TATA STEEL
WeAlsoMakeTomorrow

IIM
Metallurgy
Materials Engineering

Presents

International Conference on

GREEN & SUSTAINABLE IRON MAKING

January 17 – 18, 2024

Advanced and Reliable Refractory Solutions for a Green and Sustainable Approach to Blast Furnace Iron Production

Giuliano Copetti – RHI Magnesita – Alumina Monolithic Solutions

Introduction

The modern steelmaking process is subject to significant changes, moving towards the **Green and Sustainable Steel Production**.

Almost all steelmakers worldwide have already started projects to:

- decrease the direct and indirect CO2 emissions of their processes and products
- improve their energy efficiency accordingly
- reduce the general environmental impact of their activity.

Examples of the new emerging process routes are application of hydrogen gas as alternative reduction agent, direct reduction of iron ores (DRI), Carbon Capture and Utilization (CCU), and continuous improvements of raw materials.

Introduction

Besides important mid-term and long-term projects with significant project resources and investments, it is also important to consider existing technologies and products able to move in the same direction, but with a lower CAPEX (if no one at all), and potentially immediate effect.

In this scenario, the approach to Total Cost Ownership (TCO) is of increasing importance for the collaboration between the steel plant management and refractory suppliers.

From our side, in this presentation we will focus on 4 solutions, already existing and ready to be put in place to take the first important step ahead:

Our immediate solutions

Green Taphole Clay

to increase the health conditions of the BF operators and reduce the environmental impact

Castables with high content of recycled raw materials – our "GreenLine" products

to reduce the Carbon Footprint

LCS castables for BF runners

to reduce the energy consumption during application

Blast Furnace Hearth Protection – our "Modular Hearth Shield" concept

for the BF life prolongation and energy saving

1 **Green Taphole Clay**

2 «GreenLine» castables

3 LCS castables for BF runners

4 Modular Hearth Shield

THC - Actual Market Tendency

Since many years, EU Regulations are banning from the market any product containing PAHs (Polycyclic Aromatic Hydrocarbons) over the strict given concentration limits.

Similar regulations and guidelines are starting to spread all over the world, together with an increasing attention on health-related issues and growing consciousness over environmental protection.

This means that…

there is a deadline in sight for the utilization of tar-bonded taphole clay, that everybody sooner or later will have to cope with…

SEVEN Taphole Clay - Technical Philosophy

Chemistry	Based on High Alumina / SiC / Si3N4 / C (Quarzite-based for low grades only)
Physics	Expansion controlled mix
Binding	**100% Resin bonded / Thermosetting** / Ceramic
Healthy	**Phenol free / Lowest PAH content ever** (including benzo-α-pyrene) **Environmentally and health friendly**
Character	**Fast curing** / Adhesion / Corrosion resistance / Stability / **Consistency**
Performance	**Long cast duration. Long and stable tap-hole length**
Storage	**0-35°C / No direct sunlight / No heat exposure** / No rain exposition Temperature monitoring during transportation
Use	2,0-6,0 liter/sec; 120-240 bar plugging (1750-3500 psi) 10-120 liter injected per plug
Plasticity	**Wide range of workability index** [17-45 % at 35°C (95 F) after ageing]
Packaging	5-6 kg plastic wrapped blocks in cardboard box / ergonomic access to slugs
Critical factors	**Dwell time 3-7 minutes** Adjustable sensitivity to heat exposure of the mudgun
Shelf life	6 months (minimum)

SEVEN Taphole Clay – the «Classes»

Productivity
< 2.000 t/d

Quartzite Grade

High Silica content
Medium SiC

TAP 40/70/100 CLASS

Mini BF, Ferro-Alloys & Non-Ferrous

Productivity
2.000 - 5.000 t/d

Alumina Grade

Medium alumina
Low & Medium SiC

TAP 200 CLASS

Productivity
5.000-13.000 t/d

High Alumina Grade

Medium & high alumina
Medium & high SiC+FSN4

TAP 300 CLASS

Productivity
5.000-13.000 t/d

High Alumina Special Grade

High alumina
High SiC
Medium & High Si_3N_4

TAP 600 CLASS

Medium to Big Size Blast Furnaces

SEVEN THC – Product Portfolio

Product name	Type of product	Main RM	Max Grain Size	Al2O3	Fe2O3	SiC + C	SiO2	Fe2O3 + Si3N4	BD @800	BD @1200	CCS @800	CCS @1200	AP @800	AP @1200	PLC @800
			mm	%	%	%	%	%	g/cm3	g/cm3	MPa	MPa	%	%	$
Seven Tap 600 E	Tar free THC	BFA, SiC	3	58,4		26,8	7,5	4,6	2,3	2,29	12	11	27	28	-0,25
Seven Tap 600	Tar free THC	BFA, SiC	3	61,4		26,2	7,3	4,9	2,3	2,29	12	11	27	28	-0,25
Seven Tap 375 E	Tar free THC	BFA, SiC	3	39,6		28,7	14,3	8,6	2,27	2,23	11	14	25	26	-0,3
Seven Tap 375	Tar free THC	BFA, SiC	3	39,1		28,2	14,1	8,9	2,28	2,21	11	13	25	26	
Seven Tap 300 E	Tar free THC	BFA, SiC	3	43,2		28	15,7	4,7	2,18	2,16	10	12	26	27	-0,3
Seven Tap 300	Tar free THC	BFA, SiC	3	43,5		27,4	15,5	5	2,22	2,18	10	13	25	26	-0,3
Seven Tap 200	Tar free THC	BFA, Baux, SiC	3	48,8	0,8	26,7	17,6		2,18	2,15	10	12	26	27	-0,25
Seven Tap 190 E	Tar free THC	BFA, SiC	3	39,9	0,8	24,7	24,1		2,16	2,14	10	12	26	27	-0,25
Seven Tap 190	Tar free THC	BFA, SiC	3	40,2	0,8	24,1	23,9		2,17	2,14	9	11	26	27	-0,25
Seven Tap 100	Tar free THC	High Silica RM, SiC	3	2,3	0,3	21,9	73,6		1,84	1,83	11	10	26	27	0,15
Seven Tap 70	Tar free THC	High Silica RM, SiC	3	2,4	0,3	15,1	80,5		1,81	1,8	11	10	26	27	0,15
Seven Tap 40	Tar free THC	High Silica RM	3	2,4	0,3		86,9		1,78	1,77	11	10	26	27	0,15
Seven Tap 055 PL	Tar free THC	BFA, SiC	1	38,1		33,5	14,9	6,6	2,13	2,12	7	10	29	30	-0,3

The PAHs issue

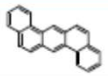
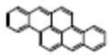
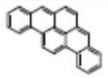
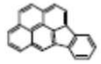
PAHs (Polycyclic Aromatic Hydrocarbons) are a large group of chemical compounds:

- entirely made by Carbon and Hydrogen
- with 2 or more **fused aromatic rings**

The biggest problem among PAHs is represented by the **highly carcinogenic benzo(a)pyrene.**

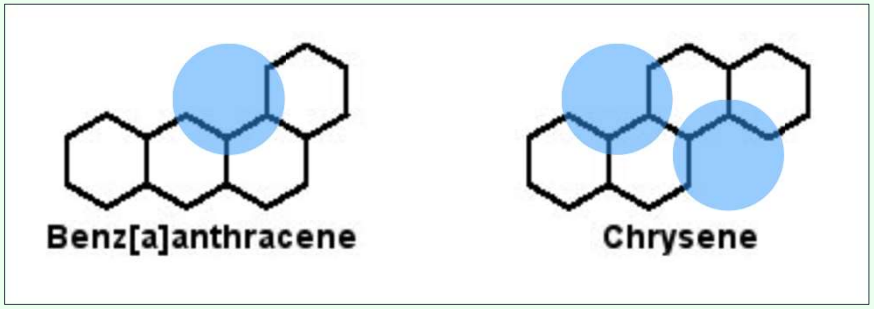
Table right: names and structures of PAHs frequently monitored according to recommendations by:

- ✓ the EU Scientific Committee for Food (SCF),
- ✓ the European Union (EU),
- ✓ the USA Environmental Protection Agency (EPA).

List	Common Name	Structure	List	Common Name	Structure
EPA, SCF, EU	Benzo[*a*] pyrene		EPA, SCF, EU	Dibenz[*a,h*] anthracene	
EPA	Acenaphthene		EU+SCF	Dibenzo [*a,e*]pyrene	
EPA	Acenaphthylene		EU+SCF	Dibenzo [*a,h*]pyrene	
EPA	Anthracene		EU+SCF	Dibenzo [*a,i*]pyrene	
EPA, SCF, EU	Benz[*a*] anthracene		EU+SCF	Dibenzo [*a,l*]pyrene	
EPA, SCF, EU	Benzo[*b*] fluoranthene		EPA	Fluoranthene	
SCF, EU	Benzo[*j*] fluoranthene		EPA	Fluorene	
EPA, SCF, EU	Benzo[*k*] fluoranthene		EPA, SCF, EU	Indeno[1,2,3-*cd*]pyrene	
EU	Benzo[*c*]fluorene		EU+SCF	5-Methyl chrysene	
EPA, SCF, EU	Benzo[*ghi*] perylene		EPA	Naphthalene	
EPA, SCF, EU	Chrysene		EPA	Phenanthrene	
SCF, EU	Cyclopenta [*cd*]pyrene		EPA	Pyrene	

