HAVE AN EYE ON OUR TECHNOLOGY
PRODUCT PORTFOLIO

MELTING & REFINING
- EAF
- LF
- RH

VACUUM TECHNOLOGY
- VOD
- VIM

CASTING
- CC
- IC
- VSD

SPECIAL (RE)MELTING
- ESR
- VAR

HEAT TREATMENT
- HT

POWDER METALLURGY
- PM

CONSULTING
VIC
Vacuum Ingot Casting
SeAH Besteel Corporation, South Korea
Project description: New Sec-Met Plant 160t LF, VD, 510t VIC plant
Product segment: Energy Sector
Project executed: 2010-2012

Taewoong Special Steel, South Korea
Project description: New Steel Shop 120t EAF, LF, VD/VOD 700t VIC plant
Product segment: Energy Sector
Project executed: 2013-2016
VIC REFERENCE PROJECTS

Vacuum Ingot Casting

- Kalyani Carpenter - 70t (2009)
- HFF - 100t (2001)
VIC EQUIPMENT & CUSTOMIZED SOLUTIONS

plant configuration Taewoong
Special Steel

plant configuration SeAH
Besteel
Demand for Large Ingots

› Nowadays larger and larger ingots are demanded

› Applications: Reactor vessels, turbine discs, ....

› EAF heat size vs. Ingot size (up to 700 tons!) !?!

› Solution: Casting multiple ladles to one ingot
  › Multi Ladle Casting (Sandwich) under atmospheric conditions
  › Vacuum Ingot Casting (for ultra low hydrogen content)
  › Additional Benefit of VIC: Eliminate or reduce flaking problems (avoid long heat treatment times)
Vacuum treatment

The "vacuum treatment" of steel is a process of prime importance owing to its versatility and the special advantages it brings. Over the last 80 year’s a wide range of different vacuum treatment processes were developed. The main driving force for this development was the requirement for lowest gas contents and improved cleanness of the steel.

Nowadays the most common processes are:

- **Ruhrstahl-Heraeus process** (RH)
- **Vacuum Degassing** (VD)
- **Vacuum Oxygen Decarburization** (VOD)
- **Vacuum Induction Melting** (VIM)
- **Vacuum Ingot Casting** (VIC)
Vacuum Ingot Casting

› **Basic Principle:**
  › Scatter the steel stream into droplets within a vacuum chamber producing a large surface area for gas removal
  › Pouring from top!

› **Vacuum Ingot Casting (Ladle to Mould)**
  › Casting directly into moulds placed in a vacuum vessel
  › Most important stream degassing process today
  › Combination with ladle stream degassing possible
  › „Ladle to Ladle“: Additional ladle support required
Vacuum Ingot Casting (VIC)

- For degassing during ingot casting (VIC)
- For heavy ingots
  - Mainly energy section (reactors vessels, turbine discs, ...)
- Ultra low hydrogen content is achievable
  - Eliminate or reduce flaking problems
- Advantages if casted ingots heavier than ladle capacity
  - Casting of multiple ladles to one ingot is possible
Degassing

The solubility of gas in liquid steel depends on the temperature and the partial pressure.

\[
[H] = K_H \times \sqrt{p_{H_2}}
\]

According to the studies especially of A. Sievert, the quantity of gas dissolved in the liquid metal, such as hydrogen \([H]\) and nitrogen \([N]\) is rather proportional to the root of the partial pressure \((p)\) which equates to the vacuum pressure \([\text{mbar}]\).

\[
[N] = K_N \times \sqrt{p_{N_2}}
\]

Sievert`s law
Degassing

Measures to increase degassing:

- Increase treatment time
  - Increased temperature losses
  - Lower Productivity
- Lower partial pressure
  - Increase reaction surface
Impressions of VIC

› Vacuum Stream Degassing of carbon steel C35
  › Steel plant of Bochumer Verein, Germany, 1959

©Institut für den wissenschaftlichen Film
Previous VD treatment is beneficial for final hydrogen content

Final hydrogen content is below the limits of bottom pouring (even if Argon shrouding is used in the latter case)
Mould Design

Example mould set for ingots 280 – 420 t including:

- Basic mould with polygonal design and cylindrical upper part
- Hot tops in different heights
- Foot rings for combination with basic mould to achieve larger ingot weights
- Stool plate
Example mould set for ingots 280 – 420 t including:

