Changing fashions in the crown jewel of the modern glass furnace

As glass manufacturers worldwide experiment with hydrogen, biofuels, electric and hybrid melting to meet sustainability targets, the full effects of these new melting techniques on existing furnace crowns are not yet understood. Fused-cast refractory supplier Monofrax is adapting to the challenges presented by these new technologies, says Valerie Weber.

While glass furnace crowns may not sparkle with the precious metals and gems of a monarch's head covering, they are impressive. There is no denying that they are marvels of chemistry, physics and engineering.

Over the years, crowns have been composed of many different refractory materials: pressed and bonded (silica, mullite, AZS, chrome-alumina) and fused cast (AZS, alumina and spinel). Chemistry, grain structure, density, furnace span and longevity all come into play. To complicate matters further, glass composition, temperature, quality and the severity of batch dusting are also variables when deciding upon the materials for a furnace crown. Silica has been a popular choice, but there is no one-size-fits-all.

Crown refractories must also exhibit sufficient mechanical strength over a range of operating temperatures and provide resistance to creep. To those unfamiliar with the term, creep resistance is the ability to withstand long-term load at high temperatures without failure. The crown span, insulation pack dimensions and density of the products used in construction determine the load. Peak loading occurs during heat-up, and the load then redistributes once the furnace reaches service temperature.


View of crown blocks set for floor inspection.

Changing crown requirements

In the 1990s, many furnaces converted from air-fuel to oxy-fuel, and crown requirements changed. Manufacturers benefited from reduced NOx and SOx emissions, reduced particulate carryover, improved glass quality and higher throughput. Existing crowns comprised of silica and mullite were exposed to more corrosive conditions, causing these crowns to experience rapid and premature deterioration and contamination of the glass product. Typical degradation included:

- Corrosion at the refractory joints
- Rat holing (formation of large voids within the blocks)
- Hot face corrosion.

This new breed of oxy-fuel furnaces produced an increased concentration of volatile, corrosive species above the glass melt. Due to their higher porosity levels, porous pressed and fired refractories degraded more than fused cast refractories. However, fused cast AZS also experienced accelerated corrosion under oxy-fuel conditions. As a result of exudation in fused AZS, ZrO_2 crystals contaminated the glass. Silica-based refractories proved to be especially vulnerable to wear due to liquid phase formation. Fortunately, there have been successes with low exudation fused AZS and fused alumina crowns.

αβ-alumina

Studies show fused αβ-alumina to be the most stable crown refractory under oxy-fuel conditions, displaying superior corrosion resistance. High alkali glass melts (more than 26% Na_2O) benefit from fused β-alumina. As a result, specialty, float and container glass furnaces in North America have used fused αβ-alumina for their oxy-fuel furnace crowns for decades. At least one fused αβ-alumina crown is over 21 years old and on its second campaign.

With experience, much has been learned about the construction and behaviour of fused alumina refractories in crowns. Today, manufacturers recommend the use of void-free castings for large span crowns to eliminate the void cavity. At temperature, the area toward the cold face of the block carries most of the load. Large cold face voids result in a shortened life span and more furnace campaign interruptions.

Floor assembly

As dramatic and impressive as a crown looks when sprung, floor inspection allows for a more thorough and accurate evaluation of the blocks. Preassembly in rings on the floor results in a better fitting crown. It also proves to be more cost-effective for both the customer and the supplier.

When a preassembly is sprung, as the building progresses, minute adjustments are made to the minor faces to provide a planed surface between rings. Two objectives drive these adjustments.

1. The levelling of the block can create a slight out of plumb condition on the vertical face.
2. If one end of the block runs up the centre slightly faster than the other end, 'saw toothing' results. If this isn't taken care of immediately in preassembly, it multiplies.

The tendency is to make small adjustments to the minor face of the block to correct and create a plane surface for ring-to-ring fit. This is not the best approach.

With floor assembly, the critical plane surfaces between rings can be controlled to a much greater degree. Blocks remain square. Field construction results are improved. Building with adjusted blocks creates difficulties for the construction crew. Floor assembly results in a better-fitted crown.

Advanced coatings

In the 1990s, when glass manufacturers were converting to oxy-fuel, NASA was developing thermal protection systems for high-speed space planes. Their research included the high emissivity coatings used as standalone replacements to the failed ceramic cladding of the space shuttle. A decade later, those coatings were made available to the glass industry through a licensing agreement. Applied to the interior of a furnace crown, products such as Emisshield resulted in significant energy savings. Over the years, high emissivity coatings have been used on various glass crowns, resulting in an average fuel savings of 7.5–10%. High emissivity coatings are currently being used on crowns for wool, container and flat glass furnaces worldwide. Now, when many in the glass industry aim to reduce their carbon footprint and their energy consumption and strive toward carbon neutrality, these coatings offer another tool for their arsenal.

Future challenges

Over the last 30 years, the glass industry has evolved to meet the demands of consumers and the planet. First came the advent of oxy-fuel. Then, manufacturers implemented high emissivity coatings. Now, glass manufacturers worldwide are experimenting with hydrogen, biofuels, electric and hybrid melting to further reduce energy consumption, operating costs and carbon production. Sustainability, both economic and environmental, is the new goal.

The effects of these new melting techniques on existing furnace crowns are not yet understood. From preliminary findings, refractories may face challenges similar to those presented by the advent of oxy-fuel. Unconsumed hydrogen appears to attack any free silica in refractories. Silica bonded with alumina seems to be less attractive to this hydrogen. Refractories in the crown and elsewhere in the furnace will need to adapt to the challenges presented by these new technologies. The future may prove to be very interesting. ●

Crown blocks sprung on steel supports for customer inspection.

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