

ceramicx		Technical Report			C <sup>2</sup> I <sup>2</sup>	
Title:	CCII 00014 Aluminised and Stainless Steel Discolouration				Full Report	
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## Introduction

This report presents two investigations measuring discolouration on the steels used for making quartz cassettes, aluminised steel and stainless steel. It shows results of furnace tests on stainless steel samples and also includes supporting material from a previous investigation into aluminium clad steel.

## Results and Discussion

Aluminised and stainless steel quartz bodies can suffer from discolouration and subsequent increase in emissivity with a decrease in reflective properties. In a stainless steel quartz heater, this discolouration can begin early in the product lifetime depending on the wattage of the quartz tubes within the cassette, and also depending on the operating environment temperature (see Figure 1). In this trial, twelve samples of stainless steel were placed in an electric thermostatically controlled kiln and allowed to soak for 30 minutes at temperatures ranging from 150°C to 600°C. Images of the samples after heating are shown in Figure 2 and Figure 3, one using camera flash, the other no flash.



Figure 1: Discoloured stainless steel body,

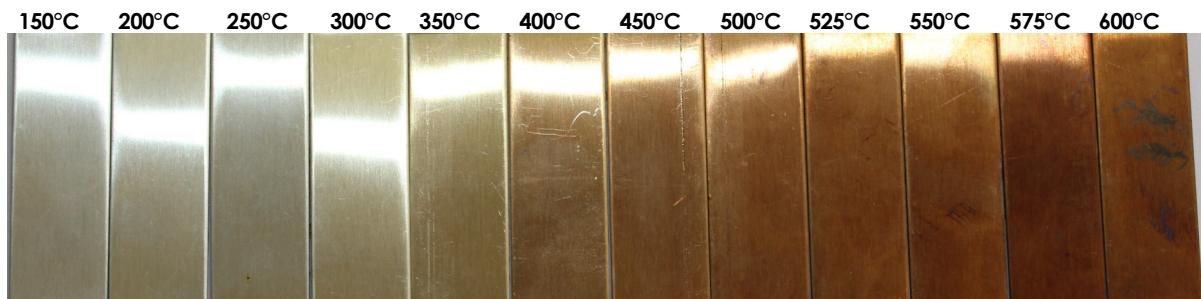


Figure 2: Discolouration of stainless steel from 150°C to 600°C. With flash

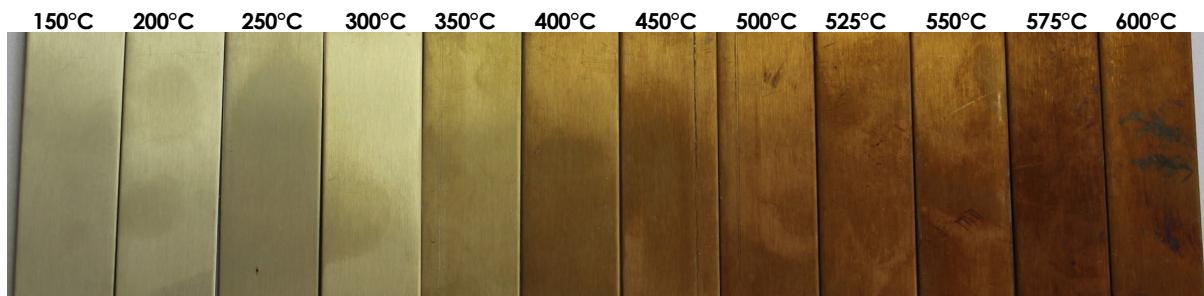


Figure 3: Discolouration of stainless steel from 150°C to 600°C. No flash.

Below temperatures of 350°C the stainless steels retain their shiny and mostly silvery hue. Some light browning is apparent as temperatures increase to 350°C after which the surface begins to darken noticeably. As a guide, a table from the BSSA (British Stainless Steel Association) is shown in Table 1 which lists typical oxide colours. However, the guide does stress that colour will vary depending on time exposed and environment, especially oxygen content. The blue colours mentioned in Table 1 did not occur on this series of kiln tests.

