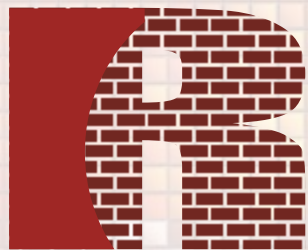




# Souvenir



## REFIS 4.0

2<sup>nd</sup> Edition

12-13  
April

Bokaro Steel City  
Jharkhand  
India

2024

International Conference on  
Refractories in Iron & Steel Industries



*Organized by:*



सेल SAIL



**Bokaro Steel Plant**



*In association with*



The Institution of Engineers (India)  
(Bokaro Chapter)



Indian Ceramic Society  
(Bokaro Chapter)



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- Steel Ladle
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BOKARO STEEL CITY-827004, BOKARO (JHARKHAND) INDIA



## International Conference on Refractories in Iron & Steel Industries

### *Contents*

Message

Our Team

Program Schedule

Abstracts of Technical Paper

Organizer Profile

Sponsor's Profile

Our well-wishers and supporter



# International Conference on Refractories in Iron & Steel Industries 12-13 April'2024, Bokaro Steel City

Organized by



बोकारो इस्पात संयंत्र  
Bokaro Steel Plant



In Association with



The Institution of Engineers (I)  
Bokaro Local Chapter



Indian Ceramic Society  
Bokaro Chapter

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# *Message*





**Amarendu Prakash**



**अध्यक्ष/ Chairman**  
**स्टील अथॉरिटी ऑफ इंडिया लिमिटेड/**  
**Steel Authority of India Limited**  
**(भारत सरकार का उपक्रम/**  
**Government of India Undertaking)**  
**नई दिल्ली/ New Delhi**

## Message

I am glad to learn that SAIL, Bokaro Steel Plant is hosting its second International conference on Refractories in Iron & Steel industry at Bokaro on 12& 13 April 2024.

Refractories play a crucial role in our steel production processes, directly impacting productivity, quality and cost-effectiveness. As we aim for a significant increase in steel production by 2030 in accordance with the National Steel Policy, the demand for refractories is expected to surge. Against this backdrop, this conference holds immense importance as it not only addresses the escalating demand for refractories but also delves into Industry 4.0, nanotechnology integration and carbon footprint reduction, all pivotal elements of our future trajectory.

I am sure that the two-day conference will be a stimulating platform for participants to exchange insights, explore the latest advancements and discuss emerging technologies in the realm of refractories.

My compliments to the organizing committee and best wishes to all for the success of the conference.

**(Amarendu Prakash)**







Atanu Bhowmick



निदेशक प्रभारी/ Director In-charge  
राउरकेला इस्पात संयंत्र, राउरकेला/  
Rourkela Steel Plant, Rourkela  
Additional Charge/अतिरिक्त प्रभार  
बोकारो इस्पात संयंत्र, बोकारो  
Bokaro Steel Plant, Bokaro

## Message

Kudos to SAIL, Bokaro Steel Plant for organizing the second International Conference on Refractories in the Iron & Steel Industry on April 12th and 13th, 2024 at Bokaro. The theme for the second edition of this conference is "Forging the future: Advancements in Refractories in the Iron and Steel Industry through sustainable solutions and Nano Technology."

With the domestic steel industry bracing-up for a massive expansion, this conference presents a good opportunity to manufacturers, users and researchers to delve into the various issues and challenges before them and explore innovative solutions which are also sustainable. I am sure, the participants will have a fruitful time of interactions, deliberations and knowledge sharing and the insights gleaned from this conference will equip us all to confront the evolving challenges within the steel and refractory sector with greater competence.

I take this opportunity to extend my best wishes to the organizing team and participants for this two-day conference.

(Atanu Bhowmick)





Anirban Dasgupta



निदेशक प्रभारी/ Director In-charge  
भिलाई इस्पात संयंत्र/  
Bhilai Steel Plant  
भिलाई/ Bhilai

## Message

It is heartening to note that SAIL, Bokaro Steel Plant in association with the Bokaro Chapter of the Institution of Engineers, India (IEI) and the Indian Ceramic Society (ICS) is hosting the second International Conference on Refractories in the Iron & Steel Industry on April 12th and 13th, 2024.

Refractory is an integral part of steel making and plays an extremely critical role in the safety & efficiency of the steel industry. With India poised to increase its steelmaking capacity to 300 MTPA by the turn of this decade, the importance of development of indigenous refractory making capability both in terms of quality & capacity cannot be overemphasized.

I am sure that in this conference many implementable suggestions would emerge leading to a vibrant refractory and steel industry in India.

I wish the conference a grand success.

(Anirban Dasgupta )





Brijendra Pratap Singh



निदेशक प्रभारी/ Director In-charge  
बर्नपुर और दुर्गापुर इस्पात संयंत्र/  
Burnpur and Durgapur Steel Plant  
पश्चिम बंगाल/ West Bengal

## Message

I am delighted to learn that SAIL, Bokaro Steel Plant is spearheading the second International Conference on Refractories in the Iron & Steel Industry. Scheduled for April 12th and 13th, 2024, this significant event in Bokaro will pave way for a valuable exchange of information and technical know-how as well as sharing of experience between industry leaders, researchers and academia.

Given the immense significance of refractories in the steel industry, this collaboration was much needed for equipping ourselves with the latest advancements and innovations in refractory management. The deliberations and interactions on the various aspects of this vital subject will empower teams across both the industries to tackle the evolving challenges in steel production with greater competence. I extend my heartfelt congratulations to the organizing team and wish them the very best for a successful conference.

(Brijendra Pratap Singh)







Krishna Kumar Singh



निदेशक (कार्मिक)/  
Director (Personnel)  
स्टील अथॉरिटी ऑफ इंडिया लिमिटेड/  
Steel Authority of India Limited  
(भारत सरकार का उपक्रम/  
Government of India Undertaking)  
नई दिल्ली/ New Delhi

## Message

I'm pleased to know that SAIL's Bokaro Steel Plant is hosting the second International Conference on "Refractories in the Iron & Steel Industry" in association with 'Institution of Engineers (India), Bokaro Chapter' & 'Indian Ceramic Society (ICS), Bokaro Chapter'.

At SAIL, we firmly believe that refractories play a crucial role in ensuring the safety and efficiency of operations in the steel industry. Their significance is so profound that their utilization is at times regarded as a benchmark for overall performance in steel facilities.

Scheduled for April 12<sup>th</sup> & 13<sup>th</sup>, 2024 in Bokaro, this event promises a valuable exchange of insights and expertise among industry leaders, academics, and researchers. Such collaboration will greatly enhance our understanding of recent advancements and innovations in refractory management, empowering us with essential skills and knowledge. I am confident that the event will further strengthen the capabilities of our teams in tackling the evolving challenges of steel production.

It's quite encouraging to learn that a significant number of entries have been submitted for presentation(s) scheduled to be held at the conference. This clearly underscores the importance of the event and its standing among experts in the steel industry. The conference's focus on critical areas such as the impact of Industry 4.0 on refractory practices and the integration of nanotechnology, adds further value to this much-awaited event.

I extend my compliments to the organizing team and best wishes for the success of the conference.

(Krishna Kumar Singh)





Arvind Kumar Singh



Director(Technical, Projects & Raw Materials)/  
निदेशक (तकनीकी, परियोजनाएं और रॉ-मैटेरियल्स)

स्टील अथॉरिटी ऑफ इंडिया लिमिटेड/  
Steel Authority of India Limited  
(भारत सरकार का उपक्रम/  
Government of India Undertaking)  
नई दिल्ली/ New Delhi

## Message

The second International Conference on Refractories in the Iron & Steel Industry, hosted by SAIL- Bokaro Steel Plant on April 12th & 13th, 2024, presents a good platform to industry leaders, researchers, manufacturers and users in the steel as well as refractory sectors to interact and brainstorm on the various issues and challenges pertaining to refractories.

By an estimate, India's steel industry consumes around 70% of the country's refractory output. For our country to achieve its ambitious target of 300 million tonne of steel production by 2030, the only way forward is synergy between the two sectors. In this background, the deliberations in the conference are expected to serve as catalysts in driving advancements in refractory technology, which, as we all know, has a huge impact on the efficiency and cost-effectiveness of steel production. A number of presentations are also planned during the conference with a special focus on innovation and sustainability in the processes and practices.

I convey my warm greetings to all the delegates and wish the conference success.

(Arvind Kumar Singh)  
Director (Technical, Projects & Raw Materials)





बी० के० तिवारी  
अधिसारी निदेशक (संकार्य)  
**B. K. TIWARI**  
Executive Director (Works)



### Message

It is with immense pride that Bokaro Steel Plant welcomes you all to the 2<sup>nd</sup> International Conference on Refractories in the Iron & Steel Industry. This esteemed event, taking place on April 12th and 13th, 2024, in Bokaro, serves as a vital platform for fostering collaboration and knowledge exchange between industry leaders and esteemed academic researchers.

This conference presents a unique opportunity to delve into the latest advancements and innovations in refractory technology. These advancements have a profound impact on the efficiency and cost-effectiveness of steel production, ultimately shaping the future of our industry.

The overwhelming response to our call for presentations, reflected in the substantial number of submissions, is truly heartening.

We believe the insights gleaned from this conference will equip us to confront the evolving challenges within the steel sector with greater competence.

On behalf of the entire team at Bokaro Steel Plant, I extend my warmest greetings to all the delegates and distinguished guests.

B. K. Tiwari  
Executive Director (Works)







**V P Upadhyaya**



**Chairman, Organizing Committee,  
REFIS 4.0 2<sup>nd</sup> Edition  
&  
Chief General Manager (Refractory),  
Bokaro Steel City**

## Message

Bokaro Steel Plant is happy to announce the upcoming 2nd Refractory Conference, on the 12th and 13th of April'2024, which aims to bring together a diverse range of stakeholders including Iron & Steel manufacturers, refractory manufacturers & users, esteemed academicians, scientists, researchers, technologists, and scholars. Our primary goal is to create a platform that fosters the exchange of experiences and knowledge, addressing the ever-evolving demands for refractories in today's dynamic industry landscape.

During the conference, we will delve deep into exploring the profound impact of Industry 4.0 on refractory practices. This includes discussions on advancements in process technology and a specific emphasis on strategies for reducing carbon footprints. Furthermore, we will explore the integration of cutting-edge nanotechnology to enhance the performance and durability of refractory materials, paving the way for improved industrial practices.

The conference's Technical Program features a plenary/keynote session alongside numerous parallel sessions dedicated to exploring future and emerging refractories technology. Over the course of one and a half days, more than 35 papers will be presented by esteemed experts selected from industry, research and development, and academia. Additionally, a significant number of graduate students from prestigious institute like Indian Institute of Technology (BHU) Varanasi, National Institute of Technology Rourkela and Alagappa College of Technology Anna University, Chennai have been invited to participate, allowing them to showcase their research and engage in meaningful interactions with their peers.

Under the guidance of Shri Rakesh Kumar Singh, CGM (SRU) at SAIL, a proficient Technical and Publication Committee successfully executed the task within the designated timeframe. However, it's important to acknowledge the diligent efforts of numerous individuals behind the scenes who worked tirelessly to ensure deadlines were met.

Our chosen theme, 'Forging the Future: Advancements in Refractories in the Iron and Steel Industry through Sustainable Solutions and Nano Technology,' encapsulates our collective vision to drive progress and sustainability within the industry. This theme is particularly relevant considering the current challenges faced by the Indian refractory market and the broader global refractory scenario.

We extend our heartfelt appreciation to the organizing team for their unwavering dedication and hard work in making this event possible. Their efforts have been instrumental in shaping a conference that promises insightful discussions, meaningful collaborations, and transformative outcomes.

**(V P Upadhyaya)**





**Dr.G.RANGANATH ME, Ph.D, FIE.,**  
**President, 2023-2024**  
**Institution of Engineers (1)**



**President,**  
**The Institution of Engineers (India)**  
**Kolkata**  
**West Bengal**

## Message

It gives me pleasure to learn that Bokaro Steel City Local Centre of The Institution of Engineers (India) in association with Bokaro Steel Plant is organizing the All India Seminar on “Forging the Future : Advancements in Refractories in the Iron and Steel Industry through Sustainable Solutions and Nano Technology” on 12-13 April 2024. Forging the future in the Iron and Steel Industry involves leveraging sustainable solutions and Nano Technology in refractories. I am sure that the experts will address the evolving demands for refractories, especially in light of Industry 4.0. The discussions should focus on process technology advancements and innovative installation techniques aimed at reducing carbon footprint. Additionally, engineers should explore the integration of nanotechnology to enhance refractory performance and durability, ensuring a sustainable future for the industry.

I am sanguine that the speakers and experts will provide newer insights on the topic. The deliberations at the Conference would surely explore and recommend need for continuous research and development in refractory materials, focusing on sustainable and Nano Technology solutions. Furthermore, collaboration among industry stakeholders and academia is also essential to drive innovation and address the challenges faced by the Iron and Steel Industry.

I convey my best wishes to the organizers and wish the Seminar a grand success.

**(DR G RANGANATH)**





**Mr Sudipta Saha**



**President  
Indian Ceramic Society  
Kolkata  
West Bengal, India**

## Message

It gives me an immense pleasure to know that the Bokaro Steel Plant, Steel Authority of India Limited (SAIL) is organizing an International Conference on “Refractories In Iron & Steel Industries (REFIS 4.0 Edition-II 2024)” during April 12th-13th, 2024 in association with Bokaro Chapter of the Indian Ceramic Society and Bokaro Chapter of The Institution of Engineers (India) at Bokaro Steel City, Jharkhand, India.

I am very happy to learn about the theme of the conference, "Forging the future: Advancements in Refractories in the Iron and Steel Industry through Sustainable solutions and Nano Technology" which will definitely explore the impact of Industry 4.0 on refractory practices, including process technology, advancements in installation techniques with specific focus on carbon footprint reduction.

As the President of the Indian Ceramic Society, I take this opportunity to thank all the members of the conference organizing committee for their outstanding efforts in preparing for this event. I sincerely appreciate the humble efforts being put by the organizing team to host this conference and wish to congratulate them for the grand success of this intellectual extravaganza.

I hope this conference will create an ample opportunity for the participants to showcase their experience and expertise meant for the theme of the conference. I request all the experts in this field across the country to partake in this conference and contribute for the advance growth of the Refractory Science & Technology in the newer area of application and promotion of Refractory Industry as well. I also believe that this will help in opening avenues for collaborations in the field of the Iron and Steel Industry. I look forward to the valuable insights and connections that will emerge from the conference.

I wish to congratulate all the dignitaries, Invited Speakers, paper presenters, delegates and the participants for having contributed their excellent research work in this conference.

My good wishes for the Bokaro Chapter for all future endeavours and also for the grand success of

*Sudipta Saha.*

**(Mr Sudipta Saha)**





**B K Prasad**



**Chairman,  
The Institution of Engineers (India)  
Bokaro Steel City Local Chapter**

## Message

I am pleased to extend my commendation to Bokaro Steel Plant for hosting the Second International Conference on Refractories in the Iron & Steel Industry, scheduled for April 12th and 13th, 2024, in Bokaro. This prestigious event showcases the plant's commitment to excellence and innovation in the steel industry.

By organizing such an important conference, Bokaro Steel Plant has provided a valuable platform for industry experts, researchers, and stakeholders to come together and discuss the latest advancements, challenges, and opportunities in the realm of refractories. This collaborative effort is essential for driving progress and fostering continuous improvement in the iron and steel sector.

The dedication and vision of Bokaro Steel Plant in hosting this conference are truly commendable. I am confident that this event will lead to fruitful discussions, knowledge sharing, and the exploration of innovative solutions that will benefit the entire industry.

A handwritten signature in blue ink, which appears to read 'B. Prasad'.

**(B K Prasad)**





### Chief Patron



**Atanu Bhowmick**  
Director In-Charge  
SAIL-Rourkela Steel Plant  
*with Addl charge of*  
SAIL-Bokaro Steel Plant

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SAIL/BSL

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(India), Bokaro

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SAIL/BSL

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9. Niharika Anand, BSL

### Cultural Event Committee

1. S S Lall, GM (RED), BSL
2. Rahul Kumar Gupta, GM (RED)
3. S T Kohade, GM (RPC), BSL
4. Saurabh Singh, AGM (EMD), BSL



### Program Schedule

|                             |                                        |
|-----------------------------|----------------------------------------|
| <b>Day-I</b>                | <b>Venue: HRD Building/ Auditorium</b> |
| 12 <sup>th</sup> April'2024 | 8:30 AM – 13:30PM                      |
| 8:30 AM- 9:00 AM            | Registration                           |
| 9:00 AM-11:00 AM            | Inaugural Session                      |
| 11:00 AM- 11:30 AM          | Exhibition Visit & Vendor Discussion   |
| 11:30 AM-12:00 PM           | High Tea                               |
| 12:00PM-13:30 PM            | Plenary Session                        |
| 13:30 PM- 14:30 PM          | Lunch                                  |

|                                  |                                                                          |
|----------------------------------|--------------------------------------------------------------------------|
| <b>Day-I</b>                     | <b>Venue: Auditorium</b>                                                 |
| 12 <sup>th</sup> April'2024      | 14:30 PM-18:00 PM                                                        |
| Session I<br>(14:30 – 16:00 PM)  | <b>Refractory for Steel making, Secondary steel refining and casting</b> |
| 16:00-16:15 PM: Tea Break        |                                                                          |
| Session II<br>(16:15 – 18:00 PM) | <b>Refractory for Steel making, Secondary steel refining and casting</b> |

|                                      |  |
|--------------------------------------|--|
| <b>Cultural Program &amp; Dinner</b> |  |
| <b>Venue: Bokaro Club</b>            |  |
| 19:30 PM onward                      |  |

|                             |                                           |
|-----------------------------|-------------------------------------------|
| <b>Day-II</b>               | <b>Venue: Auditorium</b>                  |
| 13 <sup>th</sup> April'2024 | 9:00 AM – 13:30 PM                        |
| Session III                 | <b>Emerging Technology for Refractory</b> |
| 11:00AM-11:15 AM: Tea Break |                                           |
| Session IV                  | <b>Advance Refractory Solution</b>        |

|                            |  |
|----------------------------|--|
| 13:30 PM- 14:30 PM : Lunch |  |
|----------------------------|--|

|                             |                            |
|-----------------------------|----------------------------|
| <b>Day-II</b>               | <b>Valedictory session</b> |
| 13 <sup>th</sup> April'2024 | 14:30 PM-15:30 PM          |
| <b>HRD Auditorium</b>       | Valedictory session        |

**Registration**

| Day-I                       | Venue: HRD Building |
|-----------------------------|---------------------|
| 12 <sup>th</sup> April'2024 | 8:30 AM- 9:00 AM    |

**Inaugural Session**

| Day-I                       | Venue: HRD Auditorium                                                                                                                             |
|-----------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------|
| 12 <sup>th</sup> April'2024 | 9:00 AM - 11:00 AM                                                                                                                                |
| 9:00-9:10 AM                | Welcome of Guest                                                                                                                                  |
| 9:10-9:15 AM                | Invitation of dignitaries to Dias&Lighting of Lamp                                                                                                |
| 9:15-9:20 AM                | Welcome addresses<br>Shri V P Upadhyaya, CGM (Ref), BSL, SAIL&Chairman, REFIS 4.0                                                                 |
| 9:20-9:30 AM                | Address<br>Shri B K Tiwari, ED(W), BSL                                                                                                            |
| 9:30-9:50 AM                | Address by Guest of Honour<br>Dr. Deepak Jain, Director-General, FII                                                                              |
| 9:50-10:20 AM               | Key Note Speak: "Nanotechnology and the development of future materials",<br>Dr Chacko Jacob, Professor, Indian Institute of Technology Kharagpur |
| 10:20-10:35 AM              | Felicitation of Dignitaries and Release of Souvenir                                                                                               |
| 10:35 - 10:55 AM            | Inaugural Address by Chief Guest<br>Shri Atanu Bhowmick, Director I/c RSP & BSL                                                                   |
| 10:55-11:00 AM              | Vote of Thanks<br>Convener, REFIS 4.0                                                                                                             |
| 11:00 AM                    | National Anthem                                                                                                                                   |

11:05 AM-11:30 PM Inaugural Ceremony of Technical Exhibition

11:30-12:00 PM High Tea

**Plenary Session**

| Day-I                       | Venue: HRD Auditorium                                                                                                                                                                |
|-----------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 12 <sup>th</sup> April'2024 | 12:00PM-13:30 PM                                                                                                                                                                     |
| 12:00 -12:30 PM:            | Dr. Debasish Sarkar, Professor, Ceramic Engineering NIT Rourkela                                                                                                                     |
| 12:30-13:00 PM:             | Shri Kushal Agrawal, MD, Sarvesh Refaractories Pvt. Ltd.                                                                                                                             |
| 13:00-13:30 PM:             | Shri Uditendu Verma, Additional General Secretary, Federation of Indian Industry<br>Challenges and Opportunities in Indian refractory industry towards Aatmnirbhar Bharat initiative |



## Schedule for Paper Presentation: 1<sup>st</sup> Day- 12 Apr'2024

**Session: I: Refractory for Steel making, Secondary steel refining and casting**

**Venue: HRD Auditorium**

**14:30 PM-16:00 PM**

| SN | Paper Title                                                 | Authors Institute/Organization                                                                              |
|----|-------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------|
| 1  | Basics of fluid dynamics and BOF bottom purging             | Kaushik Dasgupta<br>RHI MAGNESITA INDIA LIMITED                                                             |
| 2  | High corrosion resistant MgO-C refractory for BOF converter | Ashok Agarwal, K Agarwal, S Mukhopadhyay* G S Debasisha P Dubey, Sarvesh Ref. Pvt Ltd                       |
| 3  | Development of New Generation Alumina Graphite Ladle Shroud | Akhilesh Singh, S Banerjee, S Mishra, D Banerjee, Bikashendu Mohanty, N Mishra<br>IFGL Refractories Limited |
| 4  | BOF Hot patching bricks                                     | SAMWHA India Refractories Pvt Ltd                                                                           |
| 5  | A study on Corrosion behaviour of MgO Grade                 | N K Mishra, Gowtham Raju, Eswaran Ramasamy, Sudip Chandra, S. Arasu<br>IFGL Refractories Limited,           |
| 6  | Ladle Lip Brick                                             | SAMWHA India Refractories Pvt Ltd                                                                           |

**Session: II: Refractory for Steel making, Secondary steel refining and casting**

**Venue: HRD Auditorium**

**16:15 PM-17:45 PM**

| SN | Paper Title                                                                                                                             | Authors Institute/Organization                                                                                       |
|----|-----------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------|
| 1  | Challenges and Solutions for manufacturing of TCD SES & TCD TN refractories in Consideration of long –sequence casting and Clean steel. | H.L Rai (M.D), Lalu Prasad Malla (Manager CCR), Pankaj Kumar (Sales Head), Zircar                                    |
| 2  | High performance monolithic lining on RH Snorkel                                                                                        | Sk. Bashir Mohammed, S Mondal, C. Devanathan, S. Arasu,<br>IFGL Refractories Limited                                 |
| 3  | Modern Techniques In Improving Steel Quality In Tundish                                                                                 |                                                                                                                      |
| 4  | An Experimental Study to Improve the Zirconia Metering nozzle Performance in low carbon Steel casting (construction Grade)              | S.Mandal; B.K.Mohanty; A.Sau; A.Roy;<br>A.Polley; S.Arasu; N.K.Mishra<br>IFGL Refractories Limited, Kalunga, Odisha, |
| 5  | Safer steel casting Operation & Workplace by mitigating challenges through technical excellence                                         | Deepak Kumar*, Gaurav Pandey, Sahin Ali, H. Nagata, S. Sengupta, P. B. Panda<br>TRL Krosaki Refractories Limited     |
| 6  | Improvement of Steel Ladle life through addition of Synthetic Slag                                                                      | Sanjoy Dutta; Sushanta Pal<br>Refractories Department, SAIL-ISP, Burnpur                                             |
| 7  | Refractory materials and maintenance practices for BOF at BSP                                                                           | Satish Kumar Agrawal, S.K.Mahapatra,<br>H B Mallick, Y.K Gupta, P Singh<br>Bhilai Steel Plant, SAIL                  |

## Schedule for Paper Presentation: 2<sup>nd</sup> Day- 13 Apr'2024

### Session: III: Emerging Technology for Refractory

Venue: HRD Auditorium

9:00 AM-11:00 AM

| SN | Paper Title                                                                                                                                                       | Authors Institute/Organization                                                                                                                                   |
|----|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1  | Prospect of Manufacturing Synthetic Raw Materials in the concept of Atma Nirbhar Bharat                                                                           | Tapas Pattanaik,<br>Kosmokraft Refractory India Pvt Ltd.                                                                                                         |
| 2  | Proper use of Refractories for GHG mitigation                                                                                                                     | NP Srivastava and Nitesh Ranjan,<br>SAIL-Bokaro Steel Plant                                                                                                      |
| 3  | Innovative materials for circular economy from refractory wastes                                                                                                  | S. Harinipriya and A Khandelwal<br>Entity1 Emission Private Limited                                                                                              |
| 4  | Energy and Environment Conservation by using advanced insulation products “Low – Bio Persistence- Sueprwool ” Fibre& HT Mullite - 1600 Deg C Fibre”in Steel Plant | M Kadhivelu, Murugappa Morgan<br>Thermal Ceramics Limited                                                                                                        |
| 5  | Lime Enriched Magnesita Carbon Refractory bricks- Suitability in Si-Killed Steel ladles                                                                           | Ashok Agarwal, K Agarwal, S<br>Mukhopadhyay, D K Sinha, M K<br>Viswanatham. SarveshRef.Pvt Ltd.                                                                  |
| 6  | Application of Spinel based Steel ladles in the SMS II shop of Bokaro steel plant                                                                                 | Anand Kr Yadav, R K Gupta, Veda<br>Prakash Upadhyaya,, BSL, SAIL                                                                                                 |
| 7  | A techno-economic balance in achieving torpedo ladle life                                                                                                         | Kavita Bisoyi, Purab Das, Bibhu Prasanna<br>Sahoo, Manager, RSP, SAIL                                                                                            |
| 8  | Development of high-performance refractory bricks suitable for critical area of Electric Arc Furnace                                                              | Indranil Roy <sup>#</sup> , M K Kujur <sup>#</sup> , S Aman <sup>#</sup> ,<br>Amitava Paul <sup>#</sup> , R Kr. Pradhan* <sup>#</sup> RDCIS-<br>SAIL, * SRU-SAIL |

### Session: IV: Advance Refractory Solution

Venue: HRD Auditorium

11:15 AM-13:15 PM

| SN | Paper Title                                                                                                                                           | Authors Institute/Organization                                                                                                                                                                         |
|----|-------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1  | Interaction Behaviour between Slag Containing Cerium Oxide and MgO-C Bricks via X-ray Diffraction and Computed Tomography: A Scientific Investigation | Vikash Kumar <sup>a,b</sup> , M K Kujur <sup>a</sup> , S Acharya <sup>a</sup> ,<br>Dr A Deva <sup>a</sup> , Dr K Chattopadhyay <sup>b</sup><br><sup>a</sup> RDCIS, SAIL, <sup>b</sup> IIT BHU Varanasi |
| 2  | Experience of TRM in Torpedo Ladle in BSL and BSP                                                                                                     | Subhash Singh, S. Agarwal, Pralay<br>Chakraborty, P. Sengupta;<br>SKG Refractories Limited                                                                                                             |
| 3  | Modified burner with engraved Precast refractory – A Refractory solution for ignition furnace of SP-2, DSP                                            | MK Kujur, I Roy, S Aman, SA Balaji, RK<br>Pradhan, A Paul; RDCIS &SRU, SAIL                                                                                                                            |
| 4  | Development of suitable castable for prefabricated refractory lining of Roof of Ignition Furnace at Sinter Plant-3, RSP,                              | R.K. Pradhan*, P. Singh, B.Mahata, B.B.<br>Kanta<br>SAIL Refractory Unit IFICO, Marar                                                                                                                  |
| 5  | Use of special additive to reduce water demand of Trough Castable.                                                                                    | JogeswarGuiya and Shri Somnath Sen<br>SRU, Bhandaridah                                                                                                                                                 |
| 6  | Blast furnace refractories & cooling system – an integrated approach                                                                                  | Surendra Prasad, Advisor (Ref)<br>Centre for Engineering & Technology                                                                                                                                  |
| 7  | Slag Refractories Interaction in Pyro metallurgical process                                                                                           | Dr B.Mishra, Alok Khemka, Raj Khemka,<br>J Behera<br>Khemka Refractories Pvt Ltd                                                                                                                       |
| 8  | Unlocking the power of machine learning: enhancing predictive analytics for price forecasting                                                         | mjunction services limited                                                                                                                                                                             |

### Valedictory Session with Panel Discussion

|                             |                                                                     |
|-----------------------------|---------------------------------------------------------------------|
| <b>Day-II</b>               | <b>Venue: HRD Auditorium</b>                                        |
| 13 <sup>th</sup> April'2024 | 14:30-15:30 PM                                                      |
| 14:30-14:35 PM              | Welcome of Guest & Opening Remarks                                  |
| 14:35-15:05 PM              | Panel Discussion: Future of Refractories in Iron and Steel Industry |
| 15:05-15:15 PM              | Synopsys of the conference<br>Chairman, REFIS 4.0                   |
| 15:15-15:25 PM              | Concluding Remarks                                                  |
| 15:25-15:30 PM              | Vote of Thanks<br>Convener, REFIS 4.0                               |

# Basics of fluid dynamics and BOF bottom purging

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## Abstract

The foundational axioms of fluid dynamics had been the traditional conservation laws: conservation of mass, conservation of linear momentum and conservation of energy. Simply put in, it's basically a branch of applied science that is concerned with the movement of liquids and gases. This movement of liquids and gases we generally refer to as flow, a concept that describes how fluids behave and how they interact with their surrounding environment. Understanding the interdependent nature of pressure, flow and velocity is important when designing a BOF bottom purging system but more important is understanding when each variable is the critical design parameter. This paper tries to explain the fundamentals of the dynamics of gas flow the system handles and that upholds an efficient BOF bottom purging.

*Keywords - back pressure; mass flow; volumetric flow; flow control valve, pressure control valve, flow control and pressure control algorithms, mass flow controller*

## INTRODUCTION

MHP (Multi Hole Plug) purging plug designs for inert gas bottom purging with flow rate optimized pipe diameters and number of pipes, have been established as widely accepted state-of-the-art for some decades. Such designs are based on 100% top-grade fused magnesia, top-grade graphite, optimized grain size distribution, and additives.

Efficient purging until the end of the BOF lining campaign is the target of all gas purging projects in BOF shops and is affected by the applied range of gas flow rates, the clogging potential, and the wear rate under process conditions.

Understanding the interdependent nature of pressure, flow and velocity of the purging gas is important when designing a BOF bottom purging system but more important is understanding when each variable is the critical design parameter.

When we use a fluid to power a process it is essential that we should have the ability to control the fluid too, in other words, we should be able to manipulate the amount of energy input the fluid can provide to that process. It all boils down to either open-loop control or closed-loop control. At the end of the day, pressure and flow are not independent characteristics of fluid transport. You can't change one without changing the other. But what you can do is monitoring and controlling one thus subjugating the other to follow.

### ***A. Concepts of fluid dynamics that go into making an efficient bottom purging:***

Fluid dynamics is basically a set of empirical and semi-empirical laws derived from flow measurement, giving them a systematic structure, and using them to solve practical problems. Simply put in, it addresses how fluids behave and how they interact with their surrounding environment.

#### ***1) Back pressure***

When a fluidic substance moves through a pipe, it builds up a lot of kinetic energy and inertia. When that energy hits a wall (say a blockade by infiltrate in the plug), it bounces back like ripples. This has two major effects:

- a) Increases pressure in the pipe when the fluidic substance first encounters a change. This effect is commonly called a fluid hammer. The fluid bounces back at the fluid attempting to come through the pipe. This will increase the fluid present in that small section of pipe and, thereby, increase its pressure.
- b) It also slows down the movement of all the fluid in the pipe, from the place of change all the way back to the source.

So, the flow is essentially in the same direction, but the flow is reduced due to resistance.

#### ***2) Open-Loop vs. Closed-Loop Fluid Control***

Using a fluid to power a process calls for controlling the fluid too. It all boils down to either open-loop control or closed-loop control.

In the simplest terms, if the output response (result) generated is directly related to the input (action) supplied by the controller via feedback from the process itself, the system is closed-loop, if not it is considered open-loop. For obvious reasons, open-loop systems are less accurate, less repeatable and (generally) less costly. An efficient CIP always thrives on a closed loop control.

### 3) Volumetric flow rate

It is a measure of the 3-dimensional space that the gas occupies as it flows through the instrument under the measured pressure and temperature conditions. Volumetric flow rate can also be called actual flow rate.

Volumetric Flow Rate is dependent on Pressure & Temperature and hence are recommended for measuring volumetric flow when high accuracy is not needed.

### 4) Mass flow rate

It is a measure of the number of molecules that flow through the instrument, regardless of how much space those molecules occupy. It is often expressed as a standardized (or normalized) volumetric flow rate, which is the amount of space that those molecules would occupy if measured under standard temperature and pressure conditions (STP, or NTP).

Mass Flow Rate is independent of Pressure & Temperature and hence more reliable with higher accuracy and repeatability.

### 5) Relation between volumetric flow rate and mass flow rate:

$$\tilde{V} = \dot{m} \cdot n \cdot R \cdot T / (m \cdot P)$$

Where  $\tilde{V}$  = Volumetric flowrate,  $\dot{m}$  = Mass flow rate,  $m$  = molar weight,  $n$  = moles,  $R$  = real gas constant

$P$  = Pressure,  $T$  = Temperature

Example: a 200sccm flow sensor with a mass flow rate of 0.250 g/min (200sccm) of nitrogen.

|                       |                                      |
|-----------------------|--------------------------------------|
| $\dot{m}$             | 0.25 g/min                           |
| $m$                   | 28 g                                 |
| $n$                   | 1 mole                               |
| $R$                   | 82.1 (cm <sup>3</sup> ·atm)/(mole·K) |
| <b>STP</b>            |                                      |
| $P$                   | 1 atm                                |
| $T$                   | 273.15 °K                            |
| $\tilde{V}$           | = 200 cm <sup>3</sup> /min           |
| <b>MASS FLOW RATE</b> | = 0.25 g/min                         |

If mass in the system does not change, and mass being independent of pressure and temperature, mass flow rate also does not change with pressure and temperature even though the volumetric flow rate changes.

This calculation refers to standard pressure & temperature. Here volumetric flow rate  $\tilde{V}$  = 200 cm<sup>3</sup>/min can also be referred to as mass flow rate  $\dot{m}$  = 200 sccm/min (equivalent to 0.250 g/min). For non-standard conditions ( $P$  and  $T$  changing), volumetric flow rate  $\tilde{V}$  will vary but mass flow rate remains same i.e. 200 sccm/min (equivalent to 0.250 g/min) as long as we do not bring about any change in mass.

### B) Pressure control valve (PCV)

The PCV is what you use to regulate the pressure of a fluid passing through the pipe.

PCV is controlled using a pressure transmitter (PT) which is basically an electronic pressure gauge that sends signals to the PCV and tells it whether there is enough pressure entering the equipment. The PCV opens or closes to compensate. This is based on the set point predetermined by an engineer.

They are not designed to act as flow controllers.



Flow is critical when the fluid needs to fill a space. We need to supply a given volumetric flow rate that continuously fills and replenishes the application space.

### 3) *Pressure*

If an application is expected to have a high back pressure, the system must be rated to operate at that pressure. Characteristics of a system with a high level of back pressure include multiple lengths or long lengths of hose or pipe and applications where gas is forced through small openings.

### *F) Control System:*

- 1) PLC (Programmable Logic Controller): The flow control and pressure control systems are typically integrated into a central control system using a PLC. The PLC receives input from various sensors, such as flow meters and pressure sensors, and controls the gas valves and other components accordingly.
- 2) Human-Machine Interface (HMI): An HMI is used to provide operators with real-time information about the flow rates, pressures, and other relevant parameters. Operators can make adjustment and set desired process conditions through the HMI.

### *G) Monitor and control pressure:*

Implement a pressure monitoring system and connect it to a feedback control mechanism. This allows for real-time monitoring of the back pressure and automatic adjustment of the flow control system to maintain the desired pressure levels.

### *H) Coordinated System Optimization*

When flow control and pressure control algorithms work together, they can optimize the system's overall performance. By coordinating their actions, they can minimize reduce pressure drops and improve system efficiency.

For example, if the pressure control algorithm detects excessive pressure, it can communicate with the flow control algorithm to reduce the flow rate, thereby reducing pressure and preventing overpressure situations.

### *Conclusion*

A bottom purging element alone doesn't suffice the purpose of an efficient purging system. It is only a part of a much bigger setup that gives due cognizance to the interdependent nature of pressure, flow and velocity of the gas the system handles in a coordinated manner.

### *References*

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- [2]. Andreas Viertauer, Michael Schacher, Stanislav Ulitsky, Matthias Scheibmayr, Erich Röllin, ReinhardEhrenguber, Matthias Stalzer, Oswin Dolzer, Teodor Staicu, Thomas Kollmann, Bernd Trummer, Alexander F. Orlov, Alexander Papushev, Sergey Razgulyaev, Marcus Kirschen and Sergey G. Zhuravlev, "Implementation of BOF Gas PurgingTechnology and Current Process ResultsAfter One Year of SuccessfulOperationatSeverstal Cherepovets".
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## High corrosion resistant MgO-C refractory for BOF converter

Ashok Agarwal Kushal Agarwal Santanu Mukhopadhyay\* G S Debasisha P Dubey  
Sarvesh Refractories Pvt Ltd

### ABSTRACT:

Fast changing scenario in specific consumption of steel per capita demands for a faster steel making technology using the available resources of mineralogical iron ore grades. At present we are not left with the luxury of using only premium grades of iron ore. It becomes essential to use the then throw-away second and low-grade iron ores as well. This demands for a pressure on refractories to withstand the aggressive operating parameters. BOF, being the most important metallurgical equipment in integrated steel plant, the refractory manufacturer should go hand-in-hand with the increasing demand of quality parameters. This demands for a newer refractory with a higher resistance towards aggressive BOF slags. Secondly, with the development of bottom purging technology in BOF, it demands for a refractory with higher oxidation resistance to address the carbon depletion at a faster rate. With this backdrop, the present paper describes the development of a MgO-C refractory with high corrosion resistance and higher oxidation resistance. The performance feedback from the user steel plants are also presented in this paper.

### 1.0 Introduction:

Basically, Mag-C bricks are made from four major ingredients, e.g. magnesia, graphite, resin as a binder and anti-oxidants. Magnesia are broadly available in three categories, dead burnt magnesia, sea water magnesia and fused magnesia. Depending on the application area either single type or a combination of different magnesia is selected. For designing of MgO-C, the amount of graphite plays a great role in determining the most critical properties like slag corrosion, oxidation resistance and spalling resistance and thereby the lining life. The optimum quantity of graphite and the distribution of carbon bond in the brick restrict the carbon pick-up by the steel. Carbon in the form of graphite is used in converter generally are of crystalline variety, but other varieties of carbon are also available in non-crystalline form, which are also selected depending on the application area. Graphite is also available in different purity, normally a purity of 94% is considered as standard, but a higher purity is also used, with an aim to reduce the level of impurities. Furthermore, the proper selection of anti-oxidants also enhances the converter life under specific operational parameters by reducing the rate of depletion of carbon from the brick. Resin is used as a bonder either phenolic or resol type. In fact, a converter has different zones, which demand for specific property of refractories. So, a zonal concept of lining is very popular which meets the different demanded properties and finally meet the demand and enhances converter life. The present paper describes the development of a high slag corrosion resistant MgO-C brick, which was designed for application in BOF converter taking care of the prevailing operational parameters thereof. The newly designed quality has already been applied to one of the steel plants and achieved encouraging life. Some of them are still running.

### 2.0 Experimental:

As explained above, a BOF converter has different zone like bottom, barrel, trunnion, charge pad, tap hole and top cone. The refractory property required in different zone are different. To design a converter lining thickness and recipe, it is necessary to understand the requirement. Fig-1 shows a typical BOF converter and Table-1 shows zone wise property requirement from the refractory.



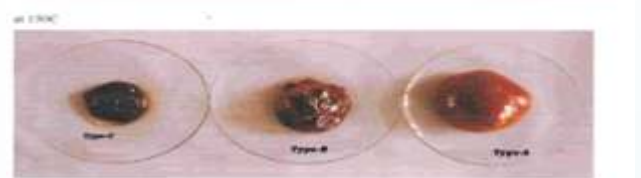
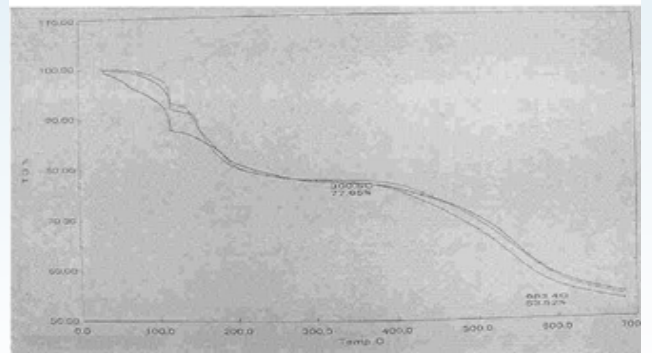
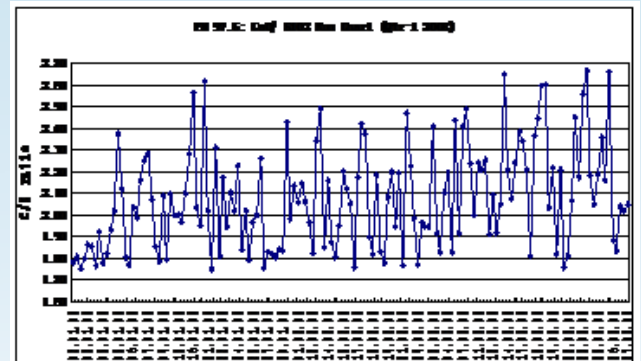
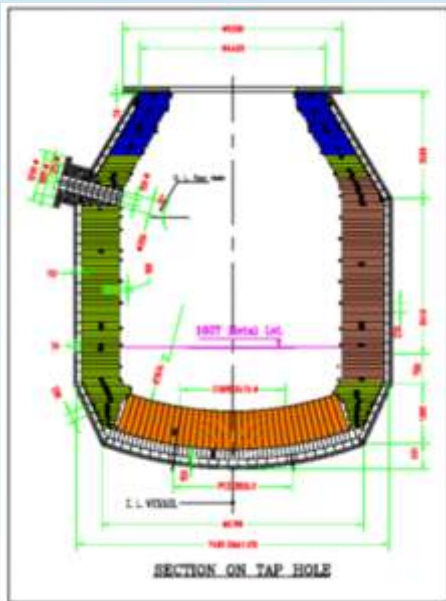
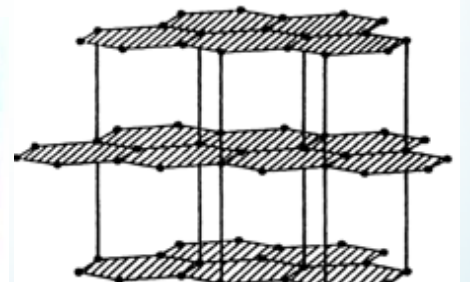
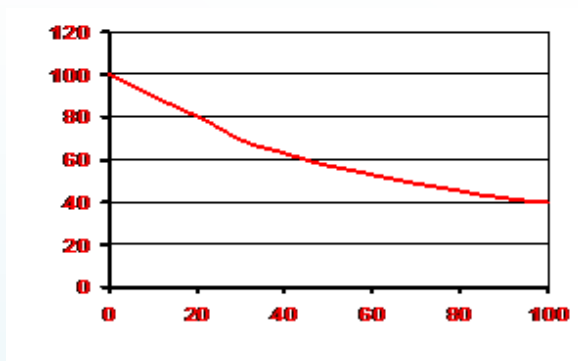


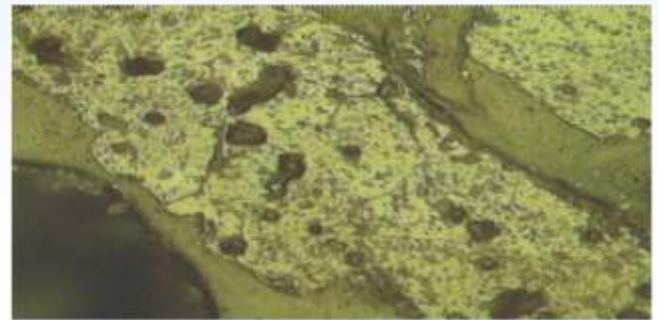
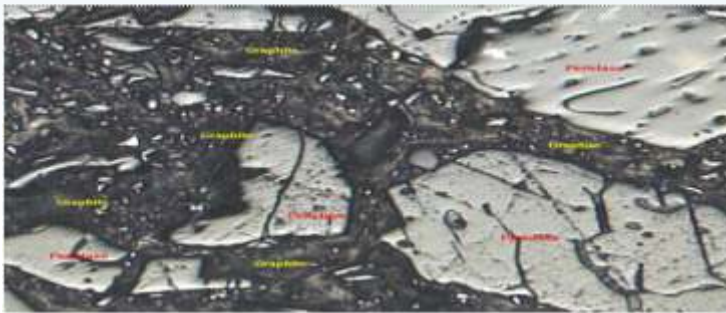
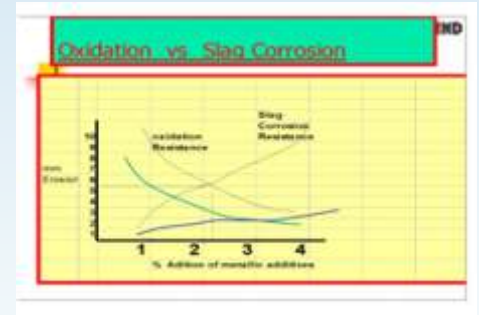
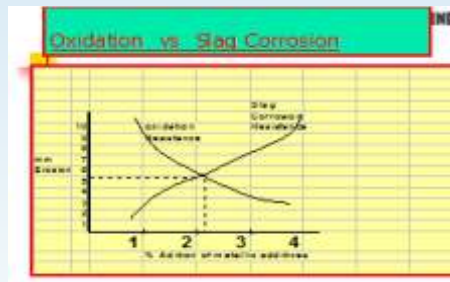
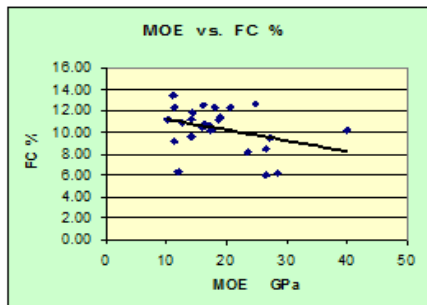
Fig-1 A typical BOF converter

| Zone        | Therm<br>spall | Corsn<br>resist | Oxidn<br>Resist | Flexibility | Compr<br>Strength |
|-------------|----------------|-----------------|-----------------|-------------|-------------------|
| Bottom      | ✓              | ✓               | ✓               | ✓           | ✓                 |
| Barrel      | ✓              | ✓               | ✓               | ✓           | ✓                 |
| Trunion     | ✓              | ✓               | ✓               | ✓           | ✓                 |
| Ch Pad      | ✓              | ✓               | ✓               | ✓           | ✓                 |
| Tap<br>Hole | ✓              | ✓               | ✓               | ✓           | ✓                 |
| T Cone      | ✓              | ✓               | ✓               | ✓           | ✓                 |



Improvement in withstanding tensile stress. This requires increase in Graphite content to have lower MOE of the bricks which in turn increases the flexibility of the bricks. As you increase graphite content the bricks becomes oxidation prone.

Improvement Oxidation resistance and Slag Corrosion resistance simultaneously. This requires a optimum balancing combination of anti-oxidants.



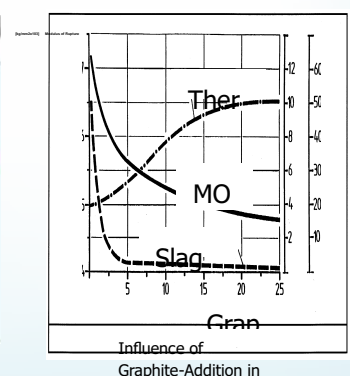
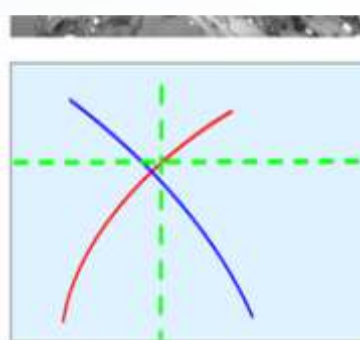
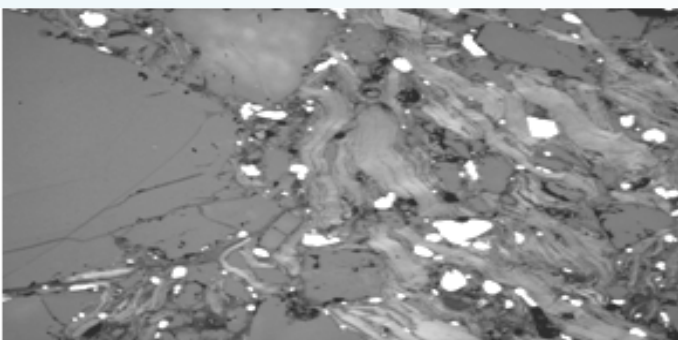
## Effects of Antioxidants:

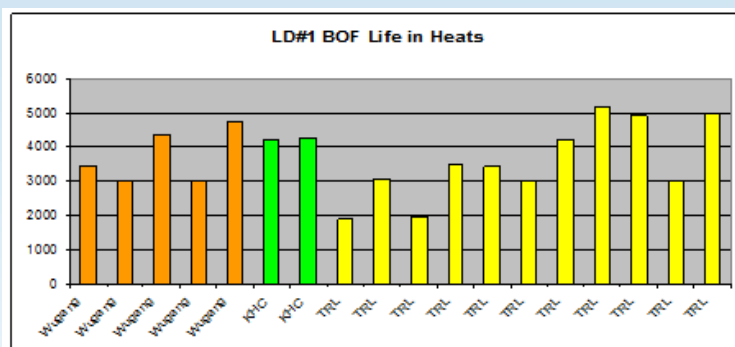
### Protection from oxidation!

