1. Abstract

The increasing requirements for high performance furnaces in the metal industries has resulted in increased standards for refractory products. There are multiple refractory concepts available for vessel lining construction, including unshaped products, prefabricated elements, and bricks. Furthermore, in most cases several refractory layers and additional insulation materials are necessary to protect the steel structure from the aggressive process conditions. The multilayered lining system must be designed to minimize stress exerted upon the steel shell due to thermal expansion, whilst ensuring all joints are closed at the end of the heat up procedure and afterwards during the time of furnaces operation. With more than 100 years of experience in the refractory sector RHI is one of the leaders in the development of new refractory products and furnace lining concepts tailor made for the Iron and Steel, Cement and Lime, Environmental and Chemical and for the Non Ferrous Metals Industry. This paper focuses especially on refractory applications in the Non Ferrous Metals area and describes briefly refractory quality concepts, refractory testing methods, corrosion mechanism and the RHI R&D possibilities and customer services.
2. Historic roots of RHI

RHI is one of the world market and technology leaders in high-grade ceramic refractory products and system solutions used in industrial high-temperature processes. Refractory materials are indispensable to all industrial processes involving high temperatures. RHI itself has a long history which is illustrated in Diagram 1.

![Diagram 1: RHI roots]

Our customers include global key industries such as iron and steel, cement, lime, glass non ferrous metals, environment, energy, chemicals and petrochemicals. RHI employs roughly 7,800 people worldwide at 32 production worldwide. RHI is represented worldwide by more than 70 sales offices. RHI supplies currently more than 10,000 customers in over 180 countries. Picture 1 gives an overview about revenues by customer industries.

![Picture 1: Revenues by customer industries]

 customer industries
Revenues Q1 – Q3 / 2009 by customer industry

- 55% Steel
- 15% Cement/Lime
- 13% Glass
- 10% Nonferrous metals
- 5% Environment, Energy, Chemicals
- 2% Raw materials

Steel Division

Industrial Division

Raw Materials/Production

 Global market coverage
Revenues Q1 – Q3 / 2009 by region

- 32% Western Europe
- 20% North America (incl. Mexico)
- 15% Asia/Pacific
- 10% Africa
- 9% Eastern Europe
- 9% Near/Middle East
- 5% South America
Picture 2 gives an overview about RHI’s production, mines and sales offices.

3. Global player with its own raw material production

In Austria, Italy and Turkey, more than 1.3 million annual tonnes of high grade refractory raw materials magnesite and dolomite are extracted in underground and surface mining and processes on site. RHI thus covers more than half of the group’s raw material requirements internally. Picture 3 shows the location of the RHI mines.

This clear strategy of backwards integration to include raw materials means enhanced security of supply and quality assurance for RHI and therefore greater independence from the international raw material markets.

4. Most comprehensive refractories portfolio in the industry

RHI manufactures tailor-made products for any production process of its customer, always using the best suited raw materials and recipes, more than 20.000, for the respective industry.
RHI is the only refractory supplier in a position to offer products for all aggregates of the basic industry. In addition RHI designs special machinery for efficient application of all products and offers top engineering competence in lining concepts and simulations. The RHI brand comprises a series of successfully established trade marks as shown in picture 4.

![RHI brand family](image)

**Picture 4: RHI brand family**

5. **Leading in research and development**

The power of innovation is based on decades of successful research and development activities, which have established comprehensive refractories knowledge – from raw materials to applications in all relevant industries – and especially understanding of refractories in all application processes. The R&D expertise gained in this process is concentrated at the RHI Technology Center Leoben, Austria, which continuously develops refractories innovation and potential for customers and their processes.

Apart from application-orientated basic research, the experts focus on development of natural and synthetic raw materials as well as recycling concepts of refractory scrap materials from high grade refractory products. The R&D center in Leoben is organized into 12 principal departments and three support departments:


- The Chemistry, Mineralogy, and Physics Department focus on stringent product and raw material testing, and development of new testing methods.

- The Technical Service Department (Pilot Plant) is responsible for the manufacture of product prototypes, wear evaluation, and investigative analysis under simulated in service conditions.

- The Computer Modelling and Simulation Department and the Patents, Trade marks and Licence Department support and expedite the developmental projects.
Today, the Technology Center collaborates with Austrian and foreign public and private research institutes. The higher-risk basic research, which is mainly conducted with the University partners, accounts for a third of the budget. The remaining two thirds are invested in development projects for product development, further development of methods and customer-oriented contract developments. Investments in R&D amount approx. 2% of RHI’s sales revenue. Apart from conventional refractories research, which compromises the interaction of attacks by thermal, physical and chemical action with refractory materials, simulation methodology based on fluid-dynamics and finite-element method is increasingly gaining significance.

