# New Refractory Lining Direction at Jindal Stainless

# New Refractory Lining Direction at Jindal Stainless - first Indian FeCr producer to install UCAR® ChillKote™ linings

**P. L. Duncanson[1], P. Sylven[2]**

[1]GrafTech, UCAR® Refractory Systems E-mail: Peter.Duncanson@graftech.com
[2]GrafTech, UCAR® Refractory Systems E-mail: Peter.Sylven@graftech.com

## ABSTRACT

*Many of the leading ferroalloy producers in the world today are taking advantage of the ChillKote™ refractory furnace lining system. They rely on the proven extended campaign life, the reduction in cost of ownership, the enhanced safety and the reduction in maintenance cost. This paper will present the successful first conversions in India to this technology from conventional linings by Jindal Stainless Ltd. (JSL). The document will also outline the measures employed by JSL to ensure optimum furnace availability and metal production in their two 60MVA furnaces. In addition it will present the experiences from other high productivity producers in the world, especially in South Africa, where more than 80% of the manganese and chrome furnaces are now committed to ChillKote™ linings. Other benchmark SAFs will be discussed, including CYMCO Kunming FeMn, the largest submerged arc furnace in China, POS Himetal in South Korea, and Vale (RDME) in France, the largest FeMn furnace in Europe. Details will be presented on how this technology is able to offer these profitable results for a long list of ferroalloy producers internationally and how Indian producers can now benefit from these experiences.*

## 1. Jindal Stainless Greenfield project in Odisha

As part of their integrated stainless steel plant in the state of Odisha, Jindal Stainless Ltd. (JSL) operates two 60 MVA ferrochrome furnaces. JSL is also planning for the construction of additional ferroalloy units of ferromanganese and silicomanganese in Odisha. At the melt shop, charge chrome is produced through a single stage process by smelting a mix of chromite, reductant and fluxes at temperatures in excess of 2000 °C. Electrical energy, required for the chemical reactions to occur, is supplied to the submerged arc furnaces through Söderberg electrodes. The molten waste slag and metallic charge chrome are continually (every 2 to 3 hours) drained from the smelting furnaces and tapped into ladles. The metal is allowed to cool down before a final crushing and screening beneficiation step is performed that allows for the production of sized charge chrome.

The Jindal #1 furnace is a 60 MVA SMS Demag furnace with a daily hot metal production of approximately 200 tons FeCr. This furnace was relined and commissioned during March 2008 and has been showing exceptional operational and lining performance prior to being idled. The furnace was constructed incorporating the GrafTech ChillKote™ lining technology. This technology has significantly improved the expected lifetime of this furnace after the failure of the big block lining.

The Jindal #2 FeCr furnace was also rebuilt with this technology during December 2008 after having experienced a similar premature failure with a large block lining. Back in full operation and with increased product demand, Jindal Stainless is confident that these high productivity German designed furnaces will be able to last at least another decade with the ChillKote™ lining technology, as they should be. Similar size furnaces in South Africa are showing campaign lives exceeding this estimate. Hernic

Ferrochrome #3 had a 9 year campaign life before even having its first small taphole repair. The furnace is currently in its 12th year of operation.

Both Jindal #1 and #2 are 11.6m diameter FeCr furnaces installed with GrafTech ChillKote™ linings. Figure 1 shows the current freeze lining configuration used on the #1 and #2 furnaces. Notable is that both these furnaces were originally constructed incorporating conventional “big block” carbon technology. Unfortunately, but rather predictably, this lining technology failed prematurely. Previous repairs were attempted with limited success prior to the complete technology change.

