MODERN REFRACTORY CONCEPTS FOR REHEATING FURNACES
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1. THE CONCEPT OF FURNACE

A furnace is an equipment generally used:

> to melt metals for subsequent casting (smelting furnaces)
> to heat metals to change their shape (rolling, forging furnaces)
> to heat metals to change their metallurgical, physical properties (heat treatment furnaces).

In this presentation we will focus on **rolling mills furnaces** only, also known as **reheating furnaces**, with specific regard to the continuous-operating furnaces.
SCHEMATIC VIEW OF A REHEATING FURNACE

Chimney: to remove combustion gases

Furnace chamber: lined with insulating and refractory materials

Burners: to raise and/or to maintain chamber temperature

Charging doors for loading stock

Hearth: to support or to carry the steel. Consists of refractory materials

Discharging doors for unloading stock
TOPICS FOR THE REHEATING FURNACES: TYPE & QUALITY OF FUEL

The flue gases from the combustion come in direct contact with the refractory materials, therefore the selection of the fuel is important.

Or, vice versa: for the correct selection of the refractory materials, the characteristics of the fuel have to be taken into account.

For example:

> Some materials will not tolerate Sulphur in the combustion atmosphere, in which case you can use light diesel oil.

> Some solid fuels generate particulate matter, that can interfere with the materials installed inside the furnace, therefore coal is not often used as fuel.
> From the efficiency point of view, every furnace should – ideally - heat up as much of material as possible to a uniform temperature with the lowest possible consumption of fuel and power.

> The key to efficient furnace operation lies in the complete combustion of the fuel, with minimum excess air, and in the complete deployment of the generated heat.

> Unfortunately, furnaces operate with relatively low efficiencies, if compared to other combustion equipment such as the boiler (where efficiency can be, in some cases, over 90%).

> This is caused by the necessity of having high operating temperatures in the whole furnace, with subsequent emissions of very hot exhaust gases as well, which results in significant heat losses through the chimney.
2. CLASSIFICATION OF THE REHEATING FURNACES

There are many ways for the classification of reheating furnaces.

Based on the heat generation:

> Combustion furnaces → further, based on the kind of combustion (and used fuel):
  oil fired - coal fired - gas fired
> Electric furnaces

Based on the method of charging the material into the furnace:

> Batch / Intermittent / Periodical furnaces
> Continuous furnace
2. CLASSIFICATION OF THE REHEATING FURNACES

Based on the waste heat recovery:
>
> Recuperative furnaces
>
> Regenerative furnaces

Based on the heat transfer characteristics:
>
> Radiation furnaces
>
> Convection furnaces
### Classification method

<table>
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<th>Types and examples</th>
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<td>1. Fuel used</td>
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<td>Gas-fired</td>
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<td>Coal-fired</td>
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<td>2. Operations (charging materials)</td>
</tr>
<tr>
<td>Intermittent / Batch</td>
</tr>
<tr>
<td>Periodical</td>
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<tr>
<td>Forging</td>
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<td>Re-rolling (batch/pusher)</td>
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<td>Pot</td>
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<td>Pusher</td>
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<td>Walking beam</td>
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<td>Walking hearth</td>
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<td>Continuous recirculating bogie furnaces</td>
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<td>Rotary hearth furnaces</td>
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<tr>
<td>3. Heat Transfer</td>
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<tr>
<td>Radiation (open fire place)</td>
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<tr>
<td>Convection (heated through medium)</td>
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<tr>
<td>4. Waste Heat Recovery</td>
</tr>
<tr>
<td>Recuperative</td>
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<tr>
<td>Regenerative</td>
</tr>
</tbody>
</table>
FURNACE CLASSIFICATION

Heat Transfer
- Open Fire Place Furnaces
- Heated trough Medium

Mode of Charge
- BATCH
- CONTINUOUS

Heat Recovery
- RECUPERATIVE
- REGENERATIVE

- Forging
- Re-rolling
- Pot
- Pusher
- Walking Beam
- Walking Hearth
- Continuous recirculating bogie furnaces
- Rotary Hearth furnaces
Heat is generated by the combustion of solid, liquid, or gaseous fuels, and transferred either directly (convection) or indirectly (radiation) to the material.