New ideas for product and system development are constantly accumulated, evaluated and integrated into the R&D program, and the global R&D network is an invaluable source of information of this scheme. The entire R&D process is documented using a quality management system that complies with the requirements of ISO 9001:2000.

6. RHI’s business unit structure and the Nonferrous Metal Division

To guarantee RHI’s clients the best customer support and service, RHI’s operating structure is split into two business units. One business unit is dealing only with iron and steel applications and the other one with all other high temperature industries like the base metal and light metal industry, the cement and lime industry, the glass industry and the energy industry. Picture 5 indicates the basic material industry and reflects also the reason of the split in business units and sub divisions.

![Picture 5: Basic material industry and RHI BU’s](image)

Due to the size of the nonferrous market in South Africa the paper will focus in more detail on the responsibilities and capabilities of the RHI Nonferrous Metals Division. The Non Ferrous Metal Division deals with all refractory applications in the base metal industry (Cu, Ni, Pb, Zn, Au, Ag, PGM, etc), the light metal industry (Al, Mg) and the ferroalloy industry (FeNi, FeCr, FeMn, SiMn, etc.). The RHI Non Ferrous Metal Division is structured to provide a worldwide process orientated service for all customers, supported by a competent team of employees.
7. Refractory production of shaped and fired bricks tailor-made for the Nonferrous Industry

In the common language materials are called refractory if they are applied at temperatures above 600 °C. In the refractory industry itself the terminology is split according to DIN 51060 / ISO/R 836 as follows:

- Heat resistant below 1.500 °C
- Refractory min. 1.500 °C
- Highly refractory min. 1.800 °C

More than 75% of the materials used in non ferrous applications are based on high fired magnesia, magnesia chrome, alumina, alumina chrome, etc. bricks which require a special firing technique to resist high temperature applications. Picture 6 illustrates the product split within the RHI Non Ferrous Metal Division.

Within the global production site network of RHI several plants have been positioned as manufacturer of special products and shapes to fulfil the requirement of the nonferrous metal industry. To ensure the highest product quality, for commodities and tailor made products, a very high level of expertise and flexibility in production process, state-of-the-art manufacturing technologies and extensive quality planning is required. The experience and motivation of the plant employees are vital to the plants’ success. Therefore, top priority is attached to continuous further training and education programs, as well as maximum safety and comprehensive health protection at the sites.

Comprehensive quality management is of special importance to the quality of all RHI products. This starts in mining and continues along the entire processing chain to the final
control of the products. Pictures 7 shows a typical flow chart for the production of shaped and fired refractory bricks.

The characteristics of refractory bricks and their behaviour when used in customer aggregates is greatly influenced by the selection of the raw materials, pressing method and temperature treatment.

The raw materials supplied by the crushing plant are mixed with bonds and additives to so-called moulding mixes. Here, not only the homogeneity of the aggregates but also the mixing order, time and temperature play a crucial role. All recipes, which are determined by the research department, guarantee that the requirements placed on each product are met.

The slightly moist pressing mixes are formed to bricks by fully automated hydraulic presses with a pressing force up to 2.200 tons. To ensure the homogeneity of the brick structure, complex filling and pressing programs are used. Bricks, which from today’s perspective cannot be produced economically (small quantities with a complex shape) on the hydraulic presses, are press semi-automatically or rammed manually with pneumatic hammers.

The firing process is done in tunnel kilns with a total length of up to 150 metres. The temperature between 1.500 °C and 1.800 °C in the tunnel kiln are required to accomplish ceramic bonding. In addition to the firing temperature, the heating and cooling times as well as the atmosphere in the kiln are of vital importance.

Depending on the product requirements, a brick after-treatment will take place in form of cutting, grinding, impregnation etc.
Picture 8 and 9 indicate the total tonnage of material produced in the year 2008 and a split for the Non Ferrous Metal Business Unit.

**Picture 8:** Produced refractory materials within the RHI group for the year 2008

**Picture 9:** Produced refractory materials within the NFM group for the year 2008
8. Wear phenomenon in the nonferrous metal industry

In the form of refractory linings RHI products ensure that a wide range of different aggregates resist extreme thermal, mechanical and chemical stress. This is crucial as temperature differences of more than 1,000 °C occur frequently in wall structure of kilns. Depending on the process conditions and various application forms in vessels of the non ferrous industry, refractory products are confronted with different wear scenarios, but in general all refractory materials are more or less exposed to one or several of the below listed loads.

