

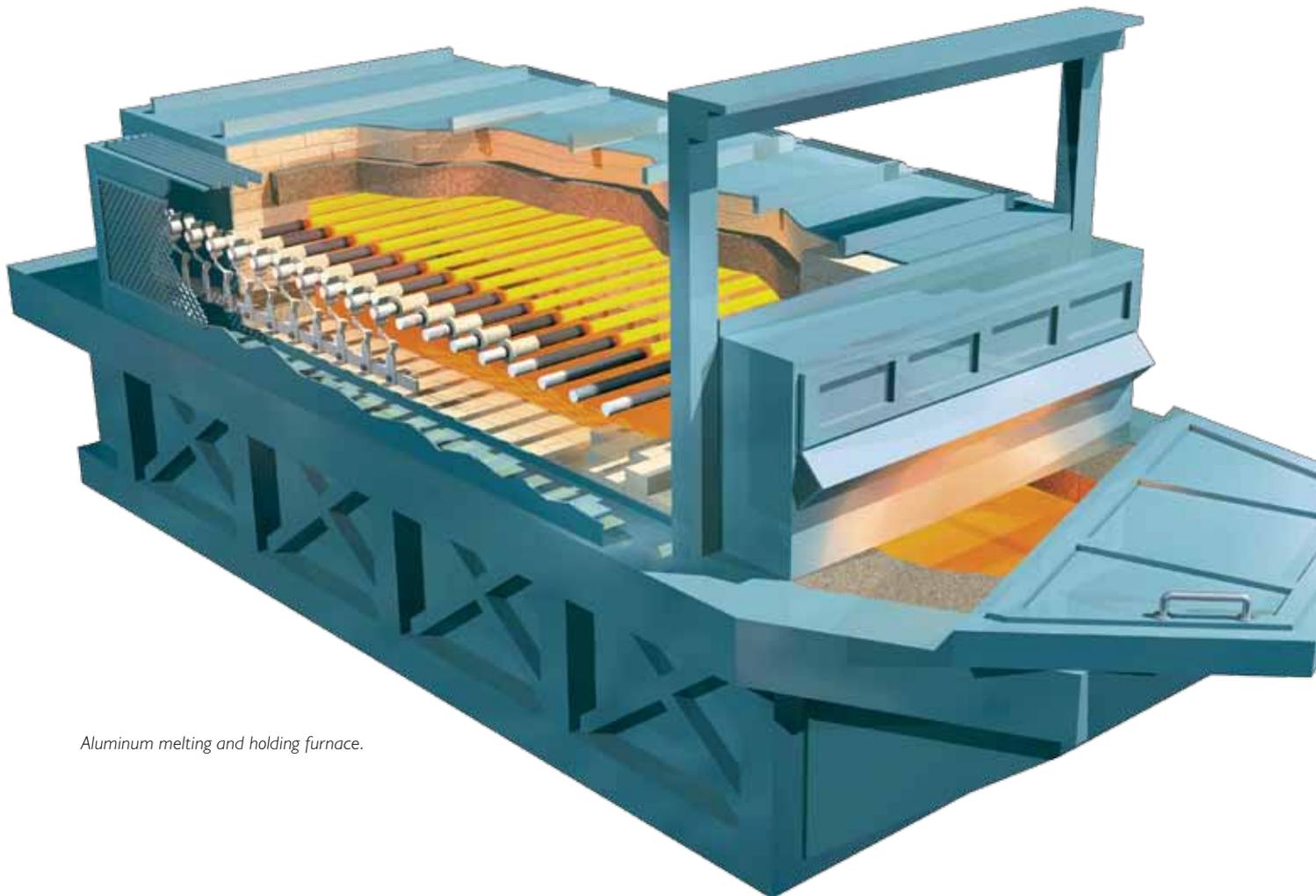
Kanthal® Globalbar® SDA elements

Element life improvement in electric aluminum reverberatory furnaces

Electric wet-bath holding and melting furnaces using silicon carbide (SiC) elements have been in common use for over 50 years, and the design has changed only in detail since their inception. Generally speaking, the furnaces will vary in capacity from a few pounds to several tones, with rated power from below 10kW to an upper limit of around 1MW. However, the majority of industrial units range in output from 100–400kW.

