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Kevin Christmann, Bernd Neubauer, Alexander Ratz, Matthias Höck, Markus Hochegger, Riccardo Magrofuoco, Walter Cassete, Thales Fonseca Paula and Carlos Soares

XXL Electric Arc Furnace Taphole Solution

The steel industry is entering the so-called green steel transformation worldwide. To reduce scope 1 emissions, producers are transitioning primary steelmaking from the blast furnace route to electric steelmaking, with the electric arc furnace (EAF) route being combined with hydrogen-based direct reduction. This shift is leading to a significant number of new EAFs being built all over the globe, often with tapping weights of 300 tonnes or more. To support this industrial transformation, RHI Magnesita has developed suitable tapping systems tailored to these XXL EAFs.

Introduction

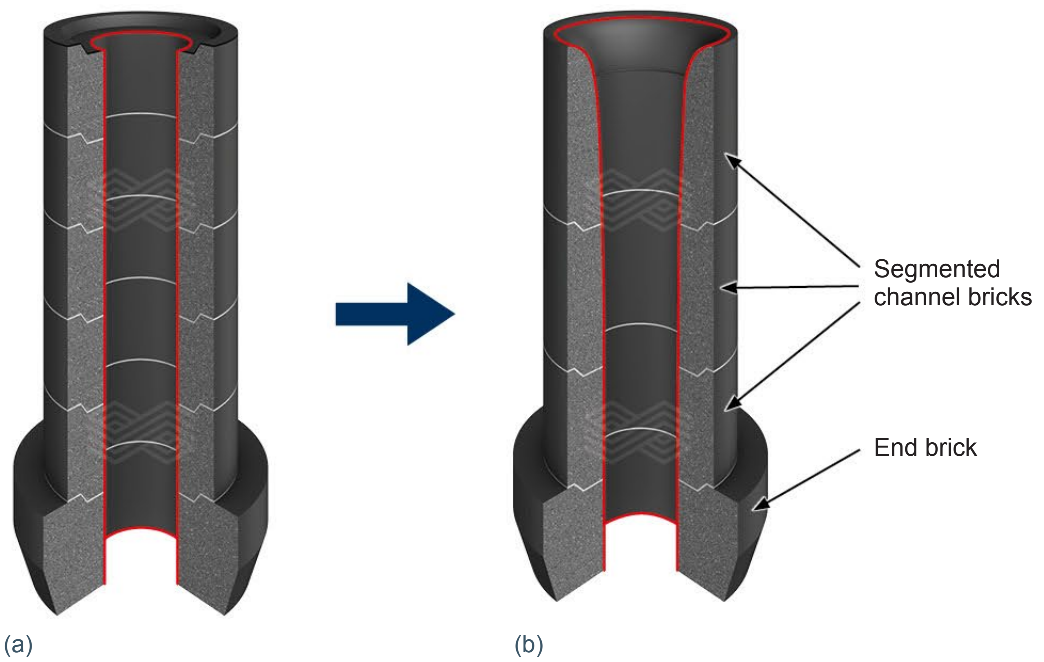
The so-called green steel initiatives are leading to a fundamental transformation in the classic steelmaking process. The traditional integrated route, combining the blast furnace and basic oxygen furnace, is being replaced by direct reduction and electric arc furnace (EAF) technology. Therefore, a significant number of new EAFs are expected to be built over the coming two decades. Many of these new EAFs will be quite large, with production capacities of ≥300 tonnes. Accordingly, such large vessels require a suitable tapping system specifically designed to meet the technical requirements of such high-volume tapping.

Supporting the ongoing industrial transformation, RHI Magnesita is providing proven tapping technology that ensures process safety, long tapping channel lifetimes, and short tapping times. This paper provides an overview of available EAF tapping systems combined with case studies and presents an established XXL EAF taphole solution, which is based on the existing technology.

High-Performance Tapping Systems for Electric Arc Furnaces

RHI Magnesita has been supplying tapholes to customers globally for decades. Eccentric bottom tapping (EBT) technology, developed in the 1980s and established in the 1990s [1], is the successor of classic spout tapping in EAFs. Since then, EBT technology has evolved from a simple cylindrical channel shape to conical, and ultimately to CFD-optimised EAF taphole channel designs (Figure 1).

Figure 1.
(a) cylindrical and (b) CFD-optimised EBT channel designs [2].



