Tap-hole repair: the UCAR®V Repair solution

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While the refractory lining contains the process on a steady-state basis, the tap-hole must provide a channel for transport of molten materials at discreet intervals, with thermal cycling as routine. The tap-hole introduces a discontinuity in any lining, and this fact can lead to failure in the region around the tap-hole before general lining failure occurs. Hence there is a need for a rapid and reliable tap-hole repair technique that can be readily implemented in conjunction with all types of linings. The UCAR®V Repair supplied by GrafTech is a durable solution capable of repairing all types of lining designs and has been extensively utilized in the ferroalloy industry. More than 20 UCAR®V Repairs have been successfully performed in South Africa alone. This paper describes the system in general and reviews recent repairs and their unique challenges.

Introduction

Every process needs a containment system. The refractory lining, whatever the component parts, is used to retain the products of the smelting process until such time that they must be removed. Many furnace operations are semi-continuous. While the smelting process is operated continuously, raw materials are added and products are discharged on a batch basis. Continuous discharge of products is not standard and is limited to a small number of processes. Whatever operating practices are selected, at least one tap-hole is required. There can be three types of tap-hole, namely for metal and slag, for metal only, and for slag only

In a blast furnace, sidewall heat distribution is uniform and therefore non-uniform wear may be attributed to operational rather than design problems. The tap-hole, however, remains the principal region for erosion. In a three-phase submerged arc furnace, the triangular arrangement of the three electrodes in a circular cross-section introduces three principal wear zones in the sidewalls:

- High wear: tap-holes and vicinity
- Medium wear: closest point to electrodes
- Low wear: furthest from tap-holes and electrodes.

While the tap-hole introduces a weak point into the lining, the installation of a tap-hole cannot be avoided. Therefore the challenge is to provide a durable and repairable solution.

The metal and metal and slag tap-holes need to be in the lower sidewalls at an elevation that allows the hearth to be drained. A slag tap-hole will be at a higher elevation in the sidewalls, consistent with allowing for efficient separation of the metal from slag based on their differences in density. Some typical tap-hole systems for ferrous and ferroalloy operations are:

- A carbon block
- A carbon block with graphite sleeve
- A silicon carbide bricked arch with a paste, ceramic, or silicon carbide plug.

The channel through which the metal and slag flow will generally be eroded during use and therefore needs to be replaced on a regular basis. The material used to close the tap-hole should perform this role of repair between taps, but is usually drained away and replaced after every tap. The durability of the tap-hole structure generally determines the number of tap-holes required.

The principal tapping tools are a drill, a mudgun, and an oxygen lance. The purpose of the drill is to enable the operators to retain the orientation of the hole every time. The mudgun is used to ensure effective closure of the tap-hole and to force the plug material deep into the hole, sometimes against the flow of metal and slag. The oxygen lance then bridges the gap between where drilling ends and the molten pool of metal and slag begins. Minimal oxygen usage is always preferred since lancing provides conditions under which tap-hole material erosion will increase.

Repair options

Tap-hole wear is to be expected but premature damage is usually a function of the extent to which oxygen lancing is employed. Damage caused by oxygen lancing often extends to the adjacent parts of the channel itself. It has been found that the sidewalls often need to be incorporated into a tap-hole repair assignment.

The tap-hole is an integral part of the furnace sidewall, for which the three principal lining types are as follows:

- Ceramic castable or brick on the cold face and carbon paste on the hot face
- Carbon paste on the cold face and carbon block on the hot face
- Graphite tile on the cold face and carbon brick on the hot face.

These lining types may be categorized by their conductive or insulating characteristics.

Tap-hole damage quite often also leads to unplanned furnace shutdowns with the need for a quick repair so that production can be resumed. Tap-hole damage is invariably non-uniform yet repairs can start only from an undamaged foundation. The base for a repair must be structurally competent. The following five types of repair are possible:

- Ceramic castable
- Carbon ramming paste
- Carbon block for block replacement
- Carbon brick for carbon block replacement
- Carbon brick for carbon brick replacement.

Repairs requiring a short turn-around time utilize the most convenient materials, which are rams and castables. However, the properties of most ramming and castable products are often dependent on the skills at point of use. Many variables come into consideration because an emergency repair takes place under hot conditions. Therefore access to and time at the work site are limited. Short-cuts occur and the repair is less than ideal. Once carbon ramming paste is heated, the material becomes plastic and the volatiles burn off causing shrinkage. This will cause voids and cracks in the lining, making the properties of the repair altogether different to those of carbon ramming paste applied under ideal conditions. Similarly, castables applied during a hot repair will lose moisture faster than desirable and their physical properties will be less than ideal.