Common fuel types are fossil fuels (e.g. oil, natural gas, coal). The combustion gases can be either in contact with the material (direct heating), or can be confined and thus be separated from the material (indirect heating; e.g., radiant burner tube, radiant panel, muffle).
3. BATCH FURNACES

> The “basic” batch furnace normally consists of an insulated chamber with an external reinforced steel shell, a heating system for the chamber, and one or more access doors to the heated chamber. These furnaces (such as box, bell, elevator, car bottom, and pit types) are most commonly used when a wide variety of heat-hold-cool temperature cycles are required.

These are normally used:
> for heat treatment of low quantities (in terms of weight per hour, i.e. low flowrates);
> for carburization of parts that require heavy case depths and long cycle times.

These furnaces are either electrically heated or gas/oil fired. The gas/oil fired furnaces can further be classified as direct fired and indirect fired (radiant tube burners).
3. BATCH FURNACES

Typical example of a batch type furnace:

> Box type furnace
> Heating up of scrap/ingots/billets
> Manual charge/discharge of the batches
> Operating $T = 1200 \, ^\circ C$
> Operating cycle: heat-up / hold / cool down
> Output: 10 - 15 tons/day
> Fuel used: depending on material and number of reheating cycles per day
> Continuous furnaces consist of: an insulated chamber, heating system and access doors. Continuous furnaces operate in uninterrupted cycles as the metallic parts in treatment move through them.

> Consequently, continuous furnaces are readily adaptable to automation and thus are generally used for high-volume work. Another advantage of continuous furnaces is the precise repetition of time-temperature cycles, which are a function of the rate of travel through the various furnace zones. These furnaces can have separate chambers to allow different cycles: heating - carburizing and diffusion.
> Continuous charging and discharging operations
> Temp = 1250 ÷ 1350 °C
> Operating cycle: continuous heating. The parts in treatment undergo pre-heating / heating / soaking according to their position inside the furnace
> Output: 20-100 tons/h
> Heat absorption by material is slow, steady, uniform
> The pusher device pushes the stock on water cooled "skids" (rails).
> The final part of the hearth is steep, or tilted (slide) to allow the unloading.
> Burners are located in the end zone (soaking zone) and at the top and bottom of the heating zone.
> Chimney is equipped with recuperator(s) for waste heat recovery.
The pusher-type furnaces, among all the re-heating furnaces, belong to the so-called "first generation“ furnaces.

The entire furnace load is pushed mechanically forward, and the charging step/tempo determines the discharging rate as well: one pieces in, one piece out (slab, billet...).

The length of the furnace, and the speed of operation, is limited by the strong friction produced by the slabs/billets sliding on the floor skids. In this condition, all transversal faces of the slab/billets are in mutual contact, so they do not receive direct heat.
Longer heating time means:

- scale formation (dangerous especially when billets slide over a hearth)
- higher fuel consumption

Since the faces of the slabs are in contact each other, a longer heating time is necessary.
### Pusher Furnace - PROs & CONTRAs

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
<th>Advantages</th>
<th>Disadvantages</th>
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</table>
| Pusher furnace    | **Main features:**  
> Furnaces may have solid hearth, but in most of the cases pusher furnaces are used to charge and discharge stock, that move on “skids” (rails) with water-cooled supports.  
> These furnaces typically are slightly sloping towards the discharge end, with a length up to 35 meters, divided into five zones in top-fired furnaces.  
> Firing is achieved by burners located at the discharge end of the furnace, or at top and/or bottom, to heat the stock uniformly from all sides.  
> These furnaces have a chimney (with recuperator) at the charging side, for waste heat recovery. | Low installation and maintenance costs (compared with moving hearth furnaces).  
Advantages of top and bottom firing:  
> Faster heating of the stock.  
> Lower temperature differences within the stock.  
> Reduced stock permanence time.  
> Shorter furnace length (if compared to solid hearth furnaces). | > Water cooling energy losses from the skids and the stock supporting structure in top and bottom fired furnaces  
> Discharge must be accompanied by charge.  
> Stock sizes/weights and furnace length are limited by friction and possibility of stock pile-ups.  
> Furnace needs facilities to be completely emptied.  
> Quality reduction by physical marking by skids or ‘skid marks’ temperature differences along the stock length caused by the water cooled supports in top and bottom fired furnaces. |
WALKING BEAM FURNACE

The most versatile type of furnace.

The charge (slabs or billets) lays on cooled pipe frames. Some frames are fixed, some frames are movable.
The charge (slabs or billets) is put on the stationary rails.

