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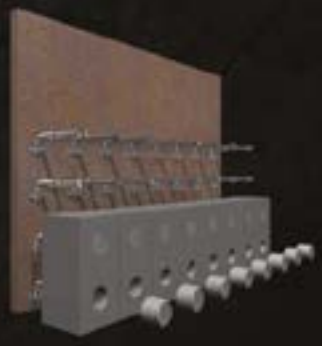


Preshaped block System

READY FOR RAPID RECOVERY & REPAIR

Herbert Hoenl, REFKO, explains how successful and long-lasting emergency rotary kiln repairs can be achieved, resulting in safer operation of the kiln until a planned shutdown can take place.

Worldwide, the demand for cement remains at a high level. Modern, more environmentally friendly production methods for cement are increasingly conquering the market. This is leading to a reduction in 'classic' cement plants and a concentration on plants that are converted according to the most modern environmental aspects or, in some cases, directly to new kilns. In such plants, higher quantities of cement have to be produced by fewer cement kilns, and a high degree of operational safety is required. Downtimes must be shortened and kept to a minimum, and unscheduled downtimes must be completely avoided.

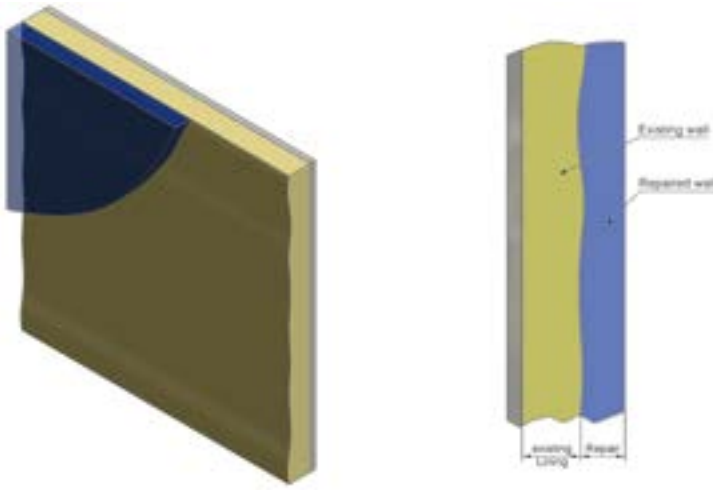
In particular, emergency situations, such as sudden hot spots that arise on the rotary tube, have in the past often led to longer unscheduled downtimes in order to replace the worn areas with new bricks. It often happens that in such emergency situations, not enough bricks are available for repair and are not easily procured on such short notice. Plants may also find that there are no skilled or trained installation personnel or required installation machines (e.g. DAT devices) available at the time.

In this case, emergency solutions may be required, such as cooling or other measures in the running process. Not infrequently, however, the continued operation of a kiln with brick damage in the rotary tube then leads to serious subsequent damage, for example deformation of the steel shell, problems in the kiln drive areas, etc. Therefore, the process reliability of the kiln system is at stake.

This is where the REFKO Recovery System comes into play. This material and system development allows a hot spot situation (caused by brick damage) on the rotary kiln to be quickly rectified and enables safer operation of the kiln until a planned, usually annual, shutdown.

The following example will show how a repair was carried out at a hotspot area using a modern designed gunning refractory concrete, based on magnesite/spinel. This led to a short shutdown that allowed the cement plant to operate safely again and without any problems until the next regular and planned annual repair shutdown.

The special binding system and selected material composition of the REFKO Recovery System provides a good bond with the existing worn out lining. The installation can be completed with classic dry gunning machines, which are available worldwide.

