SEVERSTAL L-BLAST FURNACE HEARTH REFRACTORIES FINDINGS AND REPAIR AT SPARROWS POINT

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Abstract

This paper will discuss the findings and repair of Severstal NA Sparrows Point "L" Furnace hearth refractories during the late 2008 to early 2009 planned outage. The significance of improving the refractory configuration, upgrading of the hearth monitoring systems & practices to match the campaign strategy goals will be discussed.

Introduction

Sparrows Point "L" Furnace was commissioned in 1978 and a complete reline was completed in 1990. In 1999, new hearth walls and bosh were installed. The furnace was blown down in the fall of 2008 for a 30 day scheduled internal taphole repair. The hearth wall and bottom had 24.6 and 50.3 million tons of hot metal production, respectively, before this outage (see figures 1 and 2). External taphole repairs were made from 2003 to 2005.

More time was available to do the repair than originally scheduled as a result of the poor market conditions in late 2008. The two original planned taphole repairs were then changed from an external repair to an internal repair and included all four tapholes.

To facilitate the internal repair, the furnace was blown down and the salamander was successfully tapped and the furnace was quenched. Additional hearth wear was identified after core drilling the rest of the hearth bottom. Thus, the furnace outage was extended to facilitate a bottom repair. In a compressed time frame the bottom was engineered, manufactured and installed to meet the scheduled blow-in date.

In addition to the upgraded bottom and taphole refractories, the hearth instrumentation was upgraded with over 250 thermocouples installed HM improvement to allow for improved monitoring during the campaign following this repair. At the same time, the bottom cooling system has been restored to full function.

The furnace stack required only local brick repairs which were followed by shotcrete to reprofile the lining. The high conductivity graphite bosh with dense plate cooling was in good condition, as anticipated and did not require repair.

