ICSTI
6th International Congress on the Science and Technology of Ironmaking - ICSTI
42th Ironmaking and Raw Materials Seminar/ 42º Seminário de Redução de Minério de Ferro e Matérias-primas
13th Brazilian Symposium on Iron Ore / 13º Seminário Brasileiro de Minério de Ferro
ISSN 2176-3135

APERAM (ACESITA) BLAST FURNACE NO. 2 – DESIGN AND PERFORMANCE OF THE BLAST FURNACE COOLING AND LINING SYSTEM[1]

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Abstract
The objective is to discuss the performance of the blast furnace after a repair performed in 2005 of the Upper hearth layer, Tuyere zone, Bosh and Belly. In May 2012 the furnace reached the seven year target of the repair for the Belly of the furnace. The article will cover the following items: design of the repair; start up and ramping up the production; casting practices; way of operating, using both coke and charcoal as fuel; devices and system for measuring the lining thickness over time; the continuation of the furnace campaign, campaign lifetime, the future.
Key words: Blast furnace; Campaign life; Bosh repair; Coke and charcoal; Casting practices; Measuring the lining thickness.

1 *Technical contribution to the 6th International Congress on the Science and Technology of Ironmaking – ICSTI, 42nd International Meeting on Ironmaking and 13th International Symposium on Iron Ore, October 14th to 18th, 2012, Rio de Janeiro, RJ, Brazil.*
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1 INTRODUCTION

Aperam operates two blast furnaces at its Timóteo-MG plant. The total Hot metal production is about 2,000 tonne per day maximum. Blast furnace no. 2, the largest of the two, produces a maximum of 1,270 tonne Hot metal per day, it has a 630 m^3 Working volume, and a 6.5 m Hearth diameter.
Problems in the bosh occurred in the fifth campaign of this blast furnace only two months after blow-in in 2002. High heat loads and hot spots were observed in the bosh and belly area followed by a breakout 6 months after start-up as (hot spots are indicated in Figure 1).

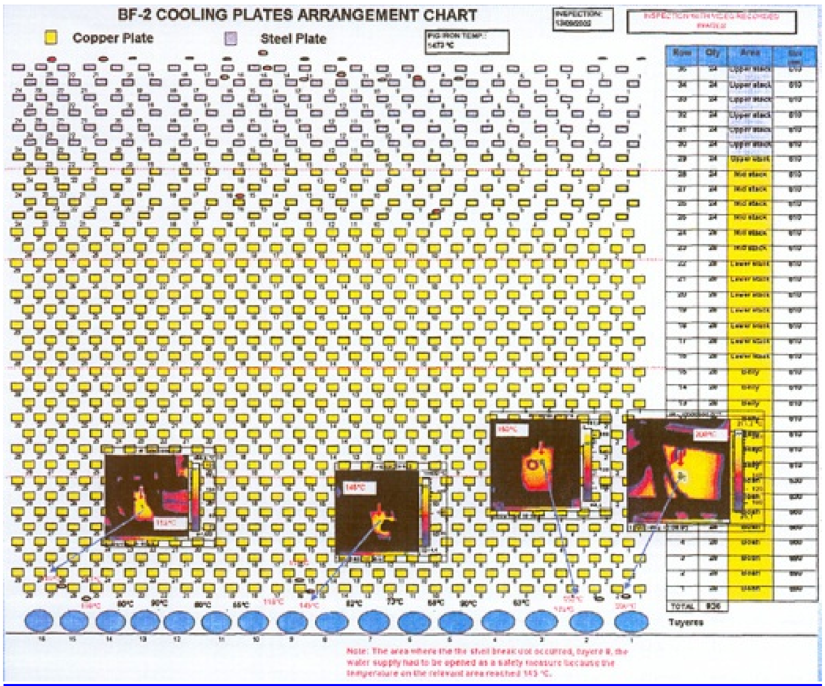

Figure 1. Locations of hot spots in 2002.

The furnace underwent a temporary repair to get back into production while at the end of year 2003 the engineering and procurement for a more permanent repair started. Up until the permanent repair could be executed the furnace continued operating with maximum attention on protecting the bosh, utilizing a ‘special charge’ that promoted a stable scab to form and be maintained on the bosh. Although effective, the use of this ‘special charge’ practice and consequent process modifications limited the productivity of the furnace.
The furnace was stopped and underwent the permanent repair in 2005, the repair included the top layer of the Hearth wall, Tuyere belt, Bosh and Belly. Some repair work was also carried out in the taphole area when damage was identified during the shutdown. A Hoogovens integrated cooling and refractory lining design was installed in the bosh and belly. An additional row of plate coolers was installed just above the tuyere coolers.

