TITLE

Thermal performance of Aluminised Steel: Ceramicx vs competitor

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CERAMICX CENTRE FOR
INFRARED INNOVATION

Contents

Introduction

The following report details investigations into the degradation and performance of Ceramicx's aluminised steel material used in the body of quartz medium cassette heaters and a leading competitor's material.

Both materials were formed into the shape of Ceramicx FQE cassette body using Ceramicx standard, propriety forming process. These bodies were then assembled into fully formed quartz cassette heaters complete with 7 quartz glass tubes, ceramic end caps and stainless steel clinch studs. Each element was wired with a 1kW electrical resistance coil. The only difference between the two heaters was the embedded type K (t/cK) thermocouple in the Ceramicx heater.

Materials

Ceramicx aluminised steel material is aluminium clad steel strip with 5% aluminium on both sides. Once side is highly polished while the other remains a 'mill finish'. The competitor's material is identical in all respects except that both surfaces have a 'mill finish'

Method

Material durability

The durability of the aluminised steel was tested by placing it in a small furnace and increasing the temperature in a series of ramps and dwells. Both heaters were placed in a small furnace with the same orientation. The temperature dwell times used are set out in Table 1, below.

Table 1: Temperature dwell times for experiment

Temperature (°C)	Dwell time (hrs)
500	8
550	15
600	8
605	15

At the end of the test, the elements were removed and allowed to cool at room temperature.

Infrared output performance

The performance of each material was analysed using the Herschel infrared heat flux routine. Three instances of each heater were analysed four times to eliminate experimental and atmospheric variations.

Ceramicx Herschel heat flux robot examines the total heat flux ($W.cm^{-2}$) which is incident on the sensor. Heaters can be mounted in the Herschel and analysed using the 3D Infrared heat flux mapping routine. This automated system uses an infra-red sensor that is robotically guided around a pre-determined coordinate grid system in front of the heater emitter under test. The sensor has a maximum heat flux level of 2.3 $W.cm^{-2}$ and measures IR in the band

0.4-10 micrometres. The coordinate system is a 500mm cubic grid in front of the heating emitter, see Figure 1. The robot moves the sensor in 25mm increments along a serpentine path in the *X*- and *Z*- directions, while the heating emitter is mounted on a slide carriage which increments in 50mm steps along the *Y*- direction.

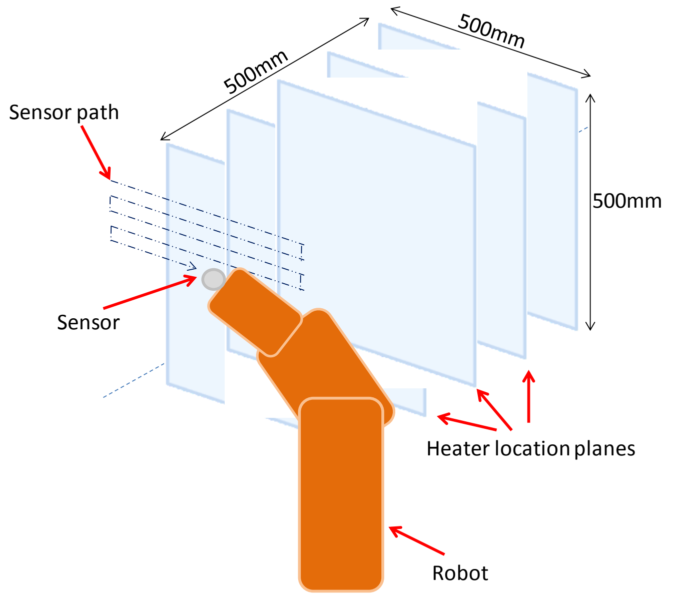


Figure 1: Schematic of measuring grid showing sensor path and planes of heater emitter location.

The results from the machine can be correlated into a percentage of total energy consumed returned as radiant heat flux from the heater. This decreases with distance from the heater as the radiant heat flux diverges from the heater.

Results

The stainless steel clinch studs discolour during normal operation and during the oven test, there was no deviation in this. The polished surface of Ceramicx's aluminised steel becomes duller as temperature increases and during normal operation. Below 600^{o}C and in the time periods used, no change was observed in the appearance of the aluminised steel body beyond that of normal operation in the atmosphere.