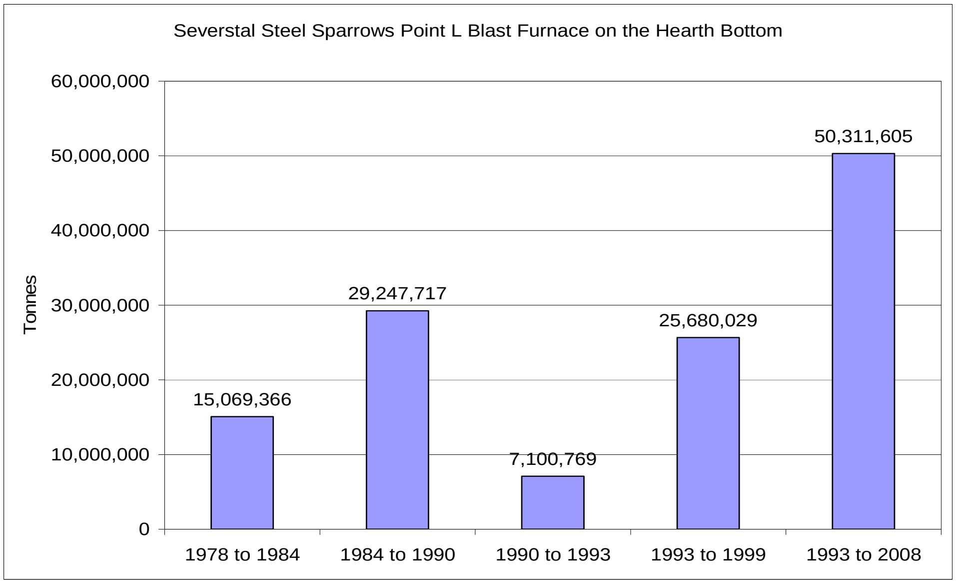

Figure 1 Severstal Steel Sparrows Point Tonnes on Hearth Bottom

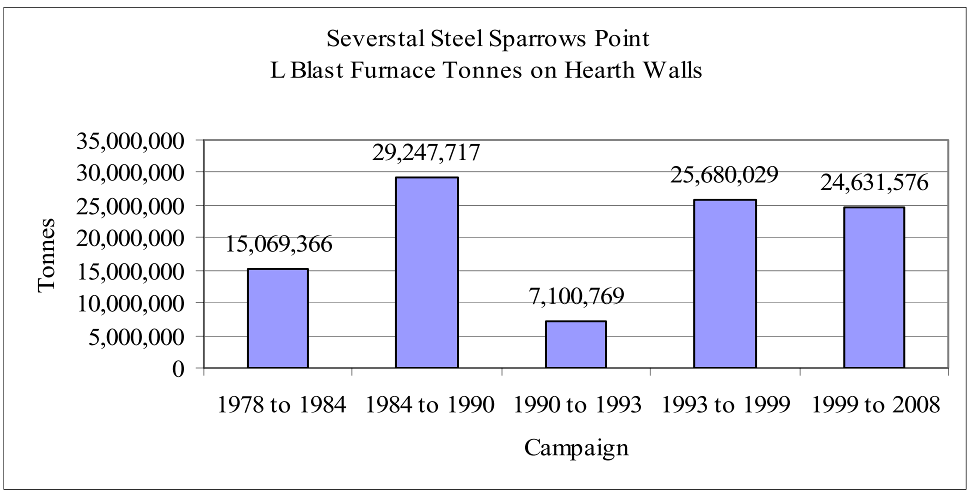

Figure 2 Severstal Steel Sparrows Point Tonnes on Hearth Walls

Table 1: Characteristics of Severstal L Blast Furnace in Sparrows Point USA

Hearth Diameter ID Refractory	M	14
Working Volume	m^3	3908
Charging System		Bell-less top
No. of Tuyeres		38
No. of Tapholes		4
Bottom Cooling		Air pipes
Hearth Wall Cooling		Channels
Daily Maximum Production	tonnes	9000
Hearth Productivity	tonnes/m^2/day	58.5
Hearth Sump Depth (Taphole to bottom)	M	Before 1.67 m (after the repair 2.28m)
Blast Furnace Productivity	thm/24hr/m^3WV	2.53

Blow-Down and Quench

"L" Blast Furnace was successfully blown down and quenched between November 2nd the 6th to prepare the furnace for taphole repairs and shotcreting of the furnace stack and belly (see figures 3 and 4). Prior to these events the salamander was tapped and ~ 438 tonnes of hot metal and slag were removed from the furnace. The last time this was accomplished was in 1999. For the new team, this was the first time they executed the task. Unfortunately business conditions extended the scheduled duration of the outage longer than required for the original scope of work. This allowed additional time to address critical repairs and concentrate on the quality of the repair.