Multiple advantages are associated with CFD-optimisation of the taphole channel [2,3], including:

- Reduced tapping time through higher flow rates and increased throughput (Figure 2).
- Extended taphole lifetime due to non-turbulent flow of the tapped steel melt inside the channel, leading to a reduction of mechanical wear (Figure 3).
- Reduced risk of reoxidation and H_2/N_2 pickup due to a bundled tapping stream, resulting from less turbulences in the channel (Figures 4 and 5).
- Less slag carry-over due to reduced vortex formation (Figure 6).

Figure 2.

Comparison of flow rates between (a) cylindrical and (b) CFD-optimised EBT channel designs [2].

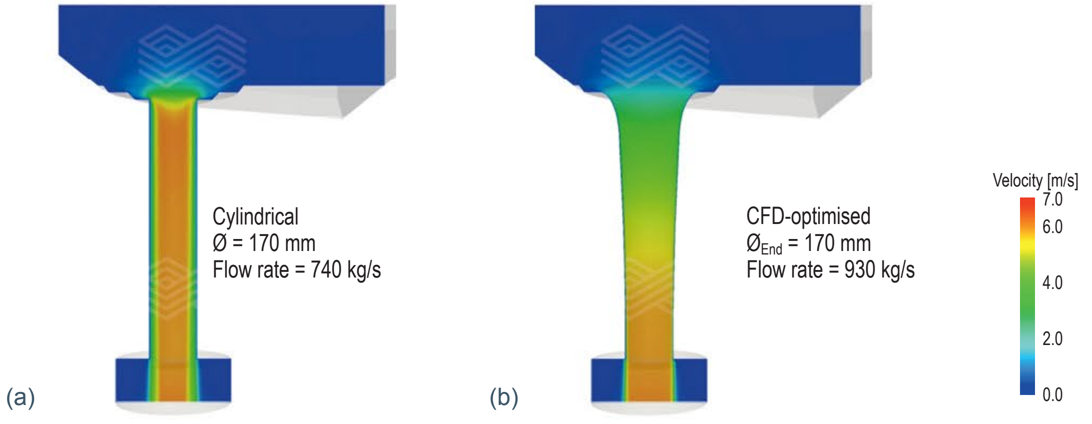


Figure 3.

Comparison of turbulences inside the tapping channel between (a) cylindrical and (b) CFD-optimised EBT channel designs [2].

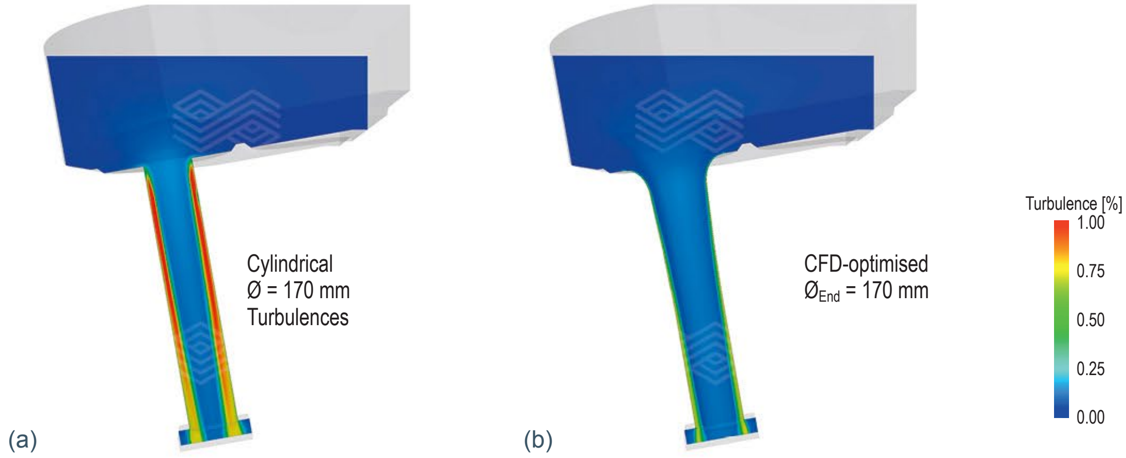
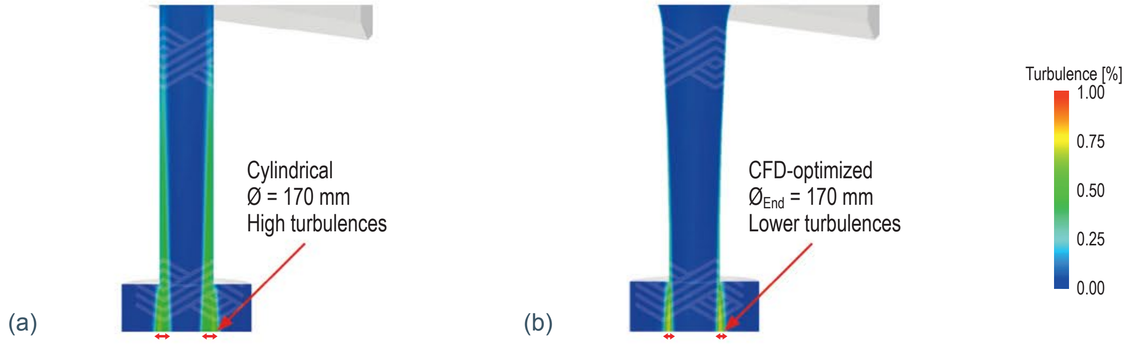


