

Practices and Design for Extending the Hearth life in the Mittal Steel Company Blast Furnaces

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Abstract - The Mittal Steel Company operates about 36 blast furnaces on four continents. Furnaces range from 1100 m³ to 4800 m³ inner volume. The focus of the group is to push for increasing productivity and increasing campaign life. This has been especially challenging, as many of these furnaces were not equipped for long campaigns during their prior rebuilds. Monitoring and operating practices have to be modified to match the new philosophy. Mid-campaign hearth repair strategies and hearth design philosophies have had to be reconsidered. The paper describes experiences with the current hearth designs and measures taken for hearth life extension. Additionally, the philosophy of recent hearth re-designs is discussed.

INTRODUCTION

It is agreed by consensus among blast furnace (BF) operators worldwide that an extended stop for a major repair will be driven by the condition of the hearth. This is also the philosophy at Mittal Steel's blast furnaces. At Mittal Steel, we drive the operational philosophy changes required to move towards a campaign-extension frame of mind, through our Knowledge Management Programs. This allows for quick transfer of learning, and building on experiences at each plant. Here we use the examples of Ispat Inland No. 7 BF (II7) (13.7 m diameter, 40 tuyeres, 4 tapholes) and South Africa Newcastle No. 5 BF (NEW5) (10.14 m diameter, 30 tuyeres, 3 tapholes) to describe how we are addressing hearth management for campaign extension.

Figure 1 shows a benchmark of some furnaces worldwide. II7 completed its second campaign in June 2003. NEW5 is currently in the middle of its campaign, with a planned reline in 2008. Clearly, achieving world-class campaigns is the aim of our plants.

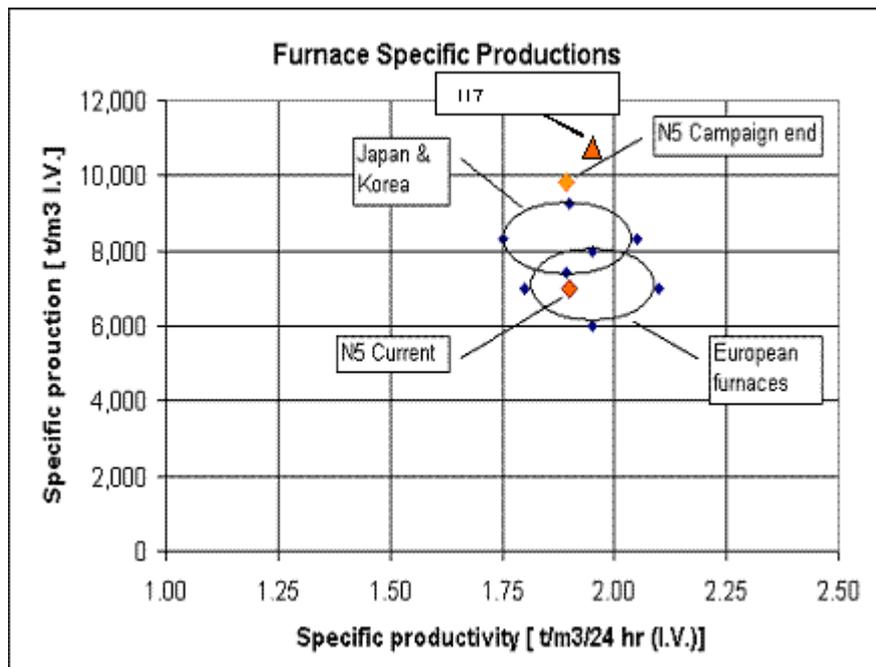


Figure 1: Benchmarking blast furnaces on campaign production per m³ inner volume against average productivity during the campaign (II7: Ispat inland No. 7, N5: South Africa Newcastle No. 5)