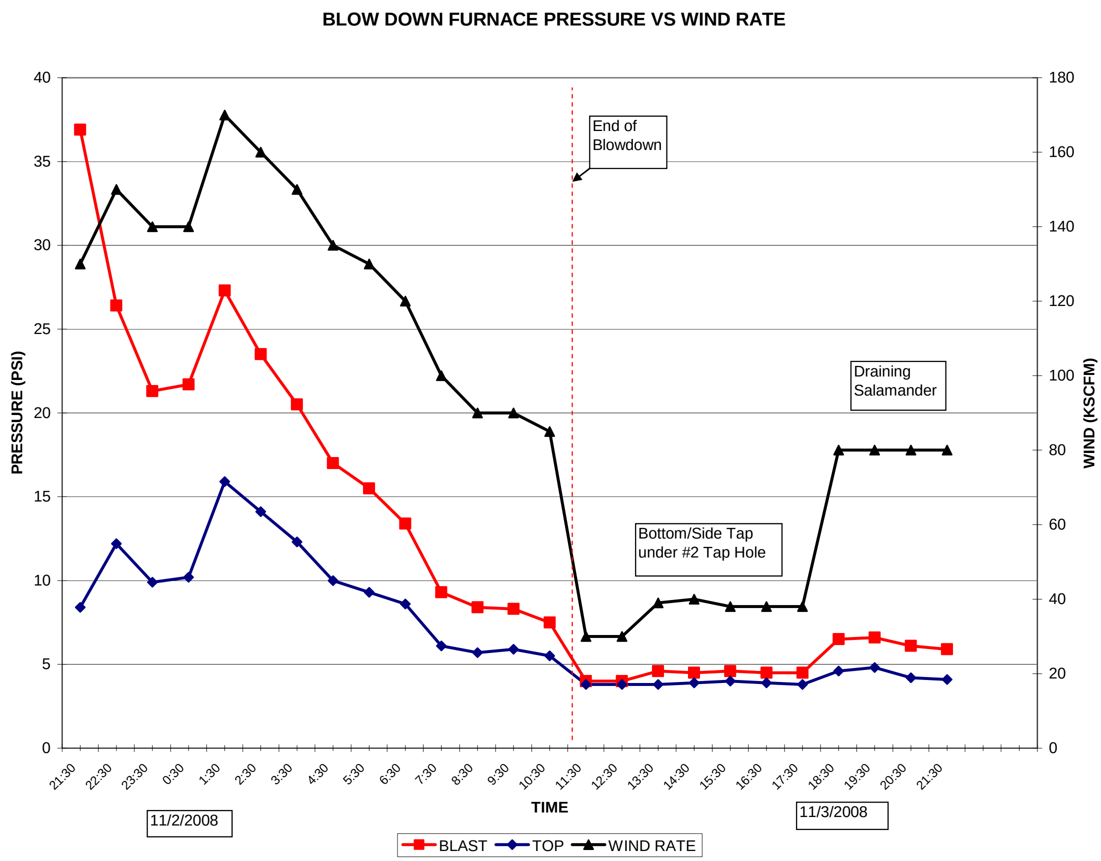

Figure 3 Blow down Pressure vs. Wind rate

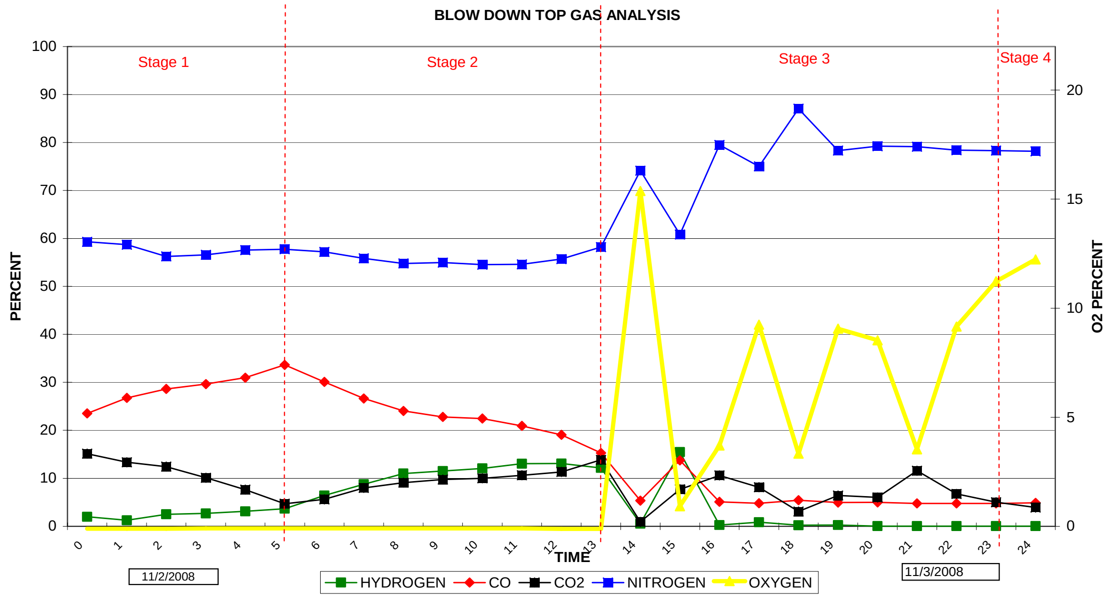

Figure 4 Blow down Top Gas Analysis

The Salamander Tap

Normally after blow down with the practice of this plant, the wind would be taken off and the furnace prepared for the quench. Instead, the pressure was maintained on the furnace to help cast the salamander (see figure 3). The wind was reduced to 64000 Nm^3/hr due to the noise at the bleeders until iron was tapped at 18:00 hours. Then the wind was raised to 128000 Nm^3/hr. About 398 tonnes of iron and slag were cast into the pig bed (see figure 5). The tap was deemed a success since enough liquid slag and iron were removed to insure a safe taphole repair. The tap was declared over at 21:47 hours on November 2 and the wind was taken off.

Figure 5 Bottom Tap

The Quench

The quench was started at 00:05 hours on November 5th with a water flow of 389 L/min. Very little activity was seen at both the bleeders and the top gas analysis and it was decided to further increase the water flow to 778 L/min at 00:20 hours, 1167 L/min at 00:46 hours, and to 1525 L/min at 01:30 hours. At that point, it was found that the gas samples taken at the demister were being diluted by the nitrogen blanket. When the nitrogen was turned off we discovered the actual hydrogen level in the furnace was around 40%. This level is high, but still within reason. The plan called for us to increase the water flow 389 L/min per hour until we reached 2723 L/min, but 1517 L/min was as much as we could get. The same restriction that occurred during the blow down was in place for the quench. This probably didn't increase the length of the quench, but it just took longer to submerge and less water leaked out the blowpipes. Essentially the quench was completed in 14 hours when the top gas hydrogen dropped below 0.5%. Since no one was scheduled to work until the following morning, and the contractor had concerns about the re-ignition of the coke and the temperature inside the furnace, it was decided to continue putting water in the furnace until the next morning. The water was secured at 05:54 hours on November 6th and the quench procedure was completed. A total of 1,801.9484 Liters of water was used during the quench.

Hearth Excavation

As the remaining burden was removed from the hearth, test cores were taken to validate condition of the remaining bottom refractory and compare with those test cores taken in 1992. These cores were also taken to further validate the bottom to determine if the refractories left in the bottom would be compatible with the expected campaign life. At this time, it was discovered that the bottom had worn (the test core results shown, see figure 6). The location of the deepest core also correlated with the earlier bottom thermal data.

The hearth bottom was completely mapped by additional core-drilling. Samples were taken and analyzed to determine the integrity of the remaining material.