- Stool plate
- 2 types of additionally “Foot Ring” with different height’s
- “Basic mould” with nominal capacity of 320 t
- 3 types of “Hot Top’s” with different height’s
Hot Top Design

Isolating concept consist of 2 parts

- Permanent lining
  - Material type: Fireclay
  - Lifetime: Normally > 1 year

- Wear lining
  - Material type: Silica or olivine sand, corrugated boards
  - Lifetime: 1 heat
Mould Design

› Example mould set for ingots 60 – 140t
Mould Design

› Example mould set for ingots 280 – 420t

Ingot casting set 280-420t
downhill casting
Covering or exothermic powder must be added before flooding to avoid reactions of the liquid steel in the hot top of the ingot with the oxygen from ambient air.

To use an exothermic powder first is recommended because of the optimized hot top volume.

Reaction of exothermic powder (metallic Al, Si) starts 30 – 60 s after access of oxygen.

Fume generation of exothermic powder can be sucked of by a water ring pump.

Covering powder should be added after the exothermic reaction becomes slower (most metallic Al is oxidized, no more oxygen for reaction necessary) under atmospheric pressure via crane.
Process Example
(Casting of 5 Ladles to 1 Ingot)

Casting speed: 4 - 6 t/min
Safety space between the heats necessary
Bottleneck: EAF-sequence = fix
          Casting-sequence = fix
Possibility to go back to LF after VD is considered
Manipulation time between EAF/LF/VD considered
Possible Plant Set Ups

Casting via Pony Ladle

Direct Casting from Ladle
## Pony Ladle vs. Direct Casting

<table>
<thead>
<tr>
<th></th>
<th>Pony Ladle</th>
<th>Direct Casting</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Casting speed</strong></td>
<td>constant</td>
<td>ferrostatic</td>
</tr>
<tr>
<td><strong>Casting rate control</strong></td>
<td>via crane weighing</td>
<td>No weighing control or complex weighing system required</td>
</tr>
<tr>
<td><strong>Process stability</strong></td>
<td>safer casting, safer change of ladles</td>
<td>uncertainty in the start of casting</td>
</tr>
<tr>
<td><strong>Temperature losses</strong></td>
<td>Additional losses in pony ladle</td>
<td>minimal</td>
</tr>
<tr>
<td><strong>Refractory</strong></td>
<td>additional refractory for pony ladle required</td>
<td>none</td>
</tr>
<tr>
<td><strong>Purity degree</strong></td>
<td>potential inclusions from pony ladle refractory</td>
<td>no possibility of separation of non metallic inclusions</td>
</tr>
<tr>
<td><strong>Geometric issues</strong></td>
<td></td>
<td>very high shop required</td>
</tr>
<tr>
<td><strong>Ladle design</strong></td>
<td>standard</td>
<td>with vacuum ring at the bottom</td>
</tr>
<tr>
<td><strong>Additional costs</strong></td>
<td>Pony ladle and Refractory, Preheater</td>
<td>Higher ladle costs</td>
</tr>
<tr>
<td><strong>Timing if more than 1 ladle to be cast</strong></td>
<td>quick exchange required</td>
<td>second ladle immediately after the first one</td>
</tr>
</tbody>
</table>
VIC via Pony Ladle

Start casting into pony ladle

Filling of pony ladle

Start casting of ingot

Ingot Casting

Casting finished, flooding
Direct VIC

Placing Ladle  Start Casting  2nd ladle on top  Casting

Remove/Exchange of upper ladle  Casting of last ladle  Casting finished, flooding
Ladle to ladle casting can also be operated with VIC equipment and additional ladle support placed in the vacuum vessel.
**Required Equipment**

- **Vacuum Vessel**
  - Usually several vessels (with different sizes) are installed
- **Vacuum Cover**
  - Carrying Pony Ladle or suitable for connecting ladle directly
- **Pony Ladle (optional)**
- **Cover Powder Hopper**
  - For addition of exothermic powder
- **Vacuum System**
  - Vacuum pumps, vacuum flaps and pipes
- **Moulds, ...**
  - Same as for conventional bottom pouring
Vacuum Vessel

- Usually located below shop floor
- Several vessels of different size are installed
  - Welded plate construction
  - Beam grid bottom
  - Water cooled flanges
Ladle Support (optional)

- Used for ladle-to-ladle casting
- Placed in the vacuum vessel
- Possibility of gas stirring
  - Heavy duty welded structure
  - Gas coupling on board
Vacuum Cover

- Supports for ladle / pony ladle
- Re-moveable cover powder hopper
- Slide gate hydraulic on-board
- Hydraulic can be easily removed and mounted on a spare cover
- Movement by car or crane
  - Dished head welded construction
  - Flat inner surface water-cooled
  - Carrying all necessary platforms
Vacuum Cover

› Camera and the sight glass device has to enable a view to:
  › bottom plate for start casting
  › hot top lining for end casting
Additions of exothermic powders have to be done immediately after end of casting. To avoid reoxidation this has to be done under vacuum.