Figure 4.

Comparison of turbulences at the end brick between (a) cylindrical and (b) CFD-optimised EBT channel designs [2].



Case Studies of CFD-Optimised Tapholes

The following is an example comparing a cylindrical and a CFD-optimised tapping channel design for an 80-tonne EBT furnace. The overall furnace refractory lifetime was around 300 heats, and the key requirement for the taphole channel was to minimise downtime for taphole repair or replacement. The typical taphole lifetime was approximately 110 heats. Figure 7 shows a direct comparison between the cylindrical and CFD-optimised taphole designs for this steel producer.

Figure 5.

Comparison of tapping streams exiting the taphole between (a) cylindrical and (b) CFD-optimised EBT channel designs [4].

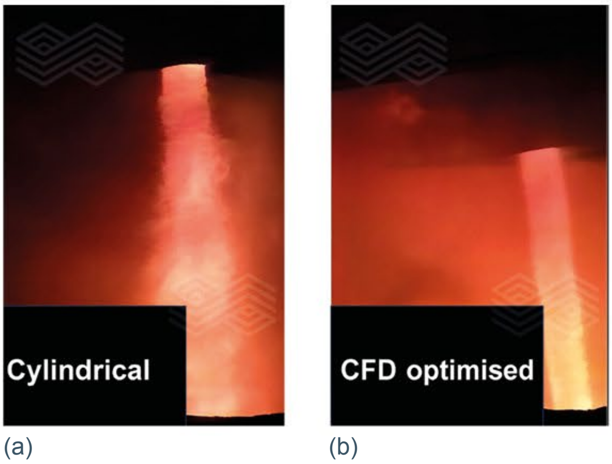


Figure 6.

Comparison of vortex formation between (a) cylindrical and (b) CFD-optimised EBT channel designs [2].

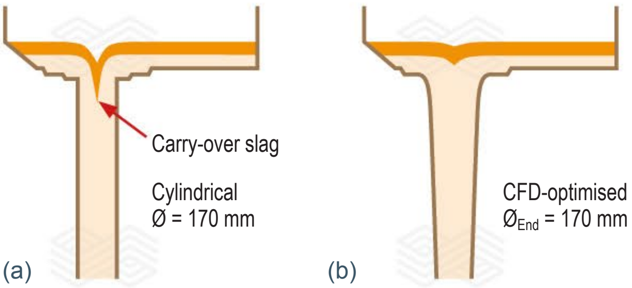
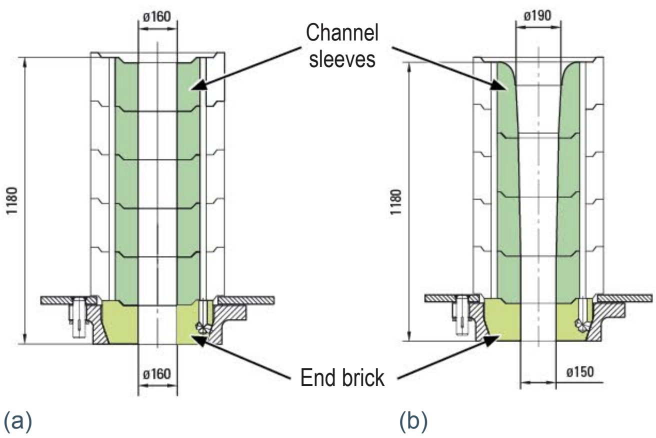


Figure 7.