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This paper addresses the history and the repair design solution, the blow-in and ramp-up of the furnace as well as the performance to date after the repair.

2 APERAM BLAST FURNACE No. 2

The Blast furnace No. 2 was blown in after the reline on February 4th, 2002. It was designed using copper plate coolers (in 29 rows of copper, and in 6 steel plate coolers)and a lining of Silicon carbide bricks (Refrax 20 SBF Saint Gobain) and a High Alumina (Mulibar 70 Ibar) hot face in the Bosh, Belly, Lower and Middle Stack.
In the first months of the campaign hot spots were observed and grouting was initiated based on advise of the designer. Also an external spray system was installed. Two plate coolers in the bosh leaked and were isolated from the water system. At the end of the month of August a break out occurred in between plate cooler rows 2 and 3. In October again two plate coolers were found leaking, cooling water entering the furnace forced it to be stopped. The furnace was grouted at the tuyere zone and lower bosh where quite some refractory was found to be missing detected by drilling into the furnace tuyere zone and lower bosh.

Table 1. Campaign lengths and operational data

Campaign	I	II	III	IV	V	V (ext.)
Start	April 1979	April 1982	November 1987	February 1995	February 2001	June 2005
End	December 1981	September 1987	January 1995	November 2001	Present	Present

Campaign	IV	V	V (ext.)
Working volume (m³)		600?	631
Hearth diameter (m)		6.5	6.5
Tuyeres		16	16
Fuel	Charcoal till 1996	Coke	Coke, later in the campaign Charcoal
Pulverized Charcoal Injection (kg/THM)		150 (+/- 50)	150 (+/- 50)
Top charging equipment		Bell less top	Bell less top
Throat armor		Fixed, metallic	Fixed, metalic
Raw materials	Till June 2001: Sinter	70% Pellets and 30% Lump ore	70% Pellets and 30% Lump ore

Aperam had made a clear scope of work for the repair. However, during extensive negotiations with Aperam, Acesita at the time, the scope of repair was further defined. Insufficient funds were available to install new machined plate coolers and machined graphite refractory in both the Bosh and Belly, which was considered necessary to obtain the desired 10+ year campaign.
It was decided to reuse the existing platecoolers in the Belly and design the system such that the contact between each of the platecoolers (that were not machined) and the refractory was established by means of a ramming mass. By doing so small deformations that may have existed in the plate coolers could still be accepted as long as the plate cooler was in sound condition, as would be established by inspection.

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The Bosh was designed as per the full Hoogovens design, the so-called Hoogovens Intregrated lining and cooling system.
See the drawing below for the scope of work according to the General arrangement drawing that was part of the proposal and the contract.