![Diagram](image)

**Picture 10:** Different wear mechanism in metallurgical vessels

The in service brick characteristics of most of the different brick brands are hot erosion resistance as well as the absorption of stresses that are caused by the fluctuating temperature conditions. Additionally the bricks have to be very resistant against corrosion of different basicities. For certain applications, to protect the bricks from hydration (causing the brick to crack and collapse) and foreign matter infiltrations they are after-soaked in a magnesium sulphate solution so-called kieserite.
The main wear mechanism observed in the non ferrous metal industry are as follows:

- Chemical corrosion of fayalithic slag type
- Chemical corrosion of ca-ferritic slag type
- Sulfate corrosion
- Metal infiltration
- Copper oxide bursting
- Redox reaction
- Lead oxide bursting
- Chloride attack
- Thermomechanical load
- Carbon bursting
- Hydration

As the hydration issue becomes more and more a topic this paper will give a short overview how brick hydration takes place. The protection of MgO and MgCr bricks against hydration by means of impregnation with an aqueous kieserite solution is state-of-the-art and offers sufficient hydration protection under normal circumstances. However, the potential of hydration of basic products made of magnesia is always present, in particular during the transport (contact with seawater, rainwater or condensation water), disadvantageous storing conditions in a warehouse and during operation (e.g. contact with water-cooled coolers).

It's not only the kieserite impregnation which can help to overcome the hydration issue. There are many more possibilities, but one has to take into account what can happen to the brick properties by applying various methods for hydration protection. Alternatives to the standard kieserite impregnation are:

- Use of different types of sintered or fused magnesia
- Protection by using boric acid
- Addition of CaO-acceptors like TiO2, ZrO2, WO3 and FeMo

After long years of successful research and development times RHI enjoys a leading position on the world refractory market and for an optimal unique hydration protection treatment for magnesia and magnesia chrome bricks. Offered only by RHI and specified by the suffix „R1“ behind the brand name this treatment is a special feature of all basic burned bricks in the non ferrous metal industry. This treatment represents a very efficient protection against hydration, hydration being a dangerous problem for basic refractories especially and strongly water-cooled furnaces. Hydration can take place during transport and storing of the bricks. Also the furnace heat up where high amounts of moisture brought in by gaseous fuels can lead to condensation of water on the brick surfaces. Additionally moisture might be brought into the furnaces by un-dried wet kiln feeds and process water of mortars, castables and concretes.
The main hydration mechanism is the transformation of the magnesia into Brucite (see equation) which is directly related to a volume expansion of 115%.

\[ \text{MgO} + \text{H}_2\text{O} \leftrightarrow \text{Mg(OH)}_2 \]

The risk of hydration damages can be avoided by using our special brick hydration protection treatment. This treatment is not limited to a simple surface protection, but it gets through the brick structure and is maintained even under intensive mechanical operation conditions.

Hydration testing is performed in a state-of-the-art steam chest, which operates with saturated steam under ambient pressure. This testing method was established because of its practicability and easy determination of crack formation. The test is carried out in 24 hour intervals up to 96 hours. The bricks without any impregnation (picture 11) show hydration signs already after 24 hours, while the impregnated version (picture 12) last 96 hours without any hydration.

**Picture 11:** MgO brick without hydration protection after 24 hours inside the steam chest

**Picture 12:** MgO brick with hydration protection after 96 hours inside the steam chest
Driving forces of disintegration of periclase are:

- Distance of MgO-cations in brucite is bigger than in periclase
- Any crystallographic orientation of the growing brucite will cause strong tensions in the periclase lattice
- Repeatedly splitting along the (100) lattice plans of the periclase

The Brucite appearance inside the brick matrix can be easily determined by a thermal gravimetric analysis. Picture 13 shows a brucite crystal formation.

The long storage life of magnesite bricks achieved by this special protection system is a further advantage, especially in regions of high humidity even if stored in precipitation-protection areas.

9. Conclusion

As an industrial group with strong local roots and tradition going back more than a century, sustainable action vis-à-vis all shareholders is a central element of RHI’s corporate orientation, with the most important being a sustainable increase in company value. RHI undertakes great efforts to make the production process highly energy-efficient while at the same time saving resources. As an important employer, RHI takes numerous local initiatives and initiates activities to improve the quality of life of people, focusing on disadvantages children and young people. As a global leader in refractory research and development, RHI is strongly orientated to develop new raw materials and products to increase service lifetime and customer satisfaction.
The Author

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Thomas Prietl started his professional education at the school for Mechanical Engineering in Kapfenberg and afterwards studied Process Engineering at the Montanuniversity Leoben, Austria. December 2006 he obtained his PhD in non ferrous metallurgy at the University of Leoben. Since January 2004 he has been working as a research assistant at the Christian Doppler Laboratory for Secondary Metallurgy of Non Ferrous Metals. In January 2007 he started his carrier at the RHI Refractories Company, where he is responsible for technical marketing activities in the Industrial Division.