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INDIAN REFRACTORY MAKERS ASSOCIATION

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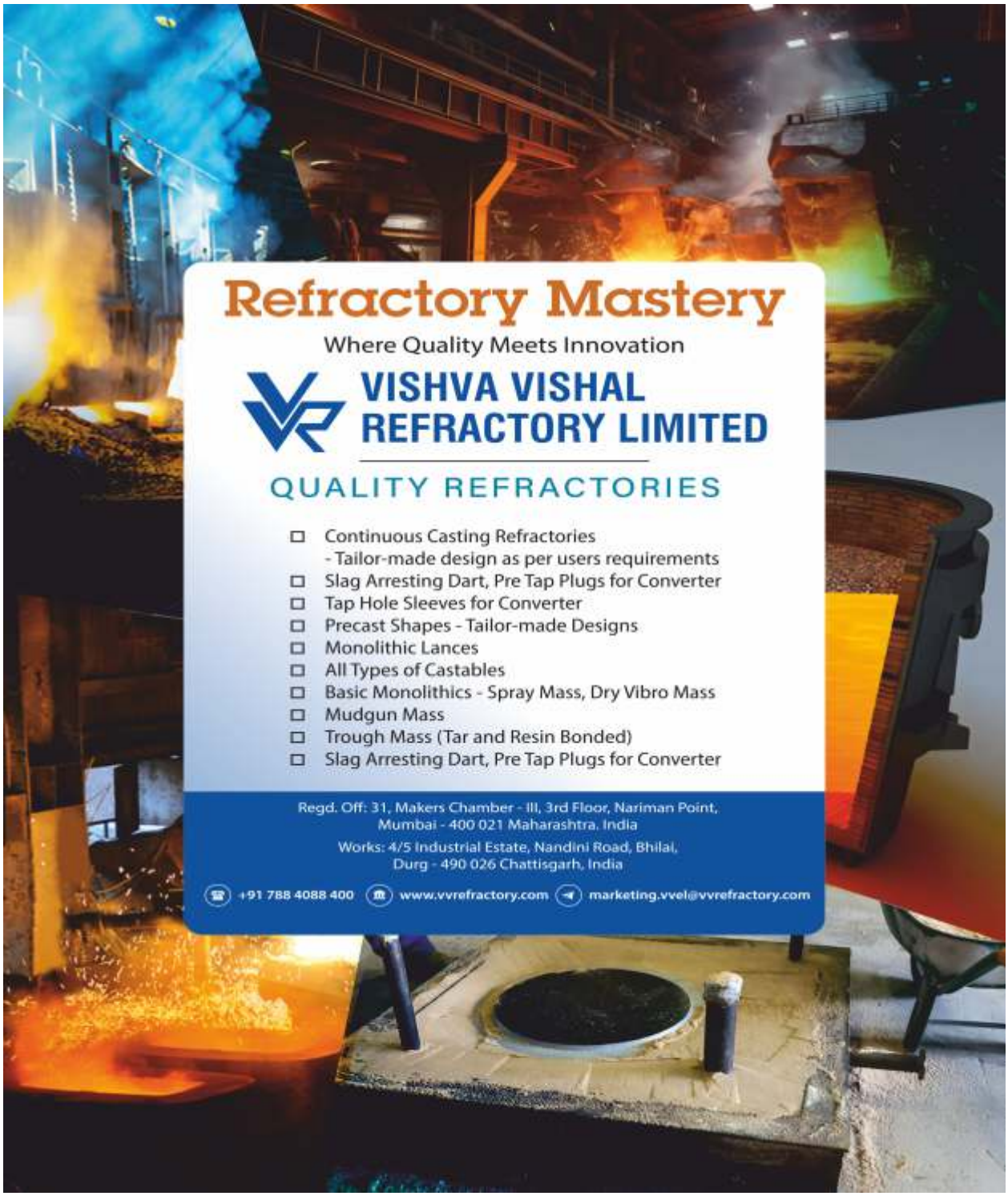
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MESSAGE FROM THE CHAIRMAN

Dear Colleagues,

It is imminent that global economy will slow down due to US led tariff war. This uncertainty in global trade policies throws up lots of challenges for the entire business fraternity in terms of sudden inaccessibility of some established markets, rise in container tariff while at the same time beckons for some rays of hope for the Indian manufacturing sector. India might be in a good position to replace China as USA's sourcing hub for value added engineering services, semiconductor and electronic items. However there is a word of caution for us refractory makers. Trump's tariff may open floodgate for cheaper Chinese imports into India and other markets of EU, SE Asia and Africa where Indian refractories have strong penetration.

Govt. of India is well aware of the possibilities of flurry of cheaper imports for which it has imposed a 12 per cent safeguard duty on non-alloy and alloy steel flat products. Yet the market situation is still pretty fluid for which we need to keep our fingers crossed.

Moving to the activities of our Association, I am proud to inform you that this year, we have decided to host a student IREFCON which is purely 'for the students, of the students and by the students'. The two-day long event will feature talks by industry experts, intensive technical training for the students as well as technical papers to be presented by the students. This will help us attract bright minds towards our industry which is facing an acute crisis of skilled manpower. Development of human resource has always been a core area of our activity and with this event we want to intensify IRMA's interface with students as well as the academic institutes.

Thanking you, one and all

Sunanda Sengupta
Chairman

ASSOCIATION ACTIVITIES

IRMA Board of Directors Meeting

IRMA Board of Directors meeting was held on 21st February 2025 at Hotel Vivanta by Taj, Kolkata under the chairmanship of IRMA Chairman Mr. Sunanda Sengupta. Issues discussed were collection of safety data for the industries, IRMA's future initiatives, student IREFCON and IREFCON 2026

Student IREFCON 2025

IRMA will be organizing a student IREFCON some time in October-November at Kolkata for the students of degree and diploma courses of ceramic engineering. The programme will comprise technical presentations by students, talks by industry experts as well as technical training programme by industry experts.

The Organizing Committee of Student IREFCON 2025 comprises:

- Mr. Jyotirmoy Bhattacherjee (Chairman) (RHI Magnesita India Ltd.)
- Mr. Amit Banik (TRL Krosaki Refractories Ltd.)
- Mr. Shishir Kumar Naik (IFGL Refractories Ltd.)

The first meeting of the Organizing Committee was held on 28th March 2025 under the chairmanship of Mr. Jyotirmoy Bhattacherjee. Issues discussed were programme outline, suggested faculties for the technical training programme, participating colleges, venue and the date of the event.

IN THE NEWS

Capacity of Indian Steel Industry

As per SAIL Chairman Mr. Amarendu Prakash, India is expected to surpass the 300 million tonnes (MT) steel capacity target by 2030 on the back of firm demand. Mr. Prakash said the number looked unrealistic when the national steel policy was launched in 2017 to scale up India's total steel manufacturing capacity to 300 million tonnes per annum. Last year, the Indian steel sector grew at 14 per cent against GDP growth of 6.5 per cent to 7 per cent. This year, in the first 10 months, it has grown by 11 per cent.

Tata Steel

Tata Steel has reported a 5 per cent fall in its consolidated steel production to 7.45 million tonnes (MT) for the last quarter of FY25, mainly due to ongoing transition at the company's operations in the UK. The company had produced 7.85 MT in the January-March quarter of the preceding 2023-24 fiscal, with 0.31 MT coming from the UK plant. In FY25, the consolidated steel production in India, the Netherlands, the UK and Thailand increased 3.53 per cent to 30.75 MT from 29.7 MT in FY24.

Arcelor Mittal Nippon Steel

The Andhra Pradesh Cabinet has approved a proposal for the establishment of a 17.8-million-tonne Arcelor Mittal Nippon Steel India (AM/NS India) steel plant worth Rs 1.35 lakh crore. The project will be executed in two phases, generating employment for 20,000 people by 2029. This is the first large greenfield plant to be set up in the country in nearly a decade, after the first phase of Tata Steel's Kalinganagar project was commissioned in 2016.

Rourkela Steel Plant

State-owned SAIL has plans to more than double the capacity of its Rourkela Steel Plant (RSP) to around 9 million tonne per annum at an investment of Rs 30,000 crore, a move which will

boost supplies to sectors like defence, oil & gas, automobiles among others. Post expansion, which will come up over an area of 1,200 acre, RSP will alone contribute around 25 per cent to SAIL's overall 35 million tonne per annum (MTPA) production capacity target by 2030.

Baldota Group

Karnataka based, Baldota Group plans to invest Rs 54,000 crore to set up an integrated steel plant with a production capacity of 10.50 million tons per annum in Koppal taluk, Karnataka. The new steel plant will be established under the name Baldota Steel and Power Limited (BSPL).

Bokaro Steel Plant

Govt. of India has announced a Rs. 20,000 crore expansion plan for the Bokaro Steel plant, Jharkhand, which will ramp up the unit's production capacity from 5.25 million tonnes per annum to 7.55 MTPA. Under the plan, a new blast furnace and other facilities will be built to facilitate the production expansion. "The plant is now set for a massive overhaul with a new 4500 cubic meter blast furnace, a thin slab casting and direct rolling facility, a calcining plant, a stamp-charged coke oven battery, and a sinter plant expansion.

OVERSEAS NEWS

RHI Magnesita

RHI MAgnesita has delivered robust margins, disciplined cost management, and progress on its strategic growth agenda. Revenue was €3,487 million (2023:€3,572), decreased by 2%. The financial performance was resilient considering the challenging end market conditions, which saw a decrease in sales volumes of 1% in the base business and 6% lower pricing. The contribution from M&A and operational efficiency delivered stable revenues and Adjusted EBITA of €407 million (2023: €409 million) with margin increasing to 11.7% (2023: 11.4%).

Shinagawa Refractories

The Shinagawa Group has agreed to acquire 60% of the issued share capital of Reframax Engenharia Ltda. (hereafter "Reframax"), a Brazil-based engineering company specializing in installation and other engineering services for refractories used in a wide variety of end-markets. The acquisition will be executed through a newly established Brazilian special-purpose subsidiary of Shinagawa. The transaction values Reframax at BRL 1,000 million on a debt-free, cash-free basis. Upon completion of the transaction, Shinagawa will indirectly hold 60% of the issued share capital of Reframax.

Rusal

Rusal has agreed to buy a 26% stake in Pioneer Aluminium Industries Limited, an Indian alumina refinery owner, for $243.75 million, with plans to increase its stake to 50% in stages. This move aims to reduce Rusal's reliance on third-party raw materials. The world's largest aluminum producer outside China, Rusal lost about 40% of its alumina supply after Australia halted exports to Russia and the company shut down its Ukrainian refinery.