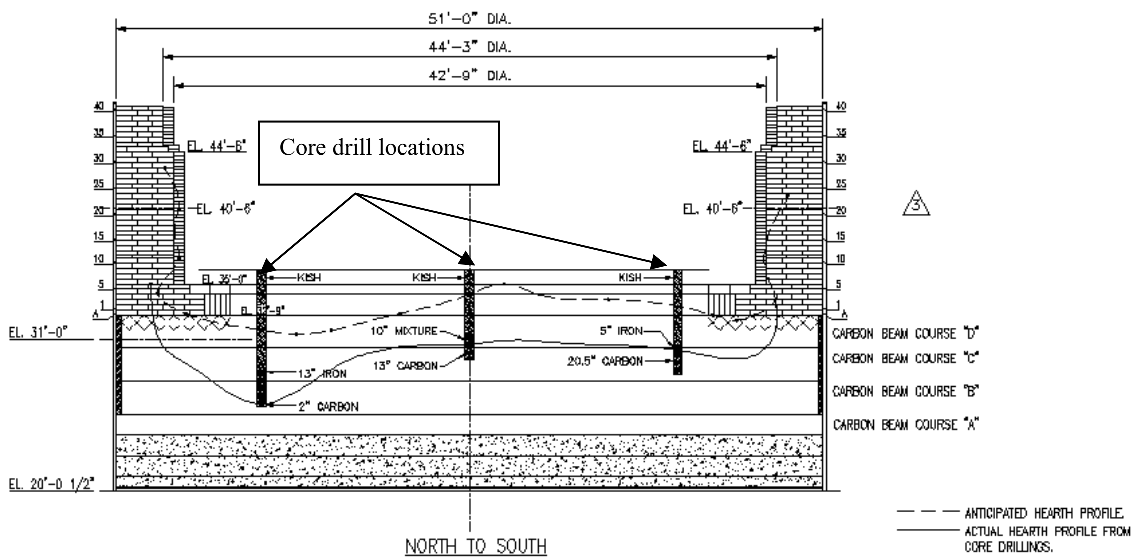

Figure 6 Profile of the Remaining Bottom

To facilitate a bottom replacement without removing the complete hearth wall, an underpinning system was designed to support the remaining hearth wall while the bottom work took place.

The remaining lower hearth walls and top two (2) bottom carbon beam layers were completely removed. The damaged section (approximately 25%) of course B between tapholes 1 and 4 was also replaced. To monitor the hearth for the next campaign from the remaining section of course B, several samples were taken to obtain actual thermal data the material left in place. This layer has been in place since 1990. Table 2 is a summary of the current thermal conductivity of the remaining Level B carbon.

Table 2 Course B Current Thermal Conductivity of Material Left In Place

	Actual test data from the remaining course B		
Carbon manufacturer published data	Tested Dec 2008	Tested Dec 2008	Tested Dec 2008
Conductivity @ 20C	Conductivity @ 20C	Conductivity @ 175C	Conductivity @ 300C
W/m.K (With Grain direction)	W/m.K (random direction)	W/m.K (random direction)	W/m.K (random direction)
10	7.5	9.1	10
10	7.3	8.8	9.6
10	8.8	10.4	11.3
10	10.5	13.6	15.6
10	9.1	11	12
Average ⟶	8.64	10.58	11.7

The remaining exposed hearth wall in general had a very thick skull. Lower in the furnace there was about 900 mm of wall away from the tapholes. It was remarkable to see the well-known "brittle layer" phenomenon in the sidewall. In front of the wall there was a powdery skull type zone followed by a zone which contained good bricks (see figure 7 @ Tuyere #21 and figure 8 @ Tuyere #22)