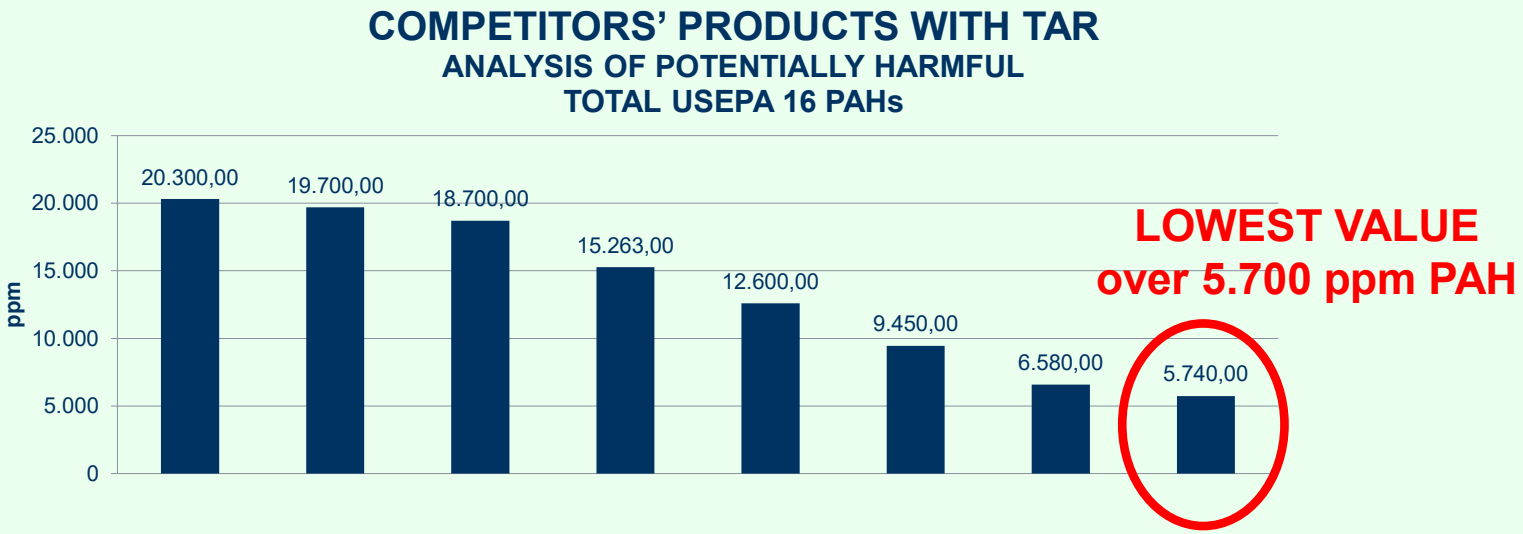
The PAHs issue

- PAHs are characterized by **high biochemical reactivity**, deriving from the special organization of the C atoms present in the so-called "*bay-region*" at benzene-rings ramifications, which is a feature common to each of the PAH.
- PAHs are **highly carcinogenic compounds**, due to their ability to form adducts with DNA.



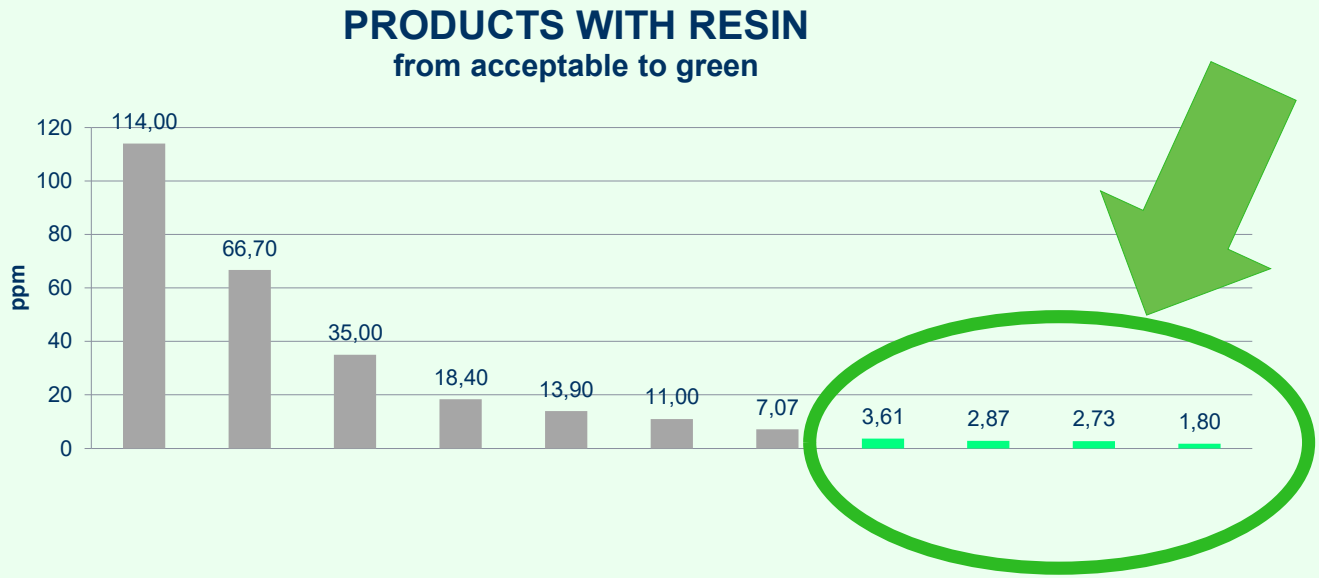
Picture left: Examples of "bay-regions" location for different PAH compounds

PAH levels for TAR-bonded Taphole Clay



Polycyclic Aromatic Hydrocarbons – Total USEPA 16 PAH [mg/kg]

PAH levels of our Taphole Clay



Reasons to choose SEVEN Taphole Clay:

- **Most eco-friendly tap hole clay worldwide ever**, without any coal tar or pitch inside
- **100% Resin-bonded** for a complete reduction of all the potentially noxious components
- **Highly performing material**. With our resin-bonded THC we can now reach the same technical performance of any Tar-bonded THC.
- **High consistency** during the application. This is steadily verified by means of statistical analysis of casting data taken during THC trial or during standard application of our clay.
- **Easy to inject** ➔ Reduced mechanical stress on the mudgun ➔ Cost saving.
- **Limited dwell time** ➔ Reduced thermal stress on the mudgun ➔ Cost saving.
- **Easy to drill** ➔ Not more than 1 drill bit necessary per each cast ➔ Cost saving.
- **Total absence of smell**. Very appreciated by the operators. And the Unions.
- **Ergonomic packaging**. Very appreciated by the operators.

THC References

COUNTRY	COMPANY	PLANT	BLAST FURNACE	WORKING VOLUME [m3]	HEARTH DIAMETER [m]	DAILY PRODUCTION [tons]	PRODUCT NAME
AUSTRIA	Voest Alpine	Linz	A	3.126	12,0	8.200	Seven TAP 300/325
							Seven TAP 325
			5	1.258	8,0	2.800	Seven TAP 300 E
			6				
		Donawitz	1	1.205	8,0	1.900	Seven TAP 200
							Seven TAP 100
			4	1.343	8,0	2.100	Seven TAP 200/100
GERMANY	Salzgitter AG	Salzgitter	A	2.410	11,2	6.000	TAP 300 family
			B	2.530	11,2	6.000	TAP 300 family
	AM Eisenhüttenstadt	Eisenhüttenstadt	5A	1.760	9,8	5.500	TAP 300 family
	DK Recycling	Duisburg	3	580	6,5	1.000	TAP 100 AD
	HKM	Duisburg	B	2.500	10,6	7.600	TAP 300 family
	Rogesa	Dillingen	4	2.358	11,2	6.400	TAP 310 E (300 E/300)
			5	2.580	12,0	6.800	TAP 310 E (300 E/300)
AUSTRALIA	Liberty Steel Whyalla	Whyalla	2	1.882	9,6	3.000	TAP 300 E
FRANCE	Saint Gobain PAM	Pont - a -	3	400	6,0	1.000	TAP 100 family
ITALY	ADI Taranto	Taranto	1+2+4	2.026	10,6	5.400	Seven TAP 300 / 300 E
	Acciaierie Arvedi	Trieste	3	420	6,2	1.350	Seven TAP 200/190 AD
CZECH REPUBLIC	Trinec	Trinec	4+6	1.333	8,0	3.200	Seven TAP 300 E
	Liberty Steel	Ostrava	3	1.333	8,0	3.000	Seven TAP 300 E
SWEDEN	SSAB	Lulea	3	2.540	11,4	6.800	Seven TAP 375 E
CHINA	Ansteel	Anshan	10	3.178	12,2	7.000	Seven TAP 300

THC References

COUNTRY	COMPANY	PLANT	BLAST FURNACE	WORKING VOLUME [m3]	HEARTH DIAMETER [m]	DAILY PRODUCTION [tons]	PRODUCT NAME
RUSSIA	NLMK	Lipetsk	3	2.000	10,0	4.400	Seven TAP 300
			4	2.000	10,0	6.000	Seven TAP 300
			5	3.200	12,0	9.000	Seven TAP 300
			6	3.200	12,0	9.000	Seven TAP 300
			7	4.400	13,1	12.500	Seven TAP 300
RUSSIA	Severstal	Cherepovets	1	1.033	7,7	3.100	Seven TAP 300
			2	1.033	7,7	2.800	Seven TAP 300
			3	3.000	11,5	8.500	Seven TAP 304
			4	2.700	11,0	7.000	Seven TAP 375
			5	5.550	15,0	13.000	Seven TAP 375 E
RUSSIA	EVRAZ - NTMK	Nizhny Tagil	6+7	2.200	11,8	6.500	Seven TAP 600
	EVRAZ - ZSMK	Novokuznetsk	1	3.000	11,6	7.000	Seven TAP 300
			2	2.000	9,8	5.400	Seven TAP 300
			3	3.000	11,6	6.500	Seven TAP 300
	MMK	Magnitogorsk	9+10	2.014	10,0	5.000	Seven TAP 200/ 200 KAZ
			1+2+4+6+7	1.371	8,4	3.800	Seven TAP 200 KAZ
RUSSIA	Metalloinvest - Ural Steel	Novotroitsk	1	1.007	7,5	2.150	Seven TAP 180
			2	1.007	7,5	2.150	Seven TAP 200
			3	1.513	9,0	3.100	Seven TAP 200
	Tulachermet	Tula	3	2.200	9,8	4.250	Seven TAP 200/ 300
			1	1.386	8,6	2.800	Seven TAP 190 KAZ
	Mechel	Cheliabinsk	1	2.034	10,0	3.300	Seven TAP 200 KAZ
	KMZ	Kosaya Gora	3	2.200	9,8	3.000	Seven TAP 150
SLOVAKIA	US Steel	Kosice	1	1.845	10,0	4.000	Seven TAP 200/ 190
			2	2.050	11,0	4.500	Seven TAP 200
			3	1.845	10,0	4.000	Seven TAP 190
							Seven TAP 200