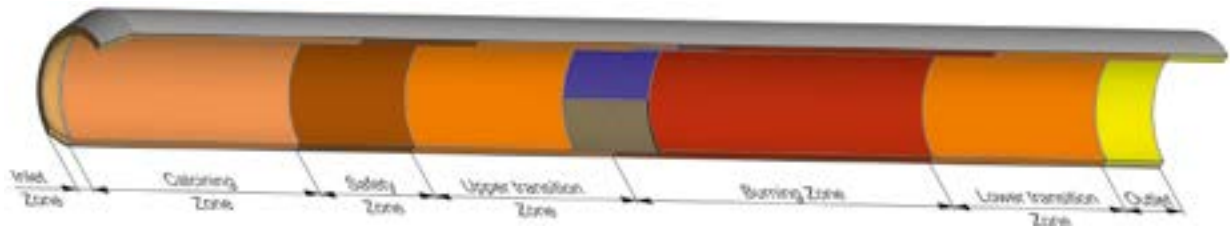


Lining sketch.

Premature wear of MgO/Spinel bricks.

Case study

In the area of the burning zone, in a kiln with a length of approximately 60 m and a diameter of approximately 4 m, a premature wear of the MgO/spinel bricks occurred. The affected areas were cleaned well with compressed air. All loose adhesions and dust deposits were also removed as much as possible by this process. Further pretreatment of the worn brick lining may also be necessary in cases such as these, depending on the damage pattern. The repair areas prepared in this way are usually divided into installation fields. Depending on the desired layer thickness, the use of anchors can also be considered. This must be decided individually ‘on site’. REFKO does not recommend gun layers below 5 cm thickness.



Sketch of a rotary kiln.

Cleaned surface and marking of the installation fields.

Example of a commercially available dry gunning machine.

The installation fields are separated from each other by working joints and the joints should follow the stone joints. This is necessary to give flexibility to the mechanical loads in the heating up and operational phase, as well as the thermal expansion of the monolithic layer. To achieve optimal mechanical stability, complete rings should always be gunned. The selective repair of damaged areas is not advisable.

The gunning of the REFKO Recovery MG concrete was carried out in this case with a commercially available dry- or respectively rotor-gunning machine. These machines are in use worldwide and can be easily organised for emergency repair work.

The REFKO Recovery products do not require any special machines that can only be operated by specialists.

The only special feature is the use of a high-pressure membrane spray nozzle, or the 'REFKO nozzle.' In combination with a high-pressure water pump, a practically dust-free gunning installation can be achieved and this special refractory concrete can be gunned with good results.

The REFKO nozzle and high-pressure water pump are now standard in many cement plants and installation companies. If, however, no REFKO nozzle and/or high-pressure pump are available, equipment will be provided by REFKO. Also, during the first installation of one of REFKO's technical service co-workers will always be on site.

After setting, the concrete developed a stable connection with the subsoil, so that the furnace could be turned to the next mounting position without any problem.

REFKO had to deal with very low outside temperatures, but even under these conditions, the concrete could be safely installed.

24 hours after completing the gunning, the kiln was ignited again. The binding system of the REFKO Recovery MG System also allows for a quick restart of the furnaces. Furnaces can be heated according to the respective plant-specific specifications for re-starting.

The heat-up to operating temperature and the first material feed in the repaired area went ahead without any problem. No material spalling was detected in the kiln during the start phase.

After reaching the operating temperature, the repaired zone was monitored with thermal cameras throughout the whole

kiln journey. At no time were new hotspots detected in the repaired area.

After almost four months it was time for the annual, planned shutdown of the cement kiln.

The repair area was still completely preserved. A sintering connection with the subsoil could be detected in the post-mortem samples. No larger or more problematic formations of build-ups were detected. If a planned shutdown had not taken place, the repaired area could have lasted much longer.

The cement plant operator was satisfied with the repair using REFKO Recovery. The REFKO Recovery product and system range is made up of products for quick repairs in all hot areas of a cement kiln. Like for the rotary tube repair described above, REFKO Recovery products can be applied to the worn-out areas. The insulating kiln layers can be completely preserved. As a result, less material is required for the restoration of the desired wall thickness than with a completely new installation. There is also likely to be less outbreak material.

The type of repair and installation described in this article uses a resource friendly method. This method also significantly lowers expenditure on demolition- and installation-times. REFKO Recovery ZSI solutions can also be heated quickly, at up to 75˚C/h without holding times. This means that the kiln can be quickly put back into operation after a repair.

Results

With the REFKO Recovery MG products based on Mgo/Spinel, successful and long-lasting repairs can be carried out in the rotary kiln area.