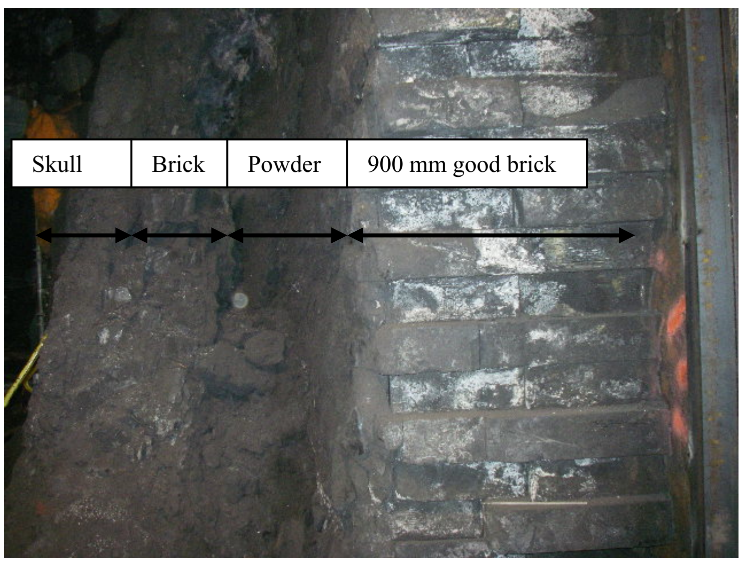

Figure 7 Hearth Sidewall Brittle Zone and Skull

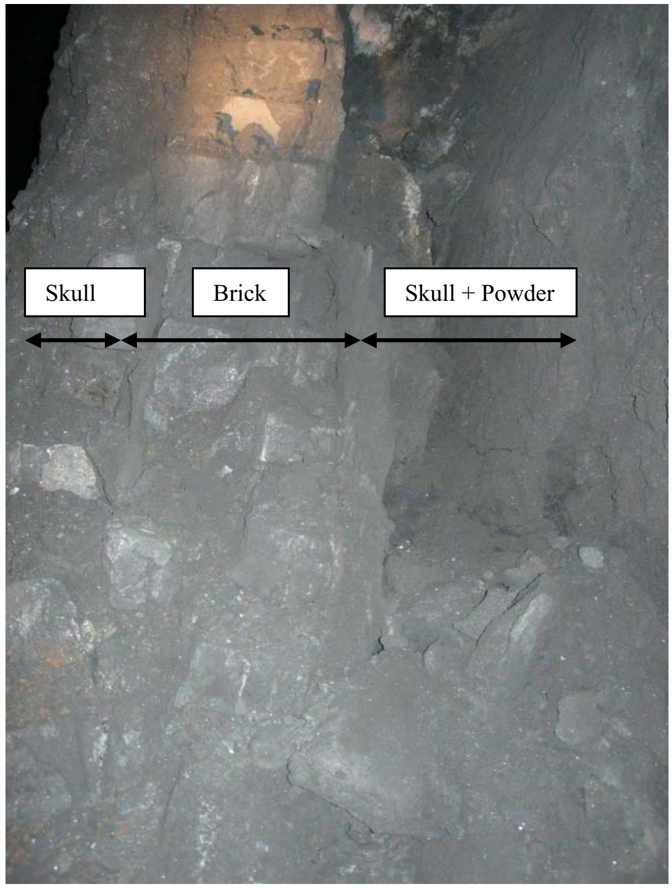

Figure 8 Good bricks in the skull separated from the wall

To be able to repair the bottom, the hearth skull had to be removed from around the furnace. The remaining hearth wall was checked and measured (i.e. outside the taphole areas) as shown in the figure 9.

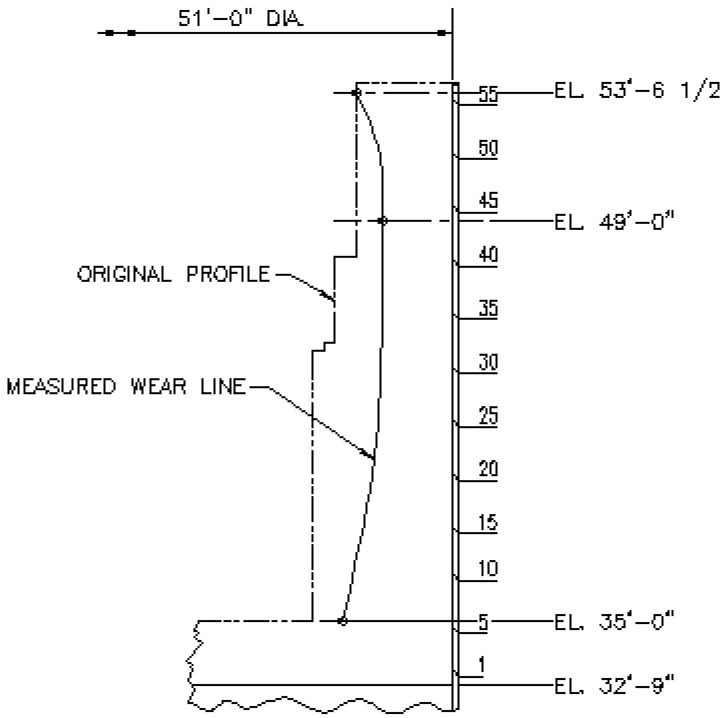

Figure 9 Typical Section through the Hearth Wall outside the Taphole Area

The Repair – The Project was Executed by Severstal Project Engineering Group.

The hearth repair, detailed engineering and construction was carried out by 2 local contractors (Forest City Erectors and BISCO Refractories), engineering and quality control was accomplished by the partnership between (Cim-Tech of Valparaiso Indiana and Allied Mineral Products of Columbus Ohio) in close cooperation with the Severstal Sparrows Point Engineering and Blast Furnace Groups.

The original project scope included the repair of 2 tapholes, which would be completed from the outside. In October 2008, the business climate changed and the scope was modified to repair all 4 tapholes from the inside. Eventually, as the calculated position of the wear line for the bottom was validated by means of core drillings (figure 6) the decision was made to use this opportunity to repair the bottom as well, which extended the outage further.

The planned repair included refractories for a 3 meter by 3 meter section on all four tapholes for including upgraded cooling at the taphole panels. The stack would be lined with a shotcrete lining. When the scope changed, the bottom was replaced with 2 layers of low iron graphite blocks, 1 layer of super micropore carbon blocks and 1 layer of pre-cast shapes having a low permeability for the ceramic arrestor course. Figure 10 shows the bottom repair in progress and the hearth wall solely supported by underpinning.

In addition to the Taphole areas, several sections above the Taphole were also deteriorated and needed repair (see Figure 11).