- **STEP 1** - Walking beams in rest position;
- **STEP 2** - Walking beams rise, above the pass line, and lift the charge;
- **STEP 3** - Walking beams advance one step, bringing forward the charge;
- **STEP 4** - Walking beams lowered below the pass line, come back to the original position.
Typical position of burners

Typical temperatures 1230 – 1250 °C

Output: 80 – 280 t/h

Preheating zone

Heating zone

Soaking zone
## WALKING BEAM FURNACE – PROs & CONTRAs

<table>
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</table>
| Walking beam furnace     | These furnaces operate as follows:  
  > The stock is placed on stationary ridges [at the inlet of the furnace].  
  > Walking beams are raised from the bottom to raise the stock.  
  > Walking beams holding the stock move forwards, with cyclic movements.  
  > Walking beams are lowered at end of the furnace to place the stock on stationary ridges [at the outlet of the furnace].  
  > The stock is removed from the furnace, taking it away from the stationary ridges.                                                                 | > Overcomes many of the problems of pusher furnaces [skid marks, stock pile-ups, charge/discharge].  
  > Possible to heat the bottom face of the stock, resulting in shorter stock heating time and minor furnace lengths, thus better control of heating rates, uniform stock discharge temperatures and operational flexibility.  
  > Easily emptied.                                                                                                                                         | > High energy loss through water cooling [compared with walking hearth furnaces].  
  > Much of the furnace [the mechanical apparatus] is below the main level of the mill; this may be a constraint in some applications.  
  > Sometimes when operating mechanism of beam make it necessary to fire from the sides, this results in non-uniform heating of the stock. |
The charge (slabs or billets) is introduced through the charging door.

The charge is placed on the fixed hearth (at least two bands).

As for the walking beams, the movable hearth performs the steps: lifting - stroke - lowering - return into the original position.
Scale formation may be a problem

No skid marks and no heat extracted by cooled pipes (potentially high efficiency)

Typical temperatures 1230 – 1280 °C

Output: 50 – 100 t/h
<table>
<thead>
<tr>
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</table>
| Walking hearth furnace | These furnaces are designed so that the stock rests on fixed refractory blocks, which are extended through openings in the hearth. The stock is transported towards the discharge end in discrete steps by “walking the hearth”, similar to walking beam furnaces. | > Simple design.  
> Easy construction.  
> Ability to operate with different stock sizes (within limits).  
> Negligible water cooling energy losses.  
> Easily emptied.  
> Minimal physical marking of the stock. | > Temperatures across the stock are not uniform because the bottom of the stock cannot be heated, and the small gaps between the stock limits its side heating. Larger spaces between stocks can partially compensate this, but this increases the stock residence time up to several hours, which affects furnace flexibility and yield. |
The furnace have long and narrow shape (gallery).
The charge is placed on the bogies with wheels (refractory on their hearth).
The different bogies move in a row, like a train.
The charge is removed at the tunnel exit.
The trucks are reloaded and back at the entrance.
## BOGIE FURNACE – PROs & CONTRAs

<table>
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</table>
| **Continuous recirculating bogie furnace** | The furnace has the shape of a long and narrow tunnel with rails inside; it and works as follows:  
> The stock is placed on a bogie (a cart with wheels), equipped with a refractory hearth.  
> Several bogies move like a train through the entire length of the furnace.  
> The stock is removed from the bogie at the discharge end, and the bogie returns to the charging section of the furnace. | > Suitable for compact stock of variable size and geometry.                  | > The stock in the bogie has to undergo a cycle of heating and cooling then again heating.  
> Heat storage loss through heating and cooling of the bogies.  
> Inadequate sealing of the gap between the bogies and furnace shell, difficulties in removing the scale, and difficulties in firing across a narrow hearth width caused by the narrow and long furnace shape. |
Walls and roof remain stationary.
The hearth moves in a circular way (pinion and gearing).
The charge lays on the travelling hearth.
The heat has direction opposite to that of the hearth.
Mainly adopted for pipe rolling mills.
Typical temperature: 1250 - 1300 °C.
Output: 80 - 180 t/h
## ROTARY HEARTH FURNACE – PROs & CONTRAs

### Comparison of Different Continuous Reheating Furnaces

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<thead>
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</table>
| Rotary hearth furnace   | More recent developed furnace type, now overtaking the bogie furnace. The walls and the roof of the furnace remain stationery, while the hearth moves in a circle on rollers, carrying the stock. The heated gas moves in opposite direction to the hearth, and the flue gases are discharged near the charging door. The temperature can reach 1300 °C. | > Suitable for stock of variable size and geometry.  
> Reduced heat storage loss compared to bogie furnaces. | > More complex design with an annular shape and revolving hearth.  
> Possible logistic problems in layout of some rolling mills, because of the proximity between charge and discharge positions. |
5. ACTUAL MARKET TRENDS

The most recent technological and operational developments, taking place in the rolling mills, turn out having a strong impact on the heating furnaces.