Furnaces are heated by an array of silicon carbide heating elements, installed horizontally across the width of the roof, and these radiate directly on to the metal surface, or re-radiate from the roof or walls of the furnace, to transfer energy to the melt.

The electric reverberatory furnace typically is multi-functional, and many units spend the majority of their use in holding metal that has been melted, alloyed and de-gassed elsewhere. The primary function in that case is simply to maintain the metal at temperature and maintain a supply of clean metal to the foundry. Where the furnaces are used for melting, then higher temperatures are of course required, thus increasing the demands on the heating elements.



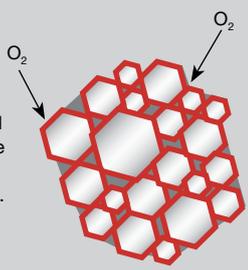
Aluminum melting and holding furnace.

Element failure mode

Experience has shown that elements used in holding applications can have very long lives, usually measured in years. The operating temperature of the elements is relatively low, typically below 980°C (1800°F) and if the metal is clean, and if fluxing is not carried out in the bath, then the elements will simply degrade slowly, due to the effects of oxidation.

Passive oxidation
 $2\text{SiC} + 3\text{O}_2 \rightarrow 2\text{SiO}_2 + 2\text{CO}$

The SiO_2 layer is protective, and oxygen from the air must diffuse through the silica layer before further oxidation can take place. This limits the oxidation rate



This oxidation results in the well documented “ageing” of silicon carbide elements, where silicon carbide oxidizes to silica, and the resistance of the elements increases with time. The silica formed acts as protection to the silicon carbide substrate, by coating the grains with an amorphous silica film, and the process is termed “passive oxidation” due to the protective nature of the oxidation product. In melting furnaces, the same rules apply, but the rate of oxidation will be higher, due to the higher operating temperature of the elements.

Attack mechanisms

Element life may be reduced by several factors in the operation of the furnace, the key ones being mechanical damage, caused by operators or by corundum growth,

incorrect operation and chemical attack. Clearly, the quality and performance of the heating elements becomes irrelevant where mechanical damage or misuse are the primary causes of failure, and steps must be taken to correct the cause of breakage. Mechanical breakage can be reduced by careful selection of the refractory lining, to minimize or eliminate growth of corundum, which can result in element breakage by growing on to the elements or into the lead-through holes, or by attempts by operators to remove the corundum mechanically, resulting in shock or impact to the elements.

If it is assumed that the elements are operated according to the manufacturer’s recommendations, and that steps are taken to prevent accidental breakage, then chemical attack then becomes the primary factor that affects element life. This attack stems from the use of aggressive fluxes in the melt, and these are likely to comprise salts of alkali metals, such as sodium (Na), potassium (K), calcium (Ca), etc. Vapors from these salts, which will melt on the metals surface, or on any surface on which they are deposited within the furnace interior, are transferred easily to the elements by convection, and splashing of the metal, when charging, or due to the use of dirty scrap, etc., will bring these materials into contact with the elements.

Molten aluminum will not wet silicon carbide, but the addition of the flux components allows the molten metal to stick to the elements, potentially leading to electrical problems, and containing the flux contamination on the element surface, where it continues to attack the element structure. The contaminants degrade the elements indirectly, and do not react directly with the silicon carbide from which the heating section is manufactured. Attack generally is on the silica, the product of oxidation of silicon carbide, and such attack can damage or destroy the protection afforded by the silica layer.



Conventional SiC element with eroded element surface.

Typically, the glasses formed will be liquid when the elements are energized, and they will drip readily from the surface, exposing the elements to further oxidation, by stripping away the protective layer. Localized attack can lead to localized hot spots, where the element resistance increases disproportionately in the area of attack. The hot spot clearly operates at a higher temperature than the bulk of the hot zone, and degrades more rapidly, often leading to crack formation, or erosion of the element surface, as shown below.