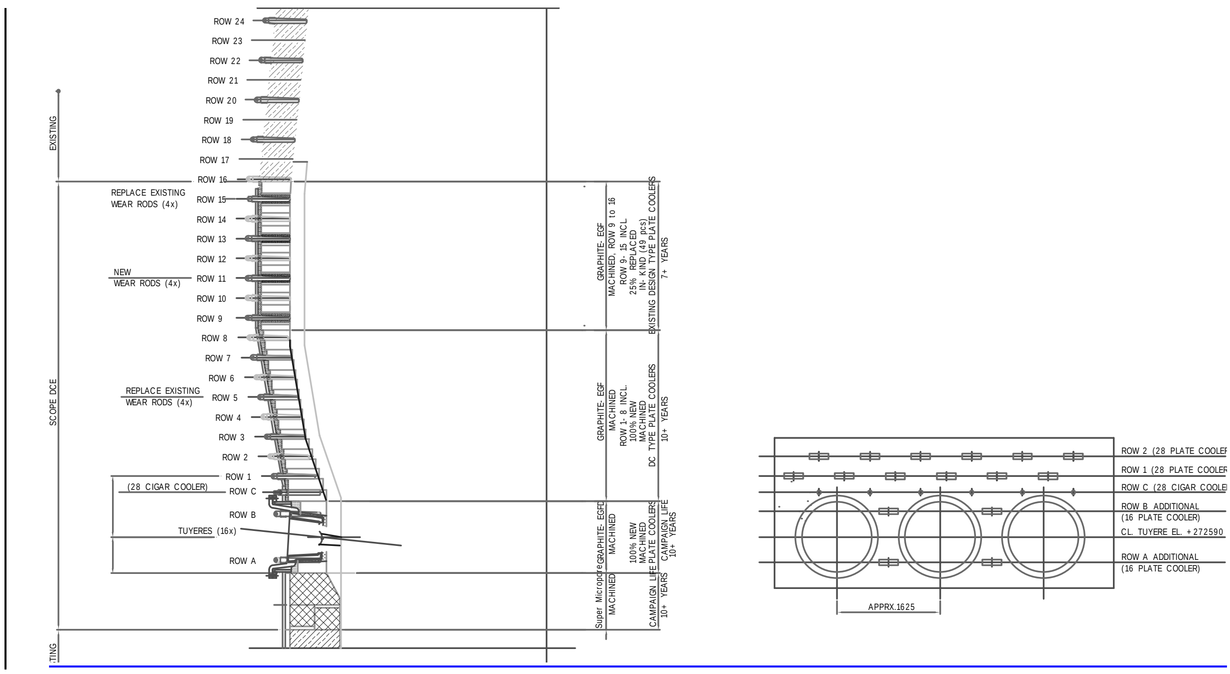

Figure 2. Drawing of the proposed design for repair.

The expected life time was established as being ten years for the Tuyere zone and Bosh and seven years for the Belly.
After a contract was awarded by Aperam in November 2003, the Basic and detail engineering activities were started. These lasted four months.
Knowing the fast deteriorating condition of the blast furnace the necessary equipment, such as plate coolers, refractory and miscellaneous materials were purchased already two months after order award when engineering was still ongoing.
The engineering team visited Aperam site several times, for site verification, but mostly to have discussions with the engineers and operators of Aperam to fully satisfy their wishes and desires as reflected in the design.
Aperam worked with a local contractor to prepare the repair activities at site.
The layout of the cooling water piping was re-arranged to accommodate the Hoogovens Heat flux monitoring system that was part of the scope of repair (Figure 3). Such a system provides the heat load information for the different zones of the furnace wall and are a tool for the operator in operating the furnace more efficiently. Also leak searching of possible leaking plate coolers could then be easily applied in the piping layout that was engineered. Local engineering companies were involved to make the detail and shop drawings.

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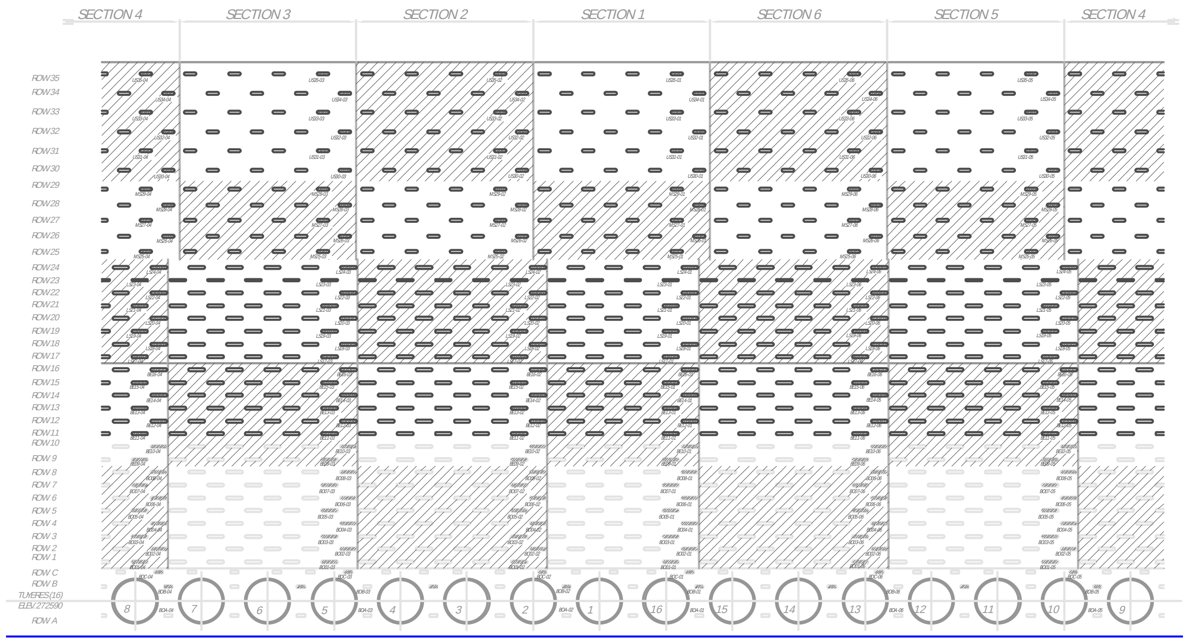