For new, or for heavily revamped furnaces:

- Increase of the furnaces dimensions.
- Decrease of the energy consumption.
- Improvement of thermal performance and thermal efficiency.
- Increase of the discharging speed.
For existing furnaces (especially pusher type):

> Discharging system.
> Charge preheating extension.
> Replacement of existing burners with regenerative/recuperative ones.
> Improvements of refractory linings.
> Coatings to increase the emissivity (both inside and outside).
6. THE SELECTION OF THE REFRACTORY MATERIALS

The optimum use of the refractories is achieved by careful study of the furnace design, and evaluating the operating conditions prior to the selection of refractory products, which have to meet the design and the operating requirements.

Given the multiple factors to be considered, the choice of the most suitable materials often seems to be quite complex. And sometimes this is true.

When selecting the refractories for a furnace, the following major factors – linked to Operational and well as to Design issues factors - must be identified and considered:
OPERATIONAL FACTORS

> Functionality of the furnace
> Smoothness of operation (continuity, discontinuity)
> Nature of the processed material
> Rate of operation (furnace capacity)
> Range and rapidity of temperature changes
> Chemical attack by metals, slags, ash, etc. (because of fuel, operation, nature of the charge)
> Velocity of furnace gases
> Abrasion from contained solids or fast moving gases
> Impact from charge handling
> Erosion by molten contents
> Impinging flames or hot spots
> Requested skin temperature

DESIGN AND CONSTRUCTION FACTORS

> Type of furnace
> General furnace conditions
> Heating curve (for blow-in and shut-down) and potential dry-out constraints
> Design and dimensions of insulated walls
> Amount of insulating material
> Type of refractory construction (e.g. bricks or monolithic)
> Allowance for thermal expansion
> Requested thermal expansion
> Loads on the lining (mechanical / thermal)
> Distribution of the burners
> Conditions of heating (one or more sides)
> Type of cooling (by air or by water)
> Methods of bonding or support
> Mechanics of any moving furnace parts
Usually, technical (operational/design) data are available from previous experience under similar conditions.

Moreover, the best refractory selection often depends on a few requirements so important that other factors play a minor role.

In some cases, refractoriness (i.e. maximum service temperature) alone will be the leading factor, while in other cases high refractoriness will have to be coupled with resistance to thermal shock...

Under other circumstances, resistance to metals, slags, or disintegration by reducing gases may be the governing elements. Sometimes high insulating value is desirable, but in other situations high thermal conductivity may be needed.
HEAT LOSSES FROM THE FURNACE WALLS

In furnaces and kilns, heat losses from furnace walls affect the fuel economy substantially.

The extent of wall losses depends on factors like:

1. Emissivity of walls.
2. Conductivity of refractories.
3. Thickness and composition of the walls.
4. Whether furnace or kiln is operated continuously or intermittently.
1. Emissivity of the walls.

Different materials have different radiation power (emissivity). For example, the emissivity of walls coated with Aluminum paint is lower than that of bricks. Thus, at a mean temperature of 600 °C, the conductivity of the insulation brick is only 20% of that of fireclay bricks.

2. Conductivity of refractory materials.

Heat losses can be reduced by selecting the proper refractory materials, avoiding for example the utilization of those with high thermal conductivity...
3. Composition of the walls.

Heat losses can be reduced by increasing the wall thickness, or through the application of insulating materials (bricks or boards).

The outside wall temperature, and the heat losses for a composite wall of a certain thickness of dense and insulating layers (firebrick, castable, ramming) are much lower if compared to an only dense refractory wall, due to lesser conductivity of insulating materials.