Vesuvius Plc

The salient features of Vesuvius Plc's financial results for 2024 are:

- Revenue: UK£1.82b (down 5.7% from FY 2023).
- Net income: UK£87.2m (down 26% from FY 2023).
- Profit margin: 4.8% (down from 6.1% in FY 2023). The decrease in margin was driven by lower revenue.
- EPS: UK£0.34 (down from UK£0.44 in FY 2023).

Vesuvius has acquired Piromet, one of Turkey's leading mining technology companies. With this acquisition, Vesuvius aims to strengthen its position in the global steel and mining technologies market by expanding its operations in Turkey.

CREMER ERZKONTOR

CREMER ERZKONTOR has entered into a new partnership based on a long-term exclusive contract with The Alumina Industrial Company LLC (TAC) in the United Arab Emirates. Through this partnership, CREMER ERZKONTOR is taking its business "Beyond Trading" while ensuring the availability and high quality of critical products to key regions with a unique new source.

Imerys

Imerys reports its financial results for 2024, which shows that FY 2024 revenue at €3,605 million, up 1% organic growth versus last year.

For Q4 2024, it shows a 3.5% increase than that in Q4 2023 like-for-like, and the third consecutive quarter of organic growth. Continued volume recovery, driven by additional industrial capacities, new product launches and commercial actions were main drivers of growth. Other salient features are:

- FY 2024 adjusted EBITDA at €675 million, in line with guidance, with 11.4% growth versus last year like-for-like, and adjusted EBITDA in Q4 2024 up 13.9% vs Q4 2023 like-for-like.
- Improved adjusted EBITDA margin to 18.7% for 2024, +110 bps above last year, reflecting enhanced operating leverage and higher contribution of JVs.

MEMBERSCAN

Mahakoshal Refractories

Mahakoshal Refractories has been awarded the prestigious Ecovadis certification, recognizing its unwavering commitment to Environment, Labor & Human Rights, Ethics, and Sustainable Procurement.

IFGL Refractories Ltd

IFGL Refractories Limited reported earnings results for the third quarter and nine months ended December 31, 2024.

For the third quarter, the company reported sales was INR 3,788.4 million compared to INR 3,661.8 million a year ago. Revenue was INR 3,817.3 million compared to INR 3,703.4 million a year ago. Net loss was INR 21.8 million compared to net income of INR 15.2 million a year ago. Basic loss per share from continuing operations was INR 0.6 compared to basic earnings per share from continuing operations of INR 0.42 a year ago. Diluted loss per share from continuing operations was INR 0.6 compared to diluted earnings per share from continuing operations of INR 0.42 a year ago.

For the nine months, sales was INR 12,045 million compared to INR 12,455.5 million a year ago. Revenue was INR 12,182.3 million compared to INR 12,571 million a year ago. Net income was INR 345.5 million compared to INR 691.3 million a year ago.

TRL Krosaki Refractories Ltd

TRL Krosaki Refractories Limited has achieved the highest campaign life on pan-India basis in more than 300 MT capacity of RH Snorkel. "We have achieved an extraordinary milestone with our RH Snorkel campaign life, reaching an impressive 105 heats in a snorkel capacity of 310 MT at Tata Steel Kalinganagar", said the company in a statement.

OBITUARY

Mr. Kashi Prasad Jhunjhunwala, former IRMA Chairman (1983-1986) peacefully passed away on 25th March 2025. He was previously the Chairman at Orind Exports Ltd., and the Joint Managing Director at Orissa Industries Ltd. He obtained his undergraduate degree from Harvard University. He had left an indelible mark in the growth of Indian refractory industry and was the first company to initiate Indo-Chinese collaboration to bring in their latest products and technology to india. May His Soul Rest in Eternal Peace.

ECONOMY AT A GLANCE

BUDGET ESTIMATES 2025-26

* The total receipts other than borrowings and the total expenditure are estimated at Rs. 34.96 lakh crore and Rs. 50.65 lakh crore respectively.
* The net tax receipts are estimated at Rs. 28.37 lakh crore.
* The fiscal deficit is estimated to be 4.4 per cent of GDP.
* The gross market borrowings are estimated at Rs. 14.82 lakh crore.
* Capex Expenditure of Rs. 11.21 lakh crore (3.1% of GDP) earmarked in FY2025-26.

MSMEs AS THE 2ND ENGINE OF DEVELOPMENT

- Revision in classification criteria for MSMEs
- The investment and turnover limits for classification of all MSMEs to be enhanced to 2.5 and 2 times respectively.
- Credit Cards for Micro Enterprises
- Customized Credit Cards with ₹ 5 lakh limit for micro enterprises registered on Udyam portal, 10 lakh cards to be issued in the first year.
- Fund of Funds for Startups
- A new Fund of Funds, with expanded scope and a fresh contribution of ₹10,000 crore to be set up.
- Scheme for First-time Entrepreneurs
- A new scheme for 5 lakh women, Scheduled Castes and Scheduled Tribes first-time entrepreneurs to provide term-loans upto ₹ 2 crore in the next 5 years announced.
- A National Manufacturing Mission covering small, medium and large industries for furthering “Make in India” announced.

INVESTING IN THE ECONOMY

- Infrastructure-related ministries to come up with a 3-year pipeline of projects in PPP mode, States also encouraged.
- Support to States for Infrastructure
- An outlay of Rs. 1.5 lakh crore proposed for the 50-year interest free loans to states for capital expenditure and incentives for reforms.
- Asset Monetization Plan 2025-30·
- Second Plan for 2025-30 to plough back capital of Rs. 10 lakh crore in new projects announced.
- Jal Jeevan Mission
- Mission to be extended until 2028 with an enhanced total outlay.

URBAN CHALLENGE FUND

- An Urban Challenge Fund of Rs. 1 lakh crore announced to implement the proposals for 'Cities as Growth Hubs', 'Creative Redevelopment of Cities' and 'Water and Sanitation', allocation of Rs. 10,000 crore proposed for 2025-26.
- Nuclear Energy Mission for Viksit Bharat
- Amendments to the Atomic Energy Act and the Civil Liability for Nuclear Damage Act to be taken up.
- Nuclear Energy Mission for research & development of Small Modular Reactors (SMR) with an outlay of Rs. 20,000 crore to be set up, 5 indigenously developed SMRs to be operational by 2033.
- The Shipbuilding Financial Assistance Policy to be revamped.
- Large ships above a specified size to be included in the infrastructure harmonized master list (HML).

MARITIME DEVELOPMENT FUND

A Maritime Development Fund with a corpus of Rs. 25,000 crore to be set up, with up to 49 per cent contribution by the Government, and the balance from ports and private sector.

UDAN - REGIONAL CONNECTIVITY SCHEME

- A modified UDAN scheme announced to enhance regional connectivity to 120 new destinations and carry 4 crore passengers in the next 10 years.
- Also to support helipads and smaller airports in hilly, aspirational, and North East region districts.

MINING SECTOR REFORMS

- A policy for recovery of critical minerals from tailings to be brought out.

SWAMIH FUND 2

- A fund of Rs. 15,000 crore aimed at expeditious completion of another 1 lakh dwelling units, with contribution from the Government, banks and private investors announced.
- Tourism for employment-led growth
- Top 50 tourist destination sites in the country to be developed in partnership with states through a challenge mode.

INVESTING IN INNOVATION, RESEARCH, DEVELOPMENT

- Rs. 20,000 crore to be allocated to implement private sector driven Research, Development and Innovation initiative announced in the July Budget.
- Deep Tech Fund of Funds to be explored to catalyze the next generation startups.
- 10,000 fellowships for technological research in IITs and IISc with enhanced financial support.

- Gene Bank for Crops Germplasm
- 2nd Gene Bank with 10 lakh germplasm lines to be set up for future food and nutritional security.
- A National Geospatial Mission announced to develop foundational geospatial infrastructure and data.

EXPORTS AS THE 4TH ENGINE OF DEVELOPMENT

- An Export Promotion Mission, with sectoral and ministerial targets, driven jointly by the Ministries of Commerce, MSME, and Finance to be set up.
- BharatTradeNet' (BTN) for international trade to be set-up as a unified platform for trade documentation and financing solutions.
- National Framework for GCC

TDS/TCS rationalization for easing difficulties

- Rationalization of Tax Deduction at Source (TDS) by reducing number of rates and thresholds above which TDS is deducted.
- The limit for tax deduction on interest for senior citizens doubled from the present Rs 50,000 to Rs 1 lakh.
- The annual limit of Rs 2.40 lakh for TDS on rent increased to Rs 6 lakh.
- The threshold to collect tax at source (TCS) on remittances under RBI's Liberalized Remittance Scheme (LRS) increased from Rs 7 lakh to Rs 10 lakh.
- The provisions of the higher TDS deduction will apply only in non-PAN cases.
- Decriminalization for the cases of delay of payment of TCS up to the due date of filing statement.

Reducing Compliance Burden

- Reduction of compliance burden for small charitable trusts/institutions by increasing their period of registration from 5 years to 10 years.
- The benefit of claiming the annual value of self-occupied properties as nil will be extended for two such self-occupied properties without any condition.

Ease of Doing Business

- Introduction of a scheme for determining arm's length price of international transaction for a block period of three years.
- Expansion of the scope of safe harbour rules to reduce litigation and provide certainty in international taxation.
- Exemption of withdrawals made from National Savings Scheme (NSS) by individuals on or after the 29th of August, 2024.
- Similar treatment to NPS Vatsalya accounts as is available to normal NPS accounts, subject to overall limits.

Employment and Investment

Tax certainty for electronics manufacturing Schemes

- Presumptive taxation regime for non-residents who provide services to a resident company that is establishing or operating an electronics manufacturing facility.

- o Introduction of a safe harbour for tax certainty for non-residents who store components for supply to specified electronics manufacturing units.

Tonnage Tax Scheme for Inland Vessels

The benefits of existing tonnage tax scheme to be extended to inland vessels registered under the Indian Vessels Act, 2021 to promote inland water transport in the country.

Extension for incorporation of Start-Ups

Extension of the period of incorporation by 5 years to allow the benefit available to start-ups incorporated before 1.4.2030.

Alternate Investment Funds (AIFs)

INDIRECT TAX

Rationalisation of Customs Tariff Structure for Industrial Goods

Union Budget 2025-26 proposes to:

i. Remove seven tariff rates. This is over and above the seven tariff rates removed in 2023-24 budget. After this, there will be only eight remaining tariff rates including 'zero' rate.

ii. Apply appropriate cess to broadly maintain effective duty incidence except on a few items, where such incidence will reduce marginally.

iii. Levy not more than one cess or surcharge. Therefore Social Welfare Surcharge on 82 tariff lines that are subject to a cess, exempted.

Certainty of taxation on the gains from securities to Category I and Category II AIFs which are undertaking investments in infrastructure and other such sectors.

- **Extension of investment date for Sovereign and Pension Funds**

Extension of the date of making investments in Sovereign Wealth Funds and Pension Funds by five more years, to 31st March, 2030, to promote funding from them to the infrastructure sector.