Comparison between (a) cylindrical and (b) CFD-optimised taphole channel designs for an 80-tonne EBT furnace.



For the cylindrical design, the inner diameter was 160 mm, whereas the CFD-optimised version had an inlet diameter of 190 mm and an outlet diameter of 150 mm. As refractory wear progresses, the taphole diameter increases, allowing a higher steel flow rate and thereby reducing the required tapping time. If the tapping time becomes too short, this indicates critically high wear of the EBT, which must then be repaired or replaced. Figure 8 provides a direct comparison of the CFD-optimised and cylindrical tapping channel designs with respect to tapping time over successive heats.

The CFD-optimised taphole showed lower wear (slope of the blue line in Figure 8), resulting in an increased taphole channel lifetime from 110 heats to 140 heats before a repair was required. In addition to this 27% lifetime increase with the CFD-optimised geometry, the initial tapping time significantly decreased from approximately 300 seconds to 200 seconds.

The next example provides the same type of comparison at another steel producer with a 125-tonne EBT furnace. In this scenario, the cylindrical channel had an inner diameter of 180 mm, while the CFD-optimised channel had an inlet diameter of 190 mm and an outlet diameter is of 160 mm. As shown in Figure 9, the CFD-optimised

Figure 8.

Taphole lifetime increase by changing from a cylindrical to CFD-optimised design in an 80-tonne EBT furnace.

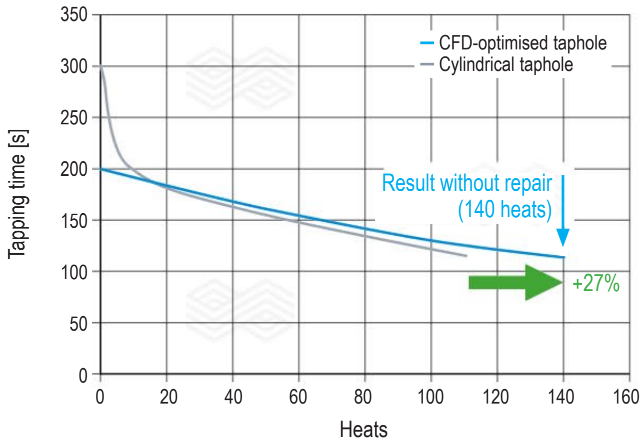
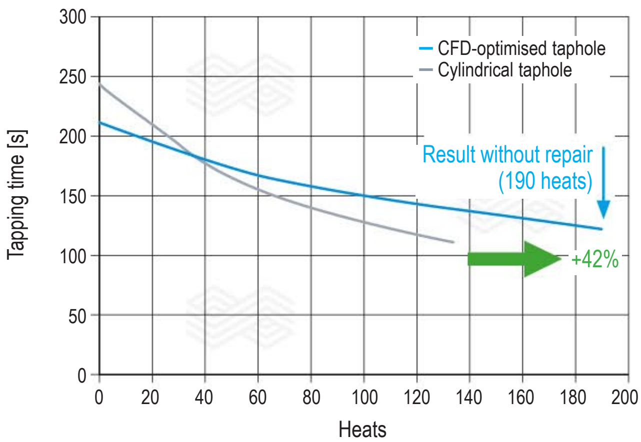


Figure 9.

Taphole lifetime increase by changing from a cylindrical to CFD-optimised design in a 125-tonne EBT furnace.



taphole lifetime increased from 134 heats to 190 heats, a 42% improvement, while the initial tapping time decreased from about 250 seconds to approximately 210 seconds. Once again, the wear rate of the CFD-optimised taphole design was clearly lower.

A direct comparison between a standard cylindrical taphole design and a CFD-optimised channel used in a 45-tonne EAF is shown in the following case study. The steel plant was equipped with one ladle furnace and a continuous casting machine. The EAF had an average lifetime of approximately 1400 heats, with the taphole lifetime averaging 215 heats without repair. The target was to achieve about 280 heats by the end of one week, which could only be reached with additional piping repairs. The cylindrical channel design had an initial inner diameter of 130 mm, while the CFD-optimised design had an initial inner diameter of 160 mm at the inlet and 120 mm at the outlet. From each channel design, 6 sets were tested in the same period. Figure 10 shows a comparison of the achieved lifetimes.

The 160* and 174* heats achieved with the CFD-optimised channel design in Trials 5 and 6 were the result of premature shutdowns due to logistical reasons. Excluding these results, leads to a more representative lifetime average of 255 heats for the CFD-optimised channel compared to 222 heats for the cylindrical channel design—an increase of 15%.