Figure 3. Heat Flux monitoring system, arrangement of zones of the furnace wall.

3 DESIGN DETAILS

3.1 Hearth Wall

The replacement of the upper 900 mm of the Hearth wall was part of the scope of work, the design included an expansion joint made in the form of a ramming joint.
The hearth wall material was super micropore refractory, the layer being designed as big blocks.
The shell remained unchanged.

3.2 Tuyere Zone

The tuyere zone was designed having two additional rows of plates coolers. , In between each set of adjacent tuyeres two plate coolers were added, respectively in a new Row ''A'' and a new Row ''B''.
The refractory was installed on top of the Hearth wall block layer above mentioned. The contact between the tuyere cooler and the refractory was by means of a ramming mass.
The refractory in this tuyere zone was an extra dense type of graphite refractory.
It is foreseen that the design will obtain a ten (10) year campaign minimum lifetime.

3.3 Tuyere Zone and Bosh Transition

The cooling in the bosh was improved by the addition of a row of plate coolers, Row ''C'', located just above the existing tuyere cooler opening in the shell.
In the initial design stages cigar coolers were foreseen, however later in the design phase it became clear that the shell strength was sufficient to accept the larger openings necessary for plate coolers, which naturally have a larger cooling effect.

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This area was of concern as it has been prone to showing problems in other blast furnaces, so the design that was selected, by adding plate coolers, guaranteed proper cooling of the refractory in this area.
Also for this area of the furnace a ten (10) year minimum lifetime is foreseen.

3.4 Bosh

The bosh is designed with new copper plate coolers and new graphite refractory. The top and bottom face of the plate coolers are machined as well as all six sides of the refractory shapes, so to have total, intimate contact between the two elements mentioned and the adjoining refractory blocks.
The shell of the bosh was damaged caused by the break out and local hot spots, it was repaired locally.
Lifetime foreseen for the Bosh area of the furnace is 10 years minimum.

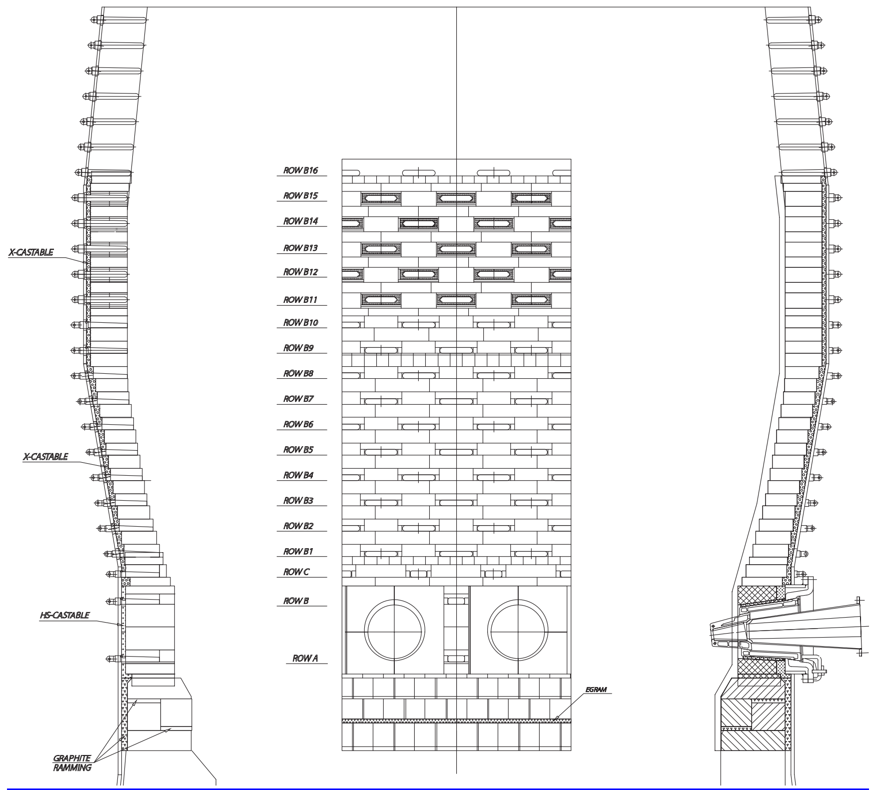

Figure 4. Final design, General arrangement and furnace lines.