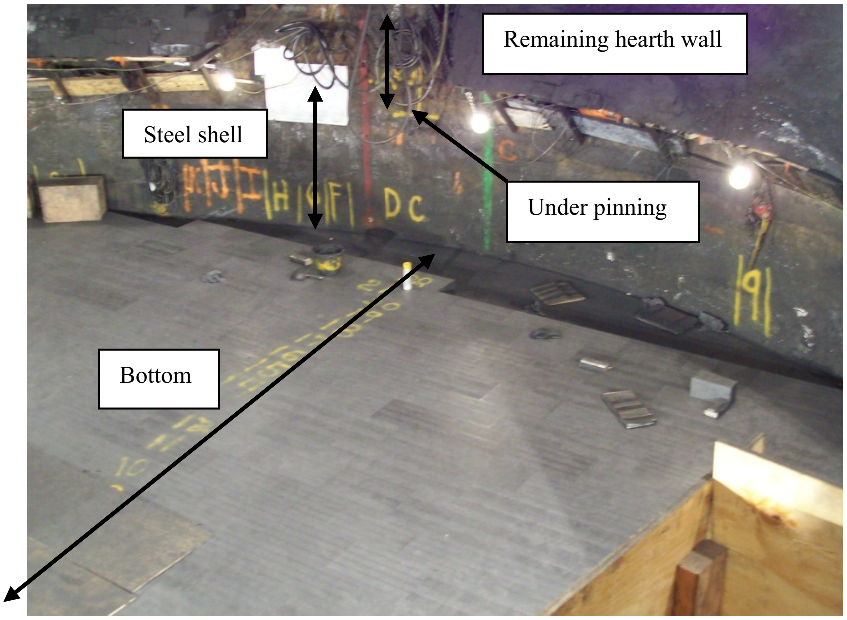

Figure 10 A View of the New Bottom Repair In Progress and the Underpinned Hearth Wall Caps.

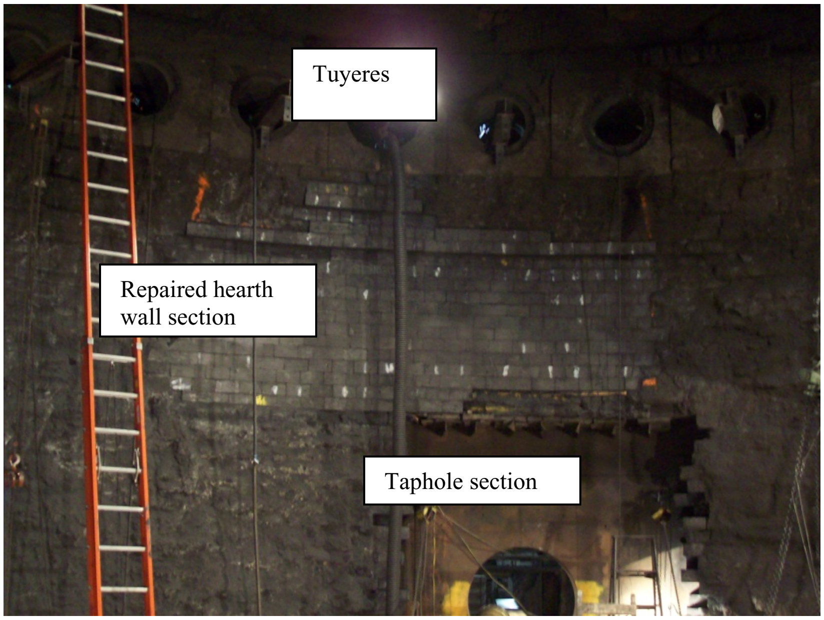

Figure 11 The Taphole Section Removed and the Repaired Zone above the Taphole.

The planned outage did not originally include a repair to the hearth bottom. Upon discovering of the core sample analysis, a bottom repair became necessary. Several options were considered. The area selected was quickly determined based on various requirements and based on the materials that would be required and could be made available to the Sparrows Point team within the given time constraints.

The materials for the bottom were selected for their chemical composition and thermal properties. However, a feature of this hearth is that the top layer or so called “arrestor course”, was made of a material composed of a combination of a high grade brown fused alumina combined with silicon carbide. This will provide the hearth bottom with excellent resistance to iron and slag corrosion and erosion; also this material has good resistance against thermal shock compared to a mullite layer.

For comparison of the permeability of the different materials, the ASTM testing procedure C-577 was used (see results Table 3).

Table 3 Permeability of Materials

		Permeability in centidarcies	
Material type	Location in the furnace	Average	Maximum individual sample
Hot pressed carbon bricks	Hot face of the wall	0.11	0.30
Ceramic Pre-cast shape	The top layer of the bottom	0.11	0.13
Super Micropore Carbon	The 1st layer below the ceramic	0.11	0.13
Ceramic Pre-cast shape	The hot face of the taphole	0.11	0.13

The sump depth of L Furnace in the previous campaign was 5'-6" (1.67 meters); this repair allowed re-engineering by means of changing bottom qualities to 7'-8" (2.33 meters) within the given constraints (see figure 12).