Trade facilitation

- **Time limit for Provisional Assessment**:
  - o For finalising the provisional assessment, time-limit of two years fixed, extendable by a year.
- **Voluntary Compliance:**
  - o A new provision introduced to enable importers or exporters, after clearance of goods, to voluntarily declare material facts and pay duty with interest but without penalty.
- **Extended Time for End Use**:
  - o Time limit for the end-use of imported inputs in the relevant rules extended from six months to one year.
  - o Such importers to file only quarterly statements instead of a monthly statement.

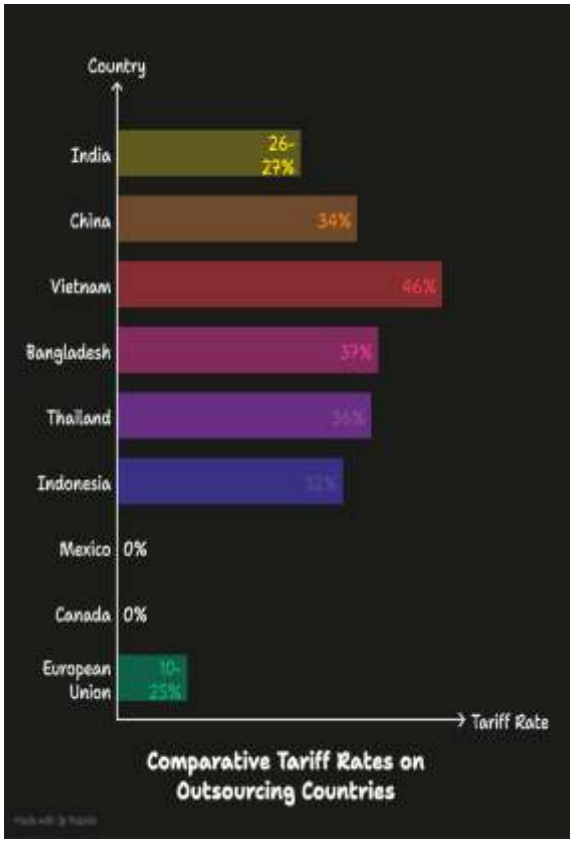
BUSINESS SECTION:

IMPACT OF DONALD TRUMP'S TARIFF POLICIES ON GLOBAL ECONOMY

Introduction

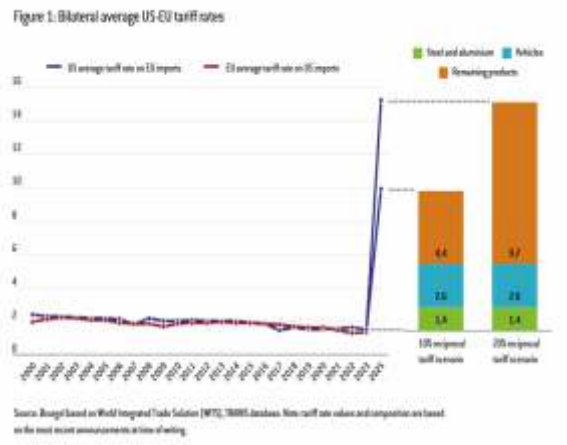
The global business fraternity is navigating a wave of uncertainty as US President Donald Trump's new tariffs reroute trade flows, raise concerns about rates volatility, change the established demand-supply linkages and stir uncertainty on transport demand.

Donald Trump's baseline tariffs of 10 per cent on many countries' imports into the US has come into effect, triggering customs agents' collections at airports, seaports and customs warehouses across the US. Higher levies on goods from larger trading partners are scheduled to start on April 9.



The economic impact of Trump's tariffs on Europe & China: an initial assessment

The EU and US do not have a free trade agreement (FTA) and until now have traded under the most-favoured nation (MFN) tariffs they offer to all World Trade Organisation members. Figure 1 shows the average tariffs rate on EU-US trade since 2000 (weighted by trade volumes) and the expected average level of the US tariffs on the EU announced by Trump.

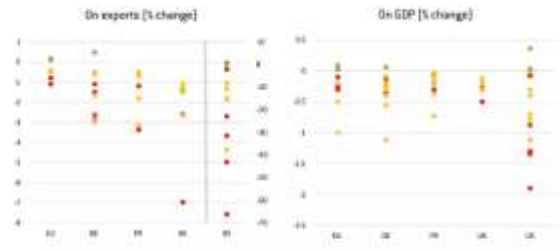


Before the trade war, the average US tariff rate on imports from the EU was 1.47 percent, while on EU imports from the US it was 1.35 percent. Based on 2023 trade volumes, full implementation of Trump's tariffs (Figure 1) would raise the average tariff rate on imports from the EU to 15.2 percent. Most of this comes from the 20 percent 'reciprocal' tariff on most products (9.7 of an increase of 13.7 percentage points), while tariffs on steel and aluminium (1.4 percentage points) and vehicles (2.6 percentage points) contribute relatively little. Tariff exemptions at time of writing for some goods (mainly pharmaceuticals and

electronic products such as smartphones) reduce the average tariff rate somewhat.

Beyond the direct impacts of the tariffs on EU GDP, the astronomical tariffs on China could lead to diversion of Chinese goods from the US to the EU, a pattern observed during the 2017-2019 US-China trade war (Evenett and Espejo, 2025). An inflow of Chinese goods would put pressure on domestic manufacturers insofar as the same goods are produced within the EU. However, even before Trump's latest tariff announcements there were already relatively high US tariffs on many Chinese products and only 13.5 percent of Chinese exports go to the US.

Figure 2: Long-run impact estimates of tariff scenarios



Source: Bruegel based on Felbermayr et al (2024), Boulet et al (2024), Goldman Sachs (2024), Du and Shepotylo (2025) and McKibbin and Noland (2025). Note: colours represent scenarios: green = US-EU deal on manufacturing or agriculture; orange = unilateral US tariffs; red = retaliation by US partners.

Figure 2 plots the relationship between Chinese exports to the US and the ratio of Chinese exports to the US to EU exports to the world, as a proxy for the extent to which Chinese goods that could potentially be redirected to EU are produced in the EU. The further to the right a product category is on the x-axis, the more disruptive the impact of a Chinese trade diversion to Europe. The higher a product category on the y-axis, the greater the value of the trade flow that could shift towards the EU.

The salient features of the market volatility are:

- Stock market volatility was among the first visible consequences. Hang Seng fell by over 13%, Nikkei by 8%, and Kospi by 5.6%.
- Indian markets were hit with Sensex and Nifty fell ~3%, eroding investor wealth by over Rs. 20 lakh crore.
- European and US markets also experienced wild swings, reflecting heightened uncertainty.
- Brent crude prices dropped over 15% in April, reflecting slowed demand expectations due to trade disruptions.
- Gold has crossed the much-anticipated Rs 1 lakh milestone in the retail market, suggesting risk aversion and a flight to safety by investors.

Impact on India

India's 27% tariff position sits in the middle range of Trump's global tariff strategy. Significantly higher rates have been imposed on major exporters including China (54%), Vietnam (36%), Thailand (36%), and Bangladesh (37%). This stepped approach creates a complex new competitive landscape that may inadvertently benefit India in certain sectors relative to these more heavily tariffed countries. The immediate short-term losses in market capitalization (₹20 lakh crore) reflect India's vulnerability to global shocks which by all possible means is a natural outcome in the era of globalization.

India could potentially benefit from shifting global supply chains to its own soil, but only if it reforms its trade infrastructure. However, in the short term, currency depreciation, capital outflows, and higher input costs could hurt Indian industries.

Yet there are silver linings as well. China now faces up to 245% tariffs on imports to the US because of its retaliatory tariffs. The latest additional tariffs came after China ordered its airlines not to take any further deliveries of Boeing jets in response to the earlier US decision to impose 145% tariffs on Chinese goods. This means neither of the two countries is ready to blink, hinting at prolonged tensions, a golden time when India can ramp up its manufacturing to tap new export opportunities created by Trump tariffs.

As per Economic Times, India has identified at least 10 sectors, including apparel and clothing accessories, chemicals, plastics and rubber, where high US tariffs give New Delhi a competitive advantage in the American market over other suppliers. The US imports electronics worth $900 billion, of which China's share is over 50% against India's 7%, again giving scope to New Delhi to increase shipments. Imposition of steep tariffs on China by the US could help Indian products from sectors such as textiles, leather, engineering, and electronics become more competitive in America, think tank GTRI has said. As per industry body ICEA, export of iPhones, smartphones, tablets, laptops from India to the US will be cheaper by 20 per cent compared to those from China following the exemptions given by the Trump administration. The US government soon after amended its tariff order to exempt smartphones, tablets, laptops, and some other electronic devices from the new taxes.

CONCLUSION

The international trade landscape has seen major disruption in recent weeks, largely due to a growing tariff war triggered by new U.S. trade measures. As countries respond with their own tariffs, the situation is escalating quickly, adding complexity to global commerce. These developments are already having a knock-on effect across supply chains worldwide, placing increased pressure on freight movements, customs processes, and logistics planning.

The minimum 10 per cent reciprocal tariff on all exports to the US, with additional levies that are set to bring total tariffs up to 54 per cent for China, will hurt demand for cargoes from key trading partners including China, Vietnam, Japan, South Korea and Taiwan, which in turn could hit freight rates and earnings of shipping companies such as NYK, Cosco, Maersk and others in coming quarters, according to Bloomberg Intelligence analysts. This will certainly hurt the interest of the refractory industry which is dependent on imported raw materials.

To sum up, the trade war marks a possible shift toward a neo-mercantilist global economy, driven more by national interest than global cooperation.

With rules-based trade under threat, countries must act prudently to safeguard economic stability, uphold open trade norms, and restructure global alliances.

India is at an advantageous position because its economy is driven more by internal consumption than by export. However, possibility of cheaper imports from China and South East Asia looms large amidst this trade doldrum.

TECHNICAL SECTION

BROWN FIELD CHANGE TO GREEN STEEL MAKING

Marcel Peekel, Ana Gouveia Gil Tata Steel, IJmuiden, the Netherlands

ABSTRACT

Tata Steel in the Netherlands has committed to produce clean, green and circular steel by 2045. The current production process will undergo extensive changes including the replacement of blast furnaces and enabler utilities by EAF, DRP and/or REF units. Consequently, current facilities and installations will need to be modified to meet the future production process requirements. In this paper, the key challenges are described as well as the strategies followed to mitigate the effects of changes in production process on steel ladle refractory wear.

1. GREENIFICATION STRATEGY

The Paris Climate Agreement of 2016, which set the goal of reaching CO_2 neutrality by 2050, has driven the Dutch government to set a target of reducing the CO_2 emission by 60% by 2030. Similarly, Tata Steel (TSN) has devised a plan to reach CO_2 neutrality by 2045. The key change for TSN is to evolve from the conventional hot metal and steel production processes towards sustainable alternatives (Figure 1). Therefore, the combination of the sinter plant. cokes plants and blast furnaces (BF), which are responsible for the majority of the CO_2-emission, must be replaced.