Together with the REFKO Recovery products for the static areas of a cement kiln, a product and system portfolio is available which optimally meets the modern requirements for safe and fast repairs.

These modern product developments show that by repairing existing lining, breakout is avoided and less 'fresh' material is needed. In addition, savings can be made due to lower assembly costs.

New developments in the field of monolithic refractory materials can save resources and can represent a small step in the reduction of the cement industry's CO_2 footprint. ■

About the author

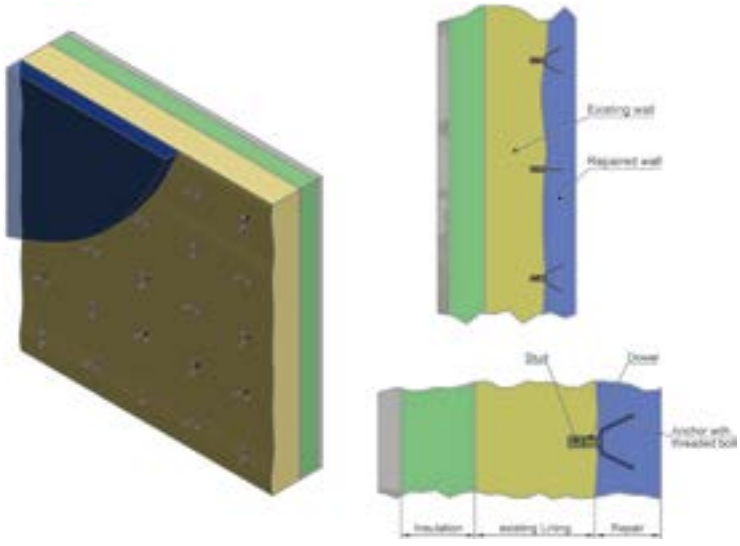
Herbert Hoenl is Managing Director at REFKO Feuerfest Gmbh. Herbert studied Materials Engineering at the Koblenz University of Applied Sciences, and graduated as Dipl.Ing (FH).

Herbert has worked at REFKO Feuerfest GmbH for 30 years. He started in the R&D and QM department and has since remained personally involved in the development of new refractory materials, product concepts, and technical solutions.

He is also boardmember of the DGFS (Deutsche Gesellschaft Feuerfest- und Schornsteinbau e.V. /German Association of Refractory & Chimney Contractors).

REFKO nozzle and high-pressure water pump.

Almost dust-free gunning of REFKO Recovery MG (left) and repair zone after installation (right).



Sketch of lining, with insulation and anchors.

REVISITING RAPID RECOVERY AND REPAIR

Florian Laux, REFKO, revisits the performance of a lining technology that has been used to repair cement kilns in a number of different plants.

Who would have thought that one year later the industry at-large would be facing problems with raw material procurement, fossil fuel supplies, temporarily closed industries, and a completely uncertain future? Things that many took for granted are becoming luxuries, and the refractory industry, with all of the industries both upstream and downstream of it, is also facing major challenges. This article will revisit some of the points made in an article published in the September 2021 issue of *World Cement*, and will also report on REFKO's experiences working with the material over the past two years.[1]

A safely operating rotary kiln over the course of several months, for the best part of a year, within the scheduled inspection periods, is certainly the ambition of every cement producer. Unscheduled shutdowns cause high costs due to production losses and are, of course, anything but beneficial for the refractory material used. Unfortunately, unplanned emergency stops cannot always be avoided due to various factors. This is exactly where the REFKO Recovery system and in particular the concrete REFKO Recovery MG 78 comes in. This product was developed to repair damage in the lining, especially on old

MgO/Spinell bricks. In the best case scenario, the kiln should continue to run safely and trouble-free until the next scheduled annual shutdown.