3.5 Belly

Starting in the second row of the Belly, existing plate coolers were reused. Contact between the non-machined surface of the plate coolers and the graphite refractory blocks was provided for by a ramming joint.
An adjustment course assured the connection between the new and the existing lining.
A 10 year minimum lifetime is foreseen for the Belly area of the furnace.

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3.6 Measuring Rods

In both Bosh and Belly ceramic wear rods were installed to be able to know by measuring the wear of the refractory lining, regular measurement taking furnish the wear over time.

4 BLOW DOWN

The blow down began on April 9th 2005, with the salamander tap completed the day after. The preparations for the blow-down had of course started some weeks previously with technical discussions and practical arrangements made to clean the furnace walls and assure a smooth, successful salamander tap. The DC team arrived on site 1 week prior to the planned blow-down date to ensure that the final preparations were complete, and to be present during the preparatory stop. The blow-down was completed in 11 hours, with the salamander running within 90 minutes of furnace stop. A total of 85 t was tapped, as was expected from the relatively small size of the furnace hearth.
Due to the close proximity of the town of Timóteo, and the idyllic natural surroundings where the blast furnace is located, measures were taken to ensure that the blow-down was conducted with the minimum impact to the environment. The BF was isolated from the gas network prior to the blow-down so that there was no need to blow-out via the bleeders, which had the added benefit of a ‘silent’ blow-down, particularly important when conducted through the night and into the early morning hours. Cold water from a separate bassin was used in the Bischoff washer to keep temperature at the outlet of the Bischoff washer as long below the critical temperature (protecting coating) and cyanide and ammonia levels were monitored to avoid any contamination of the waterways.
The blow-down ran very successfully with the deadman coke burned to a significant degree. The measurement of the top gas analysis remained reliable throughout, with excellent control of the top gas temperature. The blow-down was halted after 11 hours when the oxygen in the top gas reached 0.3%.

5 REPAIR

The construction lasted 27 days, starting April 10th through May 7th, 2005. Supervision was furnished by Danieli Corus during the full time period of the repair.
Removal of burden, capping the remaining burden, and demolition took 7 days.
Shell repairs, 3 days. Installation of Upper layer of hearth wall, 2 days (Figure 5).
Repair to the taphole, (Aperam using existing materials, work not foreseen in the original scope of work).
Building the tuyere zone, 2 days (Figure 6).

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Figure 5.

Figure 6.

Bosh construction, 5 days (Figure 7).
Belly installation, 4 days (Figure 8).

Figure 7.

Figure 8.

Welding of coverplates, these form the plate cooler to shell connection, 2 days (on critical path).
Pressure test, connection to cooling water piping system, and cold commissioning, 2 days.

6 BLOW IN AND RAMP UP

Following the repair, the furnace was ready to be blown in on 8th May 2005. Prior to the blow-in itself a burdening plan was put together that would see a decreasing coke rate and a rapid resumption of usable hot metal quality, with respect to hot metal silicon percentage. Once this was established, and good separation of iron and slag on the casthouse was assured, then the production rate was to be increased. The number of tuyere open started at 6 with all 16 open after 55 hours from the start. By this time the hot metal temperature was already above 1,400°C and after 80 hours the hot metal silicon was <2%.

ISSN 2176-3135

Casting was observed to be critical at 20-30 hours after the start of the blow-in with slag observed at the tuyeres. But after 4 days the furnace was considered to be in a reasonable condition so production level could start to be increased, and also the level of charcoal fines injection. This point then marked the beginning of the Optimization stage, starting on 12th May 2005.

