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Managing Slag Build-up in Channel Furnaces

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Melt/Pour - Rod Naro

Managing Slag Build-up in Channel Induction Furnaces - Jan. 9, 2025

Foundries today must reduce melting costs and improve operating efficiency – so for induction melting operations it's critical to minimize the oxides, silicates, and sulfides that decrease furnace capacity.

In the past 60 years foundries have changed the methods they use to melt and hold molten irons. For example, prior to the passage of the Clean Air Act legislation in 1970, there were an estimated 2,817 cupolas operating in the United States (*see Table 1*.) Today, the number of cupola foundries has diminished to less than 42. [1,2,3]

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North American Cupola Foundries					
Year	1967	1975	1980	1995	2018
Cupolas in operation	2,817 [1]	1,618 [1]	1,286 [1]	150 [2]	42 [3]

Table 1

As cupola melting declined, electrically powered channel furnaces initially became the preferred iron melting method. With improvements in electrical power supplies, coreless induction furnaces have replaced both cupolas and channel furnaces for melting. However, it has been estimated that cupolas still account for over 53% of an estimated 7,424 metric tons of gray and ductile irons shipped in 2018[4] and channel furnaces continue to remain the preferred method to hold cupola-melted irons.

What has not changed during this period is the ever-challenging task of securing high-quality scrap feedstocks for melting. A major economic factor for foundries today is to reduce melting costs and improve operating efficiency. These two approaches do not always yield the same result. For example, buying relatively inexpensive scrap metal units can reduce overall raw material costs, but at the same time can have a significant and deleterious effect on melting efficiency by promoting increased slag build-up.

The generation of slag during melting is inevitable unless drastic steps such as sand-blasting scrap and foundry generated returns is implemented, processing steps that are impractical. Slag build-up is defined as a complex ceramic deposit of insoluble oxides and sulfides on colder furnace walls during melting.

Insoluble oxide formation results from oxygen availability in the furnace. Insoluble sulfides can originate from charge materials as well as various contaminants, such as machining fluids, dirt, and by-products from desulfurization.

Among the commonly recognized sources of primary oxides or sulfides are:
- Oxidation of molten metal surfaces;
- Dirty, rusty scrap or oxidized charge materials;
- Erosion of upstream refractories in the furnace uppercase or receiver;
- Contamination from minor elements used for inoculation or nodulizing;
- By-products from metal treatment operations, such as desulfurization.

Slag build-up usually manifests as a deposition of low melting oxides, silicates, and sulfides on the side walls of the furnace refractory that reduces furnace capacity. But more important, build-up in the critical inductor loop in channel furnaces can be very harmful. It is critical that this loop of molten metal be continuously maintained. If this loop is allowed to freeze, extreme care is necessary in remelting because the loop may rupture and disrupt the circuit. The relatively narrow melting loops or channels must be kept as clean as possible.

An example of slag build-up on upper case sidewalls, and in the inductor loop and throat areas is shown in Figure 1.

Slag build-up is an on-going process, and a classic nucleation- and crystalline-growth phenomena. Shortly after the initial liquid slag phases start to precipitate as a thin solid film or substrate on any furnace refractory surface, subsequent build-up can proceed more easily and rapidly. This liquid glass or slag phase nucleates easily and grows on the just deposited build-up because the surface of the initial build-up is crystallographically similar to the emulsified slag phases attempting to precipitate out of solution.

Failure to "flux" or remove these emulsified phases from the metal bath during the melting and holding process will allow greater amounts of build-up to form and reduce the overall efficiency of the metal handling system. Frequent additions of specific Redux EF40 fluxes can prevent these problems while having no adverse effect on furnace refractories.
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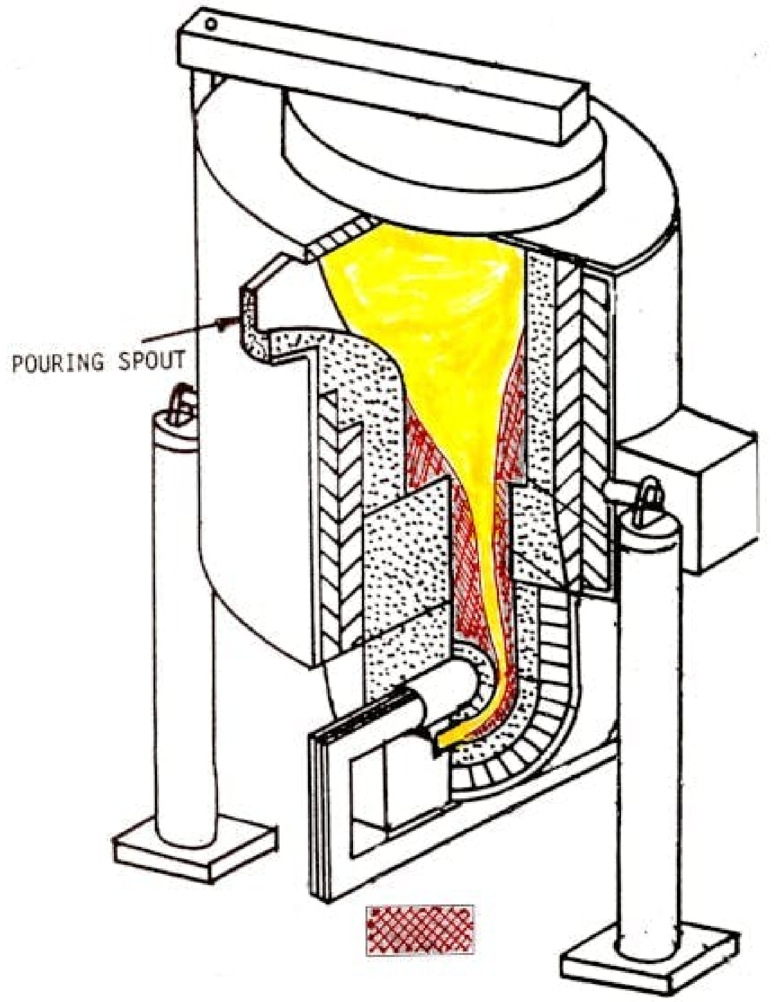