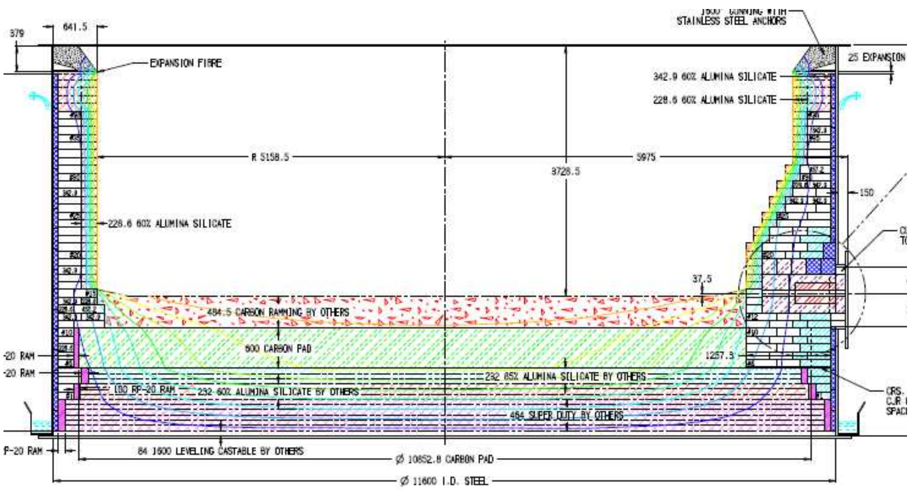


**Figure 1: GrafTech ChillKote™ lining Jindal #2 (similar to Jindal #1)**

Both Jindal linings were installed by experienced domestic Indian installation firms, with supervision supplied by South African firm IRCI as part of GrafTech’s supply contract. Jindal Management expressed that they were highly satisfied with both the installation quality as well as the supervision, which is a very critical, but sometime neglected, part of a successful lining performance.

Figure 2 shows the new and improved GrafTech taphole configuration that was installed in the Jindal furnaces. Having the two carbon side blocks using GrafTech’s Smart Ram® RP20 Ramming Paste joints will enable fast and easy changing of the carbon front block and graphite sleeve, if needed. The ramming will also form the joint between the taphole abutment and the physical tap block. When a front block or sleeve requires changing, only the applicable components will be broken out. No damage will be done to the remainder of the refractory, as was seen at previous taphole repairs on large SAFs around the world. Being a very critical part of any furnace lining, the taphole design, integrity and maintenance should always have the highest priority.

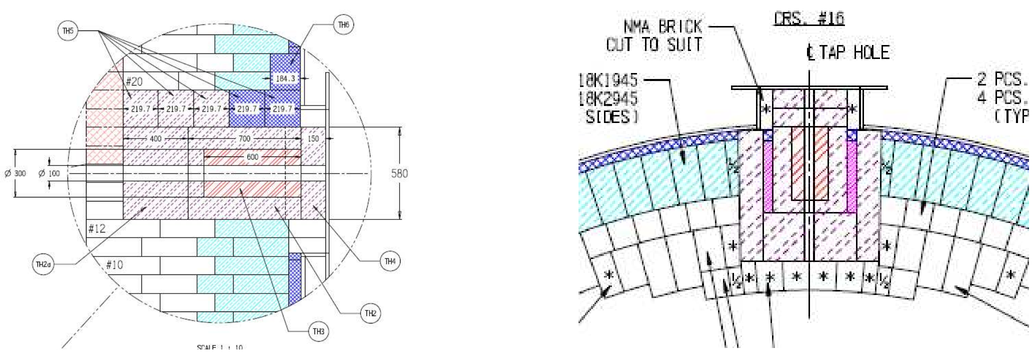


**Figure 2: GrafTech improved taphole configuration**

## 2. Monitoring of Jindal #1

In order to assist the Jindal Management team with monitoring their refractory lining temperatures, numerous thermocouples were installed in the refractory bottom and sidewalls. A complete thermal monitoring system was designed and installed in both furnaces.

Figure 3 shows the thermocouple layout at the metal line. Dual type K thermocouples were installed 300mm and 150mm from the inside of the shell. After start-up, the furnace has shown little significant increase in temperature due to lining wear. The trending looks very favorable as both the inner and outer thermocouples follow the same trend. Temperatures increased to just below 200 deg C during tapping but decreased again after tapping. Although excessive lancing has been employed for an extended period, there is little concern about the lining condition at this stage. However, much more disciplined taphole practices are recommended in order to extend this and any other taphole life in submerged arc furnaces.

It is advisable that the following four variables be checked and recorded regularly. Corrective actions should be part of the standard operating procedures for the operator.

1. Drill lengths
2. Mudgun and drill availability
3. Lancing pipes used
4. Tap hole clay consumption

In a carbon refractory lining, the hot face temperature of the carbon should always be less than 600 deg C to prevent alkali attack and oxidation in the refractories. Similar to all submerged arc furnaces, the Jindal furnaces shows increased temperatures around the tap hole and across the electrodes. This is expected and the heat flux in these areas is also higher than between the electrodes. Higher temperatures can also be attributed to the loss of protective skull, electrode lengths and breaks, and changes in power input. Spikes in temperature should be carefully analyzed and a cause determined whenever possible, and should return to normal so that trends are steady over a period of time. Any upward trend over time in any thermocouple temperature should be taken very seriously and the reason(s) should be identified and rectified.