Figure 11 compares the tapping time of the two channel designs, for the two campaigns with highest lifetime during the trial. These results show that the initial tapping time of both channels was similar, at about 2 minutes. However, while the tapping time of the cylindrical channel dropped quickly, the tapping time of the CFD-optimised channel declined at a much slower rate. At this steel plant, the minimum allowed tapping time was 1 minute. Since the cylindrical channel reached this limit too quickly and did not stabilise like the CFD-optimised channel, a repair was required at about 209 heats. Another repair followed at 245 heats for the cylindrical channel, while the CFD-optimised channel only required a single repair at 256 heats. Clearly, the CFD-optimised channel showed a lower wear rate, resulting in less maintenance and more production time gained.

Figure 11.

Comparison of the tapping time with cylindrical and CFD-optimised designs in a 45-tonne EBT furnace, as well as the repair requirements.

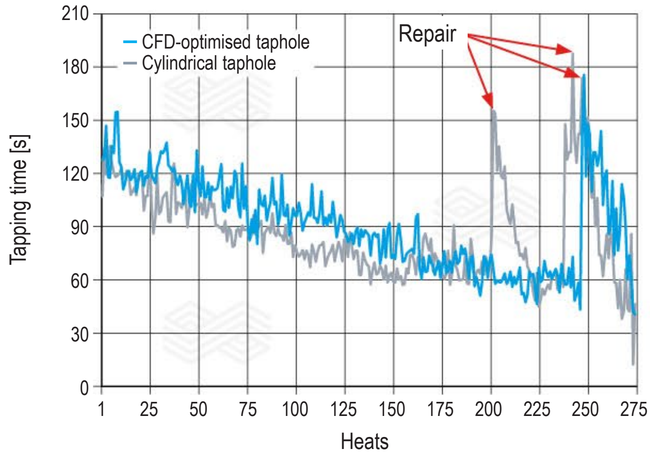
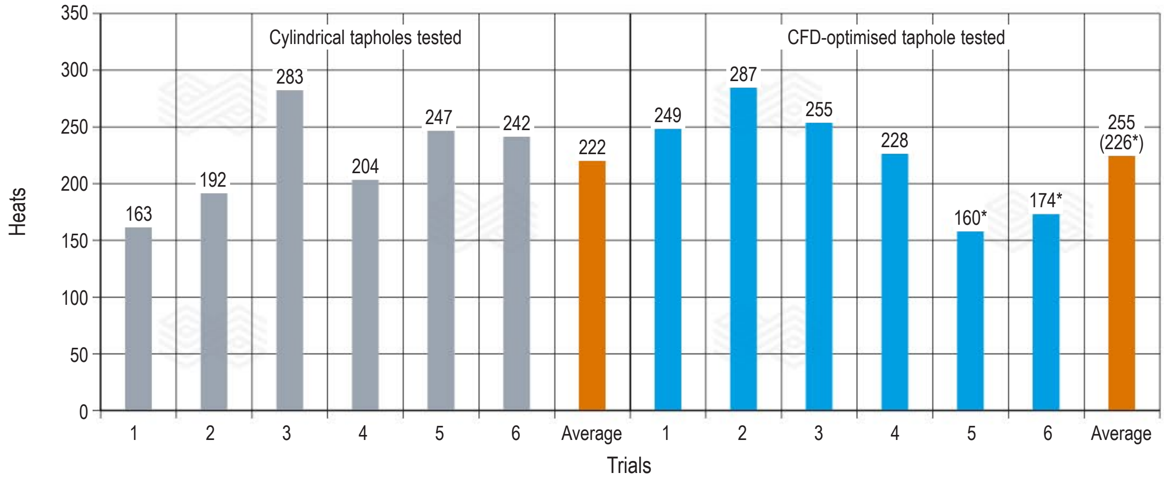


Figure 10.

Achieved taphole lifetimes of the standard cylindrical and CFD-optimised channel designs.