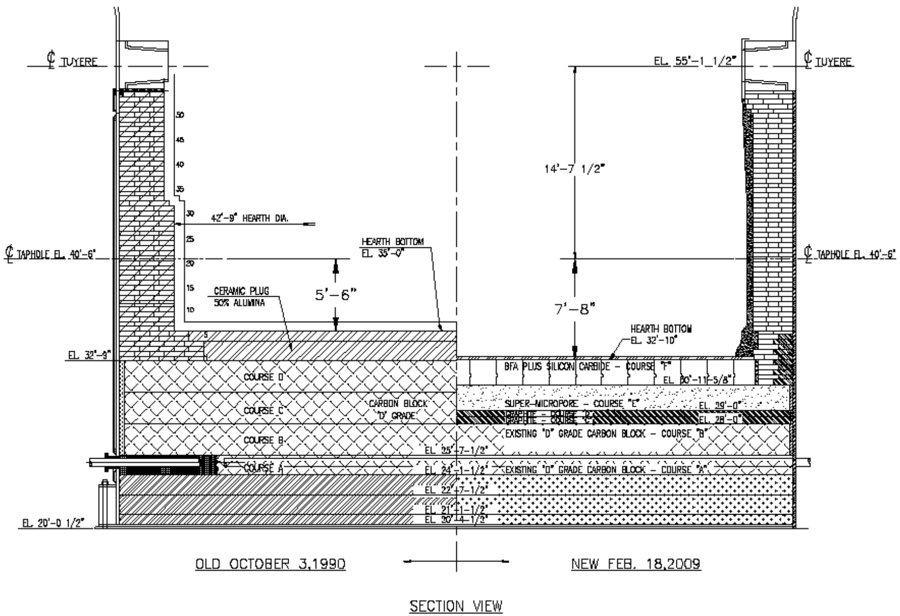

Figure 12 L Furnace Sump Depth Comparison

Hearth Management

Severstal NA Sparrows Point Project Group was to maximize the total return from this project achieving the maximum possible tonnage, campaign length and operating with-in safe limits.

The implementation of a Hearth Management Program through the hearth thermocouples via the monitoring system, operational knowledge, preventative maintenance and thermal models are an integral part of the know-how needed to safely guide the Blast Furnace to its last tap, safely.

The initial goals of the hearth management program include the following:
1. A daily production of 9,000 metric tons.
2. A campaign extension target of 6 (six) years minimum.
3. A total tonnage during the 6 (six) years of operation is 19,000,000 metric tons

The hearth management program at Severstal NA Sparrows Point "L" Blast Furnace was improved from a reactionary to preventative program. This includes the monitoring of the lining heat flux, temperature measurements at a number of lining & shell points, measurements of the as built and remaining lining thickness, core drilling(s) as the hearth ages, grouting records and operational data such as productivity, water leakage and tapping events.

Blow-in and Preliminary results

The Severstal Steel Sparrows Point "L" Blast Furnace blow-in took place in February, 2009 and hot metal was successful cast from the furnace to ladles in 36 hours (see figure 13).

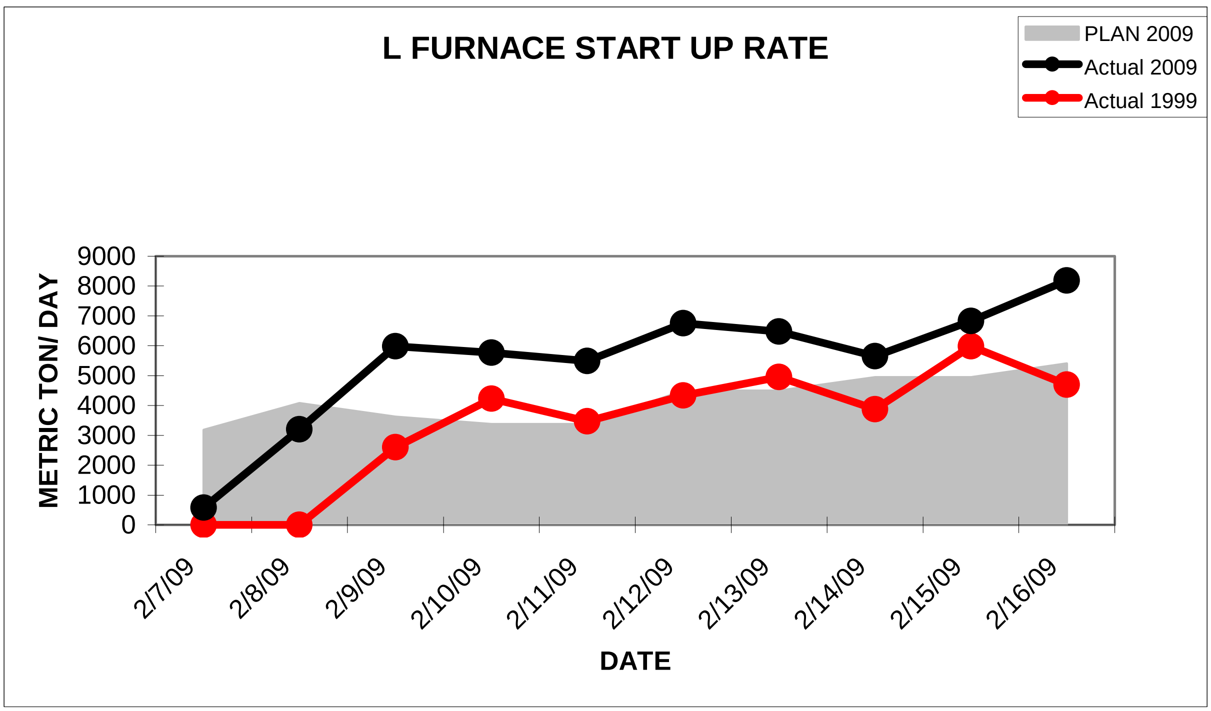

Figure 13 L Furnace Start Up February 2009

The initial taphole temperatures in the graphite are below 300°C, thus the lining if fully intact. Both the repaired and unrepaired areas of the hearth sidewall and bottom have temperatures that are within safe operating limits. Although this is expected with lower throughput, the initial temperature distribution in the hearth has improved from the previous designs.

