ECONOMIC CONSEQUENCES OF INSOLUBLE BUILDUP ON CORELESS MELTING EFFICIENCY

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ARTICLE TAKEAWAYS:

- Improve Coreless Induction Melting Efficiency
- Reduce Melting Electrical Costs
- Eliminate Refractory Wall Slag Buildup

Most foundries will attest that over the past 25 years, scrap quality has steadily deteriorated. Consequently, insoluble buildup and slag related problems have increased, resulting in instances of slower melting rates and inefficient furnace utilization.

The coreless induction furnace is essentially a refractory-lined vessel surrounded by an electrically energized, current-carrying, water-cooled copper coil. Electrical current in the coil induces an electromagnetic field, which magnetically "couples" with the magnetic charge, producing electrical current within the charge itself. Each piece of charge has its own internal resistance which, when energized by these internal currents, will heat up and eventually melt. The resulting magnetic field in the molten metal causes a stirring action, thus ensuring a homogenous liquid mass.

In all coreless induction furnaces, there is an "ideal" refractory wall thickness, carefully calculated by the furnace manufacturers to offer the optimum melting performance. Designed into this calculation are safety considerations, electrical characteristics of the coil, metallic charge resistance / electrical conductivity, structural and refractory considerations, operational constraints and production needs. When the furnace melt diameter is reduced by buildup, the melting process efficiency becomes compromised. The result is a reduction in the percent power utilization that causes the energy consumption to increase, which is graphically illustrated in Figure 1.

Traditionally, to remove the buildup, furnace operators are forced to mechanically scrape the lining which may also damage the refractory face. During this scraping process, the power is turned off for safety reasons.

The formation of slag during the melting of metal is an inevitable process. In a coreless induction furnace, slag residuals normally deposit along the refractory walls within or slightly above the active power coil. The composition of slag varies with the type of metal being melted. The cleanliness of the metallic charge, (often consisting of sand-encrusted gates and risers, or rust- and dirt-encrusted scrap) significantly affects the type of

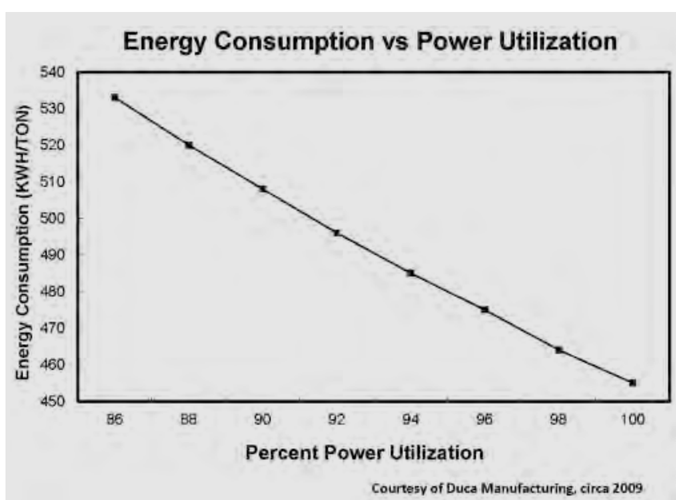

Figure 1. *Generalized Relationship between Energy Consumption (kWH/ton) and Power Utilization (1).*

slag formed during the melting operation. Because these oxides and nonmetallics are not soluble in the molten metal, they float in the liquid metal as an emulsion. This emulsion of slag particles remains stable if the molten metal is continuously agitated, the result of the magnetic stirring inherent in coreless induction melting. Until the particle size of the nonmetallic increases to the point where buoyancy effects countervail the stirring action, the particle will remain suspended. When flotation effects become great enough, nonmetallics rise to the surface of the molten metal and agglomerate as a slag. Once the nonmetallics coalesce into a floating mass on the liquid metal they can be removed. The use of a suitable flux greatly accelerates this floatation process.

When slag makes contact with an area of the refractory wall that is colder than the melting point of the slag, the cooling slag will adhere to the lining. That adhering material is called buildup. High melting point slags are especially prone to promoting buildup. If not prevented from forming or not removed early during formation, buildup will reduce the overall efficiency and capacity of the furnace.

The mineral composition of the refractory lining utilized for melting iron will almost invariably be silica. Silica constitutes a compromise between good thermal insulation, adequate mechanical impact strength to protect the coil, and good thermal shock resistance during a batch melting process.