BACKGROUND

History of II7

II7 started the second campaign in 1987. In 1993, during a mid-campaign stop to install a graphite high-density cooling lining in the bosh, belly, and lower stack, severe wear was noted in the taphole region and the sidewalls (many regions were in the neighbourhood of 550 mm). Figure 2 shows the measured wear. The taphole blocks were replaced with graphite shapes during this stop. The furnace was then operated for another ten years, during which PCI was introduced, ramping up to levels of 180 kg/thm; production records were set, and conversion from 100% conventional slot oven coke to 100% energy recovery oven coke was successfully completed. Figure 2 also shows the average wear observed at the end of the campaign in 2003. It is clear that the furnace lining condition was largely managed until the end of the campaign. However, the temperatures in a band 1-2 m below tapholes 1 and 2 (tapholes are 60° apart) proved very difficult to contain during the past two years of the campaign. Increased monitoring efforts during this period can be seen from Figure 3, in which we show the number of hearth thermocouples. Among various measures, to be outlined later, two important ones are mentioned here – a permanent decrease of output by about 15–20%, and the use of No. 1 taphole only as an emergency in the past year, are notable. Figure 4 shows a graphic representation of an area below tuyere 37 where the bricks had completely disappeared and the shell was protected by a large island of grout.

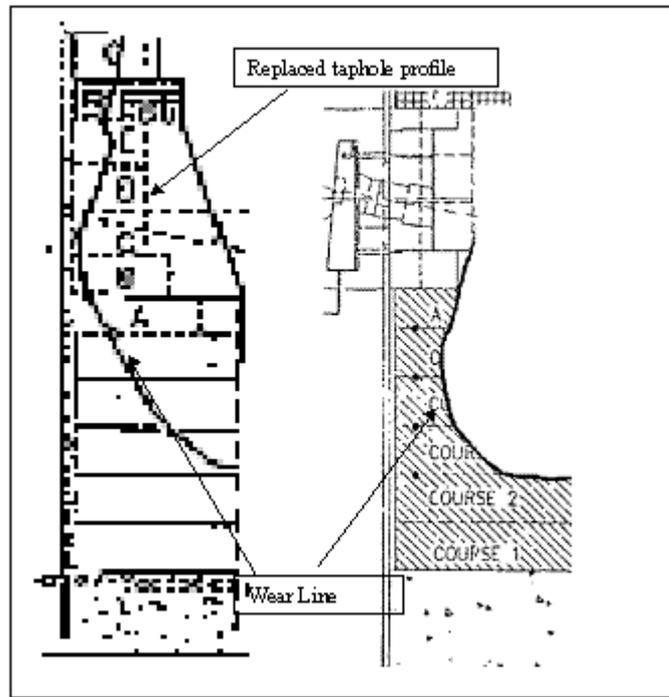


Figure 2: Average wear profiles at II7: left - 1993; right -2003

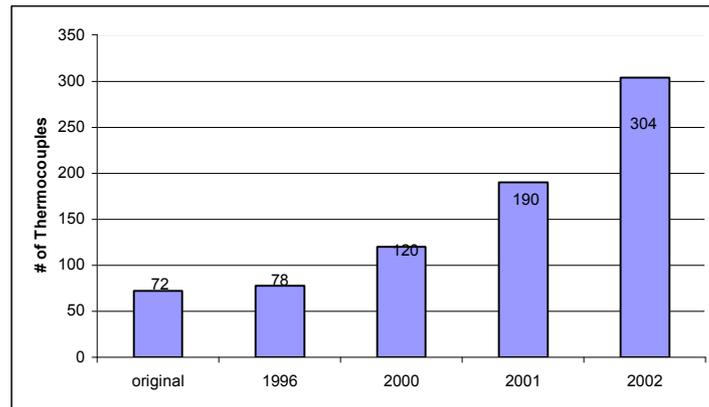


Figure 3: Increase of thermocouples at II7 during second campaign

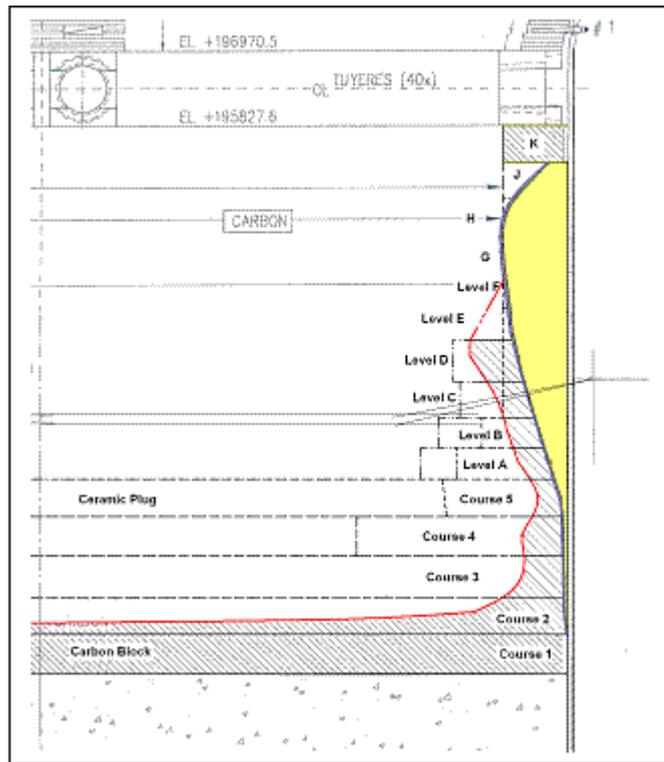


Figure 4: Critical-area wear profiles at II7: under tuyere 35; 2003 reline

Figure 5 is a picture of a neighbouring region wherein the separation of the brick and the iron penetration is clearly visible. These areas in the region of taphole 1, which necessitated the actions mentioned earlier, were the main reason to take the furnace down to carry out the reline.

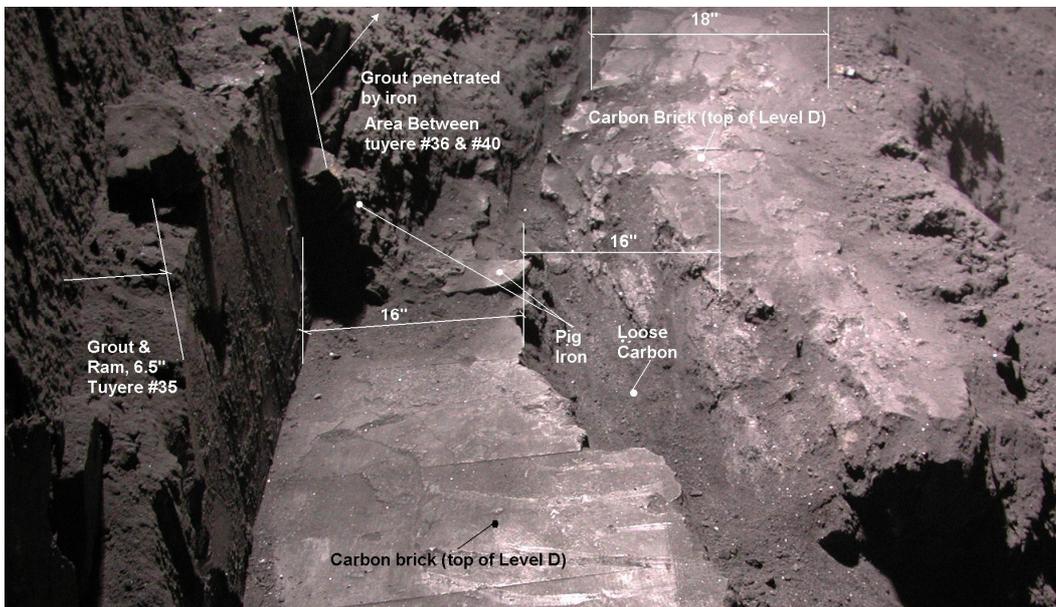


Figure 5: Photograph showing iron penetration under tuyere 35 at 2003 reline

The major learning from this experience at II7 was the requirement of a detailed monitoring and assessment system and the diligence required to establish the root causes for the incidences of increasing hearth temperatures. We also gained valuable experience with various control measures.