First Year of Operation

Business conditions remained unfavorable the remainder of 2009 and prevented the purchase of the desired Hearth Management computer model. Instead all the data was input to the existing Level 2 system. Alarms points were set for all thermocouples and in-house personnel developed graphic displays to aid in the monitoring of critical data. (see figures 14 and 15)

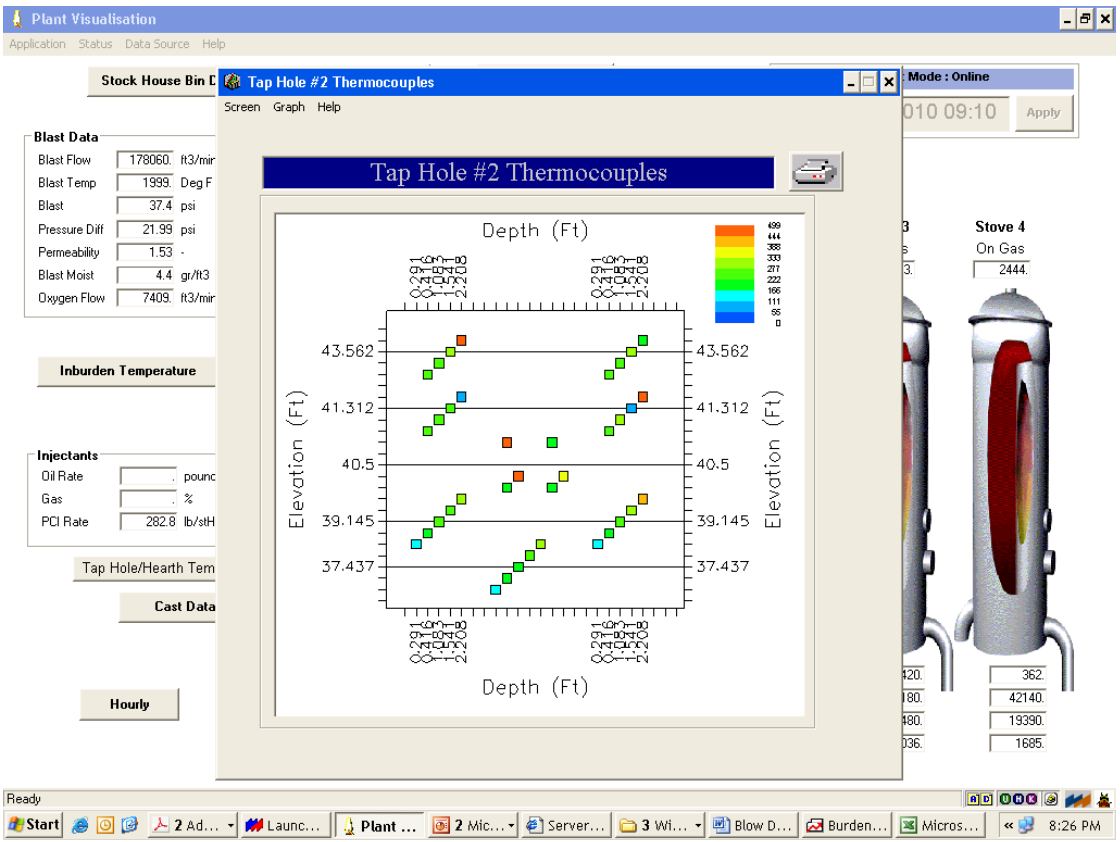

Figure 14 Seven thermocouple arrays in the #2 tap hole panel and six thermocouples embedded in the core of the taphole can easily be viewed from the Level 2 Plant Visualization screen.

Figure 15 The under hearth thermocouples in-line with #1 tap hole are trended in the Level 2 system.

L furnace was designed to operate with 40-60% of its burden being sinter. With the relative cost of sintering fines approaching that of pellets, it became evident that shutting down the sinter plant and operating with a predominately pellet burden was likely to happen. While operating at a reduced capacity in the spring and summer, tests were conducted with high pellet burdens and new injected fuel materials. These tests were successful, but unfortunately did not translate well in the fall when the sinter plant was shut down and improved business required higher production than anticipated through the transition period. The furnace operation was often unstable and highlighted by periods of heavy tuyere burning. Despite these severe conditions, the increased monitoring has provided the operators with a sense of security since it has not detected any trouble spots.

Conclusions

- A cross functional team approach between the Severstal NA Sparrows Point personnel and contractors proved to be an excellent team effort.
- When a Blast Furnace is down for a local repair it has proven to be a very effective technique to core drill the hearth and measure the remaining lining in the expected worst location outside the planned repair.
- When an aged hearth is down for a repair use all possible opportunities to upgrade the instrumentation to get more extensive thermal data of the hearth.
- Installation of additional grout nipples and grouting the hearth while cold is essential to maintain contact with the cooling.

- The new instrumentation has assisted operations in determining if the lining is in a safe mode during times of operational problems.