4. Continuous / Discontinuous furnace operation

In the case of batch furnace operation, operating periods (‘ON’) alternate with idle periods (‘OFF’). During the “OFF” period, the heat stored in the refractories during the previous “ON”-period is gradually dissipated, mainly through radiation and convection from the cold face.
As a summarization, the heat losses from the furnace walls, and the thermal profile through them will depend on:

- Inside temperature
- Outside (air) temperature
- Outside air velocity
- Configuration of the wall layers (number and sequence of layers, selected materials)
- Emissivity of the walls
- Thickness of the walls
- Conductivity of materials used for the walls lining
All mentioned parameters can be easily simulated with a suitable software.

This way it is possible to verify the thermal conditions of the new design, and to find the better walls configurations to match the requirements, both from the technical and the economical point of view.
Conclusions:

> Thickness and conductivity of the walls can be easily controlled and defined in the design phase.
> As the wall thickness increases, the heat losses reduce.
> As thickness of insulation is increased, heat losses reduce.
> The effect of insulation in reducing heat losses is higher than the effect of thicker walls (roughly 1 cm of insulation brick is equivalent to 5 to 8 cm of refractory firebrick).
> For intermittent furnace operations, thin walls of insulating refractories are better than thick walls of a dense refractories, since less heat is stored in them.
> One approach to achieve less heat storage capacity would be to utilize insulating material itself to form the inner refractory lining. Robust refractories with fairly good strength and spalling resistance can be used for temperatures in the range of 1300 °C.
> Hot face insulating bricks are lighter than normal refractories, weighing only one-third to one-half as much. Therefore, heat storage in the hot face insulation is very much reduced.
The chemistry of all refractories suitable for reheating furnaces is based on raw materials belonging to the Al2O3-SiO2 system.

**Traditional Materials:**
- Dense Castables
- Plastic Products
- Gunning Mixes
- Insulating Castables
- Dense Bricks
- Insulating Bricks
- Insulating boards
- Ceramic fiber products

**Innovative materials:**
- Plastic Castables
- Plastic Gunning Mixes
- No cement chemical bond castables
- Shotcreting products
- Precast solutions
Hydraulic-bonded to be applied by vibrating casting

**DS Cast 59 ND**
Andalusite based low cement castable, high refractoriness and thermal shock resistance, very versatile.
Walls and roofs of heating and soaking zone, burner tiles, skid insulation, hearth of walking beam furnaces.

**DS Cast 80 NX**
Bauxite based low cement castable, refractoriness strength and abrasion resistance.
Hearth of walking hearth, rotary hearth and pusher furnaces.

**DS Cast 78 NB**
Corundum based low cement castable, refractoriness strength and abrasion resistance.
Hearth in heating and soaking zone of walking hearth, rotary hearth and pusher furnaces.

**DS Cast 57 RM**
Chamotte based regular castable, balanced refractoriness and strength.
All walls and roofs, hearth of walking beam furnaces.

**DS Cast 43 NM**
Chamotte based regular castable, balanced refractoriness and strength.
Walls, roofs and hearth of walking beam plus skid insulation, all in pre-heating zone.
Castable installation on side walls
Castable in the hearth, contact with the charge (walking hearth, pusher)
Pusher Furnace – soaking platform casting
Walking Beam Furnace: fixed and movable posts in preparation
Walking Beam Furnace: welding tools and work in progress
Walking Beam Furnace: castable in the hearth, no contact with the charge
Plastic materials to be rammed are the historical perfect choice for reheating furnaces, since they are reliable and can last for ages. But they need skilled crews to be properly installed!

**DS Plast 42 AKM**
Chamotte based air-bonded plastic material with balanced properties. Walls and roofs in preheating zone of all RHF.

**DS Plast 62 AKM**
High alumina chamotte based air-bonded plastic material, high refractoriness and thermal shock resistance. Walls and roofs in heating and soaking zone of all RHF.

**DS Plast 70 AKX**
Bauxite based air-bonded plastic mass, high refractoriness and thermal shock resistance. Burners and high thermal load areas of all RHF (where strength is not needed).

**DS Plast 85 CX -3**
Bauxite based chemical bond plastic material, high refractoriness, thermal shock resistance and strength. Burners, cooled pipes (esp. bents, T joints) and high thermal/mechanical load areas of all RHF.
Plastic application on sidewalls and roof nose

Sidewalls

Roof nose
Dense Gunning Castable

They can be specifically recommended in case of repair of large, extended sidewalls portions.

In some cases, plastic gunning mixes may be preferred (see later).