THC References

COUNTRY	COMPANY	PLANT	BLAST FURNACE	WORKING VOLUME [m3]	HEARTH DIAMETER [m]	DAILY PRODUCTION [tons]	PRODUCT NAME
TURKEY	Isdemir Celik	Iskenderun	2	1.450	8,5	3.500	Seven TAP 200/ 260
			3	2.100	10,2	5.500	Seven TAP 200/ 300/ 260
			4	2.500	11,8	7.000	Seven TAP 300/ 260
							Seven TAP 055PL
	Erdemir Celik	Eregli	1	1.850	10,0	5.200	Seven TAP 300
			2	1.707	9,7	4.500	Seven TAP 300
	Kardemir Celik	Karabuk	5	1.650	9,4	3.500	Seven TAP 200
							Seven TAP 300
UKRAINE	EVRAZ - Petrovska Zavod	Dnepropetrovsk	2	1.200	7,9	2.400	Seven TAP 200
			3	1.200	7,9	2.500	Seven TAP 200 Dnep A1
	Metinvest Enakievo Zavod	Enakievo	1	1.200	7,9	2.200	Seven TAP 300
			3	1.700	8,4	3.500	Seven TAP 300
	Zaporovhstal	Zaporozye	3	1.500	-	2.500	Seven TAP 200
	Azovstal	Mariupol	2	1.719	-	2.300	Seven TAP 200
							Seven TAP 055PL
CANADA	AM Dofasco	Hamilton	3	963	6,6	2.260	Seven TAP 200
			2	1.062	7,3	2.450	Seven TAP 300
	Algoma Steel	Saint - Sault Marie	7	2.477	10,7	7.570	Seven TAP 300
MEXICO	AHMSA	Monclova, Coahuila	5	2.199	11,2	7.200	Seven TAP 300
			6	1.392	8,4	4.430	Seven TAP 300
USA	US Steel	Edgar Thomson	1	1.541	8,8	3.200	Seven TAP 300
		Granite City	B	1.402	7,8	4.200	Seven TAP 300 E
		Gary	4	1.496	8,8	3.500	Seven TAP 300 E
	Cleveland Cliffs	Dearborn	C	1.797	9,2	6.200	Seven TAP 300
		Indiana Harbor	7	4.079	13,7	10.000	Seven TAP 375 E

THC References

COUNTRY	COMPANY	PLANT	BLAST FURNACE	WORKING VOLUME [m3]	HEARTH DIAMETER [m]	DAILY PRODUCTION [tons]	PRODUCT NAME
SERBIA	HBIS	Smederevo	1+2	1.455	9,0	3.000	Seven TAP 200 EAD
BOSNIA	AM ZENICA	Zenica	4	2.400	10,0	3.300	Seven TAP 200/ 190
KAZAKHSTAN	AM TEMIRTAU	Temirtau	2	2.500	10,0	3.300	Seven TAP 101 KAZ
			3	3.800	12,0	5.400	Seven TAP 101 KAZ
KAZAKHSTAN	KAZCHROME	Aktobe	1-2-3-4	65 MW EAF for Ferrochromit Production			Seven TAP 101 KAZ
ROMANIA	Liberty Steel	Galati	5	3.120	12,0	6.000	Seven TAP 300 E
SOUTH AFRICA	ARCELOR MITTAL	Vanderbijlpark	D	2.162	10,2	4.100	Seven TAP 190
			C	1.626	9,6	3.200	Seven TAP 190
GREAT BRITAIN	BRITISH STEEL	Scunthorpe	Queen Anne	1.580	9,0	4.000	Seven TAP 300 E
			Queen Victoria	1.580	9,0	4.000	Seven TAP 300 E
BELGIUM	ARCELOR MITTAL	Gent - Zelzate	B	2.550	10,5	7.500	Seven TAP 375 E

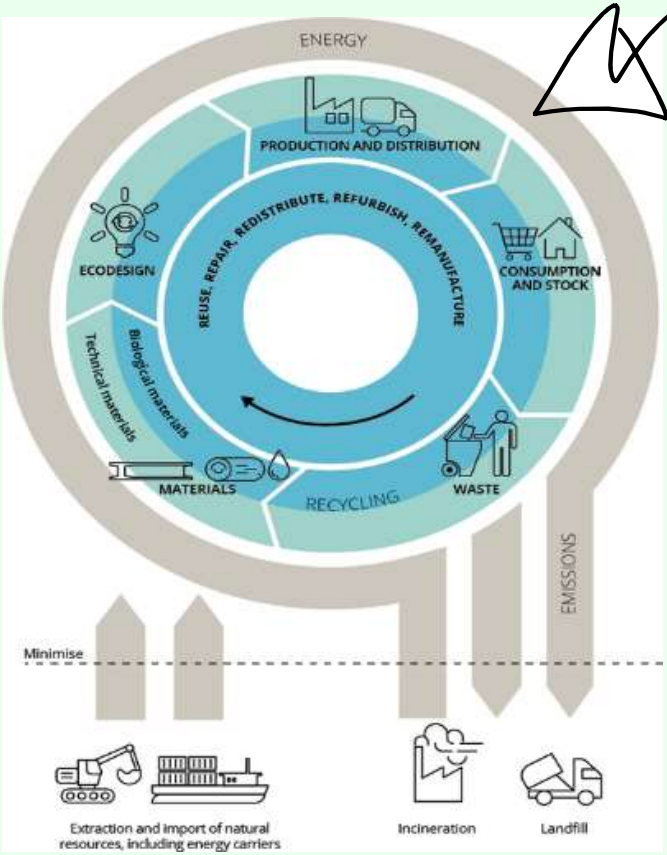
1 Green Taphole Clay

2 **«GreenLine» castables**

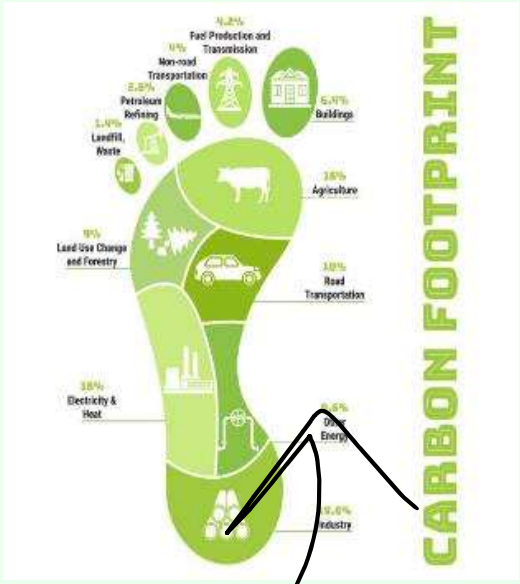
3 LCS castables for BF runners

4 Modular Hearth Shield

Circular Economy and Carbon Footprint



According to the World Economic Forum, a **circular economy** is "an industrial system that is restorative or regenerative by intention and design."



A **carbon footprint** is the total greenhouse gas (GHG) emissions caused by an individual, event, organization, service, place or product, expressed as carbon dioxide equivalent (CO_2e).

Definitions

Scope 1 Emissions

Direct GHG emissions that derive from sources owned or directly controlled by the organization.

GREENHOUSE GAS EMISSION

✓ NO CO_2 emission
✓ NO INDUSTRIAL LIQUID WASTE

Definitions

Scope 2 Emissions

Indirect GHG emissions associated with the purchase and utilization of the energy by the organization.

✓ **PRODUCING GREEN ENERGY BY SOLAR ROOF**

From the very beginning we have been focused on green energy and enviromentally friendly approach

✓ **PURCHASING ELECTRICITY FROM FOSSIL FREE SOURCES**

Definitions

Scope 3 Emissions

All other indirect GHG emissions, upstream and downstream of the organization

- ✓ proven and reliable suppliers of raw materials
- ✓ managing of logistic operations due to our strategic position
- ✓ **REUSE pallets**
  REDUCE transportation
  RECYCLE cardboard & paper

What is GreenLine?

- The production of castable **DOES NOT NEED ANY HEATING nor ANY SINTERING PROCESS.**
- **Highest technically possible rate of spent raw materials from reliable and proven sources**
- Advanced production line optimization to secure carbon neutral footprint and **NO EMISSION**.
- Features of the castable kept as close as possible to the formulation with virgin raw materials.
- Eco-sustainable approach.

GreenLine – Key Facts

- **20+ developed GREEN PRODUCTS** and counting
- **40% LESS CO_2 EMISSIONS** vs Fired Bricks
- **20% LESS CO_2 EMISSIONS** vs Conventional Castables
- **15 - 20%** forecast **REDUCTION OF NATURAL RESOURCES CONSUMPTION**


Seven
GreenLine
Data Sheet
Seven GL Cast 59 ND

General information

Type of product	Low Cement Castable
Type of bond	Hydraulic
Maximum recommended temperature	1600°C
Main raw material	Andalusite
Material required (kg/m³)	2400
Maximum grain size (mm)	6
Water required for installation	5,5-7,5%
Installation method	Vibrating casting

>>> Environmental indicators

Product Carbon Footprint (kg CO_2 / t prod.)	ISO 14067	800

Chemical properties according to EN ISO 1927-3

	Al_2O_3	Fe_2O_3	CaO	SiO_2
Typical (%)	58,8	1,1	2,3	35,0
Limit (%)	min 55,0	max 1,4	min 1,9	max 37

Physical properties according to EN ISO 1927-5, 1927-6, 1927-6

		110 °C	800 °C	1200 °C
Bulk density (g/cm³)		2,35	2,40	2,45
Cold Crushing strength (MPa)		70	80	80
Apparent Porosity (%)			20	22
Perm. Linear Change (%)		-0,15	-0,25	-0,40
Thermal Cond. (W/mK)			1,21	1,77
RTE at 1000°C (%) after firing at 1000°C	EN 993-19			0,65
Abrasion after firing at 815°C (cm³)	ISO 16282/ASTM C704			<10

Other properties

Packaging	Paper bags or Big bags
State of delivery	Dry
Shelf life (storage in dry conditions)	6 months
Installation guideline / Heating-up curve	IG 02A / HC 01-02

In order to preserve the quality of the product it is strictly recommended to respect the general guidelines provided by Seven Refractories about storage condition, handling and application of the material. In case of non-compliance with these guidelines, the product may suffer irreversible transformations compromising its final application and performances.