Preparatory work

Preparatory operations before any installation are mostly the same. The areas to be repaired must be cleaned and free of loose material from the old brickwork. The rubbish must be removed from the kiln so that it does not roll over the fresh lining during the rotation of the kiln during installation. An appropriate bond preparation of the surface is recommended. The spray application is carried out with a standard dry spraying machine/rotor spraying machine in combination with a booster pump and high-pressure membrane spray nozzle or 'REFKO nozzle'. The company also recommends a field division of four quarters, which can vary in width, but should be based on the joints of the old brick lining. To date, widths up to 100 cm have been undertaken. The widths are also dictated somewhat by the format of the bricks.

North Rhine-Westphalia: (top) old brickwork, almost dust-free gunning with field classification. (Bottom) final result after installation.

Case study: Germany

Initial test cement plant: North Rhine-Westphalia, (Germany) January 2021

The initial field trial was carried out in cooperation with a German cement plant in January 2021, in fairly adverse conditions. On the one hand, a strong, seasonal frost, provided typical European climate conditions, although the company tends to assume that this material and lining concept are more likely to be used in the fall months from September onwards, since most annual overhauls begin in January and the kiln should simply be kept alive until then.

- Furnace length: 60 m.
- Kiln diameter: 3.8 m.
- Installation point: kiln 7 – 10 m (burning zone).
- Layer thicknesses: 10 – 90 mm (partly tapered to 0).
- Running time: 11 weeks.

Conclusion

Good adhesion with the old brick lining was achieved right from the start. In each case, whole quarters were sprayed in the corresponding lining width. After initial stiffening, the kiln was rotated, and quarter after quarter was sprayed. For the lining of an area of approximately 38 m^3, a time of approximately 12 hours was required. After 24 hours of drying, the kiln was started up with the plant-specific heating-up curve without any problems or disturbances. Regular thermal imaging camera shots of the lining area were inconspicuous over the entire run time, which in any case indicated that there was no major damage to the lining. Even afterwards, during the main inspection, a residual thickness of the spray lining with REFKO Recovery MG 78 was still visible at all points, even where only a few millimetres had been applied.

Follow-up test cement plant: North Rhine-Westphalia, (Germany) January 2022

- Furnace length: 60 m.
- Kiln diameter: 3.8 m.
- Installation location: Furnace inlet, sintering zone, furnace outlet.
- Layer thickness: 20 – 160 mm.
- Running time: 4 weeks.

Conclusion

In the kiln inlet zone, the material held for a while. Once again, no abnormalities were detected by external temperature measurements of the kiln shell. During the inspection, however, the material was heavily worn. Due to low temperatures, mechanical

and chemical abrasion occurs in this area, the wear resistance is most likely insufficient here and must be replaced by another product from the RECOVERY range. The results in the sintering zone and the furnace outlet were completely different. Here REFKO were able to reproduce the results from January 2021. Decent residual thicknesses were visible and the protection of the old brickwork was still given.

Test cement plant: Lower-Saxony (Germany), December 2021

- Kiln length: 50 m.
- Kiln diameter: ~ 4 m.
- Installation location: sintering zone.
- Layer thickness: 80 – 140 mm.
- Running time: 8 weeks (until annual shutdown).

Conclusion

In this plant, REFKO had the opportunity to carry out the gunning up from a DAT-unit. This unit remained in the kiln because it was decided to use bricks in some areas, and to cover special areas with the Recovery MG 78 system. This gave a time advantage, since the ceiling shells could be sprayed without constant kiln rotation. The kiln was back in operation just 12 hours after the completion of the spraying work. The plant operator was very satisfied with the repair and can imagine stockpiling the material for unexpected furnace problems.

South Austria: Old masonry and discernible thickness of application, field grading, final result after installation.

Case study: Austria

Test cement plant: South Austria, September 2021

- Kiln length: 49 m.
- Kiln diameter: 3.4 m.
- Installation location: Kiln 14.20 – 15.60 m (burning zone).
- Layer thickness: 20 – 180 mm.
- Running time: 13 weeks (until annual inspection).