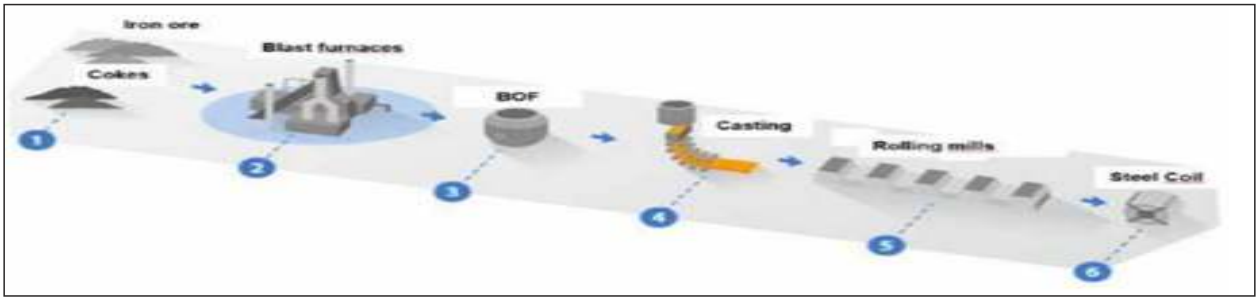


Figure 1- Schematic diagram of the current brown-field process lay-out of TSN.

The transition to green and circular steel will be performed in two phases. Phase 1 consists of replacing one blast furnace and one coke plant by a combination of Electric Arc Furnace (EAF) and a Direct Reduction Plant (DRP). A reduction in CO_2 emission of 40% can then be reached and is set to be completed by 2030. In phase 2, the second blast furnace will be shut-down and replaced by an additional DRP or an Electric Iron Smelting Furnace. A step further to CO_2 neutrality is then taken by 2035. Subsequently, several other measures within the production site (including circularity) will be implemented to reach CO_2 neutrality in 2045. Maintaining a sustainable greeniflcation will lastly require green energy such as green power and hydrogen.

1. STEEL MAKING 2030

The transition to Green and Circular Steel Production has a colossal impact on the TSN site. While producing approximately 7 Mt of steel per year, the TSN infrastructure must undergo changes required to build the EAF and DRP units, culminating in relocation of BOS-installations. Buildings *need* to be demolished to provide room for the new installations. For

example, the refractory plant DSF is closed and the ladle maintenance area moved to another location. This represents a time challenge as all activities must be completed within six years. The Heracless program is the top level program under which all sub-projects are organised. Focussing on the impact onto BOS plant, several multi-disciplinary teams have been assigned to develop and execute the project. The main focus is on building and startup of the EAF, the associated new secondary steelmaking installations, and re-design of the steel ladle refractory linings.

PROCESS FLOW

Process 2030 will be comprised of two main steel production routes (Figure 2). The standard BOS route with liquid hot metal from the blast furnace in combination with two BOFs (approximately 50% of total output). This route incorporates secondary treatments over the existing purging stand (50%), ladle furnace (26%) and RH-OB (24%) stations. Process conditions will remain similar as currently applied. The new EAF route features a 370 ton EAF (approximately the remaining 50% of total output). The EAF will be a continuously fed by scrap and ORI-pellets. A standard secondary treatment sequence of ladle furnace followed by de-sulphurisation station and RH-OB (de-nitrification) will be followed. A schematic figure of the two steel production routes is shown in Figure 2.

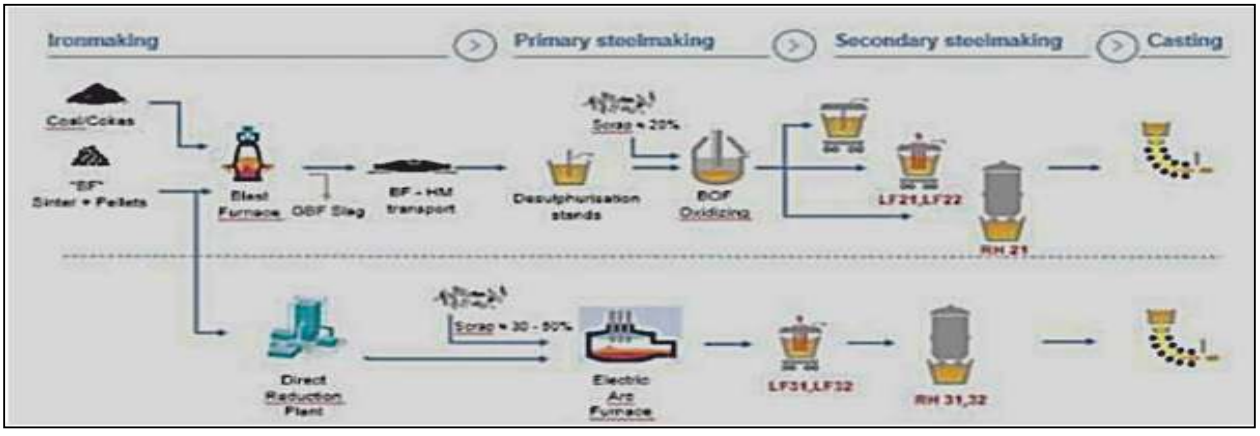


Figure 2- Schematic diagram of the production process at TSN in 2030.

IMPACT ON BOS PLANT OPERATION

The combined production routes for the 2030 process represent significant challenges on logistics and operation of standard installations at the BOS plant. In particular and of highest importance are the expected increase of BOF and steel ladle refractory wear, and the capability to efficiently remove sulphur and nitrogen from the molten steel. Past experiences have shown that a low production pace has a severe impact on BOF-wear, especially in the knuckle area. Extensive and unpredictable wear of the knuckle area requires intensive gunning maintenance to ensure safe operation and life extension. Therefore, TSN must tackle this challenge beforehand. Even though the removal of sulphur and nitrogen can be executed, it requires multiple trials to develop understanding of best practices. The nitrogen removal process, in particular, will differ from the current practice at BOS plant since the new RH-OB units will not be equipped with oxygen tuyeres. The use of lances is therefore required. The highest refractory wear impact of the 2030 process is expected to be on the steel ladle, significantly affecting the number of annual repairs as well as the workforce required to execute them. The following sections describe the challenges and mitigation plan.

1. STEEL LADLE

The current steel ladle refractory design has been developed and optimized to withstand the operational conditions of the BOS process route. The bricked design features an alumina-magnesia-carbonbottom and impact pad, a fired spine! wall and a magnesia-carbon slag line wear-linings. A high alumina sol-gel castable is applied as wear lining for both the top-ring (with addition of stainless steel needles) and the bottom ring. The permanent lining is composed of a bauxite brick safety lining followed by an insulation brick and an insulation board. The introduction of an EAF production route in 2030 will represent significant changes on process conditions and on secondary steel treatment sequences for approximately 50% of the heats. This will ultimately affect the steel ladle refractory wear and culminate in loss of performance. Therefore, it is critical to predict and quantify the potential effects of the new process conditions on refractory wear.

Figure 3- Schematic drawing of the current TSN steel ladle design.

IMPACT ON STEEL LADLE PERFORMANCE

In order to predict the effect of the EAF process conditions on refractory wear, basic wear models have been developed for each ladle area. Of all the considered areas, the slag line is predicted to be impacted the most with a wear rate increase of 65-70%. Although lower, a wear rate increase is expected for all other areas reaching values between 20 and 38%. Subsequently, the slag line is predicted to become limiting in 99% of the campaigns and the ladle life to decrease by around 40%. Process 2030 will have a major impact on refractory value-in-use (VIU) as well as labour conditions and health, safety and environment. Optimization of the current refractory VIU towards the 2030 process is limited since trials under similar process conditions cannot be carried out at large scale. Hence, it is critical to adopt an alternative path to mitigate:

- Increase in required man hours to perform the annual repairs;

Increase in labour intensity;

- Increase in footprint of maintenance stands;
- Reduction of ladle availability;
- Decrease in average ladle capacity;
- Increase in logistic challenges; Increasei n consumables(e.Q.. refractories and energy);
- Increase in annual emissions;
- Increase in refractory waste stream due to underutilization of the refractory in non-limiting areas.

When searching far and wide, the monolithic steel ladle presented itself as a potential solution.

NEW REFRACTORY PHILOSOPHY

A monolithic steel ladle design is usually comprised of a monolithic impact pad, bottom and sidewall, and a bricked slag line wear linings. Regarding the permanent lining, several designs have been successfully implemented with bricks, castables, boards or their combination. In so-called endless monolithic lining philosophy, the wear lining at the cast areas is not removed completely when performing a regular repair. Instead, the cast areas are cleaned thoroughly and re-cast to the original thickness, enabling the reduction of waste and maximization of refractory VIU.

However, a complete repair must be performed periodically (typically on a yearly basis) so that the steel ladle shell can be inspected. The endless monolithic lining philosophy for steel ladles has been successfully implemented by several competitors, worldwide, on ladles with different sizes and shapes. Thus, it is a proven technology which might be the answer to a suitable steel ladle design in **TSN.**

Although a one-to-one transfer of a design between two steel companies cannot be done due to differences in operation processes, bench marking with competitors enables learning from experiences and identifying key points for a successful transition from a bricked design to an endless monolithic lining philosophy. An endless monolithic steel ladle design will enable:

- Reduction of the man hours due to the nature of the installation process;
- Reduction of the labour intensity due to the automation of defined installation steps;
- Sustaining the current footprint of maintenance stands due to shorter installation times;
- Optimization of the average ladle capacity by adjusting the wear lining thickness. The lack of joints allows lower thicknesses of the refractory wear lining without compromising operational safety;
- Mitigation of the increase in logistic challenges as maintenance space is no longer an issue;
- Lowering the consumption of refractory due to cleaning of the remaining wear lining instead of removing as well as preserving the permanent lining for a longer period of time;
- Reduction of refractory waste stream.

However, the decrease in ladle availability cannot be mitigated as the total turnover time will remain similar. Thus, additional shells are required.

In Figure 3, a diagram with the improvement opportunities in different areas for both refractory philosophies is provided.

Figure 3 Schematic diagram of improvement opportunities in different areas for bricked and monolithic refractory philosophies.

A monolithic steel ladle program has been created in order to implement this new refractory philosophy at TSN by 2028.

