Casthouse Refractory Methods for Risk Control and Quality Assurance

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Abstract

Casthouse operations require the use of various types of refractory materials along the entire value chain that need to be properly maintained. Indeed, refractory maintenance operations in aluminium casting furnaces can expose workers to a variety of severe health and safety risks, such as exposure to hazardous substances, falling objects or contact with heavy machinery. Additionally, improper process control during the refractory dry-out and furnace start-up phases can create dangerous conditions (e.g. steam explosions). Business risks such as premature failure can also stem from insufficient quality assurance during shutdown planning and execution. While these risks have long been recognized, they were in the past managed trough administrative controls, which are inherently fallible and have led to several incidents. In the last five years, Rio Tinto has used new technology and novel techniques to implement engineering controls for risks created by refractory maintenance in casting furnaces. These innovations have led to a safer work environment for refractory maintenance crews and in certain cases have eliminated risks associated with legacy work practices.

Keywords: Refractory maintenance, Casting furnace, Steam explosion, Health and safety, Casthouse risk reduction.

1. Context and Present Situation

Rio Tinto currently operates 28 aluminium casting furnaces within its Atlantic Operations division, while an additional 4 furnaces are currently at the design or construction phase. Most of these furnaces consists of tilting units, with an average capacity around 100 tonnes. All furnaces rely on a monolithic refractory lining for metal confinement and major components of such linings typically require replacement every 12 to 36 months (the exact frequency and extent of repairs depends on process conditions and furnace design). For Atlantic Operations, this translates into 6 to 8 major shutdowns per calendar year, during which around 2 000 man-hours are required in each furnace for refractory maintenance.

Refractory maintenance in casting furnaces can be a hazardous task. For example, during most steps workers are routinely exposed to crystalline silica dust, which is a known carcinogenic substance [1]. Other specific tasks such as demolition and work inside chimneys involve additional risks: the former involves working in very close proximity to heavy machinery, while the latter exposes employees to falling pieces of refractory or debris from great heights. Because of process risks, even steps where no manual labour is involved can be dangerous to nearby personnel. The penultimate stage of a furnace shutdown is the dry-out, during which new refractories must be carefully brought up to temperature following a precise schedule. If the schedule is not strictly adhered to, a steam explosion within the new lining may occur. Such an explosion can also occur during the first batch in the furnace if molten metal penetrates the lining through expansion joints or cracks and contacts trapped residual water from the dry-out. Although rare, severe steam explosions in casting furnaces can be quite destructive, as shown on Figure 1.

Figure 1. 100 t furnace severely damaged by a steam explosion in 2015 during dry-out [2].

2. Challenges or Required Expected Improvements.

This paper will focus on safety improvements in three separate steps of furnace refractory maintenance: refractory tear-out (i.e. demolition), stack maintenance and dry-out. Since each area presented unique challenges, they will be separated henceforth to simplify the text.

2.1 Challenges with Demolition Machinery

Until recently, refractory tear-out was performed using conventional excavation machinery, like the backhoe shown on Figure 2. This figure clearly shows the main problem with this type of equipment: the operator sitting in the cab is too high to have a direct line of sight on many areas inside the furnace (roof, front ramp, floor, etc.).

Figure 2. Typical backhoe used for furnace demolition (author's image).

This issue mandated the use of a spotter to guide the backhoe operator when tearing out components invisible to the operator. Unfortunately, to be able to see the jackhammer while visually communicating with the machine's operator, the spotter had to stand extremely close to the backhoe's swing arm. Figure 3 shows a spotter near the machine.

6. Conclusions and further work

Since 2019, Rio Tinto has successfully implemented new methods and tools to reduce risks associated with refractory maintenance in casting furnaces. Some improvements were achieved using off-the-shelf technology adapted to the needs of aluminium casthouses, while others required. These successes were made possible through partnerships with highly specialized and competent contractors. The introduction of demolition robots has resulted in a decrease in hand injuries among refractory workers. Drones have minimized personnel exposure to height-related risks and falling objects, while vacuum pumps have reduced the likelihood of steam explosions during furnace start-up.

Despite these reductions in risk, further work is needed to fully harness the potential of these new tools. For instance, tasks currently performed from a man-basket suspended from a crane could potentially be carried out by a drone if the technology allowed. As for the vacuum pump system, additional cooling enhancements are required to use the system for extended periods above 800 °C. Twin pumps for simultaneous dry-outs are also considered, as the current use of a single large pump prevents output analysis as the water coming out from both furnaces ends up in a single tank.

Further work is also required to reduce the environmental impact related to the disposition of spent furnace refractory materials. Rio Tinto currently recycles in-house a portion of the refractory waste generated by the maintenance of casting furnaces, thanks to its unique spent pot lining (SPL) treatment plant. However, this plant cannot accept refractories with imbedded metallic components, such as anchors or stainless steel fibres; these refractories must be landfilled. New technologies are required to facilitate the sorting of refractories containing metallic components, as well as to extract these components from recyclable materials.

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