- Reduction of Oxides with high oxygen potential ( $\text{FeO}$ ,  $\text{MnO}$ ,  $\text{Na}_2\text{O}$ ,...) melting point of infiltrated slag increases, slag solidifies  
> infiltration - stop
- Prevention of Carbon-Attack mainly by  $\text{FeO}$   
> reduction of carbon burn out

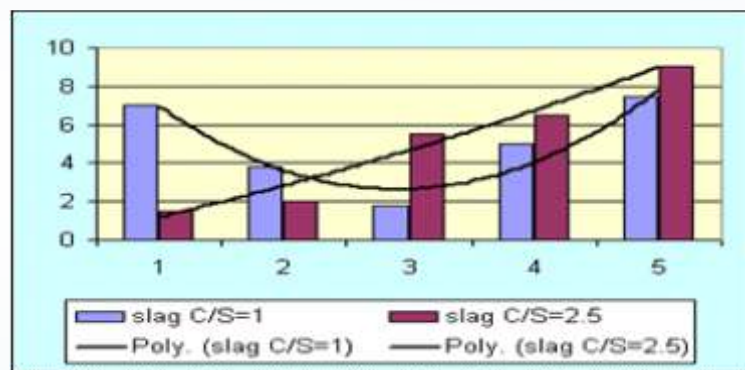
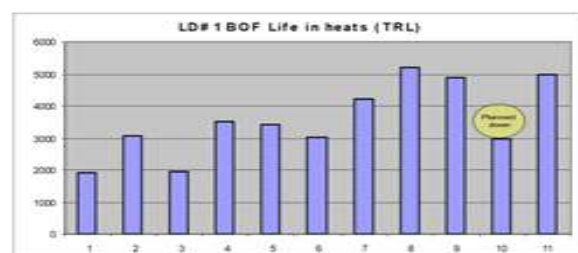
### Types of Antioxidants for the Ladle:

- Al-, Si-Powder, 2.7%Al, 0.5%Si = standard mix for slagzone
- Al-, Al-Mg-Powder, 1%Al, 2%Al-Mg = special mix for slag zone
- Al-Powder, 1.5%Al = only used for AMC-bricks in ladle sidewall

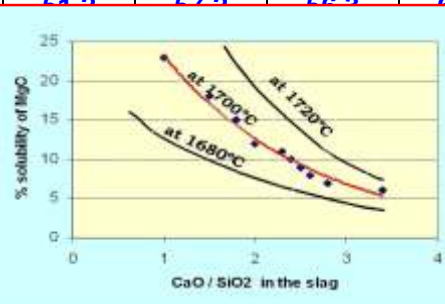
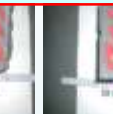




**Performance of Refractories by Tata Refractories Ltd**



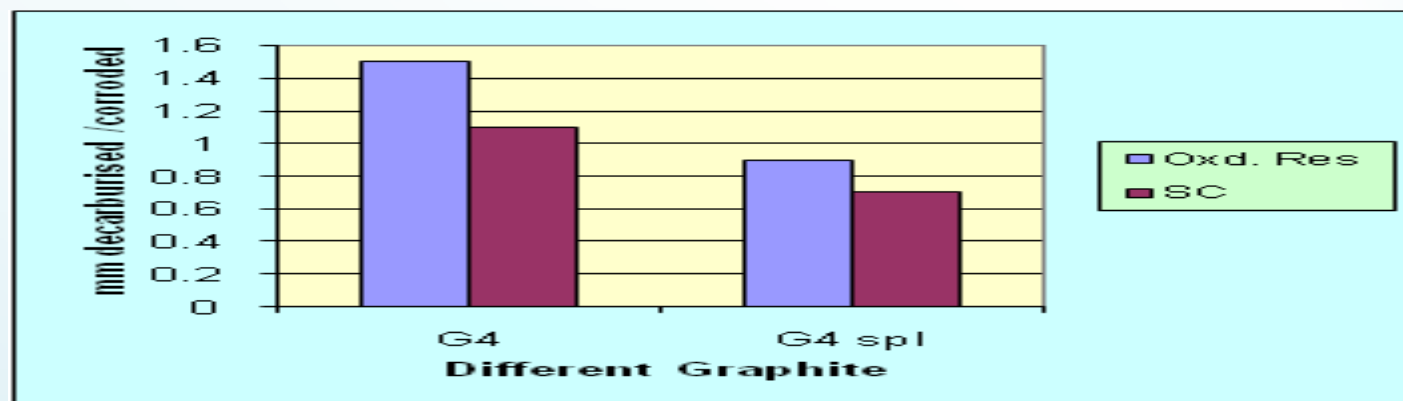
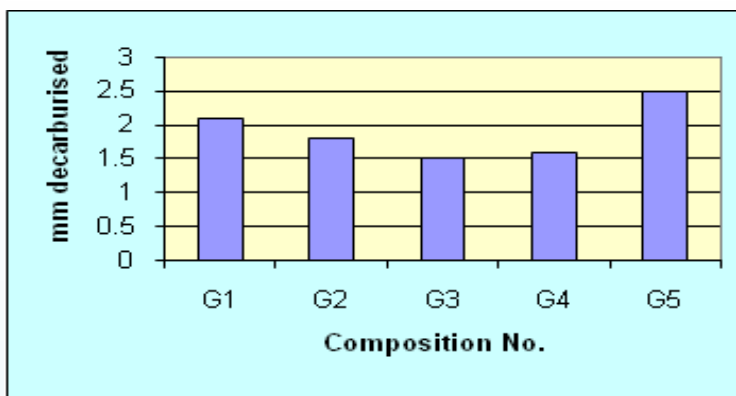
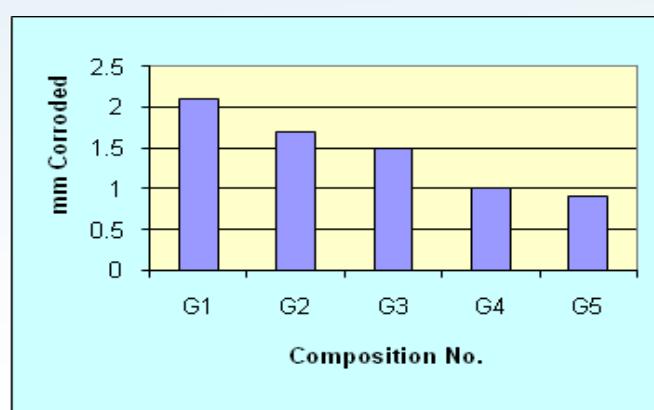
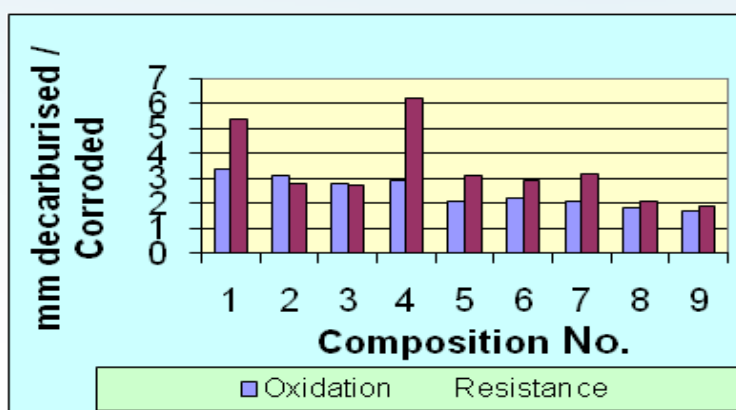
| Comp.    | 1 | 2 | 3  | 4  | 5  |
|----------|---|---|----|----|----|
| Spinel % | 0 | 5 | 10 | 15 | 20 |

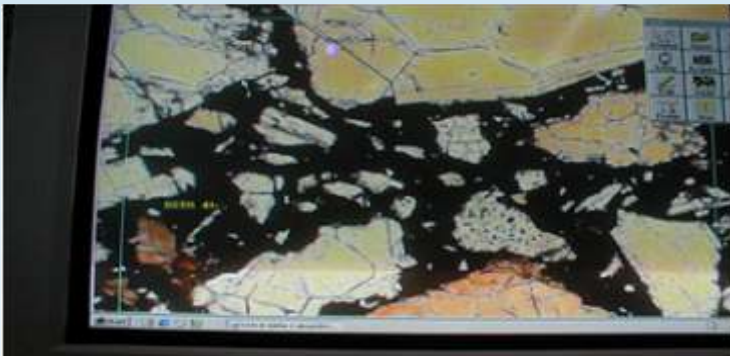
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|-------------------------------------------------------|--------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------|
| AP %                                                  | 3.2                                                                                        | 3.1                                                                                        | 3.7                                                                                        | 4.2                                                                                        | 3.1                                                                                        | 3.2                                                                                          | 4.7                                                                                          | 3.2                                                                                          | 3.6                                                                                          |
| BD g/cc                                               | 3.08                                                                                       | 3.07                                                                                       | 3.03                                                                                       | 3.05                                                                                       | 3.07                                                                                       | 3.04                                                                                         | 3.03                                                                                         | 3.03                                                                                         | 3.05                                                                                         |
| CCS MPa                                               | 63.2                                                                                       | 57.8                                                                                       | 54.2                                                                                       | 57.2                                                                                       | 56.2                                                                                       | 61.2                                                                                         | 53.2                                                                                         | 55.7                                                                                         | 47.9                                                                                         |
| HMOR Mpa                                              | 8.3                                                                                        | 11.4                                                                                       |                                                                                            |                                                                                            |                                                                                            | 2.8                                                                                          | 10.2                                                                                         | 14.2                                                                                         | 14.3                                                                                         |
| PLC %                                                 | +0.18                                                                                      | +0.13                                                                                      |                                                                                            |                                                                                            |                                                                                            | -0.2                                                                                         | +0.15                                                                                        | +0.09                                                                                        | +0.08                                                                                        |
| Oxidation Resistance at 1500°C/2hr mm                 | <br>3.4 | <br>3.1 |        |                                                                                            |                                                                                            | <br>2.2 | <br>2.1 | <br>1.8 | <br>1.7 |
| Slag Corrosion at 1600°C for 10 hrs; mm Slag CaO/SiO2 | <br>5.4 | <br>2.8 | <br>2.7 | <br>6.2 | <br>3.1 | <br>2.9  | <br>3.2 | <br>2.1 | <br>1.9 |



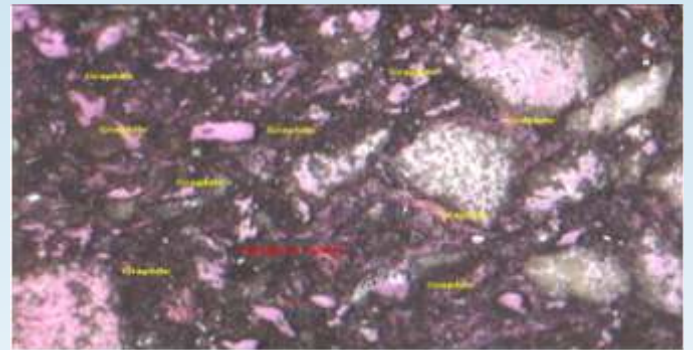
It is seen that, out of three different combinations shown above, the combination with anti-oxidant A and B, which was given in composition 4,5 and 6 has given the best oxidation resistance, but the slag corrosion resistance becomes poor when compared against the similar composition of 1,2 and 3. On the other hand the slag corrosion resistance is better in the composition 7, 8 and 9. But if we see the oxidation and corrosion resistance jointly, the combination of anti-oxidant A and C is the best. It is also revealed that the slag corrosion resistance does not much change with 5 % and 7 % carbon; it almost remain at the same level. Keeping in view the carbon pick up by the low carbon steel, we decided to keep the carbon % at 5 % level.

As a second step, we experimented with different purity of graphite, keeping the graphite addition in the same level i.e. at 5 %. The different purity is identified as G1, G2, G3, G4 and G5. The anti-oxidant combination was taken with A and C as shown in Table-I. Fig-2 shows the result of slag corrosion of the bricks with increase in graphite purity. As expected, slag corrosion resistance improved with the increase in purity of graphite, but one





**Fig-6 Microstructure of developed brick**  
Ref. X 200



**Fig-7 Distribution of Graphite  
+ N in Ref. X 200**

### **3.0 FIELD APPLICATION:**

After the successful pilot trial bricks were made with the above idea in our plant in China and these have been sent to a plant in USA. This plant is making mostly (90 %) 409 grade stainless steel in their 110 T capacity ladle. The tapping temperature is 1760 °C or 3200 °F and the residence time 4-5 hrs per heat. The bricks were successfully used and have given a life of 104 heats (Avg. of 3 sets) against their normal life of average 90 heats. Customer was happy and we got repeat order. The environment remains clean and pollution free. No hazardous toxic fumes were generated.

### **CONCLUSION:**

For stainless steel or extra low carbon steel, Magnesita carbon bricks with 5 % special graphite with a specific combination of anti-oxidant can work. Since this brick does not contain any chrome, so it does not pollute the environment.

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## Development of New Generation Alumina Graphite Ladle Shroud

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### Abstract

ladle shroud (LS) is a crucial component in the continuous casting (CC) process of steel making, contributing to the efficiency, quality, and reliability of steel production. Their design and material selection play a vital role in maintaining controlled steel flow, preventing oxidation, enhancing cleanliness, minimizing splashing and slag carryover, providing thermal insulation and hence plays an important part in tundish metallurgy.

As new technological challenges appear in steelmaking practices, a new concept of liner LS (LLS) has been introduced in recent years. The LLS uses a high insulating liner material with significantly lower thermal conductivity which acts as a heat insulator. This results in the reduction of thermal stress especially at the start of casting. Another advantage, in this case, is higher erosion resistance compared to oxidized bore of normal LS. Due to the improved erosion resistance, this product can be used for high throughput applications. The performance of this liner product is analysed on-site at various steel plants with different ladle capacities and throughput and encouraging results are found.

**Keywords:** *steel making; ladle shroud; continuous casting; high throughput.*

### 1. Introduction

The most important roles of the ladle shroud are to prevent re-oxidation of the molten steel, steel flow turbulence in the tundish and tundish slag picking up. They contribute to improving steel quality. Cold-start ladle shrouds (without preheating before use) are widely used, and hot-start ladle shrouds (with preheating before use) are also used in long casting sequence.

There is a continuous demand for the development of ladle shrouds for higher production efficiency, better steel quality and longer service life. The ladle shroud requires very good thermal spalling resistance because it receives huge thermal shock especially at the start of casting. In conventional ladle shroud (LS), the inner wall (bore) is made carbon free (pre-oxidised to remove carbon), which acts as a heat insulator reducing thermal shock.

Alumina-Carbon material, which has good thermal spalling resistance, is generally used for both of cold and hot-start ladle shrouds. Silica raw materials such as fused silica and zirconia mullite materials are widely used notably for the cold-start ladle shroud, because their low thermal expansion characteristics improve thermal spalling resistance. However, silica raw materials have poor wear resistance to tundish slag and manganese oxides in molten steel.

A new concept of liner LS (LLS) has been introduced in recent years to cope the new technological challenges arising as a result of need for higher throughput in steel making process. In LLS, a high insulating liner material, generally carbon free or reduced carbon content, is provided along the bore region. Carbon-free material has significantly low thermal conductivity and its inner liner acts as a heat insulator to reduce thermal shock. This material with significantly lower thermal conductivity thus results in the reduction of thermal stress especially at the start of casting.

This concept has been utilized and series of liner mixes were developed and liner LS were prepared and studied in-house. The one with the best in-house result is then tested at three of our customer sites having higher throughputs

with varying degree of casting parameters. In this paper, we discussed the successful trial results of LLS at actual casters.

## 2. Methodology

The in-house trial consists of designing a LLS which is made of a base mix IFL-937 for cup area, a body mix IFL-236 and different liner mixes for the inner bore region. The LLS were prepared in-house using different liner mixes, tested for their various green and fired properties. The in-house trial results are given in below sections.

### Typical Physical Properties and Chemical Compositions of liner mixes used

The liner mix used earlier at our customer site was IFL-01 and the result was not satisfactory at that time. Since then number of liner mixes from IFL-02 to IFL-06 were developed in-house and tested but didn't get properties similar to IFL-01. The newer developed liner mix IFL-07Y-02 showed better properties compared to other liner mixes developed in-house and hence used in LLS for on-site trial at our customer end. The various properties of the developed liner mixes were given in table below.

**Table 1 Physical and Chemical properties of some Liner mixes for high throughput LS.**

| Quality                                      | IFL-01      | IFL-07Y-01  | IFL-08Y     | IFL-09Y     | IFL-07Y-02  |
|----------------------------------------------|-------------|-------------|-------------|-------------|-------------|
| <b>Date of production</b>                    | 19.11.2022  | 20.11.2022  | 07.12.2022  | 07.12.2022  | 06.01.2023  |
| <b>VM(%)</b>                                 | 1.069       | 1.174       | 1.129       | 1.141       | 0.939       |
| <b>Bar Height (mm)</b>                       | 34.58       | 32.37       | 36.27       | 31.95       | 30.76       |
| <b>CIP density (@350 Kgf/cm<sup>2</sup>)</b> | 2.355,2.392 | 2.368,2.356 | 2.330,2.338 | 2.307,2.303 | 2.342,2.348 |
| <b>Green MOR (Kgf/cm<sup>2</sup>)</b>        | 20          | 25          | 24          | 28          | 31          |
| <b>(Grading) ASTM Mesh</b>                   |             |             |             |             |             |
| <b>+30</b>                                   | 9.28        | 49.03       | 59.15       | 60.52       | 78.77       |
| <b>+70</b>                                   | 72.57       | 45.06       | 34.91       | 31.90       | 17.95       |
| <b>-70</b>                                   | 18.15       | 5.91        | 5.94        | 7.58        | 3.28        |
| <b>Fired Result</b>                          |             |             |             |             | OPEN FIRING |
| <b>1000°C</b>                                | 9.88        | 11.805      | 11.776      | 12.313      | 11.121      |
| <b>%AP</b>                                   | 36.07,36.08 | 34.89,35.43 | 34.70,34.25 | 32.96,32.53 | 35.40,35.33 |
| <b>B.D(gm/cc)</b>                            | 2.28,2.28   | 2.27,2.26   | 2.17,2.19   | 2.25,2.25   | 2.21,2.21   |
| <b>CCS(Kgf/cm<sup>2</sup>)</b>               | 72,72       | 64,65       | 92,96       | 91,92       | 69,69       |
| <b>MOR(Kgf/cm<sup>2</sup>)</b>               | 48,48       | 39,43       | 45,46       | 46,46       | 51,47       |
| <b>Lamination</b>                            | NO          | NO          | NO          | NO          | NO          |
| <b>Al<sub>2</sub>O<sub>3</sub></b>           | 88.597      | 86.520      | 80.785      | 76.558      | 87.326      |
| <b>SiO<sub>2</sub></b>                       | 2.669       | 4.735       | 7.616       | 8.356       | 4.945       |
| <b>ZrO<sub>2</sub></b>                       | 0.945       | 0.987       | 2.732       | 6.600       | 0.065       |
| <b>TiO<sub>2</sub></b>                       | 0.613       | 0.647       | 0.169       | 0.204       | 0.230       |
| <b>Na<sub>2</sub>O</b>                       | 0.382       | 0.265       | 0.296       | 0.318       | 0.312       |
| <b>CaO</b>                                   | 0.298       | 0.332       | 0.216       | 0.386       | 0.178       |
| <b>Fe<sub>2</sub>O<sub>3</sub></b>           | 0.167       | 0.259       | 0.193       | 0.210       | 0.229       |
| <b>%Carbon</b>                               | 5.740       | 5.540       | 7.930       | 6.777       | 6.270       |
| <b>LOI(%)</b>                                | 6.037       | 5.950       | 7.772       | 7.102       | 6.443       |



### 3. Trial Results

The shrouds were first tested in-house for various properties and later on send to our customers to check its efficiency at the application site that is during actual casting condition. Each customer has different steel casting parameters and hence shroud design and dimensions varies accordingly.

#### **In- House Trial-1: Liner Mix IFL-01 and IFL-07Y-01**

As discussed earlier, the base mix used is IFL-937 and body mix used is IFL-236. The two liner mixes IFL-01 and IFL-07Y-01 were used and LS were prepared conventionally by isostatic pressing. The liner thickness was measured using a profoscope. The pressed products were slowly dried, glazed and close bore fired in a shuttle kiln. The fired products were analyzed for liner and body mix compatibility, lamination, crack formation and fired properties.



The analysis shows that there is compatibility issue between the body mix IFA-236 and the liner mix IFL-01. The LS body cracked in case of liner IFL-01; also surface crack appears on the inner liner surface of the LS. No such issues seen in the LS made with the liner mix IFL-07Y-01. The LS sections were further oxidized (open fire) to check for any lamination. The image below shows that no lamination observed between the body mix and liner mix in both cases in open firing.



**Figure: After oxidation analysis. No lamination observed between layers.**

Left to Right: IFL-01 and IFL-07Y-01.

### Conclusion:

#### Liner Mix- IFL-01 and IFL-07Y-01:-

1. Bar height in case of IFL-01 is more as compared to IFL-07.
2. Fired AP, CCS & MOR values for IFL-01 mix is more as compared to IFL-07. BD values are almost same.

#### LS Product - IFL-01 and IFL-07Y-01:-

1. Liner thickness after demolding, measured from profoscope, found to be around 6 mm.
2. LS with liner mix IFL-01- surface cracked after firing whereas LS from IFL-07Y-01 appears to be OK after firing.

#### In-House Trial- 2: Liner Mix - IFL-08Y and IFL-09Y



**Figure: LS after close bore firing**



**Figure: LS after close bore firing**

The visual analysis of the LS section in both cases shows smooth liner surface and no cracks appear internally or externally in either of the products. A part of the section is open fired (see figure below) and its fired properties are evaluated.



**Figure: After oxidation analysis. No lamination observed between layers.**

**TABLE 2: liner analysis before and after firing**

| Quality                                        | IFL-08Y         | IFL-09Y | IFL-08Y        | IFL-09Y |
|------------------------------------------------|-----------------|---------|----------------|---------|
|                                                | Before Oxidized |         | After Oxidized |         |
| %AP                                            | 32.43           | 32.09   | 30.51          | 29.87   |
| B.D(gm/cc)                                     | 2.25            | 2.29    | 2.07           | 2.16    |
| %Thermal Expansion (Up to 1400 <sup>0</sup> C) | ND              | ND      | ND             | ND      |
| Oxidation (mm) at 1000 <sup>0</sup> C          | 8.381           | 7.460   | ===            | ===     |
| Lamination                                     | NO              | NO      | NO             | NO      |
|                                                |                 |         |                |         |
| XRF-(%)                                        | IFL-08Y         | IFL-09Y | IFL-08Y        | IFL-09Y |
| Na <sub>2</sub> O                              | 0.299           | 0.352   | 0.445          | 0.426   |
| Al <sub>2</sub> O <sub>3</sub>                 | 80.835          | 77.431  | 87.916         | 81.853  |
| SiO <sub>2</sub>                               | 7.444           | 7.821   | 7.887          | 9.092   |
| CaO                                            | 0.236           | 0.355   | 0.261          | 0.454   |
| TiO <sub>2</sub>                               | 0.171           | 0.189   | 0.318          | 0.227   |
| Fe <sub>2</sub> O <sub>3</sub>                 | 0.175           | 0.204   | 0.247          | 0.250   |
| ZrO <sub>2</sub>                               | 2.682           | 6.220   | 2.665          | 7.425   |
| LOI(%)                                         | 7.933           | 7.175   | NIL            | NIL     |

#### **Conclusion:**

##### **Liner Mix- IFL-08 and IFL-09 :-**

1. Bar height of IFL-08Y is more as compared to IFL-09. VM & CIP Density is similar for both. Green MOR for IFL-09 is more.
2. Fired AP is more for IFL-08 whereas BD is less. CCS & MOR values are similar for both.

##### **LS - IFL-08 and IFL-09:-**

1. LS from both mixes have smooth internal lining surface. No lamination is observed in either LS.

##### **In-House Trial-3: (LS with Liner Mix - IFL-07Y-02)**

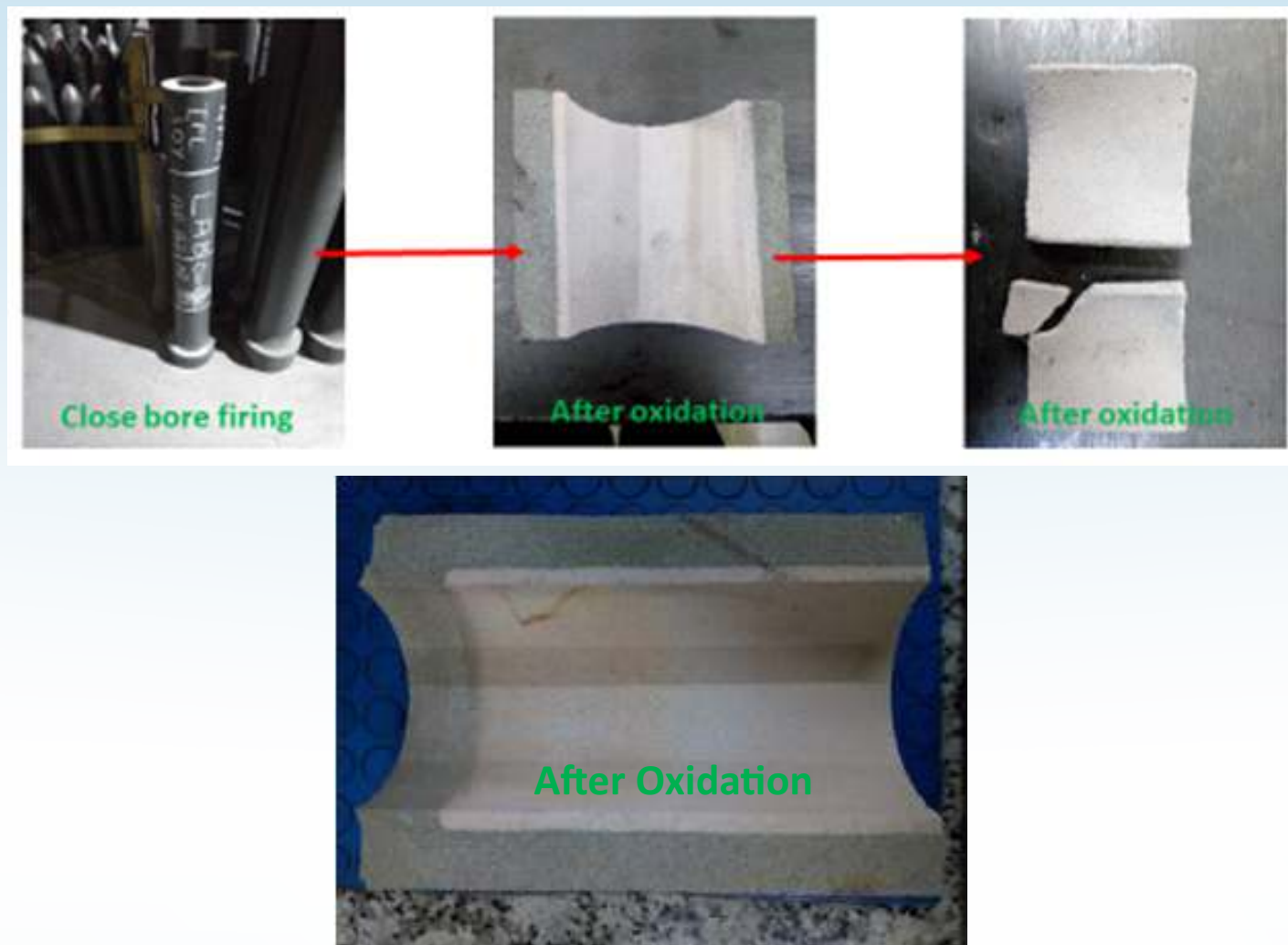


Figure: After firing analysis

|                       |              |            |
|-----------------------|--------------|------------|
| Product code: P-47-01 | %AP          | BD         |
| Dried liner mix       | 24.44        | 2.32       |
| Fired liner mix       | 32.47, 32.46 | 2.29, 2.29 |

| Quality                | IFL-08Y         | IFL-09Y | IFL-07Y-02  | P-4701(IFL-07Y-02) | IFL-08Y        | IFL-09Y | P-47-01(IFL-07Y-02) |
|------------------------|-----------------|---------|-------------|--------------------|----------------|---------|---------------------|
|                        | Before oxidised |         |             |                    | After oxidised |         |                     |
| %AP                    | 32.09           | 32.43   | 35.40,35.33 | 32.47,32.46        | 29.87          | 30.51   | 41.02,40.88         |
| B.D(gm/cc)             | 2.29            | 2.25    | 2.21,2.21   | 2.29,2.29          | 2.16           | 2.07    | 2.14,2.14           |
| Oxidation at 1000deg.C | 7.460           | 8.381   | ===         | ===                | ===            | ===     | ===                 |
| Lamination             | NO              | NO      | NO          | NO                 | NO             | NO      | NO                  |



**Figure: LS liner analysis after oxidation**

| Quality                        | IFL-08Y         | IFL-09Y | IFL-07Y-02 | P-4701(IFL-10Y) | IFL-08Y        | IFL-09Y | P-47-01(IFL-10Y) |
|--------------------------------|-----------------|---------|------------|-----------------|----------------|---------|------------------|
| XRF-(%)                        | Before oxidised |         |            |                 | After oxidised |         |                  |
| Na <sub>2</sub> O              | 0.352           | 0.299   | 0.312      | 0.312           | 0.426          | 0.445   | 0.303            |
| Al <sub>2</sub> O <sub>3</sub> | 77.431          | 80.835  | 87.326     | 87.326          | 81.853         | 87.916  | 93.269           |
| SiO <sub>2</sub>               | 7.821           | 7.444   | 4.945      | 4.945           | 9.092          | 7.887   | 5.297            |
| CaO                            | 0.355           | 0.236   | 0.178      | 0.178           | 0.454          | 0.261   | 0.186            |
| TiO <sub>2</sub>               | 0.189           | 0.171   | 0.230      | 0.230           | 0.227          | 0.318   | 0.253            |
| Fe <sub>2</sub> O <sub>3</sub> | 0.204           | 0.175   | 0.229      | 0.229           | 0.250          | 0.247   | 0.255            |
| ZrO <sub>2</sub>               | 6.220           | 2.682   | 0.065      | 0.065           | 7.425          | 2.665   | 0.125            |
| LOI(%)                         | 7.175           | 7.933   | 6.443      | 6.443           | NIL            | NIL     | NIL              |
| TOTAL                          | 99.997          | 99.987  | 99.978     | 99.978          | 100.001        | 100.001 | 99.979           |

**Figure: LS liner Chemistry before and after oxidation**

**Onsite Planning: (LS with Liner Mix - IFL-07Y-02)**

➤ **RSPTRIAL: LS with Liner Mix - IFL-07Y-02**

**Parameters**

- Ladle Capacity :150 T.
- Tundish Capacity : 30 T.
- Thru Put : 2.5 T / Min.
- Casting Speed : 0.9 Mtr to 1.1Mtr / Min
- Casting Type : SLAB
- Tundish Type : **SLAB**
- Sequence Length : 10 Heat.
- Argon Purging : YES
- Cleaning Practice : Lancing
- Manipulator : Pnumetic
- Monobox used : YES
- CNT : Flowcon 6300
- LS immersion Depth : 250 mm
- Distance Between Monobox to LS exit bore:300 mm

**Trial Observation**

| SI No | No. of Heat | Duration  | Remarks                                              |
|-------|-------------|-----------|------------------------------------------------------|
| 1     | 5           | 06.00 hrs | Metal Overflow , LS needs to be changed              |
| 2     | 10          | 11.10 hrs | Neck Puncture after 10 heats.                        |
| 3     | 7           | 10.20 hrs | Sequence End                                         |
| 4     | 7           | 10.02 hrs | Sequence end, LS was broken while removing from CNT. |
| 5     | 4           | 05.00 hrs | LS broken due to manipulator Jam / issue             |



After 5<sup>th</sup> Heat, LS changed due to Metal Overflow.



After 10<sup>th</sup> Heat, LS changed due to Neck Puncture



After 7<sup>th</sup> Heat, sequence END

LS needs to be changed

Figure: LS images After trial at RSP

➤ **BOKARO TRIAL: LS with Liner Mix - IFL-07Y-02**

**In-house after firing Observation:**

1. Good cohesiveness between body mix and Liner mix.
2. No lamination observed between two mix.
3. Mostly uniform liner thickness varies from 7 to 9 mm, maximum variation is 2 mm.



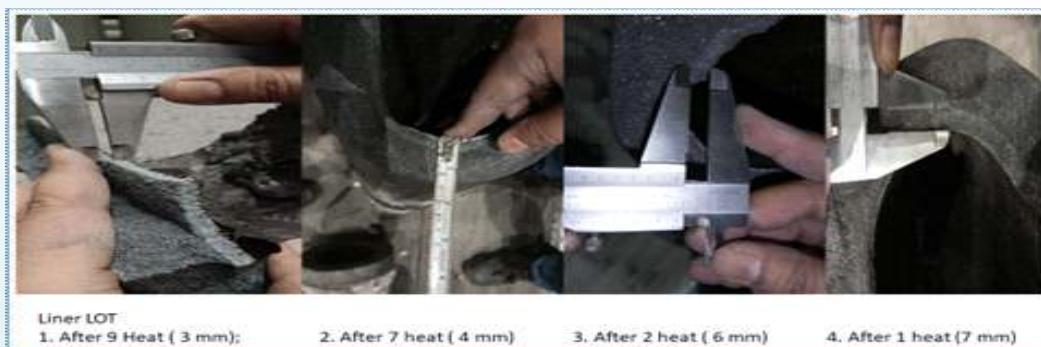
**Figure: After firing (close firing), LS section analysis  
Trial @ Bokaro Steel Plant – Twin Slab Caster**

**Parameters:**

- Ladle Capacity : 300 T.
- Tundish Capacity : 43 T.
- Thru Put : 5.22 T / Min.
- Casting Speed : 0.79 Mtr to 1.3 Mtr / Min
- Casting Type : SLAB.
- Tundish Type : Board or DVM
- Sequence Length : Board 12-14 Heat / DVM – 18 – 25 Heat.
- Argon Purging : Optional.
- Cleaning Practice : Lancing thru pipe. No SHOWER.
- Manipulator : HYD
- Monobox used : YES
- CNT : VIL / IFGL / OCL (During trial only one CNT of IFGL, and one CNT of OCL was in circulation, rest all were VIL CNT)
- LS immersion Depth : 300 to 430 mm.
- Distance Between Monobox to LS exit bore: 250 to 300 mm
- Gasket : YES

**Trial Performance (LS Box No.: 82/9)**

| S.N. | Date    | Caster/<br>Car<br>No. | LS No  | Usage<br>Time<br>(mins) | No<br>of<br>Heats | Observation                                                        |
|------|---------|-----------------------|--------|-------------------------|-------------------|--------------------------------------------------------------------|
| 1    | 20.5.23 | 1/2                   | E04/AV | 100                     | 1                 | Mold overflow in strand II, Casting Abort.                         |
| 2    | 22.5.23 | 1/1                   | E01/AV | 167                     | 2                 | EOC as per BSL, Strand I Break Out.                                |
| 3    | 22.5.23 | .                     | E03/AV | 418                     | 7                 | Change AS per BSL plan                                             |
| 4    | 22.5.23 | ½                     | E02/AV | 409                     | 7                 | EOC , Heat Not Available                                           |
| 5    | 23.5.23 | ½                     | E05/AV | 526                     | 9                 | AS per BSL plan , reported AS Neck Erosion, Neck condition was OK. |



**Some Snapshot -- Liner Condition**





**Some Snapshot -- Neck Condition – No Such Erosion Observed**



**Some Snapshot -- Barrel Part Condition After 9 Heat**



**Some Snapshot -- Barrel Part Condition After 9 Heat**

#### **Observation:**

- No Initial Set back.
- No Thermal spalling crack during use, or change over.
- Maximum Change over time is 2 – 4 mins.
- Cold to Red Hot condition change over time is 18 – 23 mins.
- No Abnormalities observed.

➤ **TATAKPO TRIAL: LS with Liner Mix - IFL-07Y-02**

**Previous trial details**

**Trial 1:** In 2018, 7 pcs used with drawing no. P-1221 01AR3.

Result-Cup and body crack.

**Trial 2:** In 2019, 5 pcs used with drawing no. P-1221 01AR7.

Result-Crack reduced and internal erosion led to low life.

**Summary of Changes done (based on analysis of issues for Trial2)**

| Sl. No. | Changes Proposed                       | Reasons                                                                                                                                |
|---------|----------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------|
| 1       | High strength inner layer mix (IFL 01) | Throughout ID, 6 mm high strength (IFL 01, >80% Al <sub>2</sub> O <sub>3</sub> based) mix to take care grousing due to high throughput |
| 2       | Mix IFA 1704 removed                   | The said mix was given to reduce bottom crack. However it is not required when IFL 01 mix is introduced throughout                     |

The change was expected to lessen uneven ID erosion or grousing during use, in order to reduce tendencies of punctures.

**Trial 3:** In 2020, 1 pc used with drawing no. P-1221 01B.

- Supplied : 6 pcs                      Used: 1 pc
- Performance detail : Horse-Shoe crack from bottom. Customer did not use any further.

**Trial 4 (Present trial):** In 2023, 3 pcs used with drawing no. P-1221 01E R1.

**Parameters:**

- **Present throughput : 8.5 Ton / Min**
- **Steel Ladle : 300 Ton**
- **Tundish Capacity : 60 Ton**
- **Casting time per heat : 35 min**
- **Caster : Twin Strand Slab with 230 mm slab thickness**
- **Nozzle fixing Compound : 60 Kgs/ heat.**

**Changes in Snapshot:**

| Trial Status   | Mix Name | LOI % TY | Al <sub>2</sub> O <sub>3</sub> % TY | SiO <sub>2</sub> % TY |
|----------------|----------|----------|-------------------------------------|-----------------------|
| Previous Trial | IFA 23   | 26       | 64                                  | 6                     |
| Proposed Trial | IFA 236  | 30       | 58                                  | 8 - 9                 |

1. Increased carbon percentage will increase thermal spalling resistance as well as increase non wettability characteristic of LS.
2. Increase Silica percentage will help us to increase resistance to crack properties of LS.

We have developed a liner mix, which is having 87 % alumina percentage with a higher level of apparent porosity. This liner is having sufficient strength to withstand higher throughput, as well as it shows great properties in terms of thermal shock resistance.

| Trial Status   | Mix Name | LOI % TY | Al <sub>2</sub> O <sub>3</sub> % TY | SiO <sub>2</sub> % TY |
|----------------|----------|----------|-------------------------------------|-----------------------|
| Previous Trial | IFL 01 Y | 13.5     | 88.5                                | 2.66                  |
| Proposed Trial | IFL 07 Y | 11.12    | 87                                  | 4.945                 |

In terms of design, we have optimized the design to achieve desired results. Drawing attached for your reference. |

### Details of Parameters during casting (Trial 1)

|     | Sequence No | No of Heats | Tundish No | Car No | Strand 1 |             | Strand 2 |             | Casting Start | Casting End | Duration in Min | Metal Temp Deg C | Superheat Deg C | N2 Pick Up ppm | Vibration Timing sec |
|-----|-------------|-------------|------------|--------|----------|-------------|----------|-------------|---------------|-------------|-----------------|------------------|-----------------|----------------|----------------------|
|     |             |             |            |        | Width mm | Speed m/min | Width mm | Speed m/min |               |             |                 |                  |                 |                |                      |
| E 6 | 12          | 1           | 8          | 1      | 1350     | 1.75        | 1600     | 1.4         | 16:05         | 16:39       | 34              | 1550             | 19              | 0              | 23                   |
|     | 13          | 2           | 8          | 1      | 1350     | 1.7         | 1600     | 1.3         | 16:42         | 17:19       | 37              | 1560             | 30              | 1              |                      |
|     | 14          | 3           | 8          | 1      | 1350     | 1.75        | 1600     | 1.4         | 17:22         | 17:54       | 32              | 1556             | 25              | 7              |                      |
|     | 15          | 4           | 8          | 1      | 1350     | 1.75        | 1600     | 1.4         | 17:56         | 18:38       | 42              | 1553             | 20              | 4              |                      |

**Remarks:** LS condition was NORMAL. Ar pressure of LS is normally 4 bar. It may go max 6 bar.



VIL LS After after 7 heat, IFGL LS After 4 heat



No Air ingression , internal erosion , liner intact



Liner present after 4 heat , Liner thickness was 6 mm

**Figure: LS analysis after trial 1**

### Details of Parameters during casting (Trial 2)

|    | Sequence No | No of Heats | Tundish No | Car No | Strand 1 |             | Strand 2 |             | Casting Start | Casting End | Duration in Min | Metal Temp Deg. C | Superheat Deg. C | N2 Pick Up ppm | Vibration Timing sec |
|----|-------------|-------------|------------|--------|----------|-------------|----------|-------------|---------------|-------------|-----------------|-------------------|------------------|----------------|----------------------|
|    |             |             |            |        | Width mm | Speed m/min | Width mm | Speed m/min |               |             |                 |                   |                  |                |                      |
| E2 | 1           | 1           | 2          | 1      | 1550     | 1.5         | 1825     | 1.1         | 12:29         | 13:14       | 45              | 1563              | 31               | 5              | 18                   |
|    | 2           | 2           | 2          | 1      | 1550     | 1.7         | 1825     | 1.35        | 13:16         | 13:47       | 31              | 1556              | 23               | 2              | 58                   |

**Remarks:** Heavy vibration during start up with 2<sup>nd</sup> heat, Ladle no 10. Horse Shoe Crack after 2<sup>nd</sup> Heat.





Horse Shoe Crack After 2<sup>nd</sup> Heat, From exit bore 210 mm to 230 mm . Metal dipping zone.



No Air ingress, internal erosion , Neck Area is clean and no erosion



Liner present after 2 heat. Liner thickness was 6 mm, only 580 mm down from cup area, liner was eroded , eroded span is 60 mm, Rest of the barrel part is having 5 to 6 mm liner.



Figure: LS analysis after trial 2

### Details of Parameters during casting (Trial 3)

| LS No | Sequence No | No of Heats | Tundish No | Car No | Strand 1 |             | Strand 2 |             | Casting Start | Casting End | Duration in Min | Metal Temp Deg C | Superheat Deg C | N2 Pick Up ppm | Vibration Timing sec |
|-------|-------------|-------------|------------|--------|----------|-------------|----------|-------------|---------------|-------------|-----------------|------------------|-----------------|----------------|----------------------|
|       |             |             |            |        | Width mm | Speed m/min | Width mm | Speed m/min |               |             |                 |                  |                 |                |                      |
| E 3   | 1           | 1           | 1          | 1      | 1650     | 1.3         | 1700     | 1.25        | 11:41         | 12:24       | 43              | 1556             | 34              | 4              | No Vibration         |
|       | 2           | 2           | 1          | 1      | 1650     | 1.35        | 1700     | 1.35        | 12:26         | 13:04       | 38              | 1549             | 28              | 2              | 40                   |
|       | 3           | 3           | 1          | 1      | 1650     | 1.35        | 1700     | 1.3         | 13:06         | 13:39       | 33              | 1538             | 16              | 1              | 60                   |

Remarks: Heavy vibration during start up with 2<sup>nd</sup> and 3<sup>rd</sup> heat, Ladle no 10 was in 3<sup>rd</sup> heat. Horse Shoe Crack after 3<sup>rd</sup> Heat.



### Figure: LS analysis after trial 3

Same Phenomenon, 180 – 210 mm from metal dipping zone, remaining LOT was 30 mm with liner. Only one observation, while change over after 2<sup>nd</sup> heat due to argon pipe setting, LS heat side wall twice, and 60 sec vibration observed.

### Some Operational Tools and tackles details



**Shower** - Periodical checking of shower is essential, if it is mis aligned or if there is any hole in shower, it may cause localized erosion.



**Shower Box** – Periodical cleaning is required to align LS straight during showering. Now practice is cleaning is every shift based on available height.

**Shower** - Periodical checking of shower is essential, if it is misaligned or if there is any hole in shower, it may cause localized erosion.

**Shower Box** – Periodical cleaning is required to align LS straight during showering. Now practice is cleaning is every shift based on available height.

Way Forward (based on analysis of issues for all trials)

| Sl. No. | Changes Proposed                                                                     | Reasons                                                                                                                                                                                                                              |
|---------|--------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1       | Height will be reduced by 50 mm.                                                     | There was tendency to HIT the side wall during change over. Immersion depth is sufficient to reduce 50 mm height. With this reduction of height, CG of the product will be shifted towards cup area, and will create less vibration. |
| 2       | Introduce Anti chunking Mix                                                          | Initial Two trials were with anti-chunking mix IFA -1704; we did not find any horse shoe crack. We'll reintroduce IFA-1704 mix to avoid horse shoe crack.                                                                            |
| 3       | 10 mm OD decrease at bottom.<br>(Existing 220 mm & 158 mm; Proposed 210 mm & 158 mm) | This will make the submerged part of the LS little more straight. This change will ensure better compatibility of Mix-3 (given as to prevent chunking) with the main LS body.                                                        |
| 4       | We'll continue with Liner IFL-07Y-02mix.                                             | Liner was in place even after 4 heats, we'll continue with liner mix (IFL-07Y-02).                                                                                                                                                   |

These changes help to reduce thermo mechanical stress on LS, which will give better result with high throughput.

## **Conclusion:**

1. Series of liner mixes were developed and tested for their various green and fired properties.
2. The developed mixes were used to prepare liner LS and the products were tested in-house for their compatibility with the body mixes.
3. The liner mix IFL-07Y-02 has found to have better properties and compatibility with the body mix and hence used for liner LS preparation.
4. These liner LS were tested on-site to our customers having varying ladle and tundish capacities and satisfactory results were found.
5. The liner LS doesn't face any significant challenge at RSP and Bokaro sites but horse shoe type cracks generated at our TATA KPO site.
6. The issue faced at the TATA site is more due to LS design and other process parameters and these issues will be addressed in our next trial.
7. Ceramics-Silikáty 64 (3), 278-288 (2020): Corrosion tests for refractory materials intended for the steel industry – A review.



## BOF Hot Patching Bricks

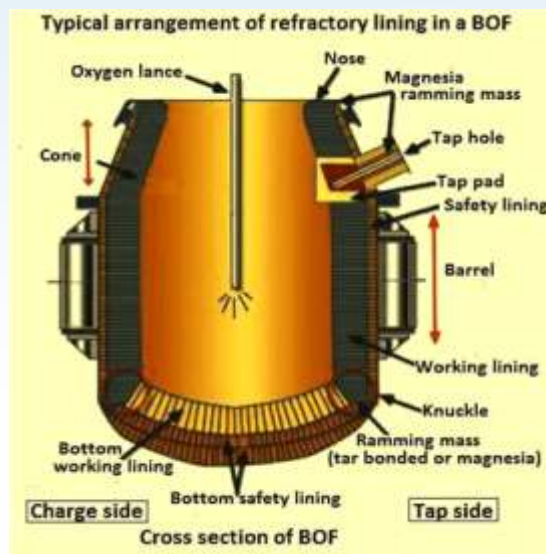
*SAMWHA India Refractories Pvt Ltd*

The purpose of a refractory lining in a basic oxygen furnace (BOF) is to provide maximum furnace availability during operation of the converter in order to meet production requirements and to ensure lowest possible specific refractory consumption. For achieving this, it is essential

(I) to optimize the design of the lining,

(ii) to optimize the lining maintenance practices, and

(iii) to have good technological discipline during converter operation. Typical refractory lining is shown in the cross-section of a converter in Fig 1.



**Fig1: Typical arrangement of the refractory lining in a BOF**

### Lining design

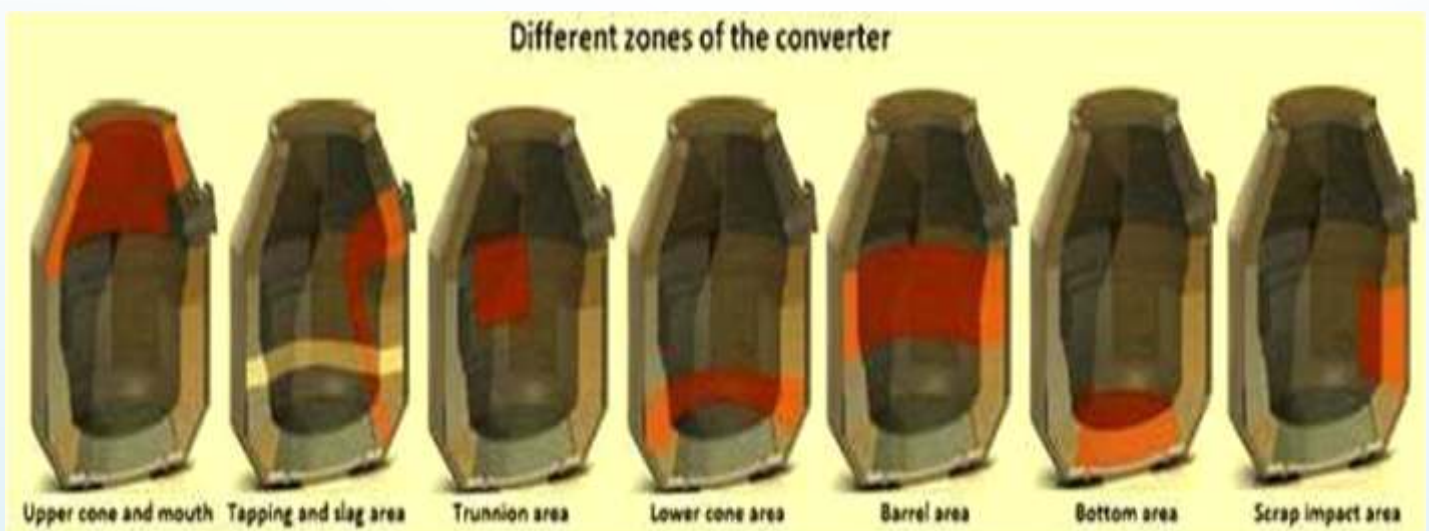
Wear of the refractory lining of the BOF is due to either the individual or the combined effect of the several agents which have their influence on the wear mechanism. These agents are (i) heat duration determining the residence time of the slag and the metal in the converter, (ii) corrosion due to chemical attack of the slag because of its chemistry, (iii) temperature of the liquid steel and the slag, (iv) corrosion due to the state of oxidation of the melt, (v) erosion due to slag and metal during the blowing of oxygen ( $O_2$ ) and during the tilting of the BOF, (vi) impact and abrasion of dust and gases, (vii) impact of scrap and metal during charging, (viii) impact and penetration of  $O_2$  jet, (ix) thermal cycling during the heat, and (x) mechanical damage during the deskulling of the converter. Due to varying action of these agents, there are many wear areas in a converter.

