

# R2U—Ready-to-Use Castables

**A novel ready-to-use magnesia-carbon castable has been developed for efficient and cost saving hot repair of steelmaking components**

*by Carlos Pagliosa and Victor Carlos Pandolfelli*

**A** novel generation of MgO-C castables has been conceived to be delivered to the customer as a ready-to-use (R2U) product and applied by self-flowing, pumping, or shotcreting. All liquid is already incorporated into the mixture and no segregation was observed during storing and transportation. Easy installation and increased performance have been observed in some steel shops.

Basic dry gunning mixtures have been conventionally used to hot-repair basic oxygen furnaces (BOF) and ladle slag lines since the 1970s<sup>1,2</sup> when phosphate-bonded materials were mainly applied. The increasing demand of lower-carbon steel has caused severe operating conditions to BOF converters. As a consequence, MgO brick and repairing mixtures needed to be redesigned.

This novel conception for a hot repairing mixture was based on MgO-C brick formulations to develop an MgO-C castable. Nevertheless, usual hydraulic binders have serious limitations when used with basic aggregates (such as MgO sources) or for metallic additives in water-containing compositions. Graphite also presents low oxidation resistance and poor wettability in water. Therefore, phenolic resin has been selected as the main binder because:<sup>3-5</sup>

- It is a low-polluting organic binder;
- It has full compatibility with antioxidant additives and carbon;
- It generates carbon bonds after firing;
- It has an easy incorporation of carbon in the mixture; and
- It can be handled easily and added to the mixture.

Conventional dry gunning mixtures usually need water to wet the castable. Especially for BOF repair, water is not suitable because of thermal shock damage and oxidation of MgO-C bricks. Additionally, the water amount for gunning is not easy to control and the final properties present a large scatter.

An MgO-C self-flow hot shotcrete castable has been developed to replace conventional dry gunning mixtures. Experience at field trials has shown that installation of pumping and shotcreting castable requires some special features:

- Refractory double-piston pump and accessories;
- Mixer incorporated with the pump;
- Controlled liquid addition and time to homogenize the mixture; and
- Clean pump and mixer.

Some of these features are not required with the new R2U product because castables eliminate all liquid addition and mixing procedures by the customer. This saves time and makes pumping easy to perform.

## **R2U MgO-C Castable Development**

A novel hot-repair product has been idealized to fulfill some of the requirements:

- R2U castable is compatible with MgO-C brick;
- R2U castable allows multifunctional installation (self-flowing, pumping, and shotcreting); and
- R2U castable is delivered to the customer with all liquid incorporated in the mixture.

The latter topic already considers that, by precontrolling the amount of liquid, the properties are more reliable and predictable.

Some challenges needed to be overcome in terms of making this product real. A new phenolic resin was developed with a special solvent that provides wettability to carbon and oxide sources. Sintered MgO was used as a main aggregate in all particle-size ranges, although fused MgO could also be employed. To cover all the range of Andreasen's particle-size distribution model, submicron MgO and carbon particles were used. Metallic additives to provide a high hot modulus of rupture (HMOR) were also incorporated.

A special dispersant for a nonaqueous medium was selected as resin. The only liquid and the fine powders in the matrix need to be fully incorporated in the castable. Therefore, electrosteric dispersants were the best choice, because they were effective in both MgO and carbon surfaces and helped to decrease the content of resin by 25 wt%. The minimum self-flowing index attained for the castable was 70%.

High fluidity is necessary for product installation, but it could promote segregation during

transportation or storing. Grain-size distribution and matrix viscosity were designed to prevent these drawbacks. By special matrix engineering, the R2U MgO-C castable maintained its original properties after 30 days.

## Chemical and Physical Properties

Table 1 shows the chemical and physical properties of a conventional phosphate-bonded dry gunning mixture and the novel R2U MgO-C castable.

The R2U MgO-C castable had a lower density because of the carbon content, but it attained similar porosity after curing. Mechanical and hot properties were also improved in this novel material. Corrosion resistance was clearly superior and performed better in shop trials. Nevertheless, results after firing at 2552 °F (1400 °C) were similar for both materials. The HMOR was improved more than fivefold for the R2U MgO-C castable due to carbon-carbon bonds and also the presence of metallic powders.

A cross section of the novel material is similar to the MgO-C brick, as shown in Fig. 1. Figure 2 shows the self-flow behavior of the castable just after production. The self-flow test can be applied as quality control in the production process and at the repairing site. Acceptable flow is in the range of 70 to 90%.

Installation can be easily performed using self-flowing or pumping equipment. The novel R2U MgO-C castable was designed to be applied and shotcreted in a usual refractory pump (double piston). No mixer or extra mixing is necessary for homogenization.

## Steel Shop Trials in BOF Converter

The R2U MgO-C castable was installed using self-flowing and shotcreting in a 353 ton (320 metric ton) BOF converter. Material was delivered in 1 ton big bags or less, depending on customer requirement.

Figure 3 shows the sequence for hot repairing a converter tap pad. First, material is charged by the scrap crane into the impact pad. Then, the converter is rotated up to the point that the material flows through to the tap pad. The whole operation is completed in less than 40 seconds. The BOF is maintained in this position for material setting. After 15 minutes, the vessel can resume normal operation.