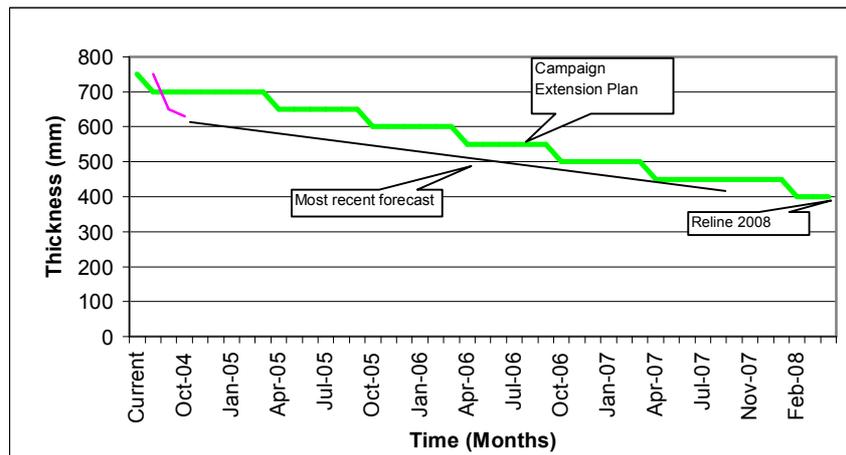


Figure 7: Blast Furnace N5 – Planned vs actual wear rate in the hearth wall at high wear rate area

HEARTH MONITORING SYSTEM

A robust, exhaustive hearth monitoring system is the first step to campaign extension and must have the following aspects:

- Sufficient number of thermocouples in sidewall and pad, with increased concentration in high-wear areas, and accessibility to test integrity as needed
- In the sidewall installation should be in pairs *i.e.*, replaceable duplex thermocouples
- In the bottom vertically-aligned thermocouples
- I/O space to add thermocouples as campaign proceeds
- A simple clear calculation scheme for thermocouple checks and skull build-up
- A user-friendly display and warning system with trending capabilities.

Since most of our furnaces were not well instrumented to start with, adequate thermocouple installations have been a priority. A hearth monitoring system, incorporating the above principles, was developed and implemented at Mittal Steel - South Africa NEW5. It is being subsequently implemented at most of the other locations throughout the group. It is a relevant, not costly, programme running on actual data, monitoring the hearth wear rates continuously by giving the actual equivalent lining thickness to operators which can implement the action steps to be taken immediately depending on the situation.

Calculation Scheme

The duplex thermocouples and, where available, the vertical pairs allow a simple calculation of one-dimensional heat transfer. An equivalent carbon thickness, along with the historical database of the 1150°C isotherm, estimates the 'equivalent iron skull' thickness - the calculations assume the same conductivity for the carbon and the skull. Rate of change of the duplex thermocouples and the rate of change of the difference of the duplex thermocouples allow us to estimate the continuity of the thermal energy extraction path, the carbon thickness, and integrity of the system. Keeping a simple set of rules is the best option for an on-line system. For more detailed calculations, we also have 2D models for backward heat transfer calculations,

and these are used mostly off-line by the process engineers for long-term assessments.

Monitoring System

The monitoring system at NEW5 is described below using some of the graphic interfaces to show its versatility.

An overview of the hearth thermocouple layout (Figure 8) can be accessed directly from the furnace control system. All of the temperature readings are displayed on this graphic, with certain alarm limits for thermocouples. Green is normal, orange means the couple temperature is 50 degrees from its previous campaign maximum, red means the couple temperature is 30 degrees from its previous campaign maximum and, if flashing, it has reached the maximum temperature ever recorded during the current campaign. These alarm limits are being reviewed every three months by management. From this menu, every level in the hearth can be accessed for more information regarding equivalent lining thickness. The monitoring system's data is then also transferred to a cross-sectional drawing of the hearth to get a more graphical wear pattern, as shown in Figure 6.

All hearth temperatures, as well as equivalent hearth wall thickness measurements, are compiled in a monthly report and discussed as well as certain decisions taken by management to prolong the life of the hearth, which then determines whether the campaign can be lengthened without taking unnecessary risks or huge production losses. Core-drilling data is used close to the end of the campaign, to correlate the functionality and accuracy of our monitoring system. The core-drilling data can also then be used to verify the presence of a brittle zone, which will also affect the model's calculations. Thermographics are also employed when hot spots develop.