The properties refered to the declared nominal average values obtained from quality control during production and cannot be considered as guarantee ones. The stated properties might slightly change as consequence of the workability parameters.

preliminary issue

Revision: mar_2022

www.sevenrefractories.com

#beingGREEN

Calculation procedure…

The Carbon Footprint calculation method has been defined based on the **International Standard ISO 14067-2018**.

The simplified formula looks like:

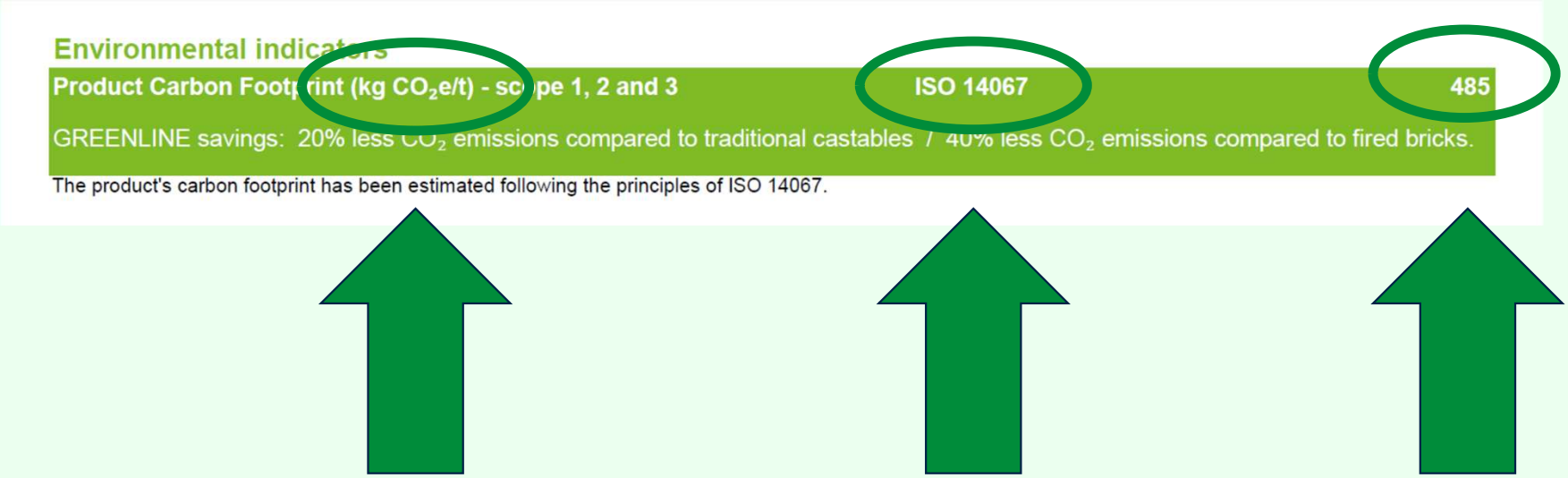
[Product Formulation] x [Footprint of the different RM] +
[Transport of raw materials] +
[Conversion to Finished Product (Energy cons., Packaging…)] =

CO_2 Footprint per single product

… and declaration of the results

The Carbon Footprint calculation results are shown on each Technical Data Sheet, expressed in terms of

“kg of equivalent CO2 per ton of castable”:



GreenLine: portfolio examples

Seven GL **Cast** 35 RMZ 5
Seven GL **Cast** 39 RM 4
Seven GL **Cast** 40 RM 4
Seven GL **Cast** 50 NM 5
Seven GL **Cast** 57 RM 5
Seven GL **Cast** 59 ND 5
Seven GL **Cast** 60 RM 5
Seven GL **Cast** 77 RX 5
Seven GL **Cast** 80 NX 5

Seven GL **Ram** 2565 KX
Seven GL **D Ram** 2565 KX

Seven GL **Gun** 35 RMZ 5
Seven GL **Gun** 75 RX 5
Seven GL **Gun** 2363 NX

Seven GL **Trow** 45 RM 5 -6
Seven GL **Trow** 80 RX 5 -6

1 Green Taphole Clay

2 «GreenLine» castables

3 **LCS castable for BF runners**

4 Modular Hearth Shield

BF casthouse - the application area

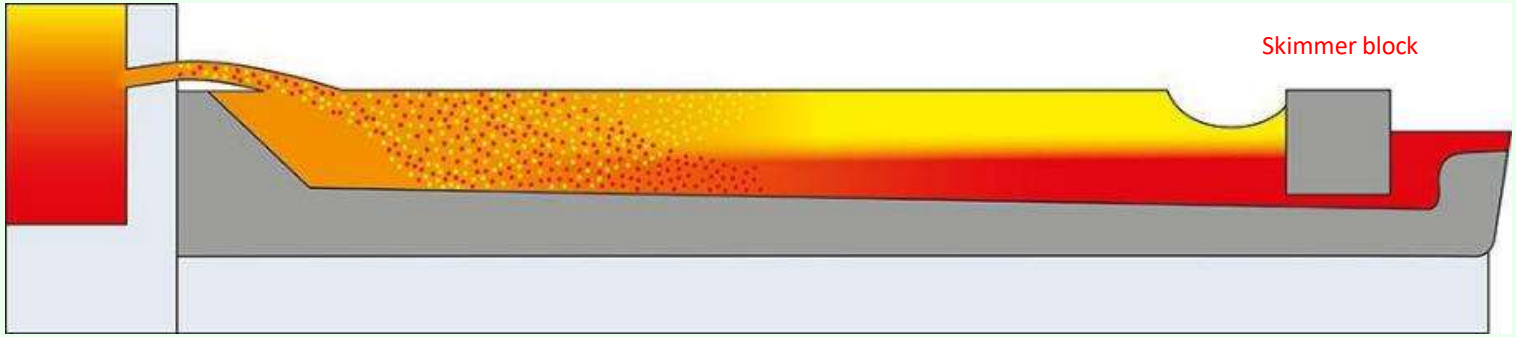
Blast furnace with taphole

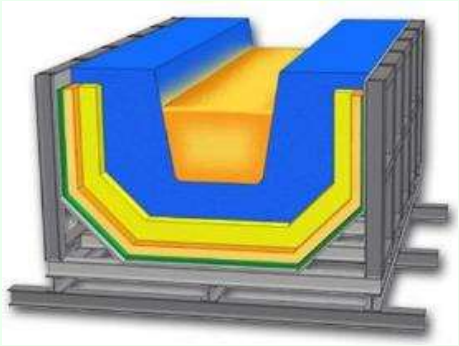
Impact area – high turbulent zone

Separation zone – separation of hot metal & slag

Slag runner – slag discharge

Hot metal runner –





Working line
Safety line
Insulating brick
Insulating plate
Metal shell
(with or without cooling system)

Product category overview

CONVENTIONAL PRODUCTS

Products adjusted according to the BF operating condition:

- Single line
- Balanced line

SKIMMER

Product with greater resistance to erosion and thermal shock to prolong skimmer campaign

CEMENT FREE TECHNOLOGY

Product developed with focus on hot applications and operational availability

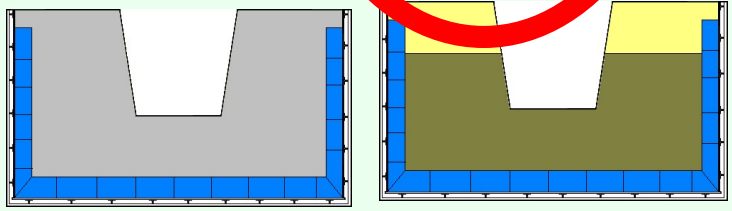
AGGRESSIVE OPERATING CONDITIONS

Products used in runners operating with high hot metal temperature and slag rate

CASTABLES FOR TAPHOLE AREA

Product with fast sintering, high impact resistance and low permeability avoiding gas passage