Decreasing refractory wall thickness in a coreless furnace improves the coil efficiency and increases the effective power input. Studies have shown a substantial reduction in power consumption with decreasing thickness of the refractory lining. (2) With increasing furnace operating time and progressive refractory wear, power consumption decreased by 9% three weeks after a new lining was installed on a 3 metric ton coreless furnace. Conversely, the accumulation of insoluble slag buildup on the refractory wall will have the exact opposite effect. Not only will buildup increase the effective refractory wall thickness, but coil efficiency will decrease as shown in Figure 2.(3) As the effective refractory thickness increases from slag buildup, coil efficiency decreases and the amount of electrical energy required to melt increases (shown as the approximated percentage of rated power). The coil efficiency at the optimum lining thickness is 82% and the percentage of rated power in kW's is 100%. As the buildup thickness approaches 2.5 inches, it is estimated that an additional 25% increase in kW's will be required to melt.

A thicker effective refractory lining equates to the metal bath being further away from the coil. This results in a lower coil-power factor and lower coil efficiency that produces higher current and greater electrical losses. Insoluble slag buildup has the same effect as increasing refractory thickness. Since there are more electrical losses in the coil, there is less energy available to melt metal, so every melt will take somewhat longer than it would with a standard refractory thickness. This causes increased conductive and radiated heat losses, increasing the amount of energy consumed even further. Adding to this scenario is the overall capacity of the furnace will decrease, resulting in reduced production. (4)

Controlling buildup allows for more continuous furnace operation. Buildup can be controlled or eliminated with the addition of fluxes. It should be noted that the use of fluxes in ferrous foundries has been widely discouraged by refractory companies in the past. However, new developments in flux chemistry (Redux U.S. Patent 7,68,473) allow use in furnaces lined with even silica refractories without refractory attack. Generally, adding fluxes ensures that slags have a melting point below the coldest temperature in the system. Fluxes can help prevent slags and other insolubles from freezing on the cooler refractory surfaces. The use of a flux allows for the flotation of the emulsified oxides; it also reduces the melting point of the slag to below the lowest temperature encountered in the melting furnace and associated liquid metal handling system. An example of severe buildup in a coreless furnace is shown in Figure 3.

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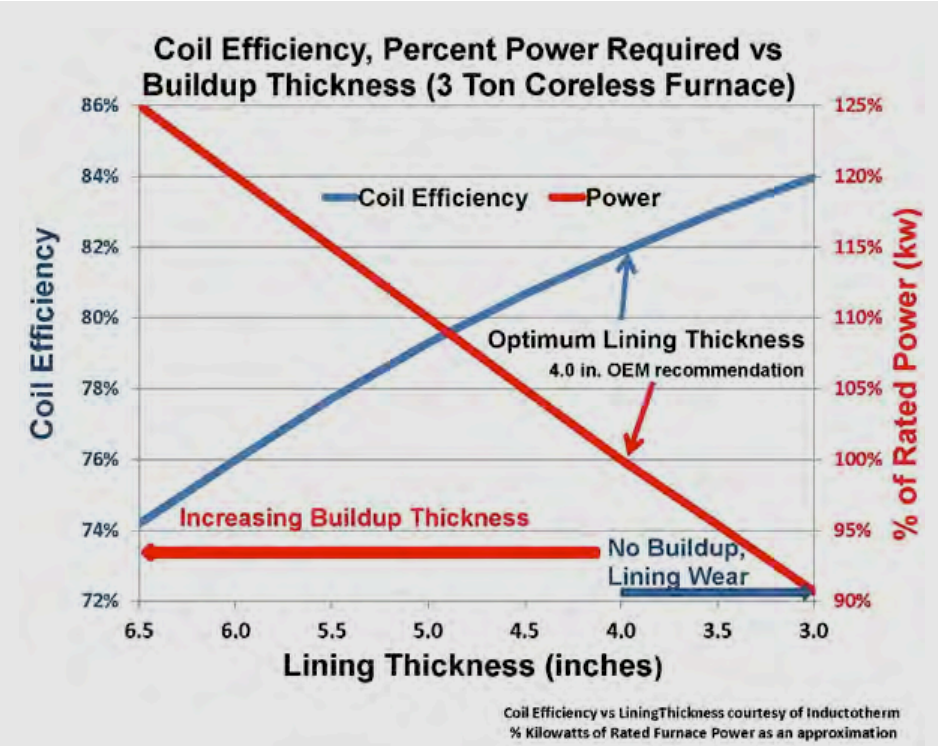

Figure 2.
Effect of Lining Thickness on Coil Efficiency and Percentage of Power Requirements for a 3 ton coreless induction furnace.