Conclusion

A damaged area was also repaired in the burning zone. The approximately 1.4 m were divided into two sections. The refractory consumption for this area amounted to 3.5 t of gunning material. The lining, including all necessary preparatory work, took 10 hours. According to the furnace operator, the lining with bricks in this area alone would have taken at least 24 hours, plus the effort of moving the appropriate equipment into the furnace. After the completion of all the work in the kiln it was brought up to operating temperature within 36 hours. Despite an emergency shutdown of the plant in the area of the cyclones one month after lining, the kiln ran through until the scheduled inspection and showed no abnormalities. Here, too, the Recovery system can be used as a preventive measure to extend kiln downtimes until the next scheduled stop.

Case study: Turkey

Cement plant: Northern Turkey, July 2022

- Kiln length: 60.5 m.
- Kiln diameter: 4.2 m.
- Installation point: Kiln 0 – 1.2 m (outlet zone + outlet cone).
- Layer thickness: 130 – 150 mm.

Cement plant: Northern of Turkey, September 2022

- Kiln length: 60.5 m.
- Kiln diameter: 4.2 m.
- Installation point: Kiln 18 – 23 m (burning zone) + kiln 0 – 1.2 m (outlet zone + outlet cone).
- Layer thickness: 100 – 150 mm.
- Running time: Both kilns are still in operation without any abnormalities.

Conclusion

In cooperation with their Turkish partner DAS Metalürji Makine San. Tic. Ltd. Şti, REFKO have been able to offer the Turkish cement

works high-quality refractory solutions made in Germany. This successful cooperation also enabled them to gain a foothold and carry out initial trials with the REFKO Recovery MG 78 outside the EU. Here, too, the company were able to continue the series of successes. The area to be repaired has now lasted for 3 months and the factory has reported no abnormalities. Based on this, several parts in kiln 2 and kiln 3 were scheduled for repair in October 2022. The operator was enthusiastic about the opportunity for dust-free spraying, quick repair, and the possibility to heat up without a specific heating plan. In this particular case, the kiln was back up to operating temperature in less than 24 hours after the gunning work was completed. Whilst this is not a procedure that the company would want to propagate or advertise, it nevertheless shows the flexibility and properties of this unique product.

Turkey: Old brickwork outlet zone, before and after installation with REFKO Recovery MG 78.

Results/outlook

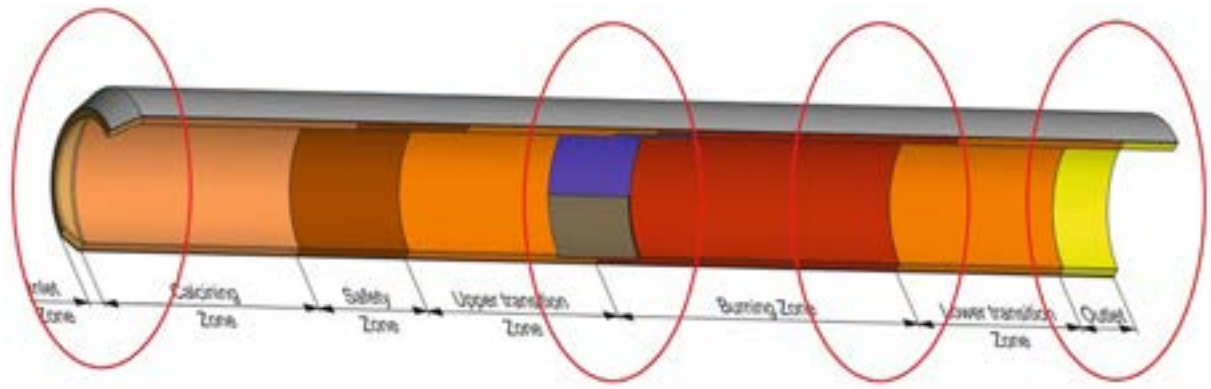
So far, REFKO Recovery MG 78 has been able to demonstrate itself as a unique product that enables fast, safe, and successful temporary repairs in the rotary kiln. The product allows advantages in production speed, flexible-use, and low energy input. Especially in the current situation, this makes an even greater contribution to CO_2 and energy savings. It eliminates the need to break out the old delivery and thus saves time and money. Based on these results, REFKO are constantly striving to expand their product portfolio to cover all the requirements of the repair process in the rotary kiln. New products have already been developed and are currently in the trial phase with end customers willing to try them out. REFKO, and some of their customers, are confident that this material is capable of much more, such that they are planning to monolithically line some areas with this material at the next opportunity. The company is also considering expanding its warehouse network worldwide in order to be able to enable fast deliveries in many parts of the world within a few days. ■