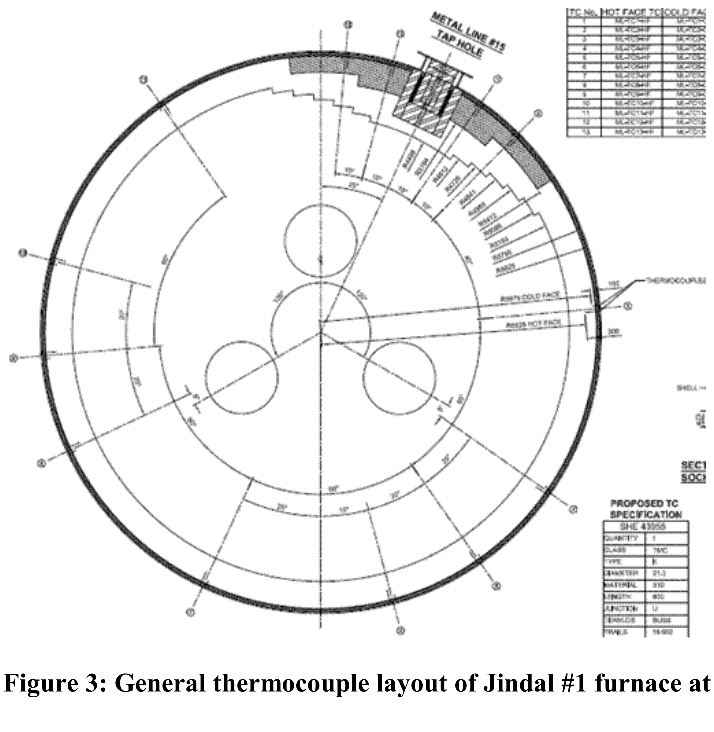


**Figure 3: General thermocouple layout of Jindal #1 furnace at Metal Line**

## 3. UCAR® Freeze linings in service in other parts of the world

The ChillKote™ lining as adopted by JSL has proven to offer advantageous to other furnace operators around the world:

- Increased campaign life
- Reduced total cost of ownership
- Enhanced safety
- Reduced maintenance

GrafTech and its local representative in India, Norinco Pvt Ltd, are presently in discussions with several manganese and chrome smelters in India. Being a rapidly developing country, many metals producers are looking to expand production and to invest in large, high productivity furnaces. And with this follows a need to take advantage of the leading refractory technology, or most of the effort and capital could be wasted. Other producers in the world presently using ChillKote™ linings in their large furnaces include:

- Assmang Cato Ridge, South Africa
- Ferbasa, Brazil
- Ferrometals Witbank, South Africa
- Hernic Ferrochrome, South Africa
- Minera Autlan, Mexico
- BHP Billiton Metalloys, South Africa
- SA Chrome, South Africa
- Temco, Australia
- Tubatse Ferrochrome, South Africa
- XSTRATA, South Africa
- Yiwang Ferroalloys, China
- CYMCO Kunming, China
- POS Himetal, South Korea
- VALE Manganese, France

In the following section, we will present additional details of a few well known producers who have recently adopted the ChillKote™ technology, namely POS Himetal, CYMCO and Vale.

South Korea

POSCO, the world's number three steel producer in 2010, has recently formed a joint venture with Dongbu Metal (Korea's largest ferroalloy producer). The new company, POS Himetal, has inaugurated smelting facilities inside the steelmaker's Gwangyang works on Korea's south coast to produce ultra-low phosphorus ferro-manganese, medium- and low-carbon FeMn, and SiMn. All ferroalloy production from the smelter is to supply POSCO's Gwangyang steelworks.

The company's second furnace, of 30 MVA, is using a ChillKote™ lining, and POS Himetal plans to formally commission it in September 2011 to produce SiMn. GrafTech supplied all the carbonaceous materials, including HotPressed™ carbon and semigraphite brick, GradeD™ carbon blocks, CJR™ graphite, and the necessary cements and ramming pastes.