Single line



Zone lining

Slag line

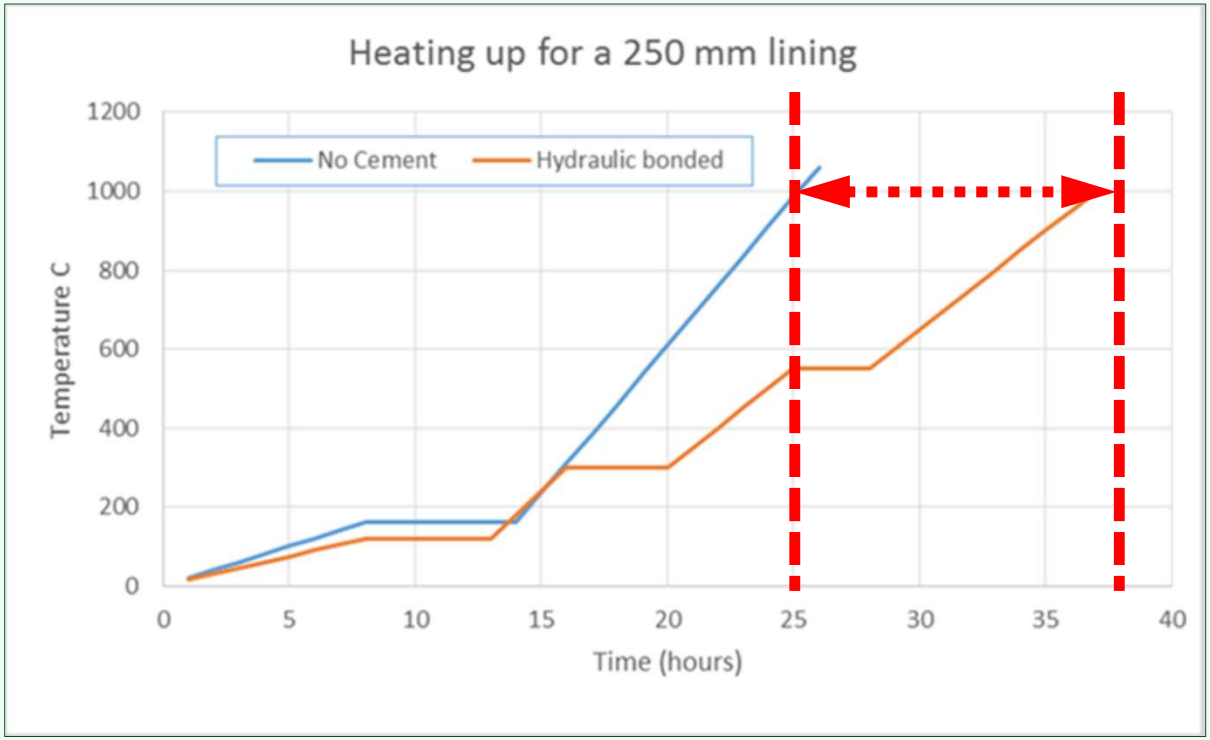
SiC ➔ max. 70%
Anti-oxidant ➔ Si + B_4C

Hot metal line

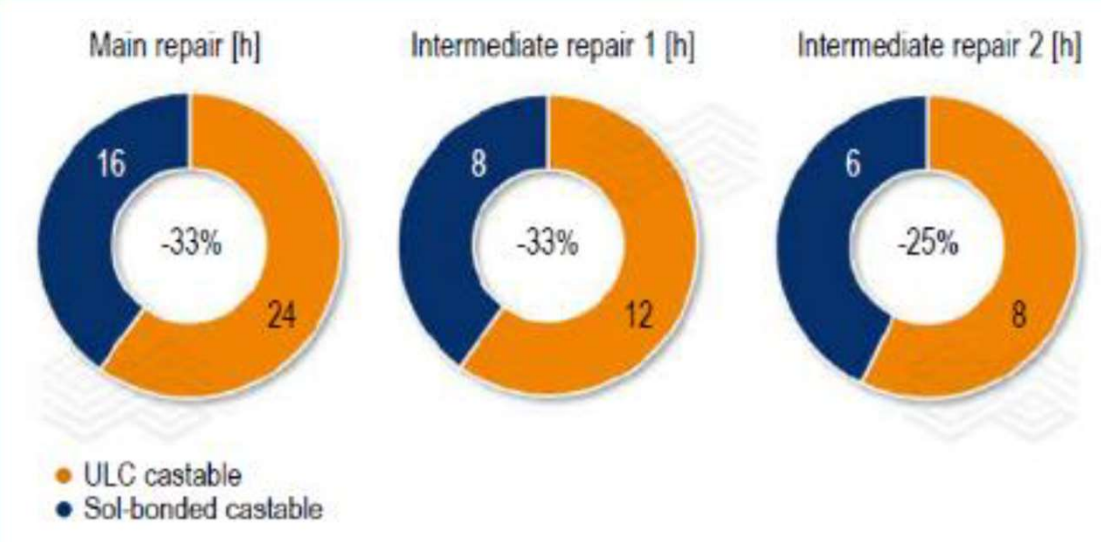
SiC ➔ max. 18%
Spinel agregates (MgAl O)

Heating-up: hydraulic bonded vs LCS castable

Compared to standard ULC (ultra-low cement) castables, a drastic reduction in the drying/heat-up curve was implemented for the sol-bonded castables in working lining application.



Heating-up: hydraulic bonded vs LCS castable

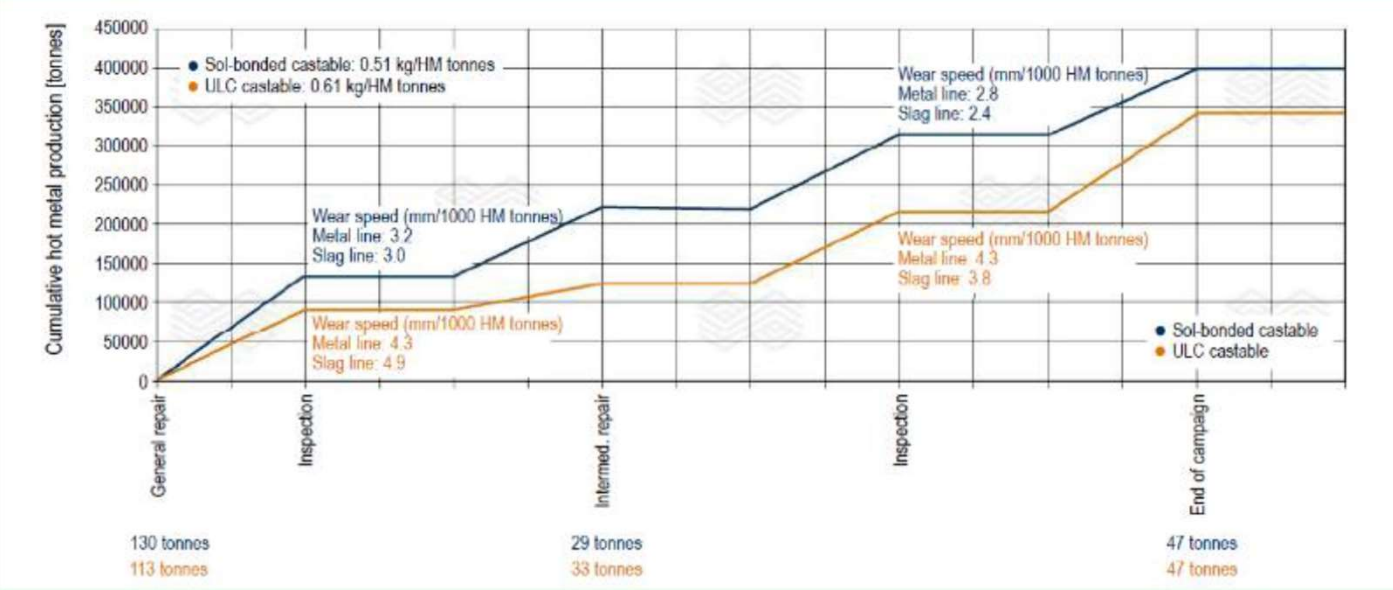


The sol-bonded refractory castable technology demonstrates higher explosion resistance when exposed to fast heating curves, due to the higher permeability and absence of the hydraulic phases present in the ULC castables.

Performance comparison

The performance of ULC and sol-bonded castable technologies were compared in main runner working lining applications (with an intermediate shotcrete repair carried out in both cases).

The wear speed measured at the end of the campaigns was significantly lower with sol-bonded castables, and the performance accordingly higher.



LCS castables – a summarization

PROs

- No low melting point CaO-SiO2-Al2O3 phases in the matrix
- Superior thermal shock resistance and lining life
- Improved high temperature properties (RUL, HMOR)
- Higher permeability to gases
- No chemical entrapped water
- Energy and Time saving during dry out

CONTRAs

- Low strength below 100 °C
- Separated liquid binder

TYPICAL APPLICATIONS

- Urgent need of repair and restart of operation
- Energy reduction during heat up
- Difficult heta-up conditions
- Longer shelf life required

1 Green Taphole Clay

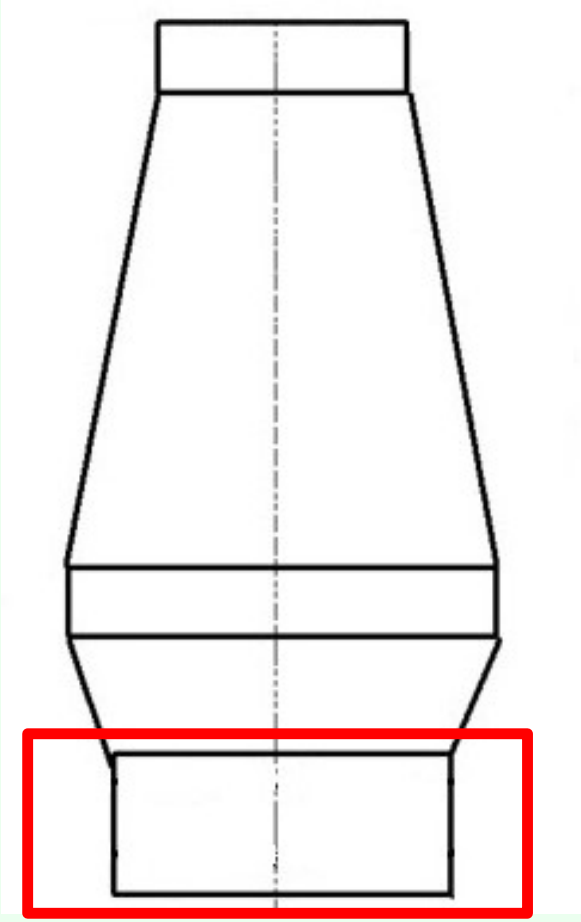
2 «GreenLine» castables

3 LCS castavles for BF runners

4 **Modular Hearth Shield**

RENOVATION TECHNIQUES FOR THE BLAST FURNACE HEARTH:

1. MONOLITHIC HEARTH REPAIR
2. MODULAR HEARTH SHIELD



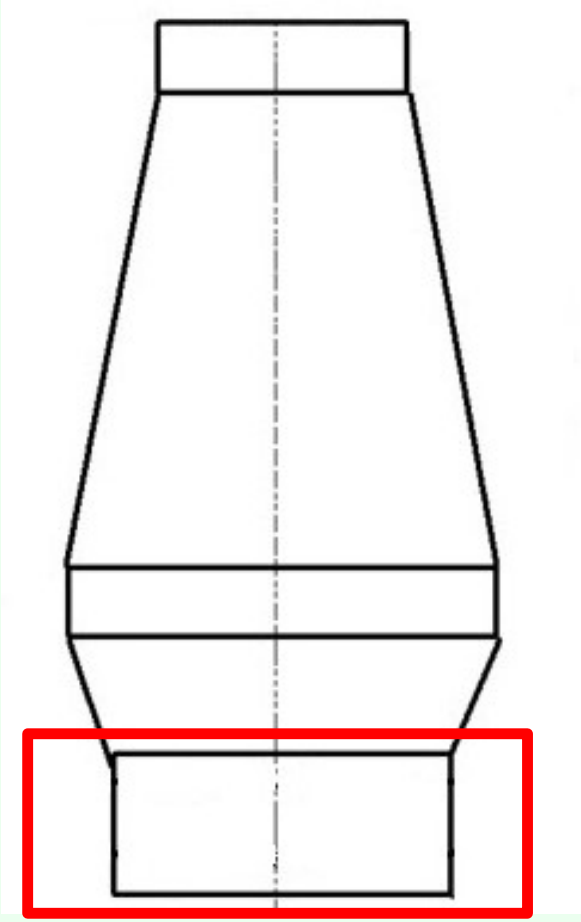
MODULAR HEARTH SHIELD (MHS)

BF Hearth Reconstruction / Renewal

A way to re-build the hearth, protect new C-blocks, using a **PRE-SHAPED STRUCTURE**, extend their technical service life, thus increase the expected campaign life of the BF, increasing the energy saving of the system.

