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 (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, 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 more than 250 thermocouples installed for 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 re-profile the lining. The high-conductivity graphite bosh with dense plate cooling was in good condition, as anticipated, and did not require repair.

Blowdown and Quench
‘L’ blast furnace was successfully blown down and quenched between 2 Nov and 6 Nov 2008 to prepare the furnace for taphole repairs and shotcreting of the furnace stack and belly (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.

The Salamander Tap
Normally after blowdown at 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 (Figure 3). The wind was reduced to 64,000 Nm³/hr due to the noise at the bleeders until iron was tapped at 18:00 hours. Then the wind was raised to 128,000 Nm³/hr. About

Due to certain discoveries during an outage, the repair of Severstal NA Sparrows Point ‘L’ furnace hearth refractories became more extensive than originally planned. Plant practices were updated to match the campaign strategy goals.
398 tonnes of iron and slag were cast into the pig bed (Figure 5). The tap was deemed a success since enough liquid slag and iron were removed to ensure a safe taphole repair. The tap was declared over at 21:47 hours on 2 Nov, and the wind was taken off.

The Quench
The quench was started at 00:05 hours on 5 Nov with a water flow of 389 L/minute. 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/minute at 00:20 hours, 1,167 L/minute at 00:46 hours, and to 1,525 L/minute 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, it was discovered that the actual hydrogen level in the furnace was around 40%. This level is high, but still within reason. The plan called for increasing the water flow by 389 L/minute per hour until 2,723 L/minute was reached, but 1,517 L/minute was as much as could be achieved. The same restriction that occurred during the blowdown 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 6 Nov, 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 the condition of the remaining bottom refractory and compare with the 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 (as the test core results showed, 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.
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 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 for 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.

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 that contained good bricks (see Figure 7, which shows Tuyere #21, and Figure 8, which shows Tuyere #22).

So that the bottom could be repaired, 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 Figure 9.

**The Repair**

The project was executed by Severstal’s Project Engineering Group. The hearth repair, detailed engineering and construction were carried out by two local contractors, Forest City Erectors and BISCO Refractories. Engineering and quality control were accomplished by the partnership between CIM-TECH of Valparaiso, Ind., and Allied Mineral Products Inc. of
Columbus, Ohio, in close cooperation with the Severstal Sparrows Point Engineering and Blast Furnace groups.

The original project scope included the repair of two tapholes, which would be completed from the outside. In October 2008, the business climate changed, and the scope was modified to repair all four 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.

### Figure 5

Bottom tap.

### Figure 6

Profile of the remaining bottom.

### Table 2

**Course B Current Thermal Conductivity of Material Left in Place**

<table>
<thead>
<tr>
<th>Carbon manufacturer published data</th>
<th>Tested Dec 2008</th>
<th>Tested Dec 2008</th>
<th>Tested Dec 2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conductivity @ 20°C</td>
<td>Conductivity @ 20°C</td>
<td>Conductivity @ 175°C</td>
<td>Conductivity @ 300°C</td>
</tr>
<tr>
<td>W/m·K (with grain direction)</td>
<td>W/m·K (random direction)</td>
<td>W/m·K (random direction)</td>
<td>W/m·K (random direction)</td>
</tr>
<tr>
<td>10</td>
<td>7.5</td>
<td>9.1</td>
<td>10</td>
</tr>
<tr>
<td>10</td>
<td>7.3</td>
<td>8.8</td>
<td>9.6</td>
</tr>
<tr>
<td>10</td>
<td>8.8</td>
<td>10.4</td>
<td>11.3</td>
</tr>
<tr>
<td>10</td>
<td>10.5</td>
<td>13.6</td>
<td>15.6</td>
</tr>
<tr>
<td>10</td>
<td>9.1</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td>Average</td>
<td>8.64</td>
<td>10.58</td>
<td>11.7</td>
</tr>
</tbody>
</table>
The planned repair included refractories for a 3 x 3 m section on all four tapholes, 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 two layers of low-iron graphite blocks, one layer of super-micropore carbon blocks and one 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 (Figure 11).

The planned outage did not originally include a repair to the hearth bottom. Upon discovery 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 (Table 3).

The sump depth of ‘L’ furnace in the previous campaign was 5 feet, 6 inches (1.67 m); this repair allowed re-engineering by means of changing bottom qualities to 7 feet, 8 inches (2.33 m) within the given constraints (Figure 12).

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 within safe limits.

The implementation of a hearth management program through the hearth thermocouples via the monitoring system, operational knowledge, preventive maintenance and thermal models are an integral part of the know-how needed to safely guide the blast furnace to its last tap.

The initial goals of the hearth management program include the following:

- A daily production of 9,000 tonnes.
- A campaign extension target of a minimum of six years.
- Total tonnage during the six years of operation is 19,000,000 tonnes.

The hearth management program at Severstal NA Sparrows Point ‘L’ blast furnace was improved from a reactionary to preventive program. This includes the monitoring of the lining heat flux, temperature measurements at a number of lining and 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 successfully cast from the furnace to ladles in 36 hours (Figure 13).

The initial taphole temperatures in the graphite are below 300°C; thus, the lining is fully intact. Both the repaired and unrepaired areas of the hearth sidewall and bottom have temperatures that are within safe

### Table 3

<table>
<thead>
<tr>
<th>Material type</th>
<th>Location in the furnace</th>
<th>Average</th>
<th>Max. individual sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot pressed carbon bricks</td>
<td>Hot face of the wall</td>
<td>0.11</td>
<td>0.30</td>
</tr>
<tr>
<td>Ceramic pre-cast shape</td>
<td>The top layer of the bottom</td>
<td>0.11</td>
<td>0.13</td>
</tr>
<tr>
<td>Super-micropore carbon</td>
<td>The first layer below the ceramic</td>
<td>0.11</td>
<td>0.13</td>
</tr>
<tr>
<td>Ceramic pre-cast shape</td>
<td>The hot face of the taphole</td>
<td>0.11</td>
<td>0.13</td>
</tr>
</tbody>
</table>
operating limits. Although this is expected with lower throughput, the initial temperature distribution in the hearth has improved from the previous designs.

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 proved 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 are essential to maintain contact with the cooling.

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