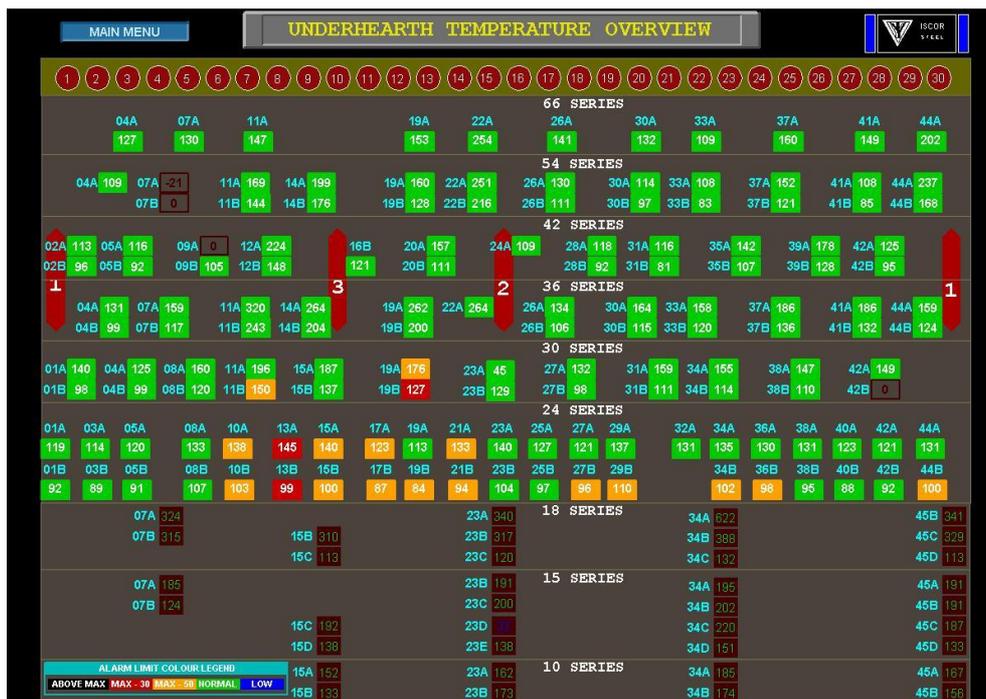


Figure 8: Blast Furnace N5 – Under-hearth temperature overview

In Figure 9, a cross-sectional overview is given, with all the thermocouples installed on this level. The temperatures, as well as the equivalent lining thickness, are displayed, and with a quick glance it is easy for the operator to determine a specific problem area. The alarm limits on this screen are set to the remaining equivalent lining thickness, where green is the original installed thickness, and then flashing red if the critical campaign thickness has been reached. At this stage, certain pre-determined action steps have to be taken by the operator.

By selecting a certain area on the lining thickness overview, a trend for the past seven days will be displayed as in Figure 10. This can be helpful in determining the behaviour of certain thermocouples and if certain actions need to be implemented pro-actively, for example, reducing nut coke to increase the deadman permeability without affecting stable furnace operation too much.