The R2U MgO-C castable has also been used for hot repairing the impact pad and the BOF bottom region. The working life is at least twice for this new castable when compared with the previous commercial resin basic material. The setting time has also been reduced by one-half.

For a 353 ton (320 metric ton) vessel and a 42 minute tap-to-tap repair, saving time implies

Table 1: Properties of Phosphate-Bonded Dry Gunning Mixture and R2U MgO-C Castable

Property	Dry gunning mixture	R2U MgO-C
Composition, %		
MgO	94.2	89.3
Al <sub>2</sub> O <sub>3</sub>	0.2	2.2
Carbon	—	6.5
Others	5.6	8.5
After 392 °F (200 °C)		
Density, oz/in. <sup>3</sup> (g/cm <sup>3</sup> )	1.6 (2.77)	1.43 (2.47)
Porosity, %	17.1	17.3
CCS, psi (MPa)	3176 (21.9)	4018 (27.7)
HMOR, psi (MPa)*	537 (3.7)	609 (4.2)
Slag corrosion, %†	45.3	32.5
After coking at 2552 °F (1400 °C)		
Density, oz/in. <sup>3</sup> (g/cm <sup>3</sup> )	1.57 (2.71)	1.46 (2.52)
Porosity, %	23.2	25.4
CCS, psi (MPa)	3176 (21.9)	3524 (24.3)
HMOR, psi (MPa)*	102 (0.70)	537 (3.7)

\*At 2552 °F (1400 °C) under argon atmosphere.

† Induction furnace at 3002 °F (1650 °C) for 3 hours; steel + 40% FeO slag.



Fig. 1: Cross section of the novel R2U MgO-C castable



Fig. 2: Self-flow test for the R2U MgO-C castable

more steel production. It means that 15 minutes to resume operation of the BOF converter represents a benefit of about \$70,000. Taking this into account, for a BOF campaign of close to 7000 heats with a hot repairing mixture consumption of 331 tons (300 metric tons—1 metric ton for each repair), this new R2U MgO-C castable will save 4500 minutes.



Fig. 3: BOF hot-repair procedure: (a) loading R2U MgO-C castable on scrap crane; (b) castable is applied at the impact pad; (c) castable flows to the tap pad; and (d) castable is set and BOF is ready to resume operation. Illustrations inset in (b) and (c) indicate ladle orientation at those points in the process

All this time converted to steel production represents revenues close to 37,809 tons (34,300 metric tons) of steel and an extra profit of \$20.5 million. If the performance of the R2U castable is considered, customer benefits will be even higher.

Figure 4 shows the R2U MgO-C castable that has been applied by shotcreting on the tap hole sleeve changing. The castable was loaded directly to the pump without previous mixing. This application was conducted using a double-piston pump. The application steps were as simple as the conventional dry gunning mixtures.

Setting time for the resin material has to be adjusted to promote flow, but also to follow the tap-to-tap time required to resume the BOF operation.

### Steel Shop Trials in Ladle

A slag line trial was conducted in a 243 ton (220 metric ton) ladle. The R2U MgO-C castable was shotcreted and replaced the conventional phosphate-bonded dry gunning mixture. The ladle remained in the cradle and shotcrete was conducted all around the slag line (360 degrees). Material

adhesion was very good even with overhead projection. The performance of the novel material was improved by at least 200% compared with the phosphate-bonded material.

### Flexible Use

The novel MgO-C castable has been developed and used to hot repair BOF and ladle slag lines. This material has shown to be compatible with MgO-C bricks and steel making process basic slags. Trials conducted on steel shops increased the performance compared with conventional dry gunning mixtures and resin-bonded mixtures.

This novel material technology has been also applied to other developments such as hot repairing of well and plug blocks for steel ladles and BOF bottoms.

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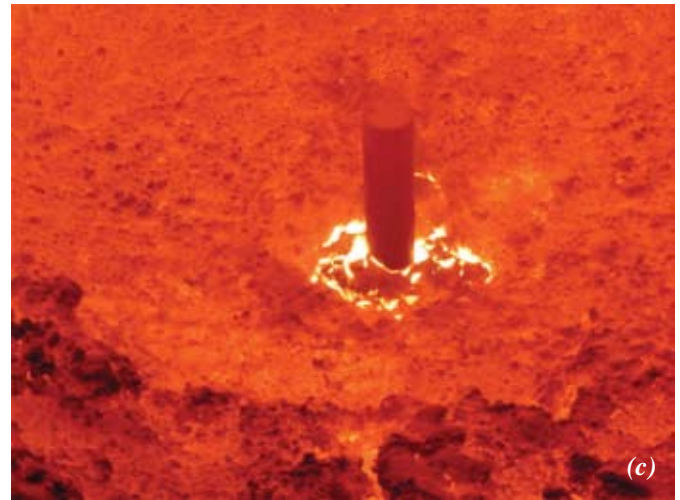


Fig. 4: Tap hole sleeve changing: (a) pumping equipment is placed near BOF mouth; (b) hot shotcreting R2U MgO-C castable for sleeve repairing; and (c) repaired region after shotcreting

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