**Seven Gun 50 RM**
Chamotte based gunning mix with balanced properties.
Walls in preheating zone of all RHF.

**Seven Gun 60 NM**
High alumina chamotte based low cement gunning mix, refractoriness and thermal shock resistance.
Walls, skids in heating and soaking zone of all RHF.
Waste Gas Duct (WGD) - medium weight (MW) castable application

Recuperator

Downstream
Walking Beam Furnace: hoppers for scale collection
Special products, able to combine the easier installation method of castables and gunning products with the advantages of the ceramic bond of plastic products:

**DS Cast PLAST**: specifically dedicated for the roof applications.

**DS Gun PLAST**: specifically dedicated for the sidewalls applications.

**DS Gun PLAST** products are especially interesting, since:

> They represent a very good option for repairs activities.
> They are easy to be gunned with a normal gunning machine.
> They have a very little rebound.
DS Cast 42 KM PLAST / DS Gun 42 KM PLAST
Chamotte based, ceramic bond, thermal shock resistance. Walls, roofs and skids in preheating zone of all RHF.

DS Cast 60 KM PLAST / DS Gun 65 KM PLAST
High alumina chamotte based, ceramic bond, thermal shock resistance an refractoriness. Walls, roofs and skids in heating and soaking zone of all RHF.

DS Gun 70 KH PLAST
High alumina chamotte based, ceramic bond, high thermal shock resistance and refractoriness. All zones with high thermal load of all RHF's (and where strength is not needed).
Plastic gun application on sidewalls
No-Cement, Chemical Bonded (LCS) castable for RHF

Benefits:
> No low-melting-point CaO-SiO2-Al2O3 phases in the matrix.
> Superior thermal shock resistance and lining life.
> Improved high temperature properties (RUL, HMDR).
> Higher permeability to gases.
> No chemical entrapped water.
> Reduced curing time.
> Reduced heating-up time, with associated reduced energy consumption.

Limits:
> Low “green” strength below 100°C.
> Necessity to supply a liquid separated binder.

Typical applications:
> Any refractory application with urgent need of repair and restart of operation.
> When it is difficult to apply a proper dry-out procedure.
> When longer shelf life is wished (because of the absence of cement).
> In RHF for repair of Discharge Zone and Hearth.
Heating up for a 250 mm lining

- No Cement
- Hydraulic bonded

Temperature (°C)

Time (hours)
DS Cast 59 CD LCS
No cement version of Seven Cast 59 ND.
2 components.

DS Cast 80 CX LCS
No cement version of Seven Cast 80 NX.
2 components.

DS Cast 80 NH DCS -10
Mullite based, high thermal shock resistance and refractoriness.
1 component.
Very versatile product for RHF.
Precast solutions and applications

- Precast shells ("modules") for the insulation of cooled pipes (skids and posts for walking beam furnaces, fixed pipes for pusher furnaces)
- Precast roof blocks
- Movable slots for vertical pipes
- Burner Tiles/Blocks
- Diaphragms
- Shaped hearth blocks for rotary hearth, walking hearth or heat treatment furnaces
- Special precast blocks for pusher furnace to replace ZAC electro-fused blocks
## In Situ Casting vs. Pre-casted modules – general comparison

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<th>LINING TYPE</th>
<th>In Situ</th>
<th>Precastened Modules</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>The lining is generally made by a layer of castable held by metal anchors welded to the pipe. Moulds are needed to perform the casting.</td>
<td>The lining is made by precast modules with a layer of casting and a ceramic fiber (made out of work). They have a sheet metal support.</td>
</tr>
<tr>
<td><strong>Pros</strong></td>
<td>✔ Lower initial costs</td>
<td>✔ Low assembly time</td>
</tr>
<tr>
<td></td>
<td>✔ Long erection time (welding anchors – curing time)</td>
<td>✔ Higher initial cost</td>
</tr>
<tr>
<td></td>
<td>✔ Excess water to be eliminated</td>
<td>✔ Quick dry out (modules are dried out already)</td>
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<tr>
<td></td>
<td>✔ Limited durability</td>
<td>✔ Higher durability</td>
</tr>
<tr>
<td></td>
<td>✔ Higher material losses</td>
<td>✔ Better insulation</td>
</tr>
</tbody>
</table>

**In Situ**

- Linings are made by castable material held by metal anchors welded to the pipe.
- Moulds are required for casting.