MONOLITHIC STEEL LADLE PROGRAM

The arrival of the EAF by 2029 has set the ambitious target to complete the transition of bricked to endless monolithic steel ladle design by the end of 2028 and to realize the first plant trial with an in-situ cast monolithic steel ladle by September 2025. A dynamic and multidisciplinary team, consisting of experts on refractory materials, engineering, refractory installation and thermo-mechanical modelling, have been assigned to develop and realize the program. During the ideation phase, two work streams have been defined: pre-cast impact-pad and bottom wear lining (WS1); and, in-situ cast monolithic steel ladle (WS2).

PRE-CAST IMPACT-PAO AND BOTTOM WEAR LINING

The pre-cast impact pad and bottom wear lining work stream (WS1) has been designed to enable fast acquisition of performance data as well as to train the operators on inspecting monolithic linings in production (hot conditions). Furthermore, the influence of the thermo-mechanical and chemical properties of different materials, i.e. spinel-containing and spinel-forming, on performance can be investigated and the learnings transferred towards the selection of the materials for the in-situ cast monolithic steel ladle work stream. The reduced prerequisites regarding purchase or adaptation in hardware, an area needed to execute the trial and additional health and safety measures, permits the trials to be executed within a much shorter timeline. The general timeline of the WS1 is presented in Figure 4.

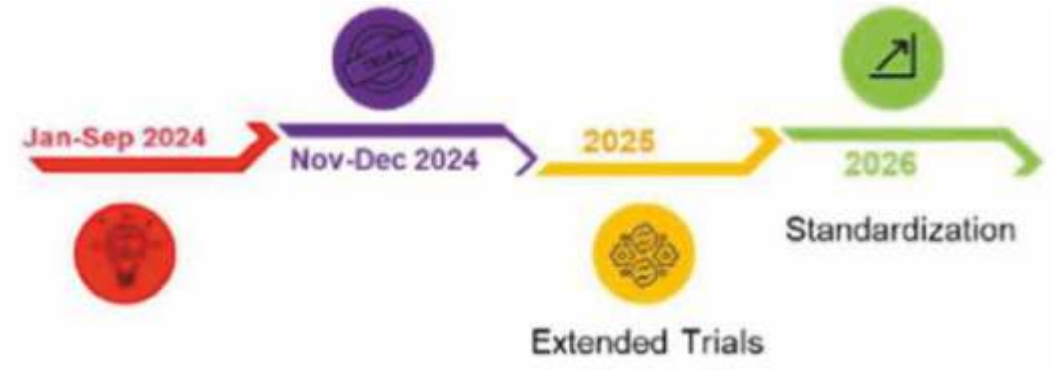


Figure 4 - Timeline of the pre-cast impact pad and bottom wear lining workstream (WS1).

Due to the complexity of the asymmetric curved bottom of the TSN steel ladle, the area was divided in 4 different regions. Prior to finalizing the engineering of the pre-cast shapes styrofoam dummy bottom pieces were manufactured and a mock-trial was carried out (Figure 5).

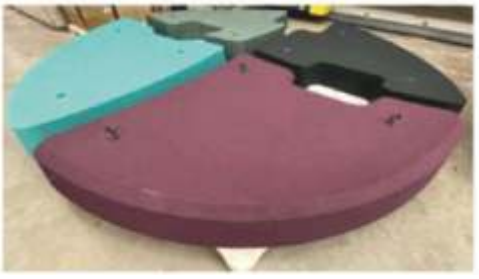


Figure 5 - Styrofoam dummy pieces manufactured to validate the profile of the ladle bottom

IN-SITU CAST MONOLITHIC STEEL LADLE

The in-situ cast monolithic steel ladle workstream (WS2) is comprised of several activities which must be meticulously and timely executed in order to ensure the targets are reached. The main activities include:

- Refractory design; Material selection;
- Shell design;
- Mouldesign, manufacturing and installation;
- Installation and cleaning equipment;
- Drying equipment and procedure;
- Health, safety and environment;
- Monitoring systems;
- Thermo-mechanical modelling.

The first steps have been taken to define the requirements for each activity as well as to identify their interdependencies. An industrial partner will be selected to support and execute the transition according to the timeline shown in Figure 6.

Figure 6 - Timeline of the in-situ monolithic steel ladle workstream (WP2).

Even though the steps forward have been defined, the complexity and extent of the transition to green, clean and circular steel poses challenges and requires the contribution of all TSN employees. A challenging and exciting future lies in front of TSN.

TECHNICAL SECTION

BULK DENSITY MEASUREMENT OF REFRACTORY RAW MATERIALS – FASTER AND BETTER WITH A SPIN DRYER

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Abstract:

In order to determine the bulk density of refractory raw materials, the so-called water method following the Archimedes principle is normally used. This is where the effect of water displacement on the weight of the sample is used to determine the bulk volume of the sample grains. During this test procedure, the surface of water infiltrated sample grains must be dried with a wet towel. Experience shows, that this drying step is the main root cause for variation in reproducibility of results and even repeatability of tests. A new spin dryer (centrifuge) was developed and introduced to automate this surface drying step, and is now included as a new method in ISO 8840:2021. The paper discusses the improvement of measurement with the new approach and industrial experiences from two big industrial players in the raw material business.

Keywords: Bulk density, centrifuge, drying, infiltration

1. Introduction

The bulk density is an important property for refractory raw materials and the apparent (open) porosity is also an essential part of the specification. It is measured frequently as in-process control in refractory aggregate production. During tabular production, Almatis performs about 23,000 bulk density measurements per year over its five sites in the USA, The Netherlands, India, China, and Japan.

The different standard methods for determination of bulk density are briefly and comprehensively described by Lorenzoni[1] and will not be discussed in detail here. Popular methods such as DIN-EN 993-18[2] and ASTM C357-07[3] include sample volume determination by weighing the immersed sample in water following the Archimedes principle with buoyancy related to the volume of the immersed body. An important part of that procedure is weighing the water - infiltrated sample without excess water on the surface of the sample. This would lead to grain bulk density appearing lower. However, undesired removal of water from open pores at the grain surface would give apparently higher bulk density.

Therefore a wet cotton towel is wrung and then used to manually blot the grains to dry the surface until the wet sheen on the grains has disappeared (figure 1). It is clear that this procedure adds variability to the results because of slight differences between operators and their subjective judgements. This has been proven by multiple round robin tests both internally and externally at Almatis and RHI Magnesita. A bulk density variation of +/- 0.02g/cm³ is commonly accepted for tabular alumina or other refractory aggregate grain density measurements.

RHI Magnesita has developed a new method for this critical step in grain bulk density measurement, This replaces the manual and subjective method by the use of a centrifuge (spin dryer), to give an automated and more reproducible process[1]. It has been included in ISO 8840:2021[4]. Almatis, at first, tested the centrifuge and then purchased six machines from RHI Magnesita for use in all worldwide tabular alumina sinter plants. The experiences gained during qualification and implementation of the centrifuge method in Almatis are described as

Nevertheless, BSG was and is used with g/cm³ as unit in data sheets and all technical communication.

The process of establishing the centrifuge method and qualifying it as a replacement of the towel method for drying is ongoing in Almatis sinter plants. The plants that started first have already implemented this change.

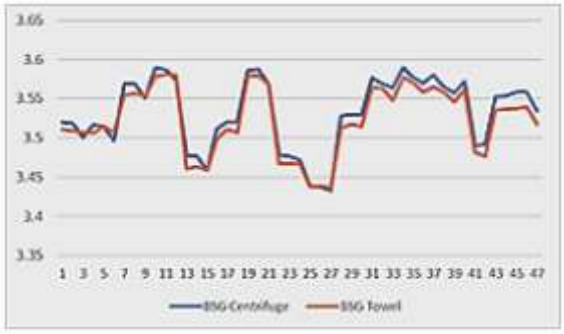


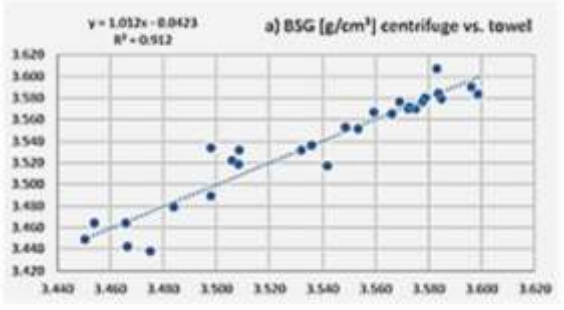
Fig. 3: Bulk Specific Gravity (BSG) of tabular alumina - centrifuge vs. towel drying.

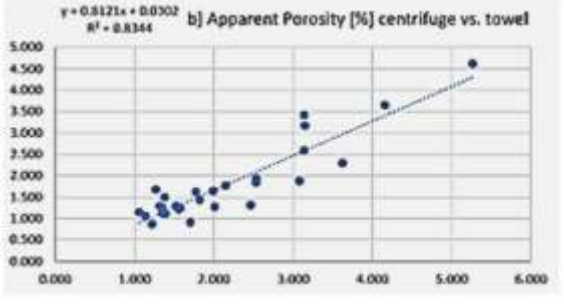
1.1 Centrifuge for grain infiltration

The centrifuge provides another interesting opportunity for improving the bulk density measurement of raw material aggregates. RHI Magnesita has successfully tested grain infiltration with the centrifuge. In the standard methods, the sample is infiltrated with water either by the vacuum method[2] or by boiling in water[3]. Both procedures require a minimum of 45 minutes to achieve the required infiltration of the grains. At Almatis, boiling the sample in water is the common way for infiltration. When the dry sample is put into a plastic container with water and then into the centrifuge basket (figure 4), the spinning can be used to infiltrate the sample grains. Here, rotation speed and time have to be increased when compared to the surface drying step later in the procedure. For Almatis tabular alumina samples, 880 RPM for 220 seconds was established as the standard setting for achieving stable infiltration results. This is significantly faster than the boiling method.

With this new approach, using the centrifuge for infiltration and drying the surface, results from bulk density measurement are already available after about 15 minutes. This compares to about 90minutes using the old approach. It also means that the lab analysts can perform the testing in one operation instead of having interruptions, waiting for the infiltration to be finished.

Fig. 4: Basket with plastic container for infiltration of tabular grains by centrifuge.