The converter operation as well as the lining configuration has a huge effect on the lining life of a converter. The tapping temperature of the liquid steel varies significantly with the superheat needed to cast a particular grade of steel, and the secondary steelmaking facilities available to a particular plant. The state of oxidation of the melt in the converter is extremely significant in terms of BOF lining wear and is aggravated by the high temperature. Slag chemistry is important in several ways. Magnesia-carbon (Mag-C) bricks are basic refractories which require a basic slag. The basic slags formed also attempt to dissolve up to their saturation level of magnesia ( $MgO$ ) from the brick. Typical  $MgO$  saturation occurs at around 8 % again depending on the temperature and state of oxidation, so if  $MgO$  is not added, usually in the form of calcined dolomite, the slag

dissolve the lining preferentially and thereby increase lining wear. Slag chemistry is again related to state of oxidation and temperature as the basicity and the MgO content are diluted by high levels of FeO and temperature increases the kinetic reaction rates. Erosion and abrasion effects are much related to the practices adopted during the steelmaking.

Theoretically the refractory lining of a converter is to be designed by the refractory type and different thicknesses so that no material is wasted at the end of the converter campaign. This means that all the zones (Fig2) of the converter lining is to worn out to the stopping thickness at the same time. But in practice this does not happen and the refractories in some zones are worn out faster than the refractories in other zones. A balanced lining design is always aimed to improve lining life at the optimum refractory cost. A balanced lining is the lining where different qualities and thicknesses of refractories are used in different zones of the converter after careful study of the wear pattern of the refractories in the converter. This type of lining is also called zonal lining since in such type of lining the refractories are zoned such that a given segment of lining having lesser wear is assigned a lower quality or lesser thickness of refractory. Similarly refractories of greater wear resistance and normally having higher cost are assigned to those segments of the converter lining which are having higher wear pattern so as to have longer life of these severe wear areas. dissolve the lining preferentially and thereby increase lining wear. Slag chemistry is again related to state of oxidation and temperature as the basicity and the MgO content are diluted by high levels of FeO and temperature increases the kinetic reaction rates. Erosion and abrasion effects are much related to the practices adopted during the steelmaking.

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**Fig2 Different zones of the converter**

## Lining maintenance practices

### Characteristic and Application of BOF Hot Patching Blocks.

**Charge pad**-Charge pad in the converter is normally directly opposite the tap-hole. The charge pad is subjected to impact load by falling scrap, sometimes of heavy nature such as bloom ends. Molten steel also cause erosion of the charge pad. In addition, sampling probes and temperature probes are introduced from this side of the tilted vessel and this leads to slag at high temperature carrying out the washing of the charge pad area. Initial refractory solutions to the charge pad were found with pitch impregnated fired MgO bricks. As converter lives have increased owing to the use of Mag-C materials, the charge pad became a major wear area, and resin bonded Mag-C with metal additions are being used to get good performance. These materials offer good resistance to impact, provide resilience coupled with strength, and resistance to slag ingress owing to the presence of graphite.

**Tapping area**-Tapping area is subjected to erosion by liquid steel at high temperature and subject to corrosion by liquid slag. Refractory development in the tapping area has been on the lines of the development of the charge pad area. The earlier materials are being replaced with pitch bonded and impregnated Mag-C with metal additions. Since the dominant wear process in the tapping area involves high temperature slag attack, refractory blocks manufactured from large crystal sized MgO are rapidly becoming the standard. Pitch bonded and impregnated refractories have been found to give superior performance in the tapping area due to the reduction of penetrating slag oxides by the action of C in the refractory block porosity.

**The technology and phase changes of the Patching materials for its successful working**-The elementary carbon of the patching material is a favourable carbon for the reason of six members ring arrangement of the proprietary pitch being used in the recipe. It becomes possible by way of intermediary liquid crystals (Mesophase), laminated carbon packages are formed with good structure in the hexagonal base plane. Typical structure of the carbon package makes it easy to graphitize faster with possible good anisotropy.



Several lining maintenance practices are employed to enhance the refractory lining life in a converter. These are given below.

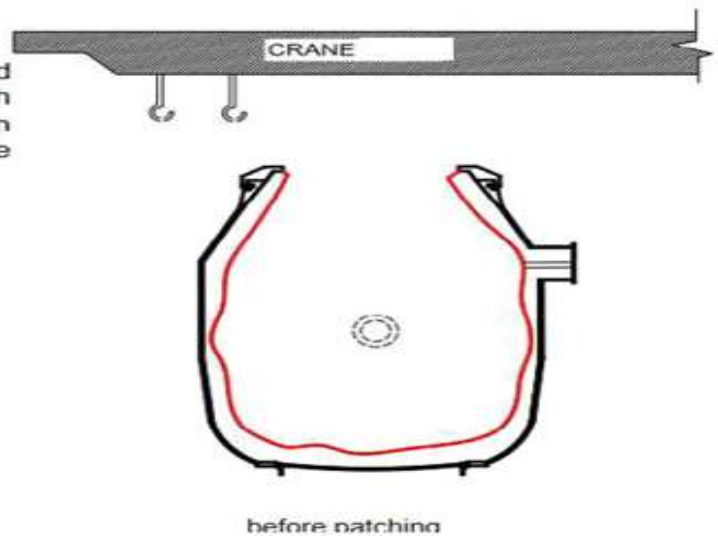


### 1. Products and Specifications

Base on high purity fused magnesite and high purity sintered magnesite, bonded with special pitch based binding system which integrated with agglutinant and graphite mixing then pressed into brick shapes.

#### Specifications:

MgO : 85%min  
F/C : 5%min ;  
CaO : 2.5%max ;  
FeO3 : 1.5%max ;  
Al2O3 : 1%max ;  
SiO2 : 2.5%max  
BD: 2.95g/cm3 min ;  
A.P.: 8%max ;  
C.C.S. : 45MPa min



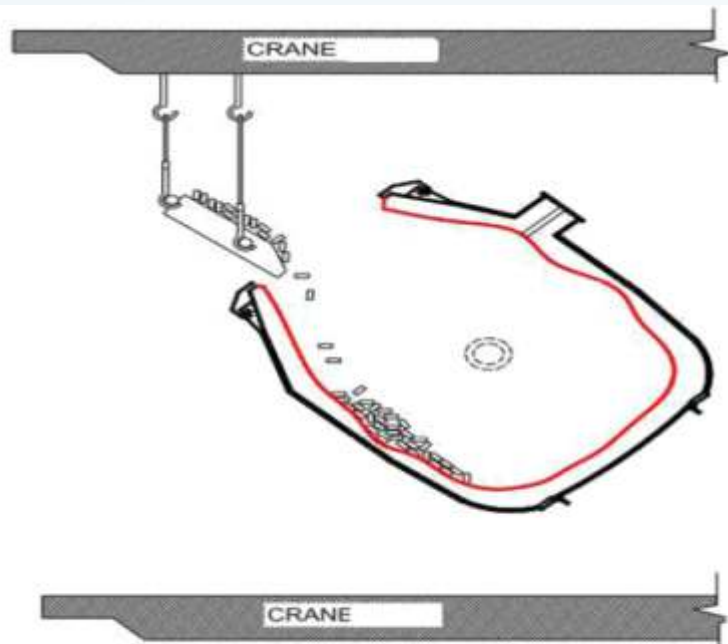
### 2. Application and Repair

#### Application:

Working lining of Mag Carbon bricks and dolomite bricks.

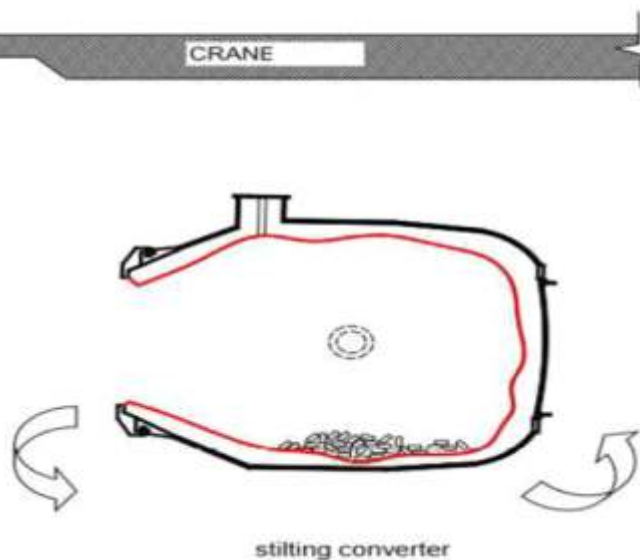
#### Hot patching repair:

Bricks are thrown into the converter either mechanically or manually depending on the vessel design. If the vessel size below 50tons , just throw by manually for numbers of bricks to charge is less in each time and for the large converter , we suggest to throw by mechanical according to quantity of the patching bricks to be used for each repair as of erosions.



### 3. Leveling bricks in converter

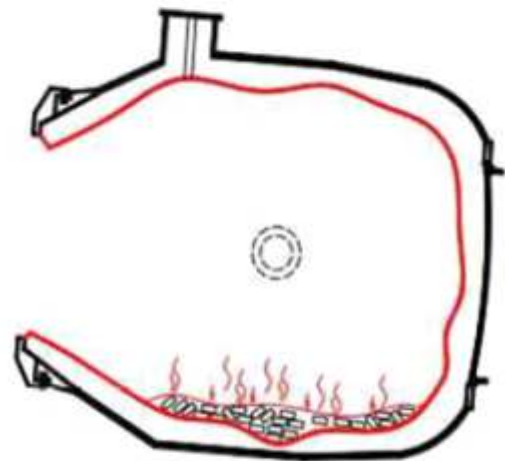
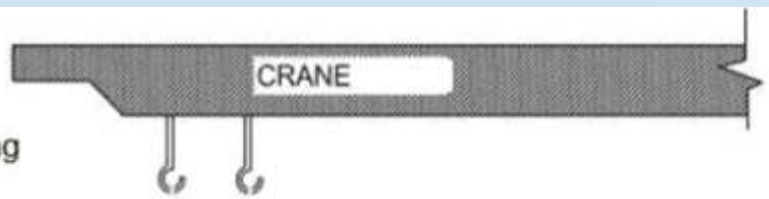
After charging the patching bricks, depending on the quantity charged the operator shall set either the converter still for sintering or tilting several times to make the molten bricks leveled during sintering.



#### 4 Reference:

Since 2005 , Samwha have been supplying hot patching bricks for converters in Severstal, MMK, Tamirto Plant AM and so on.

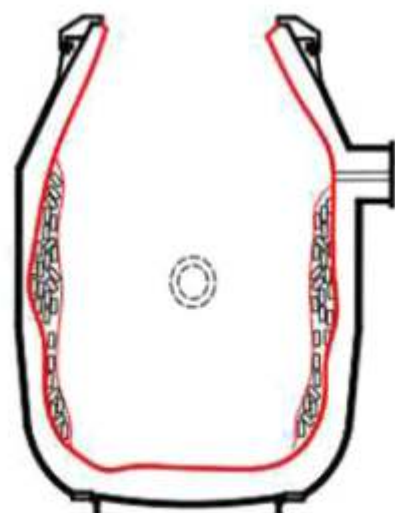
The repaired area served for more than twenty heats or even longer depends on the quantity of patching bricks charged in. And the charging quantity of patching bricks will be decided according to the eroded situation.



sintering

#### 5 Characteristic

- a. Reduction of slag splashing and improvement in smelting time.
- b. Short sintering time, super strength, excellent erosion resistance and extended service life of working lining.
- c. Less fumes from sintering, environment friendly.
- d. Easy operation, improved sintered strength, lower consumption.



finished patching

## Samwha India Refractories Offered Three Different Types of Hot Bricks Patching Materials.

### PRODUCT DATA SHEET PRODUCT: SM LDP M80

- SM LDP M80 is an MgO-C Pitch Bonded Magnesia Carbon patching Bricks Suitable for repair of wear-out zones of Basic Oxygen Furnace.
- SM LDP M80 Product is the combination of MgO with good quality of pitch which having good patching quality.
- The product is specially designed granulometry which impacts good spalling resistance to the bricks with quick setting and good strength properties.

#### BOF Patching Bricks ( SM LDP M-80 )

##### Chemical

| Substituted               | Range | Typical |
|---------------------------|-------|---------|
| MgO (%)                   | >70   | 80.2    |
| Carbon (%)                | >4    | 5.5     |
| <b>Physical</b>           |       |         |
| C.C.S (MPa)               | >40   | 48      |
| A.F. (%)                  | <7.0  | 6.2     |
| B.D. (g/cm <sup>3</sup> ) | >2.96 | 2.98    |

- The above data is applicable to standard product design and is subject to usual variations in the manufacturing process.
- The above are based on 100 standard testing units.

**Note:** The above are typical data and are not to be taken as binding specifications. Please contact your nearest TRSM representative for latest specifications and individualized information on the above.

### PRODUCT DATA SHEET PRODUCT: SM LDP M83

- SM LDP M83 is an MgO-C Pitch Bonded Magnesia Carbon patching Bricks Suitable for repair of wear-out zones of Basic Oxygen Furnace.
- SM LDP M83 Product is the combination of Electro fused and sintered magnesia with good quality of liquid pitch which having good patching quality.
- The product is specially designed granulometry which impacts good spalling resistance to the bricks with quick setting and good strength properties.

#### BOF Patching Bricks ( SM LDP M-83 )

##### Chemical

| % in final product        | Range  | Typical |
|---------------------------|--------|---------|
| MgO (%)                   | >62    | 82      |
| Carbon (%)                | >4     | 6.8     |
| <b>Physical</b>           |        |         |
| C.C.S (MPa)               | >40    | 48      |
| A.F. (%)                  | <6.0   | 5.5     |
| B.D. (g/cm <sup>3</sup> ) | >2.94  | 2.96    |
| Self Life                 | 1 Year |         |

- The above data is applicable to standard product design and is subject to usual variations in the manufacturing process.
- The above are based on 100 standard testing units.

### PRODUCT DATA SHEET PRODUCT: SM LDP M85

- SM LDP M85 is an MgO-C Pitch Bonded Magnesia Carbon patching Bricks Suitable for repair of wear-out zones of Basic Oxygen Furnace.
- SM LDP M85 Product is the combination of high purity Magnesia (SM) and sintered magnesia with good quality of liquid pitch which having good patching quality.
- The product is specially designed granulometry which impacts good spalling resistance to the bricks with quick setting and good Thermo-Mechanical strength.

#### BOF Patching Bricks ( SM LDP M-85 )

##### Chemical

|                           | Range  | Typical |
|---------------------------|--------|---------|
| MgO (%)                   | >64    | 85      |
| Carbon (%)                | >5     | 5.5     |
| SiO <sub>2</sub> (%)      | <5.5   | 5.3     |
| <b>Physical</b>           |        |         |
| C.C.S (MPa)               | >45    | 50      |
| A.F. (%)                  | <5.8   | 4.2     |
| B.D. (g/cm <sup>3</sup> ) | >2.96  | 2.9     |
| Self Life                 | 1 YEAR |         |

- The above data is applicable to standard product design and is subject to usual variations in the manufacturing process.
- The above are based on 100 standard testing units.

## SAMWHA INDIA REFRACTORIES PVT LTD



### LIST OF CUSTOMERS USED OUR BOF PATCHING BRICKS

SAMWHA GROUP

| Sl.No. | Nationality  | Customers' name          | Products description | Capacity | Remarks |
|--------|--------------|--------------------------|----------------------|----------|---------|
| 1      | South Korea  | Hyundai Steel Co.,Ltd    | Patching Bricks      | 320MT    |         |
| 2      | South Africa | ArcelorMittal New Castle | Patching Bricks      | 180MT    |         |
| 3      | Kazakhstan   | ArcelorMittal Temirtau   | Patching Bricks      | 300MT    |         |
| 4      | Ukraine      | ArcelorMittal Kryviy Rih | Patching Bricks      | 150MT    |         |
| 5      | India        | Bokaro Steel Plant       | Patching Bricks      | 300MT    |         |
| 6      | India        | Rourkela Steel Plant     | Patching Bricks      | 150 MT   |         |
| 7      | India        | Tata Steel NINL          | Patching Bricks      | 150 MT   |         |
| 8      | India        | Electro Steel Limited    | Patching Bricks      | 60MT     |         |
| 9      | India        | Electro Steel Limited    | Patching Bricks      | 60MT     |         |
| 10     | India        | DURGAPUR STEEL PLANT     | Patching Bricks      | 130 MT   |         |



# A study on Corrosion behaviour of MgO Grade in MgO–C Refractories for Ladle slag zone application

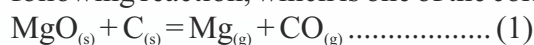
*N K Mishra; Gowtham Raju; Eswaran Ramasamy; Sudip Chandra S.Arasu  
IFGL Refractories Limited, Kalunga, Odisha, India*

## Abstract:

MgO-C bricks are one type of high-performance lining material that is required for steelmaking operations because of its high refractoriness and resilience to thermal shock and slag corrosion resistance. In present study slag corrosion tests of MgO-C samples carried out in mild steel at 1600 °C in an induction furnace along with slag. The interactions behaviour of slag between three varieties of MgO–C bricks that differ in the used MgO grade were evaluated. On the test sample elemental composition of the inclusions studied in scanning electron microscopy and X-ray diffraction to characterize the macro- and microstructure of test specimens. Correlations of corrosion behaviour are made considering Cao/SiO<sub>2</sub> ratio and grade of MgO used in the brick manufacturing, keeping granulometry, Carbon content and binder system and related process parameters same. Physical, chemical and microstructure properties of the bricks are evaluated and correlated with slag corrosion behaviour. It is found that Purity of MgO of the base material along with its periclase crystal size are factors for achieving optimum Slag corrosion resistance in MgO-C bricks for Slag zone application.

## 1. INTRODUCTION

Magnesia in MgO–C refractory has characteristics such as a high melting point and high refractoriness. High thermal conductivity, minimal thermal expansion, and low slag wettability are some of the properties of carbon. Excellent resistance against corrosion and thermal shock is achieved when these two are coupled. However, the refractory corrosion is mostly caused by the MgO-C refractory flaw when it comes into contact with the molten slag. It has been demonstrated that when the temperature rises and pressure falls, MgO oxidizes carbon by the following reaction, which is one of the corrosion factors of the MgO–C refractory.



The MgO-C refractory's carbon has better resistance to slag seeping into brick, but one of its main weaknesses is that it is easily susceptible to oxidation, which can cause the refractory to degrade.

There are three basic ingredients for making magnesia carbon bricks, viz. 1) Magnesite 2) graphite 3) Anti-oxidants. The quality and quantity of this raw material greatly influence the critical properties and performance of the brick, taking it for granted that the process control parameters remain consistent during manufacturing. On the other hand, to excel in the performance, it is required to analyze the attacking forces and thereby design the brick composition. Through simulative testing, it is possible to measure the critical properties.

## 2. EXPERIMENT

Three distinct MgO-C bricks (Fig1), denoted as A, B, and C, underwent analysis. Porosity and bulk density were measured using samples of the original bricks and tested by vacuum method with the cylindrical sample size of 50mm height and 50mm diameter.



Fig1: Three Distinct Mag-C Bricks

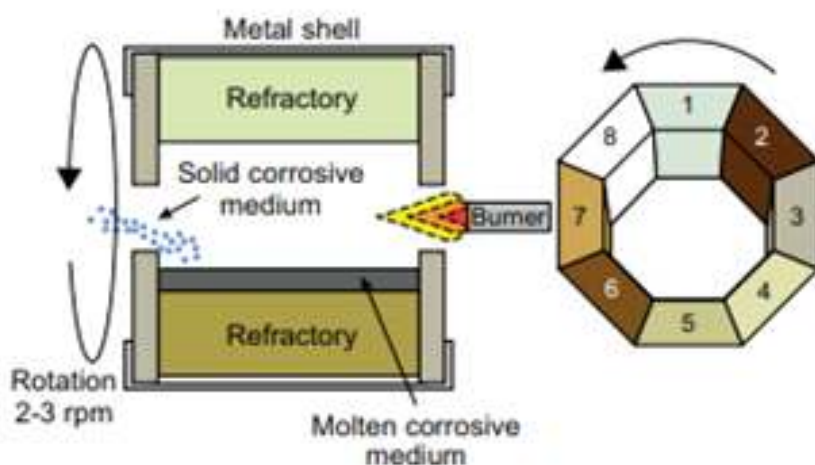
## 2.1 Rotary slag test

The rotary slag test, as seen in Figure 2a, in which slag and/or steel are added to a cylindrical chamber and melted using a burner. As seen in Figure 2b, Ceramics-Silikáty 64 (3), 278-288 (2020), the cylindrical chamber is lined with refractory bricks to provide a chamber.

| MgO   | S     | CaO   | SiO <sub>2</sub> | Cr <sub>2</sub> O <sub>3</sub> | FeO  | Al <sub>2</sub> O <sub>3</sub> | Mn    |
|-------|-------|-------|------------------|--------------------------------|------|--------------------------------|-------|
| 6.08% | 0.51% | 58.4% | 7.45%            | 0.03%                          | 0.6% | 26.34%                         | 0.18% |

**Table 1: Chemical composition of the slag**

The chamber is spun horizontally at a slow speed (between 2 and 7 rpm) to perform this test. Solid slag is added to the cold chamber or the chamber at the desired temperature occasionally in the form of tiny pellets or fine powder. A burner is positioned within the chamber to provide heat; it is commonly powered by oxygen and propane. Since the fuel flow in the burner determines the temperature inside the chamber, a pyrometer is used to measure the temperature at predetermined intervals to help control the flow. The test comprised three consecutive cycles in which slag (Table 1) was added to the hot chamber after steel was added. Every cycle had a 2 rpm rotation speed, and the steel and slag were held at 1600 °C for 30 minutes. Then the chamber was cleared out and allowed to cool down organically before the bricks were taken out. This rotational slag test has multiple benefits: the steel/slag is churned, there is a thermal gradient inside the brick because of the heating at the center of the chamber, and the steel/slag cannot approach saturation if it is refreshed frequently and at suitably short intervals. Nevertheless, there are a few drawbacks to this test as well: it is hard to regulate the temperature, the refractories might interfere with one another, and the test's repeatability is poor. Moreover, it is difficult to accomplish and needs large amounts of slag, at least several hundred grams.



**Fig2. Rotating Furnace (a) and crucible used in the rotating furnace (b)**

## 2.2 Oxidation Resistance

Test for the oxidation resistance (oxidizing area procedure) was performed on test specimens - cubes measuring 75x75x75mm. Samples were heated simultaneously (at the same time) in the electric laboratory furnace with the air atmosphere at a rate of 5°C/1min. to a temperature of 1450°C with a holding time of 5 hours at the maximum temperature. After firing, cooling, and cutting the samples, the extent of the oxidized area, compared to the original unoxidized area, and then the percentage of the oxidized area was calculated.

## 1. RESULTS AND DISCUSSION

### 3.1 Physical properties

The apparent porosity and bulk density of the bricks are shown in Table 2. To determine these values three specimens of each brick were used.



| Brick | AP% | BD(g/cc) |
|-------|-----|----------|
| A     | 1.4 | 3.02     |
| B     | 1.8 | 3.01     |
| C     | 2.1 | 2.99     |

Table2 Apparent porosity and bulk density of MgO-C bricks

### 3.2 Microstructure of the bricks

Reflected light microscopy was used to examine the brick's microstructure before the corrosion test. A picture (x100) of block A as received is displayed in Figure 3. A grain of Fused Magnesia ( $M_o$ ) FM97.5  $\text{CaO/SiO}_2 \sim 2:1(M_o)$  with sub-grains inside is discovered, and the matrix contains antioxidants, graphite, and finer MgO grains (size  $< 600 \mu\text{m}$ ).

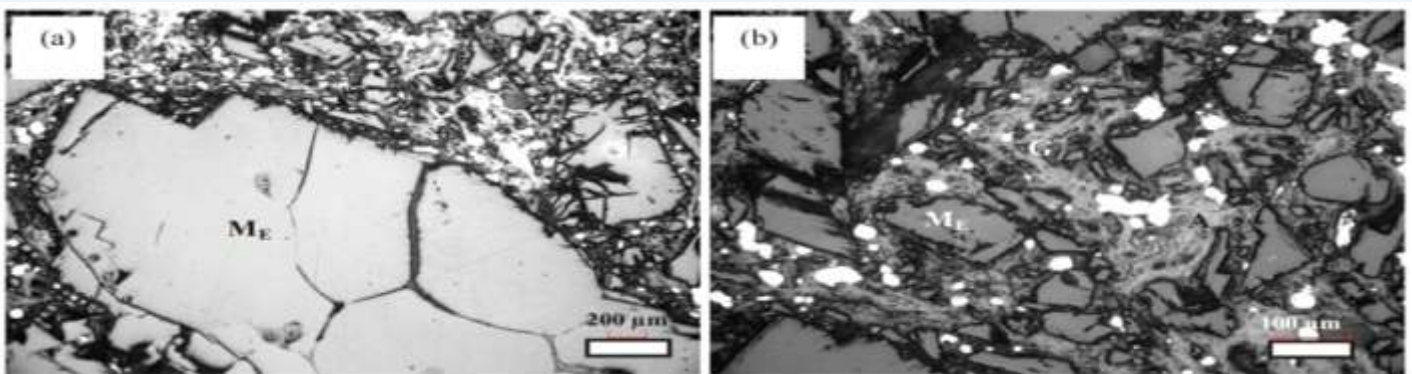


Fig3:Brick Microstructure A a). Fused Magnesia grains b). Matrix detail

Brick A's matrix is seen in more depth in Figure 1b (x200). This demonstrates the graphite (G) and antioxidants (A). According to Lee et al. (2004), the antioxidant material may be distinguished by its brightness (size  $< 50 \mu\text{m}$ ), whereas graphite is shown in the form of "flakes". Different sized MgO grains were observed to be FM97  $\text{CaO/SiO}_2 \sim 2:1(M_o)$  and FM96  $\text{CaO/SiO}_2 \sim 1:1(M_d)$  in brick B (size  $< 500 \mu\text{m}$ ) (Figure 2a). While FM96  $\text{CaO/SiO}_2 \sim 1:1$  grains have a porous microstructure, FM97  $\text{CaO/SiO}_2 \sim 2:1$  grains are dense.

The  $M_o$  grains are often larger than the  $M_d$  ones. Antioxidants (bright spots) and graphite "flakes" are seen in the matrix. Lastly, a significant amount of FM96  $\text{CaO/SiO}_2 \sim 1:1$  grains and a larger area occupied by tiny particles are visible in brick C (size  $< 400 \mu\text{m}$ ) (Fig. 4b). Both FM96  $\text{CaO/SiO}_2 \sim 2:1$  and FM96  $\text{CaO/SiO}_2 \sim 1:1$  grain types are found in this region. In terms of appearance, brick C has more FM96  $\text{CaO/SiO}_2 \sim 1:1$  than brick B.

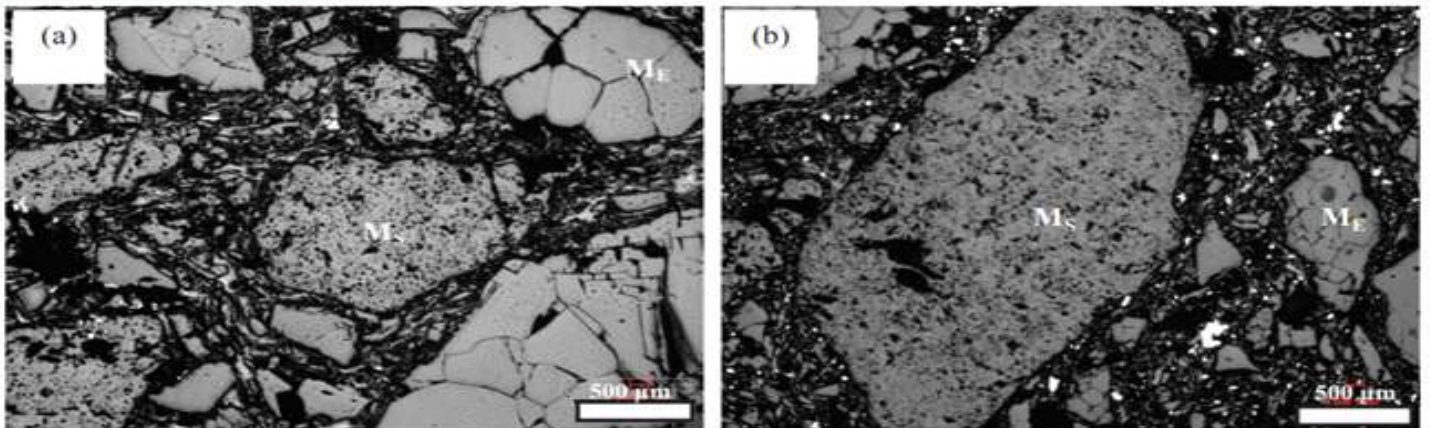
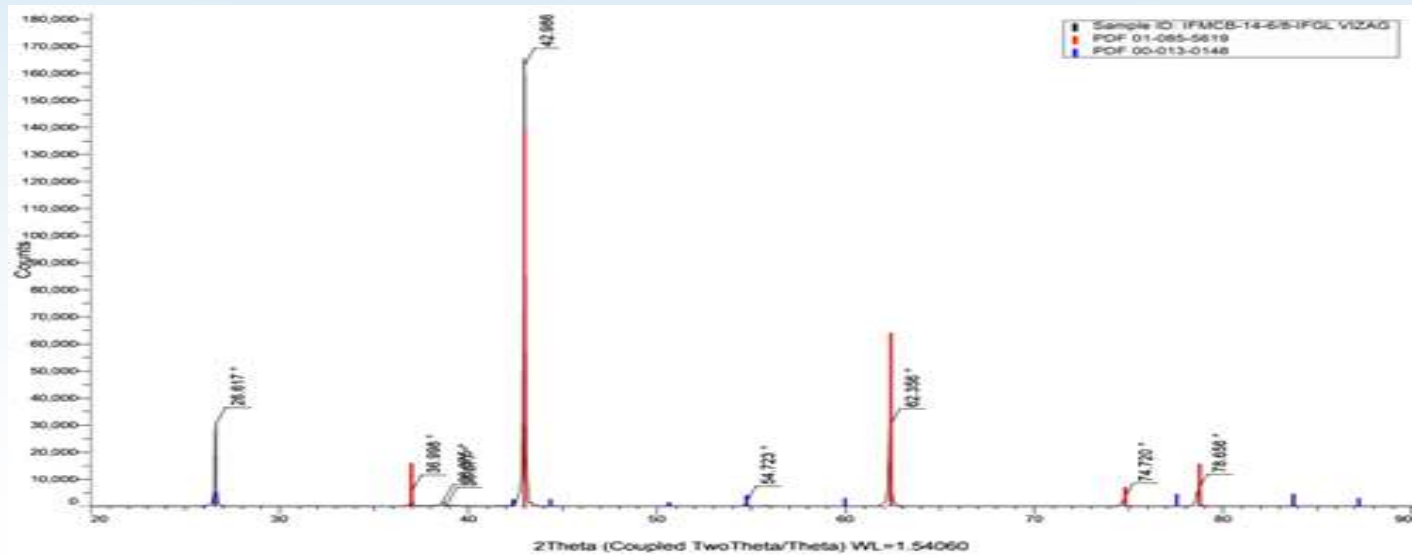


Fig 4:Microstructure a). sample B & b) sample C

In conclusion, the microscope study indicates that sample C has a higher volume occupied by the fine fraction. Consequently, there are the most FM96CaO/SiO<sub>2</sub>~ 1:1 periclase granules in this brick. Furthermore, no evidence of FM96CaO/SiO<sub>2</sub>~ 1:1 MgO granules is seen in sample A.

### 3.2 Phase Compositions

To indicate the influence of Periclase & carbon content on phase compositions of magnesia-carbon specimens, Brick A wasanalyzed via XRD, and the results are displayed in Fig.5 and Table 3.



| Index | Name            | Compound Name | Formula | %    |
|-------|-----------------|---------------|---------|------|
| 1     | PDF 01-085-5619 | Periclase     | MgO     | 89.9 |
| 2     | PDF 00-013-0148 | Graphite      | C       | 10   |

### 3.3 Slag Corrosion Resistance:

Table 4 shows the matrix of zone-wise attacking forces in a ladle. Since the type of attacking forces acting in the bricks are different at different zones, it is evident that the composition of the bricksis supposed to be different at different zones. For example, slag zone brick requires strong slag corrosion resistance and a little oxidation resistance.Now, slag corrosion properties can be improved by selecting purer raw material, on the other

Table 4 Analysis of attacking forces in Ladle

|                   | Slag Corrosion | Oxidation Resistance | Hot Abrasion resistance | Thermal Spalling | Structural spalling |
|-------------------|----------------|----------------------|-------------------------|------------------|---------------------|
| Bottom Non-Impact |                |                      | ✓                       | ✓                | ✓                   |
| Bottom impact     |                |                      | ✓✓✓                     | ✓                | ✓                   |
| Metal Zone        |                |                      | ✓✓                      | ✓                | ✓                   |
| Slag Zone         | ✓✓✓            | ✓                    |                         | ✓                | ✓                   |
| Free Board        | ✓              | ✓✓✓                  |                         | ✓                | ✓                   |

hand, oxidation resistance can be imparted by adding antioxidants. This is also to be noted that, as the amount of anti-oxidant increases it adversely affects the slag corrosion resistance. Fig-6 shows such inter-dependence of these two critical properties. An optimum balance is required where both properties are equally important. From this figure, it is seen that about 2 % addition of anti-oxidant is optimum. Again, this is true in the case of a single anti-oxidant. If double or bimetallic alloy anti-oxidants are

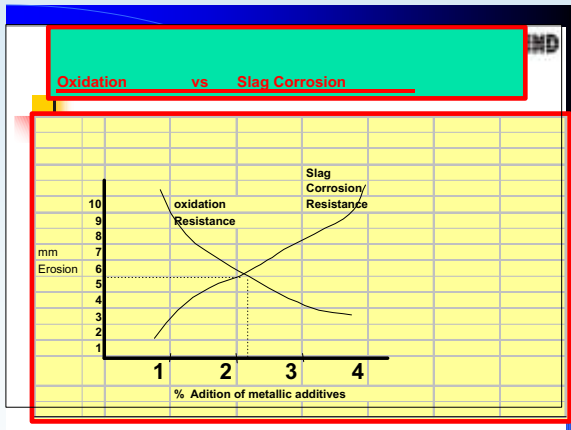


Fig-6: Slag corrosion resistance and oxidation

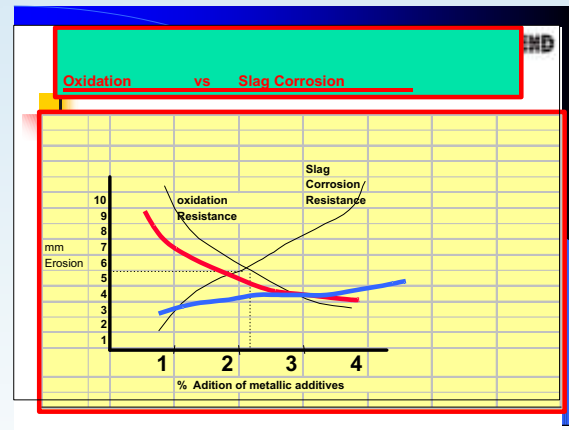


Fig-7: Slag corrosion resistance and oxidation

**Resistance measurement with Single anti-oxidant**      **Resistance measurement with double bi-metallic anti-oxidant**

used, the graph becomes a little different. Fig-7 shows the effect of bi-metallic addition. In this figure, a higher amount of addition is permitted as the point of interception is shifted to 3%. Moreover, the level of eroded/oxidized portion has also come down. So, it is concluded that bi-metallic addition can uplift both the properties of slag corrosion resistance and oxidation resistance more strongly than a single anti-oxidant.

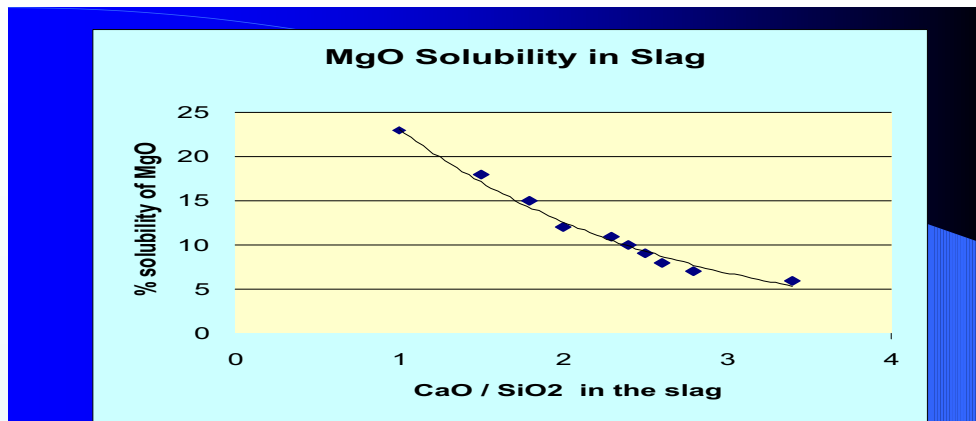
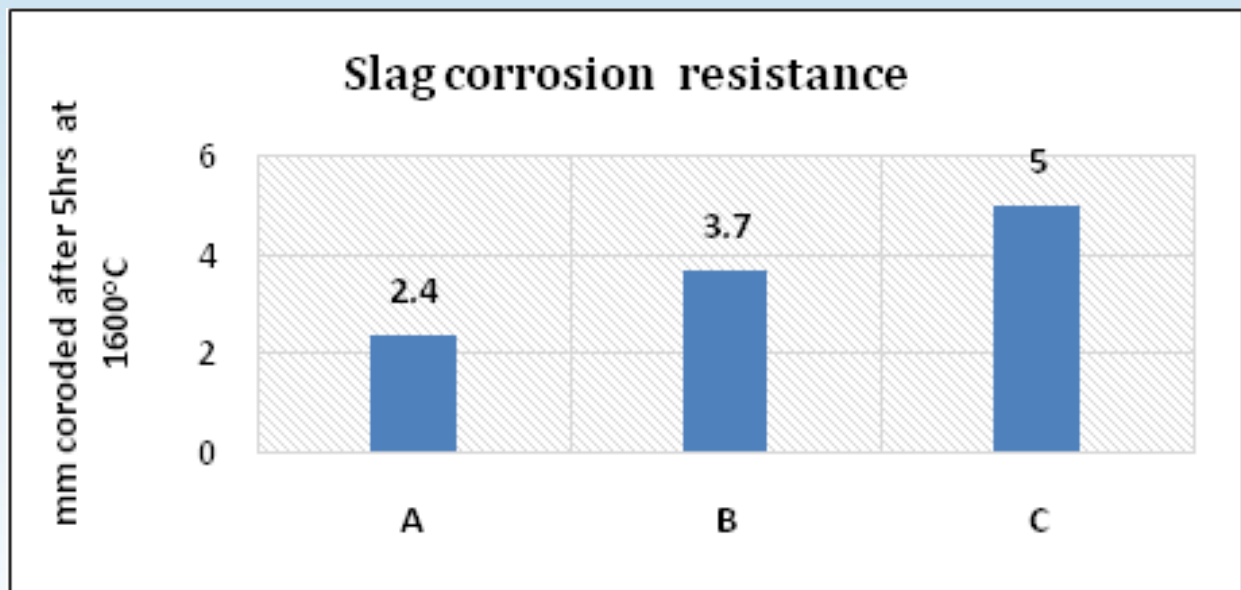


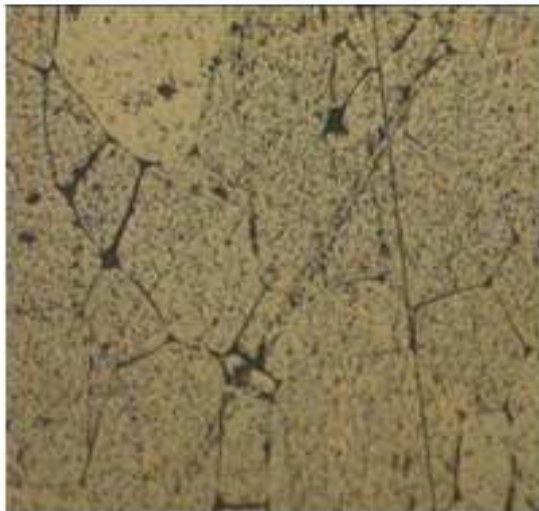
Fig 8: Solubility of MgO in slag

Fig-2a shows the rotary slag corrosion furnace where 3 different samples are put in a hexagonal structure the furnace is rotated at 6-7 rpm and the temperature is raised at 1600°C. Synthetic slag is added at an interval of ½ hour because as time goes on, the slag corrodes the sample and becomes saturated because of the solubility of MgO. Fig-8 shows how the solubility of MgO drops with a high basicity slag. Fig-9 shows the effect of different Mag-C bricks in determining the slag corrosion resistance. Fig 10 and Fig 11 show the periclase crystal size of FM97CaO/SiO<sub>2</sub> ~ 2:1 and FM97.5 CaO/SiO<sub>2</sub> ~ 2:1. fused magnesite under the microscope respectively. These two magnesites can be sort listed depending on the degree of slag attack.

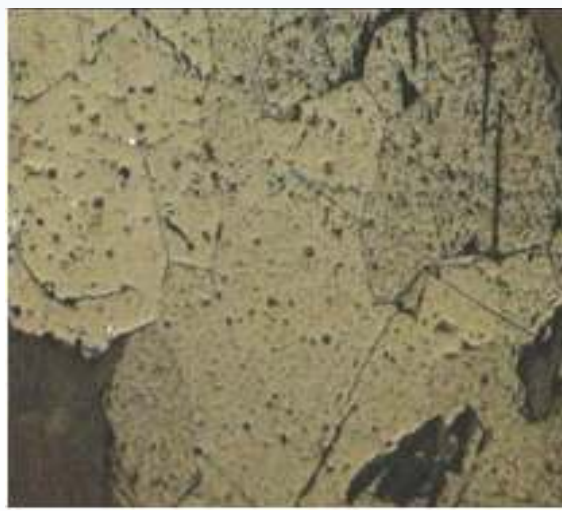




**Fig 9: Slag Corrosion resistance with three different Mag-C samples**



**Fig 10: Periclase crystal size of FM 97CaO/SiO<sub>2</sub> ~ 2:1**



**Fig 11: Periclase crystal size of FM97.5CaO/SiO<sub>2</sub> ~ 2:1**

The quantity of impurities in brick C, which contains a lot of aggregates of FM96 CaO/SiO<sub>2</sub> ~ 1:1, matters because it might keep the MgO crystals apart within the aggregate and prevent direct joining during the creation of MgO-MgO sintering. Landy (2004). The CaO/SiO<sub>2</sub> ratio is crucial in this situation. The softening of grain boundaries at high-temperature metallurgical applications thus causes a loss of aggregate stability and creates crucial pathways for slag entry.

Since the slag rich in CaO can dissolve or disintegrate FM96 CaO/SiO<sub>2</sub> ~ 1:1 grains or smaller FM97 CaO/SiO<sub>2</sub> ~ 2:1 more readily, it is thought that the zone of stronger reactivity with the slag for brick B is conducted through these materials. Brick A stronger defense against the slag attack might be attributed to higher-quality FM97.5 CaO/SiO<sub>2</sub> ~ 2:1.

Notably, the liquid formation can exist at lower temperatures due to the presence of contaminants like iron oxide. It is seen that the CaO-rich slag assault always passes through the fine grains zone (matrix) and grain boundaries in MgO aggregates. This is not the same as an attack by a slag high in FeO, as described by Galliatti et al. (2003),

where penetration occurs through MgO grains and at grain boundaries.

The purity of graphite also plays a great role in slag corrosion resistance, because the ash content increases the SiO<sub>2</sub> content and forms low melting compounds, which decreases the slag corrosion resistance. It also affects the oxidation resistance, so, this has been discussed in the oxidation resistance part.

### 3.4 Oxidation resistance:

For metal zone bricks, since oxidation resistance is not important, so anti-oxidants are not generally added. This is important mainly for the freeboard area and slag zone bricks. Fig-12 shows the oxidation resistance test result with a combination of different anti-oxidants. A specific combination of anti-oxidants gives the best oxidation resistance. This also depends upon the amount of graphite. The present study was made based on 10% graphite.

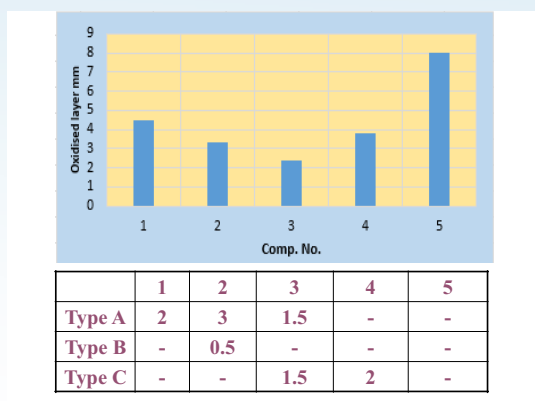
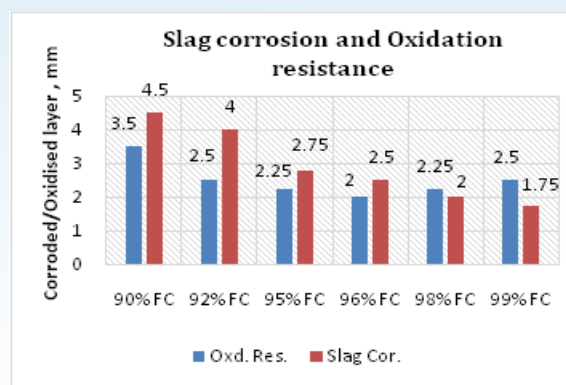


Fig 12: Oxidation resistance with differentig



13: Test data with different purity of graphite anti-oxidants

Fig-13 shows the change in oxidation resistance and slag corrosion resistance with the change in purity of graphite. The slag corrosion resistance gradually comes down with the increase in purity as expected, but the oxidation resistance results are very interesting. It improves up to a certain level of purity (96%), after that it deteriorates. This is probably due to the high reactivity of graphite flakes at higher purity levels. So, if oxidation resistance is more prominently demanded than slag corrosion, higher-purity graphite is not required. The amount of graphite has also an effect on the oxidation resistance, so normally the amount of anti-oxidant is increased with the increase in the amount of graphite to resist the graphite away from bricks. In the case of a higher % of graphite, the flake size also becomes important. Fig-14 shows a study with 20% graphite addition, and how the oxidation resistance is changed with different flake sizes.

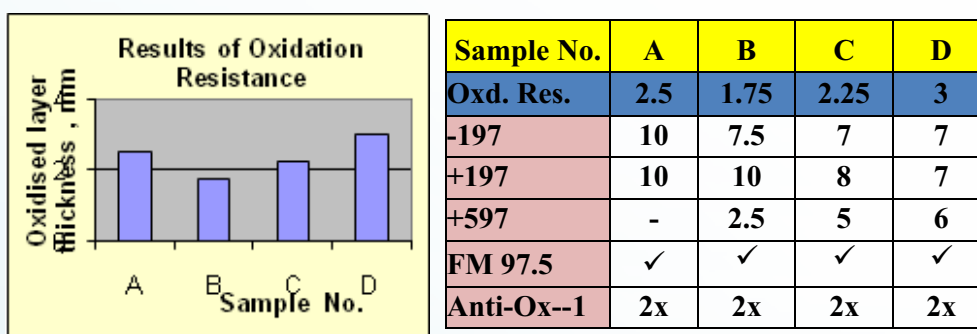


Fig 14: Oxidation resistance with different flaky graphite

## 4. CONCLUSIONS

- Even though all three materials have low open porosity (<3%), brick C is more vulnerable to slag attack because of the higher proportion of FM 96 (CaO/SiO<sub>2</sub> ~ 1:1) (with internal pores) and the higher percentage of MgO grains <400 μm.

1.

2. Fused magnesia used for manufacturing of samples A and B appears to play a major role & observed the very little extent of corrosion suffered by both materials.
2. 3. The corroded zone gives insight to observe the penetration of slag, primarily moving through the fine crystal region (matrix), and disaggregating Fused 96% MgO grains ( $\text{CaO/SiO}_2 \sim 1:1$ ).
3. 4. Comparing the corrosion behavior of three MgO-C containing distinct magnesia sources, it was attested that the conditioning practice was more effective in enhancing the refractory corrosion resistance than the use of a high-quality (higher purity) raw material. It is important to note, however, that the refractory bricks with coarser and higher-quality MgO sources had a little superior wear rate.
1. Graphite purity also plays a great role in slag corrosion resistance, because the ash content increases the  $\text{SiO}_2$  content and forms low melting compounds, which decreases the slag corrosion resistance.
4. 6. The addition of antioxidants also plays a major role in the control of slag corrosion, as the above experiments concluded that bi-metallic addition can uplift both the properties of slag corrosion resistance and oxidation resistance more strongly than single anti-oxidant.

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## **Ladle Lip Brick**

*SAMWHA INDIA REFRACTORIES PRIVATE LIMITED*

### **Abstract**

A quantity of crushable material is disposed between the outer side surface of each lip closure segment and a flange extending at an angle from the side wall over the open top end of the vessel to maintain the lip closure segments in a tight fit on top of the lining of refractory bricks. The ladle lip ring holds the wall (barrel and slag line) tight in compression throughout the ladle campaign and withstand the steel/slag dumping process and associated clean-up of the ladle lip.

### **Thermal**

**Peak Temperature:** The temperature of the lip is similar to that of the ambient temperature of the air and can be higher due to radiant heat in the process and can rise abruptly at the time of dumping from the steel/slag. Although the lip ring can experience high temperature during ladle overweight and arc heating in the ladle metallurgy area. Thus, high temperature resistant materials are to be considered for the application.

### **Thermal Shock:**

The thermal cycling for the working lining is considerably high and it experiences shock during the dumping of slag in every heat. Thus it ultimately depends on the number of heats per day (Although the number of heats per day varies from 4 to more than 6 in certain shops).

### **Mechanical**

**Impact:** The impact is high due cleaning of the lip for dumping skulls or lip skull removal process.

**Abrasion:** The abrasion on the lip is least. The bath turbulence does not affect the abrasion of the lip. The lip lining suffers from abrasion only at the time of steel/slag dumping in the pot.

**Applied stress:** The height of the lining is less to cause any applied stress. However, when monolithic material is used, expansion tolerance is to be provided or flexible material is to be used.

### **Chemical**

**Dissolution:** Wear by dissolution depends on the chemical compatibility of the slags with bricks. The slag gets in touch with the ladle lip only at the time of dumping and thus it is not considered a major wear factor.

**Penetration:** Penetration is caused by low viscosity metal/ slag or highly wetting metal/slag penetrating into porous refractories. Which is not a problem for the slag line area.

### **Thermo-Mechanical**

**Strain of thermal expansion-**The height of the lining is very less to cause any applied stress. However, when monolithic material is used, expansion stress is generated. Expansion allowance is to be provided or flexible material is to be used.