**Precastened Modules**

- Linings are made by precast modules with a layer of casting and a ceramic fiber (made out of work).
- They have a sheet metal support.
Skid and Posts lining – *in situ* casting vs. pre-casted modules
Walking Beam Furnace – Skids lining (mixed technique) - work phases
Pusher Furnace – cooling pipes lining with pre-casted modules
Walking Beam Furnace – Posts lining with pre-casted modules
Walking Beam Furnace – Posts/Skids lining – alternative design

Design for *In Situ* Casting
Longitudinal Section

Design for PCPF modules
Longitudinal section
Walking Beam Furnace – Posts/Skids lining – alternative design

Design for *In Situ* Casting
Cross-Section of Skid Lining

Design for PCPF modules
Cross-Section of Skid Modules
Walking Beam Furnace - PCPF modules for Posts lining

Phase 1: metallic shell with anchors

Phase 2: application of insulating fiber

Phase 3: after casting and heating/firing
Pusher Furnace – Special Projects – sidewall lined with pre-casted modules
Heating Furnace – PCPF burner blocks
Pusher Furnace - pre-casted burner block in place

On a roof made by PCPF blocks

On a roof made by ramming castable
Pusher Furnace - pre-casted blocks of the hearth
Heat Treatment Furnace – PCPF for the hearth
PCPF diaphragms
The fast, flexible shotcreting installation represents a highly reliable solution to reduce downtime of major repairs.

**DS Shot 49 NM CO**  
Chamotte based with balanced refractoriness and thermal shock resistance.  
Walls, roofs in preheating zone of all RHF.

**DS Shot 60 NH CO**  
High alumina chamotte based, thermal shock resistance an refractoriness.  
Walls, roofs and in heating and soaking zone of all RHF.
Despite the big steps forward this industry has experienced during the last 20 years, nowadays there are still many “open” areas of improvement for reheating furnaces.

Some of them are not focused on refractory technology, some of them needs the full involvement of the refractory technology. The main areas are:

- Mechanical improvements: handling, charging and discharging systems.
- Thermal improvements: stock/charge preheating.
- Thermal efficiency: replacement/modification of burners, process control for combustion efficiency.
- Thermal saving: improved refractory solutions.
- Thermal saving: improved insulation of masonry (walls, roof, hearth).
- Thermal saving: reduction size and losses from doors, slots (hearth of WBF), descaling tunnels, hoppers.
- Reduction of scale formation: control of furnace atmosphere.
MECHANICAL SOLUTIONS – IMPROVED CHARGE HANDLING

Example of improved discharging mechanism – already in use:

Before

Slabs/billetts

Cooled pipe

Bumper

After
An extended, unfired pre-heating zone is a key factor for the thermal efficiency and the productivity of the furnace:
Combustion improvement:
> Process control
> Air regulation / Automation

Replacement burners:
A major advantage of this type of system is that it can be retrofitted to an existing furnace structure to increase production capability without having to alter the existing exhaust gas.
ADVANCED REFRACTORY SOLUTIONS

Improving the insulation of existing furnace components (roof, walls, cooled pipes - skids and posts), by:

> Better performing materials (e.g. microporous)
> Better design, more layers
> Application of specific external and/or internal coatings
> Utilization of less conductive materials
> Extended use of pre-casted modules
• Thermal efficiency of a furnace is defined as:

\[
\text{Thermal efficiency of the furnace} = \frac{\text{Heat in the stock}}{\text{Heat in the fuel consumed for heating the stock}}
\]

• Typical thermal efficiency of reheating furnaces range: 10 - 30 %

A quick evaluation figure is:

- volume of natural gas
- 1 ton of heated stock

- > 34-36 m³ gas/ t ➔ standard
- > 32 m³ gas/ t ➔ very good
- > 28 m³ gas/ t ➔ outstanding
10. TECHNICAL SOLUTIONS

> Minimization of excess air for combustion
> Optimize the heat distribution ([heating curve and preheating is key](#))
> Optimize furnace temperature
(with the following hot working operations)
> Optimize burning process
   > Recuperative burners
   > Regenerative burners
> Reducing heat losses from furnace openings
> Maintaining the correct amount of furnace draft
> Avoid over or under lading of the furnace
> Improve waste heat recovery from the flue gases
> Minimize furnace skin losses
> Minimize cooled pipes losses
> Use of ceramic coatings
> Selecting the right refractories
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