References

1. HOENL. H.,'Ready For Rapid Recovery & Repair', *World Cement*, September 2021, p. 43.

About the author

Florian Laux is the head of Product Development at REFKO Feuerfest GmbH. After finishing his diploma thesis in 2013 at the University of Applied Sciences Koblenz in cooperation with the company REFKO Feuerfest GmbH, he started in the R&D and QM department in the eponymous company and was involved in the development of new refractory materials, product concepts, and technical solutions. Florian is now also a Partner in the company.



Installation areas of the previous field tests until now.

A masterclass in castables

Herbert Hoenl, REFKO, outlines the benefits of a new castable magnesia spinel solution which promises new opportunities for rotary kiln lining repair.

The development of a magnesia spinel castable is the next step in efforts to help cement plant operators with serious refractory problems in the hot part of the rotary kiln. Together with a state-of-the-art gunning material (REFKO Recovery MG 78), the new magnesia spinel-based castable (Vimag SP 86 B) provides a monolithic solution to manage and resolve critical failures of the standard brick lining.

The benefits of the Recovery MG 78 gunning material have been described in detail in previous issues of *World Cement*. This material is already widely used in many cement plants, achieving reliable performance and significantly reducing the shutdown time caused by emergency stops. This article will instead focus on the newest addition to REFKO's portfolio.

Table 1. Chemical composition comparison.

	VIMAG SP 86 B	Magnesia spinel brick
MgO	84 – 88	87 – 89
Al_2O_3	6 – 8	9 – 11
SiO_2	4 – 6	0.8
CaO	<1	0.8

Table 2. Physical and mechanical properties comparison.

	VIMAG SP 86 B			Magnesia Spinel Brick
After heating at:	**120˚C**	**1000˚C**	**1500˚C**	**In state of delivery:**
BD (g/cm^3)	2.83	2.79	2.87	3 – 3.05
CCS (MPa)	96	66	85	65

BD= Bulk density

CCS= Cold crushing strength

Kiln shell deformation

Some rotary kilns face serious kiln shell deformation issues that lead to the collapse of multiple rows of bricks in a short time of service, therefore necessitating a different approach to repair.

Causes and consequences

Kiln shell deformation can be caused by a range of factors. For example, overheating caused by extended operation of the kiln with refractory damage.
Or an overheated shell that becomes choked inside the tyre gear. The cause of deformation could even be as simple as a the steel shell being extremely worn by age.

These kinds of damage are not easy to repair and, in most cases, ultimately require replacement of the deformed steel shell section. As such, repairs are time-consuming and expensive. Also, due to the long delivery time of steel shell segments, the cement plant will usually have no choice other than to operate the kiln with a deformed shell until a proper repair can be undertaken.

With regard to refractories, such defects can also lead to an extremely short brick lining lifetime. Furthermore, with such a deformed steel shell, proper bricklaying is very complicated, or in some cases, close to impossible.

This leads to refractory failures in the brick lining much faster than under good kiln shell conditions. In the worst cases, the brick lining can

Figure 1. (Left) VIMAG SP 86 B with no cracks. (Right) Magnesia spinel brick with no cracks.

collapse after three weeks or less of operation. This forces the cement plant into many unplanned, time-consuming, and expensive emergency shutdowns. A further consequence is an increased consumption of refractory material that, in the end, is an environmental issue in terms of the high CO_2 consumption involved in the production of refractory bricks.

A castable solution

In such cases, a castable would be a perfect solution. The installation can be completed easily, even on a deformed steel shell. A castable can 'follow' the deformed shell structure, making a well-balanced lining possible; all without increasing mechanical stress inside the lining during operation.

Consequently, people within the cement producing community have already been looking for a castable magnesia spinel solution.

The Vimag SP 86 B product offers a castable solution and has similar properties to common magnesia spinel bricks.