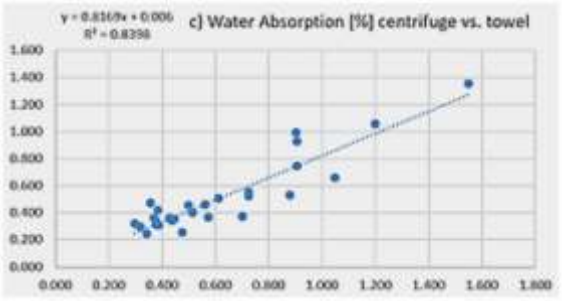
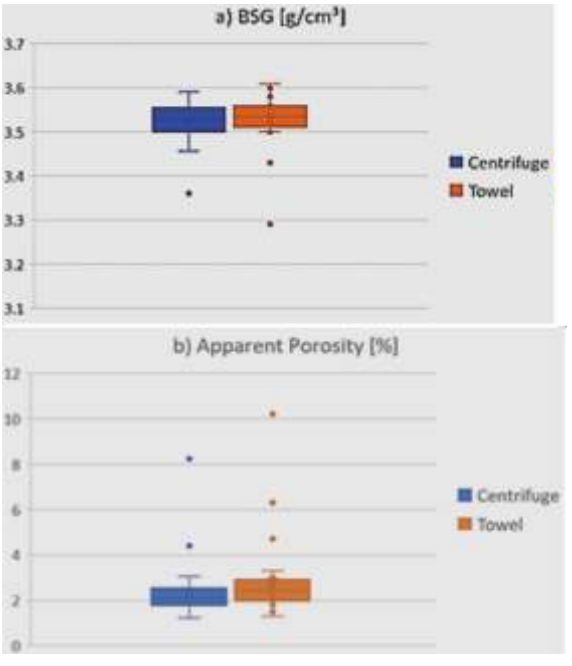


Fig. 5: Correlation of BSG, AP, and WA - centrifuge vs. towel method at Almatis Rotterdam, The Netherlands.

2.3 Results from new method with tabular alumina

Test series were started in different locations to compare results using the new method (centrifuge for infiltration and surface drying) with the old method (boiling in water and surface drying with wet towel). Fig. 5 shows good correlation of BSG between both methods from a test series of 48 samples and six different analysts at Almatis Rotterdam. There were only slight differences in apparent porosity (AP), and water absorption (WA).



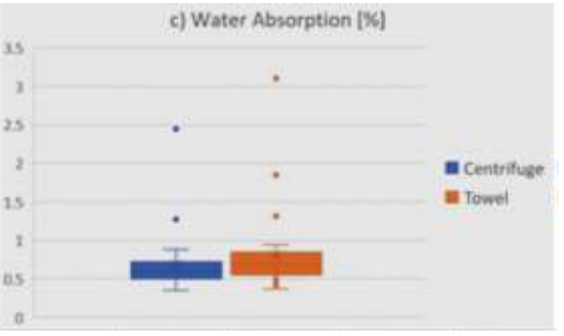


Fig. 6: Box plot of BSG, AP, and WA results Almatis Benton, USA.

Fig. 6 shows box plots from the same comparison at Almatis Benton, AR with 30 samples and 4 different analysts. In addition, correlation for BSG is good here, and differences in AP and WA are small.

Based on these encouraging results, a global Gage R&R study was performed in the five tabular alumina sintering plants. 29 unique differentsamples covering a range of bulk density and including samples with bulk density clearly below specification limit of tabular alumina were tested in the five different quality laboratories by 21 different operators with the classical (boiling and towel drying) and the new method (centrifuge spinning for infiltration and drying).

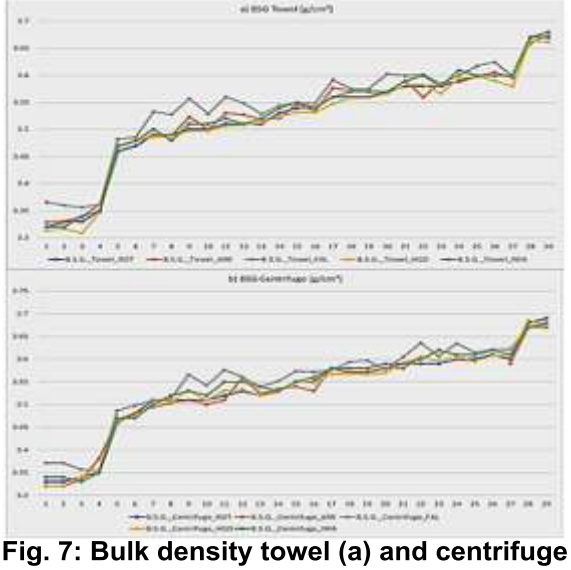


Fig. 7: Bulk density towel (a) and centrifuge (b) results from Gage R&R.

Fig. 7 to 9 show measurement results from the Gage R&R test for the specified tabular alumina properties bulk density (BSG), apparent porosity (AP), and water absorption (WA) with both methods at the different sites. In general, variation is higher for very low bulk density samples with values clearly out of the specification range for tabular alumina (min. 3.50 g/cm³). For the other samples, results are well aligned.

Fig. 10 shows the result from the Total Gage R&R test as % Study Variance. The general rules to determine the capability of the system are: <10% acceptable; 10-30% marginal; >30% unacceptable. With total Gage R&R contribution between 14 and 24%, the variance is within acceptable limits due to tool type and application. In general, the variance for the centrifuge method is a bit lower than for the towel method. Based on the positive results from the Gage R&R test the new method has become the standard within Almatis.

Fig. 8: Apparent porosity towel (a) and centrifuge (b) results from Gage R&R.

Fig. 9: Water absorption towel (a) and centrifuge (b) results from Gage R&R.

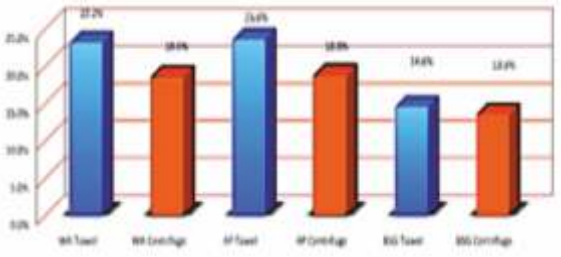


Fig. 10: % Study Variance results of Total Gage R&R. General rules to determine the capability of the system:

<10% acceptable; 10-30% marginal; >30% unacceptable.

CONCLUSION

The centrifuge enables automation of the surface drying step in bulk density measurement based on the water method. It can help to reduce human element variation in lab work. This will improve repeatability and reproducibility in bulk density measurement in the laboratory and between different laboratories. The extension of centrifuge usage for the infiltration of the grains replacing the vacuum or boiling method leads to significantly reduced times for the entire measurement. The new approach was established as the future standard within Almatis.

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TECHNICAL SECTION

JOURNEY TOWARDS FLUORINE FREE MOULD FLUX FORMULATION FOR HIGH-SPEED CASTING

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Abstract

In the continuous casting of steel, mould fluxes play a crucial role in ensuring smooth operations and high- quality outputs. However, mould fluxes typically contain high levels of fluorine, which pose significant environmental and health risks. This paper explores the innovative development of low-fluorine mould fluxes, by 2not using any Li_O and B_2O_3 based raw materials, and specifically designed for high-speed slab casting, by using thermodynamic simulation techniques.

Our research begins with a comprehensive review of the critical functions of mould fluxes, including lubrication, heat transfer control, and melting behaviour. The detrimental effects of fluorine on the environment, human safety and caster machinery are highlighted, establishing the necessity for low-fluorine alternatives. Before any laboratory-based testing, Thermodynamic simulation model has been utilized to predict the recrystallization behaviour and viscosity at different temperatures of various low-fluorine formulations, namely α, β and γ. This approach allows for the efficient screening of numerous potential compositions, significantly reducing the time and resources required for extensive testing like Hot Stage Microscopy. The parameters like crystallization tendency, viscosity and the amount of slag generation at specific temperature are critical for maintaining the delicate balance between lubrication and heat extraction necessary for high-speed casting.

One of the key findings of this study is the identification of optimal low-fluorine flux compositions that match or exceed the performance of traditional high-fluorine fluxes. The paper discusses the potential industrial implications of these findings, including the transition process from high-fluorine to low-fluorine fluxes in existing casting operations. Trial of the developed low fluorine mould flux has been taken in a full-fledged integrated steel plant having process route BF-LD-LRF- CCS. The real time parameters like mould heat transfer, BDS thermographs, mould slag pool depth, mould slag rim tendency etc have been monitored during the casting process. The developed mould flux provides adequate lubrication, prevents sticking, and ensures uniform heat transfer, all while significantly reducing the environmental footprint. In totality, the performance of the mould flux comes out satisfactory, revolutionizing the continuous casting process, making it more responsive and efficient.

The integration of advanced simulation techniques not only accelerates the development process but also enhances the precision and effectiveness of the resulting products. This research paves the way for more sustainable and safer steel production practices, aligning with global environmental goals and industry standards.

Keywords: Low Fluorine, Mould Flux, High-Speed Slab Casting, Viscosity, Simulation

Introduction

Mould Fluxes are indispensable requirement for continuous casting of steel, due to multi-dimensional functions, i.e., lubrication to the steel strand, heat transfer control in the mould, thermal insulation of the steel, prevention from reoxidation of steel and the inclusion absorption from the steel.[1] Fluorine is a very effective element for controlling the viscosity, crystallinity and heat transfer of the mould slag. Fluorine helps in the formation of Cuspidine ($3CaO*2SiO_2*CaF_2$) crystals. Anyprecipitated

crystals like Cuspidine scatter the Infrared radiation and decreases the heat transfer in the mould.[2] (As shown in Figure 1)

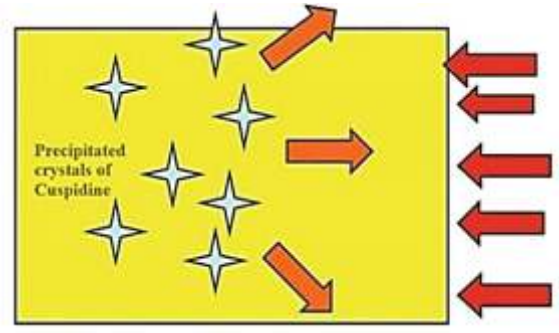


Figure 1: Schematic diagram showing the scattering of IR radiation by Cuspidine crystals[2]

But High Fluorine containing mould leads to wear of the components of the continuous casting machine, which is caused by the absorption of fluorine ions in the secondary cooling water of continuous casting machine and the associated lowering of the pH value of secondary cooling water. In addition to it, high fluorine mould flux leads to the environmental concerns due to possible pollution of the ambient air of the continuous caster area by release of gaseous SiF_4. "Stollberg" started the development of fluorine free/reduced powders in 1992. The following reactions for fluorine volatilization from SiO_2 containing slags are identified (mentioned in equations 1-6). [3]

Eq (1): $2CaF_2 + SiO_2 \rightarrow 2CaO + SiF4\ (g)$

Eq (2): $Na_2[SiF_6] \rightarrow 2NaF + SiF_4\ (g)$

Eq (3): $4NaF + SiO_2 \rightarrow 2Na_2O + SiF4\ (g)$

Eq (4): $2Na_3[AlF6]+3SiO_2 \rightarrow 3Na_2O+Al_2O_3+ 3SiF_4(g)$

Eq (5): $SiF_4 + 2\,H_2O \rightarrow SiO_2 + 4\,HF$

Eq (6): $SiF_4 + 2\,HF \rightarrow H_2[SiF_6]$

SiF_4 gas bubbles are trapped in the liquid solidifying mould slag and released in two ways: a) out of liquid slag at the interface between liquid slag and the subsequent sintered layer. These gas bubbles condense in the cooler areas of the mould powder bed, b) out of the solidified and bursting slag in secondary cooling under the mould, then, these gas bubbles dissolve in the secondary cooling water. This contaminated cooling water with Hexafluorosilicic acid $H_2[SiF_6]$ corrodes the secondary cooling metallic rolls and segments. Along with this, fluorine present in liquid mould slag accelerates the destabilization of ZrO_2 present in Submerged entry nozzle(SEN), which tends to give large SEN erosion during continuous casting of steel.[4] To reduce the detrimental effects imposed by Fluorine, there is requirement of Fluorine free/low fluorine mould fluxes. replace fluorine, mould fluxes with different other raw materials have been analyzed as given in Table 1.[3]

Table 1: Mould Fluxes based on different raw materials for replacement of Fluorine

Mould Flux Base	Observations
Li_2O	Lithium Oxide is scarce raw material, not a sustainable solution
TiO2	Decreases heat transfer by forming Perovskite ($CaTiO_2$) crystals but excessively high melting point
B_2O_3	Boron picks up by steel leads to surface cracks & Boron is also harmful to health
High Na_2O	Extensive CO_2 emission
Fe_2O_3 + MnO_2	Decreases heat transfer, decreases viscosity, lower melting point

Based on the observations given in Table 1, we have proceeded with Fe_2O_3 and MnO_2 based raw materials for the development of low fluorine mould fluxes.