### **Background Of the Invention**

#### **1. Field of the Invention**

The present invention relates, in general, to metallurgical vessels and, more specifically, to top ring or lip closure devices for metallurgical vessels, such as ladles used in the steel industry.

#### **2. State of the Art**

Metallurgical vessels, such as ladles used in the steel industry for handling molten steel, are formed of an outer steel shell and a refractory brick inner lining. The refractory bricks are stacked along the bottom surface and the inner surface of the steel shell along the entire height of the ladle from the bottom to the top, open mouth of the ladle.

Refractory bricks transfer a thermal load, i.e., heat radiation from the molten steel, from a "hot face" immediately adjacent the molten steel to a "cold face", i.e., the refractory plane most distant from the molten metal and located adjacent to the outer steel shell. During steel making, the ladle is frequently tipped for steel pouring or slag skimming operations and completely upended for deslagging. In order to provide mechanical support for the refractory brick stack, it is known to form an inwardly extending, angled flange immediately adjacent the top end of the steel shell.

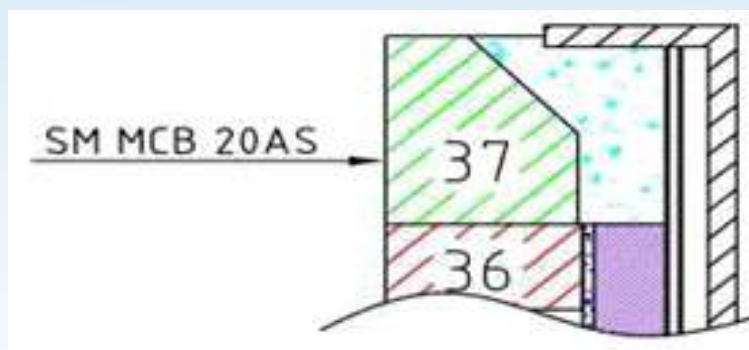
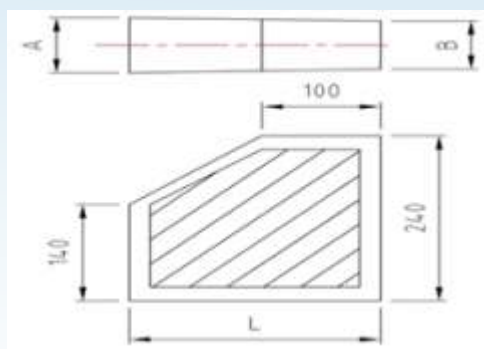


A removable lip ring or lip closure ring is inserted inside of the flange and on top of the refractory brick stack. The lip closure ring is typically formed of a number of identical, arcuate segments cast from a refractory or ceramic material. A smaller segment or "key" is custom shaped and inserted between two adjacent segments to close the lip ring and to provide integrity in the ring to support the refractory brick stack.

## SAMWHA LIP Brick

## SAMWHA LIP Brick

### Assembly



All such metallurgical vessels have a maximum service life limit before the refractory bricks must be replaced. Such a limit, which can be from twenty to twenty-five heats of molten steel, is determined in part by the life of the refractory bricks which are continually consumed by the repeated thermal transfer cycles of heat from the molten steel to the outer shell.

Further, the service life limit is affected by the expansion of the refractory bricks from their original cold-cure state during initial burn in and the first few heats. Most of the expansion, which can be as much as 2 1/2 inches over the entire height of the refractory brick stack, occurs during the first few heats and remains constant thereafter for the service life of the brick stack. This expansion exerts a considerable force on the lip closure ring which can cause deformation, warpage or even breakage of the ring and thereby reduce or limit the useful service life of the vessel. Thus, it would be desirable to provide a lip closure ring apparatus which overcomes the problems encountered with previously constructed lip closure rings. It would also be desirable to provide a lip closure ring apparatus which resists deformation despite thermal expansion of a refractory brick stack. It would also be desirable to provide a lip closure ring apparatus which increases the useful service life of a metallurgical vessel.

### SUMMARY OF THE INVENTION

The present invention is a lip closure apparatus for a metallurgical vessel, such as a steel ladle, having a bottom, a side wall, an open top end opposite from the bottom, and an inner lining of refractory bricks covering the bottom and the side wall.

The lip closure apparatus comprises a flange mounted on the vessel adjacent the top end thereof which extends inward at a predetermined angle from the side wall of the vessel. A plurality of arcuate lip closure segments, each having an inclined outer face complementary to the angle of the flange, are inter-fitted into a continuous lip closure ring interiorly of the flange and overlying the top end of the inner lining of the refractory bricks to retain the inner lining of refractory bricks in a fixed position within a vessel.

The lip closure apparatus of the present invention solves several problems existing with previously devised lip closure apparatus for metallurgical vessels, such as steel ladles.





## **SAMWHA Ladle Lip Locking Bricks' Trial Report at M/s SAMPL, Pune.**

02 sets SAMWHA Ladle special Lip Locking Bricks were supplied to M/s SAARLOHA Pune.

PO No: 4504000447 Dtd. 09.01.2020.

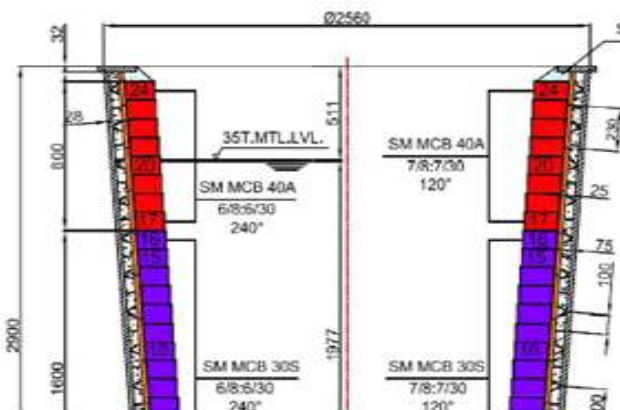
Objectives of Ladle Lip Locking Bricks:

- 1) Provide robust support to Free Board and Slag Zone bricks.
- 2) Arrest/minimise metal leakages from the Free Board areas.
- 3) Increase in overall Ladle life

SAMWHA special Ladle Lip Locking bricks were used in Ladle Nos 11 & 04 on trial basis:

| SAMWHA special Ladle Lip Locking Bricks Performance |           |            |             |            |      |              |          |                          |                       |                                    |
|-----------------------------------------------------|-----------|------------|-------------|------------|------|--------------|----------|--------------------------|-----------------------|------------------------------------|
| Sl.No                                               | Ladle No. | Status     | Lining Date | Down Date  | Life | Process Time | HT Heats | Life as per Process Time | Reason for Ladle Down | Observation at the end of campaign |
| 1                                                   | 11        | New Lining | 06.09.2020  | 14.09.2020 | 35   | 4702         | 8        |                          | Down As per Planning  | FB, MZ & SZ are still strong       |
|                                                     |           | 1st repair | 21.09.2020  | 01.10.2020 | 34   | 4413         | 12       |                          |                       | FB, MZ & SZ are still strong       |
|                                                     |           | 2nd Repair | 10.10.2020  | 18.10.2020 | 31   | 4416         | 9        |                          |                       | FB, MZ & SZ are still strong       |
|                                                     |           |            |             |            | 100  | 13531        | 29       | 130.26                   |                       | FB, MZ & SZ are still strong       |
| 2                                                   | 4         | New Lining | 13.09.2020  | 21.09.2020 | 32   | 5302         | 9        |                          | Down As per Planning  | FB, MZ & SZ are still strong       |
|                                                     |           | 1st Repair | 27.09.2020  | 06.10.2020 | 32   | 4074         | 6        |                          |                       | FB, MZ & SZ are still strong       |
|                                                     |           | 2nd Repair | 16.10.2020  | 23.10.2020 | 31   | 4436         | 6        |                          |                       | FB, MZ & SZ are still strong       |
|                                                     |           |            |             |            | 95   | 13812        | 21       | 130.81                   |                       | FB, MZ & SZ are still strong       |

**Ladle Bricks Design without Lip Locking**



**Ladle Bricks with Samwha Sp. Lip Locking Lip Locking at Ring #28in Green.**



## **Ladle Condition without Lip Locking Bricks (Disturbed FB Bricks causing Metal Leakages due to Gap)**





### Ladle Lining With Samwha Lip Locking Bricks, Ladle # 11 & 14.



**Samwha Lip- Locking Bricks Ladle In Operation (FB is very Robust even during Frequent hard Lip jam removals)**



#### Observation

It is observed during operation that SAMWHA special Lip Locking bricks have shown excellent resistance to hard lip jam removals protecting the FB & SZ bricks.

M/s SAARLOHA can target higher ladle life safely with SAMWHA special Lip locking bricks.

#### Summary

In summary, there has been disclosed a unique lip closure apparatus for a metallurgical vessel, such as a steel ladle, which overcomes several of the problems existent with previously devised lip closure apparatus.

### **SAMWHA Ladle Special Lip Locking Bricks' Customers**

**SAMWHA GROUP**

| Sl. No | Customers' name                    | Products Used | Process Route                                    | Capacity In MT | SAMWHA Performance (Heats) List | Competitors' Performance (Heats) List | Improvements with Lip Locking bricks                            |
|--------|------------------------------------|---------------|--------------------------------------------------|----------------|---------------------------------|---------------------------------------|-----------------------------------------------------------------|
| 1      | Jindal Steel & Power Ltd, Raigarh  | MCB           | EAF-100% LF-100% VD.RH with One slag line Repair | 100            | >150                            | 125 to 150                            | Metal leakages from FB area decreased and Ladle life increased. |
| 2      | JSW Steel Ltd, Vijayanagar         | MCB           | EAF-100% LF One slag line Repair                 | 160            | >100                            | 70 to 100                             |                                                                 |
| 3      | Visakhapatnam Steel Plant (RINL)   | MCB, AMC      | BOF-100% LF with One slag line Repair            | 160            | >90                             | 60 to 80                              |                                                                 |
| 4      | SAARLOHA (Kalyani Carpenter), Pune | MCB           | EAF-100% LF-100% VD with Two slag line Repair    | 35             | >125                            | 90 to 115                             |                                                                 |
| 5      | GPH Ispat Ltd (Bangladesh)         | MCB           | QEAF-100% LF with One slag line repair           | 80             | >150                            | 110 to 130                            |                                                                 |

## **Challenges and Solutions for manufacturing of TCD SES & TCD TN refractories in Consideration of long –sequence casting and Clean steel.**

*H.L Rai (M.D), Lalu Prasad Malla (Manager CCR), Pankaj Kumar (Sales Head).*

### **Abstract.**

Continuous casting of steel has become a widely used process and an important step in steel production. The worldwide share of continuous cast steel has increased significantly to strict composition control, Increase in production level and reduces the cost. Tundish is the last metallurgical vessel through which molten metal flows before solidifying in the continuous casting mold. In recent year, most of the steel producer upgrade their design and has shifted to TCD caster for high quality and long sequence casting. In the TCD caster, mainly Mon block Stopper, Tundish Nozzle and Tube changing SES is used. In case of clogging or any failure which is attributing to the refractories during the casting process is impacting the productivity loss and quality problem of steel. In order to prevent the failure, good application, suitable materials chemistry, product design and good process control is essential.

In this article, we demonstrate about how different design, materials selection and methods of manufacturing are encouraging to good results.

### **1. Introduction:**

Tube changers are used in the continuous casting of steel and as the name implies this device for changing the submerged entry shroud (SES) commonly known as “tube”, which is used to protect the metal stream between the tundish and the mould. Mainly tube changing is applicable only to slab or sometimes in bloom caster. The developments of tube changer machine and its refractories are varying from company to company based on the safety feature and design part. Sometime tube changer related refractories are basically combination of SES & TN with bottom sliding surface. These refractories are mainly made of Alumina-graphite due to their high thermal-Spalling resistance. Recently carbon free liners with purging system to the tundish nozzles are used for the purpose of clogging prevention. On the other hand, purging failure in tundish nozzle, breakage of liner due to purging pressure and oxidation of AG refractories cause to abort the casting process. In this report, we introduced various technologies which can solve the problems.

### **2. Purpose of TCD SES & TCD TN refractories:**

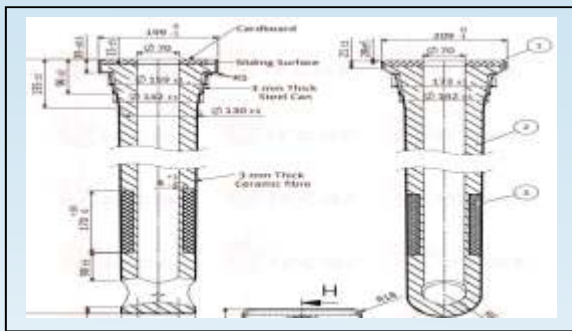
- Easy Installations and Quick exchange of SEN during casting.
- Increase production yield.
- Improved operational safety.
- Extend tundish life and caster productivity.

### **3. Challenges and task given to Zircar:**

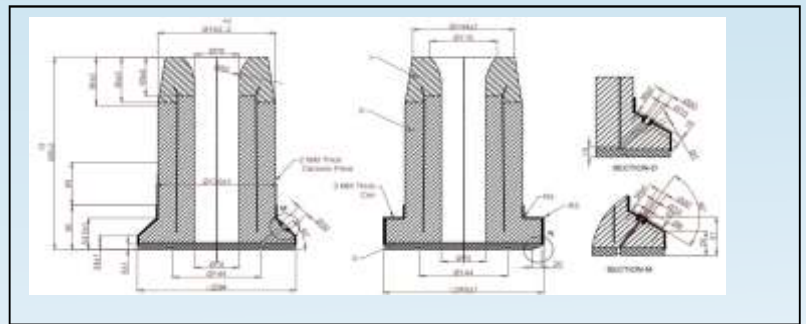
- Regular supplier of TCD SES and TCD TN was with 14-15 heats and 24heats respectively. Most of the time both SES & TN was performing less than the desired life due to inconsistency, resulting more consumptions as well as breaking the sequence.
- Zircar received the order of TCD SES & TCD Tundish nozzle from the customer with the life guarantee of 15heats & 24 heats.

### **4. Probable reason for Refractory failure:**

We've collected and understood the operation parameter of Customer. We tried to analyze the failure patterns to find out possible reasons. We have been provided TCD SES and TCD TN drawings as per Fig.1.1 & Fig 1.2 by Customer. We concluded the following problems which need to be addressed by us while manufacturing of products.



**Fig 1.1**



**Fig 1.2**

- Product not fitted in to the mechanism.
- Materials stocked in to the mechanism due to sliding surface.
- Gas leakage from gasket and bottom part of product.
- Purging failure.
- Centering and alignment issue.
- Graphite gasket Quality and Fitting issue.
- Product oxidation and hole.
- Slag Band Corrosion.
- Alumina -clogging.

## **1. Design Features of Refractory Component:**

Following are the designs to overcome the above said problems by us:

- Product to be made as per customer drawing, no change of base & Cassette dimensions.
- Providing graphite seal to avoid any mechanical damage.
- Argon purging in both side of TN.
- Product is tightly fitted with mechanism.
- Hard Surface mix in the flat surface.
- Seating area reinforcement with high alumina or magnesia base materials.
- Carbon free liner for prevention of anti-clogging & better spalling resistance.
- High Quality Zirconia-mix for good erosion resistance.

## **2. Zircar's Concepts to Counter the Problems:**

### **Alumina – Clogging:**

When Carbon containing refractories contact with molten steel, carbon exposed on the surface dissolving into the molten steel, resulting a rough condition. As our products are made with Alumina Graphite materials, where carbon located in refractories reacts with the  $\text{SiO}_2$  component and generates  $\text{SiO}$  and  $\text{CO}$  gas. These gases move to refractories surface and reacts with the  $\text{Al}$  in molten steel to form network alumina on the refractory surface. Since the reaction promotes surface deteriorations, the wettability of the surface become worse, making it easier to promote the clogging.

In order to suppress the Alumina – Clogging, we have selected our Carbon free recipe & installed in the bore, since carbon free materials does not contain carbon raw materials, the surface roughness deterioration doesn't take place or less likely generated. This make it possible to maintain a smooth refractory surface during casting.

### **Slag Band Corrosion:**

- ✓ Increase the thickness of slag band.
- ✓ Anti-oxidant glaze materials with combination of under coat to avoid oxidation during pre-heating.
- ✓ Erosion resistance  $\text{ZrO}_2$ - mix.

### **Product not fitted in to the mechanism**

#### **Steel Cassette and fixing:**



- Product is not fitting with the mechanism due to Sliding surface / metallic-Can dimension variations.
- Steel cassette thickness increased without change the outer dimensions i.e. 240mm & Stainless steel quality used to prevent any rusting and swelling during production.

#### **Sliding surface:**

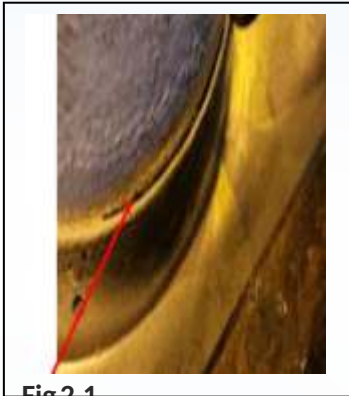
The sliding surface is a key component that determines function of the sliding. Sliding surface should be completely smooth so that during nozzle changing, it won't stuck in mechanism.

Following are the properties of Sliding surface:

- Flatness of Sliding Surface – 0.05mm.
- High mechanical strength & Peeling resistance.
- Excellent anti-oxidation performance.
- Good abrasion resistance.

#### **Gas Leakage, Purging failure & Oxidation:**

During installation, gap has been found in most of the pieces in between refractory and metallic cassette, also in deformed metallic-can that leads to air entrap from gap, promote gas leakage & Oxidation , that causes puncture during casting and cut in sequence. Failed pic reference from Fig 2.1 to 2.4.



**Fig 2.1**



**Fig 2.2**



**Fig 2.3**



**Fig 2.4**

Zircem cement & Sealing mortar used in a uniform way to fix the metallic-can with refractory .This mortar neither get cracked nor shrink after preheating. Also it is having less porosity & good sticking properties, which helps to reduce air suction.

Before wrapping ceramic paper, the border of metallic can and refractory sealed with 360 degree extra layer of mortar and 2 layers of anti-oxidation glaze applied over the mortar and in metallic cassette, which withstand during preheating and solve the Oxidation problem.

#### **SEN Centering and alignment:**

Alignment of refractory body and can is so critical in case of improper alignment. It will cause various problems during casting. Port alignment, centering of port and perpendicularity is being checked through aser.



**Fig 3.1**

#### **Graphite Gasket:**

- ✓ Gaskets installed in center of metallic-can with heat resisting mortar.
- ✓ Uniformed projection with metallic-can helps for better fitment of mechanism.
- ✓ Both gaskets in same line and align with each other.

### Graphite Gasket:

- ✓ Gaskets installed in center of metallic-can with heat resisting mortar.
- ✓ Uniformed projection with metallic-can helps for better fitment of mechanism.
- ✓ Both gaskets in same line and align with each other.



Fig 4.1



Fig 4.2

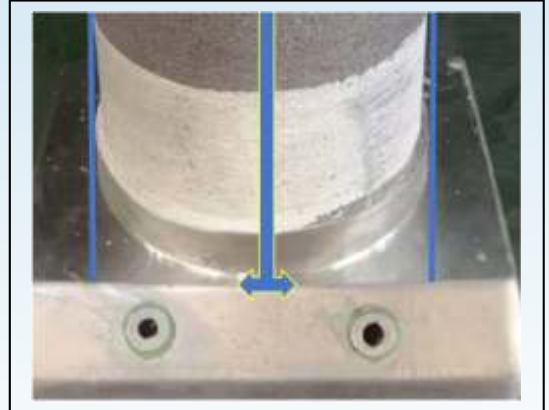


Fig 4.3

### Argon Purging:

During casting argon is injected through the nozzle wall to reduce nozzle clogging. In Tundish Nozzle, there are 2 holes for argon purging. Right side purging goes inside body and left side purging goes to sliding surface (shielding). A special type of tool is designed to avoid any link between these 2 holes and channels. A thin layer is created in between two refractory bodies. The inside material is very porous without impacting the strength and working well at 3bar pressure with 12litre/minute flow rate. Pl refer the Fig 5.1 to 5.3.



Fig 5.1



Fig 5.2



Fig 5.3

### Conclusion:

It was very first experience to go for TCD SES and TCD Tundish nozzle manufacturing , we have not only supplied to the export customer also solved the major problem like “ **Clogging , Good slide surface ,negligible erosion on the top surface, no leakage & good purging in the Tundish nozzle**”. These refractory products installed to TCD caster and our various solutions were reviewed in this paper. We successfully executed the order and product performance as per the customer requirements. Tundish nozzle purging failure, alignment of SES and gap between metallic Cassette & refractory is the major failure concern for the customer. In conclusion, our technology has shown that understanding the problems, usage of proper tool and controlling the process parameter which significantly impacting the product performance.

Some the Despatch pic for reference : Fig 6.1 to Fig 6.3



**Fig 6.1**



**Fig 6.2**



**Fig 6.3**



# High performance monolithic lining on RH Snorkel

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## Abstract

In the life cycle of RH degasser, the snorkels are the most important component that controls the operation and at the same time is subjected to severe thermo-mechanical and chemical wear. In most cases it decides the life cycle time of RH Snorkel. The life of snorkels can be extended by focusing on the outer and inner refractory lining. The external monolithic lining of the snorkel assembly is very important with significant bearing on the life cycle of the snorkels. This paper highlights the mechanical and chemical abuses encountered during the operation. An attempt is made to develop a product which addresses the above operation conditions of corrosion caused by slag, erosion caused by flowing metal and spalling due to temperature cycling and thermo-mechanical impact of the steel structure holding the castable and bricks. The properties of castable are discussed, to arrive at an optimum product for the outer monolithic lining.

## Introduction

The RH process is employed to meet the steadily rising demand of ultra-carbon steels. It is supposed to degas steel primarily by reducing carbon, hydrogen, and nitrogen contents to ultra low levels (ppm). The steel circulation can go as high as 200 tons per minute depending on design of the RH vessel and pump capacity. The treatments take 20-35 minutes between 1460°C (carbon steels) and 1640°C (ultra-low carbon steels) as a function of steel quality and metallurgical targets. The loads and stresses to which refractory materials are subjected are correspondingly intensive. The wear mechanisms are mainly thermal, mechanical, or chemical which influence one another and therefore need to be considered collectively when designing the refractory materials.

## Operational environment

The different stresses that come into play are indicated below:

- Thermal
  - ✓ Thermal shocks due to intermittent operation.
  - ✓ Strong overheating by alumino-thermic heating
- Chemical
  - ✓ Slag attack esp. on snorkel outside lining
  - ✓ Switching between oxidizing and reducing atmospheres
- Mechanical
  - ✓ Erosion by steel circulation
  - ✓ Bath agitation by top lancing
  - ✓ Skull removal from snorkels

In Table 1 the average refractory life of the different sections of an RH vessel in Europe is given alongside with Indian ones. It shows that the Snorkel section is the one with the shortest life and therefore the decisive factor for refractory maintenance. In addition to the required replacement of snorkels there is a continuous need to maintain them at regular intervals.

| AREA INSIDE RH<br>DEGASSER | LIFE            |                 |
|----------------------------|-----------------|-----------------|
|                            | INDIA           | EUROPE          |
| GAS DUCT                   | > 4000 Heats    | 6000 Heats      |
| UPPER VESSEL               | 1000-1500 Heats | 1500-3000 Heats |
| LOWER VESSEL               | 200-500 Heats   | 200-600 Heats   |
| SNORKELS                   | 90-140 Heats    | 120-180Heats    |

The maintenance is usually executed in two stages. First the snorkels are cleaned from outside by snorkel cleaning device which removes attached skulls and slag. In the second stage the snorkels refractory is repaired by gunning from inside and outside with a proper refractory mass. Both the devices are usually installed on a so-called snorkels maintenance car and serve to improve and extend the refractory life of snorkel.

It is also a fact that the specific consumption of refractory material is consequently the highest for the snorkels and throats, more so, if snorkel gunning is also considered.

### ***Prefabricated snorkel***

It has been previously mentioned that RH Snorkels are the highest consumer of refractories in the RH Degasser domain. The wear lining of snorkels and throats together consume more than one kg per ton of liquid steel or almost two-third of the total RH Degasser refractory consumption. Hence the focus on development of a robust, abrasion and erosion resistance castable, which will be dealt with in our subsequent discussion. Before that, let us discuss in brief the standard snorkel design, as this has a significant bearing on the performances and stresses on precast snorkel.

### ***Standard Snorkel Design***

In general, two different brick holding designs exist. (Fig.1 & Fig. 2)

1. Conical brick holding system.
2. Holding design by means of a flat flange.

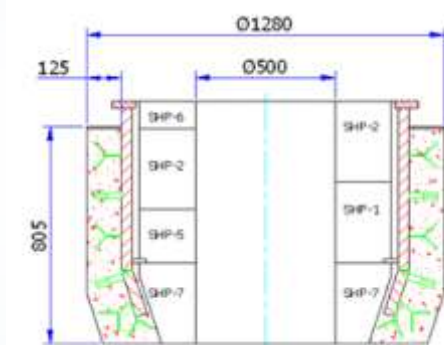


Fig. 1

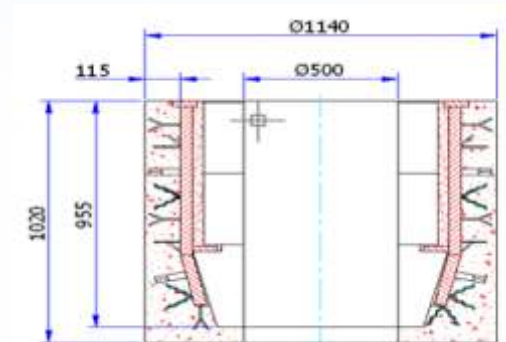


Fig. 2

Both design are in practice and accepted. In both systems bricks can be lined a vertically bonded construction. We will also have a closer look in to steel Construction for precast snorkel assembly as it is vital to counteract thermal stresses during repeated use.

### ***Steel Design of a Precast Snorkel Assembly***

The steel components of the snorkel comprises of

- Steel shell, with or without cooling flange
- Gas tubing system
- Anchoring system of outer castable

Generally, the steel shell is 25-40mm thick in boiler sheet quality. The conical part is reinforced by welding a round bar of 40-50mm in diameter all around the outer periphery of the shell. The gas pipe is made with heat resistance stainless steel. Argon tubing is skillfully embedded between the steel shell and bricks, to protect it from any possible steel ingress. The anchoring system is extremely important for the outer castable. Anchors are selected in heat resistance stainless steel grade and effort is made to embed a stainless-steel wire-mesh in the middle. This feature provides resistance to heavy cracking tendency of the castable during operation cycles.



### *Selection of Castable*

The castable selection process considers the above-mentioned thermal, chemical, and mechanical stresses in addition to metal penetration that takes place. The stresses are developed in the steel structure during high temperature cycling and this largely impact upon the castable lining than the corrosion-erosion by metal penetration. The repeated thermal shocks lead to heavy stress build-ups and deforms the steel structure thus impacting on castable lining which becomes prone to cracking, slabbing and subsequently eroding

### *Design of the Castable*

Accordingly, a high alumina, silica free, high purity material with and without spinel addition has been designed, for which detailed property study followed by simulative rotary slag corrosion test was undertaken to estimate the suitability. In the castable Tabular alumina is considered for its superior high temperature mechanical and abrasive properties coupled with fused alumina for its abrasion resistance. Fused and sintered spinel is added in the mix to enhance the corrosion and thermal shock resistance and check the ingress of molten steel into the precast. The rest of the properties are controlled by a special combination of reactives and high alumina cement. The product selected type is represented in Table 2. HA1 is high alumina castable, while HA 35M is alumina spinel based.

| Comp/Material              | HA 1    | HA 35M  |
|----------------------------|---------|---------|
| Tabular/Fused Alumina      | 70-80   | 70-80   |
| Sintered/Fused Spinel      | -       | 05-20   |
| Calcined/Reactive Alumina  | 08-10   | 10-15   |
| High Alumina Binder        | 08-10   | 8-10    |
| Deflocculants+ Stabilisers | 0.1-0.2 | 0.1-0.2 |

Small batches were prepared and mixed in a laboratory scale mixer and samples were cast and tested as per ASTM standards. The flowability was checked using ASTM C 860 by vibrating the mix for 30 sec and high temperatures properties were tested. The properties are detailed in Table 3.

| Criteria                         | HA 1               | HA 35M            |
|----------------------------------|--------------------|-------------------|
| Al <sub>2</sub> O <sub>3</sub> % | 95.89              | 92.3              |
| CaO %                            | 3.41               | 2.46              |
| MgO %                            | -                  | 5.1               |
| BD (gm/cc)                       | 3.16, 3.12         | 3.07, 3.10        |
| CCS(MOR) (kg/cm <sup>2</sup> )   | 805, 798 (182,196) | 822,912 (181,178) |
| <b>At 1000°C/3hr</b>             |                    |                   |
| BD (gm/cc)                       | 3.06, 3.07         | 3.04, 3.07        |
| CCS (MOR) (kg/cm <sup>2</sup> )  | 1027 (191)         | 1063 (211)        |
| PLC (%)                          | +0.13              | +0.09             |
| <b>At 1650°C/3hr</b>             |                    |                   |
| BD (gm/cc)                       | 3.06               | 3.04              |
| CCS (MOR) (kg/cm <sup>2</sup> )  | 905(229)           | 1224(231)         |
| PLC (%)                          | +0.14, 0.96        | +0.31, +0.42      |
| RTE (%)                          | 0.53               | +0.56             |
| Erosion (mm)                     | 5.5                | 3.5               |

Corrosion and penetration resistance of the mix was carried on in a Rotary Slag furnace with a compatible slag (Table 4) from the steel unit. The slag corrosion was checked at 1650°C with this slag, in which the total residence time of the metal was 8 hrs and slag was tapped after each hour.

Table 4

| SiO <sub>2</sub> % | Al <sub>2</sub> O <sub>3</sub> % | MnO % | CaO % | MgO % | P <sub>2</sub> O <sub>5</sub> % | Fe %  | S %  |
|--------------------|----------------------------------|-------|-------|-------|---------------------------------|-------|------|
| 15.66              | 1.04                             | 1.39  | 45.19 | 11.5  | 1.68                            | 13.36 | 0.08 |

### *Analysis*

The result after corrosion is displayed in figure 3 gives the penetration depth of the samples. It is observed that the corrosion in both HA1 and HA35 has progressed to the similar extent, but in HA35M the penetration depth is uniform and to a lesser degree. This can be attributed to the presence of spinel crystals considered to increase corrosion resistance because reactivity of the preformed spinel with slag was less and the reaction to produce fluxing materials could not take place. Thus the ingress of the metal into the matrix of castable is restricted. On the other hand the alumina rich matrix is very effective in resisting the metal erosion by virtue of its high mechanical properties but the penetration of CaO, MnO bearing slag leads to penetration and dissolution of matrix is promoted and the resulting phase alteration leads to structural spalling. This phenomenon primarily leads to higher erosion of the material.



### *Conclusion*

An attempt has been made to design the castable required for the outer precast portion, giving due importance to the turbulent conditions to which the snorkel precast is subjected. The simulative test comes out with a representative result of the material selected for the purpose. The high alumina and spinel-based material have commendable properties in terms of erosion and penetration. But the spinel-based material has an edge over high alumina by virtue of its superior resistance to structural spalling due to metal ingress in the castable matrix. For all practical and technical purposes, this material is expected to work in tandem with the inner brick lining subject to the steel reinforcement design.

### *Acknowledgement*

The authors express their sincere gratitude to the management of IFGL for providing scope and permission for publishing this work in the proceedings of Refbis 4.0

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## Modern Techniques In Improving Steel Quality In Tundish

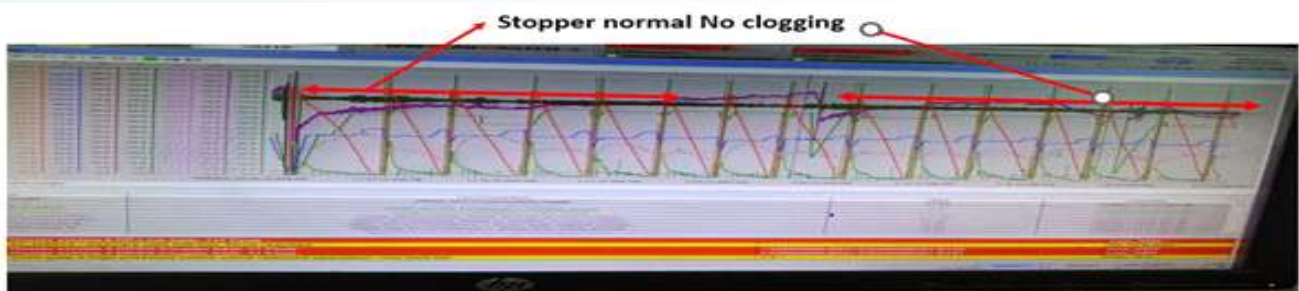
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In high productive steel making shop, the challenge has been to maintain or even enhance the steel quality without compromising on the steel plant productivity. The challenge has been to maintain or improve the steel quality in the tundish during the casting without affecting the overall productivity.

This directs the whole focus in having the perfect blanket of the active flux / synthetic slag in the tundish which remain in fluid form even after the changes in composition and temperature during course of casting. Also to offer good effect on improving the steel quality the active flux need to have high potential to catch and importantly retain the detrimental inclusions like  $Al_2O_3$ .

Allied Metallurgical Products Pvt Ltd, Bangalore has come up with excellent solution with the low alumina , carbon free active tundish flux – Insulux Basi 1. The product is easy to use and supplied in fine granular form. The product is carbon free low melting active flux which remains in liquid form even after absorbing large quantity of floating inclusions including  $Al_2O_3$ . The surface tensions of the product during casting is such that the floated inclusions are held tight and not allowing it to flow towards the SEN. The product is very effective in all steel grades specially Al killed low and ultra low carbon steel through slab and CSP casting.

The industrial use of product by steel majors have reported absorption of alumina to tune of 25 - 30 % , reduction in start up failure & rejections and control on slivers. Its also been reported to have uniform stopper position due to less deposits in nozzle. It is also reported that there is no silicon reversal.





# An Experimental Study to Improve the Zirconia Metering nozzle Performance in low carbon Steel casting (construction Grade)

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## Abstract:

The performance of zirconia metering nozzle in low carbon steel (construction grade carbon <0.1%) casting much lower comparative to high carbon steel (construction grade carbon >0.2%) casting in mini mills. An experimental study carried out for improving the performance of metering nozzle in low carbon grade steel casting. Developed product of metering nozzle are characterised for Chemical and physical properties by X-ray fluorescence spectroscopy (XRF), Microstructure characterization with scanning electron microscopy (SEM) and analysis of pore size distribution using Mercury Porosity Meter. It is found that controlled pore size helps in reducing the reaction with metal inclusions.

## 1. INTRODUCTION

The metering nozzle is a crucial tool in the steelmaking process for managing the flow of molten steel and regulating the continuous casting pace. However, the metering nozzle's service life is much less than the tundish lining's, which is the entire tundish's bottleneck. In the current scenario, quick-change institutions must coordinate to meet the requirements for the tundish's service life. In low carbon steel casting, regular quality metering nozzles performance is very less i.e. 5-6 hours only & there after casting speed increase due to irregular erosion of zirconia insert, flow flickering, flow vibration and splattered of steel flow observed frequently. To boost up metering nozzles life, optimized the physical and chemical properties with reduction of total pore size diameter to obtain the best performance of metering nozzle.

## 2. EXPERIMENTAL METHOD

Starting raw materials used in this experiments Mg-PSZ partials & monoclinic zirconia powder, analysis given in table -1. Zirconia mix made with optimization of the mix granulometry for shaping with controlled pressure, fired in regular schedule. Then fired nozzles pass through visual inspection, dimensional inspection, physical and chemical properties.

Table – 1, The composition of Raw material (wt%)

| Elements     | ZrO <sub>2</sub> | Al <sub>2</sub> O <sub>3</sub> | MgO  | SiO <sub>2</sub> | Fe <sub>2</sub> O <sub>3</sub> | CaO  | TiO <sub>2</sub> | Na <sub>2</sub> O |
|--------------|------------------|--------------------------------|------|------------------|--------------------------------|------|------------------|-------------------|
| Zirconia Mix | 95.57            | 0.07                           | 3.89 | 0.12             | 0.16                           | 0.05 | 0.06             | 0.08              |

### 1. TEST RESULTS AND ANALYSIS

Characterization of test sample and regular Mg-PSZ zirconia nozzles i.e. apparent porosity, bulk density & main oxide content of two types of nozzles are shown in Table - 2

Table – 2, Characterization of fired Mg-PSZ zirconia nozzles

| Sl. No. | Type of test Nozzles | Bulk Density (gm/cc) | Open porosity (%) | Main Oxide content (%) |
|---------|----------------------|----------------------|-------------------|------------------------|
| 1       | Regular              | .. . .               | 13 – 16           | 93.27 ZrO <sub>2</sub> |
| 2       | Experimental         | 5.05 – 5.15          | 7 – 9             | 95.18 ZrO <sub>2</sub> |

The main observation in physical and chemical properties from the table – 2, Mg-PSZ experimental nozzles bulk density, open porosity and main oxide content is higher than the regular nozzles.

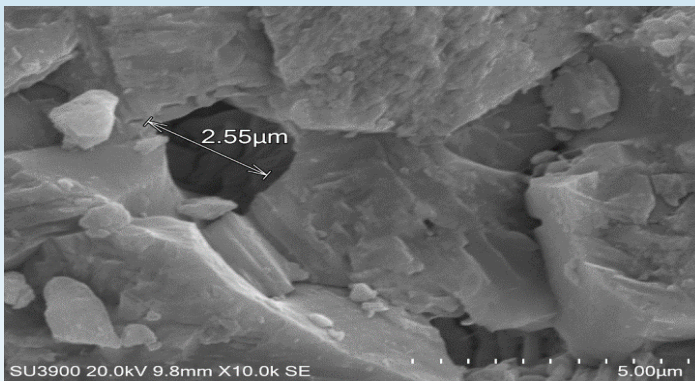
SEM analysis for microstructure characterization for pores diameter analysis of test samples (Regular & Experimental) shown in Figure no. 1, 2, 3 & 4, with X10.0K & X3.0k.

SEM images on zirconia insert surface (left for regular & Right for Developed)

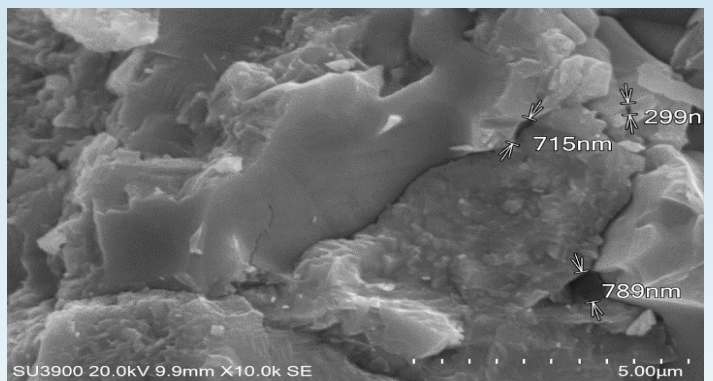


### Regular Sample

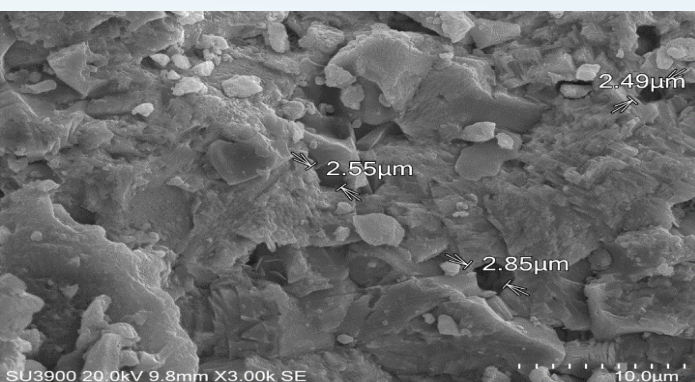
### Experimental Developed Sample



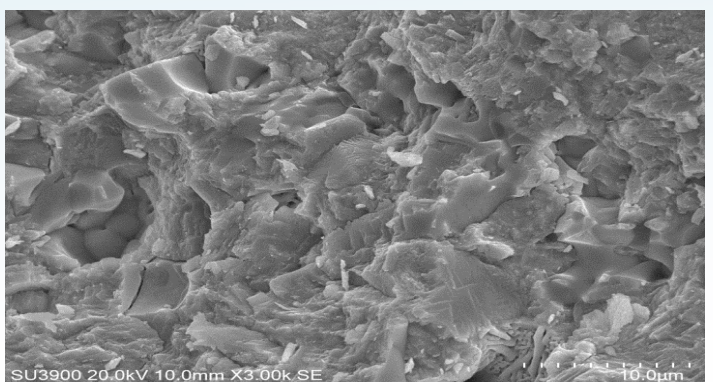
*Fig – 1 pore size avg. 2.5 μm with X10k*



*Fig – 2 pore size avg. 0.7 μm with X10k*



*Fig – 3 SEM image with X3k*

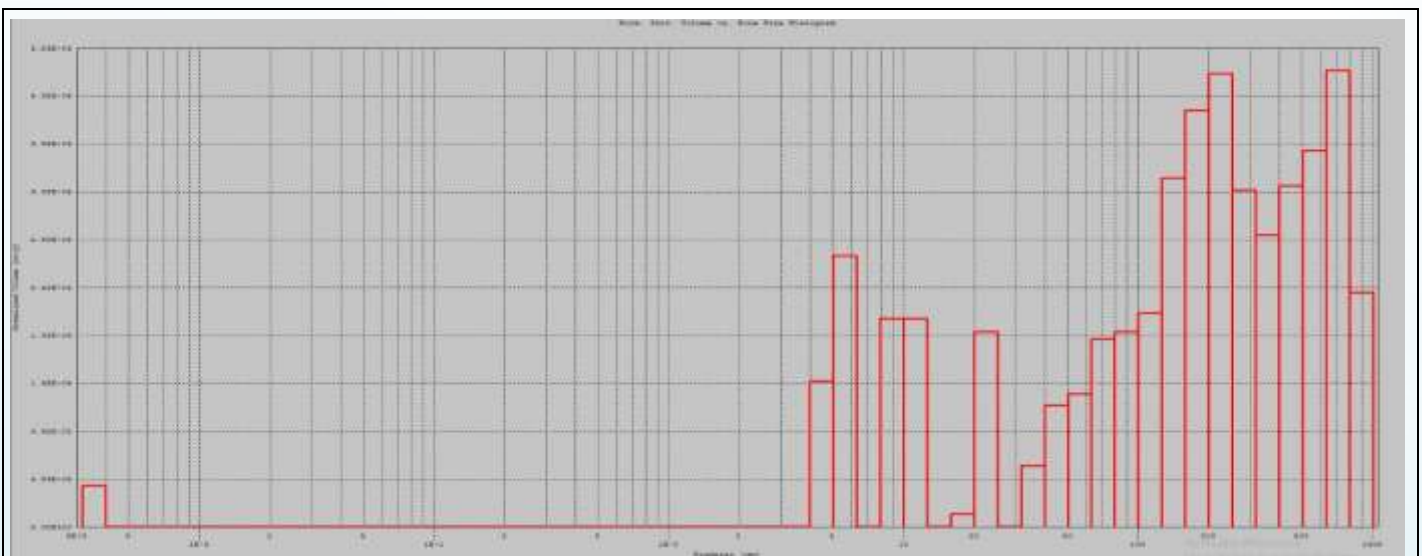


*Fig – 4 SEM image with X3k*

From the above SEM microstructure pore size characterization, study the pore size of developed experimental insert contains lower size pores i.e. average 0.7 μm. in regular sample it is avg. 2.5 μm.

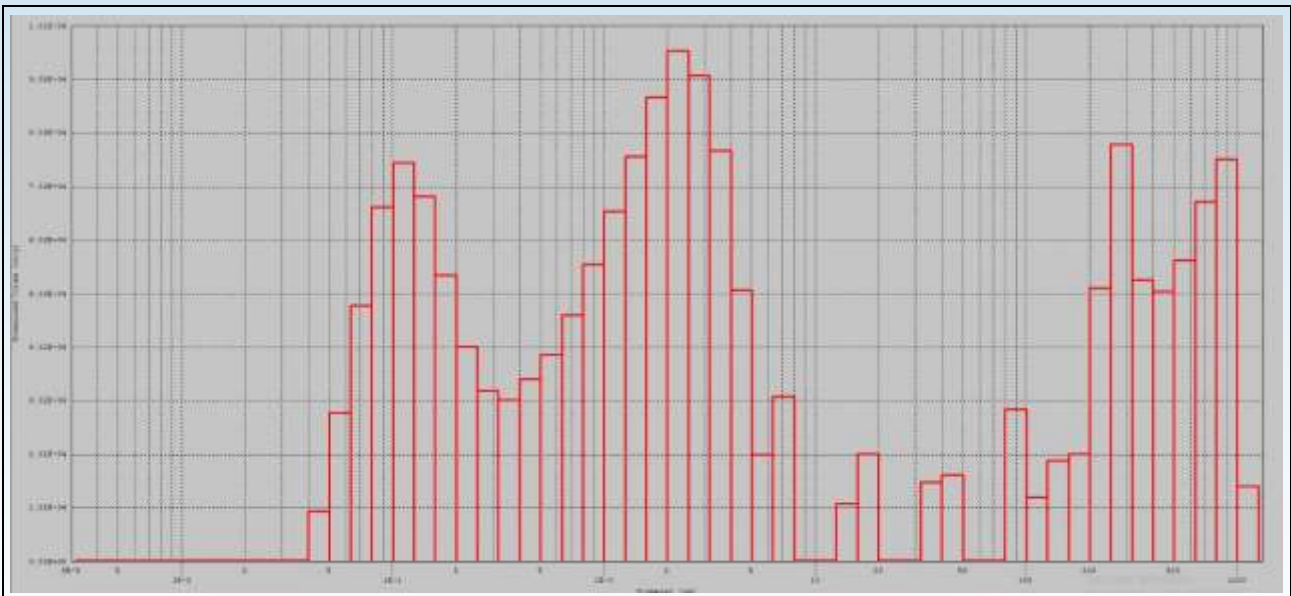
Total pore size distribution structure characterization with porosimeters for developed experimental and regular Mg-PSZ nozzles.

Regular zirconia nozzle pore size distribution graph shown in figure – 5 and developed experimental nozzle pore size distribution shown in figure – 6.



*Fig – 5 porosimeter graph image for regular zirconia insert*

From the above pore size distribution graph for regular zirconia nozzle, approx. 60% pore size lies on **1.5 – 6.5  $\mu\text{m}$** .



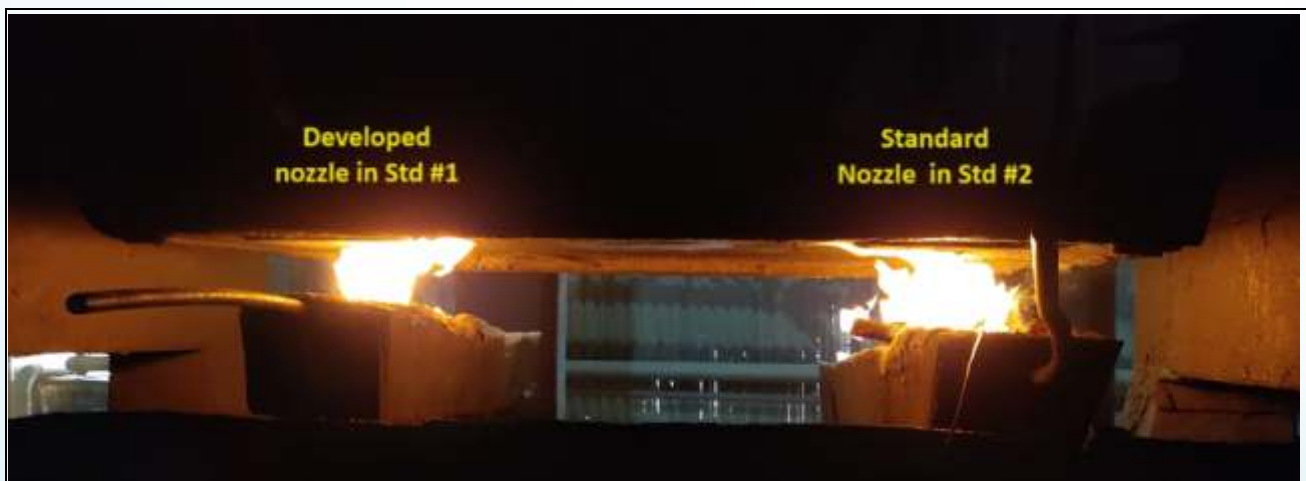
*Fig – 6 porosimeter graph image for Developed experimental zirconia insert*

From the above pore size distribution graph for regular zirconia nozzle, approx. 60% pore size lies on **0.5 – 0.9  $\mu\text{m}$** . The above study indicates that the pore diameter decreased in developed experimental Mg-PSZ nozzle in comparison with regular Mg-PSZ nozzle.

#### 1. FIELD TRIAL

A practical field trial was conducted to assess the performance of both developed and regular Mg-PSZ (Magnesia Partially Stabilized Zirconia) nozzles to observe the efficiency of zirconia metering nozzles during low carbon structural grade casting under the close observation condition.

In a double strand tundish fix developed nozzle in strand – 1 & regular nozzle in strand – 2. Before fixing, the nozzles pre-heated the nozzles around 110-150 degree Celsius in hot air oven. After fixing the nozzles in tundish arranging flame in launders and place the launders below the nozzles for continuous heating until the tundish placed in caster for casting operation. After fixing nozzles in tundish, nozzle pre-heating procedure shown in Figure – 7.



*Fig – 7 Pre-heating of Zirconia metering nozzle after fixing in tundish*



Practical field trial casting steel grade and steel chemistry shown in table – 3.

Table – 3, The composition of structural grade steel (%)

| Elements            | C     | Mn   | S    | Ni   | Al   | Fe    | Cr   |
|---------------------|-------|------|------|------|------|-------|------|
| Steel Grade - LCS22 | 0.086 | 0.45 | 0.03 | 0.03 | 0.01 | 99.14 | 0.06 |

#### Casting details:

Enlisted all parameters related to field trial during application / casting operation for developed and regular Mg-PSZ metering nozzle details data shown in the below table – 4.