These properties were achieved by focusing on chemical composition, mechanical properties, thermoshock resistance, and the flexibility of the microstructure. REFKO also worked to ensure that, after a repair, the kiln can be heated up via the normal heating-up procedure.

Chemical comparison

In Table 1, a comparison between the Vimag SP 86 B and a widely sold magnesia spinel brick is shown. In comparison to the brick, the castable is a little lower in Al_2O_3 content. This could be caused by the slightly different spinel content.

Physical and mechanical properties

The results of a test (Table 2) demonstrate that the ratio of spinel to magnesia is perfect in terms of thermoshock resistance and flexibility of the microstructure.

The slightly higher amount of SiO_2 is a concept from REFKO, designed to produce the necessary properties for this new kind of magnesia spinel castable.

As is typical for castable, the physical properties develop during the heating-up process. This normally achieves additional flexibility inside the lining. On the other hand, a brick is a fired product and is defined by its properties at the state of delivery.

The magnesia spinel castable has a slightly lower bulk density. This is potentially advantageous regarding slightly better insulating properties. However, this will need to be investigated separately, once there has been time to monitor it during test installations.

In terms of cold crushing strength, the castable has the same or higher values than the brick.

Thermal shock resistance (TSR)

REFKO undertook an in-house test for TSR on magnesia-containing materials.

The probes were heated up to 1200°C and held at this temperature for 4 hours. The probes were then taken out of the furnace and allowed to cool down at normal room temperature for 30 minutes.

After this, the probes were placed back into the furnace, which was still at 1200°C. After being held at 1200°C for another four hours, the cool down process started again. This was done 20 times, after which, an optical inspection of the probes was conducted.

Neither the brick sample nor the castable sample showed any cracks after having cooled down 20 times (Figure 1). This is, for both products, a very good result. It can therefore be argued that Vimag SP 86 B is on the same level as common magnesia spinel bricks in terms of TSR.

Table 3. High temperature flexibility comparison.

	VIMAG SP 86 B	Magnesia Spinel Brick
HMOR (MPa)	2.64	2.75
E-Modulus (MPa)	990	1007
D-Modulus (MPa)	728	740

Figure 2. A block of the castable solution was cast and then used as the door of the test furnace.

Figure 3. No cracks could be found in the cast block after the kiln heating up procedure.

High temperature flexibility
To find out if a castable has the same flexibility under load and, therefore, the same flexibility of the binding matrix of a brick, the following tests were undertaken:

- Hot temperature modulus of rupture (HMOR).
- Hot temperature Young's modulus/modulus of elasticity (E-Modulus).
- Hot temperature deformation modulus (D-Modulus).

The test temperature for all of the above was 1200˚C. The data from the castable is very similar from the data of the brick (Table 3).

Based on the results of TSR in combination with the data of the E- and D-modulus, it is clear that VIMAG SP 86 B has similar flexibility in the microstructure as a common magnesia spinel brick.

Heating up test
A disadvantage of castable solutions is that sometimes they have to follow a special heating-up pattern. Therefore, the goal was to design a castable that can be heated up with the standard heat-up procedure of a rotary kiln. Accordingly, another REFKO in-house test procedure was developed.

A block, including anchors, with dimensions of 500 mm x 500 mm and a thickness of 250 mm was cast (Figure 2). This block was then used as the door of the test furnace. The furnace was then heated up following a procedure obtained from a cement kiln operator. Once cooled, the block was inspected for cracks. In this instance, no cracks were found after the test (Figure 3).

Evidently, the rotary kiln can be heated up under the same heating-up schema that is valid for the normal start of a kiln after refractory repair.

Summary

Having completed various tests, REFKO has demonstrated that its magnesia spinel castable solution has similar properties to a common magnesia spinel brick. It is clear, therefore, that VIMAG SP 86 B is a suitable alternative to a brick in every situation where bricklaying is difficult to undertake. Or for other installation situations where a monolithic magnesia-spinel lining would be a more adequate solution.

The first installation in a cement plant has just been completed, and updates on its progress will be provided. At the time of writing, the kiln with the test installation has already been up and running for three months without issue. ■

NOTES

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