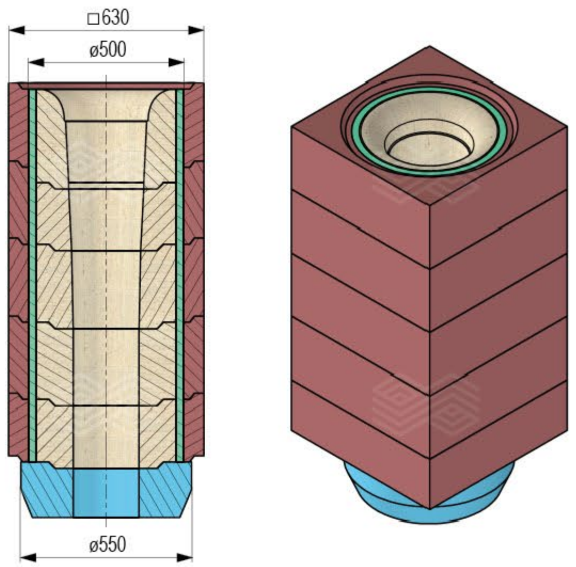


High-Performance Tapping Systems for XXL Electric Arc Furnaces

The aforementioned examples consistently demonstrate the advantages of the CFD-optimised taphole channel design. Therefore, CFD-optimisation was also applied in the development of XXL taphole solutions. The following example illustrates such a design for a 350-tonne EAF (Figure 12). The steel plant operates four ladle furnaces, one vacuum oxygen decarburisation unit, and two continuous casting machines, producing hot-rolled steel. As shown in Figure 12, this XXL EBT solution follows the CFD-optimised design to achieve optimal performance. For this type of XXL taphole installation, a wider outer diameter of the channel sleeves was required—in this case 450 mm, compared to the standard 350 mm.

Figure 12.

Tapping system for a 350-tonne EAF: (a) cross section through the inner channel bricks and surrounding sleeve and (b) outer view of XXL EBT solution.



(a) (b)

The inner channel diameter on the outlet side at the end brick was 210 mm. Due to the large channel bricks, also the surrounding sleeves required a wider inner (500 mm) and outer diameter (630 mm). This created a potential issue: The space between the outer shell of the taphole channel and the surrounding sleeves, which is called the ring gap (marked in green in Figure 12), was not sealed by the end brick, since the global standard outer diameter of an end brick is 457 mm. To address this, an extra-large surrounding brick was designed and implemented. With this new end brick (550 mm outer diameter), the ring gap could be safely sealed. RHI Magnesita can provide XXL end bricks and adapt the geometry to meet customer-specific requirements.

The standard refractory lifetime of this 350-tonne furnace was 340 heats, with approximately 170 heats per week. The taphole lifetime was therefore targeted at 170 heats. The initial tapping time was around 220 to 250 seconds. With the prescribed CFD-optimised design, after 150 heats the tapping time typically decreased to about 120 seconds, which meant that the target lifetime of 170 heats could be safely achieved without falling below the minimum allowed tapping time of 60 seconds.

Summary and Conclusion

In this article, the theoretical advantages of CFD-optimised taphole design have been described and supported with multiple case studies demonstrating the benefits of this concept. This technology has also been applied to XXL EBT solutions, for EAF furnaces with capacities of 300 tonnes and more. An example was presented, highlighting RHI Magnesita's ability to provide a reliable taphole design solution for XXL EAFs, based on extensive experience gained over decades. With this customer-focused approach, RHI Magnesita is able to adapt taphole designs to specific on-site requirements, thereby positioning itself as a strong partner in the green steel transformation.

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Authors

Kevin Christmann, RHI Magnesita, Wiesbaden, Germany.
Bernd Neubauer, RHI Magnesita, Leoben, Austria.
Alexander Ratz, RHI Magnesita, Vienna, Austria.
Matthias Höck, RHI Magnesita, Vienna, Austria.
Markus Hochegger, RHI Magnesita, Vienna, Austria.
Riccardo Magrofuoco, RHI Magnesita, Brescia, Italy.
Walter De Queiroz Cassete, RHI Magnesita, Contagem, Brazil.
Thales Fonseca Paula, RHI Magnesita, Contagem, Brazil.
Carlos Soares, RHI Magnesita, Contagem, Brazil.
Corresponding author: Kevin Christmann, Kevin.Christmann@rhimagnesita.com

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Project Manager Michaela Hall
Design and Typesetting Universal Druckerei GmbH, Leoben, Austria

Contact Michaela Hall
RHI Magnesita GmbH, Technology Center
Magnesitstrasse 2
8700 Leoben, Austria

E-mail bulletin@rhimagnesita.com
Phone +43 50213 5300
Website rhimagnesita.com
LinkedIn https://www.linkedin.com/company/rhi-magnesita

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