Starting point:

- New blast furnace commissioning (sometimes with life-guarantee issues)
- Complete hearth renovation
- Availability of new Carbon blocks
- No time issues for production and delivery of the goods

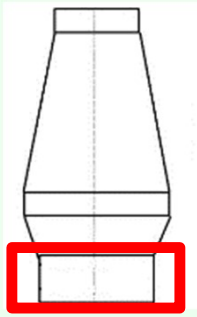


MODULAR HEARTH SHIELD (MHS)

- **DURABILITY** – MHS offers a proven increase in the expected life of the hearth, therefore of the blast furnace as a whole
- **RELIABILITY** – the highly associated technological content makes it to almost a must for every modern blast furnace
- **SUSTAINABILITY** – guarantees an effective energy saving with high benefits extended over the whole iron and steel production process

Main features:

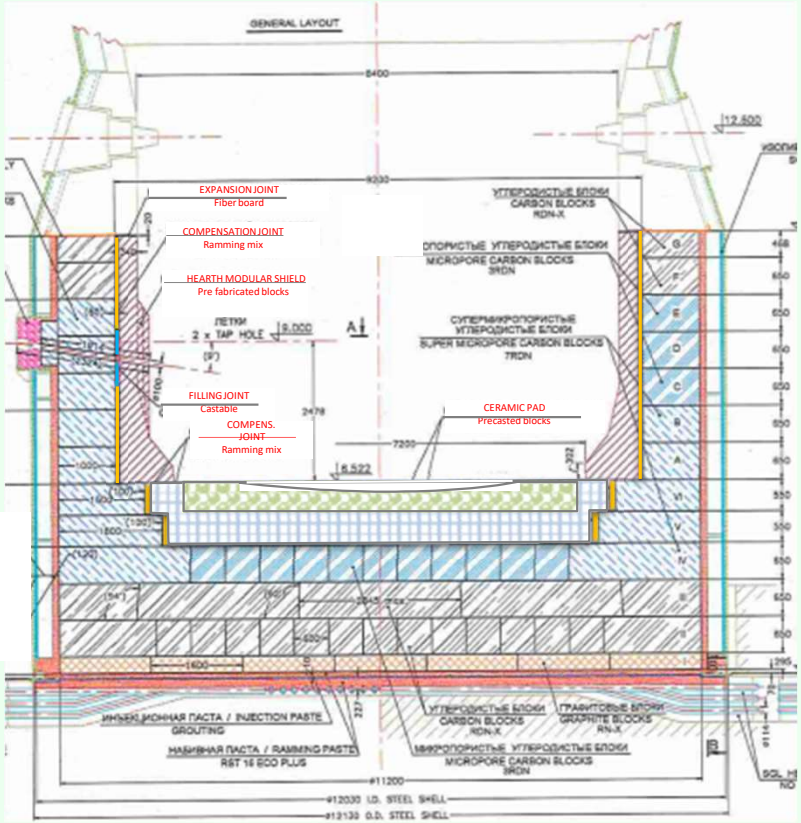
- Material installed at its most stable conditions → pre-casted & pre-dried blocks
- 4 different blocks layers (zoning concept)
- 4 specifically developed castables → based on the different BF stress factors
- Designed to resist the highest thermo-mechanical stresses
- Verified by Finite-Elements Method analysis (FEM)
- Detailed geometry, perfectly fitting to the underlying C-blocks lining → preassembly



MODULAR HEARTH SHIELD

THE TARGET

- Protection of the Carbon Lining
- Contrast the erosion mechanism given by:
  - ✓Oxidation
  - ✓Corrosion by alkali
  - ✓Disintegration by CO
  - ✓Hot metal and slag penetration
  - ✓Thermal stress
  - ✓Dissolution due to hot metal and slag flow
- Adopt precast solutions, since it allows any geometry for the blocks, in terms of thickness, shapes and material quality distribution



MODULAR HEARTH SHIELD

THE DEVELOPMENT

Compound Alumina / Silica / Silicon Carbide + C has been selected because of its:

- High thermomechanical stability
- High thermal conductivity
- High hardness and fracture toughness
- Low thermal expansion coefficient
- High alkali and slag resistant
- High CO resistance

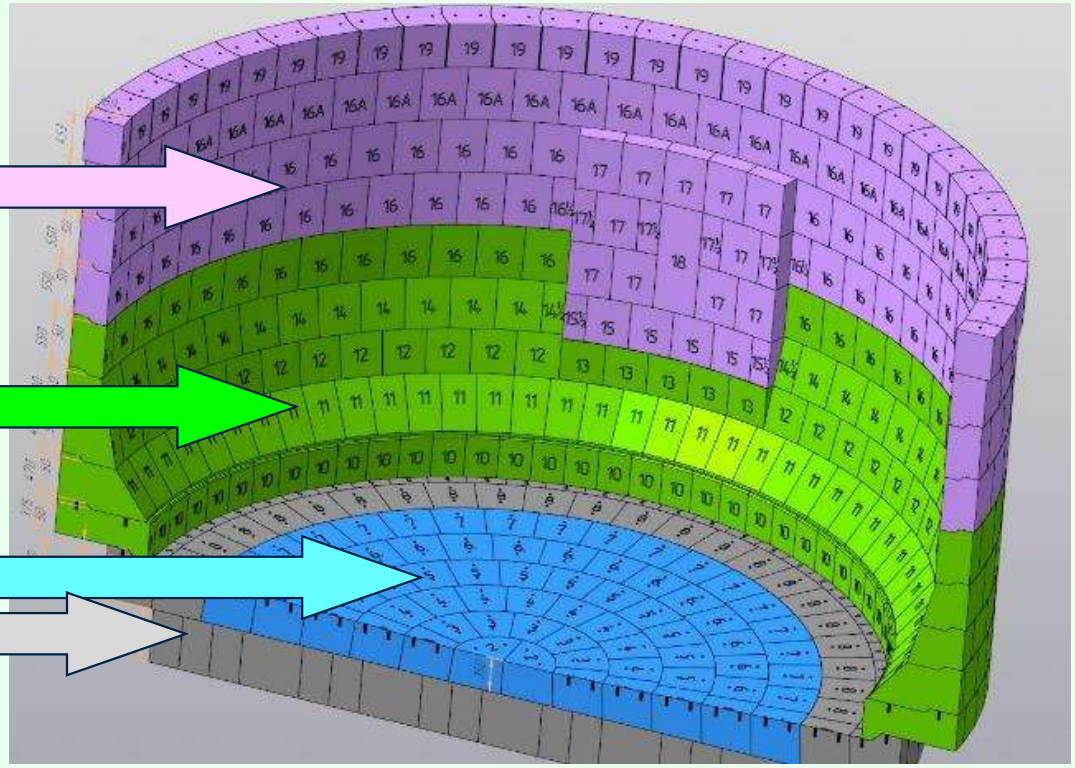
The SiC sensitivity to oxidation is not detrimetal for the lining, because the newly generated SiO_2 will then react with the surrounding Al_2O_3, thus forming new Mullite.

The formed SiO_2 glassy phase will also reduce the porosity, thus the possible infiltrations of liquid metals due to the capillarity effect into the matrix of the blocks.

MODULAR HEARTH SHIELD (MHS)

The **MODULAR HEARTH SHIELD** always consist of 4 layers:

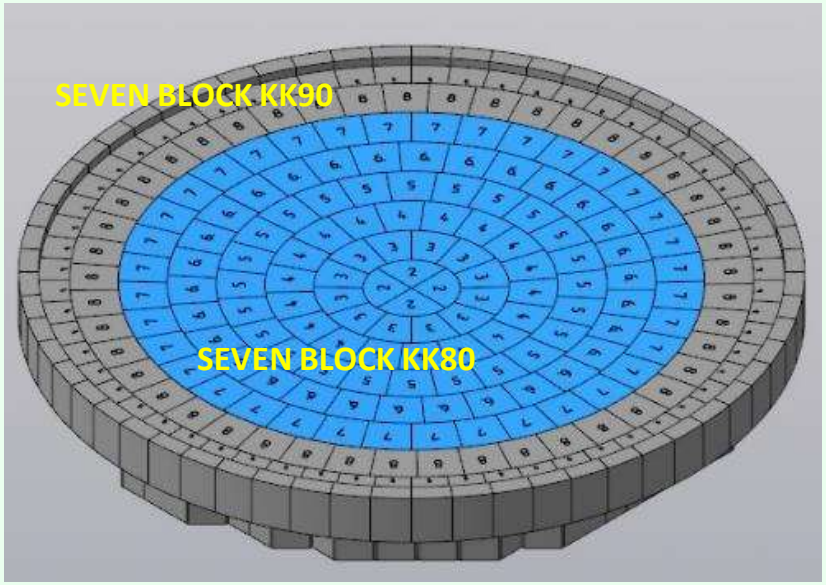
- Upper Sidewall
- Lower Sidewall
- Upper Bottom Pad
- Lower Bottom Pad



MODULAR HEARTH SHIELD (MHS)

Materials for the **Bottom** layers:

- Based on a mix of Corundum / Mullite
- Different ratios because of major / minimal exposure to the molten products
- No Silicon Carbide