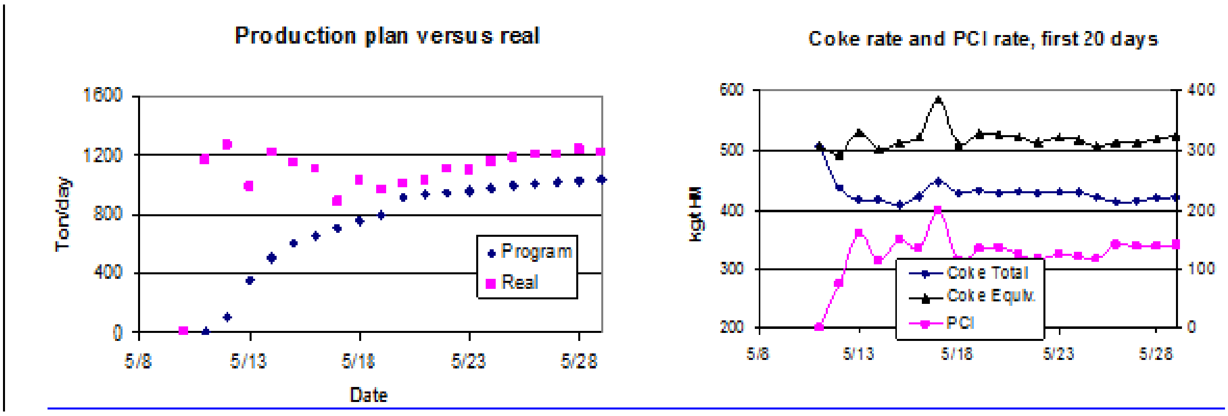

Figure 9. Production data, actual versus plan and actual reductant rates for first 20 days after blow-in.

7 OPTIMISATION

Some problems were encountered when trying to return the furnace back to normal operating levels. These problems began already on 13th May when frequent burden slips occurred, with relatively high bosh heat loads recorded prior to the slips. In between the slipping events there were also periods with relatively stable operation. To try and stabilize the process further the burden distribution was extensively reviewed. Changes were made and these would stabilize the process for a number of hours, and even a few days, but then peaks in the heat load to the bosh and belly would recur. This was of particular concern to the client, as it repeated the problems experienced in the beginning of the 2002 campaign, which eventually resulted in the premature failure of the bosh. The Danieli Corus team were not so concerned regarding the integrity of the bosh, as the design installed during the repair is proven to be sufficiently robust as to withstand the heat loads that were being subjected to it, however the phenomenon of the high, intermittent heat loads did suggest that an underlying root cause had not yet been identified.

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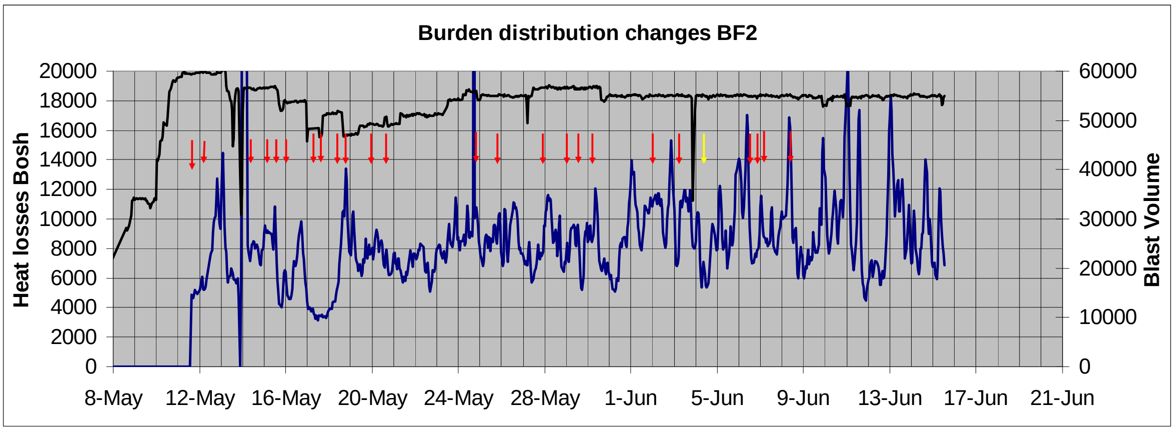

Figure 10. Arrows indicate where burden distribution changes were made.

