Bottom Pour Refractory Advancements

Technical Marketing – Flow Control

IMF – Fall Meeting – 2018 – Monterrey, Mexico
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<th>RHI Magnesita</th>
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<td>Introduction to Ingot Casting</td>
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<td>7</td>
<td>“Reading the Bones”</td>
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</tbody>
</table>
Welcome to RHI Magnesita.

KEY FACTS

- 120,000 Individual products
- 35 Main production and raw materials sites
- 70 Sales offices
- 14,000 Employees
- 2,000 Global patents and patent applications held
From Source to the Solution – with ONE Partner!

- **Raw-Material Industry**
- **Refractory-Industry**
- **Customer Industries**

   - **Refractory Brick**
   - **Unshaped Refractories**
   - **Functional Products**
   - **Lining/Installation**
   - **Maintenance/Service**
   - **Steel**
   - **Cement / Lime**
   - **Non-Ferrous-Metals**
   - **Glass**
   - **Environment-Energy-Chemical**

**Customer Industries:**
- Steel
- Cement / Lime
- Non-Ferrous-Metals
- Glass
- Environment-Energy-Chemical

**Raw Material Industry:**
- Unshaped Refractories
- Functional Products

**Refractory Industry:**
- Refractory Brick
- Lining/Installation
- Maintenance/Service
Kruft plant - Germany
Hollowware Products - Manufacturing

Highlights:

- **Decades of experience** in the refractory business for Ingot Casting (Ferrous, non-Ferrous, Super Alloys, etc.)

- Providing high quality Hollowware tiles to wide range of customers in **14 different countries** totaling:
  - 41 customers in Europe;
  - 17 customers in North America

- Hollowware tiles quality ranging from **42% to 84% of Alumina**
Agenda

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7. “Reading the Bones”
Bottom Pouring

Introduction

The worldwide percentage of steel and alloy produced via ingot casting has decreased during the last couple of decades. This is primarily due to technical advancement in the continuous casting process and new manufacturing infrastructure. However some steel and alloy applications will continue to be bottom poured in the foreseeable future. This includes steel and alloy ingots for intermediate and large forgings for the transportation, oil, heavy equipment and aeronautical industries. Vacuum remelt electrodes and specialty alloys such as nickel based, nickel cobalt, nickel copper and those alloys which can’t be economically continuously cast will continue to be ingot cast. “Yes” bottom pour will survive as a somewhat leaner but still viable entity!
Types of Ingot casting

Top casting
- Easy to use
- Fast process
- Better for low viscosity alloys
- Greater metal contact with the air;
- More inclusions and voids;
- More superficial defects along the Ingot
- Not suitable for high quality steels

Bottom casting
- Lower level of inclusions
- Better teeming speed control;
- Better Ingot external superficial condition
- Non-oxidizing atmosphere
- More added value to the final product
- Requires more real state and hardware investment;
- Requires more manpower for tiles and hardware set-ups
Bottom Pouring
Hardware Set-up

- Ladle
- Argon protection
- Trumpet
- Hot top cover
- Hot top side liner
- Iron mould
- Mould powder
- Bottom plate
- Runner bricks
Segregations cannot be avoided, only reduced. They can be influenced by the ingot shape, casting parameters, ingot head treatment and casting rate.

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7. “Reading the Bones”
BP tiles set-up
Tiles nomenclature
BP tiles

Raw materials

- **Clay**
- **Andalusite**
- **Fire clay**
- **Synthetic Mullite**
- **Tabular Alumina**
- **Bauxite (RK and UD)**