Experimental Work

The experiments for the study have been conducted with six numbers of granular mould flux. The compositions of the fluxes are shown in Table 2. These six fluxes were made with different indigenous and imported raw materials. Out of six mould fluxes, mould fluxes φ, χ and ψ are high fluorine mould fluxes, already established fluxes in Steel plants P1, P2 and P3 respectively for slab casting of low carbon steel. To replace these three existing fluxes, three low fluorine mould fluxes, α, β and γ, have been designed with 6% lower F content. The

composition of each mould flux has been analysed in the laboratory by the XRF. The Total Carbon content of each sample is measured by Carbon-Sulphur Determinator.

Table 2: Chemical composition of different mould fluxes during the work

%	φ	χ	ψ	α	β	γ
SiO_2	J+1	J	J	J-2	J-3	J-5
CaO	K+2	K	K+1	J+3	J+4	J+9
MgO	L-2	L	L-1	L-2	L-2	L-2
Al_2O_3	M	M	M+1	M-2	M-2	M-2
Fe_2O_3	N	N	N	N+4	N+5	N+5
MnO_2	O	O	O	O+4	O+3	O+2
Na_2O	P-1	P	P-2	P-1	P-1	P-3
F	9.0	9.0	9.0	3.0	3.0	3.0
C Total	Q	Q	Q+1	Q+2	Q+2	Q+2

The viscosity of the mould flux has been determined by the theoretical IRSID models (which has been described in equation 7).

Eq (7): Viscosity(in Pa*s), η = A.T.exp(B/T)

where A and B are constants determined by molar fractions of various oxides and fluorides, and T is the temperature [K].[5] (1 Pa*s = 10 Poise)

Non-Bridging Oxygen NBO/T of each flux were calculated by using chemical constituents of individual fluxes and the calculated results of NBO/T have been given in Table 3. NBO/T represents the amount of de- polymerization of the melt as a measure of crystalline fraction.[6] Heat transfer index is calculated by Mills method[1]and the calculated results given in Table 3. Itis to be noted that increase in heat transfer index (a unitless index) indicates the increase in heat transfer through the mould flux. The Hot Stage Microscopy has also been used for the measurement of the melting point and the flowing point of each mould flux and the results have been shown in Figure 2 and Table 4. Thermodynamics Software FactSage 8.2 is also used for the calculation of crystallographic phases during recrystallization process of different mould fluxes.

Results and Discussion

The data generated during this work have been collated in Table 3

Table 3: Characterization of different types of mould flux through theoretical models

	φ	χ	ψ	α	β	γ
Heat Transfer Index	0.30	1.19	0.78	1.16	0.80	0.30
NBO/T	2.12	2.23	2.21	2.80	2.90	3.44
Viscosity at 1300 °C (Poise)	1.2	1.0	1.2	1.2	1.2	1.4

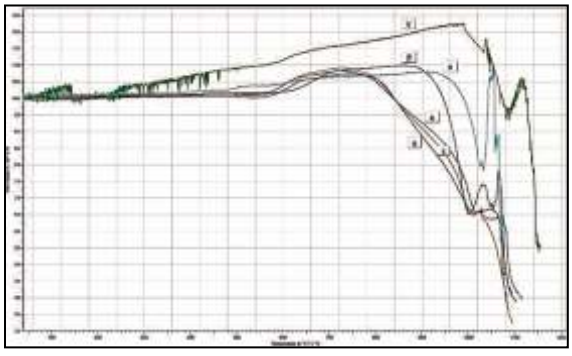


Figure 2: Melting behaviour of different fluxes determined by Hot Stage Microscopy.

Table 4: Details of Melting and Flowing points of different mould flux obtained from HSM analysis

°C	Melting Point	Flowing Point
φ	1086	1107
χ	1066	1085
ψ	1075	1094
α	1060	1079
β	1047	1084
γ	1136	1146

The plot drawn through FactSage software of low fluorine containing mould flux α has been shown in

Figure 3. The amount of Crystallographic phases & Liquid Slag at 1000°C and 1100°C, which is determined by FactSage software, as given in Table 6 and 7.

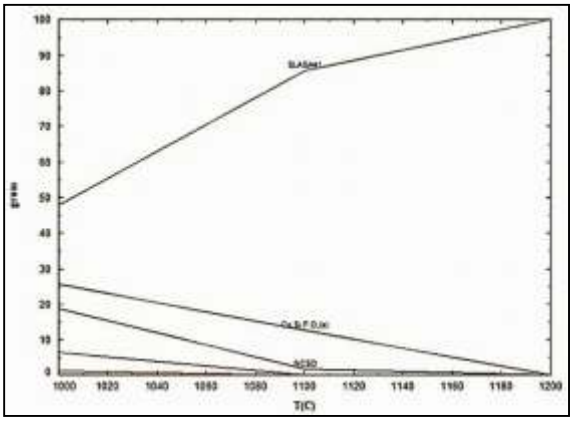


Figure 3: Plot drawn using thermodynamic Software FactSage of Flux α

Table 5: Crystallographic phases & Slag amount at 1000°C determined by FactSage software

	φ	χ	ψ	α	β	γ
Slag	69.1	72.4	67.3	47.8	41.0	26.5
Cuspidine	30.9	27.6	32.7	25.8	28.3	31.0
Combeite	0	0	0	18.7	23.6	6.5
Bredigite	0	0	0	6.4	3.8	10.1
Spinel	0	0	0	1.3	3.3	6.1
Rankinite	0	0	0	0	0	19.8

Table 6: Crystallographic phases & Slag amount at 1100°C determined by FactSage software

	φ	χ	ψ	α	β	γ
Slag	87.1	92.5	86.4	85.7	79.8	57.0
Cuspidine	12.9	7.5	13.6	12.7	15.4	23.0
Combeite	0	0	0	1.6	4.8	0
Bredigite	0	0	0	0	0	5.5
Rankinite	0	0	0	0	0	14.5

From Table 3, it is found that NBO/T of mould fluxes α, β and γ are higher than mould fluxes φ, χ and ψ, this is due to Fe_2O_3 is more impactful factor than CaF_2 for increase in NBO/T. Due to higher amount of CaO and lower amount of SiO_2, there is much higher NBO/T in case of Flux γ in compared to others. Heat Transfer Index of mould fluxes α and χ , β and ψ , γ and φ aresimilar. Viscosity at 1300 °C for all the flux are within the range of 1.0 to 1.4 Poise, among which γ has highest viscosity. From Table 4, it is clear that low fluorine mould fluxes α and β has lower melting point than φ, χ and ψ, but γ has higher melting point than that. From Table 5 and 6, it is understood that there is significant amount of Cuspidine phase in low fluorine containing mould fluxes α, β and γ, which is quite comparable to high fluorine containing mould fluxes φ, χ and ψ.

The field examination has been conducted with three low fluorine mould fluxes α, β and γ in different steel plants for slab casting of Low Carbon Steel. These trials have been divided into four cases; the details of mould fluxes and steel plants in different cases are mentioned in Table 7.

Table 7: Details of Mould Fluxes and Steel plants in different cases

	Case I	Case II	Case III	Case IV
Mould Flux	**α**	**β**	**γ**	**α**
Steel	**S1**	**S2**	**S3**	**S4**
Steel Plant	**P2**	**P3**	**P1**	**P1**

The details of caster parameters, steel chemistry and mould flux performance in different cases are mentioned in Table 8, 9 and 10, respectively.

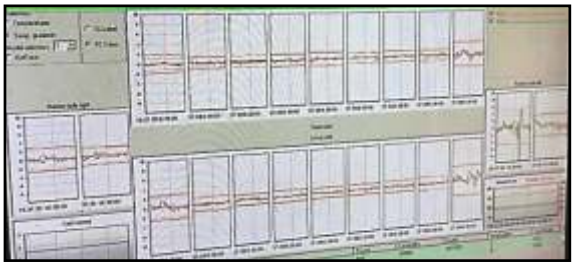
Table 8: Details of Caster parameters in different cases

Caster Parameters	Case I	Case II	Case III	Case IV
Casting Speed, m/min	1.85	1.65	1.60	1.60
Section Size, mm2	1560x230	1290x230	1500x230	1500x230
Stroke Length, mm	7.0	6.8	6.6	6.6
Mould Water Flow Broad Face, L/min	3600	3900	4100	4100
Mould Water Flow Narrow Face, L/min	470	490	440	440

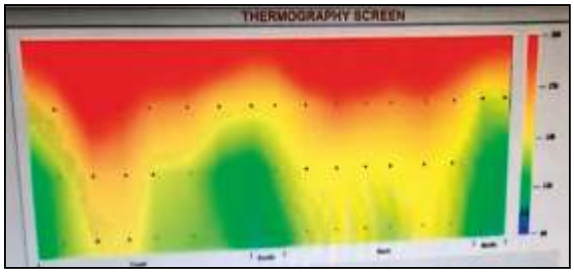
Table 9: Details of Steel Chemistry in different cases				
%	S1	S2	S3	S4
C	0.0346	0.056	0.046	0.029
Mn	0.164	0.023	0.204	0.163
S	0.008	0.006	0.006	0.005
p	0.009	0.005	0.006	0.008
Si	0.011	0.007	0.008	0.007
Al	0.046	0.056	0.051	0.058
Ca	0.002	0.002	0.002	0.002
N	0.007	0.006	0.007	0.003