Once all attempts to improve the burden distribution had been exhausted (Figure 4), and no further improvements could be realized, a different approach was taken by the Danieli Corus team. The burden distribution was still monitored, as it had led to a lowering of the average heat loading, but the intermittent peaks were still to be investigated. An extensive review of the date, both after the blow-in and before suggested that the liquid drainage from the furnace may not be as good as it should be, compared to before the blow down. Further investigations, including detailed observations of the casthouse practices, revealed that although the furnace appeared dry, as indicated by witnessing a blow at the taphole, the team suspected that it was withholding liquids in the hearth. This was confirmed after trials with a short (2 min) stop practice after one cast where the taphole had been seen to be blowing. The results were that it then continued to cast only hot metal for 10 minutes and hot metal and slag for an additional 25 minutes.

Further trials and changes were made until a combination of increasing the soaking bar diameter by 6 mm, reducing the aim taphole length by 0.2 m, reducing the gap time by 5 minutes and using the short stop practice when heat loads were high or on an increasing trend was implemented. This combination of changes improved the drainage of the furnace, as shown in the increase of the slag coverage (Figure 11).

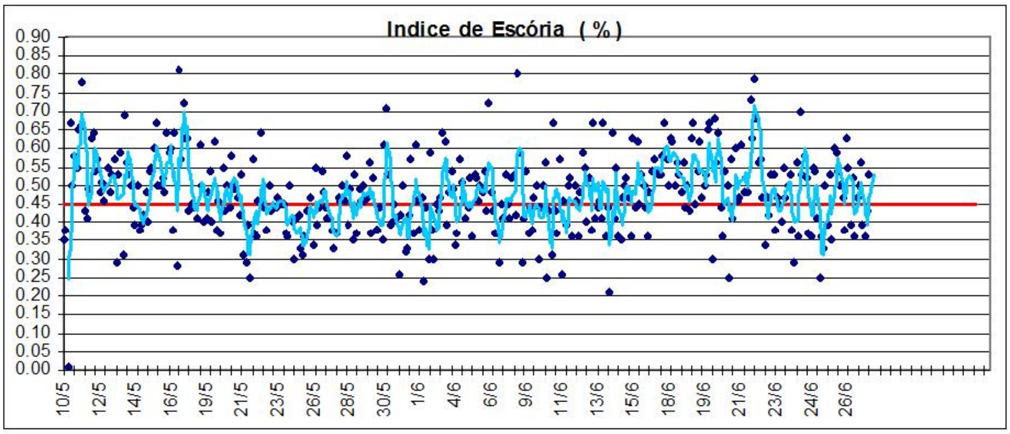

Figure 11. Slag coverage from start of blow-in.

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The heat load peaks were also eliminated, which could be used as evidence to support the working hypothesis that slag levels in the hearth had been limiting the extent of the raceway, promoting the flow of fresh raceways gasses, with some hot slag carryover (slag splashing) against the bosh. This then lead to high heat load measurements in localized regions of the bosh, with the continued flow of hot gas against the wall also increasing the heat load in localized regions of the belly. When taking into account the relatively small hearth, which was then made smaller by the rest materials that were left in after the salamander tap (only the area around the taphole was excavated), it was further postulated that the reduced available volume for the flow of fresh liquids through the hearth to the taphole will have contributed to the fluctuating, occasionally high, liquid levels in the hearth. This rest material, made up of coke and solidified iron and slag, would only be replaced with fresh deadman coke once sufficient passage of hot metal had re-melted and absorbed the coke. As it was only in contact with hot metal on once surface, it was expected that this process may take some weeks rather than days to occur.
The changes made and the process stability that followed allowed the production to be increased so that the full capacity of the furnace could be demonstrated (Figure 12). The knowledge gained during the investigation process also presented a credible theory as to the mechanism behind why the original design failed so catastrophically in the first 6 months after the 2002 reline. The refractory material used in the 2002 reline has a resistance to thermal fluctuations ten times lower than that as used in the Hoogovens design. In the case where process irregularities result in high heat loading, the Hoogovens lining is sufficiently robust to allow investigations and trials to take place to remedy the situation. This cannot be said for many other linings, where process parameters, including burden distribution and production rate, must be adapted to accommodate premature damage in the bosh and belly area.