Carbon block of any grade does have a structure. However, the temperature differential across a carbon block of 700 mm or more during operation is enough to induce cracking and spalling, which leads to hot face irregularities. In addition, since damage around the tap-hole is invariably non-uniform, the removal of entire blocks is usually needed, which results in a large amount of prime material wastage. It is very difficult to accurately measure the contours of the remaining carbon block after removal of damaged sections because of the relative movement of adjacent blocks and erosion at the interface between blocks. In addition, the tap-hole block itself is tapered and so can be installed only from the outside, which may require removal of a section of shell plate. The installation of a replacement tap-hole block into a repaired block section will therefore require the use of a mortar or grout to fill gaps, whereas the original block design would have been based on dry joints. Therefore a block for block repair also requires off-site machining, with all the problems related to handling large sections of carbon. A compromise needs to be reached between a paste repair, which is considered only short-term, and a complete reline, which is difficult to accept when the remainder of the lining is still in good condition.

The UCAR carbon brick design consists of small sections measuring 114 x 228 mm at the hot face with lengths of 230 mm, 343 mm, and 457 mm. Therefore between 15 and 25 bricks might be required to replace a single carbon block at the hot face surface, depending on initial design. As a result, excavation to a competent surface results in minimum wastage of undamaged material when utilizing carbon bricks since small bricks can be more readily fitted into irregular sections. Repair of a conductive lining entails like-for-like replacement of carbon bricks.

Repair examples

Although furnace designs and operating practices may be considered as similar, every installation and operation is unique. What works for one furnace is not necessarily transferrable to another, and this is also true for repairs to a lining. A repair requires a solid base to work from that is volume stable and mechanically sound. Excavation to between 300 mm and 500 mm below the base of the tap block is fairly common when looking for a solid foundation. Damage in the lateral direction either side of the tap-hole tends to be less as the depth increases. Hence the use of the term UCAR®V Repair for this type of work.

In a submerged arc furnace, a carbon ramming paste repair might provide adequate life if the hearth power or energy density is less than 250 kW /m^2. However, this type of repair will not be reviewed in this paper since it is generally applied as a short-term solution, with no expectation of permanence. The extent of excavation is dependent on the life requirement from the repair. A furnace due for a full reline in the near future would of course not be repaired as competently as a repair that needs to last.

Brick for brick repair

A brick for brick repair is illustrated in Figures 1–5. This UCAR®V Repair was carried out on a ferrochrome furnace.

Figure 1. The tap-hole block has been removed and unsupported bricks have fallen into the cavity. This is the first stage of demolition

Figure 2. The sidewalls have been cleared back to the shell. Adjacent graphite tiles and carbon bricks that are structurally sound have been left in place

Figure 3. External view of carbon brick sidewall level with the bottom of the tap-hole block placed central to the arch. This is the first stage of UCAR®V Repair reconstruction

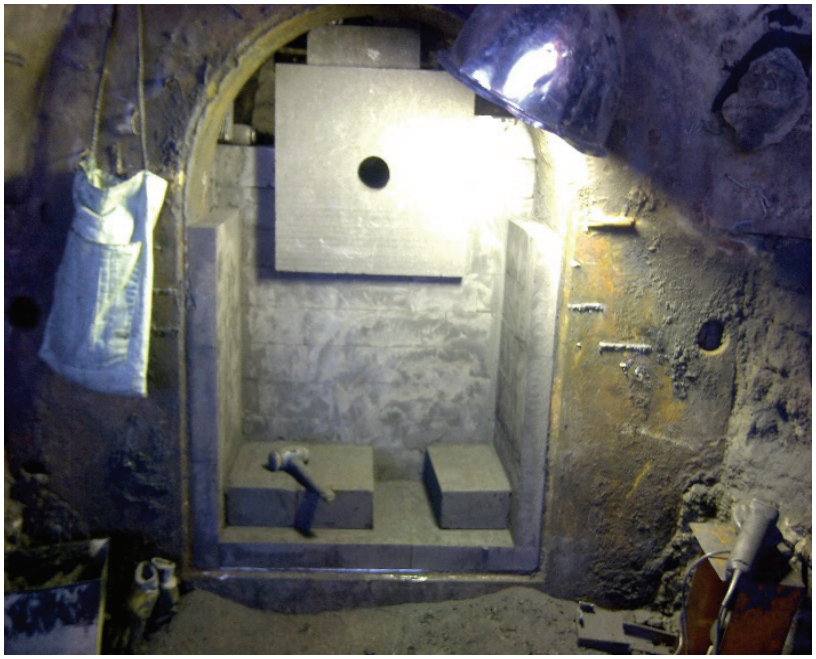

Figure 4. Internal view of the carbon brick sidewall, illustrating the extent of hearth damage around and below the tap-hole block

Figure 5. Installation of the abutment around the tap-hole block

Brick–for-block repair

A brick for block repair is illustrated in Figures 6–8. This UCAR®V Repair was carried out on a blast furnace.

