In late 2003, INI Steel Co. embarked on an energy savings program for its large structural mill in Incheon, Korea. In February 2004, four pairs of regenerative burners were purchased to replace the burners in the bottom preheat zone of the existing walking beam furnace. The burners were installed during the mill shutdown in August 2004 and were immediately put into production. The burners were provided by Bloom Engineering Co. The combustion system was engineered and installed by Combustech Ltd., Incheon, Korea. Commissioning and testing were a joint effort between Combustech and Bloom.

Regenerative Burners
Regenerative burners are typically installed in pairs. As shown in Figure 1, when one burner is fired, the other is exhausting through the burner head, media and media case. The hot exhaust gases transfer heat to the media, where it is stored until the cycle reverses. After reversal, the burner that was firing becomes the flue, while the burner that was exhausting now begins to fire. The cold combustion air passes through the heated media, where the stored energy is recovered. Air preheat levels within 200–400°F of the products of combustion in the furnace are typically achieved, making the regenerative burners extremely efficient.

Figure 1
The cyclic nature of regenerative burners: (a) first cycle and (b) second cycle.

As part of a fuel savings program at INI Steel, regenerative burners replaced the existing side-fired burners in the bottom preheat zone of a 6-zone walking beam furnace. A fuel savings of 10 percent was realized, as well as an improvement in steel heating quality.

Authors
Steven J. O’Connor, senior applications engineer, and James Kondziela, international sales manager, Bloom Engineering Co., Pittsburgh, Pa. (soconnor@bloomeng.com, jkondziela@bloomeng.com); Yoo In, chief executive officer, Combustech Ltd., Incheon, Korea (yooin@tonky.co.kr); and Kim Byung Gi, rolling mill manager, INI Steel Ltd., Incheon, Korea (Kbg9999@yahoo.co.kr)
Furnace Description
The large structural mill furnace is a 6-zone, top- and bottom-fired walking beam furnace. The rated capacity is 200 metric tons/hour. The furnace heats near-net-shape beam blanks and large (8 x 8-foot to 12 x 12-foot) blooms. It was built by ChugaiKo in 1989 and was converted to LNG firing in 2000. The burners are fired with LNG and hot air. The air preheat temperature is 950°F. The discharge temperature varies between 2,100 and 2,250°F. Typical furnace setpoints are 2,200°F for the preheat zones, 2,270°F for the heat zones and 2,250°F for the soak zones. A longitudinal section of the furnace is shown in Figure 2. The furnace is controlled by a Yokogawa distributed control system.

Burner Description
The eight bottom preheat zone burners were replaced by four pairs of Bloom regenerative burners. The existing burners had an installed capacity of 12.5 MM Btu/hour, giving the zone a capacity of 100 MM Btu/hour. These burners were replaced by Bloom 1150-150 burners. These burners have a nominal capacity of 15 MM Btu/hour, giving the zone a nominal capacity of 60 MM Btu/hour. The burners were supplied with oversized media cases, so that the firing rate could be pushed over the nominal capacity if required. The media for air preheating is comprised of 3/4-inch high-alumina ceramic balls.

The burners are air staged to minimize NOx emissions. The hottest region of the flame is where the majority of thermal NOx is created. These areas typically occur where the flame front is propagated. In order to reduce this peak flame temperature, the burner geometry is optimized to recirculate waste gases into this area (Figure 3). The recirculation reduces the peak temperatures, thus significantly reducing NOx formation. Bulk flame temperatures are relatively unchanged. By utilizing this technique, flame luminosity can be maintained without increasing NOx emissions, and exhaust gas recirculation is not required.

The regenerative system utilizes pneumatically operated cycling valves for the exhaust and air and electrically operated cycling valves for the gas. The air and exhaust valves are heavy-duty step-seat butterfly valves. The cycling time is 40 seconds.
Typically, furnace pressure control during switchover has been a problem. In order to minimize fluctuations in furnace pressure, the switchover time is kept at 1.5 seconds and no two burners are switching over at any given time. Pulse firing is employed under low-fire conditions. The system also utilizes a track-and-hold control to stabilize furnace pressure during burner switchover. The track-and-hold control maintains the furnace pressure control damper at a constant position during the burner cycling switchover. The track-and-hold is employed to eliminate the fluctuation of the pressure control loop.

**Project Description**
The combustion system was purchased on April 10, 2004. The equipment was delivered

**Figure 5**
The step-seat butterfly valve for air and exhaust.

**Figure 6**
The regenerative burners installed in the furnace.

**Table 1**

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Preheat zone</th>
<th>Heat zone</th>
<th>Soak zone</th>
<th>Unit Total m³/Hour Nm³/ton</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Top</td>
<td>Bottom</td>
<td>Top</td>
<td>Bottom</td>
</tr>
<tr>
<td>SP temp.</td>
<td>1,190°C</td>
<td>1,200°C</td>
<td>1,235°C</td>
<td>1,270°C</td>
</tr>
<tr>
<td>Orifice meter (percent)</td>
<td>1,611 (21.8)</td>
<td>1,607 (21.7)</td>
<td>1,406 (19.0)</td>
<td>1,587 (21.5)</td>
</tr>
<tr>
<td>Gas flowmeter</td>
<td>1,669</td>
<td>1,665</td>
<td>1,457</td>
<td>1,645</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1,260°C</td>
<td>1,260°C</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>511</td>
<td>674</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>530</td>
<td>698</td>
</tr>
</tbody>
</table>

Date: 06/15/2004

Test section: 9:30 – 12:30

Cold charge: 100 percent

Length of beam blank: 9.73 m

Unit weight: 1,020 kg/m

Total beam blank weight: 9,925 kg each

Quantity of beam blank in furnace: 56 each

Beam blank total weight in furnace: 555,778 kg

Beam blank retention time in furnace: 2.5 hours

Tons/hour: 222

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✦✦
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to the site on July 15, 2004. The installation period was 15 days during the planned furnace shutdown. It started on July 18, 2004, and the burners were ready for production on Aug. 3, 2004. All piping installation that could be done while the furnace was running was completed prior to shutdown. The regenerative burners were placed in the same positions as the burners that they replaced. Figure 4 is a picture of a burner formerly in use.

Performance and Testing

On June 14–15, 2004, representatives of Combustech and Bloom were on-site to record the testing of the furnace under the former operating conditions. On Aug. 10 and 17, 2004, these same personnel recorded the testing for the furnace under the modified conditions. Table 1 summarizes the results for the pretest condition. Tables 2–3 summarize the results of the data taken with the regenerative burners in place.

Results

The fuel savings were between 8.8 and 12.3 percent over the tonnage of steel produced. The predicted fuel savings was 8 percent. During the first several hours of operation with regenerative burners, the mill reported a noticeable reduction in horsepower consumed.
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