Figure 1: Slag buildup on upper-case sidewalls and inductor throat of a vertical channel furnace.

Many techniques have been used over the years to combat build-up in channel furnaces, including:
- Scraping upper-case sidewall walls
- Rodding inductor loops;
- Adding silicon carbide and iron-oxide mixtures;
- Low heel superheating and/or power pulsing;
- Green poling the inductor loop;
- Adding fluoride-based fluxes that may harm refractories.

In the last dozen or so years, a patented fluoride-free flux called Redux EF40 has been proven effective in removing slag build-up without refractory attack. A major advantage of using Redux EF40 flux when confronted with a dense, fused build-up is Redux alters the glass-like structure of the build-up that results in a “softening” of the build-up. Removing the build-up is greatly simplified after fluxing and the time required for build-up removal can be reduced by up to 90%.

If Redux EF40 is not used, slag build-up will usually proceed more rapidly once the first stages of build-up start to appear on furnace refractories. In those cases where cupola melted iron is transferred to a vertical channel furnace, adding Redux fluxes will aid the floatation of carry-over emulsified slags from the cupola and transfer ladles, as well as keeping those transfer ladles clean.

For channel holding furnaces, adding one half to 1.5 pounds of Redux EF40 per ton of molten iron to every transfer ladle will help in keeping those ladles clean. Redux fluxing or cleansing of the metal in the ladle and removal of various slag phases from the metal helps to prevent downstream build-up in holders and pressure pours. Redux EF40 users report significantly reduced furnace maintenance as less slag or build-up adheres to furnace walls.

Additionally, fluxing will restore full furnace volume and lead to increased production. More important, the reduced quantity of build-up is accompanied by a “softer, less glass-like build-up” that is much more easily scraped from the walls, without any subsequent damage to the refractory.

The following example illustrates how Redux EF40 flux additions can improve melting efficiency and provide significant downstream melting cost reductions. Foundry “X” was experiencing extensive slag build-up on the upper sidewalls of two 65-ton vertical channel holders. Each channel furnace upper case was lined with a silica refractory while the inductor was lined with a dry-vibratable, alumina-magnesite refractory.

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Figure 2a, (left): Severe slag build-up in the upper case of a channel furnace.
Figure 2b, (right): Restriction resulting from slag build-up in the inductor loop. (5)

The condition of the channel furnace uppercase after 11 months of operation is shown in Figure 2a. After 11 months of operation from a newly relined furnace, slag build-up reduced the working furnace capacity to less than 35 tons. Build-up was so severe that adhering slag was over 15 inches thick and extremely tenacious in clinging to the furnace walls. The slag build-up was nearly impossible to remove during routine weekend maintenance. The build-up was also responsible for clogging the inductor loop and reducing the working diameter from 12 inches to barely three inches (*see Figure 2b*.) At this point, the furnaces were typically relined.

Foundry X started to add 0.05% Redux EF40 briquettes to every five-ton cupola transfer ladle and massive quantities of slag were removed daily. During two weeks of continual Redux EF40 additions, starting with one pound per ton, slag and build-up was “systematically peeled from the side walls and an estimated 30 tote bins of slag build-up was removed. This restored the full useful volume to the furnaces.

After three weeks of adding Redux to each transfer ladle, the full working volume of the furnaces was restored. One month after the furnaces were treated with Redux, each furnace was taken off-line for their yearly relines and carefully examined. Foundry X found that there was no sign of refractory erosion. Now, both furnaces last 24 months. Foundry X estimates an annual savings of $250,000 in relining expenses for each furnace. A side benefit has been improved inductor electrical readings that have improved melting efficiency.

References

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