Table 1: BSSA guide for oxide colours on AISI 304 grade stainless steel

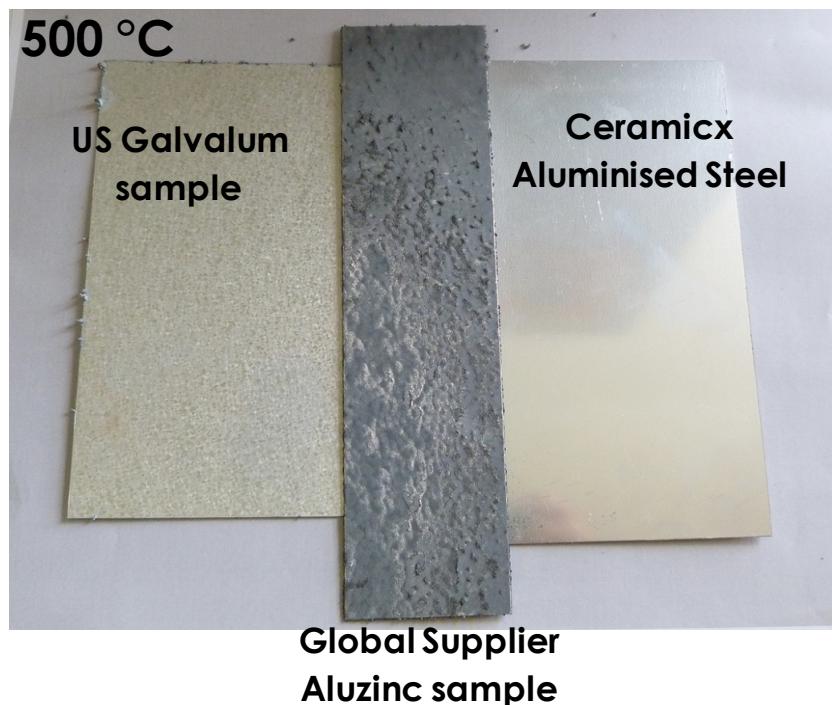
Colour Formed	Approx Temperature °C
pale yellow	290
straw yellow	340
dark yellow	370
brown	390
purple brown	420
dark purple	450
blue	540
dark blue	600

As temperature increases, emissivity of the steel will also increase. This results in the steel absorbing more infrared and heating up more which then compounds the oxidation process. As the discoloured body will absorb radiation from the heater tubes and re-emit this from the rear of the cassette, the use of a reflector is recommended when using stainless steel bodies.

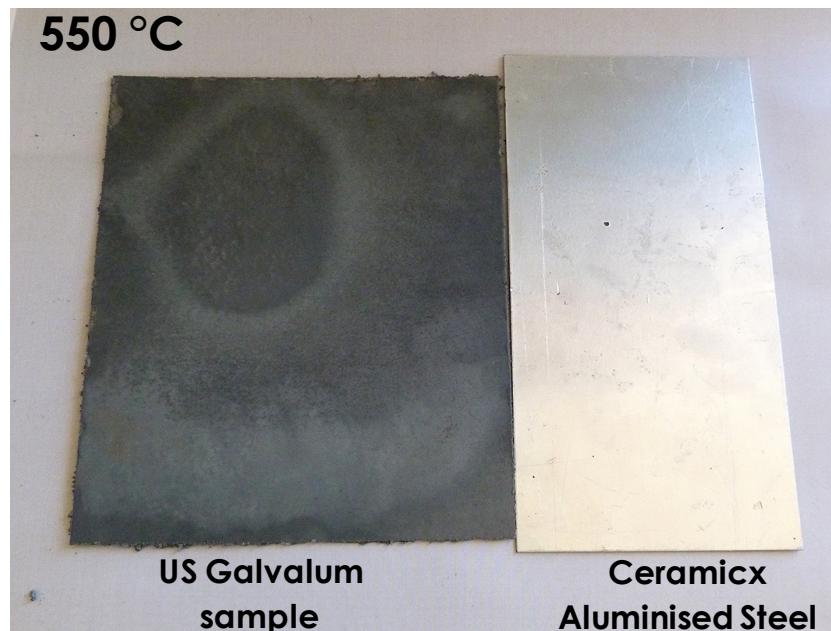
**Previous study comparing aluminised steels and galvalum/aluzinc coated steels.**

This study was performed to clarify the heat resistance of an aluminised steel quartz cassette to high operating temperatures, and the subsequent blackening or de-lamination of the body. The body of competitor quartz cassettes was thought to be made from Galvalum or Aluzinc material and this was also compared in the tests. However, from observation it appears this material is likely an Aluminised steel. In order to assess Galvalum/Aluzinc material, samples were taken from US and Global suppliers and tested against the Aluminised steel currently used by Ceramicx.