- Single hopper with vacuum tight slide gate
- Automatic addition sequence
- Pneumatically operated
Pony Ladle

› Suitable design to use pre-assembled refractories
› Optimized design to favour segregation of non-metallic inclusions
› Casting rate is regulated by stopper rod system or slide gate
Pony Ladle
Shroud manipulator

› For pony ladle casting
› Provides a reliable attachment of the ladle shroud on the lower nozzle of the slide gate
› Protects the casting stream against air
   › Additionally Argon purging
› Hydraulically movement
Casting pipe

- Placed inside the compensator after preheating and shortly before casting
- Refractory lined
- The distance between the refractory tube and the top of the ingot is important
Vacuum System

› Steam Ejector or Mechanical Vacuum Pumps
  › In-House Design
› Suction Lines
› Switching Device
  › Used to connect suction line & vessels
  › Moved by Crane or Hydraulically
› Vacuum Flaps
SeahBe Steel - Korea

- Ingot Size up to 510 tons
- 7 Vacuum Vessels
  - Vessel 1 – 4: 160 – 510 tons
  - Vessel 5 – 7: 60 – 160 tons
  - One Vessel is also suitable for ladle-to-ladle casting (Ar stirring)
- 2 Vacuum Covers
- 1 Vacuum Pump
- VSD Cover and Switching Device are moved by crane
SeahBe Steel – Layout
SeahBe Steel – Layout
SeahBe Steel – Preparation for 1st Heat
SeahBe Steel – First Heat
March, 16th 2009
SeahBe Steel – Ladle to Ladle

- Receiving ladle already in vessel
- Cover seals the vessel

Casting ladle

Finished

www.inteco.at
Ingot Size up to 700 tons (optional)

Installed equipment

5 Vacuum Vessels
  
  › Vessel 6000 1-2  80 – 120 tons
  › Vessel 7000 1-2  120– 500 tons
  › Vessel 9000 1  700 tons (not being installed yet)
  › One Vessel is also suitable for ladle-to-ladle casting (Ar stirring)

3 Vacuum Cover cars

1 Vacuum Pump

Switching Device
Plant Layout

VSD 6000

INTECO

www.inteco.at
Plant Layout

VSD 7000

Vessel 2
VSD 7000

Vessel 1
VSD 7000

Pony ladle

Cover car
max. lifting 800 mm

Cover car

Vessel

G. Cover Car

Pony Ladle

X
Pump Type: 5 Stage steam ejector pump
Suction capacity: ≥ 650 kg/h @ 0,67 mbar
Pump down of the vessel: ≤ 6 minutes
Steam:
  › Pressure: 14,5 bar,g
  › Temperature: 220 °C
  › Consumption: 15.4 t/h
Condenser Cooling Water:
  › Pressure: 5,0 bar,g
  › Max. Inlet Temperature: 35,0 °C
  › Flow: 920 m³/h
Taewoong – Preparation for 1st heat
Taewoong - First Heat, 14.10.2016

› Steel Grade: A4120
› Ingot Size: 80 t
› Casting Date: 14.10.2016
Project: 13-137 TAEWOONG - Steel flow rate for VSD -
Ladle size: 125 t, steel level start: 2,88 m; Freeboard start: 0,90 m

Steel flow rate out of ladle [t/min]

Liquid steel in ladle [t]
Casting Date: 27.02.2017

Steel Grade: A4130 (25CrMo4, DIN 1.7218)

Ingot Size: 78 t

Vacuum pressure: 0,09 – 0,12 mbar

Casting Time: 17,5 min
  - Body: 11 min (5,7 t/min)
  - Hot top: 7,5 min (2,3 t/min)
Taewoong – Direct Casting Example