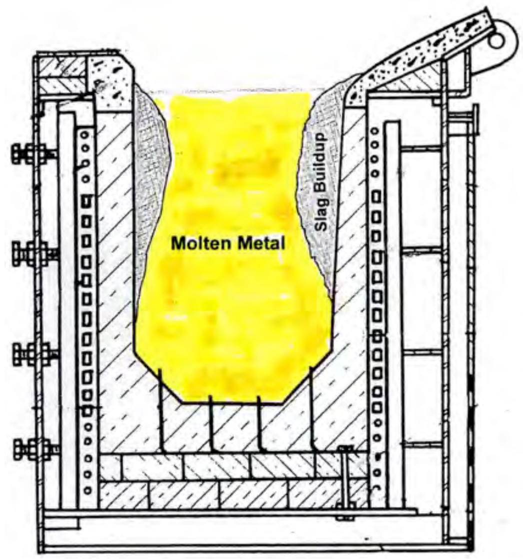

Figure 3.
Typical Slag Build Up in a Coreless Induction Furnace.

Figure 4.
Insoluble buildup removed from Foundry G's coreless induction furnace after 48 hours of operation.

Improper use of fluxes can rapidly erode refractory furnace linings, especially if potent fluorspar-based fluxes are used. However, if a flux is carefully engineered for specific applications and used properly, refractory life may actually increase. Some foundries using specialty fluxes have reported increased refractory life. One large foundry significantly increased lining life from 11 months to 26 months solely by incorporating Redux EF40 in their operation. Refractory life can also be extended by reduced damage due to mechanical chipping required to remove tenacious slag deposits. Elimination of buildup optimizes power utilization, thereby reducing energy consumption.

The following example illustrates how flux additions can improve melting efficiency. Foundry G is a medium sized foundry that manufactures gray iron castings. The foundry has historically experienced extensive slag buildup on the upper sidewalls of its four 3-ton medium frequency coreless induction furnaces in a semi-batch melting operation. With a newly installed lining, melting capacity is 1,525 tons per month with 2 furnaces running 5 days a week, 21 days per month.

Foundry G's charge consisted of 100% metallic fines and machining chips. Each coreless furnace is lined with a silica based dry vibratable refractory. During melting, slag generation and accompanying buildup immediately reduced furnace capacity and contributed to increased power consumption. After 48 hours of operation, three inches of buildup occurred along the entire sidewall. (see Figure 4)

Foundry G initially incorporated 2 pounds of Redux EF40L flux per ton of charge, added to each back-charge to determine its effect on buildup. EF40L was added to the furnace before back charging on top of existing molten metal to ensure excellent mixing, (a minimum 50% molten metal bath). Immediate improvements were observed and buildup along the sidewalls was essentially eliminated. Since the optimum refractory thickness is maintained, it is estimated that the power utilization increased by 25% compared to pre-buildup days.

Energy savings have been estimated to approach $14.4K a month or $174K per year based on electrical usage of 550 kW/ton and an electrical rate of $0.069 per kilowatt resulting from the percentage of rated power reduced by 25% (125% with buildup compared to 100% with no buildup).

Foundry G observed the following benefits by using Redux on a continuous basis:

- Using Redux EF40 has reduced charging hang up issues due to cleaner refractory walls
- Reduced power consumption during each melt
- Hourly maintenance from scraping was greatly reduced
- Consistent furnace capacities: Furnace capacity was reduced by 0.95 tons (28.7%) when slag built up to 3 inches thick
- Improved "electrical coupling" was observed with improved temperature control
- No adverse effects on the dry vibratable silica refractory linings
- Estimated electrical savings of $174,000 annually.

In summary, insoluble buildup and slag related problems have become serious issues for today's foundry operations. These problems will likely only increase as the quality of scrap continues to deteriorate. However, using fluxes properly can help alleviate these challenges while increasing melting efficiency and saving foundries time, electricity, and most importantly, improve profitability.

References:

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