Kanthal® Global® SDA elements, improved resistance to chemical attack

Kanthal Global SDA elements work on three fronts to resist this kind of attack:

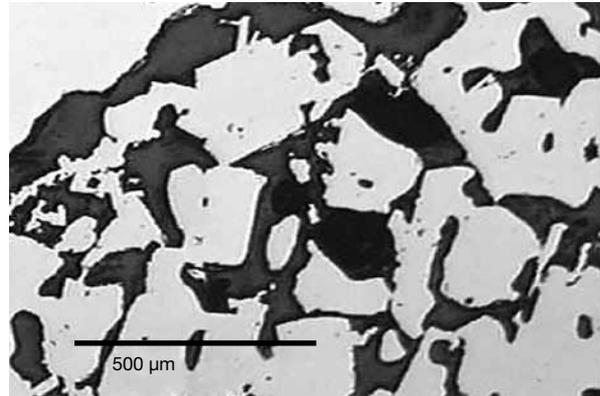
1. The hot zone material is formulated to resist oxidation, by utilizing advanced recrystallization techniques, and low surface area technology.
2. The elements are protected with a complex silicate 'A' glaze which further reduces oxidation rates, and combines with alkali materials to create a glass with a higher melting point, that is less likely to drip off.
3. The protective glaze is highly resistant to water vapor, present in new and relined furnaces, that would otherwise result in major oxidation of the silicon carbide, water vapor being far more aggressive to SiC than dry air. As the attack mechanism is on the silica and not on the SiC, then reducing oxidation rates directly affects the rate of attack by transferred flux components. Additionally, the protective nature of the glaze to alkali attack reduces the rate of degradation, and extends the life of the elements.

Experience

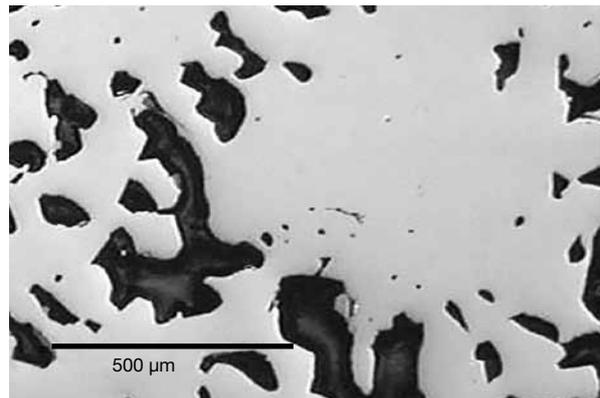
Three similar furnaces, in Japan, Spain and Portugal, were fitted with conventional SiC elements, and short lives, of six months or less, was experienced. In all three cases, the elements demonstrated classic signs of alkali attack, where the protective silica coating had become contaminated with alkali metal oxides or salts, which combined with silica to form glassy materials. The attack was worst at the charging end, where liquid flux was transferred directly to the element surface by splashing, and the use of Kanthal Global SDA glazed elements resulted in an increased life of between 25 and 100%.

In the worst affected case, average life was increased from three to six months, leading to major savings not only on element costs, but also on furnace maintenance. Steps were also taken to minimize the excessive use of fluxing materials, and greater care was taken to direct the fluxes away from the elements.

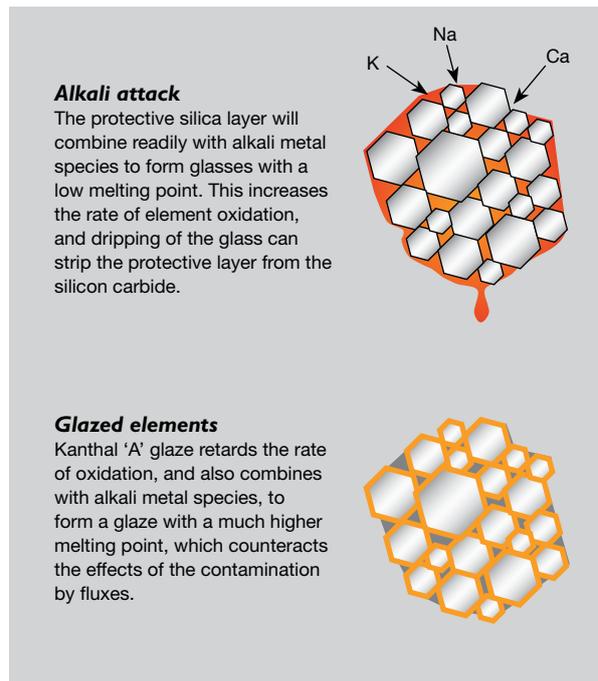
Kanthal Global SDA elements are recommended for all electric reverberatory furnace where fluxes are used, and further details are available from Sandvik.



Conventional SiC element.



Kanthal Global SD element.



Shows alkali attack and glazed element.

Sandvik Group

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