**Figure 4: The banner inside the new POS HiMetal SiMn furnace reads: "Congratulation Ceremony for successful lining installation of 30MVA SAF"**

## China

China Yunnan Metallurgical Group (CYMCO) has presently two 30 MVA Ferromanganese smelting furnaces under construction and several smaller FeMn furnaces in operation. They are now constructing a 68 MVA furnace to boost their production capacity. This will be the largest FeMn furnace in China so far, but we believe that this is the start of a conversion from smaller to larger high productivity submerged arc furnaces, and expect to see more large SAFs constructed in the near future.

GrafTech supplied and recently supervised the installation of the ChillKote™ hearth wall and graphite cooling layer. CYMCO chose ChillKote™ technology based on the excellent performance and extended lining life the system has proven to offer operators of large manganese furnaces around the world. Metix, a leading South African engineering company in the ferroalloy industry, provided key technology for the furnace, and was a partner with GrafTech for the lining supply.

The lining material installed includes well known GrafTech products such as NMA™ HotPressed™ bricks, NMD™ HotPressed™ bricks, GradeD™ carbon, and CJR™ graphite. Once commissioned and put into service, this lining will offer CYMCO a very reliable manganese smelting furnace for many years to come.

## France

Vale Manganese in Grand Synthe, Dunkerque operates the largest FeMn furnace in Europe. The plant has a single 102 MVA submerged arc furnace, supplied by a German manufacturer and first commissioned in

1991. The first campaign lasted 14 years, the second only 3. The short campaign and the resulting production loss were very costly to the furnace owners. The original furnace had forced air cooling in the bottom but no additional (water) cooling for the furnace walls. The original shell was 15.1m diameter and 6.4m high. A new furnace was constructed during the spring of 2009.

The new FeMn furnace designed by Outotec from Finland represents state-of-the-art design and technology; including water sprayed shell and improved refractory lining design. One of the major changes was to replace the existing carbon block lining with a ChillKote™ lining supplied by GrafTech. This lining includes the well proven NMA™ and NMD™ HotPressed™ bricks, GradeD™ carbon blocks, and CJR™ graphite. The RDME target is now to accomplish a very long and trouble-free campaign, similar to what is recorded at many other leading FeMn producers, utilizing the ChillKote™ lining concept and its unique materials. The results after the first years of operation are very convincing and promising for the future, showing very low, stable and consistent temperatures at all critical sections of the furnace.

## 4. The UCAR® Freeze Lining System – proven by its performance

The UCAR® Refractory System ChillKote™ lining concept combines active cooling and thermally conductive carbon and graphite refractories to maintain low refractory temperatures. Effective water sidewall cooling, together with the efficiency of the heat dissipating conductive refractories, lowers the temperature of the lining below that of the molten materials. This causes a layer of slag and process metal to freeze, which forms a protective layer or “skull” which completely coats the refractory hot face. Once formed, the slag skull insulates the refractories, reducing heat loss and protecting the lining from erosion, chemical attack, and thermal stress, the three main causes of refractory wear in smelting furnaces. The result: greatly improved refractory performance and extended life.

The ChillKote™ lining concept allows significant reductions in lining thickness and mass. As a result, the working volume and capacity of the furnace is increased, installation and commissioning time is shortened, and profit-robbing downtime is reduced. The ChillKote™ system combines high conductivity carbon, semigraphite, and graphite materials with insulating ceramic refractories to control the temperature of the steel shell. Each component provides the properties required for its application, working together in a cohesive system to enhance lining performance and protect the overall integrity of the furnace. Should the protective skull be lost during upset conditions, self healing and the replacement of the skull will occur quickly due to the low refractory hot face temperature.

GrafTech’s proprietary HotPressed™ method of manufacturing produces carbon and semigraphite refractory bricks with low permeability, superior resistance to chemical attack, and outstanding thermal conductivity. UCAR® Refractory Systems HotPressed™ bricks have an unsurpassed track record of reliable service in blast furnaces and submerged arc furnaces around the world for more than 50 years.

The UCAR® hearth wall system is based on the fact that all significant hearth wear mechanisms are related to high temperature. Alkali attack only occurs above 800 °C; thermal stress is a result of extreme thermal expansion at elevated temperatures; and erosion occurs when liquid metal contacts the carbon refractory directly for extended periods. Therefore if temperatures can be maintained at a low level, wear is prevented.