Table – 4, Casting Parameters Data

| Casting Parameters Data |                     |                              |               |                     |                |                            |                        |
|-------------------------|---------------------|------------------------------|---------------|---------------------|----------------|----------------------------|------------------------|
| Casting Start @         |                     | 10:32AM                      | Lance Details | 1                   | Free open      | Total Running (HH:MM)      | 08.2 hours             |
| Heat No.                | Steel Temp in       | Ladle Operation Time Details |               | Casting Speed m/min |                | Nozzle Dia (mm)            | 15.0 mm                |
|                         |                     | Start                        | End           | STD #1              | STD #2         | Metal Level in Tundish (%) | Remarks                |
|                         |                     |                              |               | Developed Nozzle    | Regular Nozzle |                            |                        |
| 1st                     | 1598 <sup>0</sup> C | 10.32am                      | 11.14am       | 2.32                | 2.33           | 90                         |                        |
| 6th                     | 1626 <sup>0</sup> C | 2.58pm                       | 3.46pm        | 2.37                | 2.46           | Full                       | Speed Increase Std. #2 |
| 7th                     | 1639 <sup>0</sup> C | 3.49pm                       | 4.33pm        | 2.41                | 2.55           | Full                       |                        |
| 8th                     | 1589 <sup>0</sup> C | 4.37pm                       | 5.48pm        | 2.41                | 2.63           | Full                       | Flow fluttered Std. #2 |
| 9th                     | 1592 <sup>0</sup> C | 5.53pm                       | 6.34pm        | 2.46                | 2.68           | Full                       |                        |

Above table shown from 1<sup>st</sup> heat to 9<sup>th</sup> heat however, upto 5<sup>th</sup> heat the observations are normal.

Developed and regular nozzle flow after 7<sup>th</sup> heat image shown in figure 8 & 9. Strand 1 (fig. 8) developed nozzle smooth flow after 7<sup>th</sup> heat but in regular nozzle strand – 2 (fig. 9) flow after 7<sup>th</sup> heat is fluttered and casting speed increased. After Casting used nozzle investigation we found that, the developed zirconia nozzle inner bore have smooth surface where the regular zirconia nozzle have many groove scratches in inner bore surface.

| Developed Nozzle Flow                                                               | Regular Nozzle Flow                                                                  |
|-------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
|  |  |
| Fig – 8 Smooth flow after 7 <sup>th</sup> Heat                                      | Fig – 9 Fluttered flow after 7 <sup>th</sup> Heat                                    |

## 1. DISCUSSION

Penetration of  $\text{SiO}_2$ ,  $\text{FeO} \cdot \text{SiO}_2$  fluxes from the melted steel leads to the extraction of a part of  $\text{CaO}$  and  $\text{MgO}$  from the partially stabilised zirconia grains. From the above study, the developed Mg-PSZ zirconia insert with reduced pore size distribution performed better comparing to regular nozzles in low carbon structural grade steel. Flow of molten steel was laminar and flow flickering, flow fluttering, splattered flow had not observed during the field trial in developed nozzle.

## 2. CONCLUSION

Erosion of the zirconia nozzle are common problems encountered in low carbon steel casting. To enhance the performance it is required to decrease the pore size diameter, thereby reduces the reaction rate with molten metal. These could be possible by adjusting the granulometry, with suitable additives and forming pressure for high performance zirconia nozzles.

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# Safer steel casting Operation & Workplace by mitigating challenges through technical excellence

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## Abstract:

Steel Ladle is a refractory lined vessel, and its function is to transfer liquid steel for various operations of steel making. Sliding Nozzle (SN) mechanism is fixed at ladle bottom, it is a mechanical assembly having consumable refractory components like Upper Nozzle, Slide Plates and Lower nozzle. The function of SN mechanism is to control the discharge of liquid steel from ladle to tundish by reciprocation of slide plates with help of actuator. There can be several failure types and leakage routes through SN mechanism, all leading to catastrophic process safety incident. At a steel melting shop (SMS) multiple failures were experienced, like metal leakage between upper nozzle and upper slide plate, between slide plates and typical crack leading to puncture in lower nozzle of SN mechanism. For all these failures root cause analysis and troubleshooting was conducted which is covered in this paper. Between Upper Nozzle and Slide Plate (Upper Plate)- Failures were of severe intensity as in this the whole SN system was getting washed out and causing huge damage to property. Root cause of the same was identified as instability of ladle bottom structure which was creating gap between Upper Nozzle and Slide plate leading to leakage of liquid steel during continuous casting at caster. Between Slide Plates- This also occurred with multiple frequency, in this metal was trickled from SN gate during casting at caster. Root cause of same was identified as corrosion phenomena in refractory plates and some operational issues were also observed. Various countermeasures like changing slide plate quality and operational practice were taken and the problem was solved. Lower Nozzle- In recent years typical puncture/rat hole cases with multiple frequency observed in lower nozzle body. Most of the cases observed in higher life of lower nozzle and at the end of the casting at caster. In investigation some typical phenomena of crack and oxidation observed which was leading to the puncture/rat hole formation. To solve this problem multiple actions were taken like changing the quality of the lower nozzle and some operational practices. With mitigation of all failure patterns by establishing all countermeasure ideas, the shop is presently stable. After eliminating failures, the life of consumable refractory products is in increasing trend.

## INTRODUCTION

In steel making various processes are being carried out from primary steelmaking to final casting of steel shown in (Fig.1) and in this process liquid steel is carried in Steel ladle.

First ladle is sent for tapping to BOF (Basic Oxygen Furnace) where the processed liquid is poured into the ladle and then ladle is sent for secondary refining station and then casting shown in (Fig.2) where the casting is done by opening of SN mechanism which is mounted underneath of Steel ladle and actuated with the help of hydraulic cylinder. After operating the SN mechanism, the bore of the slide plates inside the mechanism gets matched and casting starts. In the whole process of steelmaking SN mechanism plays a very crucial role for casting of steel smoothly & safely.

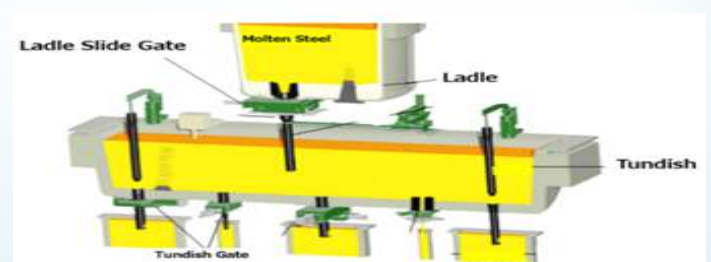
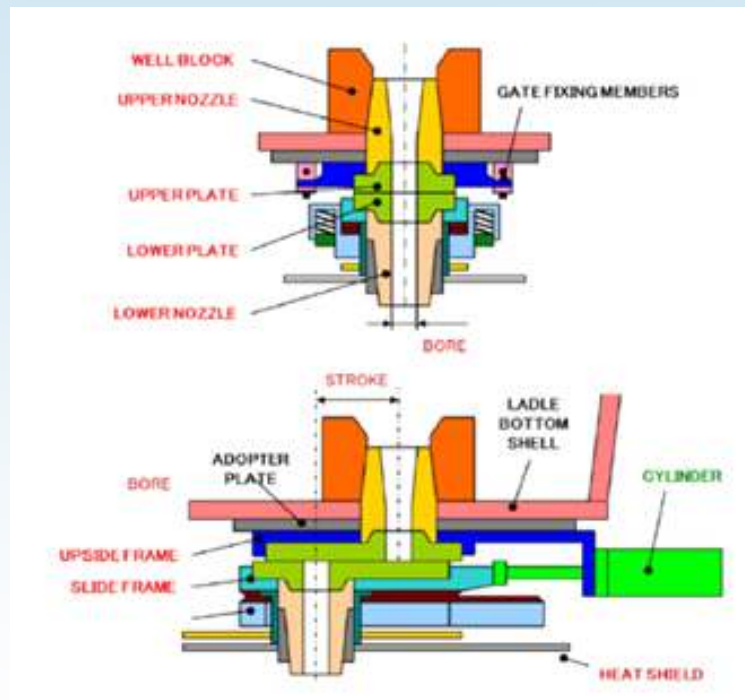


Fig. 1: Steel Making Process Fig.2: Casting Process



The schematic SN mechanism shown in (Fig.3) consists of various consumable refractories like Slide Plate (SP), Upper Nozzle (UN), Lower Nozzle (LN) and mortar which is changed after certain life based on shop operation.



*Fig 3: SN mechanism Schematic*

These refractories have multiple joints starting from well block to the lower nozzle which are filled with joints material. Any abnormality in the joint area or in the material or in the design could lead to a catastrophic failure and leakage of liquid steel which is a process safety hazard as shown in (Fig.4).

In a Steel making shop multiple instances of leakages were observed from major three zones, between Upper Nozzle and upper plate joint, between slide plates and from lower nozzle. All these cases were investigated, root causes were identified, and corrective measures were taken to eliminate the failures.



*Fig 4: SN mechanism Leakage*

#### BETWEEN UPPER NOZZLE AND UPPER PLATE

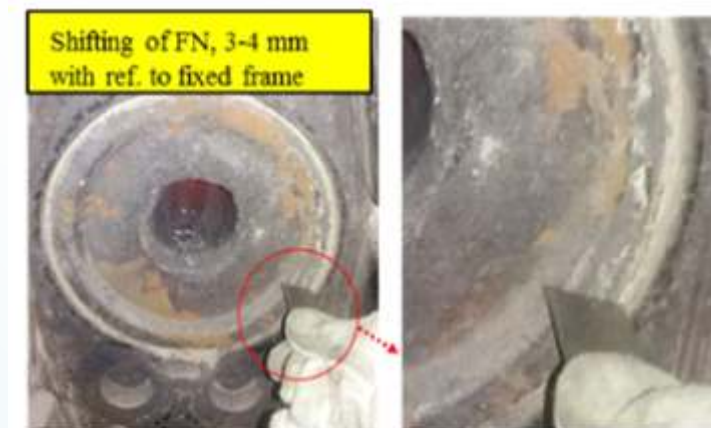
This was a very old problem persisting from more than 12 years (1-2 failures/year) and this problem was having high severity as the whole SN mechanism was getting washed out in this leakage as shown in (Fig.5).



*Fig 5: SN mechanism condition after Leakage between UN & UP*

#### Issue & Preliminary Findings

In almost all the cases of leakage just started after the start of the casting. After few minutes of casting metal starts to leak from the sides of mechanism eventually leading to mechanism wash out remaining with only upper nozzle intact in the system.



*Fig 6: Shifting of Upper Nozzle*

In investigation it was found that leakage route was between UN & UP. Also sometimes shifting of UN was observed, it was getting shifted towards well block as shown in (Fig 6). This was creating a gap creation between UN & UP leading to steel penetration from the gap.

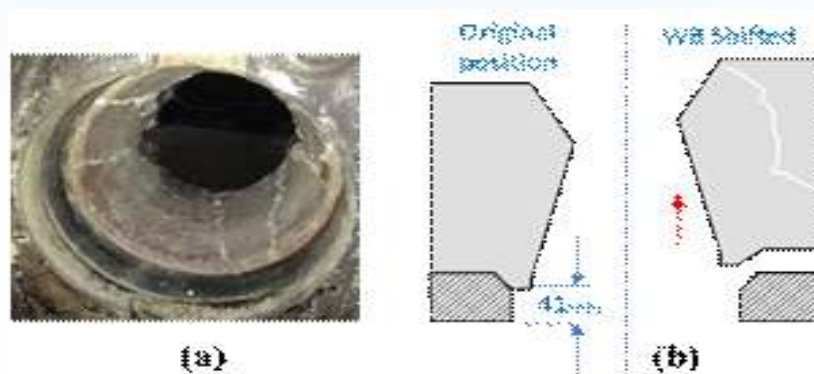
#### Root Cause Analysis-

Upper nozzle was getting shifted inwards which was causing gap between joint of UN & UP as shown in (Fig 7).

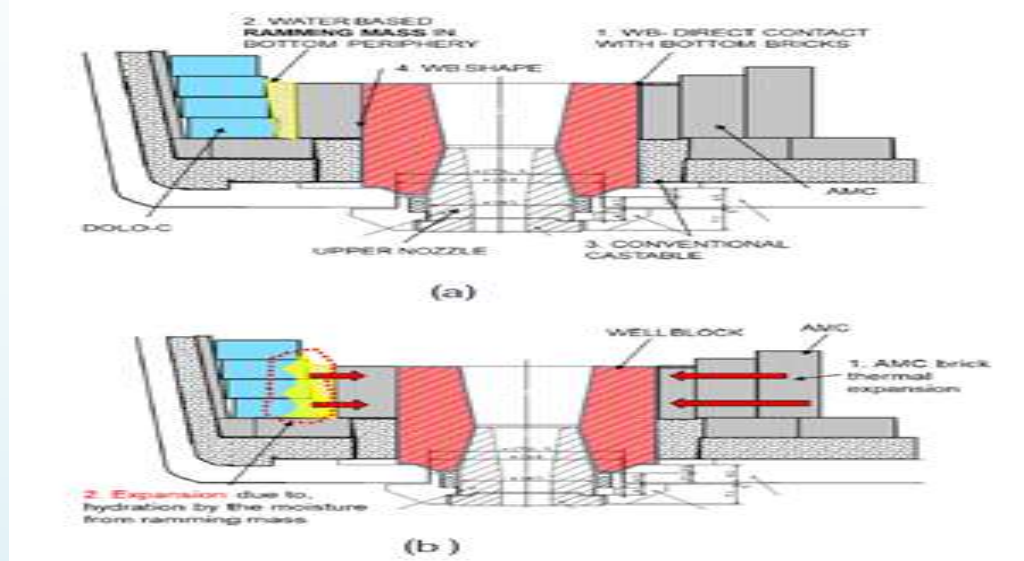


**Fig 7: Gap creation and leakage mechanism**

In all the shifting cases it was observed that after UN changing there're severe cracks in wellblock and sometimes even well block is shifted inwards along with UN as shown in (Fig 8).



After investigation of these shifting and cracking cases of WB it was found that there was instability in ladle bottom structure due to which abnormal stress was being developed in WB.



**Fig 9: (a) Ladle Bottom structure (b) Stress generation mechanism in WB**



There were multiple reason for abnormal stress in well block as mentioned below.

1. WB in direct contact with bottom bricks- during heating thermal expansion of bottom bricks (Alumina-Mag-C) generating cracks in WB
2. Water based ramming in ladle bottom periphery- causing hydration followed by expansion of bottom layers in metal zone (Dolomite) causing stress in WB.
3. Fixing well block with conventional castable (70% Alumina)- Weak clamping strength.
4. Shape of WB- Straight shape, easy to shift.

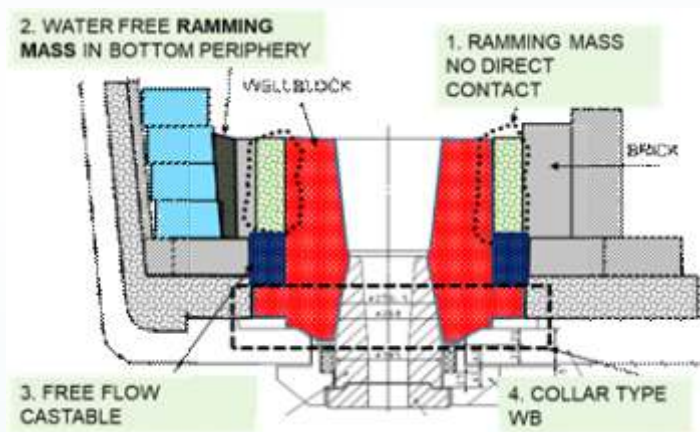
Ladle bottom structure and stress generationshown in (Fig 9).

### **Countermeasure**

As the root cause was identified as abnormal stress generation in WB causing crack and shifting of WB along with UN leading to gap creation and leakage. Various countermeasure actions were taken to minimize the stress generation in WB

1. Providig ramming mass between WB and bottom brick- to reduced the stress from expansion of bottom brick.
2. Replacing water based ramming mass by water free ramming mass- to avoid hydration of DOLO-C bricks.
3. Fixing of WB with high strength castable- to provide better clamping strength to WB.
4. Changing WB design to Collar type- for better clamping.

Modified ladle bottom& WB fixing structure explained in (Fig 10).



***Fig 10: Modified ladle bottom & WB fixing arrangement***



***Fig 11: Leakage from SN mechanism***

After implementing all these countermeasures problem of WB shifting and cracking has reduced drastically and the leakage cases from this joint is '0' now.

### **BETWEEN SLIDE PLATES**

Multiple metal trickling and few leakage cases has been witnessed between the plates.

In this failure metal gets trickled from the sides of the mechanism causing uncontrolled flow of liquid steel from ladle and unplanned caster stoppage as shown in (Fig 11).

### **Issue & Preliminary Findings**

In the slide plate sometimes high erosion/corrosion and metal fin formation was observed as shown in (Fig 12).



*Fig 12: Slide plate stroke path damaged and metal fin observed*

This metal fin was later getting chilled and during sliding of plates at the caster to control the flow of liquid steel, it was creating a gap between the plates. Because of the gap formed between plates, liquid steel gets trickled and sometimes leakage.

#### **Root Cause Analysis**

A corrosion phenomenon was occurring in the slide plate which was causing metal fin formation in the plate. To understand the corrosion mechanism in the slide plate, a detailed investigation was conducted. Analysis of used plates was done to identify the cause of damage. In the analysis, various testings like physical, chemical, and microstructure analyses were conducted. For study, one less damaged plate and one substantially high damaged plate were analysed.

After conducting various tests, no such abnormality was found in physical properties. Micro-structure of reaction layer & chemical analysis by EPMA (Electron probe micro analyzer) were also conducted. Difference between substantial damage and less damaged plates was in chemical composition of reaction layer as shown in (Fig 13).

Source of components in reaction layer of substantially damaged plates were from molten steel (Mn, Si & Ca) and plate material ( $\text{SiO}_2$ ) as well.

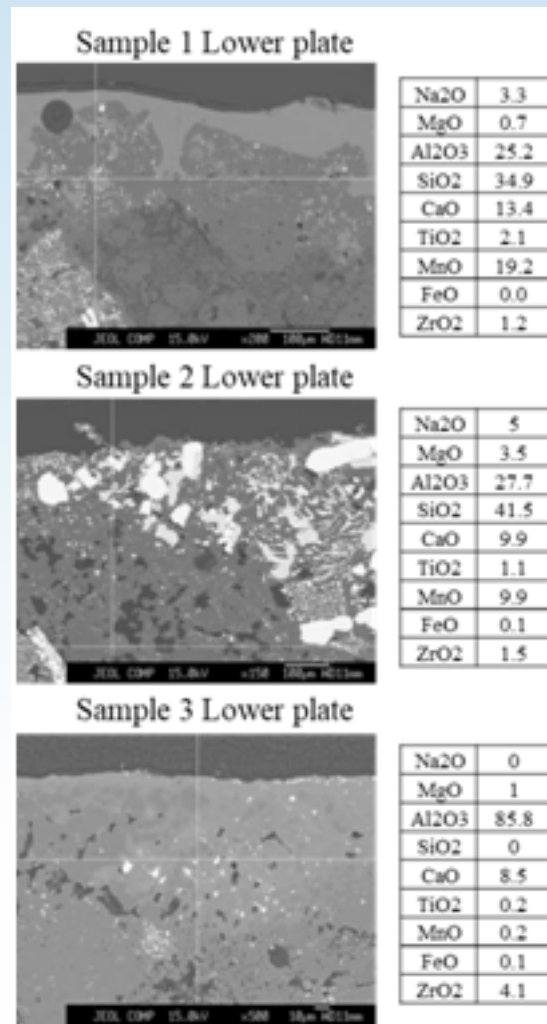
This reaction was causing damage to the stroke path and sticking of metal fin in the plate. This sometimes causes multiple metal fin layers which can lead to gap creation between plates.

#### **Countermeasure**

To minimize damage to the stroke path and metal fin formation, the quality of the plate was to be modified in such a way that the extent of reaction layer between plate refractory & molten steel is minimized.

Modification in plate refractory was done taking into account that no big difference in physical properties of the plate such as AP & BD is allowed. In case of a huge difference in AP & BD levels, more negative branches related to strength, abrasion resistance will be associated. In EPMA analysis of reaction layer, major components were  $\text{Al}_2\text{O}_3$ - $\text{SiO}_2$ - $\text{CaO}$ - $\text{MnO}$ . With an aim to eliminate or minimize reaction





*Fig 13: Checmical analysis of samples*

layer formation, SiO<sub>2</sub> content in plate was reduced to some extent and a new quality was tried.

As SiO<sub>2</sub> from plate refractory was reduced so there was risk of spalling. Based on various trials in different phases, trial plate showed better corrosion resistance and almost zero case of severe metal fin.

Even after reducing SiO<sub>2</sub> content in plates no such severe cracks due to spalling were observed. Overall performance of trial plate was better & consistent in all 3 phases as shown in (Table 1).

**Table 1: Slide Plate Performance Comparison**

|                                         | <b>Existing</b> | <b>Trial</b> |
|-----------------------------------------|-----------------|--------------|
| <b>Corrosion resistance</b>             | <b>**</b>       | <b>***</b>   |
| <b>Metal Fin formation resistance</b>   | <b>*</b>        | <b>***</b>   |
| <b>Crack generation resistance</b>      | <b>**</b>       | <b>**</b>    |
| <b>Abrasion resistance</b>              | <b>***</b>      | <b>**</b>    |
| <b>Edge damage resistance</b>           | <b>***</b>      | <b>***</b>   |
| <b>Bore erosion resistance</b>          | <b>***</b>      | <b>***</b>   |
| <b>***. Good, **. Moderate, *. Poor</b> |                 |              |

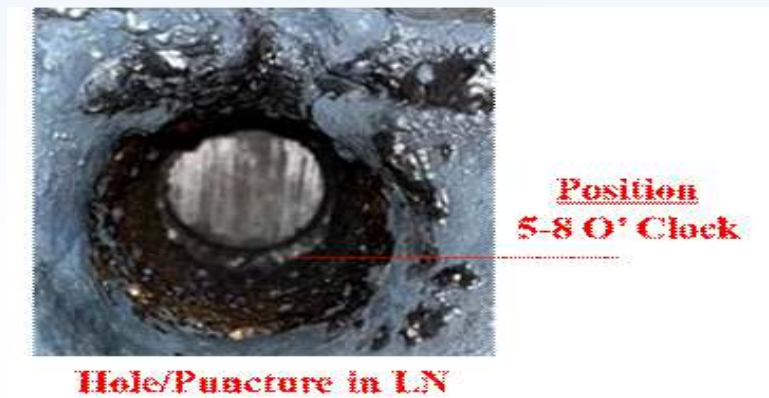
As trial plate performed consistently better so life improvement was planned with this quality. With trial quality plate condition & life improvement was also visible.

#### LOWER NOZZLE PUNCTURE (RAT HOLE)

Recently in the same shop multiple instances of lower nozzle puncture happened as shown in (Table 2).

**Table 2: Lower Nozzle puncture cases**

| # | Date                    | Ladle | LN Life | Issue       | Caster |
|---|-------------------------|-------|---------|-------------|--------|
| 1 | 10 <sup>th</sup> Feb'23 | 7     | 3       | LN Puncture | 3      |
| 2 | 11 <sup>th</sup> Feb'23 | 3     | 3       | LN Puncture | 3      |
| 3 | 20 <sup>th</sup> Sep'23 | 1     | 3       | LN Puncture | 3      |
| 4 | 4 <sup>th</sup> Oct'23  | 17    | 2       | LN Puncture | 1      |



**Fig 14: Orientation of puncture in lower nozzle**

The puncture in the lower nozzle was observed at caster during casting mostly after casting of more than 50% volume of ladle. Puncture location of all the cases were similar between 5-8 O'clock as shown in (Fig 14).

Punctures were happening mostly at casting end time due to high negative pressure; negative pressure increases with decrease in steel bath. Puncture position is in the direct hitting position of liquid steel stream as gate is in throttled (Not 100% opened) condition. Post incident lower nozzle refractory condition were checked some oxidation in outer refractory body along with vertical cracks were observed. The axis of puncture was in the line of vertical crack and also oxidation inside the cracks were observed as shown in (Fig 15).



**Fig 15: Punctured lower nozzle condition crack & oxidation**

### Root Cause Analysis

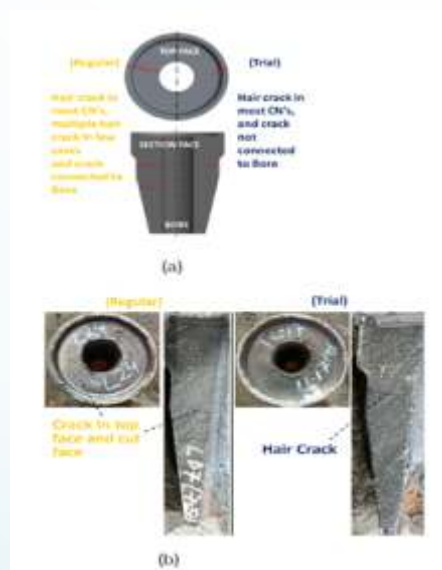
Multiple puncture cases in lower nozzle refractory observed most of the cases occurred in 3<sup>rd</sup> life of lower nozzle and at the casting end time. Position and orientation of puncture was similar in most of the cases. As this happened in different lots of lower nozzles so it was not related to specific lot issue it was a typical phenomenon. Spalling cracks were observed in the nozzle and later due to negative pressure during casting air suction was happening which was leading to puncture of lower nozzle, chronology of failure explained in (Fig 16).

### Countermeasure

Response against hammering was improved, quality of checking at supplier end was also improved but still spalling cracks were visible in the nozzles. Aim was to improve the spalling properties of lower nozzle so new material was designed in which Alumina content was reduced and silica was increased. Later, trial were conducted in different phases.



**Fig 16: Chronology of lower nozzle puncture**



**Fig 17: (a) Schematic of crack generation trial vs regular lower nozzle (b) Actual crack condition trial vs regular lower nozzle**

Trial was conducted and compared with the existing quality lower nozzle in terms of oxidation, crack generation, erosion etc. In the trial no difference in terms of erosion was observed but crack condition was improved in trial lower nozzle. Very small spalling cracks were being generated but it was not getting connected to the hot phase of lower nozzle where the liquid steel passes as shown in (Fig 17). Crack propagation condition was better in trial LN and no such puncture or hole formation observed during the usage. So it was decided to convert the existing quality with trial quality.

## CONCLUSION

SN mechanism plays a very crucial role in steel casting, any small deviation can lead to hazardous event such as leakage of liquid steel, property damage and loss of production. In a steel making shop multiple leakages from different locations of SN mechanism were observed. Some of the problems were peculiar and persisting from long back and few were recently observed. This paper shows the journey of solving the problems by doing various technical improvements related to material, design, operation and application.

Beginning from the leakage between UN & UP in this case there was no such issues related to SN mechanism design or material. It was completely linked with the stability of ladle bottom, due to unstable ladle bottom stress were being generated in the well block leading to crack and shifting of well block resulting leakage between UN & UP. After taking various actions to stabilize ladle bottom now leakage case between UN & UP is '0'.

In slide plate some leakage and trickling cases were observed, corrosion in slide plate was observed which was causing damage and metal fin formation in plate slide surface. Due to which gap between the plates were created and trickling and leakage happened. After analyzing the corrosion phenomena new quality was tried which showed better corrosion resistance and almost no such fin formation. Plate quality was changed to improved quality.

Recently few lower nozzle puncture cases observed in the shop mostly in higher life of LN. A typical phenomena of puncture/rat hole observed in these cases. Crack and oxidation of lower nozzle refractory leading to puncture at the end of casting time. To encounter that hammering practice was improved in the shop but still some cracks were observed. Later a new material with improved spalling resistance was developed and tried which showed better cracking behavior. Cracks from outer side of lower nozzle body was not getting connected to the bore of LN from where the liquid steel passes, minimizes the chances of liquid steel. Now conversion to improved quality is in progress.

With all the studies and technical improvements nos. of failure in the shop has been reduced.

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# Improvement of Steel Ladle life through addition of Synthetic Slag

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## Abstract

Magnesia-Carbon (MgO-C) refractories are widely used in ladle refining because of their favorable properties such as; low wetting by corrosive steel making slags, chemical compatibility with basic slags and better thermal properties. Ladle slag is an internal by-product generated within the steelmaking industry during the refining of steel. Ladle carrying liquid steel with some amount of slag, these two are the main causes for the deterioration of MgO-C refractories. Killing agent does impart an influential role for the life of refractories. This paper provides a comprehensive review of recent advancement and progress focused on the utilization of synthetic slag in prolonging the lifespan of steel ladles. In ISP, generally we deal with the silicate slag in the secondary process. We have investigated the effects of synthetic slag usage, on the ladle refractories life keeping other operating and refractories parameters intact. The results showed that; by addition of a suitable amount of a synthetic slag during a proper slag making process, a ~5-10% increase in the lining life would be available. This matter is described by meeting the conditions of an ideal slag including its chemistry, oxygen potential, melting point and viscosity that commonly are known as the most effective factors for determination of driving force to dissolve the refractory lining.

Keywords: Magnesia-Carbon, steel ladle, synthetic slag, lining life

## INTRODUCTION

IISCO Steel Plant is situated in the district of Paschim Bardhaman in the state of West Bengal, is having an annual crude steel capacity of 2.5 MTPA. The plant produces its crude steel through BF-HMDS-BOF-LF/RH-Caster route. The process flow sheet of steel melting shop is, the hot metal transported from Blast Furnace through Torpedo Ladle poured into open top hot metal ladle, which is then carried through EOT and being charged into BOF. The hot metal then processed into the BOF (03 nos) through oxygen injection and converted into liquid steel. The converted liquid steel ultimately captured into steel teeming ladle and further processed into ladle furnace (02 nos) and/or RH-Degasser to feed into caster (01 nos bloom-blank and 02 nos billet). As the health of steel ladle is vital for any kind of steel melt shop, so refractory personnel always pays a heavy amount of attention for the health/life improvement of the ladle.

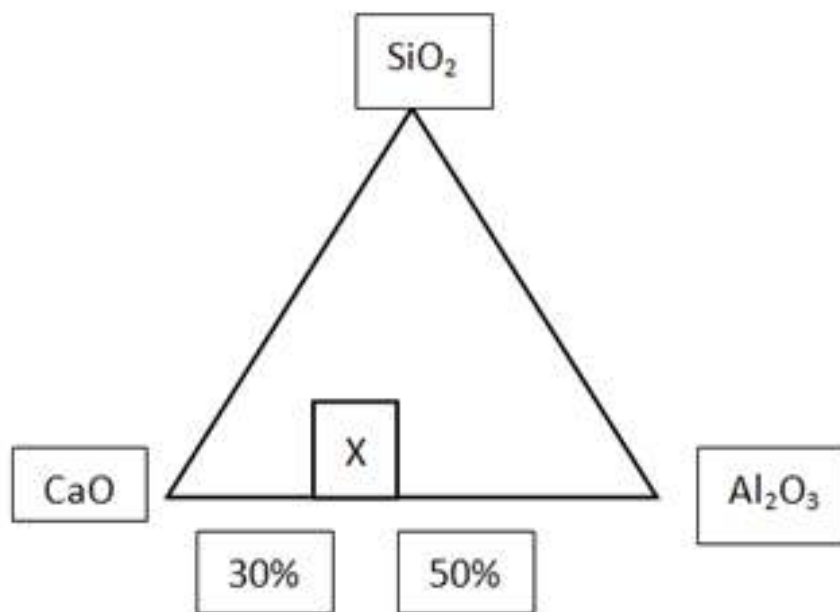
MgO-C refractories have been widely used by steelmakers for lining secondary ladle slag zones, because of their favorable properties such as low wetting by corrosive steelmaking slags, chemical compatibility with basic slags and better thermal properties.

The overall wear of a MgO-C lining depends on chemical and physical considerations. The chemical potential between the MgO-C refractories and the steelmaking slag determines the driving force to dissolve the refractory lining. The conditions of the slag include its chemistry, liquidus temperature, oxygen potential, wetting characteristics between the slag and refractory and degree of saturation of magnesia and calcia. The slag can be conditioned to decrease the potential for periclase dissolution by saturating it with magnesia and calcia. The use of large-flake graphite is a common method to achieve the low wetting characteristics. In the present study, we have chosen to highlight some effects of using calcium aluminates (as synthetic slag) on slag properties, which mostly affect the ladle refractory (slag zone) life. The properties of slag stated above include; its chemistry, oxygen potential and liquidus.

Calcium aluminates have unique characteristics derived from the binary phase diagram  $\text{CaO} - \text{Al}_2\text{O}_3$ . They are located in the low melting point region, consist mainly of  $12\text{CaO} - 7\text{Al}_2\text{O}_3$  and are mechanically and chemically stable. With melting point below  $1400^\circ\text{C}$  and as opposed to mechanical mixtures of lime and alumina or sintered materials made from these, they melt instantaneously at liquid steel temperatures, requiring much less time to form a reactive, liquid and protective slag in the steel. Table I shows the general characteristics of typical calcium aluminates.

Table I General characteristics of typical calcium aluminates

| Mineralogical Composition                                              | Chemical Composition  |                         |                          |                  | Physical Properties                                                                                                |
|------------------------------------------------------------------------|-----------------------|-------------------------|--------------------------|------------------|--------------------------------------------------------------------------------------------------------------------|
|                                                                        | Main Constituents (%) |                         | Minor Constituents (%)   |                  |                                                                                                                    |
| Principal Mineralogical Phase: $12\text{CaO} - 7\text{Al}_2\text{O}_3$ | CaO                   | $\text{Al}_2\text{O}_3$ | MgO+<br>SiO <sub>2</sub> | TiO <sub>2</sub> |                                                                                                                    |
|                                                                        | 40%<br>min            | 30%<br>min              | 7% max                   | 4% max           | <div>Working Point:1350°C</div> <div>Bulk Density: 3.1</div> <div>Specific Gravity:<br/>3.0gm/Cm<sup>3</sup></div> |



The region, X, contains the slag with the minimal wear on most ladle refractories. This is when a synthetic slag addition can be used to modify the process slag into beneficial region 'X'. Synthetic slag can be engineered with the proper  $\text{CaO} - \text{Al}_2\text{O}_3 - \text{SiO}_2$  balance, taking into account the oxidation products of aluminum killed (AK) steel making process to achieve final ladle slags that have low viscosities, lower melting points than the steel making temperatures and minimal refractory wear. Si killed steel making slags are characterized by the  $\text{CaO} - \text{MgO} - \text{SiO}_2$  system. The lowest melting point in this system is when the  $\text{CaO} - \text{MgO} - \text{SiO}_2$  ratios are approximately 2:1:2. However from a steel making prospective, this region is very corrosive to refractories. To solve these problems, most shops add enough lime or dolomite lime to make the slag more basic and less corrosive. The penalty is the possible addition of fluidizer to lower slag viscosity and increase energy consumption that also means more arc damages to the refractory.

Since there is little  $\text{Al}_2\text{O}_3$  available in Si killed steels, synthetic slags are used to achieve a beneficial  $\text{CaO} - \text{Al}_2\text{O}_3 - \text{SiO}_2$  composition in the ladle slag and an aluminum-killed practice is developed. In general, corrosion rate increases with increasing ferrous and manganous oxide. On the other hand the higher oxygen potential the higher corrosion rate we have. The use of calcium aluminates allows attaining complete fusion of all materials added during tapping when arriving at the ladle furnace, obtaining a very reactive and totally melted slag at the beginning of the refining process. This facilitates reduction of the harmful oxides ( $\text{FeO}$  and  $\text{MnO}$ ).

## EXPERIMENTS

The ladle lives for the past years were in the range of 60 to 70 heats per ladle. To come out from the stagnant life, we have decided to do some brainstorming session and finally we agreed to do experiments with addition of 200 kg synthetic slag in each and every ladle during tapping from BOF into the ladle irrespective of the killing practice and circulate every ladle more no of times in a day. And at the end we will compare the ladle life data without addition and with addition.

## RESULTS AND DISCUSSION

The period chosen for this experiment was Nov to Feb 2022-23 Vs same period of 2023-24. Supplier wise and month wise data were collected for ladle life, amount of synthetic slag added, quality of slag like % of CaO, SiO<sub>2</sub>, MgO, FeO, MnO, V-ratio and no of times any ladle circulated in a day. Fig-1 shows the ladle life for the month of Nov to Feb 2022-23 and for the same set of months of 2023-24.

A general equation useful to describe a dissolution process is, eq 1, where  $j$  is the rate of dissolution per unit area at a given temperature  $T$ ;  $K$  is the surface reaction rate constant;  $\delta$  is the thickness of the boundary layer in the liquid phase;  $C_{sat}$  is the concentration of the dissolving solid, in the liquid, at the interface;  $C_a$  is the concentration of the dissolving phase in the bulk of the liquid; and  $D$  is the effective diffusion coefficient in the solution for the exchange of solute and solvent.

$$j = \{K (1+k\delta/D)^{-1}(C_s-C_a)\} \quad \text{----- 1}$$

When,  $K < D/\delta$ — that is, when the dissolution rate is phase boundary controlled as opposed to mass trans-port controlled. Eq- 1 reduces to:

$$j=K (C_{sat}-C_a)$$

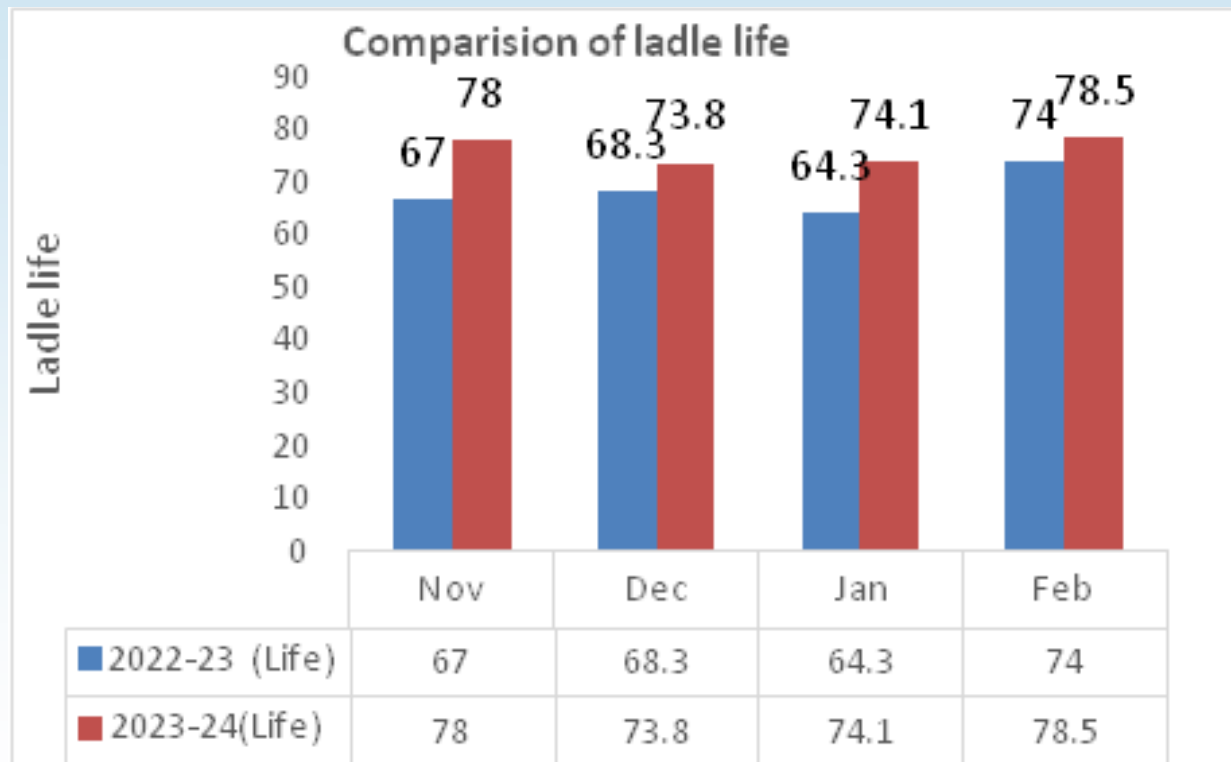
Table-2 clearly indicates that with the addition of synthetic slag and more no of heating cycle of the ladle, the requirement of dual saturation for the two basic oxides comes down and so does the  $j$  value. The chemical potential of ferrous and manganous oxides were also reduced, as it is engulfed in the CaO-Al<sub>2</sub>O<sub>3</sub>-SiO<sub>2</sub> low melting creamy matrix, as evidenced from the life of the ladle or sacrificial lining pattern on the ladle. We have also observed the behavior of the arcing pattern, arcing time and consumption of the power to dissolve the fluxes and oxides into the slag bath. Interestingly, all of these were in the favorable condition with addition of synthetic slag and more no of heat cycle of the ladle. For the same period the V-ratio, B2, B3 and B4 were also monitored and the values were slightly in the favorable direction.

**Table2: Comparative slag analysis with and without synthetic slag**

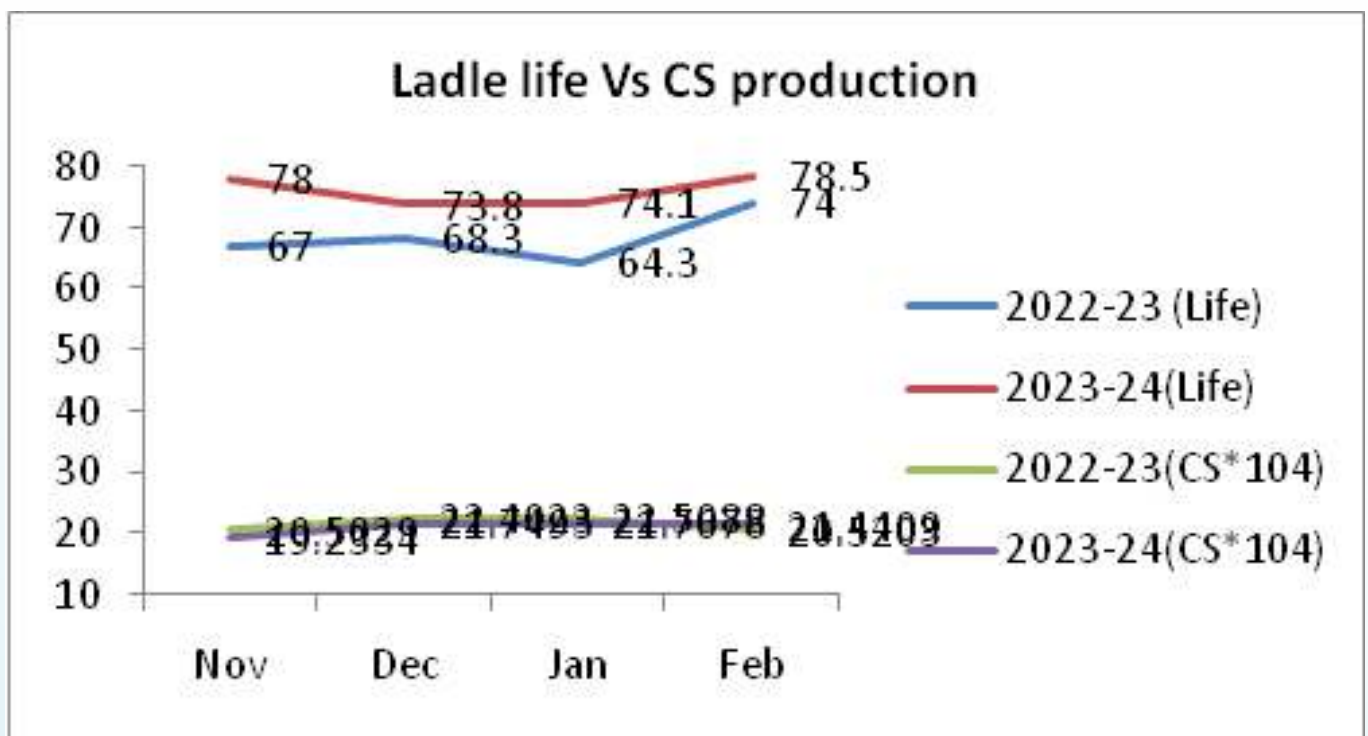
|                 | CaO   | SiO <sub>2</sub> | MgO    | FeO   | MnO   | V ratio |
|-----------------|-------|------------------|--------|-------|-------|---------|
| Nov-Feb 2022-23 | 46.29 | 27.14            | 10.065 | 1.725 | 2.065 | 1.735   |
| Nov-Feb 2023-24 | 49.11 | 30.27            | 9.22   | 1.095 | 1.055 | 1.745   |

As the depletion of MgO-C refractories is governed by the rate determining step i.e. dissolution rate and from the above discussion it is clear that the value of  $j$  decreases with the addition of synthetic slag as the saturation value comes down with addition. This theory is supported by the Fig-1: Improvement of ladle life in relation to synthetic slag.

**Fig1: Improvement of ladle life in relation to synthetic slag**



**Fig2: Correlation of ladle life with Crude steel production with and without synthetic slag**

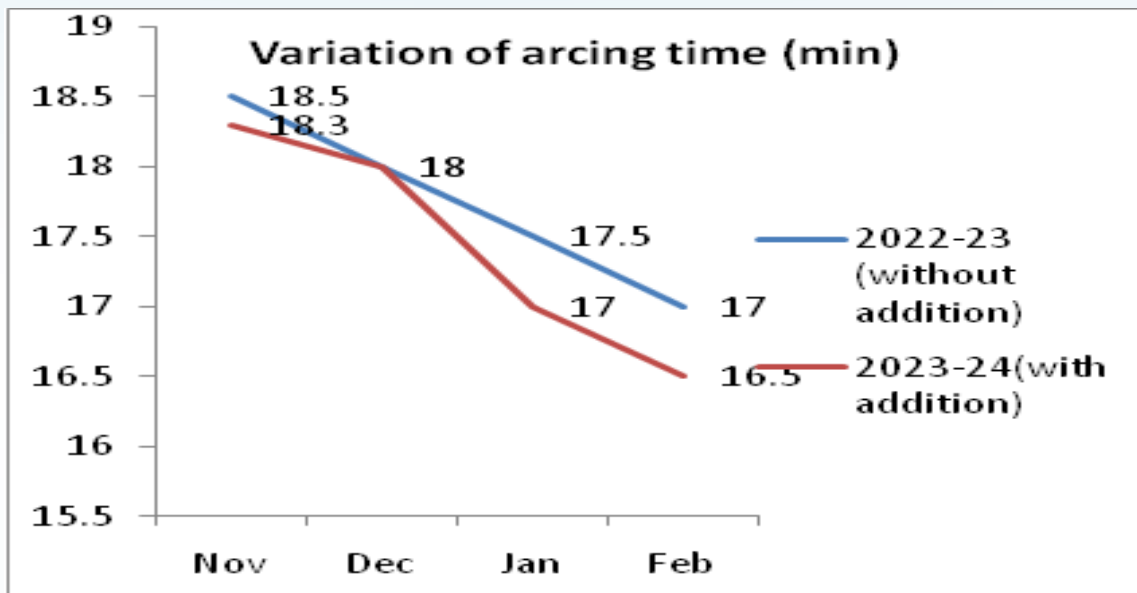




The above table-2 shows the quality of the slag formed at different times of LF process during the same period. The higher amounts of FeO and MnO, in without addition of synthetic slag, shows the higher oxygen potential of such slags in comparison to the ones with addition of synthetic slag. One of the present problems with MgO-C bricks is oxidation of carbon under high oxygen potentials (in slag) and high process temperatures. This is the same condition of our melts in group without synthetic slag addition compared to those in group with synthetic slag addition. This could be for the reason of that, in the melts group without addition, we had a solid and crusty slag at the beginning of LF operation that started to become fluid in some parts just after some arcing and argon blowing that indicated, lack of having a suitable condition for an efficient reduction of harmful oxides. The reverse condition existed for the melts with addition.

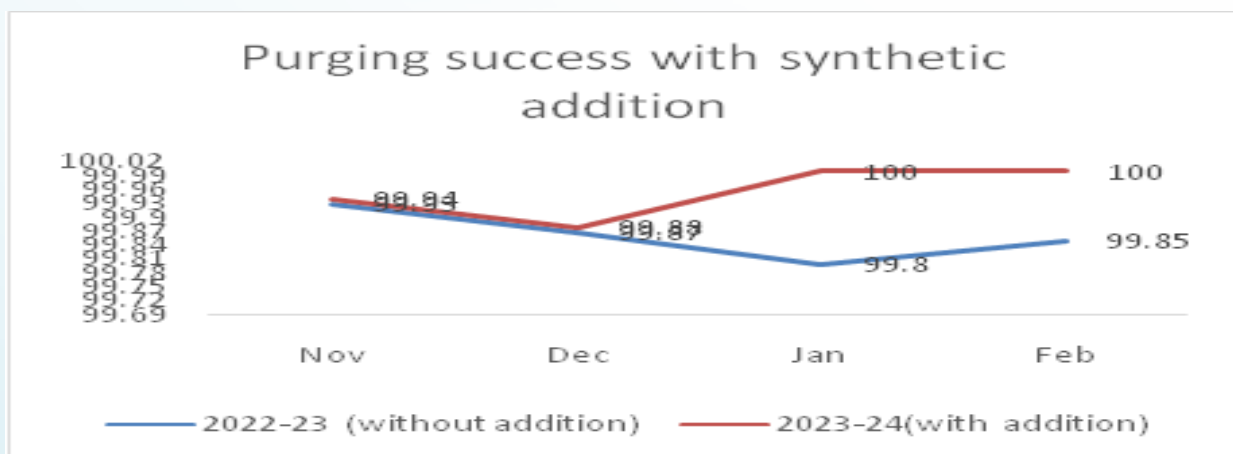
We have also studied the average arcing time and power consumption at the LF station at different times of the experimental period. Illustrative figures are put forward, and the figure/graph establishes the fact of favorable slag formation with the corresponding addition, as the power consumption and average arcing time gets reduced at LF stations.

**Fig 3: Variation of arcing time in relation to synthetic slag addition**



We have also observed the purging behaviour of ladle gone through secondary route with and without synthetic slag addition. The data were collected and plotted graphically (Fig 4) and we observed that with the addition of synthetic slag as the slag composition comes in the favourable region of CaO- Al<sub>2</sub>O<sub>3</sub> - SiO<sub>2</sub> system, the slag eye formed early which ultimately responsible to open purging at LF station initially.

**Fig 4: Variation of purging rate in relation to synthetic slag addition**



Physical observations were also carried out to see the effect of synthetic slag addition. The beneficial effects of synthetic slag were being evidenced from physical observations too. Compared to the surface coating (without addition) in the first two pictures, the last two evidenced better surface coating with addition.