Project: 13-137
Customer: Taewoong

<table>
<thead>
<tr>
<th>Project:</th>
<th>120t / 150 t Special Steel plant</th>
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<tr>
<td>Created by:</td>
<td>WeA</td>
</tr>
<tr>
<td>Date:</td>
<td>15.03.2017</td>
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<tr>
<td>Comment:</td>
<td>VSD Casting 6000</td>
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### VSD Treatment

<table>
<thead>
<tr>
<th>Steel grade:</th>
<th>A4130</th>
<th>1.7218</th>
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<tbody>
<tr>
<td>Take over Temperature</td>
<td>11 min</td>
<td>Castign time hot top</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>VD End</th>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
<th>Cr</th>
<th>Mo</th>
<th>Ni</th>
<th>Al</th>
<th>N</th>
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<tr>
<td>0,30</td>
<td>0,27</td>
<td>0,73</td>
<td>0,007</td>
<td>0,002</td>
<td>1,00</td>
<td>0,20</td>
<td>0,08</td>
<td>0,006</td>
<td>0,004</td>
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<table>
<thead>
<tr>
<th>Activity</th>
<th>Duration [min]</th>
<th>Start</th>
<th>Total duration [min]</th>
<th>End</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 End of VD- Treatment</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2 Transport to VSD transfer car</td>
<td>5</td>
<td>1</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>3 Ladle placing</td>
<td>3</td>
<td>6</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>4 Temperature measurement</td>
<td>2</td>
<td>9</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>5 Transport to VSD 6000</td>
<td>3</td>
<td>11</td>
<td>3</td>
<td>13</td>
</tr>
<tr>
<td>6 Opening of the slide gate</td>
<td>5</td>
<td>14</td>
<td>5</td>
<td>18</td>
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<tr>
<td>7 Ladle Placing on VSD</td>
<td>4</td>
<td>19</td>
<td>4</td>
<td>22</td>
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<tr>
<td>8 Evacuation</td>
<td>4</td>
<td>23</td>
<td>4</td>
<td>26</td>
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<tr>
<td>9 Deep vacuum</td>
<td>19</td>
<td>27</td>
<td>19</td>
<td>45</td>
</tr>
<tr>
<td>10 Casting</td>
<td>18</td>
<td>27</td>
<td>18</td>
<td>44</td>
</tr>
<tr>
<td>11 Powder Addition</td>
<td>1</td>
<td>45</td>
<td>1</td>
<td>45</td>
</tr>
<tr>
<td>12 Flooding</td>
<td>2</td>
<td>46</td>
<td>2</td>
<td>47</td>
</tr>
</tbody>
</table>
Opening of the Slide Gate

- After arriving and ladle positioning, connection of the slide gate hydraulic and argon hose for slide gate stirring
- Start Argon flow
- Opening the slide gate and first steel outflow
  - Oxygen lancing in case of no free opening
- Transport to VSD cover
  - After opening until start casting the slide gate is stirred with Argon to guarantee a free opening for start casting
  - Stirring is done via special channel ring in the upper plate of the slide gate
Taewoong - Direct Casting Example

VSD Casting Trend Taewoong
Project: 13-137 120 - 150 t Special Steel Plant Taewoong, Korea, Casting Date: 27.02.2017
Ingot size: 78 t

- Vacuum Pressure [mbar]
- Casting rate [t/min]
- Liquid steel weight [kg]
- Casted steel weight [t]

- Start Vacuum
- Start Casting
- Body End
- Hot top End
- Powder Addition
Taewoong – Powder Addition 6000

- Stop casting by closing Slide Gate
- Addition of covering powder (Automatic sequence)
- Automatic flooding immediately after powder addition (time dependent)
- Remove ladle from cover after reaching 920 mbar
- Start one water ring pump after start cover lifting for dedusting / Closing flooding valve
- Cover lifting immediately after ladle take off
- Transfer cover car from tank
Taewoong - Casting stream
Taewoong - Direct Casting Example
Taewoong – Pony Ladle casting
# Taewoong – Pony Ladle casting