There are four key elements of the UCAR® Refractory hearth wall system (Figure 5):

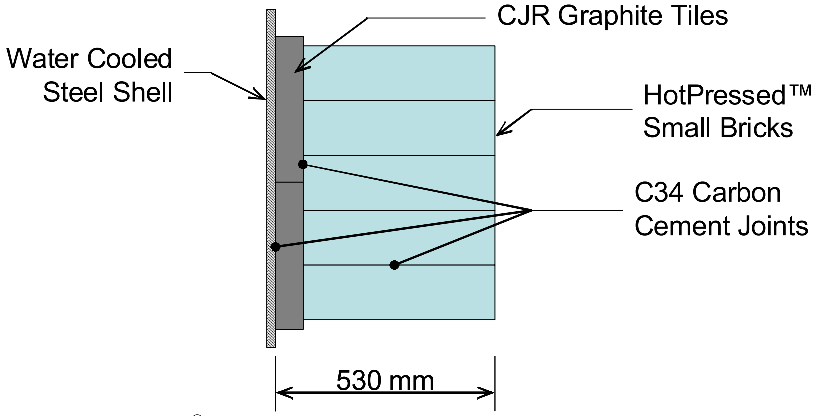


**Fig 5. The UCAR® Refractory System furnace wall, with a water cooled shell and HotPressed™ bricks**

1. The wall is thin compared to traditional designs, typically 530 mm thick, which promotes more efficient heat transfer and lower temperatures at the hot face. This also allows for a larger distance between the electrodes and the lining as well as a larger furnace crucible.

2. Small HotPressed™ bricks are used instead of large blocks, insulating ceramic, or carbon paste. Small pieces have small expansion, which reduces thermal stress. Cutting small pieces from large carbon blocks does not achieve the same effect! Properties are known to vary significantly within a block, which will translate to varying quality from brick to brick. In addition, "micropore" blocks achieve their properties through large amounts of non-carbonaceous additives, which have detrimental effects on other critical properties. HotPressed™ bricks have superior thermo-mechanical properties, and have proven their superiority in many long furnace hearth campaigns worldwide.

3. There is no ramming between the brick rings and the cooling elements (shell or stave). Ramming paste has poor conductivity compared to baked carbon refractories, and it can over time become dry and granular or separate from the refractory, causing an interruption in heat transfer.

4. Special cement is used on all brick surfaces to fill the joints, bond bricks together, transfer heat, and most importantly, absorb expansion without creating stress.

When these principles are followed, the hot face temperature of the hearth wall is below the freezing temperature of slag and iron, and a protective skull is formed on the face of the wall. The skull insulates the brick, pushing temperatures even lower, and protects the brick from iron contact and erosion.

## 5. Conclusion

Like many companies in the fast growing Indian metals industries, Jindal Stainless is investing heavily in adding new capacity. In doing so, they have decided to invest in state-of-the-art equipment, which includes the smelting furnaces. In this paper, we have shown how the large block refractory linings initially supplied with the furnaces failed prematurely and how these were replaced with the proven ChillKote™ lining systems. An advanced thermal surveillance system was installed and allows for Jindal operations management to closely monitor the condition of the lining and take immediate actions if and when abnormal situations occur. The same technology has been adopted by leading ferroalloy producers around the world, including large benchmark furnaces. We have also shown technically why the ChillKote™ linings offer long and trouble free campaigns, by addressing the true causes of refractory wear and taking steps to prevent them.

## References


1. Peter Sylvén et al, "*New Hearth Lining Direction*" at Salzgitter Flachstahl Blast Furnace B, 5th European Coke and Ironmaking Conference, Jernkontoret, Stockholm (2005).

2. Peter Sylvén, "*The Truths and Myths of Freeze Lining Technology for Blast Furnaces*", The Moscow Institute of Steel and Alloys, Moscow (2004).

3. Hearn A.M., Dzermejko A.J., Lamont P.H., "*Freeze Lining Concepts for Improving Submerged Arc Furnace Lining Life and Performance"*, 8th International Ferroalloys Congress Proceedings, Beijing, China, June 7-10, 1998, pp 401 – 426.

4. P. Duncanson and P. Sylvén, "*A Financial Model for Investment in Hearth Technology*", SAIL Equipment Manufacturers Conference, Ranchi (2007).

5. Peter Sylvén et al, "*New Lining Direction at Jindal Stainless FeCr #1 & #2*", Infacon XII, June 2010




**GrafTech International enables customer leadership better and faster than our competition, through the creation, innovation and manufacture of carbon and graphite material science based solutions.**

Visit us on the web at: www.graftech.com