Figure 6. The carbon blocks have been removed in a section three blocks wide and six blocks high, equivalent to a surface area of about 9 m^2. The tap-hole is in the lower third. Upper carbon blocks which are still in good condition have been supported to limit repair to the essential areas

Figure 7. The brick for block replacement has permitted the re-use of some partial blocks and limited the removal of competent carbon, with some of the bricks being modified to work into irregular profiles

Figure 8. Internal view of the final repair before drilling of the tap-hole through the brick section. The same principles will, however, also apply to a furnace with a tap-hole block installed into the sidewalls

Summary

In a brick for brick repair, the procedures are more predictable than for a brick for block repair. A concept drawing, an example of which is shown in Figure 9, can be prepared before work commences, based on the original design and a field assessment of the damaged section. Replacement materials, namely tiles, bricks**,** lintels, and blocks, can be clearly identified and supplied to site ahead of time, such that a minimum of field cutting and grinding will be required. The original lining design already incorporates cemented mortar joints, so a repair will follow standard practice and the original thermal design will be maintained.

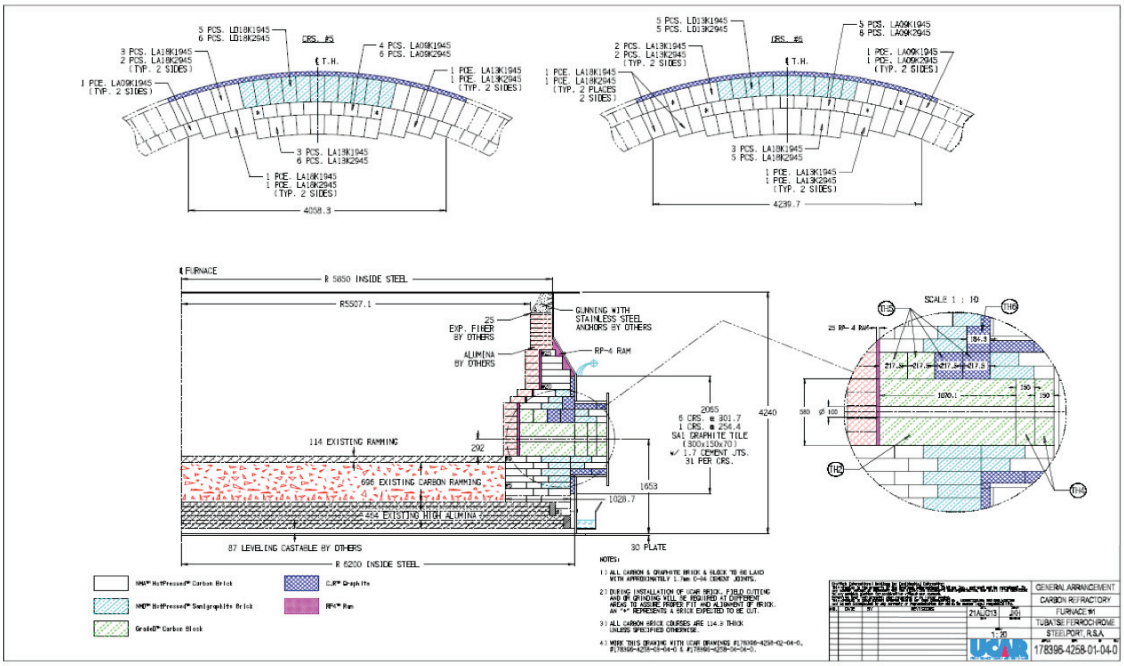

Figure 9. Example of a concept drawing for a tap-hole repair

The tap-hole area is widely accepted as the portion of the lining most subject to erosion from both the process and tapping practices. Standard repair methods, however, are typically costly, time-consuming, and unreliable. The UCAR®V Repair supplied by Graftech is a durable and cost-effective solution capable of repairing both carbon block and carbon brick sidewalls incorporating the highest wear area of the lining.

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