bricks with coke breeze	a) Bottom layers of CHROMEL —D, MAGNE—B or CHROME MAGNE—B as in hearth	Super duty firebricks — ORIND SUPER—IIH & SUPER—IH quality with good spalling resistance
		b) On the above layer ORIND AL—60 and / or ORIND AL—70 bricks	For outstanding performance. ORIND AL—60/ORIND AL—70
		c) Top courses near sand sealing, ORIND AL—60/ORIND AL—70 or ORIND SUPER—IIH/ SUPER—IH	**For monolithic covers :** ORIND AL—60 Anchor bricks with ORIND SUPER Plastic/ ORIND HA Plastic.
		For Electric Pits : Sillimax—IV or ORIND AL—60 / ORIND AL—70	
3. HEAT TREATMENT FURNACE	HITEMLITE—100, HITEMLITE—130, COROD L—1 & SUPER—IIH COROD—90, COROD—D1 & ORIND AL—60 for special application		

ANNEXURE—II

Detailed Properties of the Refractories

BRAND	PCE Orton min.	A. P. Vol. % Max.	B. D. gm/cc min.	CCS Kg/cm2 min.	RUL (2 kg/cm2) Ta °C Min.	PLC at 1450 °C for 2 hrs max. (%)	Chemical Analysis		
							Al_2O_3 % Min.	Fe_2O_3 % Max.	SiO_2 % Min.
ORIND Semisil—II	—	25	1.95—2.0	200—250	—	0.2	—	1.4	70—75
ORIND SUPER—I H	33	20	2.15	350	1450	±0.5	42 to 44	2.0	—
ORIND SUPER—II H	32	20	2.15	350	1450	±0.5	40 to 42	2.0	—
COROD L1	31	18	2.15	350	1400	±0.5	34	2.0	—
COROD L2	32	18	2.15	350	1450	±0.5	38	2.0	—
COROD D1	33	17	2.15	400	1470	±0.5	40	1.5	—
COROD SD	33	17	2.20	500	1500	±0.5	42	1.5	—
SILLIMAX—IV	36	22/23	2.3	400	1540	±0,5 at 1600 °C 2 hrs.	58	1.5	—
ORIND AL—60	35	23	2.4	400	1500 °C	±2.5 at 1600 °C 2 hrs.	60	2.5	—
ORIND AL—70	37	23	2.5	400	1520 °C	±3.5 at 1600 °C 2 hrs.	70	3.0	—
ALUMITE—72	37	18	2.8	600	1600	±0.3 at 1600 °C 2 hrs.	72	1.5	—
ORIMUL	37	12 to 15	2.6 to 2.7	800	1700	±0.3 at 1600 °C 2 hrs.	72	0.5	—
KOROND--90D	40	16 to 18	3.0	800	1700	±0,2 at 1450 °C 2 hrs. max (%)	90	0.3	—

Detailed Properties of the Refractories

BRAND	PCE Orton min.	A. P. Vol. % Max.	B. D. gm/cc min.	CCS Kg/cm² min.	RUL (2 kg/cm²) Ta °C Min.	PLC at 1450 °C for 2 hrs max. (%)	Chemical Analysis MgO	Cr₂O₃ Min.	SiO₂ Max.
MAGNE—B	38	22	—	350	1550	—	84	—	6
CHROME - MAGNE—B	38	25	—	200	1600	—	35	25	—
CHROMEL—D	38	18	3.2	600	1550	—	—	40	—
							Al_2O_3	Fe_2O_3	SiO_2
ORIND INSUL PA—9	20	68 to 72	0.6	10 to 15	—	0.42 at 1600 °C	4	0.9	82 to 85
ORIND INSUL PA—9	23	55 to 65	0.9	15 to 25	—	0.25 at 1600 °C	3.95	0.86	85 to 88
" "	35	65	0.91—0.93	50 to 60	—	—	52.0	1.5	42
" "	6	55.85—57.05	1.23—1.29	60 to 80	—	—	50.0	1.5	44

BRAND	Setting	PCE Orton Cone	Grading mm	Max. Safe App. Temp °C	Al_2O_3 Min.
MONOLYTHS					
ORIND Super Plastic	Chemical	33	0—4	1500	40
ORIND High Alumina Plastic	Chemical	Over 34/35	0—4	1600	60

BRAND	MgO% Min.	Cr_2O_3 Min.	Fe_2O_3 % Max.	Al_2O_3 % Max.	Service Temp. °C	Grain Size mm
ORIMAG	—	—	4.0	—	1750	0—4
ORICHROME A—II	17	33	19.0	20	—	—
ORICHROME A—III	16	32	15.0	20	—	—

ANNEXURE—III

Simulative Test Details

Sl. No.	Product	Dimensions of the cavity Depth mm	Dia mm	Specimen Size mm	Extent of penetration Depth wise mm	Side wise mm
1.	Corod—50	45	40	100 x 100 x 100	13	9
2.	Corod—D1	45	40	100 x 100 x 100	15	20
3.	Corod—D2	45	40	100 x 100 x 100	16	21
4.	Corod—L2	45	40	100 x 100 x 100	25	22
5.	Corod—L1	45	40	100 x 100 x 100	28	24
6.	Korond—90 D	45	40	100 x 100 x 100	6	3
7.	Orimul	45	40	100 x 100 x 100	7	4
8	Sillimax—IV	45	40	100 x 100 x 100	7	6
9.	Orind AL—70	45	40	100 x 100 x 100	8	7
10.	Orind AL—60	45	40	100 x 100 x 100	8	8
11.	Chromel—D	35	30	75 x 75 x 75	1	0.5
12.	Chrome-Magne B	35	30	75 x 75 x 75	2	3
13.	Magne—B	35	30	75 x 75 x 75	2	3.5

Experimental Details

All the groupwise specimens were packed with the equal quantities of iron oxide scale and fired in oil fired furnace at 1550 °C for 4 hrs. The specimens were then cut from the centre and studied.