<table>
<thead>
<tr>
<th>Activity</th>
<th>Duration (min)</th>
<th>Start</th>
<th>End</th>
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<tr>
<td>Placing transfer car</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Transfer VIC bay</td>
<td>1</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Pickup VIC crane</td>
<td>1</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Transfer to VIC</td>
<td>1</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Casting preparation</td>
<td>5</td>
<td>11</td>
<td>15</td>
</tr>
<tr>
<td>Transfer to pony ladle</td>
<td>1</td>
<td>12</td>
<td>12</td>
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<tr>
<td>Casting</td>
<td>25</td>
<td>37</td>
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<tr>
<td>Disconnect slide gate</td>
<td>2</td>
<td>38</td>
<td>38</td>
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<td>Transfer to Transfer car</td>
<td>3</td>
<td>40</td>
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<tr>
<td>Placing casting car</td>
<td>1</td>
<td>45</td>
<td>46</td>
</tr>
<tr>
<td>Transfer to 240t crane</td>
<td>1</td>
<td>51</td>
<td>51</td>
</tr>
<tr>
<td>Transfer to ingot car</td>
<td>2</td>
<td>54</td>
<td>54</td>
</tr>
<tr>
<td>Placing ingot car</td>
<td>1</td>
<td>65</td>
<td>66</td>
</tr>
<tr>
<td>Transfer VIC bay</td>
<td>1</td>
<td>72</td>
<td>72</td>
</tr>
<tr>
<td>Pickup VIC crane</td>
<td>1</td>
<td>82</td>
<td>82</td>
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<tr>
<td>Transfer to VIC</td>
<td>3</td>
<td>85</td>
<td>86</td>
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<tr>
<td>Casting preparation</td>
<td>2</td>
<td>87</td>
<td>87</td>
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<tr>
<td>Transfer to pony ladle</td>
<td>1</td>
<td>103</td>
<td>104</td>
</tr>
<tr>
<td>Casting</td>
<td>25</td>
<td>128</td>
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<tr>
<td>Disconnect slide gate</td>
<td>2</td>
<td>130</td>
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<tr>
<td>Transfer to Transfer car</td>
<td>3</td>
<td>130</td>
<td>132</td>
</tr>
</tbody>
</table>

**VIC Sequence casting for 500t ingot**

- Speed transfer car: 30 m/min
- Heat size: 135 t
- Speed Casting crane: 60 m/min
- Casting speed: 5.8 t/min
- Casting time: 25 min
• Stop casting by closing Stopper Rod

• Addition of covering powder (Automatic sequence)

• Automatic flooding immediately after powder addition (time dependent)

• Cover lifting immediately after reaching 920 mbar

• Start one water ring pump after start cover lifting for dedusting / Closing flooding valve

• Transfer of the cover car from tank

• Remove pony ladle from cover after reaching park position of cover car
Taewoong – Pony Ladle casting
# Large Ingot Production Technologies - Comparison

<table>
<thead>
<tr>
<th></th>
<th>Multi Ladle Casting</th>
<th>Vacuum Ingot Casting</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pouring</strong></td>
<td>Bottom</td>
<td>Top</td>
</tr>
<tr>
<td><strong>Degassing (during pouring)</strong></td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Ingot Sizes</strong></td>
<td>Up to ~ 180 tons</td>
<td>70 – 700 tons</td>
</tr>
<tr>
<td><strong>Number of ladles</strong></td>
<td>Usually 2</td>
<td>Up to 5 (or even more)</td>
</tr>
<tr>
<td><strong>Equipment</strong></td>
<td>Casting Car &amp; Crane</td>
<td>Special casting equipment</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Vacuum Pump System</td>
</tr>
<tr>
<td><strong>Most recent references</strong></td>
<td>Breitenfeld Edelstahl, Austria, 2009 (120t)</td>
<td>SeahBe Steel, Korea, 2009</td>
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<tr>
<td></td>
<td>Buderus Edelstahl, Germany 2014 (180t)</td>
<td>Taewoong Special steel, Korea, 2016</td>
</tr>
</tbody>
</table>
Multiple ladle casting

Casting via exchange of the ladles over the trumpet by using two casting cars
Multiple ladle casting
Multiple ladle casting

Casting with a ladle used as “tundish”

Using a casting car for the 1st ladle and a casting crane

First Ladle is placed into the casting car

Second Ladle is placed on top

Slide gates are opened, start casting

Casting
Inteco also has the metallurgical experts to assist our clients in every phase (commissioning, initial production phase, …)

- In-House metallurgical experts with long time experience
- Specialised consultants
- Cooperation with universities and technology providers

Inteco does not only supply the equipment but also provides the „know how“ to run the process successfully.

Inteco‘s experts ensures a fast start-up to reach full production in a very short time.
WELCOME TO AUSTRIA
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Product Manager Project Management & Engineering Services

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