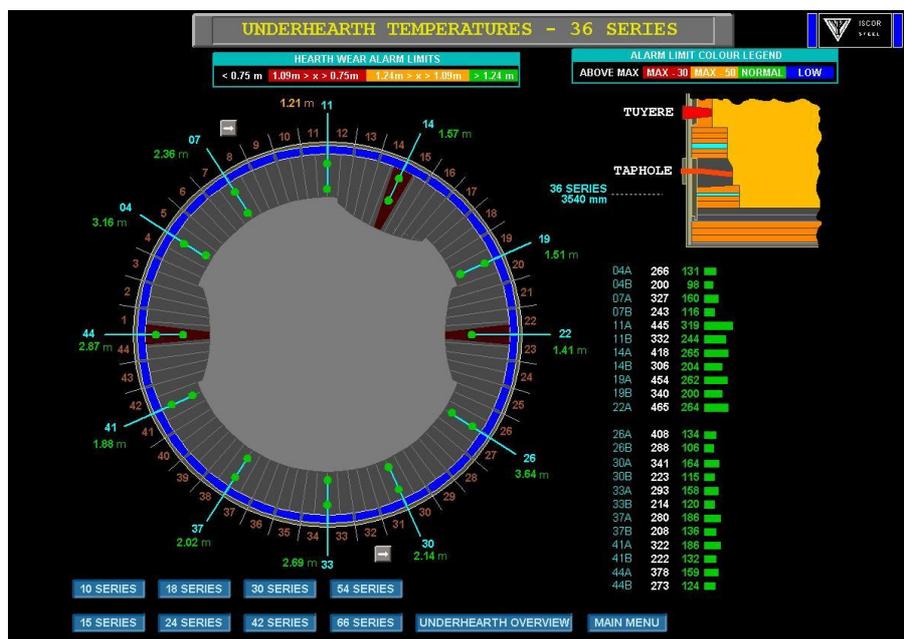


Figure 9: Blast Furnace N5 – Under-hearth temperatures - 36 Series

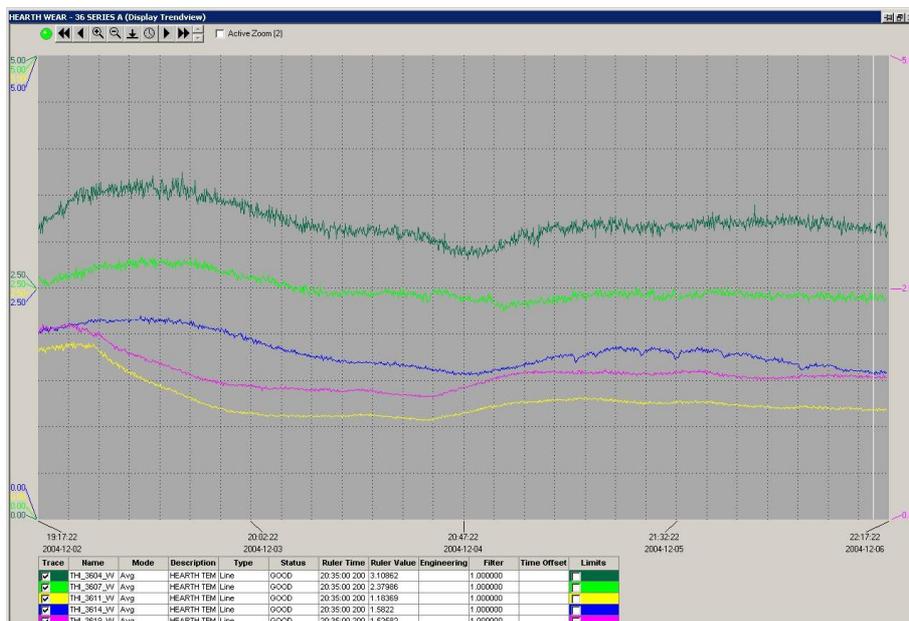


Figure 10: Blast Furnace N5 – Hearth Wear display trend-view

ACTION STEPS FOR HEARTH MANAGEMENT

Hearth management translates into a strong focused response to results and analysis from the monitoring system. Our actions are step-wise, based on the severity levels of the various alarms, and the location of the alarm region. These are mentioned in two categories:

Short Term

- Hearth wall grouting
- Casting configuration
- Taphole maintenance
- Tuyere blanking
- TiO₂ addition / Injection
- Shutdowns
- Water leak detection (top to bottom)

Long Term

- Chilled water
- Activation of deadman
 - o Minimization of fine materials
 - o Hot Metal temperature
 - o Bottom cooling control
 - o Raceway modifications via tuyere velocity
 - o Coal/coke exchanges
- Operational Stability
- Increased monitoring

HEARTH DESIGNS AT MITTAL STEEL

Our goal in hearth design is not necessarily to devise a universally common design for all of our plants, but rather to ensure that learning from one plant is used in the development of the design for the other. Combined with experiences worldwide, and the local situation, the final design is chosen. Note that, as previously mentioned, a low-quality carbon lining provided better than expected performance during the second campaign at II7. Now, much higher productivity, longer campaign life, combined with low-coke rate operation, are the requirements for our plants. Recently, we completed the relining of II7. The design features are shown in Figure 11. Advanced micropore carbon blocks are used at the sidewall, with modern-day ram for the shell-carbon interface. This is a channel-cooled hearth. A unique combination of ceramic materials and a semi-graphitic micropore along with the redesigned bottom cooling allowed us to develop a larger sump depth (although somewhat less than ideal) to promote bottom flow.