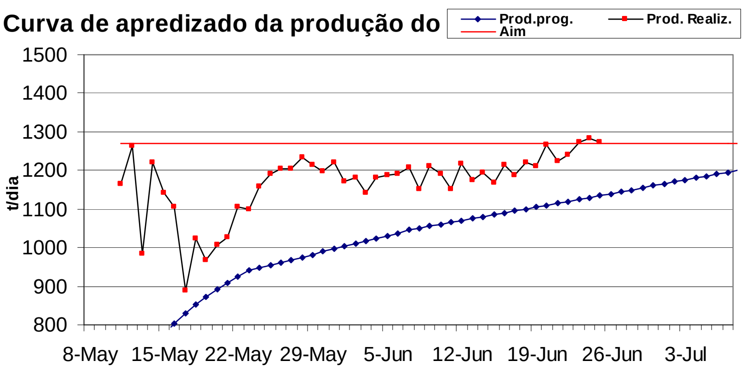

Figure 12. Hot metal output actual versus plan for first few weeks after blow-in.

8 PERFORMANCE

Since the furnace was blown in, seven years have passed, the time the Belly's campaign life should last per client's request. The furnace lining and cooling is in very good condition the furnace will continue its normal operation.
The wear in time of the lining in Figure 13.

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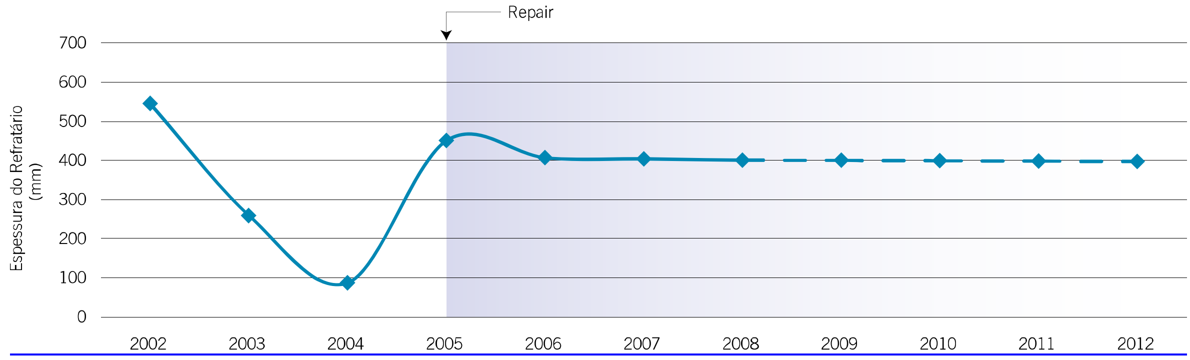

Figure 13. Refractory Thickness at Aperam No. 2 Blast Furnace.

The long term potential of the design is further illustrated in Figure 14, which indicates the remaining lining thickness (in millimetres) at two positions in the furnace throughout the first 24 years of the furnace's campaign.

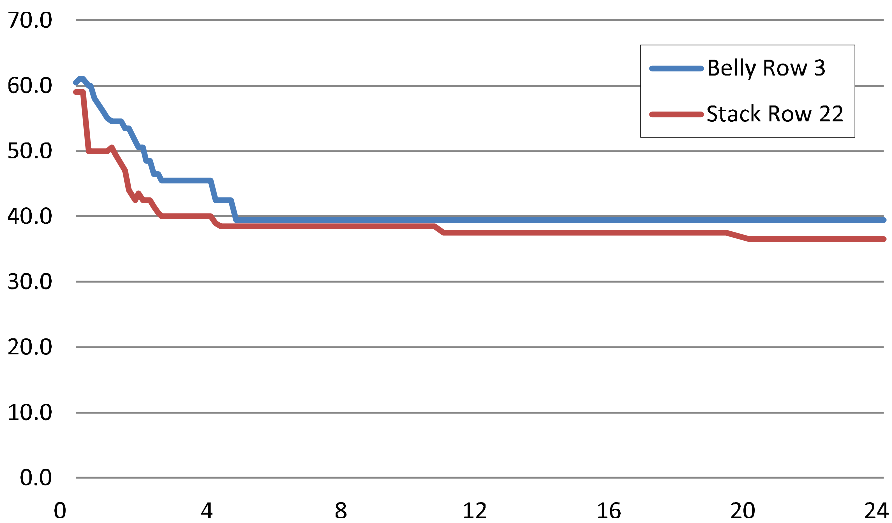

Figure 14. Lining wear at IJmuiden Blast Furnace No. 6.