Fig-4 Condition of the ladles without addition of synthetic slag

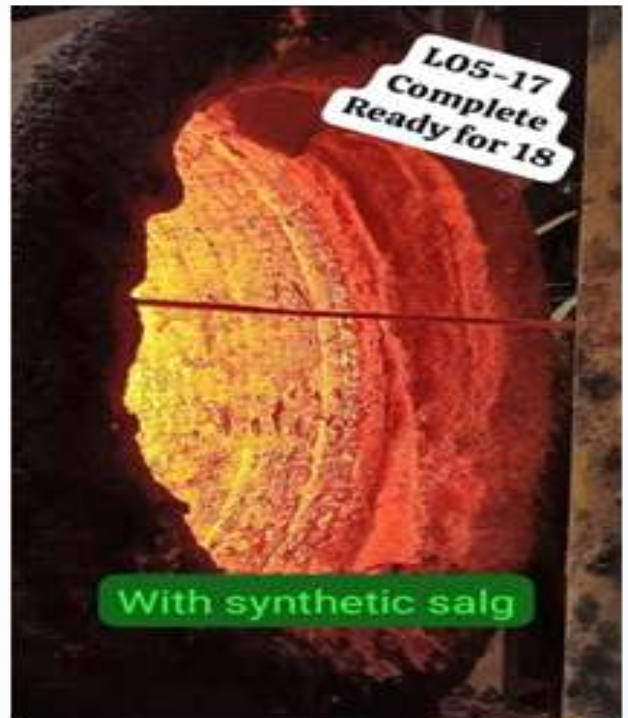


Fig-5 Condition of the ladles with addition of synthetic slag

- 1) By using calcium aluminates(as synthetic slag) we obtained creamy slags as per technical requirements, which did not need excess power input to become fluidized. This could reduce the wear of refractory compared to those we did not added any.
- 2) By using a calcium aluminates we have eliminated the consumption of any harmful fluidizer that avoids refractory attack.
- 3) Calcium aluminates produce slags, which their harmful oxides (FeO, MnO) can be completely reduced. This means the minimum oxygen potential would be available and consequently oxidation of carbon in MgO-C refractories would be reduced.
- 4) By understanding melt dynamics and engineering calcium aluminates to shift ladle slags into the beneficial region of the  $\text{CaO} - \text{Al}_2\text{O}_3 - \text{SiO}_2$  systems, ISP succeed to increase the refractory life.

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## **Prospect of Manufacturing Synthetic Raw Materials in the concept of Atma Nirbhar Bharat**

*Tapas Pattanaik, Kosmokrafit Refractory India Pvt Ltd.*

Refractories are the backbone of various manufacturing industries processing with high temperature equipments (500 to 2000 °C) like metal, cement, glass, ceramic, pottery, enamel, petroleum, power, incinerator, paper etc. Out of these metal industries may be focused as metals extracted, melted and formed with various types of furnaces, ovens, kilns lined with Refractories used above 1000 °C with stringent conditions. Iron & steel, aluminum, copper, zinc, lead etc. comes under this category. However, iron and steel is most specific industry that alone consume about 70% of Refractories in the market. Hence we may focus our topic on Refractories for steel making. Moreover the market for Indian refractory Industry is expected to grow in the tune of Rs. 9000 crore.

In steel making, use of Refractories may be broadly divided in two parts; one is conventional Refractories like Silica, Fireclay, Magnesite, Dolomite etc. and the other types are special Refractories like MgO-C, basic gunning mass, high Alumina Carbon, high Alumina castable, carbon for blast furnace hearth lining, Silicon Carbide, Mullite, MgO-Al Spinel, Zircon etc. Conventional Refractories in use are very common, for its mines of raw materials as well as its tailor made products are available in India. Silica, Fireclay, high Alumina (up to 60-65% Al<sub>2</sub>O<sub>3</sub>), Chrome Mag., Mag Chrome, Magnesite etc. Refractories are also made by many units spread all over India. So, when we think of any refractory supply crisis in the market conventional Refractories do not play on the way. Both raw materials and refractory manufacture units are plenty in our country.

But now day's Steel Plants are facing the crisis for some specific type of refractories without which special steel cannot be produced. Steel plants adopt modern technique to fulfill its market demands that require specific type of refractory. For example stringent refining process of steel where argon purging with or without arcing in ladle furnace or RH Degassing is required to make very low carbon and hydrogen free steel. In continuous casting system various flow control refractory devices like slide gate, tundish, shroud, sub entry nozzle are required. Here mostly black Refractories and high alumina castable fulfill the need. Apart from this in integrated steel plant from Coke Oven to Mill zone, a lot of improved technology have been adopted which require specific type of Refractories. Door bricks of coke oven are being replaced by high Alumina castable. In Sinter making expensive high Alumina castable is used in furnace for its long lining life. For Blast furnace casting Mullite blocks are used in tap hole area and silicon carbide based castable in trough area are used. For repair of BF Stack specific gunning mass is used for higher life with less downtime. High Alumina block with SiC is required in Torpedo ladle and high thermal shock resistant bricks are required for Reheating furnaces.

In above cases, refractory raw material is a big issue as most of these are synthetic and imported. A very few units are present in India that contribute a little part. In steel making, BOF and Steel Ladle are relined with MgO-C bricks where fused magnesia is totally imported. In India it is not available much in pure or suitable state for lining of BOF and Ladle Furnace. We have to depend on China for high purity Magnesite, Alumina and Graphite. In India the only high purity refractory raw material available is Aluminium Oxide derived from Aluminium Plants that conduct Bayer's process from Bauxite available plenty in India. Indian Bauxite and high Alumina Clays consist with high iron and therefore it cannot make super refractories directly. At the same way Magnesite are available in Tamilnadu and Uttarakhand with low Magnesium

Oxide and high Iron content not suitable for BOF or steel ladle. We may synthesize sintered or fused the above materials by mixing with Aluminium Oxide to desired specification to achieve the high standard Refractory Raw Materials. This part is missing in India presently. Thus Indian Refractory Manufacturers are mostly depending on China. A few Refractory units partly replace the imported materials with high grade used bricks. However by Electro Fusion White Fused Alumina or Brown Fused Alumina could be made in India from synthetic Alumina. Tabular Alumina and Mullite can be produced with high temperature process. This could help to manufacture special Alumina Carbon items. In fusion process MgO-Al spinel can be produced with Magnesite and Alumina. MgO-Al Spinel bricks could replace partly Mag-Carbon in stringent metallurgical furnaces.

Refractory Industry in India depends mostly on imported Raw Materials; very few make synthetic raw materials in India.



- a) Fused grains-Mostly imported, very few manufacturer in India
- b) Sintered grains-Mostly imported, very few manufacturer in India
- c) Grains from used Refractories-Available from all Steel Plants in India, Also imported from Middle east countries and China

As there are no proper grade raw materials available in India to manufacture Mag Carbon bricks for Ladle & Converter, these are imported mostly from China and European countries. To compensate the cost and availability of raw materials some Indian manufacturers mix calcined used Mag Carbon bricks for non critical areas of ladle like free board and metal zone and fired Mag Crome bricks for safety lining. All Mag Carbon bricks which are used in critical areas of Ladle and working lining of Converter are made of raw materials imported from China and other countries. So we may target to make only a part quantity (20-50% value addition) by Manufacturing synthetic raw materials in line with Make In India Policy.

Refractories for Ladles and Converters are supplied in sets that consist of safety lining, working lining and powder materials. In Ladle Set, the powder materials, free board bricks and safety lining bricks consisting about 50% of the total set, can be manufactured in India by the Raw Materials available in India. The same idea is applicable for converter set also. The safety lining bricks and powder materials which is around 40 to 50% in case of converter set may be manufactured in India with available raw materials in India. We also may use calcined used Mag Carbon bricks from different Steel Plants and DBM from Tamilnadu to make Mag Carbon bricks for non critical zones and gunning mass. We may use Dunite/DBM for making safety lining bricks both for ladle and converter set.

Synthetic Raw Materials and high Alumina Cement can be produced by inducting Rotary Kiln, Arc Furnace and Tunnel Kiln to produce cost effective and quality castables, burnt bricks (both High Allumina and Basic) for Cement Plants and Glass Industries and operational items of Ladle & Converter like purging elements, slide plates, pouring nozzles of tundish, tap hole sleeves. Synthetic Mag Alummina Spinel can be used in the metal zone of Ladle replacing Mag Carbon bricks.

#### **Synthetic Raw Materials Manufacturing- Sintering Process- By Rotary Kiln**

There is no suitable refractory grade materials are available in India. The only pure materials available are Aluminum Oxide derived in Buyer's process in the Aluminum Plants. It can be used to synthesize to different Al Grains like AL-50 to Al-90 by adding Bauxite and clays available in India. These are to be first grinded in the ball mills to fines, then mixing in a mixer in different fractions, then noddulising or briquetting and feeding in to Rotary Kiln. In high Temperature i.e. in 1750 degree it will be sintered to desired grains and feed to cooler. Then it will be grinded to required fraction. High Alumina Cement Can also produced by using Aluminum Oxide and Lime. Different types of Spinel and Mullites grains can be produced.

#### **Requirements-**

Rotary Kiln of 60 meter length and 2 meter diameter.

Operating temp-1750 degree to 1800 degree.

Fuels-300 Kg Pet Coke (8000 Caloric Value) or 270 liter Furnace Oil (10000 Caloric Value) per ton of Sintering.

Cooler of 20 meter length and 2 meter diameter.

Ball Mills-2 Nos

Nooduliser or Briqueting Machine

Mixer,Silos and other feeding arrangements, vibrating screening arrangements, magnets.

Polution Control systems and Id fans etc

#### **Fussion Process- By Arc Furnace**

It is a high electricity consuming process. Aluminum Oxide or Raw/Calcined Bauxite to melt in the Arc Furnace (1600 KVA - 2000 KVA) to produce WFA or BFA. And grinded in the Jaw Crusher,Impact Mills & Ball mills to produce different fractions. Raw or Calcined Magnesite (Indian) to melt in the Arc Furnace (3000 KVA) to produce 90 to 91% FM for manufacturing Mag Carbon bricks for free board /Top Cone/ gunning mass /Magnesite

burnt bricks or low quality Mag Carbon bricks. May be melt with Alumina to produce Spinels grains for manufacturing metal zone bricks for Steel Ladles.

Electricity requirements- For melting producing one ton WFA it requires 1500 Unit and For producing one ton FM it requires 3000 Unit of electricity. It requires appx 100 KL water per day.

### **High Grade Grains- By DD Kilns**

The used bricks are collected & sorted from different Steel Plants. These are mainly collected from Mag Carbon bricks used and debricked from Ladles and Converters, Magnesite and Magchome bricks debricked from Rotary Kilns of Cement or Lime Plants. After Calcination in the DD Kiln these can be grinded, Magnetised and screened to get different fractions.

We can manufacture the above Synthetic Raw Materials in India to compensate the burden of importing all the high grade and high valued refractory raw materials from China and other European countries to boost our **“Make In India concept”**.

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## Proper use of Refractories for GHG mitigation

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### **Abstract :-**

Refractories are specialized materials designed to withstand high temperatures and harsh conditions encountered in various industrial processes. They are classified based on their composition, physical properties, and intended applications including Fireclay Refractories, Silica Refractories, Magnesite Refractories, Dolomite Refractories, Chrome-Magnesite Refractories, Alumina Refractories, Carbon Refractories, Insulating Refractories & Insulating Refractories. Each type of refractory has its unique properties and is selected based on the specific requirements of the industrial process. By choosing the appropriate refractory material, industries can ensure optimal performance, durability, and efficiency in their high-temperature applications. Refractories play a crucial role in various industries in conserving energy through several mechanisms including Insulation, Enhancing Equipment Lifespan, Reducing Heat Transfer, Increasing Efficiency, Enhancing Equipment Lifespan, Optimizing Combustion Processes & Enabling High-Temperature Operations. So refractories play a vital role in helping industries conserve energy and reducing its Green House Gas Emissions. And divided in two parts:-

### **How proper use of refractory can help Industries to reduce its Carbon Footprint:-**

Refractories can play an important role in restricting heat losses & inefficiency in Iron & Steel sector. This in turn will help in reduction of Specific Energy & Specific CO<sub>2</sub> emission drastically by improving operational efficiency in various Industries including Iron & Steel, Cement and Power. Refractories help industries conserve energy by insulating high-temperature equipment such as furnaces, kilns, and reactors. By minimizing heat loss to the surroundings, less energy is required to maintain the operating temperatures, resulting in lower energy consumption and reduced greenhouse gas emissions. This energy efficiency directly contributes to carbon footprint reduction by decreasing the reliance on fossil fuels for heating processes. Certain types of refractories, such as those used in combustion chambers and kilns, facilitate optimized combustion processes by providing a stable and uniform environment for fuel utilization. Complete combustion of fuels reduces emissions of carbon dioxide (CO<sub>2</sub>) and other pollutants, thereby lowering the overall carbon footprint of industrial operations. High-quality refractories protect the structural integrity of equipment linings, reducing the frequency of maintenance shutdowns and replacements. This not only saves energy associated with downtime but also avoids the energy-intensive processes involved in manufacturing and installing new equipment. By extending the lifespan of equipment, refractories indirectly contribute to carbon footprint reduction by minimizing resource consumption and waste generation.

### **How used refractories can be recycled & reused:-**

With rise in Steel production especially in India, the requirements of Quality Refractories have also increased. Out of total refractories used, about 30% of refractories are dumped as waste, which can be easily recycled & reused in various applications in today's era of circular economy. Recycling and reuse of refractories offer significant environmental and economic benefits by extending the lifespan of refractory materials, reducing the demand for virgin raw materials, and minimizing waste generation.

Recycling and reuse of refractories help reduce the environmental impact of industrial operations by conserving natural resources, minimizing energy consumption, and reducing greenhouse gas emissions associated with refractory production. Additionally, recycling and reuse divert refractory waste from landfills, mitigating environmental pollution and promoting sustainable waste management practices.

### **Introduction:-**

Refractories are materials that can withstand high temperatures and are used in various industries for lining furnaces, reactors, and other equipment where high temperatures are involved. The choice of refractory material depends on the specific application and operating conditions. Here are some

common types of refractories used in industries:

**Fireclay Refractories:** These are made from fireclay (a type of clay that can withstand high temperatures) and are commonly used for lining furnaces in industries like steelmaking and glassmaking.

**Silica Refractories:** Made from silica ( $\text{SiO}_2$ ), these refractories are highly resistant to acidic slags and are used in glassmaking and in the chemical industry where acidic conditions prevail.

**Basic Refractories:** These are made from basic materials such as magnesia ( $\text{MgO}$ ) or dolomite ( $\text{MgO-CaO}$ ). Basic refractories are resistant to basic slags and are used in industries like steelmaking and cement manufacturing.

**Alumina Refractories:** These are made from high-purity alumina ( $\text{Al}_2\text{O}_3$ ) and are used in industries requiring high temperature resistance and resistance to chemical corrosion, such as in steelmaking and ceramics.

**Chromite Refractories:** These are made from chromite, which is a type of spinel (iron chromium oxide). Chromite refractories have high resistance to heat and corrosion and are used in industries like steelmaking.

**Zirconia Refractories:** These are made from zirconium dioxide ( $\text{ZrO}_2$ ) and are known for their high strength and resistance to thermal shock. They are used in applications where high mechanical stress and temperature changes occur, such as in glassmaking and aerospace.

**Carbon Refractories:** Made from carbon or graphite, these refractories are used in applications involving extremely high temperatures, such as in electric arc furnaces and in the production of silicon and phosphorus.

**Insulating Refractories:** These refractories are designed to have low thermal conductivity and are used to minimize heat loss in applications like kilns, boilers, and heaters.

**Special Refractories:** These include refractory materials designed for specific applications, such as zircon refractories for foundry applications, silicon carbide refractories for abrasive environments, and special composite materials for advanced applications.

The selection of refractory material depends on factors like the operating temperature, chemical environment, mechanical stresses, and thermal cycling conditions of the specific industrial process. Each type of refractory has its own strengths and limitations, and the choice of material is crucial to ensure the reliability and efficiency of high-temperature processes in industries.

### **Type of Refractories:-**

Refractories are classified based on various criteria including chemical composition, physical properties, manufacturing process, and application temperature. Here are the common classifications of refractories:

#### **1. Based on Chemical Composition:**

- **Acidic Refractories:** These are composed of mainly acidic materials such as silica ( $\text{SiO}_2$ ) and alumina ( $\text{Al}_2\text{O}_3$ ). They have good resistance to acidic slags.
- 
- **Basic Refractories:** These are made from basic materials like magnesia ( $\text{MgO}$ ), dolomite ( $\text{CaO-MgO}$ ), and chrome-magnesia. Basic refractories are resistant to basic slags but can react with acidic slags.
- **Neutral Refractories:** These are made from materials like chromite or alumina ( $\text{Al}_2\text{O}_3$ ) with moderate acidity or basicity. They have good resistance to both acidic and basic slags and are used in applications where the slag composition varies.

#### **2. Based on Physical Properties:**

- **Fireclay Refractories:** These are made from fireclay (a type of clay) and have good resistance to moderate temperatures. They are commonly used in low-temperature applications.
- **High Alumina Refractories:** These contain more than 45% alumina ( $\text{Al}_2\text{O}_3$ ) and have excellent refractoriness. They are used in applications requiring high temperature resistance.



- **Silica Refractories:** These are made from silica ( $\text{SiO}_2$ ) and have high thermal shock resistance. They are used in glassmaking and other applications requiring resistance to high temperatures and thermal cycling.
  - **Magnesia Refractories:** These are made from magnesia ( $\text{MgO}$ ) and have excellent resistance to high temperatures and basic slags. They are used in steelmaking and other high-temperature applications.
- .
2. **Based on Manufacturing Process:**
    - **Shaped Refractories:** These are produced in a specific shape or form (bricks, tiles, tubes) using moulding and forming techniques. They are used for lining furnaces, kilns, and reactors.
    - **Unshaped Refractories (Monolithic Refractories):** These are formed in place and are typically used as castables, gunning mixes, or ramming mixes. They provide flexibility in lining irregularly shaped equipment.
  3. **Based on Application Temperature:**
    - **Insulating Refractories:** These have low thermal conductivity and are used for insulating purposes to conserve energy and reduce heat loss in industrial processes.
    - **Refractories for Moderate Temperatures:** These are suitable for applications where temperatures range from  $1000^\circ\text{C}$  to  $1500^\circ\text{C}$ , such as in non-ferrous metal refining.
    - **Refractories for High Temperatures:** These are designed to withstand temperatures above  $1500^\circ\text{C}$ , such as in steelmaking, glassmaking, and ceramic processing.
  4. **Special Refractories:**
    - **Carbonaceous Refractories:** Made from carbon or graphite, these are used in applications requiring resistance to high temperatures and chemical stability.
    - **Zirconia Refractories:** These contain zirconium dioxide ( $\text{ZrO}_2$ ) and are used in applications requiring high mechanical strength and resistance to thermal shock.
    - **Chromite Refractories:** Made from chromite (iron chromium oxide), these have excellent resistance to corrosion by alkalis and are used in industries like steelmaking.

Each classification of refractories has unique properties and characteristics that make them suitable for specific industrial applications. The selection of the right type of refractory depends on factors such as operating temperature, chemical environment, mechanical stresses, and desired performance criteria.

### **Role of Refractories:-**

Refractories play a critical role in industries for several important reasons:

1. **High-Temperature Resistance:** Industries such as steelmaking, glass manufacturing, cement production, and petrochemical refining operate at extremely high temperatures. Refractories can withstand these elevated temperatures without deforming, softening, or failing, thus providing a stable and durable lining for equipment like furnaces, kilns, reactors, and boilers.
2. **Protection Against Chemical Attack:** Many industrial processes involve corrosive materials or chemical reactions at high temperatures. Refractories are designed to resist chemical attack from acids, alkalis, slags, and other aggressive substances, ensuring the longevity and integrity of equipment.
3. **Thermal Insulation:** Refractories can provide thermal insulation, helping to conserve energy and maintain high process efficiency. By reducing heat loss, refractories improve the overall performance and cost-effectiveness of industrial processes.
4. **Control of Heat Transfer:** Refractories help control heat transfer within industrial equipment. They can shield sensitive components from excessive heat exposure or facilitate controlled heating and cooling cycles, which is crucial for maintaining product quality and process stability.

5. **Mechanical Strength at High Temperatures:** Refractories maintain their mechanical strength and structural integrity even under extreme thermal conditions. This characteristic is essential for ensuring the safety and reliability of industrial furnaces, reactors, and other high-temperature equipment.
6. **Minimization of Downtime and Maintenance:** Using high-quality refractories can reduce downtime and maintenance costs in industrial operations. Reliable refractory linings require less frequent repairs or replacements, leading to improved operational efficiency and productivity.
7. **Facilitation of Specialized Processes:** Certain industrial processes require specific refractory materials tailored to unique operating conditions. Refractories enable the execution of specialized processes such as steelmaking, aluminium production, chemical synthesis, and incineration by providing the necessary thermal and chemical resistance.
8. **Safety and Environmental Compliance:** Properly selected refractories contribute to workplace safety and environmental compliance. They help contain hazardous materials and prevent leaks or emissions that could pose risks to workers or the environment.

Refractories are crucial components of industrial infrastructure, enabling the efficient and safe operation of high-temperature processes across various sectors. Their unique properties and capabilities contribute significantly to the performance, reliability, and longevity of industrial equipment and systems.

Therefore, selecting the right refractory materials and maintaining them properly are essential for optimizing industrial operations and ensuring sustainable manufacturing practices.

### High Temperature application of refractories:-

Refractories are essential for various high-temperature applications across industries where materials must withstand extreme heat without losing their structural integrity or functionality. Here are some common high-temperature applications of refractories:

#### 1. **Steelmaking Industry:**

- **Blast Furnace:** Refractories are used to line the walls and crucible of blast furnaces where iron ore is converted into molten iron. The refractories must withstand temperatures exceeding  $1600^{\circ}\text{C}$  and resist chemical reactions with molten iron and slag.
- **Steel Ladles and Tundishes:** Refractories line ladles and tundishes used for transferring and casting molten steel. These refractories must have high thermal shock resistance and chemical stability to withstand repeated heating and pouring cycles.
- **Reheating Furnaces:-**



### 1. Glass Industry:

- **Glass Tank Furnaces:** Refractories are used to line glass tank furnaces where raw materials are melted at temperatures around 1500°C to produce molten glass. These refractories must have low porosity and excellent resistance to alkali vapor corrosion.
- **Glass Melting Crucibles:** Refractories are also used in glass melting crucibles and molds where glass articles are shaped and formed at high temperatures.

### 2. Cement Industry:

- **Rotary Kilns:** Refractories line the inside of rotary kilns used for clinker production in cement manufacturing. The refractories must withstand temperatures exceeding 1500°C and resist abrasion and chemical attack from alkaline dust and gases.

### 3. Petro-chemical Industry:

- **Fluidized Bed Reactors:** Refractories are used in fluidized bed reactors for processes like Catalytic cracking and gasification, where high temperatures and aggressive chemical environments are present.
- **Furnaces and Boilers:** Refractories are employed in the lining of furnaces, boilers, and reactors used for refining crude oil and producing petrochemicals. These refractories must resist thermal cycling and chemical corrosion.

### 4. Non-Ferrous Metal Industry:

- **Aluminium Smelting:** Refractories line the cells used in aluminium electrolysis, where alumina is electrolyzed at temperatures above 900°C. Refractories in this application must resist chemical attack from molten aluminium and cryolite.
- **Copper Smelting:** Refractories are used in the furnaces and converters for copper smelting, where copper concentrates are melted and processed at high temperatures.

### 5. Incineration and Waste Management:

- **Waste Incinerators:** Refractories are used to line the combustion chambers and ducts of waste incinerators, where municipal and hazardous waste is combusted at temperatures ranging from 800°C to 1200°C.

### 6. Power Generation:

- **Boilers and Gasifiers:** Refractories are used in boilers, gasifiers, and combustion chambers in power plants where coal, biomass, or waste is burned to generate electricity. These refractories must withstand high temperatures and thermal cycling.

Refractories are crucial for maintaining operational efficiency, extending equipment lifespan, and ensuring safety. The selection of refractory materials is based on factors such as operating temperatures, chemical environment, mechanical stress, thermal cycling, and desired performance characteristics.

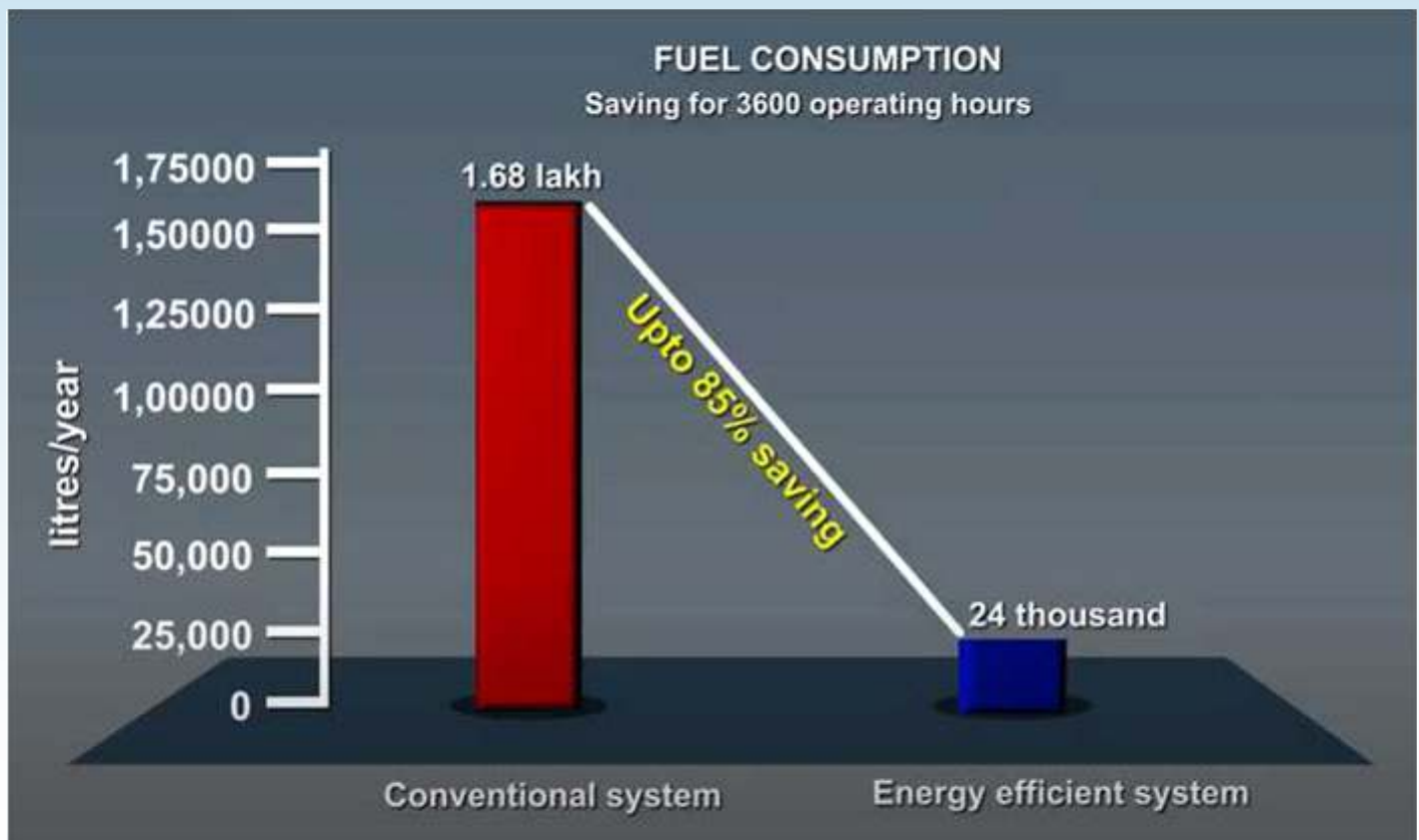
Advanced refractory technologies continue to evolve to meet the increasingly demanding requirements of high-temperature industrial processes.

### Role of Refractories in GHG mitigation

Refractories play a significant role in enhancing energy efficiency in various industrial processes where high temperatures are involved. Their impact on energy efficiency is multifaceted and can be observed in several ways:

1. **Heat Conservation:** Refractories are designed to have low thermal conductivity, which means they are effective insulators. By lining high-temperature equipment like furnaces, kilns, and boilers with refractories, heat loss to the surroundings is minimized. This reduces the amount of energy required to maintain the desired operating temperature within the equipment.





### Case Study by BEE

1. **Minimizing Reheating:** In processes like reheating furnaces and continuous casting, refractories help maintain consistent and uniform temperatures. This reduces the need for frequent reheating of metal ingots or billets, saving energy and improving productivity.
2. **Optimizing Combustion Processes:** Refractories used in combustion chambers and heating systems contribute to efficient combustion of fuels. They withstand high temperatures and harsh chemical environments, ensuring stable combustion conditions with minimal heat loss and fuel wastage.
3. **Increasing Equipment Lifespan:** High-quality refractories have excellent thermal shock resistance and durability, leading to longer life spans of furnaces, ladles, and other steelmaking equipment. This reduces the frequency of equipment replacements and maintenance shutdowns, improving overall energy efficiency..
4. **Improving Process Control:** Refractories play a critical role in maintaining precise temperature control during various stages of steel production. Stable temperature conditions optimize process parameters, reduce energy fluctuations, and minimize energy-intensive corrective measures.
5. **Enabling Innovative Technologies:** Advanced refractory materials enable the implementation of innovative technologies such as energy recovery systems, waste heat utilization, and thermal energy storage. These technologies further enhance energy conservation in industry.
6. **Reducing Environmental Impact:** Energy conservation through refractory optimization contributes to reduced greenhouse gas emissions and environmental impact associated with steelmaking operations. By minimizing energy consumption, the industry can achieve sustainability goals and comply with environmental regulations. To maximize energy conservation using refractories in the iron and steel industry, it is essential to select appropriate refractory materials based on specific process requirements, operating conditions, and desired energy-saving objectives. Regular monitoring, maintenance, and continuous improvement of refractory systems also play a key role in optimizing energy efficiency and overall performance in steelmaking operations.



### **Recycling and Reuse of refractories:-**

Recycling and reuse of refractories play important roles in promoting sustainability, reducing waste generation, and optimizing resource utilization in various industries. Refractories are used extensively in high-temperature processes such as steelmaking, glass manufacturing, cement production, and petrochemical refining. Here are key aspects and benefits of recycling and reusing refractories:

#### **Recycling of Refractories:**

1. **Collection and Sorting:** Used refractory materials are collected from industrial sites, dismantled equipment, or demolition projects. They are sorted based on type, composition, and condition.



1. **Processing and Cleaning:** Recycled refractories undergo processing to remove contaminants, such as metals, slag, and impurities, that may have accumulated during their service life.
2. **Crushing and Sizing:** The cleaned refractories are crushed and ground into suitable particle sizes for reuse in new refractory mixes or products.
3. **Blending and Formulation:** Recycled refractory materials can be blended with virgin raw materials to create customized refractory mixes with desired properties.
4. **Quality Control:** Quality control measures ensure that recycled refractories meet specific performance criteria and standards before reuse.

#### **Reuse of Refractories:**

1. **Direct Reuse:** Certain type of refractories, such as certain bricks and shapes, can be salvaged from decommissioned equipment or processes and reused directly without extensive processing.
2. **Refractory Repair and Patching:** Refractories that are still structurally sound but have localized damage or wear can be repaired or patched using recycled refractory materials.

#### **Benefits of Recycling and Reuse:**

1. **Resource Conservation:** Recycling refractories reduces the demand for virgin raw materials, conserving natural resources such as high-quality clays, minerals, and aggregates used in refractory manufacturing.
2. **Waste Reduction:** Recycling refractories reduces the volume of waste sent to landfills or disposal sites, contributing to waste reduction and promoting circular economy principles.
3. **Cost Savings:** Reusing recycled refractories can offer cost savings compared to purchasing new refractory materials, especially for non-critical applications or repairs.
4. **Energy Efficiency:** Recycling and reusing refractories can lead to energy savings compared to manufacturing new refractories from scratch, as it avoids the energy-intensive processes involved in raw material extraction and processing.
5. **Environmental Impact:** By extending the lifespan of refractories through recycling and reuse, the environmental impact associated with refractory production, transportation, and disposal is minimized.

**Customization and Innovation:** Recycled refractories can be tailored and blended to meet specific performance requirements, enabling customization and innovation in refractory design and application.

### **Challenges in Recycling:-**

1. **Quality and Performance:** Ensuring consistent quality and performance of recycled refractories is crucial to meet industry standards and application requirements.
2. **Technological Advances:** Continued research and development are needed to optimize recycling processes and improve the performance of recycled refractory materials.
3. **Industry Collaboration:** Collaboration among refractory manufacturers, end-users, and recycling facilities is essential to establish effective recycling and reuse practices throughout the supply chain.

Recycling and reuse of refractories contribute to sustainable practices in industrial operations, promote resource efficiency, and support the transition towards a circular economy in the refractory industry.

Ongoing efforts in innovation, quality control, and collaboration are key to unlocking the full potential of recycling and reusing refractories in various high-temperature applications.

### **Advantages of Recycling of Refractories in Iron & Steel Industries:-**

Recycling of refractories in the iron and steel industries offers several advantages that contribute to sustainability, cost-effectiveness, and resource conservation. Here are the key advantages of recycling refractories in this sector:

1. **Resource Conservation:** Recycling refractories conserves natural resources by reducing the demand for virgin raw materials used in refractory manufacturing. This helps preserve valuable mineral reserves and reduces environmental impact associated with raw material extraction and processing.
2. **Waste Reduction:** Recycling refractories minimizes the volume of waste generated from steelmaking operations. Rather than disposing of used refractories as waste, recycling extends their lifespan and transforms them into valuable secondary raw materials.
3. **Cost Savings:** Using recycled refractories can offer cost savings compared to purchasing new refractory materials. Recycled refractories are often available at lower costs, especially for non-critical applications or repairs, contributing to overall cost efficiency in steel production.
4. **Energy Efficiency:** Recycling refractories reduces energy consumption associated with manufacturing new refractories from scratch. The energy-intensive processes involved in raw material extraction, processing, and production of virgin refractories are minimized, leading to energy savings and reduced carbon footprint.
5. **Environmental Impact Reduction:** By diverting used refractories from landfills and promoting circular economy practices, recycling contributes to reduced greenhouse gas emissions, air pollution, and environmental degradation associated with waste disposal.
6. **Improved Sustainability:** Recycling refractories aligns with sustainability goals and initiatives in the iron and steel industries. It supports the transition towards a circular economy model, where materials are reused, recycled, and repurposed to minimize waste generation and promote resource efficiency.
7. **Customized Refractory Blends :** Recycled refractories can be blended with virgin raw materials to create customized refractory mixes tailored to specific application requirements. This flexibility allows steelmakers to optimize refractory compositions and performance based on process conditions.
8. **Supply Chain Resilience:** Incorporating recycled refractories into the supply chain enhances supply chain resilience by diversifying material sources and reducing dependency on limited natural resources. This strengthens the overall resilience of steelmaking operations against supply chain disruptions.
9. **Industry Collaboration and Innovation:** Recycling refractories fosters collaboration among refractory manufacturers, steel producers, and recycling facilities. It encourages technological innovation and the development of advanced recycling techniques to overcome technical challenges and optimize material recovery.
10. **Regulatory Compliance:** Recycling refractories helps steelmakers comply with regulatory requirements related to waste management, resource conservation, and environmental sustainability. It supports responsible waste disposal practices and contributes to achieving regulatory targets.

Recycling of refractories in the iron and steel industries offers multiple benefits, ranging from resource conservation and waste reduction to cost savings and environmental impact reduction. Embracing recycling initiatives and implementing sustainable practices contribute to the long-term viability and competitiveness of steelmaking operations while promoting environmental stewardship and societal wellbeing.

**Conclusion:**

Proper use of refractories in industries can indeed contribute significantly to greenhouse gas (GHG) reduction. By improving energy efficiency, optimizing combustion conditions, and minimizing environmental impact, Industries can achieve sustainable production practices while reducing their carbon footprint and contributing to global efforts to combat climate change. The production of refractory products is a very energy-intensive process that causes a lot of CO<sub>2</sub> emissions. Refractory makers also need to come out with innovative ways of recycling & reuse of old Refractories. Gen next Refractories that ought to be-'Lighter-Stronger-Safer-Better & Smarter' will hold the future for Energy Conservation & GHG mitigation. In order to achieve these value propositions, win-win collaborations among Steel Makers, Refractories Makers & Raw Materials suppliers with due recognition are must.

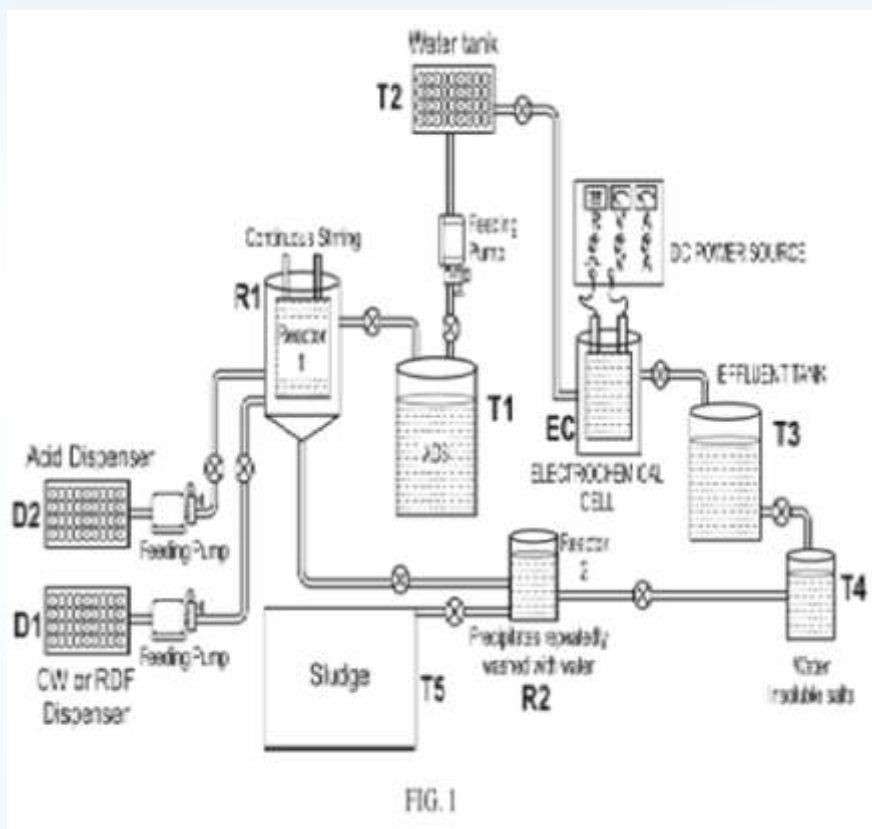
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# Innovative materials for circular economy from refractory wastes

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A method of recovery of value-added products (VAPs) such as native metals, metal alloys, and compounds from combustion wastes (CW) to form acid digested solution (ADS) and precipitate. ADS is separated from the precipitate by filtration and diluted with water to form water dissolved salt solution (WDS). The precipitate is washed with water repeatedly to separate the remaining WDS. WDS is transferred to the EC. In the EC, VAPs such as metals alloy, silica and silicon carbide are isolated from WDS on the working electrode (graphite) surface employing linear sweep voltammetry (LSV). The precipitate after WDS removal was centrifuged to isolate different Water-insoluble salts (WINS). The WINS are recrystallized; the sludge from the precipitate is subjected to CCVD to form carbon nanotubes or graphene. Rare earth elements in the sludge are separated by magnetic separation (cf. Fig 1).



**PATENTS FILED: 202341000490 (Indian); PCT/IN2024/050010**

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## **Energy and Environment Conservation by using advanced insulation products “Low – Bio Persistence- Sueprwool ” Fibre& HT Mullite -1600 Deg C Fibre”in Steel Plant**

M Kadhirvelu, Murugappa Morgan Thermal Ceramics Limited

### **Abstract :**

Energy consumption in most of the integrated steel plants in India is generally high at 6-6.5 Giga Calorie per tonne of crude steel as compared to 4.5-5.0 in steel plants abroad.

**As per Nationally Determined Contributions (NDCs) for Indian Steel Industry** of the steel sector submitted to MoEF&CC, average CO<sub>2</sub> emission intensity of the Indian steel industry was projected to reduce from 3.1 T/tcs in 2005 to 2.64 T/tcs by 2020 and 2.4 T/tcs by 2030 (i.e. approx. 1% per year).

Effective Insulation is of furnaces / Flue Gas Ducts / Hot air Ducts / Steam lines both in external and internal will play a pivot role for reduction in energy intensity and CO<sub>2</sub> emissions in steel plant operations.

In this paper, we will share our experience of using of Superwool Family of products and HT Mullite Fibre in various steel plant critical furnaces like Reheat / CGL / CAL / CSP / BAF etc in achieving the above objectives and ensure the sustainability.

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## Lime Enriched Magnesia Carbon Refractory bricks ..... Suitability in Si-Killed Steel ladles

*Ashok Agarwal, Kushal Agarwal, Santanu Mukhopadhyay, D K Sinha, M K Viswanatham  
Sarvesh Refractories Pvt Ltd.*

### Abstract:

In steel plants, specific consumption of refractory is highest in steel making ladle. To reduce the specific consumption of refractory ladle life enhancement is essential. , it is seen the ladle life greatly depends on type of killing, which is done to reduce the O<sub>2</sub> ppm in steel. The ladle life is always a critical factor in case of Si-killed steel ladles. The steel industry continually seeks innovative solutions to improve efficiency and reduce environmental impact. One such advancement involves the application of high lime magnesia carbon bricks in Si-killed steel ladles. These bricks, composed of a unique blend of magnesia, dolomite and carbon materials, Dolomite, a mineral rich in magnesium and calcium carbonate, contributes to the refractory nature of these bricks, providing excellent resistance to high temperatures and chemical corrosion. The incorporation of carbon further enhances the material's durability and thermal conductivity, crucial factors in maintaining ladle integrity during the demanding steelmaking process.

Steel ladles lined with these advanced refractories exhibit improved energy efficiency, by reducing heat loss during the transfer and holding of molten steel. This aligns with the industry's growing focus on sustainable practices.

In addition to their refractory and sustainable properties, high lime magnesia carbon bricks offer specific advantages tailored to the challenges of steel ladle applications, particularly in Si-killed environment. These bricks excel in resisting slag corrosion and thermal shocks, crucial factors in maintaining the structural integrity of ladles subjected to rapid temperature changes and corrosive materials.

In secondary steel making process, ladles are normally lined with Magnesia carbon bricks. Various grades of fused magnesia are used along with other ingredients for making such bricks. Steel ladles lined with these advanced refractories exhibit improved energy efficiency, by reducing heat loss during the transfer and holding of molten steel. This aligns with the industry's growing focus on sustainable practices.

Fused magnesia is one of the major raw material for manufacturing MgO-C brick. Higher crystal size, suitable CaO/SiO<sub>2</sub> ratio promotes its slag corrosion resistance properties. But, its suitability is subjected to the basicity of the slag. For Al killed steel, where the slag basicity can be maintained above 2, MgO-C brick is well suitable and it gives better performance without much issues. But, as per the market demand,

technological enhancement and seeing the cost economy, steel plant also produces Si-killed steel. In Si killed steel, silicon metal is introduced in the liquid metal to reduce the dissolved oxygen in the melt, which has been acquired by the steel during blowing in BOF converter. Now, this Si metal extracts the dissolved oxygen from the melt and forms SiO<sub>2</sub>. Being silica a much lighter material than steel, it immediately moves and float on the surface, forming the slag. As soon as the silica mix with the slag, the basicity of the slag drops down. As the basicity goes below 2, conventional MgO-C starts facing problem, because the MgO dissolution in the slag greatly depends inversely on the slag basicity.. The MgO dissolution increases sharply as the basicity goes down. ( Fig-1). If the required quantity of MgO is not available in the slag, it will take MgO from the refractory. So, MgO-C refractory starts deteriorating in performance in case of Si-killed steel.

### Experimental :

Dolomite, is a double carbonate of MgCO<sub>3</sub> and CaCO<sub>3</sub>. As it is very high LOI material ( around 45%) at low temp. It is not suitable for direct use in refractory as a raw material. It decomposes at a temp of 700 °C into MgO and CaO. This immediately picks up moisture from the atmosphere., when leaves open, forming Mg(OH)<sub>2</sub> and Ca(OH)<sub>2</sub>. So, this material needs to be fired at 1750 to 1800 for sintering purpose and its bd increases around 3.20 g/cc. As it sinters, it forms a solid solution, which possesses very high chemical bond strength. So, in spite of low basicity in Si-killed steel, it is difficult for the MgO to go into the dissolution. This is the background for the suitability of dolomite refractories in Si killed steel. Because of other technical demand, high quality fused base MgO-C is still used in Slag zone bricks, but for metal zone application dolomite refractories are suitable for Si-killed steel.

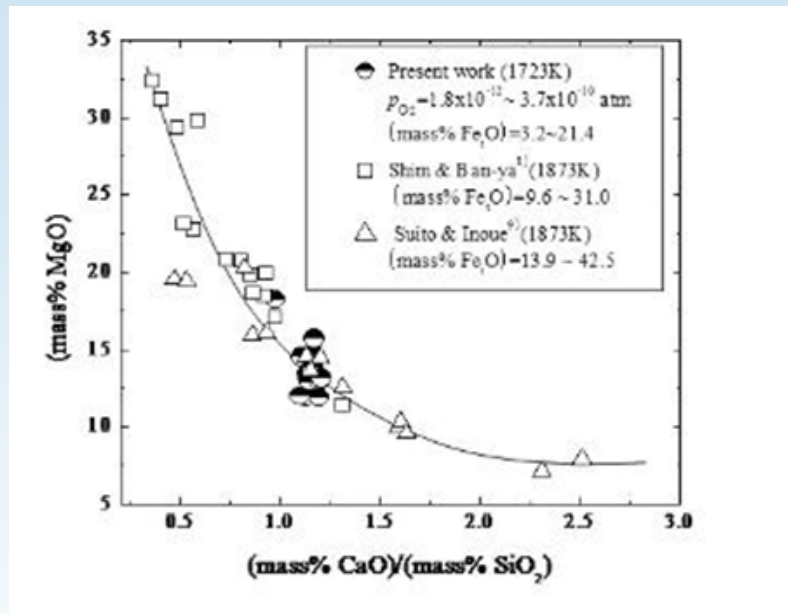


Fig-1 , MgO dissolution and slag basicity

With this backdrop, the dolomite from Bhutan belt was selected. The raw dolomite chemical analysis is given in table 2. It is to be noted that the SiO<sub>2</sub> content of raw dolomite has to be at minimum level, otherwise there is every possibility of formation of montecellite (CMS) and Merwinite (C<sub>3</sub>MS<sub>2</sub>). This dolomite was taken in the grading of 0-15 mm and then fed into rotary kiln for sintering at a temp of 1750 °C .

Table-1 Chemistry of Raw Dolomite

| LOI (%) | MgO (%) | CaO (%) | Al <sub>2</sub> O <sub>3</sub> (%) | Fe <sub>2</sub> O <sub>3</sub> (%) | SiO <sub>2</sub> (%) |
|---------|---------|---------|------------------------------------|------------------------------------|----------------------|
| 45.5    | 23.11   | 30.26   | 0.11                               | 0.47                               | 0.35                 |
| 45.5    | 23.11   | 30.26   | 0.11                               | 0.47                               | 0.35                 |
| 45.5    | 23.11   | 30.26   | 0.11                               | 0.47                               | 0.35                 |
| 45.8    | 23.43   | 30.27   | 0.15                               | 0.45                               | 0.67                 |

Table-2 gives the chemical analysis of Sintered dolomite.

Table-2 Chemistry of Sintered Dolomite

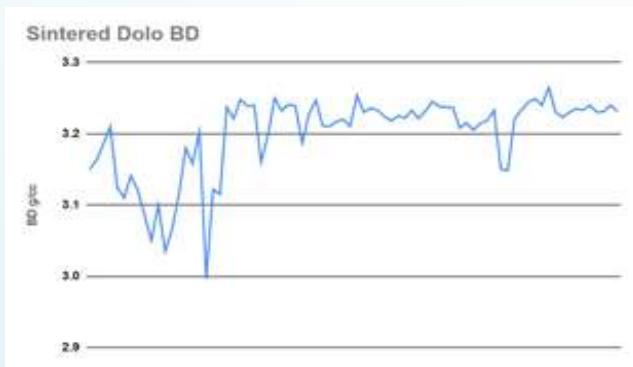


Fig-2 Trend of Sint Dolo BD

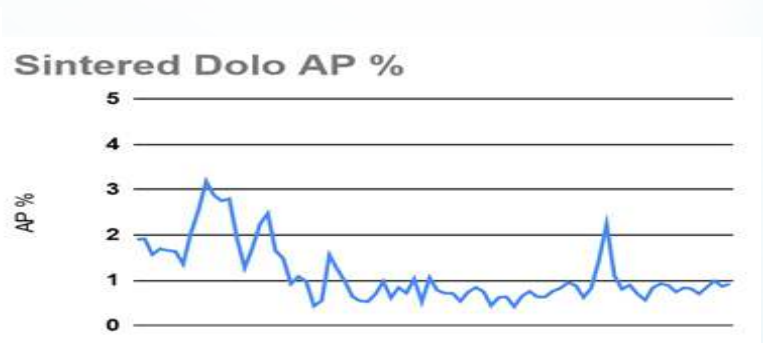
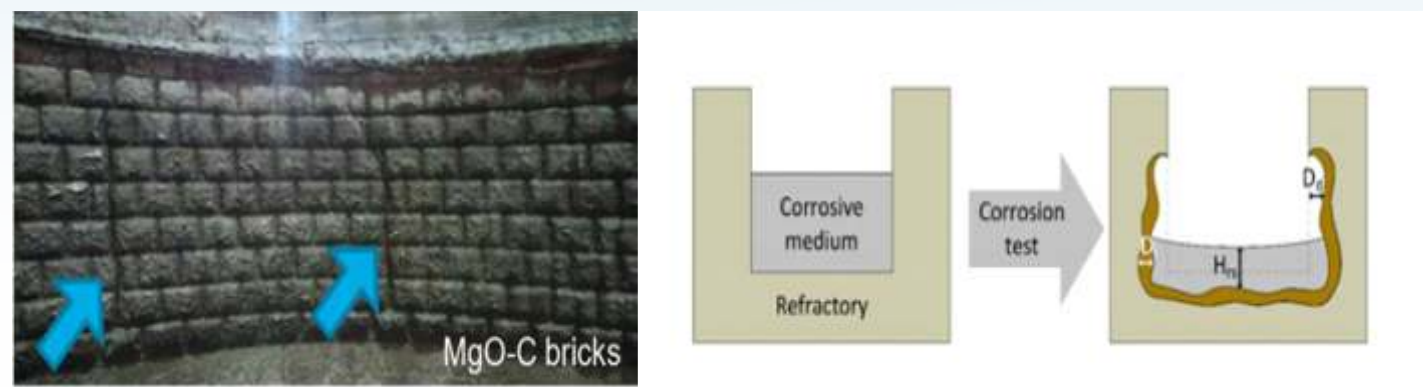


Fig-3 Trend of Sint Dolo AP

The BD and AP trends of sintered dolomite is given in Fig -2 and Fig-3 . This sintered dolomite was used as a major raw material while making the recipe of dolomite bricks along with other ingredients. Few molten metals can wet refractory, but in contrast, most slags wet refractory, Hence the most critical area is slag zone. Slag penetration is directly proportional to the porosity of the refractory. Once the slag penetrates the refractory, it desolves the refractory via chemical reaction. The various processes in secondary steel making has its own aggressive mechanical and chemical wear mechanism. There is merit in zoning various qualities of dolomite ladle bricks depending upon the duty to which they are subjected. It may be pitch bonded, resin bonded and direct bonded. In addition to their refractory and sustainable properties, high lime magnesia carbon bricks offer specific advantages tailored to the challenges of steel ladle applications, particularly in Si-killed environment. These bricks excel in resisting slag corrosion and thermal shocks, crucial factors in maintaining the structural integrity of ladles subjected to rapid temperature changes and corrosive materials Formation of vertical cracks in Mag-C ladle is a common problem in the ladles during mid-campaign. Such a vertical cracks is crating problem, because it gradually becomes bigger and gives initial way for slag penetration. This becomes more prominent in case of Si killed steel because of aggressive slags. Fig-4 depicts such a picture from a steel plant site.