Recently, we finished the designs for two more of our larger furnaces – MS Poland No. 1 and MS South Africa 'D'. The design considerations at II7, and the performance of the hearth at NEW 5, led to choices similar to that in Figure 11 for the sidewalls. For the pad, a more conventional ceramic, and

horizontal carbon blocks, were maintained given the cooling system and the space for the pad courses.

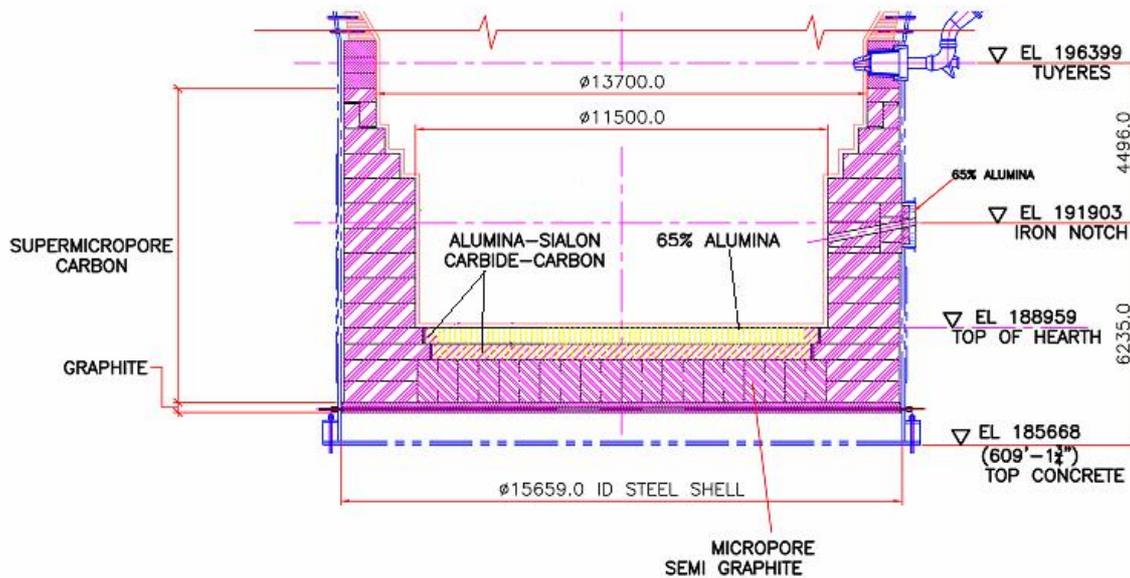


Figure 11: Hearth design for third campaign at II7

FUTURE DEVELOPMENTS

In order to have long campaigns, and a high level of productivity, our knowledge of the conditions in the hearth has to be continually improved. Provision of a comprehensive monitoring package from the start of a campaign is a standard requirement. At Mittal Steel, we are involved in the development of advanced 2D and 3D hearth simulation models. These models are used to interpret the phenomena we detect from our monitoring systems. Novel non-linear and linear acoustic techniques are being developed to determine early stages of damage to sidewall carbon, so that extensive core drilling as we have done in the past will not be required.

FINAL REMARKS

At Mittal Steel, we have been moving aggressively to develop the systems necessary to drive for long campaign life, both in terms of extending current ones and developing the foundation for the next campaign. The advantage of being able to learn quickly from a large range of furnace operations with varying raw materials and process capabilities is at the heart of our knowledge management initiatives. The challenge is to develop a robust and prudent system, within both financial and local constraints faced at each plant, to move towards longer campaign goals. It is currently not inconceivable to think in terms of an 18 -20 year campaign with high daily productivity and high campaign productivity.