Figure 4 shows how the materials behaved at 500°C. The Aluzinc sample from the global supplier deteriorated totally, becoming totally black. The Galvalum sample from the US supplier is beginning to show enlarged grain growth at this temperature. The Ceramicx aluminised steel remains clear and unaffected by the temperature.



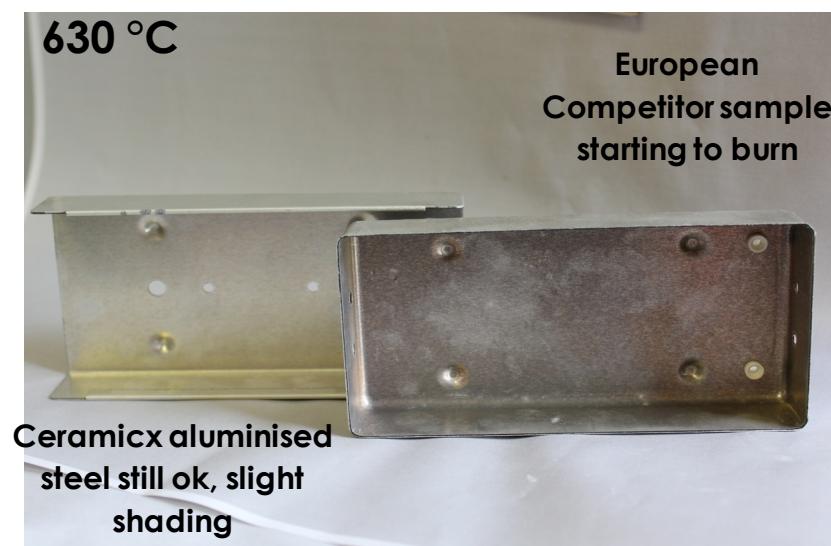
**Figure 4:** Samples of US Supplier Galvalum, Global Supplier Aluzinc and present supplier Ceramicx Aluminised Steel after heating to 500°C.



**Figure 5: Samples of US Supplier Galvalum and present supplier Ceramicx Aluminised Steel after heating to 550°C**

As can be seen from the attached photo in Figure 5, the US Galvalum materials deteriorated after reaching 550 °C (1 hour soak) in the test kiln. By contrast the Ceramicx aluminised steel is still in good condition.

Finally the European competitor body and the Ceramicx equivalent quartz body were placed in the kiln at 600 °C and allowed to soak for 1 hour. They were then checked for degradation and replaced and the temperature increased by 10°C. Both samples showed no surface degradation at 600°C, 610°C and 620°C. At 630°C the European competitor body began to degrade while the Ceramicx body showed only slight discolouring. The degradation of the competitor body and the yellowing of the Ceramicx element is visible in Figure 6.



**Figure 6: Ceramicx and Competitor bodies after a temperature of 630°C**

From this assessment it can be concluded that both Ceramicx and Competitor bodies are of a similar material (Aluminised steel) and both are stable up to 620°C. The Ceramicx body has an advantage at 630°C showing little or no breakdown where the competitor body has already begun to break down. Both bodies fail at 640°C showing large darkening of the aluminium surface. The Ceramicx body does not degrade at lower temperatures than the competitor body; in fact the opposite appears to be true albeit over a very small temperature range.

### **Summary**

Stainless steel progressively changes colour with temperature due to oxides forming on its surface. Darkening and colour change becomes significant above 350°C. As the emissivity of the oxidised surface decreases, heat is radiated from the rear of the cassette. A reflector is recommended to reflect this energy from the rear of the cassette.

The Aluminised steel as currently used by Ceramicx in its quartz cassettes resists degradation up to a temperature of 630°C, around 10°C more than the competitor body. As the material surface remains a good reflector, use of an additional reflector is not necessary for aluminised steel. Galvalum and Aluzinc type coatings degrade at much lower temperatures and consequently are not used by Ceramicx.

The choice between stainless steel or aluminised steel is often down to operating environment, especially if corrosion is a concern. Contact Ceramicx where we will be happy to advise.