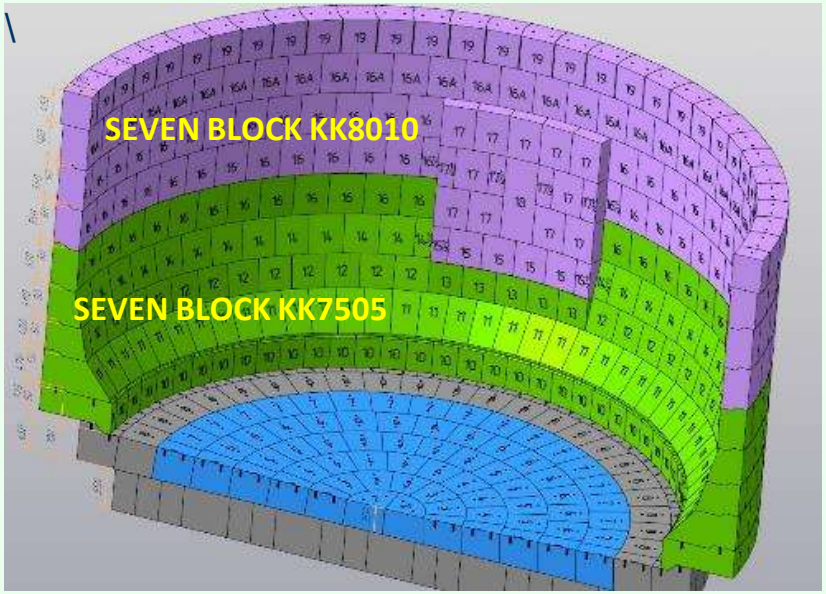
SEVEN BLOCK KK80		
GENERAL INFORMATION		
Classification	Pre-casted ceramic block	
Raw material	Corundum-Mullite	
CHEMICAL ANALYSIS (for the product)		
Al_2O_3	81,0	%
SiO_2	16,0	%
Na_2O	0,2	%
Fe_2O_3	0,6	%
PHYSICAL PROPERTIES		
Bulk density	2,72	g/cm^3
Apparent Porosity	13	%
CCS of delivered block	75	MPa

SEVEN BLOCK KK90		
GENERAL INFORMATION		
Classification	Pre-casted ceramic block	
Raw material	Corundum	
CHEMICAL ANALYSIS (for the product)		
Al_2O_3	91,0	%
SiO_2	7,0	%
Na_2O	0,1	%
Fe_2O_3	0,2	%
PHYSICAL PROPERTIES		
Bulk density	2,90	g/cm^3
Apparent Porosity	11	%
CCS of delivered block	80	MPa

MODULAR HEARTH SHIELD (MHS)

Materials for the **Sidewall** layers:

- Based on pure Corundum, mix of Corundum / Mullite
- Different composition, different content of SiC due to exposure to the molten products with different features



SEVEN BLOCK KK8010

GENERAL INFORMATION		
Classification	Pre-casted ceramic block	
Raw material	Corundum-Silicon carbide	
CHEMICAL ANALYSIS (for the product)		
Al_2O_3	80,0	%
SiO_2	7,0	%
SiC	10,0	%
Na_2O	0,3	%
Fe_2O_3	0,2	%
PHYSICAL PROPERTIES		
Bulk density	2,80	g/cm³
Apparent Porosity	13	%
CCS of delivered block	70	MPa

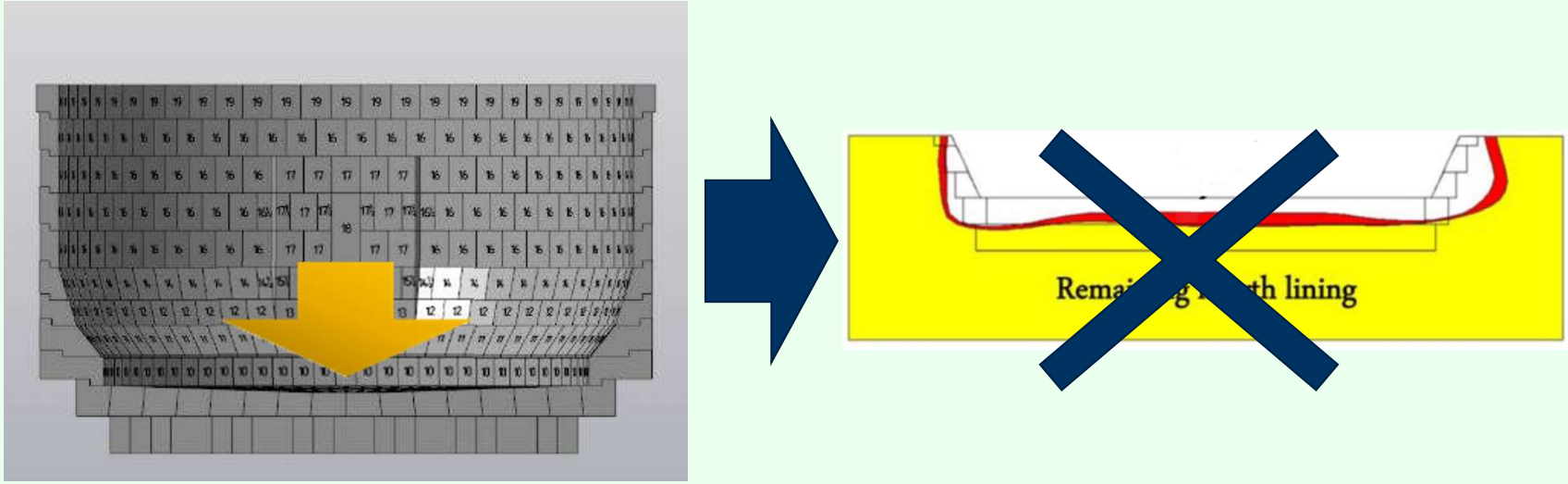
SEVEN BLOCK KK7505

GENERAL INFORMATION		
Classification	Pre-casted ceramic block	
Raw material	Corundum-Mullite-Silicon carbide	
CHEMICAL ANALYSIS (for the product)		
Al_2O_3	75,0	%
SiO_2	15,0	%
SiC	5,0	%
Na_2O	0,2	%
Fe_2O_3	0,6	%
PHYSICAL PROPERTIES		
Bulk density	2,70	g/cm³
Apparent Porosity	13	%
CCS of delivered block	70	MPa

MODULAR HEARTH SHIELD

A specific geometrical solution

The concavity of the upper bottom pad, with its central “bowl shape”, is designed to force the hot metal mass transfer towards the center of the bottom, thus preventing premature formation of the typical “elephant foot” wear pattern of the BF hearth bottoms, and improve the dead man permeability by reducing the peripheral flow of the molten products.



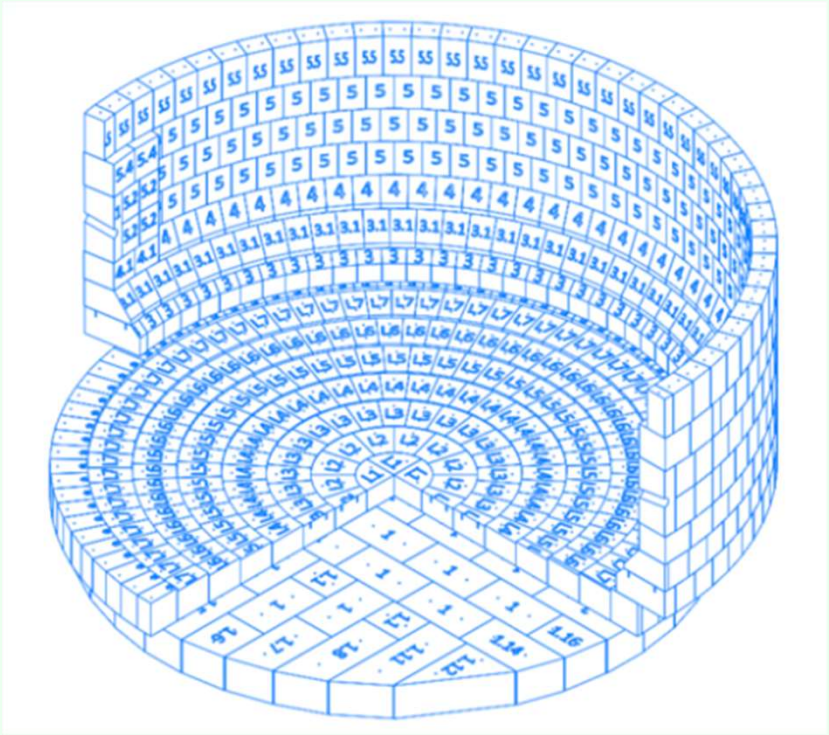
MODULAR HEARTH SHIELD

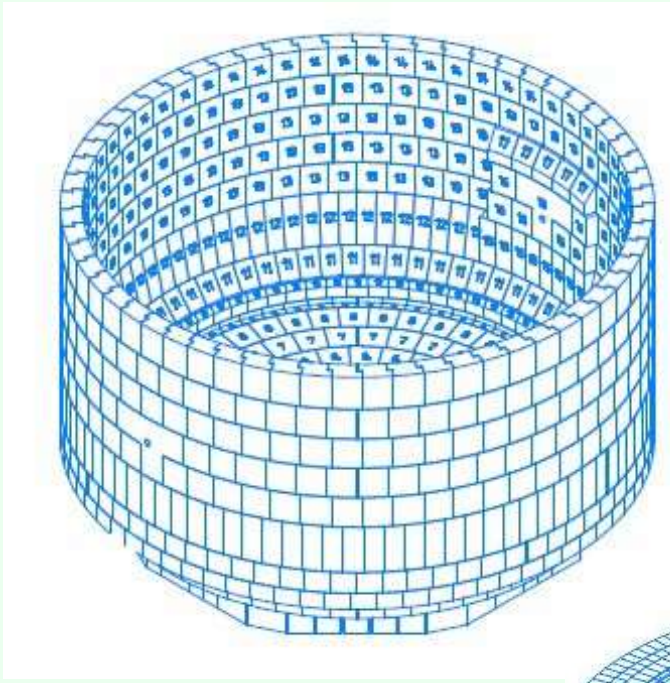
Large number of quality tests performed on the materials/blocks during development, to achieve a complete characterization of the product:

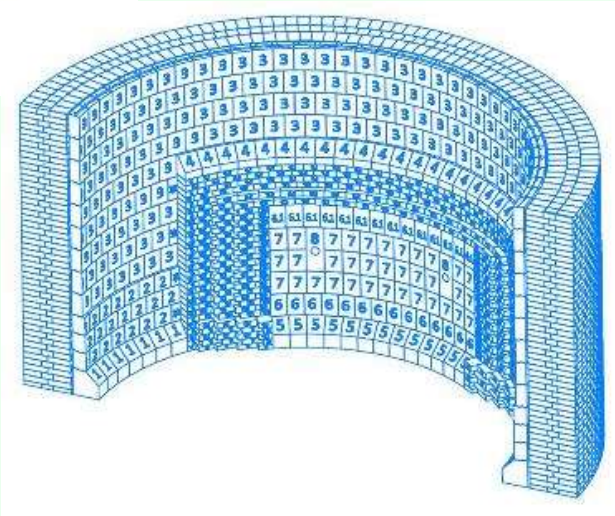
▪ Pore size distribution	ISO 15901-1 (DIN EN 66 133)
▪ Alkali resistance	DIN 51069
▪ Linear thermal expansion	EN 993-19
▪ Refractoriness Under Load (RUL)	ISO 1893
▪ Creep test in Compressions	ISO 3187
▪ Dynamic Hot Metal Resistance (Induction Furnace Test)	CEN/TS 15418: 2006
▪ Static Slag Resistance (Cup Test)	DIN 5109
▪ Gas Permeability	DIN EN 993-4
▪ Thermo-Mechanical Stress Analysis	Finite Elements Method (FEM)