Table 10: Mould Flux Performance in different cases				
Performance Indicators	Case I	Case II	Case III	Case IV
Cracks	No	No	No	No
Stickers	No	No	Yes	No
BPS Thermograph	Normal	Normal	Abnormal	Normal
Delta Temperature	Normal	Normal	Low	Normal
Mould Heat Flux	Normal	Normal	Low	Normal
Liquid slag pool depth (mm)	13-15	12-14	11-14	12-15
Slag Rim Formation	Soft & Normal	Soft & Normal	Hard & High	Soft & Normal
Mould Level Fluctuations (mm)	+/- 2	+/- 2	+/- 3	+/- 2

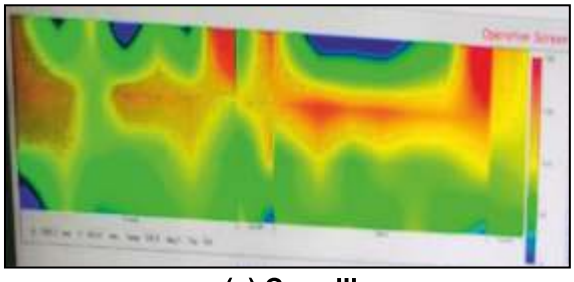
It is to be noted that Breakout prevention / detection system (BDS) attached to the mould prevents the steel strand breakout. BDS system measures the mould plate cold face temperature through thermocouples. Then it identifies the sticker tendency and act for sudden reduction in casting speed. This reduction in casting speed, increases negative strip time and help to form sufficient slag film inside the mould. BDS thermographs of different cases are shown in Figure 4.



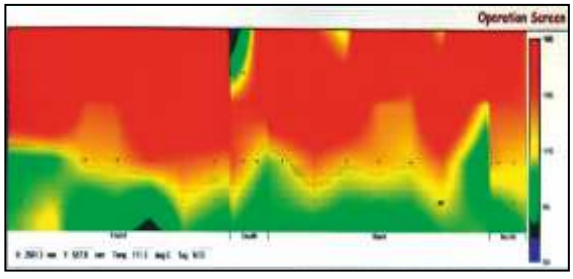
(a) Case I



(b) Case II



(c) Case III



(d) Case IV

Figure 4: Breakout Prevention System Thermographs during different cases

Figure 4 shows that in Case III, BDS thermograph has bluish and greenish colour in place of reddish colour in top of the mould, depicting non-uniform heat transfer and the possibility of sticking. BDS Thermograph in Case I shows steady nature of thermocouples. Case II

and Case IV shows good thermographs with sufficient distinction between reddish, yellowish and greenish colour.

From Table 10, it is clear that the heat flux and Delta Temperature in Case III is lower than normal, along with that in Case III, there is hard slag rim formation. In rest of cases, the performance of low fluorine mould fluxes is good. In Case III, mould flux γ has been used, which has higher viscosity, higher melting point, higher NBO/T and lower Na_2O content than other low fluorine mould fluxes, which could be a reason for hard slag rim formation, low heat transfer, bad BDS thermograph and sticker tendency.

Conclusions

This paper could be concluded with positive note as follows:

1. Development of Low fluorine mould without using Li_2O and B_2O_3 is even possible.
2. Fluorine content in mould fluxes have been reduced by 66%, but Cuspidine crystals are maintained in the system.
3. Special consideration needs to be given on melting point of the mould fluxes to avoid hard slag rim formation.
4. Heat transfer of mould flux should not be reduced much and NBO/T value should be optimized.
5. Mould flux α and β have the suitable properties to replace the high fluorine mould fluxes.
6. Mould flux γ is not performed well due to high viscosity, low heat transfer, high NBO/T and high melting point.
7. In low fluorine mould fluxes, there have been different other crystallographic phases also been there, like Combeite ($Na_2Ca_2Si_3O_9$), Bredgite ($Ca_7MgSi_4O_{16}$), Spinel($MnFe_2O_4$) and Rankinite ($Ca_3Si_2O_7$).

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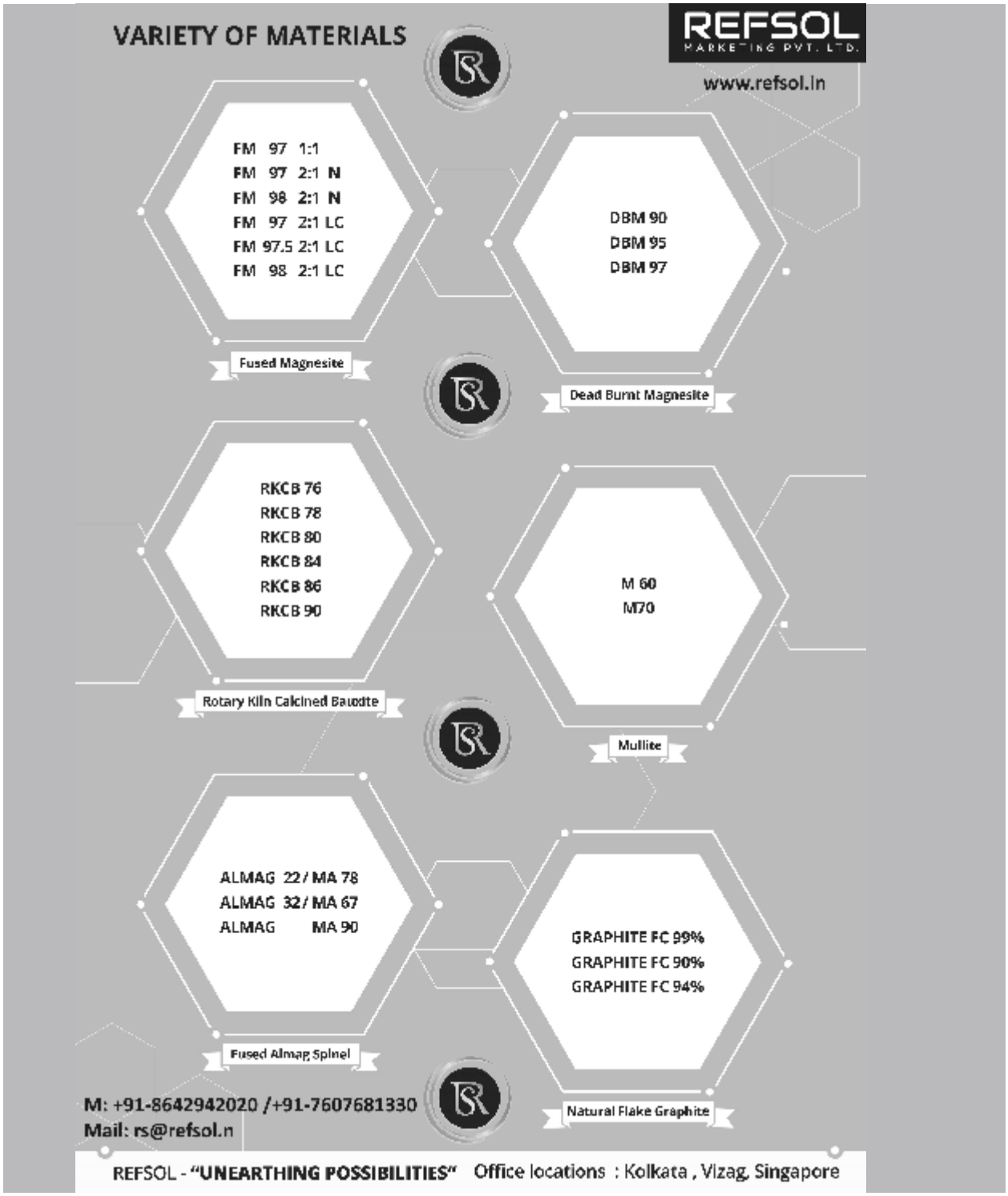
STATISTICS

EXPORT & IMPORT OF REFRACTORY ITEMS

EXPORT OF REFRACTORY ITEMS	2024-25 (Apr- Jan) Rs. Lakhs
FIRE CLAY BRICKS & SHAPES	14467.70
HIGH ALUMINA BRICKS & SHAPES	123842.94
SILICA BRICKS & SHAPES	1560.33
BASIC BRICKS & SHAPES	19191.59
MONOLITHICS/CASTABLES	56371.36
SPECIAL PRODUCTS	38656.64
CERAMIC FIBRES ETC	19280.03
OTHERS	18811.68
TOTAL	292182.27

IMPORT OF REFRACTORY ITEMS	2024-25 (Apr- Jan) Rs. Lakhs
FIRE CLAY BRICKS & SHAPES	1897.48
HIGH ALUMINA BRICKS & SHAPES	78984.68
SILICA BRICKS & SHAPES	16062.74
BASIC BRICKS & SHAPES	125215.57
MONOLITHICS/CASTABLES	113495.36
SPECIAL PRODUCTS	2785.07
CERAAMIC FIBRES & OTHERS	33141.01
OTHERS	60170.73
TOTAL	431752.64

(Source: Export Import Data Bank, Department of Commerce, Ministry of Commerce & Industry, Govt. of India)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MISSION

SSRPL's core business mission hinges on its' commitment quality and service and offering raw material products consistent in size, chemistry & physicality. Our Laboratory is equiped with latest equipment for testing as per the industry standard.

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Refractory Bauxite, also known as Calcined Bauxite is produced by sintering high alumina bauxite in rotary kilns at high temperatures.

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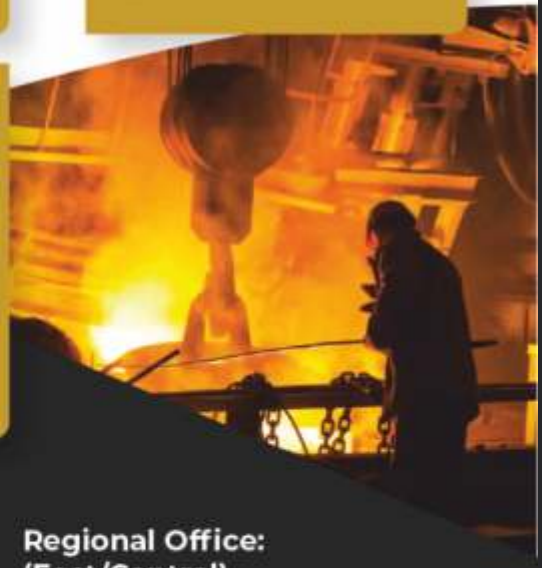
Calcined clay is obtained by calcining (heating) superior grade clay at high temperature in Rotary Kiln.

WHITE FUSED ALUMINA

White Fused Alumina is manufactured by the Fusion of Pure Quality Calcined Alumina in Arc Furnaces with Temperatures greater than 2000°C. After Slow solidification, a high purity synthetic material is obtained.



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