**Fig-4 Vertical Cracks in steel ladle    Fig-5 Dolomite slag Corrosion Test**

The dolomite bricks were made in 2000 ton hydraulic press with a specific pressure of 1.6 tons/cm2. The property data of such bricks are given in Table 3 and Table 4

**Table-3TestpropertiesofBurntdolobricks**

| Burnt Dolomite Bricks |          |                          |
|-----------------------|----------|--------------------------|
| AP(%)                 | BD(g/cc) | CCS(kg/cm <sup>2</sup> ) |
| 6.69                  | 3.16     | 857                      |
| 7.86                  | 3.15     | 936                      |
| 7.31                  | 3.11     | 986                      |



**Fig-6 Ladle condition during Campaign**

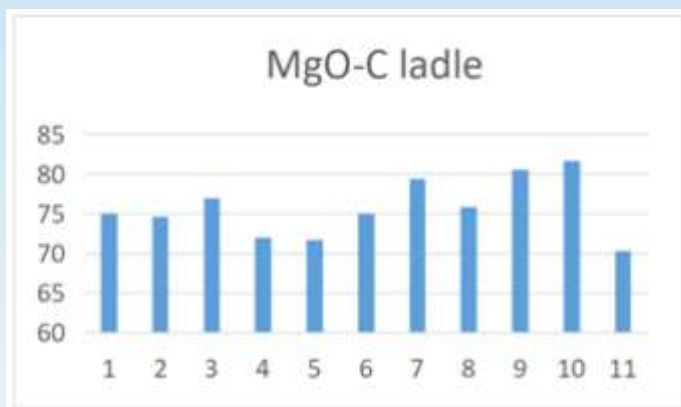
**Table-4TestpropertiesofBurntdolobricks**

| Unburnt Dolomite Bricks |          |             |
|-------------------------|----------|-------------|
| AP(%)                   | BD(g/cc) | CCS(kg/cm2) |
| 2.43                    | 3.08     | 411         |
| 2.93                    | 3.07     | 413         |
| 2.71                    | 3.09     | 425         |



**Fig-7 Ladle slag Analysis**





**Fig-8 Dolomite Ladle Performance**



**Fig-9 Dolomite Ladle Performance**

The dolomite bricks were sent to one of the Indian steel Plant. Fig 5 shows the ladle condition during campaign running with dolomite bricks

#### **Discussion :**

The raw dolomite and sintered dolomite were chemically very much consistent. The AP and BD figures of sintered dolomite was good. Low LOI in sintered dolomite indicates that the sintering has been done properly. The test properties data of conventional tests were carried out and those were found well in norms. In simulative testing, the static slag corrosion resistance was carried out and compared. In this test, The required slag was prepared by mixing required ingredients.

In dolomite ladle, there was substantial reduction in formation of vertical cracks which is very frequently happening in MgO-C ladle. As a result, the metal penetration must have been less and the consequences is the increase in ladle life. The reason of abnormal erosion of Mag-C ladle is due to dissolution of MgO grains because of low basicity of the slag in Si-killed steel ladle.

#### **Conclusion:**

Dolomite refractories are widely used as lining materials for steel refining processes, and their reaction behaviors with refining slag have been studied. However, only a few studies have been conducted on their reactions with molten steel. Furthermore, there are no reported effects of dolomite on the change of composition of inclusions. Therefore, in this study, laboratory experiments were conducted to investigate the reactions between dolomite refractory materials and Si-killed steel slag; and the corrosion behaviors were observed. Field trial conducted, which is in line with laboratory result.

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## **Application of Spinel based Steel ladles in the SMS II shop of Bokaro steel plant**

Anand Kr Yadav ,Mgr, RED ,Rahul Kr Gupta ,GM,RED ,  
Veda Prakash Upadhyaya, CGM Refractory

In response to the imperative of maximizing production capacity, the SMS II shop of BSL embarked on a strategic initiative to introduce Spinel-based steel ladles alongside the conventional Magnesite Carbon bricks (MCB). This paper offers a comprehensive analysis of the transition process, delineating the technical challenges encountered and the consequential benefits realized. Through meticulous trials and evaluations, the shift towards Spinel-based ladles was meticulously navigated, culminating in a significant adoption rate over two financial cycles. Notable benefits include increased working volume, decreased downtime, and uplift in steel quality, all contributing to enhanced cost-efficiency. As the shop continues to leverage the advantages of this change, the paper concludes by outlining strategies for ongoing optimization and refinement, underscoring a steadfast commitment to advancing the frontier of steel ladle technology.

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## **A techno-economic balance in achieving torpedo ladle life**

Kavita Bisoyi, Purab Das, Bibhu Prasanna Sahoo

Rourkela Steel plant, SAIL

### **Abstract:**

The need for high productivity, high product quality and low production costs lead to gaining interest in handling hot metal torpedo ladles lined with Alumina-silicon carbide-carbon (ASC) based resin bonded bricks. This paper covers a brief story of a techno-economic balance maintained in RSP to achieve low specific cost and consumption and attain a higher life. For decades the ASC ( $\text{Al}_2\text{O}_3\text{-SiC-C}$ ) bricks are the preferred industrial choices for torpedo ladle refractory lining application. At RSP, torpedo ladle management was introduced with a guarantee life of 1000 heats. However, with adopted strategies such as Metal Heal Practice, Window repair concept, scheduling mid repairs and other practices, RSP has been able to successfully stabilize Torpedo Ladles which has also helped in reducing maintenance cost. RSP has registered a national record of 2865 heats achieved in March'24 surpassing own previous best record of 2669 heats. Future of torpedo is not just in introducing the repair concepts, but also is in exploring the torpedo ladle refractory wear profile through laser scanner. The scanner can be used to ensure efficient and safe operation throughout its campaign.

### **1. Introduction:**

ASC brick is a composite material composed of alumina and C and high carbon containing pitch and resin is used as bonding material, with some metallic powder as anti-oxidants to prevent the carbon from oxidation.

ASC bricks consist of alumina, silicon carbide, graphite, antioxidant and binder. Alumina grains as the principle constituent of the system gives very high resistance to basic slag corrosion. Graphite due to non-wetting nature improves the corrosion and thermal shock resistance of the ASC system.

However, graphite is liable to oxidation. Antioxidants are used to prevent oxidation of carbon and to improve high temperature strength by the formation of various carbides. The carbonaceous binder keeps the different components of the refractory together, which form amorphous carbon after the coking process during which volatile species leave the resin.

ASC refractories have found the widest application in torpedo ladles due to their good thermal shock resistance and excellent slag corrosion resistance at elevated temperature. These properties occur due to the non-wetting nature (graphite) with slag, high thermal conductivity and low thermal expansion of carbon. The penetration and corrosion resistance are improved by the formation of a nascent dense layer of  $\text{Al}_2\text{O}_3$  on the working surface of ASC brick, due to oxidation of  $\text{Al}_2\text{O}_3$  (produced in the reaction between  $\text{Al}_2\text{O}_3$  and C).

But carbon has poor oxidation resistance and oxidizes to form CO and  $\text{CO}_2$  resulting in a porous structure with poor strength and corrosion resistance. To prevent oxidation of C antioxidants are used, which reacts with incoming oxygen, gets oxidized and protects carbon, thus retaining the brick structure and properties. Due to the presence of high carbon content, conductivity of ASC brick increases and results in loss of heat energy through the furnace wall.

### **Study on Improvement of Torpedo ladle life at RSP, thereby achieving highest torpedo ladle life of 2865 heats in India**

At Rourkela Steel Plant, Blast Furnace No 5 has an annual capacity of 2.8 MT. A fleet of 12 torpedo ladles, each with a capacity of 350t, transport the molten metal to the steel shop. To improve the life of the refractory lining of these ladles a state-of-the-art lining design was developed using two types of zonal lining targeting refractory quality and lining thickness. Both methods are presently in use. Previously, the torpedo lining life was 1200- 1500 cycles after carrying 300 to 350kt of iron. This required critical transport capacity to be removed from the process flow during relining. Generally the temperature of tapped HM varies in the range of 1480 deg C to 1510 deg C at BF#5 of RSP. In order to withstand high temperature, demonstrating refractoriness, resistance to thermal shock and volume stability, RSP has introduced an innovative 'window' repair programme. Here, zoning of areas of excessive refractory wear was undertaken and repairs to these regions executed either by using higher grade refractories or, in some cases, by increasing refractory thickness. Innovative repair methods

include coating a new lining with a compound developed inhouse which prevents the lining from oxidation during pre-heating. Inspections are conducted to monitor the shell temperature, by inspection of the lining; and by tracking the tons carried since the previous lining repair. Thermographic readings are recorded each week and allow partial window repairs in specific areas to extend the life of the torpedo lining in a balanced manner. These practices have almost doubled the average lining life to over 2466 cycles to date and in future the life is expected to reach over 2,800 cycles or 860kt of hot metal transported. The lining pattern of a typical torpedo is as shown below (Table.1):

| Area of Application | Quality                               |
|---------------------|---------------------------------------|
| Insulation Layer    | 45% Alumina Bricks with 50% Silica    |
| Permanent Layer     | 42% Alumina Bricks                    |
| Working layer       | Alumina-Silicon Carbide-Carbon Bricks |
| Intermediate Layer  | Fireclay50%AluminaCastable            |
| Mouth/ Spout        | 90% Alumina Low Cement Castable       |
| Splash Guard        | 90% Alumina Conventional Castable     |

*Table.1. Refractory Lining pattern of Torpedo Ladle*

Detailed studies were conducted by Refractories Department, RSP to assess the torpedo ladle Refractory. Problem encountered in the Torpedo Ladles were:

Thermal wear: caused by the heat load of hot metal

Oxidation: Especially upper arch, which is not covered with hot metal or slag.

Chemical wear involves variable slag/metal chemistry.

Thermal shock severe when the TLC is made empty

Mechanical wear: Impact on refractory during pouring, bath agitation during transport and stresses on mouth refractory during taping of hot metal.

For any type of torpedo ladles, service life is determined by refractory thickness in critical areas with high erosion rate. Presently high speed laser scanners have become more and more important in the determination of brick thickness of such vessels. Although RSP does not have a laser scanner facility, regular shell temperature recording have helped RSP is determining critical erosion sites. One is slag line area, at the SMS pouring side of the torpedo side wall, eroded by slag floating on the molten iron. Another is metal impact area at the bottom of the torpedo ladle. Third one is the locking portion bricks towards SMS pouring side below the spout. Here the decay of the refractory bricks takes place due to abrasion by metal as the entire quantity of 350T of molten metal travels on this area. Thus abrasion resistance of the refractory bricks needs to be of the highest order for this area. Therefore, timely and precise inspection of refractory accurately at high temperatures, use of efficient refractory use and its proper maintenance are the effective means in extending its service life.

In order to achieve the target, Refractory Collective RSP adopted some innovative strategies such as:

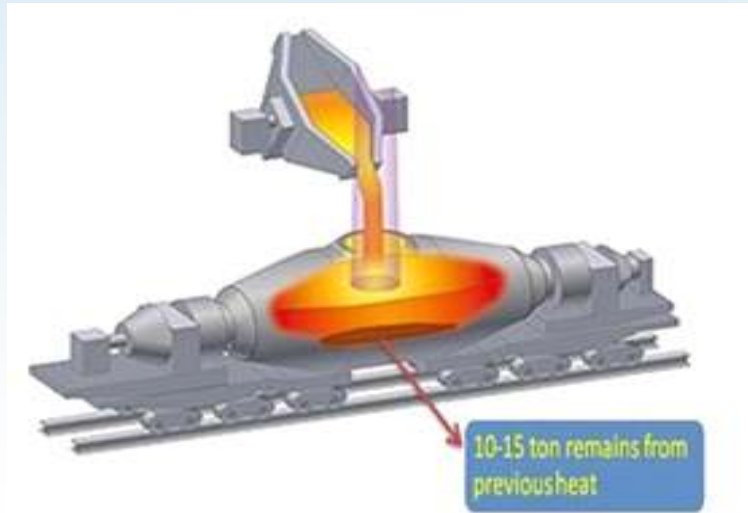
- I. Metal heal practice
- II. Window repair concept
- III. Scheduling mid repairs and service life span
- IV. Other practices



## Innovative strategies and practices:

### I. Metal Heal Practice:

One of the critical areas of erosion is metal impact area at the bottom of torpedo ladle. At the metal impact area, erosion rate is the fastest. The refractories eroded by thermomechanical shock when the molten pig iron tapped from blast furnace. Therefore, to prevent metal break out from this area, the hot metal from the torpedo is not fully discharged at Steel Melting Shop, leaving about 10-15 tons of hot metal in the torpedo ladle and this remains every time. This residual metal works as cushion to the falling stream of hot metal from Blast Furnace tapping and bricks of impact area never faces the direct impact of falling stream (Figure: 1). This is drained out completely only when the ladle is put down for midlife repairs.



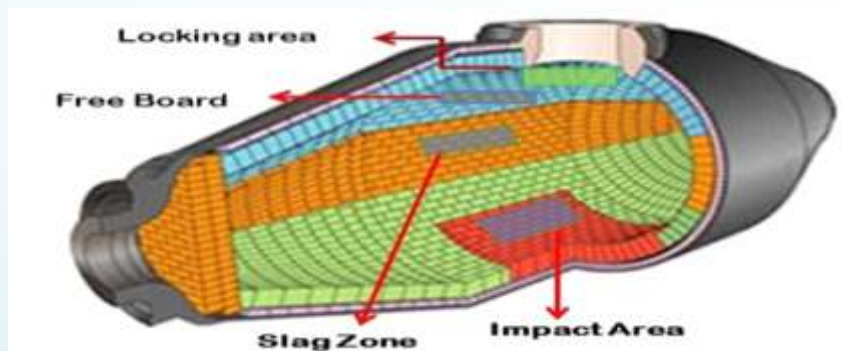
*Figure: 1 A view of torpedo with metal heal during*

#### 1. *tapping of Hot Metal*

The metal heal practice not only reduces wear at the impact zone, but also lowers thermal fluctuations before filling and after emptying the ladle. This reduces or eliminates the chances of spalling at the bottom.

### II. Window repair Concept:

To inspect the refractory accurately at high temperature is effective in extending its service life by efficient refractory use and reducing its maintenance cost. Regular inspection of torpedo and the thermographic study of torpedo reveal the condition of Refractory thickness at localized areas of torpedo. Then the vulnerable areas/zones with excessive refractory wear are identified repair. (Figure: 2)



**Figure:2 Window areas identified for Repair**

The adopted concept of Window repair is being used to repair the vulnerable and eroded areas like free board, Locking area, slag zone and impact area. In Window repair, a box or window shaped area of the highest eroded portion is de-bricked and laid instead of de- bricking the whole layer. A graphical representation of identified windows for repair is shown in figure 6. The repairs of these regions are done by using higher grade refractories or in some cases by increasing the Refractory thickness of that zone.

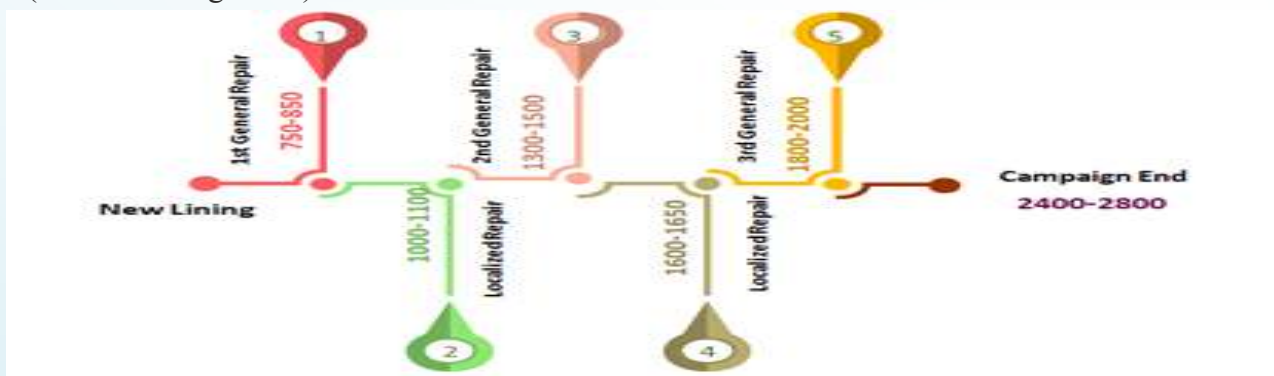
To cater to the need of increased productivity and cost reduction, localized repair of the torpedo is an innovative step in this direction. Graph 1. shows the increase in average life of torpedo after implementation of window repairs and metal heal practice.



**Graph 1: Increasing Torpedo lining life at RSP**

### III. Scheduling repair and service life span:

To increase the service life of the torpedo one of the very crucial job is regular inspection and scheduled repairs. In this connection, when the torpedo ladle is down for maintenance inspection of the ladle such as hot inspection, cold inspection and monitoring wear profile during operational cycle becomes crucial. In addition to ensuring operational safety, closely monitoring the wear profile enables a continuous optimizing of lining design with a view of enhancing service life while cutting back on maintenance cost. Therefore, regular ladle inspection and studies on thermal profile help identifying schedule for general and localized repairs within the lifespan of a torpedo. Torpedo ladles are repaired when the minimum thickness near the most worn out area is down to 120 mm and in this area bricks of up to a thickness of 150 to 180mm can be laid. The figure 3 shows a typical plan of mid repairs (localized and general).



**Figure:3 RSP Torpedo Ladle Service life plan**

#### IV. Monitoring wear Profile:

For geometric and thermal reasons, visual inspection of the refractory lining wear profile is poor and difficult and is restricted to the area close to the mouth at the central region. For visual inspection, the barrel portion only is visible. A lack of proper inspection may seriously jeopardize operating safety. If hot metal leaks from a torpedo ladle, catastrophic consequences may ensue to the blast furnace or steel shop facilities. Improved visual lining inspection procedures were instigated when the torpedo ladle was cold during maintenance, and employed thermal imaging during operating for hot inspection. In addition to ensuring operational safety as a primary function, monitoring the wear profile closely is a technorefractory- management tool, which enables continuous optimization of lining design with a view to enhancing service life while reducing maintenance cost (Table 2).

| TLC LOT of different zone |                                         |                 |      | Life-           | 1881                 |
|---------------------------|-----------------------------------------|-----------------|------|-----------------|----------------------|
| s.l.no                    | zone                                    | Original thick. | Wear | Residual Thick. | RATE OF EROSION/HEAT |
| 1                         | Impact zone                             | 410             | 260  | 150             | 0.14                 |
| 2                         | semi impact zone                        | 375             | 255  | 120             | 0.14                 |
| 3                         | Rest Bottom (both side)                 | 340             | 200  | 140             | 0.11                 |
| 4                         | Lower cone(both side)                   | 340             | 190  | 150             | 0.10                 |
| 5                         | SMS pouring Side spout locking portion  | 305             | 245  | 60              | 0.13                 |
| 6                         | SMS pouring Side Impact slag zone       | 340             | 280  | 60              | 0.15                 |
| 7                         | SMS pouring side barrel s/z (both side) | 340             | 260  | 80              | 0.14                 |
| 8                         | SMS pouring side cone. S/Z(Both side)   | 340             | 230  | 110             | 0.12                 |
| 9                         | PCM pouring Side locking portion        | 305             | 255  | 50              | 0.14                 |
| 10                        | PCM pouring side impact s/z             | 340             | 295  | 45              | 0.16                 |
| 11                        | PCM pouring Side barrel s/z(both side)  | 340             | 280  | 60              | 0.15                 |
| 12                        | PCM pouring Side cone s/z(both side)    | 340             | 240  | 100             | 0.13                 |

*Table.2 Leftover thickness of different zones after attaining final life*

#### V. Other practices:

**Modification in heating cycle:** In addition to the metal heal practice, window repairs and scheduled repairs, modification in heating cycle has been done with an aim of homogenous heating with a constant and uniform removal of water (free and combined) and binding compounds. Uniform temperature distribution with regular heating rate lessens thermal stresses upon the refractory lining, thereby mitigating the increase in number of cracks. This strengthens material properties while reducing thermal shock impact when hot metal is freshly poured right after repair is finished.

#### 3. Online Inspection & thermography:

All torpedo ladles after 450 cycle life are being inspected after emptying on everyday basis in the spout area, barrel portion, conical adjacent to barrel visually shell temperature is measured of all torpedo in filled condition at different portion like metal zone, bottom, slag zone, conical and free board. Our experience temperature of torpedo shell exceeding more than 2400C anywhere is dangerous in such events ladles are being taken out within 3/4 cycles and are dumped completely and placed under cooler for inspection and repair. Taking shell temperature

of torpedo shell on daily basis and analyzing the same for assessment of torpedo refractory lining wear profile from this data. This has proved an excellent supporting tool assess decay of torpedo ladle lining in different area & helping in taking the corrective action in absence of thermo vision cameras.

#### **4. Development of new material:**

At present worldwide Alumina-silicon Carbide- Carbon bricks are most commonly used for relining of torpedo ladles, zoning is with variation in thickness or in combination with 84% High Alumina bricks in non- vulnerable areas. In order to develop optional techno-commercial materials and lining design for respective portions of the torpedo ladles a massive programme was taken up by shop engineers along with supplier of torpedo ladle Refractories. Thermal spalling resistance is the most common requirements of torpedo ladle Refractories.

Besides this, zonal requirements – for slag line, corrosion resistance for metal impact area, abrasion resistance for free board (ceiling), oxidation resistance. In order to improve upon above said properties various research were conducted to develop new material, i.e. Alumina- Silicon Carbide-Carbon Refractories which is most suitable for repairs.

#### **5. Conclusion:**

In order to maintain Torpedo ladle availability for improving plant productivity, RSP has focused on expanding the service life of torpedo ladle and thereby reducing the maintenance cost. To effectively increase the ladle life, various innovative work practices have been brought to use for regular inspection of Torpedo ladle Refractory. At RSP, torpedo ladle management was introduced with a guarantee life of 1000 heats in Yr 2013. However, with adopted strategies such as Metal Heal Practice, Window repair concept, scheduling mid repairs and other practices RSP has not only been able to successfully stabilize of Torpedo Ladle in RSP for the first time but also have resulted in increasing life of Torpedo ladle with reducing maintenance cost. These practices have significantly helped RSP achieve highest life of 2865 heats on March 2024 and average life of 2466.6 heats in FY 2023-24, which is highest among all Steel Plants in India. RSP is marching ahead with the best Torpedo maintenance practices in its basket. Future of torpedo is not just in introducing the repair concepts, but also is in exploring the torpedo ladle refractory wear profile through laser scanner. The scanner can be used to ensure efficient and safe operation throughout its campaign, increasing availability of torpedo ladle for enhancing production availability, enhancing cost saving through energy conservation and material maintenance activity, enhancing refractory life-time and downsizing fleet size. The proactive step of exploring scanner usage in hot torpedo ladles is certainly expected to boost the cost saving in material consumption, maintenance consumption and energy conservation along with providing extra safe operation and ladle availability with prolonged refractory life.

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# Development of high performance refractory bricks suitable for critical area of Electric Arc Furnace

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## ABSTRACT

Alloy Steels Plant (ASP) of Steel Authority of India Limited (SAIL) is having facilities of making both stainless and non-stainless grades. ASP is having three nos. of Electric Arc Furnace (EAF), each having capacity of 50 Tons. Roof of the Electric Arc Furnace (EAF) is the most vulnerable area which generally decides availability of the furnace. It is evident from the operating condition of EAF and lining pattern of EAF roof that refractory of its roof should have high volume stability and high thermal shock resistance.

Suitable composition of high alumina brick for EAF roof was designed and different key properties like thermal shock resistance, Permanent Linear Change After Reheating (PLCAR), etc. were evaluated. It was found that properties of bricks with optimum amount of andalusite along with suitable sintering aid were most favourable.

Based on the study, brick was manufactured with developed composition and tried in EAF roof of Alloy Steels Plant (ASP), SAIL. It was found that developed bricks of EAF roof provided impressive performance throughout the campaign and also provide improved service life by around 1.5 times.

**Keywords:** EAF roof, High alumina brick, High thermal shock resistant brick, Volume stable brick.

## 1 INTRODUCTION

Alloy Steels Plant (ASP) of Steel Authority of India Limited (SAIL) has steelmaking facilities for stainless and non-stainless grades. ASP has three nos. of Electric Arc Furnace (EAF), each having capacity of 50 Tons.

The boundary of the EAF roof of ASP is made of water-cooled metal rings, and the refractory lining is done inside that ring using a template designed according to electrodes position in the furnace. Then Refractory lining of electrode holes is done by bricks. After that, lining of peripheral part of the roof is done with bricks. Finally, gaps between the brick lining of the central and peripheral parts filled with high alumina castable.

Under prevailing operating conditions of EAF, roof bricks need to sustain high thermal shock, abrasion and corrosion. The lining pattern demands that volume stability of refractories is a prerequisite for consistent operation. In the recent past, ASP was facing problems with the poor performance of EAF Roof Refractories due to its premature breakdown.

A study was undertaken to develop improved quality high alumina bricks for the EAF roof to enhance its performance and improve vessel availability.

The main objective of this work is to create or enhance the mullite bonding in the matrix of high alumina brick. Corundum bonding has very good refractoriness and abrasion resistance and mullite bonding has very good thermal stability and thermal shock resistance.

Hagen et al. indicate that Due to the presence of alumina and silica, Andalusite easily forms mullite when fired at high temperatures. Mullite has a high melting point at around 1850°C. It imparts high thermal shock resistance properties to high Alumina bricks. Transformation occurs through a dissolution-precipitation process inside Andalusite grains, starting from mineral inclusions and grain borders. Mineral inclusions seem to play a role in creating local melting that promotes mullite formation. Mullite precipitates during the process, and excess silica forms a liquid phase. Above 1280°C, this mineral yields 80% mullite and 20% silica glass<sup>[1]</sup>.

Okada et al.<sup>[2]</sup> and Ismail et al.<sup>[3]</sup> investigated mullite ceramics properties, structure, and synthesis. They reported some outstanding properties of mullite are low thermal expansion, low thermal conductivity, excellent creep resistance, high-temperature strength and good chemical stability. The mechanism of mullite formation depends upon the method of combining the alumina and silica-containing reactants. It is also related to the temperature at which the reaction leads to the formation of mullite<sup>[3-4]</sup>.

Generally, Andalusite decomposes as follows:

Andalusite ( $\text{Al}_2\text{O}_3\text{SiO}_2$ ) Mullite ( $3\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$ ) + Quartz glass ( $\text{SiO}_2$ ) +  $\Delta V$

Here,  $\Delta V$  is ~3–5.4% volume expansion caused by decomposition and subsequent phase transformation of quartz, resulting in micro-cracks within the matrix, which improves thermal shock resistance<sup>[1]</sup>.

The combination of corundum bonding and mullite bonding may benefit high alumina/ corundum brick.

## 2 EXPERIMENTAL

### 2.1 Raw Materials

Proper choice of raw materials is one of the most important criteria to obtain the desired property with optimum cost. Following raw materials were selected for experimentation.

#### *White tabular alumina*

White tabular alumina is produced by sintering alumina at very high temperatures. It has high density, low open and moderate closed porosity, high hardness, dimensional stability, high abrasion resistance, high thermal shock and creep resistance. Specification of white tabular alumina used for experimentation is given in Table – 1.

**Table – 1: Specification of White Tabular Alumina**

|                                                    |      |
|----------------------------------------------------|------|
| $\text{Al}_2\text{O}_3$ (Min.), %                  | 99.3 |
| $\text{Fe}_2\text{O}_3$ (Max.), %                  | 0.13 |
| $\text{Na}_2\text{O}+\text{K}_2\text{O}$ (Max.), % | 0.60 |
| Bulk Density (Min.)                                | 3.55 |

#### *Andalusite*

Specification of Andalusite used for experimentation is given in Table – 2. As mentioned earlier, it imparts excellent thermal shock resistance properties to refractory bodies.

**Table – 2: Specification of Andalusite**

|                                   |      |
|-----------------------------------|------|
| $\text{Al}_2\text{O}_3$ (Min.), % | 57   |
| $\text{Fe}_2\text{O}_3$ (Max.), % | 1    |
| Specific Gravity (Min.)           | 3.00 |

#### *Calcined alumina*

Calcined alumina used for experimentation is a highly pure micro-fine powder calcined at high temperatures. Specification of Calcined alumina used for experimentation is given in Table – 3.

**Table – 3: Specification of Calcined Alumina**

|                                                      |      |
|------------------------------------------------------|------|
| $\text{Al}_2\text{O}_3$ (Min.), %                    | 99.5 |
| $\text{Fe}_2\text{O}_3$ (Max.), %                    | 0.03 |
| $\text{Na}_2\text{O}$ (Max), %                       | 0.50 |
| $\text{SiO}_2$ (Max.), %                             | 0.03 |
| Average Particle Size d50 (Max.), $\mu$              | 5.5  |
| Specific Gravity (Min.)                              | 3.90 |
| Specific Surface Area (Max.), $\text{m}^2/\text{gm}$ | 3    |

### ***Calcined bauxite***

Calcined bauxite is a very important raw material for fired high alumina bricks. It is prepared by calcining natural bauxite at high temperatures. Specification of Calcined bauxite used for experimentation is given in Table – 4.

**Table – 4: Specification of Calcined bauxite**

|                                             |      |
|---------------------------------------------|------|
| Al <sub>2</sub> O <sub>3</sub> (Min.), %    | 87   |
| Fe <sub>2</sub> O <sub>3</sub> (Max.), %    | 2    |
| Na <sub>2</sub> O+K <sub>2</sub> O (Max), % | 0.30 |
| SiO <sub>2</sub> (Max.), %                  | 6    |
| TiO <sub>2</sub> (Max.), %                  | 4    |
| MgO (Max.), %                               | 0.4  |
| Cao (Max.), %                               | 0.4  |
| Bulk Density (Min.), gm/cc                  | 3.2  |

### ***Fused mullite***

Fused mullite is known for its high volume stability, high thermal shock resistance, high corrosion resistance, and high refractoriness. Specification of Fused Mullite used for the experimentation is given in Table – 5.

**Table – 5: Specification of Fused mullite**

|                                          |      |
|------------------------------------------|------|
| Al <sub>2</sub> O <sub>3</sub> (Min.), % | 70   |
| SiO <sub>2</sub> (Max.), %               | 29   |
| Fe <sub>2</sub> O <sub>3</sub> (Max.), % | 1    |
| Na <sub>2</sub> O (Max), %               | 0.60 |

### ***Special additive***

The special additive was used to impart plasticity in the green refractory body to facilitate brick manufacturing. It can also convert to mullite during the firing of refractory bricks. Specification of the special additive used for experimentation is given in Table – 6.

Molasses of specific gravity>1.4 was used as a green binder during refractory brick manufacturing.

### ***2.2 Development of improved quality EAF roof brick***

A detailed laboratory evaluation was done for development of improved quality EAF roof bricks. For experimentation, raw materials were taken in appropriate proportions and mixed in an intensive counter current mixer for around 10 mins. After that, 4-5% green binder was added and again mixed for another 15–20 mins. The green mix was then pressed at a specific pressure of 1 ton/cm<sup>2</sup>. The pressed bodies were air-dried for 24 hours and then dried in a dryer at 110°C for 24 hrs. Dried samples were fired at 1550°C with a soaking time of 3 hours.

Different properties like Apparent Porosity (AP), Bulk Density (BD), Cold Crushing Strength (CCS), Refractoriness Under Load (RUL), Repeat Permanent Linear Change After Reheating (Repeat PLCAR), and thermal shock resistance were evaluated for these samples.

AP was measured as per IS-1528, Part-VIII; BD was measured as per IS-1528, Part-XII; CCS was measured as per IS-1528, Part-IV; RUL was measured as per IS-1528, Part-II; thermal shock resistance was measured as per IS-1528, Part-III. Repeat PLCAR test was done by repeating the PLCAR test at 1550°C for 3hrs.

### 3 RESULTS

It was found from the existing refractory lining and operating practices that the refractory lining of the EAF roof is exposed to very high temperature, high thermal shock and high vibration (as it is retractable type), high corrosion (due to the presence of slag, metal and corrosive gases at high temperature).

Different properties of the developed bricks in the laboratory are shown in Table 7-10. The results of AP, BD, and CCS of the samples are very consistent and prove the sample's suitability as EAF roof refractory.

**Table – 7: AP and BD of samples**

| Sample ID                    | AP (%) | Avg. AP (%) | BD (gm/cc) | Avg. BD (gm/cc) |
|------------------------------|--------|-------------|------------|-----------------|
| After Firing at 1550°C 3hrs. |        |             |            |                 |
| 1                            | 19.74  | 19.44       | 2.64       | 2.63            |
| 2                            | 20.20  |             | 2.58       |                 |
| 3                            | 18.39  |             | 2.67       |                 |

**Table – 8: CCS of samples**

| Sample ID                     | CCS (kg/cm <sup>2</sup> ) | Avg. CCS (kg/cm <sup>2</sup> ) |
|-------------------------------|---------------------------|--------------------------------|
| After Firing at 1550°C/ 3hrs. |                           |                                |
| 1                             | 488                       | 482                            |
| 2                             | 492                       |                                |
| 3                             | 466                       |                                |

Other key properties like thermal shock resistance, RUL (Table – 9) and Repeat PLCAR (Table – 10) are also found within the acceptable range.

**Table – 9: RUL and thermal shock resistance of samples (Air quenching)**

| Sample ID | RUL (t <sub>a</sub> °C) | Thermal Shock Resistance (Cycles, Air Quenching) |
|-----------|-------------------------|--------------------------------------------------|
| 1         | 1650                    | 50+                                              |
| 2         | 1660                    | 50+                                              |
| 3         | 1660                    | 50+                                              |

**Table – 10: Repeat PLCAR of samples (at 1550°C for 3 hrs)**



| Samples | PLCAR-1 (%) | PLCAR-2 (%) | PLCAR-3 (%) |
|---------|-------------|-------------|-------------|
| 1       | 0.27        | 0.16        | 0.08        |
| 2       | 0.31        | 0.16        | 0.08        |
| 3       | 0.24        | 0.12        | 0.06        |

A higher RUL value shows higher strength of refractory at high temperature, and a lower Repeat PLCAR value ensures volume stability during operation. Accordingly, the final quality specification (shown in Table – 11) was formulated for bulk production and plant trial.

**Table – 11: Final quality specification**

| Parameters                                               | Value                                                                                                          |
|----------------------------------------------------------|----------------------------------------------------------------------------------------------------------------|
| Al <sub>2</sub> O <sub>3</sub> (Min.), %                 | 80                                                                                                             |
| Fe <sub>2</sub> O <sub>3</sub> (Max.), %                 | 2.5                                                                                                            |
| PCE (Min.), O.C.                                         | 38                                                                                                             |
| CCS (Min.), kg/cm <sup>2</sup>                           | 450                                                                                                            |
| RUL (t <sub>a</sub> Min.), °C                            | 1600                                                                                                           |
| AP (Max.), %                                             | 22                                                                                                             |
| BD (Min.), gm/cc                                         | 2.50                                                                                                           |
| Repeat PLCAR, %, at 1550 °C/3 hrs.                       | 1 <sup>st</sup> P.L.C.A.R.: ± 0.50<br>2 <sup>nd</sup> P.L.C.A.R.: ± 0.30<br>3 <sup>rd</sup> P.L.C.A.R.: ± 0.10 |
| Thermal Shock Resistance (Min. Cycles), By Air Quenching | 50                                                                                                             |

#### 4 PLANT TRIALS

Newly developed bricks were manufactured at the SRU unit of SAIL for lining the EAF roof of ASP, SAIL. Figure – 1 shows the refractory lining of the EAF roof in progress, and Figure – 2 shows the final stage of the EAF roof refractory lining with developed bricks.



Figure – 1: Refractory lining of EAF roof is in progress



Figure – 2: Final stage of EAF roof refractory lining

The refractory lining of the developed EAF roof achieved lining lives of 200, 146 and 133 heats, i.e. average 159.67 heats as against its average lining life of 100 heats of the earlier EAF roofs. These developed bricks reduced the cost of repair, increased furnace availability.

## 5 CONCLUSIONS

Following conclusions can be drawn from this present work:

- RDCIS and SRU jointly developed 80%  $\text{Al}_2\text{O}_3$  containing high alumina fired brick. This brick has high refractoriness, high corrosion and erosion resistance, high volume stability and thermal shock resistance.
- Permanent Linear Change after Reheating (PCLAR-1, 2, 3) for developed brick was found within 0.31, 0.16 and 0.08, respectively. This assures the high volume stability of the developed bricks. RUL ( $t_a$ , °C) value of around 1650 assures very high strength at elevated temperatures.
- Thermal shock resistance achieved more than 50 cycles of air quenching. This ensures the ability to withstand continuous heating and cooling effect on refractories due to EAF operation.
- The trial sets achieved an average lining life of 159.67 heats, around 59 % higher than the refractory lining life of the existing EAF roof.
- These developed bricks reduced the cost of repair, increased the furnace availability and also an in-house source for EAF roof lining is developed and may also use for other areas with similar operating condition.

## ACKNOWLEDGEMENT

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## Interaction Behavior between Slag Containing Cerium Oxide and MgO-C Bricks via X-ray Diffraction and Computed Tomography: A Scientific Investigation

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### Abstract

This study investigates the interaction between MgO-C refractory bricks and steelmaking slag with and without 5.59 wt% Ce<sub>2</sub>O<sub>3</sub> at high temperatures. Slag lacking cerium oxide displayed deeper penetration into the refractory material compared to cerium-containing slag. Understanding the interaction mechanism involved thermodynamic modeling using FactSage, X-Ray diffraction (XRD) analysis, and X-ray Computed Tomography (X-Ray  $\mu$ CT). FactSage traced phase evolution at 1400°C, while XRD identified phases post-interaction. X-Ray  $\mu$ CT illustrated that cerium-free slag penetrated up to 3mm into the brick wall, whereas Ce<sub>2</sub>O<sub>3</sub>-containing slag penetrated to a depth of 1.80mm. The heightened penetration of cerium-free slag was attributed to less stable oxides and a higher liquid phase fraction leading to a more vigorous reaction with MgO-C brick. The transformative effect of cerium oxide on low melting phases into stable and high melting rare earth phases like Vanadoandrosite was elucidated shedding light on its role in mitigating refractory penetration.

Keyword: Cerium oxide, Slag, MgO-C Bricks, FactSage, X-Ray  $\mu$ CT

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## Experience of TRM in Torpedo Ladle in BSL and BSP

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### Abstract:

SKG is involved in the Total Refractory Management of Torpedo Ladle lining in Bokaro and Bhilai Steel Plant. Presently five Torpedo cars lining and maintenance are being done by SKG in Bokaro steel plant and one Torpedo car lining and maintenance are being done in Bhilai steel Plant. This paper deals with the lining design, properties of the Refractory for different zone of the lining and the life obtained with intermittent repairing.

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## **Modified burner with engraved Precast refractory – A Refractory solution for ignition furnace of SP-2, DSP**

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### **Abstract:**

Sinter Plant -2 of Durgapur Steel Plant (DSP) equipped with 1 no. sinter machine of 180 m<sup>2</sup> sintering area (60m length, 3m width) along with 2 sinter machines of SP-1 feed sinter to 3 nos. of Blast furnaces(BF) at DSP. Sinter Plant Furnace Roof having curtain flame burners is made of High Alumina (90%) castable. The low life of the roof and burner is due to thermal spalling and peeling off castable. These cast roof and burner are transported after natural curing to sinter plant site. Chances of crack generation in the cast body increases during transportation leading to refractory failure. Also the tips of the curtain flame burners protected by refractory casting are more prone to failure due to crack generation and thermal spalling. With an objective to “Increase in roof and burner lining life from 6-7 months to 12 months” a user friendly in-situ mullite forming alumina silicate castable added with Stainless Steel fiber was selected for new designed refractory roof and prefabricated burner blocks for manufacturing at SAIL Refractory Unit (SRU); Ramgarh. New metallic burners were designed and procured. Installation of refractory beams of roof and burner sets was done during capital repairs of Sinter Plant. Replaced set of cast beams and burners attained more than 2 years of life.

Keywords: Key words: Andalusite, Sinter Plant

## **1 INTRODUCTION**

### **Basic Technology**

The term sintering denotes incipient fusion of iron ore particles at temperatures near their melting point, resulting in the formation of agglomerates. In sintering; heat is produced by combustion of solid fuels within moving beds of loosely packed particles, so as to agglomerate the loose particles, i.e. iron ore and other fines, into a hard, compact, lumpy, porous mass called sinter, which is used in BF as an iron bearing charge material. It utilizes the fines and waste material arising in iron ore mines and steel plants. In other words, Sintering is a technology for agglomeration of iron ore fines into useful BF burden material. This technology was developed for treatment of waste fines in the 1890s. Since then sinter has become the widely accepted and preferred BF burden material. Presently more than 70% of hot metal in the world is produced through the sinter. In India approximately 50% of hot metal is produced using sinter feed in Blast Furnace. The major advantages of using sinter in BF are:

- Utilization of iron ore fines, coke breeze, metallurgical wastes, lime fines and dolomite fines for hot metal production
- Better reducibility and other high temperature properties
- Increased BF productivity
- Improved quality of hot metal
- Reduction in coke rate in blast furnace

### **1.2 Sintering Process**

A Sinter Plant typically has the following raw materials:

Iron ore fines (-10 mm), Coke breeze (-3 mm), Limestone & Dolomite fines (- 3 mm) and metallurgical wastes like scale. The proportioned raw materials are mixed and moistened in a mixing drum. The mix is loaded on sinter machine through a feeder onto a moving grate (pallet) through segregation plate so that the coarse materials settle at the bottom and fines onto the top for better bed permeability. A large amount of heat has to be supplied during the process of sintering. At the same time, in order to ensure high productivity, the time for heating is kept as short as possible.



The melting of the particles is initially restricted to the upper layers of the bed. The top surface of the mix is ignited through stationary burners. As the pallet moves forward, the air is sucked through wind boxes situated under the grate. A high temperature combustion zone, with a temperature range of 1200 – 1300<sup>o</sup> C, is created in the charge-bed due to combustion of solid fuel of the mix and regeneration of heat of incandescent sinter and outgoing gases. The sintering layer travels vertically down. Most of the heat generated in the combustion zone is absorbed in the process of drying, calcining and preheating of the lower layers of the bed. Sinter is produced as a combined result of locally limited melting, grain boundary diffusion and re-crystallization of iron oxides. During the process, it is important that the heat of combustion zone passes through the bed as rapidly as possible. This requires a close match between heat transfer from the hot gases to the lower layers in the un-sintered portion of the bed and the rate of travel of the sintering machine. On completion of sintering process, finished sinter cake is crushed and cooled. The cooled sinter is screened and (+) 5 mm fraction is dispatched to BF and (-) 5 mm fraction is re-circulated as returned sinter.

### 1.3 Ignition of Sinter Mix

The ignition of charge exerts considerable influence on the whole sintering process. After the initial ignition, with the downward suction of air, high temperatures are reached in the combustion zone due to combustion of solid fuel of charge and regeneration of heat of the upper incandescent sinter and outgoing flue gases. In the initial stages of the process, the layer of hot sinter is absent which excludes the entry of regenerated heat from upper zone of heat transfer. Hence, in the upper elementary layers the deficiency of heat exists. This gap has to be bridged through the heat of ignition. The amount of heat supplied to the charge should be sufficient for making up the heat required for evaporation of moisture, preheating of the charge to the temperature of ignition of solid fuel and for sustaining the steady process in the upper part of the bed. Due to the endothermic reaction between carbon & carbon dioxide / moisture at elevated temperatures, some amount of heat is also absorbed. The physical–chemical processes of the charge determine the input of heat from ignition equipment also.

### 1.4 Ignition Systems

In the sinter plant, initial ignition of the sinter mix is accomplished through an ignition furnace, which is essentially an assembly of number of burners encased in a refractory hood. Three different types burners are normally used in sinter machines: wall mounted tube-in-tube burners generating long flame, wall mounted turbulent burners generating bushy flame and roof mounted flat flame burners generating flat flame almost attached to the roof. In all these burners heat transfer takes place basically through radiation. As a result, in order to avoid non-uniformity in heating, the flue products are allowed to touch the charge only after radiating most of the heat. Hence, all these three types of burners result in higher furnace height, longer furnace length, greater furnace temperature and consequently greater heat losses.

It has been reported that use of curtain flame ignition system has resulted in more than 30% reduction in energy consumption<sup>[1]</sup>. Moreover, all the above drawbacks of conventional ignition systems could be overcome to a considerable extent.

### 1.5 Curtain–flame Ignition Systems

The curtain flame burner system consists of a number of small capacity burners mounted on the roof of a low height furnace in a single row across the sinter bed, with small gap in-between. The flame configuration is such that there is continuity in the flame from one burner to another and it looks like a curtain. The flame hits the top of the sinter bed and heats the top of sinter charge mainly by convection.

### 1.6 Period of Ignition

Duration of ignition should correspond to the total time of preheating of charge of the upper layer to the temp of ignition of solid fuel and time of combustion of fuel particles, i.e. a function of combustion zone of fuel. It depends on size of coke and ore particles, reactivity of fuel, speed of air filtration etc. Increase in the ignition time affects the process in the following manner:

- a) Due to widening of the zone of high temperature, the gas permeability over the height of the bed is decreased and vertical speed of sintering is lowered.
- b) Strength of sinter in the upper part of cake is increased

### 1.7 Castables

Basic Requirement of Ignition furnace refractory must have good resistance to thermal shock, tensile & compressive strain at elevated temperature resulting from severe thermal gradients during service fulfilling the following:

- i) Low thermal expansion
- ii) Higher mechanical strength
- iii) Higher thermal shock resistance
- iv) Better chemical resistance against attack by scale
- v) L o n g e r

d u r a b i l i t y .

### 1.8 Conventional castables

Conventional castable are also called regular, classical castables and contains Calcium Aluminate Cement in the range of 15 – 40 wt% along with Alumina Silicate materials and aggregates. Total Alumina content ranges from 50 – 90 wt%. Water addition requirement ranges from 8 – 20 wt% for casting. It can be readily used as patching material and can be mixed easily on the ground, even if mixing machines are not available. Application of these castables is done where controlled pre-heating is not possible.

The conventional castable has significant high dried open porosity due to high percent of water added. On heating, hydraulic bond is destroyed & new mineral phases are formed. During this change, open porosity increases to about 15%. The porosity depends on content of cement and water added. Therefore, if water content can be reduced by careful selection of Calcium Aluminate Cement with optimized mineralogical content to achieve low Calcium / Alumina ratio, lowering of porosity is possible. At service temperature of about 1200°C, low melting phases of Calcium Alumina Silicates are formed & presence of this liquid phase reduces the thermo-mechanical performance & refractoriness. In purity cement CaO level will be as high as 3 – 4%.

Reduction in CaO content in Low Cement Castables by reducing cement quantity and filling the gap between cement & aggregates with fine powders of calcined & reactive alumina, microsilica, kyanite & andalusite helps in improving the particle packing efficiency and reduces formation of low temperature phases of Calcium Alumina Silicates, thereby favoring the development of mullite Alumino Silicates, which has good thermo-mechanical & refractory properties. Reduced lime content & fine oxide powders favor formation of fired bonding matrix giving improved hot strength, higher thermal shock resistance, lower porosity & increased corrosion resistance in comparison to conventional castables.

Ignition furnaces are one of the critical components for smooth and efficient operation of the sinter plants. Presently, 70% alumina LMC or 90% alumina conventional castable is being used. These castables starts falling from some undefined locations within 3-4 months of it application. In-depth literature survey was conducted for development and use of improved quality castable using andalusite as base raw material due to its certain advantages in the matrix and 60% alumina castable developed jointly by SRU, Ramgarh & RDCIS for some applications where thermal shock resistance is required.

A substantial increase in the performance of refractory castables has been obtained in the last three decades by reducing the content of calcium aluminate cement (CAC), in the range from 2 to 6 wt% or even its virtual absence in refractory castables. As a consequence, because of the resulting lower CaO contents in these castables matrices, a strong reduction in the amount of eventual liquid-phase development at high temperature could be achieved. In the search for refractory castables without cement for more demanding applications, the 'no cement' variety was developed using hydratable alumina, colloidal silica or colloidal alumina as binding agents. Therefore, the modern refractory castables are able to present creep and corrosion resistance similar to formed refractories of the same class<sup>[2,3]</sup> The advantage of using the hydratable alumina as a binder is that it does not need to be cured under high relative humidity. When hydratable alumina reacts with water, it forms a thick layer of pseudo boehmite gel

around the aggregates during the hydration process. Part of this gel is then transformed into boehmite ( $\text{Al}_2\text{O}_3 \cdot 2\text{H}_2\text{O}$ ) and crystalline bayerite ( $\text{Al}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$ )<sup>[4,5]</sup>. Aiming to obtain an overall improvement of properties; recently there has been a great interest in including nano particles of highly refractory oxides in ceramics. The introduction of nano-particles of refractory oxides in the matrix of advanced refractory castables can be considered a new route to improve physical and thermo-mechanical properties of these materials. Until now, the refractory oxide nano particles were generally added to castables either in powder form, or as colloidal suspensions of silica or alumina<sup>[6,7]</sup>. However, the use of the colloidal silica carries  $\text{SiO}_2$  to the castable matrix, forming low melting compounds other than mullite. In addition, the presence of silica is not desirable for several steelmaking processes. On the other hand, the use of colloidal alumina has some drawbacks such as not enough solid contents to provide strength and the need for drying over 50 °C to set and harden.