Content of alumina ($\text{Al}_2\text{O}_3$) %

- 38%
- 48%
- 58%
- 85%
- 86-90%
- 99.7%
## Hollowware tiles

### Qualities

<table>
<thead>
<tr>
<th></th>
<th>EX38 A</th>
<th>N38 A</th>
<th>EX38</th>
<th>N38</th>
<th>EX63</th>
<th>N63</th>
<th>EX63 H</th>
<th>N63 M</th>
<th>EX B-03</th>
<th>N B-01</th>
<th>EX72</th>
<th>N72</th>
<th>EX80 S</th>
<th>N80 S</th>
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</thead>
<tbody>
<tr>
<td>Typically used for</td>
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<tr>
<td>Cast irons, lower alloyed steels, short casting times</td>
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<td>Medium to higher alloyed steels</td>
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<tr>
<td>Low to medium alloyed steels</td>
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<td></td>
<td></td>
<td></td>
<td>High alloyed steels, Ni &amp; Cu based alloys, long casting times</td>
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<td></td>
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<td></td>
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<tr>
<td>Main raw material</td>
<td>Fireclay</td>
<td>Fire clay</td>
<td>Bauxite</td>
<td>Bauxite</td>
<td>Bauxite</td>
<td>Synthetic Mullite</td>
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<td>Chemical Composition [%]</td>
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<tr>
<td><strong>Al₂O₃</strong></td>
<td>42</td>
<td>38</td>
<td>42</td>
<td>40</td>
<td>69</td>
<td>68</td>
<td>67</td>
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<td>80</td>
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<td><strong>SiO₂</strong></td>
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<td>53</td>
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<td>25</td>
<td>26</td>
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<td>26</td>
<td>15</td>
<td>19</td>
<td>11</td>
<td>17</td>
<td>15</td>
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<tr>
<td><strong>Fe₂O₃</strong></td>
<td>1.9</td>
<td>1.4</td>
<td>1.5</td>
<td>1.6</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.2</td>
<td>1.4</td>
<td>1.3</td>
<td>1.2</td>
<td>0.4</td>
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<tr>
<td><strong>TiO₂</strong></td>
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<td>2.0</td>
<td>2.0</td>
<td>2.2</td>
<td>2.8</td>
<td>2.3</td>
<td>2.8</td>
<td>2.4</td>
<td>3.0</td>
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<td>2.5</td>
<td>0.3</td>
<td>0.6</td>
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<tr>
<td><strong>K₂O</strong></td>
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<td>0.7</td>
<td>0.5</td>
<td>-</td>
<td>0.5</td>
<td>0.6</td>
<td>0.5</td>
<td>0.6</td>
<td>0.5</td>
<td>0.5</td>
<td>0.2</td>
<td>0.4</td>
<td>0.2</td>
<td>0.4</td>
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<td>Physical Properties</td>
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<td></td>
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<tr>
<td><strong>BD (g/cm³)</strong></td>
<td>2.25</td>
<td>2.10</td>
<td>2.22</td>
<td>2.10</td>
<td>2.62</td>
<td>2.45</td>
<td>2.60</td>
<td>2.48</td>
<td>2.76</td>
<td>2.53</td>
<td>2.80</td>
<td>2.56</td>
<td>2.82</td>
<td>2.55</td>
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<tr>
<td><strong>Open Porosity(%)</strong></td>
<td>20</td>
<td>20</td>
<td>22</td>
<td>21</td>
<td>16</td>
<td>22</td>
<td>16</td>
<td>21</td>
<td>22</td>
<td>24</td>
<td>20</td>
<td>24</td>
<td>19</td>
<td>23</td>
</tr>
<tr>
<td><strong>CCS (MPa)</strong></td>
<td>30</td>
<td>30</td>
<td>40</td>
<td>25</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>50</td>
<td>55</td>
<td>60</td>
<td>70</td>
<td>60</td>
<td>60</td>
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<tr>
<td><strong>RuL T₀₅</strong></td>
<td>1320</td>
<td>1300</td>
<td>1320</td>
<td>1300</td>
<td>1420</td>
<td>1380</td>
<td>1420</td>
<td>1380</td>
<td>1500</td>
<td>1500</td>
<td>1540</td>
<td>1520</td>
<td>1590</td>
<td>1520</td>
</tr>
</tbody>
</table>
Hollowware tiles