MODULAR HEARTH SHIELD (MHS)

Detailed engineering

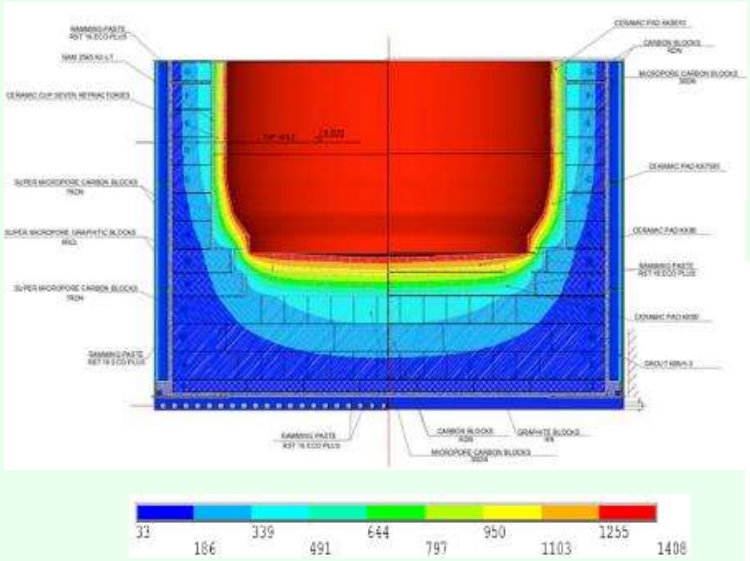


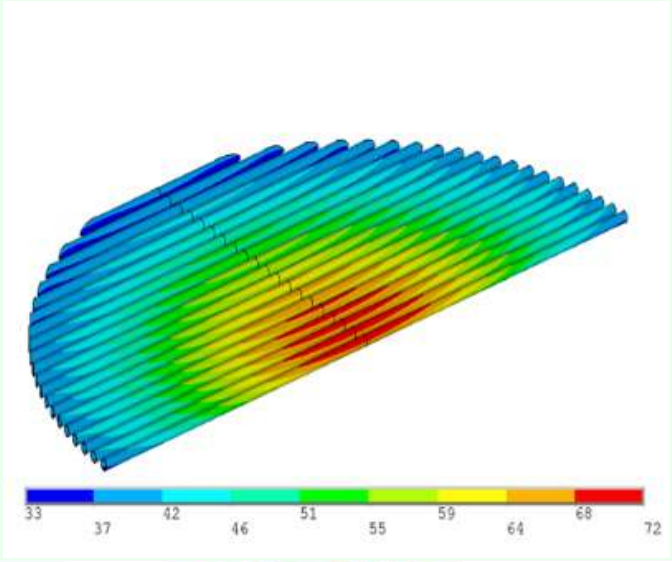


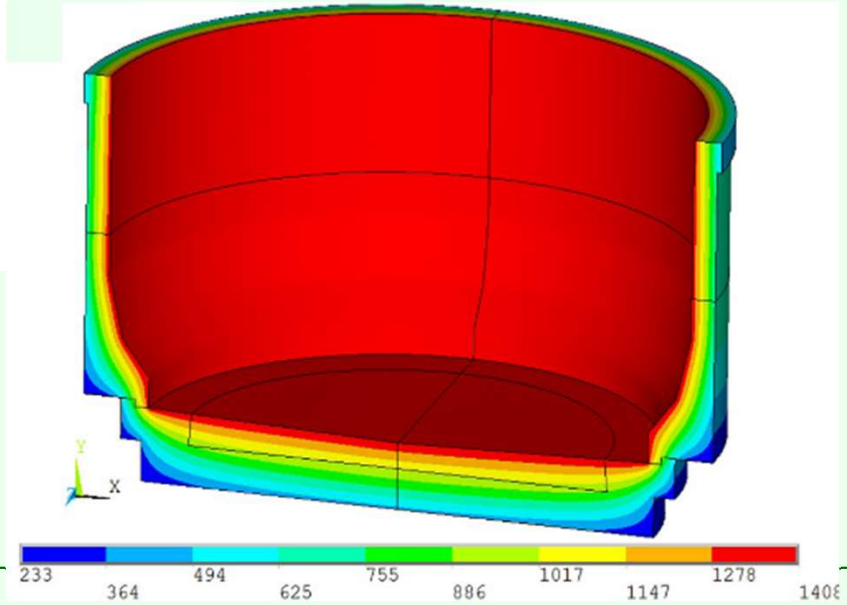


MODULAR HEARTH SHIELD

Thermo-mechanical stress analysis by FEM







MODULAR HEARTH SHIELD

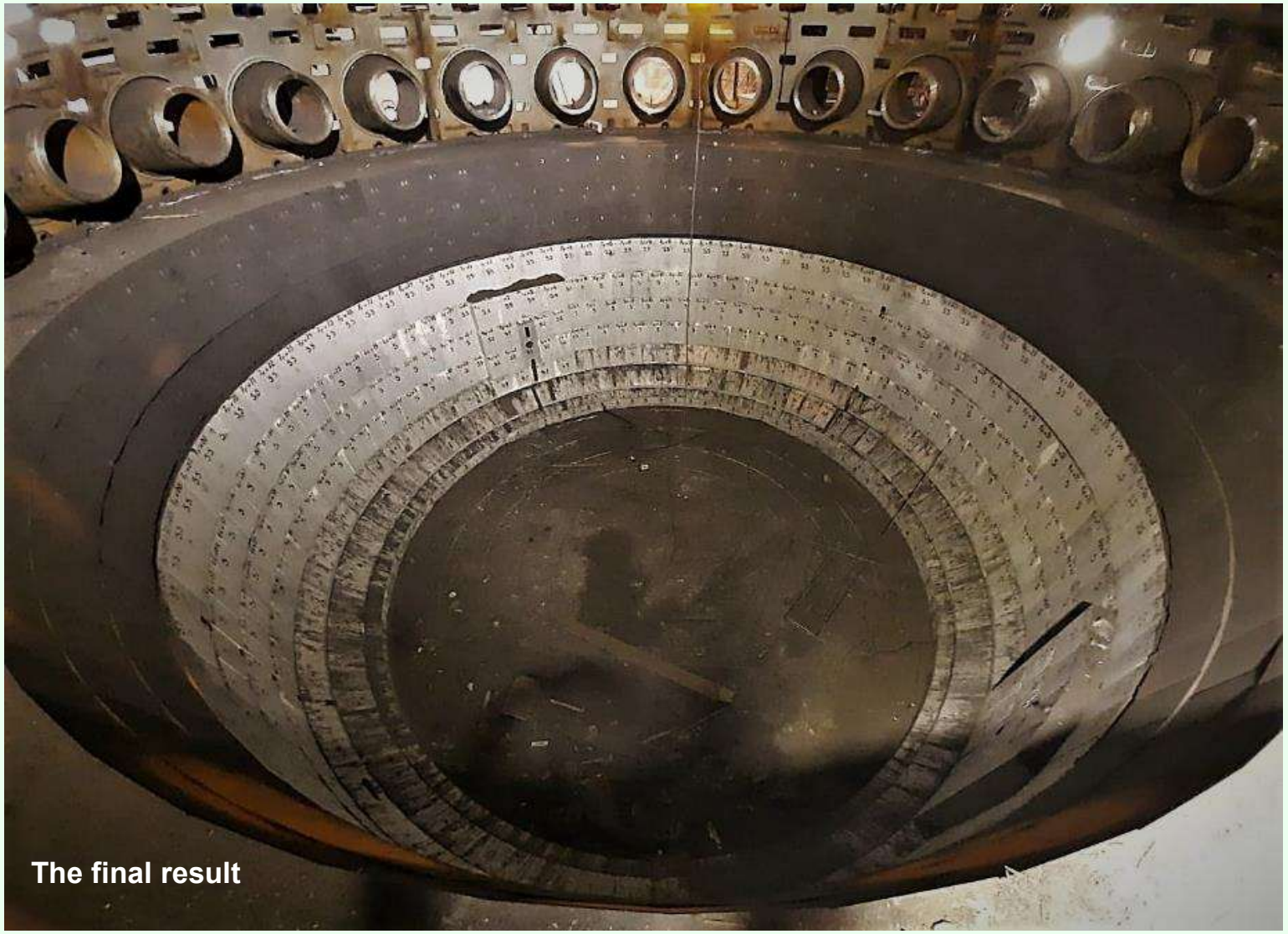
Pre-fabrication

MODULAR HEARTH SHIELD

Pre-assembly

MODULAR HEARTH SHIELD

Installation



The final result

MODULAR HEARTH SHIELD

CASE STUDY RESULTS – MMK BF9, Magnitogorsk, Russia,

Based on **customer observations**, the installed Modular Hearth Shield has shown to be able to:

- Reduce the mechanical tension on BF hearth, both on carbon blocks and shell.
- Increase the distance between the iron freezing line and the shell, therefore improving the safety of the lining.
- **Reduce the energy losses of over 70% in new conditions, and of about 30% once worn, compared to a merely carbon lining.**

MODULAR HEARTH SHIELD

References

N.	Year	Country	Customer	Location	BF	Size
1	2020	Russia	MMK	Magnitogorsk	BF2	WV 1.013 m3
2	2020	Russia	Tulachermet	Tula	BF1	WV 2.000 m3
3	2022	Russia	MMK	Magnitogorsk	BF9	WV 2.000 m3
4	2025 (in planning)	Russia	Tulachermet	Tula	BF3	WV 2.000 m3

Get in touch

Giuliano Copetti
AMS – Alumina Monolithic Solutions
Business Development India, South Africa and South America

M +1(419) 271-6853
+386 41 355 610
E Giuliano.Copetti@rhimagnesita.com