### 1.9 Advanced castable

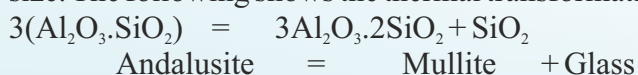
During the last few years, advances in refractory materials gave rise to castables containing less cement. Usually, either fume silica or alumina is used as super fines in the matrix to form mullite at high temperature. Mullite network formation improves the hot mechanical properties of the refractory castable. Other refractory raw materials such as andalusite are transformed into mullite at high temperature<sup>[8]</sup>. In recent publications, the potential of incorporating fine andalusite powder as a source of mullite was studied. The mullitisation of andalusite (so called primary mullite) also produces a certain amount of silica rich phase may react with alumina fines in the matrix forming a secondary mullite phase which is beneficial for increasing the hot properties of castables. After gathering this knowledge about andalusite, further studies have been carried out.

The chemical composition of andalusite is bi-oxides of aluminium and silicon:  $\text{Al}_2\text{O}_3 \cdot \text{SiO}_2$ . Because andalusite is a reactive mineral that transforms into mullite during temperature increase (above 1250°C), its properties change with temperature. Consequently, depending on the application, andalusite can be used directly as a refractory raw material without any thermal treatment (crude) or mullitisation (fired refractories). After mullitisation of andalusite, the excess of  $\text{SiO}_2$  content is transformed to glass and captured inside the mullite phase, while a small part of this glass is on the surface of the mullite crystal. The glass captured in the mullite phase is softened or fused and absorb the volume change of the mullite at high temperature. In this way, the mullite transformed from andalusite has more thermal stability than the other type of mullite. This softened glass can penetrate into possible crack fissures of mullite as a welding agent to repair the damaged mullite during the use. Andalusite has a higher refractoriness under load (RUL) and higher resistance to creep than other silico-alumina materials such as bauxite, chamotte etc<sup>[9]</sup>.

Arcelormittal (Bremen, Germany) has lined the skid pipe system in their walking beam furnace with a new concept of lining with pre-fabricated shells made of refractory castables, with the design of the shells adapted to conditions in the furnace. The layout and configuration of the shells is created using a modular concept in order to minimize the number of different parts and to allow easy installation<sup>[10]</sup>. One big advantage of this innovative modular installation concept using pre-fabricated parts, over an on-site castable installation, is significant reduction of installation time, typically around 75%. This reduces the shutdown time of the furnace and increases the productivity. Time consuming jobs such as installation of formats (moulds), mixing, transportation and installing of the castable on site and curing time before removing the formats can be eliminated. The insulating shells have a thermo-technically optimized sandwich design. Inside is a heat resistant metal sheet for attaching the shells on the pipes. The second layer is a blanket of high temperature insulation wool which is completely embedded in dense or lightweight refractory castable as the third layer on the hot face.

### 1.10 Thermal transformation of andalusite:

Andalusite will be transformed to mullite (80%) and silica glass (20%) at 1200-1400°C depending on the grain size. The following shows the thermal transformation process of 3 phases with rise of temperature:



During mullitisation of andalusite, the excess of  $\text{SiO}_2$  is transformed to glass; the majority of this glass is trapped



inside the mullite phase, while small part of this glass is on the surface of the mullite crystal. Kinetic study of the mullitisation of andalusite also reveals that the smaller the size of andalusite and the higher the temperature, the quicker the mullitisation<sup>[8]</sup>.

In the high temperature range, the glass phase softens or fuses inside the mullite which allows the absorption of the stress due to the volume change of the mullite with the temperature change. In this way, the mullite transformed from andalusite has more thermal stability than other types of mullite.

The glassy phase trapped inside mullite can act to repair the cracks that form due to thermal shock inside the mullite. This can be seen through microscopic pictures.

## 2 EXPERIMENTAL

### Designing of new metallic multi-slit burners and burner blocks

In the pre-modified burner design of burner module (Figure-3) there were 4 burners. In the new design (Figure-4) burners were reduced to three for increasing the impact area of flame and to make the curtain of the flame more thermal efficient. For protecting the impact area from direct hitting of flame and to create wider flame swirling design has been provided in the metallic burners.



Figure 3 : Pre-modified multi-slit burner module



Figure 4 : New designed multi-slit burner module



Figure 5 : New designed Refractory Burner blocks



Earlier in-situ casting was being done in the existing burners. Burner blocks were designed as per the new metallic burner (Figure-5). These burner blocks were cast at SRU, IFICO and after curing these were pre heated to 1450°C. Precast and pre-fired (PCPF) burner blocks were fixed in the metallic burners by eight no. of SS-310 pins provided in each burner. Due to PCPF quality, the damage during transportation was eliminated. During operation of ignition furnace; these burner blocks will exhibit minimum expansion avoiding the surface cracks to the burner blocks.

## 2.2 Designing of new refractory beams

Improper heat dissipation from the existing refractory beams, caused heating metallic structures of the beam, resulting in sagging and premature failure of beams as can be seen in Figure – 6. Heavy weight of beams along the furnace width also led to central sagging tendency which ultimately led to detaching of castable from metal structure.



**Figure 6 : Damaged beam**



**7 : New PCPF refractory beam**

Complete design of refractory beams were reworked and modified, so as to ensure more metal exposure to cooler environment (faster & more efficient heat dissipation). Furnace beams were redesigned with lesser metallic and refractory components as compared to existing beams, resulting in 30% reduction in beam weight per unit furnace length. (Figure – 7 & 8).



**Figure 8 : Precast prefabricated new refractory beams for burner**



### 3 RESULTS

Ignition furnaces are one of the critical components for smooth and efficient operation of the sinter plants. Presently, 70% alumina LMC or 90% alumina conventional castable is being used for casting of refractory beams of Sinter Plant. Falling of castable starts mainly from the middle portions within 3-4 months of its application. In-depth literature survey was conducted for development and use of improved quality castable using andalusite as base raw material due to its certain advantages in the matrix and developed a 60% alumina castable at SRU, IFICO, Ramgarh which has better thermal shock resistance than existing castable. Based on the test results the specification was finalised for andalusite based 60% alumina castable as per below Table 2:

**Table 2: Technical specification for andalusite based 60 % alumina castable**

| <b>Chemical analysis, % wt.</b>                                                                                                                                                        | <b>Values</b> | <b>RDCIS<br/>lab result</b> |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|-----------------------------|
| Al <sub>2</sub> O <sub>3</sub> , min.<br>(As per IS:12107 (Part 3):1987)                                                                                                               | 60            | 61                          |
| SiO <sub>2</sub> , max.<br>(As per IS:12107(Part 2):1987)                                                                                                                              | 35            | 35                          |
| Fe <sub>2</sub> O <sub>3</sub> , max.<br>(As per IS:12107(Part 6):1987)                                                                                                                | 0.90          | 0.90                        |
| CaO, max.<br>As per IS: 12107(Part 8): 1987                                                                                                                                            | 1.7           | 1.5                         |
| <b>Physical properties</b>                                                                                                                                                             |               |                             |
| B.D(gm/cc) after drying at 110°C/24h, min<br>(As per IS 1528(Part 12):2007/ISO 5016:1997)                                                                                              | 2.75          | 2.76 / 2.75                 |
| CCS(kg/cm <sup>2</sup> ) :<br>: after drying at 110°C/24h, min.                                                                                                                        | 275           | 320/310                     |
| :after firing at 800°C/3h, min.                                                                                                                                                        | 650           | 680/ 658                    |
| : After firing at 1400°C/3h, min.<br>(As per IS 1528(part 4): 1974)                                                                                                                    | 700           | 755/ 790                    |
| PLC (%) after firing at 1400°C/3h, max.<br>(As per IS 1528(Part 6):1974)                                                                                                               | ±1.0          | (+)0.15/ (+)0.11            |
| Spalling resistance of test blocks(50 x 50 x 50) mm<br>after pre-firing at 1000°C/3hrs ( No. of cycles after<br>firing at 1000°C for 15 minutes & quenching in<br>flowing water), min. | 10            | 20<br>(no crack)            |
| Grain size, mm                                                                                                                                                                         | 0-5           | 0.5                         |
| Water required for casting, %, max.                                                                                                                                                    | 5.0           | 4.5/ 4.8                    |

The developed castable was used for casting of one set consisting of five no's of refractory beams. The cast beams were dried and cured at DSP. Arrangements were made by tapping a gas pipe line which was placed around the cast beams for drying and curing. These properly cured refractory beams were installed along with existing burners during capital repair which has given the life of 30 months

The new designed metallic burners and pre-fired burner blocks along with five no. of new refractory beams were installed in SP-2 and it was replaced after 24 months.



## 5 CONCLUSIONS

Following conclusions can be drawn from this present work:

- Andalusite based 60% alumina castable was used for making refractory beams and burner blocks which exhibited better performance than existing castable.
- 1st set of refractory beam had performed for 30 months which is much better than the existing castable life of 3-4 months.
- It has been demonstrated that prefabricated refractory beams and newly designed burners can be successfully installed in the sintering machines resulting in better performance of ignition furnace with reduced production delay.

## ACKNOWLEDGEMENT

The authors thank the management of RDCIS for granting permission for publishing this paper. The taskforce wishes to record its gratitude to all the colleagues of RDCIS Durgapur RDCIS Plant Centre, SRU (IFICO), Ramgarh and Durgapur Steel Plant for all the help rendered by them for successful completion of this project

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## **Development of suitable castable for prefabricated refractory lining of Roof of Ignition Furnace at Sinter Plant-3, RSP**

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### **Abstract**

The roof and bull nose of discharging end of ignition furnace at sinter plant-3, RSP are failure prone area since inception. The roof and bull nose are made of high alumina castable. The cast roof is transported after natural curing to sinter plant site. Chances of crack generation in the cast body increases during transportation. Premature failure of roof may be due to thermal spalling of castable during operation resulting detaching of same. In order to improve refractory performance in the furnace, it has been decided for a prefabricated segmented replaceable roof of SP-3 ignition furnace using Andalusite based LC-70 castable with SS fibre reinforcement to have better volume stability and thermal shock resistance. Literature studies also reveal that Andalusite is known to be one of the best Alumino-Silicate refractory minerals due to its unique mineralogy like high purity, very high Mullite ( $3\text{Al}_2\text{O}_3, 2\text{SiO}_2$ ) content(>84%), very low thermal expansion and very high volume stability through secondary mullitisation. Accordingly, the castable was developed through several trials in our laboratory to get the desired properties. The developed castable has been used for casting of one set prefabricated segmented replaceable roof of SP-3 ignition furnace. The cast beams are under natural drying and will be taken into operation after curing as per prescribed heating schedule. This properly cured prefabricated segmented replaceable roof is expected to give a life of more than 12 months against the existing life of 6 to 7 months.

Key words: Andalusite, Mullite, Volume Stability, Sinter Plant

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## Use of special additive to reduce water demand of Trough Castable.

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### Abstract

SRU manufactures Al<sub>2</sub>O<sub>3</sub>-SiC-C system ultra low cement vibra flow castable for Blast Furnace Runner application. At present SRU is maintaining around 50 % in SAIL. Maintaining the guaranteed life of the Runners with more and more availability of the Runners for Hot metal production is demanded by the customers. One of the major factors of wear out of the castable is it's open pores after installation and handing over to operation. More water demand to place the castable during installation/ major repairs create more open pores which results in less campaign life. Apart from other aspects, the choice of deflocculant plays an important role Hence apart from other aspects SRU worked with deflocculant with an objective to reduce water demand without changing the particle size distribution and matrix composition.

Keeping all other Raw materials lot and addition percentage the same, water demand , flow value and setting behaviour was studied and compared with Trough castable made with existing additive system and a new deflocculant system , which is a polymer-based powder deflocculant on a calcium aluminate carrier, and the results were compared. Water demand was tested with 'Amil Mixer' and flow value was tested with ASTM C 230 Cone and strokes and the setting was observed by seeing the demouldingbehaviour in the laboratory. It was observed that water demand of the trough castable with new deflocculant was comparatively lower and other behaviours were comparable with the regular castable and trough castable made with the special deflocculant has the potential to increase campaign life of around 10% of hot metal throughput between two successive major repairs

Field trial was conducted and out of 3 major repairs done, in two cases the erosion rate was lower than the regular Trough Castable and in other one case the performance appeared equivalent.

It was concluded that replacing the existing deflocculant (STPP and Na salt of naphthalene sulfonic acid condensation product ) with special deflocculant (polymer-based powder deflocculant on a calcium aluminate carrier) reduces water demand and further bulk field trial is planned to be carried out to establish the potential of increase of campaign life of Blast Furnace Runners.

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## **Blast furnace refractories & cooling system – an integrated approach**

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### **Abstract:**

A blast furnace is a pressurized vessel inside which complex reactions occur simultaneously. Molten slag and iron at a very high temperature of 1400 °C -1500 °C together with streams of ascending gases and descending burden material in the form of abrasive solids form a very hostile environment inside the furnace. To sustain such environment, the blast furnace is refractory lined and water-cooled.

Blast Furnace is the established route for iron making. Today existing steel plants are looking for higher blast furnace productivity i.e. above 2, with campaign life of over 25 million tonnes throughput.

High furnace productivity has necessitated process intensification through higher blast temperature, high top pressure, oxygen enrichment & coal dust injection. Intensified furnace operation puts severe strain on its lining system.

These days' blast furnace operators are more concerned with achieving highest output per unit volume of furnace at minimum energy input to have hot metal at competitive cost. This necessitates rigorous but smooth operation and higher campaign life of blast furnace. To achieve the objective of higher productivity and longer campaign life, high quality refractory material and reliable cooling water system are the major requirements.

To sustain the modern operating practices and at the same time achieve extended campaign life of furnace, it is necessary to look into refractory & cooling system design as one entity.

This paper deals with considerations and trends in blast furnace lining & cooling systems with special reference to up-gradation programme of blast furnaces in SAIL.

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## **Slag Refractories Interaction in Pyro metallurgical process**

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*Khemka Refractories Pvt Ltd, Kamakhyanagar, ODISHA*

### **Abstract**

During pyro metallurgical extraction of metal refractories are subjected to different type of stresses like Mechanical, Thermal, Thermo-mechanical and Pyro-chemical. Deep understandings of these stresses are of paramount importance to achieve a optimum life of the refractories. In this paper slag refractories is discussed in Iron making, Steel making and copper making area which leads to corrosion of refractories leading to erosion.

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# Unlocking the power of machine learning: enhancing predictive analytics for price forecasting

## MJunction Services Limited

### **Abstract:**

For years, industries have relied on traditional methods for data analysis and decision-making. However, the explosion of data has created a demand for more sophisticated tools. This is where ML steps in. By learning from vast amounts of data, ML models can identify hidden patterns, make predictions, and automate tasks with remarkable efficiency.

Machine learning (ML) models have revolutionized numerous fields, offering powerful tools for prediction, classification, and automation.

One of the key strengths of Machine Learning is its ability to learn from data and improve over time. This iterative process results in models that continuously enhance accuracy and precision.

The impact of Machine Learning on industries is undeniable. It is reshaping business landscapes, driving efficiencies, fostering innovation, and enhancing customer experiences.

Determining the right price to buy is one of the most important call for any procurement function. This paper presents a validation study of a predictive price analytics model implemented for input materials (fuel) in the steelmaking industry. The model leverages predictive analytics techniques to forecast material prices, enabling proactive decision-making and cost optimization strategies. Through a comprehensive analysis of real-world data and industry-specific insights, this study aims to validate the effectiveness and utility of the predictive price analytics model in enhancing refractory spend management practices.

The paper begins by providing an overview of the challenges associated with refractory spend management in the steelmaking industry, including the volatility of raw material prices, the need for frequent replacements, and the impact on overall production costs. It then introduces the predictive price analytics model and its underlying methodologies, including historical data analysis, machine learning algorithms, and price forecasting techniques.

Subsequently, the paper presents a detailed case study of the successful implementation of the predictive price analytics model in a steelmaking facility. The case study examines the process of model development, implementation, and integration into existing refractory spend management practices. It highlights the model's ability to accurately predict refractory material prices, anticipate market fluctuations, and inform proactive procurement strategies.

Furthermore, the paper discusses the tangible benefits and outcomes achieved through the implementation of the predictive price analytics model. These include cost savings through optimized procurement decisions, reduced reliance on reactive purchasing practices, and improved budget forecasting accuracy.

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## **SAIL Refractory Unit (SRU), SAIL**

With its roots dating back to the establishment of Bharat Refractories Limited in 1978, SRU has emerged as a prominent entity in the realm of refractory manufacturing. The merger with Steel Authority of India Limited (SAIL) in 2007 marked a significant milestone, consolidating decades of expertise under one umbrella and catapulting SRU to the forefront of the industry. Today, SRU stands as one of India's largest manufacturers of refractories, serving diverse sectors through its extensive manufacturing and marketing network. Headquartered at Bokaro in the state of Jharkhand, SRU comprises several units equipped with a wide range of manufacturing facilities:

1. SRU, Bhandaridah
2. SRU, Ranchi Road
3. SRU, Bhilai
4. SRU, IFICO

The product mix at SRU encompasses a wide range of refractory materials tailored to various industrial applications:

1. Fireclay & High Alumina
  - Fireclay Bricks for ladles, dense quality for blast furnaces
  - High alumina bricks containing 45% to 88% alumina.
  - Mullite bricks for blast furnace application.
  - Alumina Silicon Carbide Carbon Bricks
  - Fireclay, high alumina mortar, conventional castables
2. Basic Refractories
  - Magnesite bricks with MGO 91%
  - Mag chrome burnt
  - Chrome mag burnt
  - Magnesia carbon bricks
  - Alumina Magnesia Carbon Bricks
  - Mortar, ramming mass, gunniting mass, patching mass
3. Special Products
  - Blast furnace cast house masses & castables
  - Slide gate refractories
  - Zircon refractories
  - Low cement castables & zero cement castables.





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## **Bokaro Steel Plant**

Bokaro Steel Plant - the fourth integrated plant in the Public Sector - started taking shape in 1965 in collaboration with the Soviet Union. It was originally incorporated as a limited company on 29th January 1964, and was later merged with SAIL, first as a subsidiary and then as a unit, through the Public Sector Iron & Steel Companies (Restructuring & Miscellaneous Provisions) Act 1978. The construction work started on 6th April 1968.

The Plant is hailed as the country's first Swadeshi Steel Plant, built with maximum indigenous content in terms of equipment, material and know-how. Its first Blast Furnace started on 2nd October 1972 and the first phase of 1.7 MT Ingot steel was completed on 26th February 1978 with the commissioning of the third Blast Furnace. All units of 4 MT stage have already been commissioned and the modernization taken subsequently has further upgraded this to 4.65 MT of liquid steel.

Bokaro is designed to produce flat products like Hot Rolled Coils, Hot Rolled Plates, Hot Rolled Sheets, Cold Rolled Coils, Cold Rolled Sheets, Tin Mill Black Plates (TMBP) and Galvanized Plain and Corrugated (GP/GC) Sheets. Bokaro Steel has provided a strong raw material base for a variety of modern engineering industries including automobile, pipe and tube, LPG cylinder, barrel and drum producing industries.

Bokaro Steel values its people as the fulcrum of all organisational activities. The saga of Bokaro Steel is the story of Bokaroans erecting a gigantic plant in the wilderness of Chotanagpur, reaching milestones one after another, staving off stiff challenges in the liberalised era, modernising its facilities and innovating their way to the top of the heap.

Bokaro Steel is working towards becoming a one-stop-shop for world-class flat steel in India. The modernisation plans are aimed at increasing the liquid steel production capacity, coupled with fresh rolling and coating facilities. The new facilities will be capable of producing the most premium grades required by the most discerning customer segments.

Brand Bokaro will signify assured quality and delivery, offering value for money to the customers.

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3. Special Products
  - Blast furnace cast house masses & castables
  - Slide gate refractories
  - Zircon refractories
  - Low cement castables & zero cement castables.

## The Institution of Engineers (India), Bokaro Local Chapter

The Institution of Engineers (India) is the largest multi-disciplinary professional body of engineers, established in 1920 with its Headquarters located in Kolkata and incorporated under [Royal Charter](#) on 9th September, 1935 by the then His Majesty of King George V. The Royal Charter endowed the Institution with the responsibility to promote the general advancement of engineering amongst its members and persons attached to the Institution. After Independence, the Institution is a "Body Corporate" protected under Article 372 of the Constitution of India. The Institution of Engineers (India) is administered by a National Council with the President as its Head.

The Institution has been serving the engineering fraternity for over a Century with its national and international presence through 125 Centres spread all over India, 6 Overseas Chapters, 7 Fora and an Organ namely [Engineering Staff College of India \(ESCI\)](#), Hyderabad. The Institution encompasses 15 (fifteen) engineering disciplines with a Corporate membership of over 2 lakhs.

IEI has been recognized as Scientific and Industrial Research Organization (SIRO) by the Ministry of Science & Technology, Govt. of India and besides conducting its own research, provides Grant-in-Aid to UG / PG / PhD students of Engineering Institutes & Universities.

The Institution of Engineers (India) is the first professional body to represent India in several International Bodies, such as the [World Mining Congress \(WMC\)](#), the [World Federation of Engineering Organizations \(WFEO\)](#), the '[Commonwealth Engineers Council \(CEC\)](#)', the [Federation International du Beton \(fib\)](#), and the [Federation of Engineering Institutions of South and Central Asia \(FEISCA\)](#). It also has bilateral agreements with a number of professional societies across the globe.

The Institution of Engineers (India) activities started at Bokaro phenomenally from 1975 when AMIE (Associate Member of Institution of Engineers) examination were conducted here in summer 1975 for the first time at the Training Institute of Bokaro Steel limited.

Bokaro started functioning as paper centre w.e.f. 07.07.1986 with a small strength of 168 engineers enrolled as members. Bokaro was upgraded from paper centre to Local Centre w.e.f. 01.04.1988 when membership strength raised to 600. This was unique achievement and landmark in the history of I.E.I. all over the country when a paper center was upgraded directly to Local Centre by passing the intermediate status of Sub-centre on the strength of increase in membership from 168 to 600 within a short period of two years due to vigorous membership drive.

Foundation stone for the Local Centre Building named as "Abhiyanta Bhawan" was laid on 20.02.1994 by Sri Brijlal Kshatriya, the then MD/BSL & Patron /IEI on the land allocated generously by BSL management in the Institutional Area Sector 5-A.

Bokaro Local Centre organized Engineers' Day function every year on 15th September in the Trg and Dev. Centre of BSL along with Technical Seminars on the respective Engineers' Day themes. Apart from the Engineers' Day function, Technical paper meeting, Annual General meeting & Get-togethers, were regularly organized.



## **Indian Ceramic Society, Bokaro Chapter**

Indian Ceramic Society (InCerS), a non-profit organization, was established in 1928 with the blessings and active support of Mahamana Pandit Madan Mohan Malaviya Ji, the main architect for establishing the Banaras Hindu University (BHU), Varanasi, and with the ardent efforts of a few dedicated leaders, namely, Sardar Krishen Singh (Inaugural Chairman), Mr T. W. Talwalkar (Inaugural Secretary), Mr Satyasundar Deb (First President), Dr N. N. Godbole (the then Pro-Vice-Chancellor of Banaras Hindu University), in the fields of ceramic industry and education. During the last seventy-seven years of its existence, the InCerS has grown from strength to strength under the guidance, patronage and leadership of several leading educationists, scientists, technologists and industrialists of the country who served the Society in different capacities. Presently, InCerS has more than 3000 members including foreign members, comprise a wide variety of individuals and interest groups that include scientists, engineers, researchers, manufacturers, plant personnel, educators, students, marketing and sales professionals, and others in related materials disciplines. The InCerS provides members and subscribers with access to periodicals and books, meetings and expositions, and technical information.

At present Indian Ceramic Society has 13 (thirteen) Local Chapters spread across the Country, Bokaro Chapter was inaugurated in 2022.

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# RHI Magnesita

## Company Profile

RHI Magnesita is the leading global supplier of high-grade refractory products, systems and solutions which are critical for high-temperature processes exceeding 1,200°C in a wide range of industries, including steel, cement, non-ferrous metals and glass. With a vertically integrated value chain, from raw materials to refractory products and full performance-based solutions, RHI Magnesita serves customers around the world, with around 16,000 employees in 47 refractory production sites, 8 recycling facilities and more than 70 sales offices. RHI Magnesita intends to build on its leadership in revenue, scale, product portfolio and diversified geographic presence to expand further in high growth markets.

With 7,000+ strong skilled workforce in 9 state-of-the-art manufacturing plants, 3 main offices, 30 site offices and a world-class R&D centre at Bhiwadi, RHI Magnesita has a strong presence in India. The company has manufacturing facilities strategically located across the country – Bhiwadi (Rajasthan), Jamshedpur (Jharkhand), Cuttack (Odisha), Rajgangpur (Odisha), Dalmiapuram (Tamil Nadu), Visakhapatnam (Andhra Pradesh), Khambhalia (Gujarat), Katni (Madhya Pradesh) and Bhilai (Chhattisgarh) – to serve its customers quicker and better.

The Group maintains a premium listing on the Official list of the London Stock Exchange (symbol: RHIM) and is a constituent of the FTSE 250 index, with a secondary listing on the Vienna Stock Exchange (Wiener Börse). The Indian entity of the Group company is listed with BSE: 534076 and NSE: RHIM.

For more information please visit: [www.rhimagnesita.com](http://www.rhimagnesita.com)



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## SARVESH REFRACTORIES: AT-A-GLANCE

**Sarvesh Refractories** is one of the leading manufacturers of refractories in India, having State-of-the-Art manufacturing facilities in Odisha. It caters primarily to the Iron & Steel Industry providing **Total Refractory Solutions for Steel Ladle, BOF Converter, EAF, Torpedo Ladle, Lime/Dolomite Kilns, Tundish**, etc. Major products include *Magnesia & Alumina Magnesia Carbon Bricks (AMC & Mag-C)*, *Alumina Silicon Carbide Carbon Bricks (ASC)*, *Alumina Spinel Bricks*, *Dolomite Refractories (Burnt & Unburnt)*, *Basic Bricks*, *Slide Gates*, *Purging Plugs*, *Pre-Cast Shapes*, *Basic & Alumina Monolithic*.

Furthering India's vision of being self-reliant under the **Make in India boost**, Sarvesh is only the 2nd producer in India of quality **Dolomite Refractories** that can substitute imports, thereby catering to the needs of Indian **Stainless-Steel makers** and for **Si-Killed Steel ladles**.

The production facility is equipped with latest generation machinery like SACMI Presses & Eirich Mixers, capable of producing high quality and sophisticated refractories catering to the demanding needs of quality Steel Making.

Sarvesh is one of the pioneers in Refractory Management at SAIL & RINL which includes supply, application & supervision/maintenance. Few major projects undertaken are as under:

- BOF Converter Management at RSP, BSL, BSP, DSP & VSP
- Total Ladle Management (Bricks + Slide Gates + Purging) at BSP, RSP & ISP
- Steel Ladle Management at BSL, RSP, DSP, ISP, ASP & RINL
- Operation Management (Slide Gate + Purging) at RSP & DSP
- Torpedo Ladle Management at BSL
- Tundish Management at BSL & RSP
- Lime Kiln Management at BSL
- AOD Vessel Lining at SAIL-ASP, LAXCON Steel

Sarvesh has also entered into a JV with South Korea's **Chosun Refractories** to manufacture *Tap hole clay (THC) Refractories for Blast Furnace*. The JV is in the process of setting up a new manufacturing facility in Odisha which will produce world-class THC in India for Indian Steel Makers.

Sarvesh is also at the forefront in enabling circular economy by incorporating use of recycling in their products. Circular economy is critical for the nation, especially when it comes to substituting imports. With indigenous production of Dolomite Refractories for Si-killed Steel ladles and Spinel Refractories for Al-killed Steel, Sarvesh is leading towards self-sufficiency by substantially reducing import dependencies.



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For decades, SKG has served as thought leaders and pioneers in refractory technology and services for the core sector. SKG offers an array of specially designed products and services, apart from customized services like design and turnkey solutions. All this - with an eye on assuring total quality, adherence to time schedule and value addition at each step. No wonder, when it comes to putting the heart and soul of their manufacturing plants in capable hands, most of the industry veterans turn to us.



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## Company Profile

**The leading manufacturing Company of quality Refractories with a capacity of 45000 TPA based in the central part of India at Nagpur(M.S.), Raipur (C.G.) and Salanpur (W.B.)**

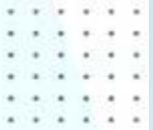
**We are an ISO 9001- 2015 certified company and it is our privilege to mention that we are the first Refractory Company in India to have ISO certification for entire range of Refractory as well as designing & refractory installation.**

A certain Product integrity is inbuilt into all our systems. Our R&D wing is genetically programmed to think out of the box to deliver customized solutions.

We take our customer's feedback to heart. Quite simply put, we don't rest till we don't improve upon existing processes in some way or the other. We take pride in saying that no two similar configurations in our product will actually be similar.

There will always be that little improvisation, that amount of lateral thinking that would be present in the final product. Continuous development of products is the sole motto at every level of our operation. By the trust that has been placed in us by our clients and our obsession with innovation and a penchant for quality, we have built up an undoubtedly long list of prestigious clientele from **Steel, Cement, Copper, Aluminium that includes all major business houses domestically, neighboring countries as well as from Middle East and Africa amongst overseas.**

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- Cast Products
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- Zirconia Nozzles
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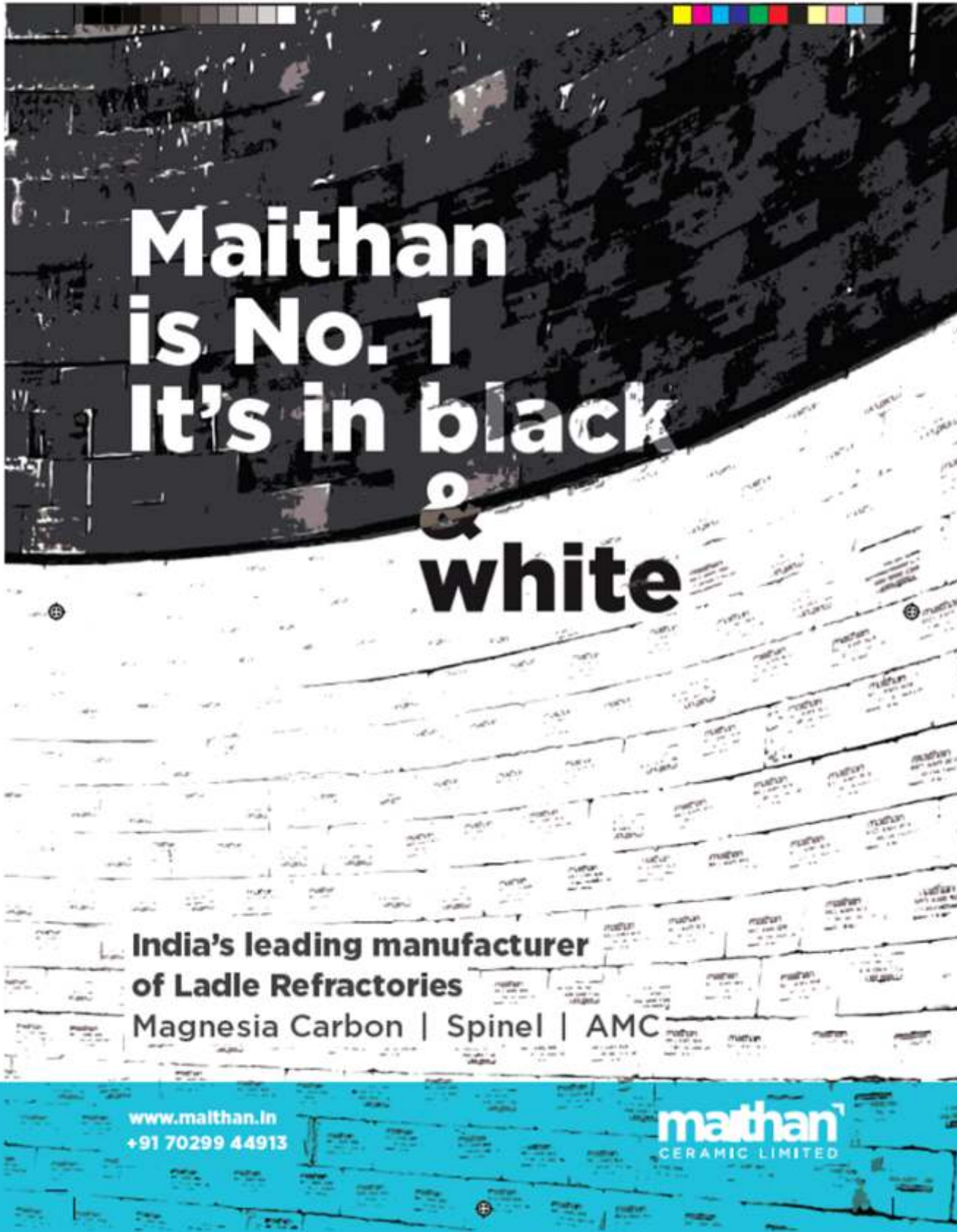


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## MAITHAN CERAMIC LIMITED

### COMPANY PROFILE

**Maithan Ceramic Limited (MCL)** is one of the leading refractory manufacturers of India, having a journey of more than 60 years. MCL is a one stop shop for multiple sectors requiring solutions for demanding applications, offering entire product spectrum from shaped to unshaped in Alumina, Basic and Special qualities.

Global leaders in Steel, Glass and Non-Ferrous Metals are our valued Customers. The manufacturing facility in India has a rated capacity of 120,000 MT per annum and has been completely modernized as recently as 2018.

#### **PRODUCT SPECTRUM: Alumina Bricks**

- High Super Duty
- Sillimanite Andalusite
- Mullite
- Corundum
- Bauxite
- Alumina Magnesia Spinel

#### **Basic Bricks**

- Magnesia
- Magnesia Chrome
- Spinel

#### **Carbon Bricks**

- Magnesia Carbon
- Alumina Carbon
- Alumina Magnesia Carbon
- Alumina Silicon Carbide Carbon
- Conventional Castables
- Low Cement Castables
- Ultra Low Cement Castables
- No Cement Castables
- Other Monolithics

#### **Basic Monolithics**

- Ramming Mass
- Gunning Mass
- Other Monolithics

#### **Special Refractories**

- Silicon Carbide
- Zircon Silicate
- Zircon Mullite
- Magnesia Zirconia
- Alumina Chrome

#### **AREA OF EXPERTISE:**

- Steel Teeming Ladle
- Torpedo Ladle Car
- Electric Arc Furnace
- Convertor
- Glass
- Lime Kiln
- Coke Oven
- Blast Furnace Stove
- Blast Furnace
- Pellet Plant

MCL always take a challenge to establish themselves as a credible channel partner to their customers ensuring best quality materials & services. MCL believe in establishing a long term partnership and endeavoring to become self-reliant (Aatma Nirbhar) through Make in India to accomplish the dream of our Prime Minister, Shri Narendra Modi.

MCL combine product customization and application knowhow to deliver a high degree of customer satisfaction.



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1. REFRACTORIES
2. FERROTRON
3. METALLURGICAL WIRE
4. PYROGENICS

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**Zircar Refractories Limited**

Zircar Refractories Limited (Zircar), an ISO 9001: 2015 certified company, is founded in 1996 has been started producing Silicon Carbide Crucibles in the beginning for non ferrous foundry industries. Soon Clay -Graphite Refractory Components like stopper head for ferrous foundries and Stopper and Ingate sleeve for Rail wheel Factory are being produced and supplying. It enjoys a broader customer base in the ferrous and nonferrous industries and has a wide and well established distributor/dealer's network across the globe. Company has started manufacturing Isostatic press Crucibles in 2017 and also started producing Isostatic Continuous Casting Refractories (CCR) for steel plants. Slide gate refractories (SGR) production line was also started in 2019.

Zircar has its plant , situated at Mehsana , in the state of Gujarat ( India ), 70 km away from Ahmedabad International Air port, having the state-of- the-art facilities to manufacture various types & sizes of Silicon Carbide Crucibles, Clay Graphite Isostatic Crucibles, Continuous Casting Refractories, Slide Gate Refractories and Monolithics which have been well accepted as a reliable product in India and overseas market. The Company plays a dominant role in domestic market to satisfy the demand of its Crucibles and other products. Besides, export of the Company's Refractory products are reaching the customers in more than 40 countries, such as Argentina, Australia, Bangladesh, Brazil, Bulgaria, Canada, China, Chech Republic, Egypt, Eritrea, France, Georgia, Ghana, Greece, Indonesia, Iran, Israel, Italy, Japan, Kenya, Kuwait, Lebanon, Malaysia, Morocco, Nepal, Nigeria, Oman, Peru, Poland, Qatar, Russia, Saudi Arabia, Singapore, South Africa, South Korea, Spain, Sri Lanka, Singapore, Sudan, Syria, Taiwan, Turkey, U.A.E., Uganda, Ukraine , USA etc.

The Company foresees a continuing and sustainable growth potential of its products in International market in the years to come.

Our Company is committed to provide high quality refractories in a geographical context of proximity for Asian, European , African Customers , the Middle East, US and neighboring countries at the complete cost.



## FOCUSING ON SUSTAINABILITY



# KROSAKI

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## **TRL KROSAKI REFRACTORIES LIMITED**

TRL Krosaki Refractories Limited (formerly Tata Refractories Limited) is a part of Krosaki Harima Group, Japan, one of the leading refractories manufacturers in the world. TRL Krosaki was incorporated in the year 1958 as a joint venture between Tata Steel Limited, India and Didier Werke, Germany under the name of 'Belpahar Refractories Limited'. Subsequently in 1986, the Company was rechristened as 'Tata Refractories Limited.' In 2011, Krosaki Harima Corporation, Japan acquired the majority of shares in the company, which helped the Company to access world class refractories technology for its long-term growth and was renamed as 'TRL Krosaki Refractories Limited'.

TRL Krosaki is the only refractory company in India which produces all types and kinds of refractories under one roof in its mother plant located at Belpahar, Odisha, India like Dolomite, Basic, High Alumina, Monolithic, Silica, Flow Control Products (FCP), Tap Hole Clay, RH Snorkel, Alumina Graphite refractories etc. It also has multiple operations facilities spread across the country in the states of Jharkhand, Tamil Nadu, Gujarat, and Madhya Pradesh. The company's Annual Revenue, at present, stands at around Rs. 2300 Crores.

TRL Krosaki is the sole manufacturer of Dolomite Refractories in India. The Tap Hole Clay, RH Snorkel and Alumina Graphite Refractories Plants are modern units with state of art facilities backed up by latest technology from Krosaki Harima Corporation (KHC).

TRL Krosaki, the premier Refractory Company in India, has been serving the customers from Steel, Cement, Glass, Copper and Aluminium industries both in India and overseas for more than 50 years now and is still growing stronger. With a staggering consolidated production capacity of over 4 lac MT per annum, the company also provides world class Technical Services to its customers in the form of Refractories Engineering Services and Technical Support Services.

TRL Krosaki is having a dedicated service team for extending the Technical support to Stainless Steel plants in India and abroad. This team is comprising of both Central Analytical & product development wings and Site services.

As a Refractories Company in India, TRL Krosaki has many Firsts to its credit, such as, it is the first Integrated Management System (IMS) certified Indian refractories company having certified to Quality Management ISO 9001:2015, Environment Management ISO 14001:2015, and Occupational Health and Safety Management ISO 45001:2018 Standards. It is also the first refractories Company in India to get certified to ISO/IEC 27001/2013 for information Security Management System. The most noteworthy achievement for TRL Krosaki is that it is the first & only Refractory Company in the World which is certified to Social Accountability standard, i.e., SA 8000: 2014. The company is having world class Technology Centre & a NABL certified Central laboratory with accreditation in accordance with ISO/IEC 17025:2017.

TRL Krosaki is the leader in safety and environmental management in the Indian refractory industry. The company has bagged numerous awards in recognition to its safety, health and environment management practices and outcomes in National, Regional and State Levels. A few of the recent awards won include Greentech Environment Management Award 2022, National Safety Award from the Government of India etc. As a responsible Corporate, TRL Krosaki is well known for its commitment to support the society under its CSR activities. This has earned many accolades & recognitions out of which the recent ones include Golden Peacock CSR Award 2021, and ICC Social Impact Award for the years 2022.

TRL Krosaki is committed for a sustainable tomorrow by taking active part in Make in India Initiatives.



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*With Best Compliment From :*



**RANCHI REFRACTORIES  
(INDIA) PVT. LTD.**

**ISO 9001:2015 & 14001:2015 Company**





# Rajhans Refractories Pvt. Ltd.

INNOVATION  
BEGINS  
WITH  
TRADITION



## PIONEERS IN:

### IRON & STEEL MAKING

- Bricks for Blast Furnace Proper & Stove
- Bricks & Castable for Rotary Kilns
- Coke Oven Refractories
- Continuous casting refractories
- Bricks & Castable for Rotary Kilns
- Total Laddle Management
- Bricks for reheating furnaces
- Refractories for Lime Kilns
- Refractories for converter

### NON-FERROUS INDUSTRIES

Refractory Solutions for

- Aluminium Industries
- Copper Industries
- Zinc & Lead industries
- Glass Industries
- Cement Industries
- Petrochemical Industries

## Our Product Range

- Fire Clay & High Alumina Bricks
- Mortar & Castable
- Sillimanite Bricks
- Mullite Bricks
- Silicon Carbide
- Basic Refractories 

## Our Valued Clients

- |            |                 |
|------------|-----------------|
| • NALCO    | • BSP           |
| • JSPL     | • JSW           |
| • HINDALCO | • RSP           |
| • SAIL     | • Danieli Corus |
| • BSL      | • Vizag Steel   |
| • DSP      | • Vendanta      |



### Works Office:

Rajhans Refractories Pvt. Ltd, P.O Katrasgarh, Rajganj Road,  
Dist: Dhanbad, Jharkhand -828114

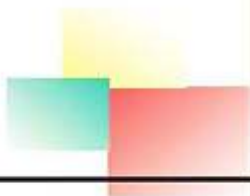
Phone: +91-8789491221, +91-326-2372460 / 301



[info@rajhansrefractories.com](mailto:info@rajhansrefractories.com)



[www.rajhansrefractories.com](http://www.rajhansrefractories.com)



# **CHAMPION CERAMICS PVT. LTD.**

(AN ISO 9001:2015 CERTIFIED COMPANY)  
**WIDE RANGE OF REFRACTORIES.**

**WE SERVE TO ALL REFRACTORY CONSUMING INDUSTRIES**



IRON AND STEEL PLANT



GLASS PLANT



COPPER PLANT



POWER PLANT



CEMENT PLANT



ALUMINIUM PLANT

**OUR PRODUCTS FOR REFRACTORY CONSUMING INDUSTRIES**



MAGNESIA BRICKS



HIGH ALUMINA



ACID RESISTANCE



CASTABLES



RAMMING MIXES



FLOW CONTROL



TUNDISH



SPECIAL REFRACTORIES



**CHAMPION**

## **CHAMPION CERAMICS PVT. LTD.**

(AN ISO 9001 : 2015 CERTIFIED COMPANY)

Manufacturers OF : Refractory Bricks, Basic Bricks, Acid Resistance Bricks/Tiles, Insulation Bricks, Mortars, Ramming Masses, Castables, Tundish Refractories & Other Refractory Products.

Industrial Area : Korba Road, P.O. CHAMPA - 495 671, Dist. Janjgir-Champa (C.G.)

Tel. (O) 07819-245693, Tele Fax : 07819-245761

E-mail : [championceramics@gmail.com](mailto:championceramics@gmail.com)

Website : [www.championceramics.com](http://www.championceramics.com)



## COSMOS POWER IN REFRACTORIES

### TOTAL REFRACTORY MANAGEMENT FOR

Ladle Furnace  
Electric Arc Furnace  
Basic Oxygen Furnace  
Blast Furnace  
Torpedo Ladle  
Charging Ladle  
Copper Converter  
Cement Rotary Kiln  
Lead Rotary Kiln  
Glass Furnace & So on

### PRODUCT RANGE

Magnesia Carbon Bricks  
Alumina Magnesia Carbon Bricks  
Magnesia Chrome Bricks  
Magnesite Bricks  
Alumina Bricks  
Silica Bricks  
Clay Bricks  
Well Blocks  
Seating Blocks  
Tap Hole Sleeves  
Nozzles  
Porous Plugs  
Slide Plates  
Monolithics & Castables

### GUARANTEE

Lowest Cost in the Market  
Best Quality  
Highest Life Guarantee  
Reduce Refractory  
Consumption Rate

### INDUSTRIES WE SERVE

Iron & Steel  
Cement  
Glass  
Non Ferrous like  
Copper / Nickle / Lead / Zinc / Tin  
& Other Metallurgical Industries

## KOSMOKRAFT REFRACTORY INDIA PRIVATE LIMITED

#### Registered Address:

NO.: 5/279, TEACHER'S COLONY, KANUVAI,  
COIMBATORE, TAMIL NADU, INDIA – 641108

#### Manufacturing Unit:

NO.: 5/196-1, PUKKULAM, VENASAPATTI ROAD,  
UDUMALPET, TIRUPPUR, TAMIL NADU, INDIA – 642154

#### Bokaro Branch Office:

PLOT NO.: 364, CO-OPERATIVE COLONY,  
BOKARO, JHARKHAND, INDIA – 827001

#### Mobile:

9886485653  
9334072414  
8102622018

#### E-Mail:

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[kosmokraft@hotmail.com](mailto:kosmokraft@hotmail.com)  
[kosmokraft@outlook.com](mailto:kosmokraft@outlook.com)  
[kosmokraft@yahoo.com](mailto:kosmokraft@yahoo.com)  
[Website:  
www.kosmokraft.com](http://www.kosmokraft.com)



# SAMWHA INDIA REFRACTORIES PVT.LTD.

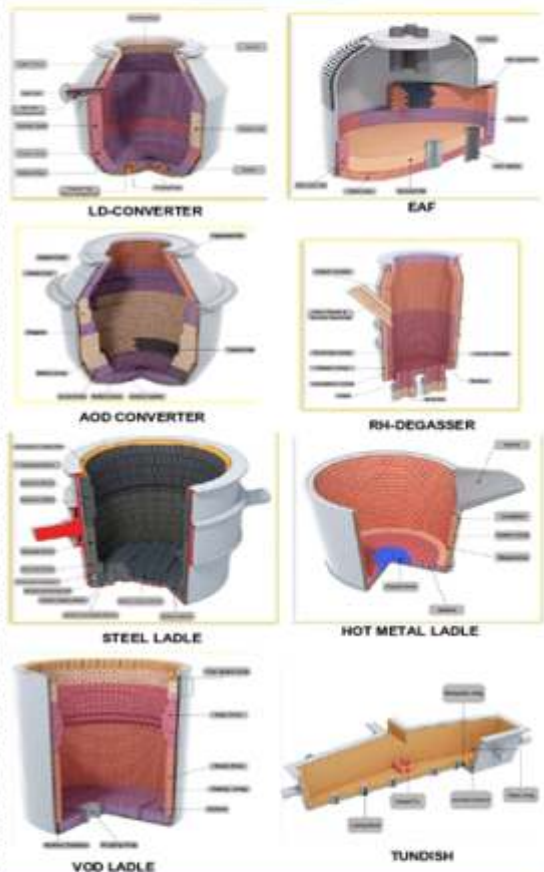
Specialist of Refractory and Best Partner of Steel



## PRODUCT PORTFOLIO



## SERVICE RANGE



## ACCOMPLISHMENTS

- JSL (Jajpur) - EAF - Capacity: 150 MT - Highest Record life till date: 827
- JSPL (Raigarh) - EAF - Capacity: 100 MT - Highest Record life till date: 912
- SAIL (Salem) - EAF - Capacity: 55 MT - Highest Record life till date: 233
- JINDAL STEEL (Angul) - EAF - Capacity: 250 MT - Highest Record life till date: 509
- JSPL (Raigarh) - EAF - Capacity: 100 MT - Highest Record life till date: 912
- JSW BPSL (Jharsuguda) - EAF - Capacity: 100 MT - Highest life till date: 529
- JSW BPSL (Jharsuguda) - EAF - Capacity: 70 MT - Highest Record life till date: 830
- GPH Ispat (Bangladesh) - QEAF - Capacity: 80 MT - Highest Record life till date: 552
- JSPL (Angul) - EAF (Delta Life) - Capacity: 250 MT - Highest Record life till date: 390
- JSPL (Raigarh)-EAF (Delta Life) - Capacity: 100 MT - Highest Record life till date: 1651
- JSL (Jajpur) - AOD - Capacity: 155 MT - Highest Record life till date: 236
- Viraj (Boisar) - AOD - Capacity: 30 MT - Highest Record life till date: 138
- Viraj (Boisar) - AOD - Capacity: 60 MT - Highest Record life till date: 137
- JSL (Hisar)AOD - Capacity: 50 MT - Highest life till date: 209
- GPH Ispat (Bangladesh)-TUNDISH-Capacity: 25 MT-Highest Record life till date: 1493
- GPH Ispat (Bangladesh) - Ladle - Capacity: 80 MT - Highest life till date: 171
- JSW (Vijayanagar)- SMS-1 Converter Capacity:130MT Taphole Sleeves- Highest life till date:171



## CLIENTELE

### Head Office



Samwha India Refractories Pvt. Ltd.  
D-192 Koelnagar, Rourkela-769014,  
Sundargarh, Odisha, India

### Manufacturing & Warehouse Unit



Kalajhar, Barapita, Mendhasala,  
Chandaka Rd, Khurda, Bhubaneswar-781315,  
Odisha, India

## CONTACT INFO.

- +91-6612952116
- headoffice@sirpl.in
- https://sirpl.in/



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D-192 Koelnagar, Rourkela-769014,  
Sundargarh, Odisha, India

Samwha India Refractories Pvt. Ltd.  
D-302 Nageswar Residency,  
Nandan Vihar, Patia, Bhubaneswar,  
751024, Khurda, Odisha, India

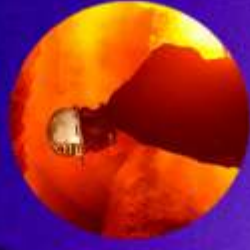




स्टील अथॉरिटी ऑफ इण्डिया लिमिटेड  
STEEL AUTHORITY OF INDIA LIMITED

बोकारो इस्पात संयंत्र  
BOKARO STEEL PLANT

हर किसी की  
जिन्दगी से जुड़ा हुआ है  
सैल . . .



*There's a little bit of SAIL in everybody's life*