Requirements on BP refractory

**High thermal shock resistance**
- To avoid cracks during the casting ➞ low thermal expansion

**High hot strength**
- To decrease refractory erosion ➞ less impurities and liquid phase

**High chemical stability at high temperatures**
- To avoid re-oxidation of the molten steel ➞ stable oxides, less free SiO$_2$, FeO, Fe$_2$O$_3$, TiO$_2$)

**Low sticking of refractory and steel after use**
- To easy „read the bones“
Hollowware tiles
3Al₂O₃·2SiO₂ Mullite “In Situ” Formation

Needle crystals of Mullite:

✓ ↑ Refractoriness (> 1800 °C)
✓ ↑ Chemical stability
✓ ↓ Thermal expansion coefficient

Caolinite transforms into Mullite + SiO₂

Al₂O₃ + SiO₂ → Mullite
Hollowware tiles
Semi-dry pressed products

3 uniaxial presses each one equipped with robot manipulator

Advantages:
- High productivity (2 or 3 cavities)
- Better dimensional accuracy (less water)
- Higher density/ lower open porosity
- Lower mould wear (carbide material)
Hollowware tiles
Plastically extruded tiles

6 extruder presses/ 7 working stations
- Used for hollowware production only
- Two stage process – first extrusion then pressing

Advantages:
- High shape complexity possible
- Able to produce longer runners: 550 mm
- Lower mould cost
Hollowware tiles
Refractory thermal treatment

Drying process:
- Reduces the water content of the products
- Bigger extruded products require prior air-drying
- Step 1: water reduction in a drying chamber for the extruded products only
- Step 2: water reduction in a hot dryier for extruded and semi-dry pressed products

Tunnel kiln
- Various stages: Pre-heating -> Burning zone -> Cooling zone
- Temperature up to 1500°C
Hollowware tiles

Finishing

1. Air cooling
2. Inspection and sorting
3. Adding ceramic gaskets and steel bands (if requested)
4. Packaging
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New qualities were developed in order to fulfil the demands for **clean steel production**

<table>
<thead>
<tr>
<th></th>
<th>Al$_2$O$_3$</th>
<th>SiO$_2$</th>
<th>TiO$_2$</th>
<th>Fe$_2$O$_3$</th>
<th>K$_2$O</th>
<th>Open Porosity (Vol. %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NORMA 80 S</td>
<td>78</td>
<td>19</td>
<td>0.6</td>
<td>0.6</td>
<td>0.4</td>
<td>23</td>
</tr>
<tr>
<td>EXAKTA 80 S</td>
<td>83</td>
<td>15</td>
<td>0.3</td>
<td>0.4</td>
<td>0.2</td>
<td>19</td>
</tr>
</tbody>
</table>
BP tiles
Market trend – Clean steel

- Mullite based products, with low content of impurities. The EXAKTA 80 S quality represents a brick of the „pure mullite“, whereby the use of high-purity clays and synthetic grains guarantees very low contents of impurities.

<table>
<thead>
<tr>
<th></th>
<th>Al₂O₃</th>
<th>SiO₂</th>
<th>TiO₂</th>
<th>Fe₂O₃</th>
<th>K₂O</th>
<th>Free SiO₂</th>
<th>Open Porosity</th>
</tr>
</thead>
<tbody>
<tr>
<td>EX 72</td>
<td>83</td>
<td>15</td>
<td>0.3</td>
<td>0.4</td>
<td>0.2</td>
<td>&lt; 1</td>
<td>19</td>
</tr>
<tr>
<td>EX 80 S</td>
<td></td>
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</tbody>
</table>

- The low content of free silica and other impurities is necessary for the casting of high-manganese and other high alloyed products.
- The high content of needle-like mullite phase guarantees high thermal shock resistance
Hollowware tiles
Research & Development – Hollowware Products – Leoben, Austria

- Research Department exclusively assigned to develop new technologies for Hollowware products
- Refractory post-morten analysis
- Water modeling laboratory to simulate steel flow
- CFD Simulation
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BP tiles
Teeming process simulation

The simulation can provide information about:

- Temperature
- Solidification process
- Optimize Refractory design
- Teeming speed / rate of rising
BP tiles
Teeming process simulation
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BP tiles
Assembly

Dry - Installation

Installation with gasket

Dry - Installation

Mortar
Gasket
BP tiles
Assembly

Runner system set-up. Clean up the sprue plate

- Remove bottom pour tile remnants from sprue plate.
- Clean sprue plate with air pipe make sure all debris are removed.
- Inspect plate for gouges and or steel leak weldments that prevent flush fit with the stool plate.
- Grind high spots to level sprue plate surface if required.
Runner system set-up. Level the sand (Customer specific)

Use the proper sand leveling tool according to the project dimensions
It is recommended to place the runners over a pre-heated sprue plate to eliminate any moisture.
Runner system set-up. Level the spider (Customer specific)

- The Spider must be set “dead zero” or perfectly leveled with the plate to make a perfect connection with the bayonet avoiding steel leakers.

- Check it using a straight edge.
BP tiles
Assembly

Runner system set-up. Wedge the spider

- Once the Spider is set, make sure that it is centered and wedge it on both sides simultaneously (use small wedges).
Runner system set-up. Installing the runner bricks

- Make sure the sand is leveled in the channels.

- Clear the low edge of the spider joint, making a slight ramp to prevent sand from keeping the runner joints apart.

- Keep making this ramp for every subsequent tile connection.
Runner system set-up. Installing the runner bricks

- Set the runner tiles inclined with banding clips set sideways preventing sand to get into the joints.

- Keep making this procedure for every subsequent tile connection.
Runner system set-up. Installing the runner bricks (Leveling)

- Set the end gate in position;

- Make sure that the entire “leg” is centered into the channel and it is not leveled above the plate.

- Use a straight edge for checking.
Runner system set-up. Wedging the End Gate

- Lock the end gate with a wooden wedge (little ones);

**CAUTION:**

-Wedge both opposite end gates at the same time made by 2 operators. The goal here is to avoid shifting the spider out of center. The Spider has to be kept untouched.
Runner system set-up. Wedging the End Gate

- Stick a hammer into the End gate bore and swing it on both sides to make sure that the “leg” is tight.

- If not, tight them up again and re-check. Note: Wedges should not be overly tight. The end gate should move slightly during the hammer check.

CAUTION:

Do this check on both opposite end gates at the same time made by 2 operators. The goal here is to avoid shifting the spider out of center. The Spider has to be kept untouched.

Check if the runners are not elevating above the plate due excess of pressure. Press the center with your foot. Finish it breaking the wedges from inside out.
Runner system. Anti-leakage preventive actions

- Add Steel Shot at the first joint of the Spider.

- Remove the Spider wedges
Built up the runner system. Anti-leakage measurements

Use u-shaped stainless/rusted steel profile. In case of a joint leakage will stop its propagation
Runner system set-up. Plug the spider & endgates bores
Runner system set-up. Sanding the channels

- Sand the sides of the runners
- Check on the sides if there are no voids of sand. Stick a trowel into it.
- Complete sanding it up to the top side.
BP tiles
Assembly

Runner system set-up. Cleaning

Clean the plate and fill-up the voids with sand
Runner system set-up. Cleaning

- Clean the runner system by blowing compressed air into the spider

- Check if air is coming out from the runner joints and end gate. If so, re-set the tile by removing the whole leg and repeating all the steps again.
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BP tiles
Reading the bones

by Bob Mascara
BP tiles
Reading the bones

Compression or Loading Failure
BP tiles
Reading the bones

Runner tile remnants
BP tiles
Reading the bones

Joint Leaks
BP tiles
Reading the bones

Critical wear points

Tile erosion
BP tiles
Reading the bones

Vapor pressure
BP tiles
Reading the bones

Runner remnants

GAS
ENTRAPMENT
PIPING

BACKFILL DISPLACEMENT
POOR BACKFILL CHILLING BOTTOM VIEW
ENTRAPED BACKFILL
GOOD BACKFILL CHILLING BOTTOM VIEW
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