The temperature increase to 605^{o}C gave a marked change in the appearance of the materials as shown in Figure 2, below. This clearly shows two effects:

1. The discolouration of the clinch studs at either end of the cassette
2. The difference in the appearance of the aluminised steel material

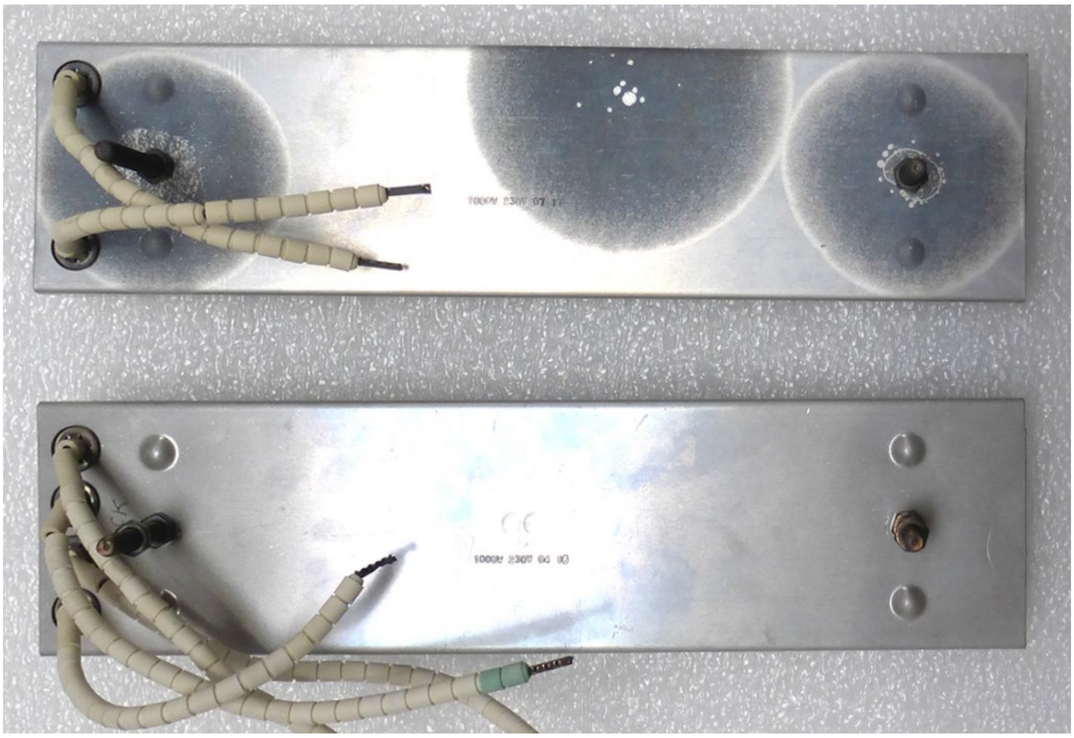


Figure 2: Difference in the back surface of the two FQE bodies (competitor - above, Ceramicx - below) after cooling to room temperature

The circular pattern, shown on the surface of the competitor's material, is repeated on the internal surface end-caps which is in contact with the back material. No obvious difference in the appearance of Ceramicx's material was found following the test procedure.

While the competitor's material shows a discolouration in the aluminised steel material at 605^{o}C, no change was observed in this material during operation in an open environment over a two week period (366+ hrs operation).

Heater performance

The performance of the two heaters was analysed using The Herschel's heat flux sensor. This showed, over 4 iterations that the performance of the competitor's body material, when formed into Ceramicx shape, the average peak heat flux output is detailed in Table 2, below

Table 2: Average peak heat flux and error for Ceramicx and the competitor's elements

	Competitor	Ceramicx
Element 1	0.9401±0.0025	0.9501±0.0034
Element 2	0.9405±0.0036	
Element 3	0.9352±0.0013	

This analysis shows that the peak heat flux emanating from the heater, for both the competitor's material and Ceramicx material is broadly similar. A statistical difference between competitor's element 3 and the Ceramicx element is seen. The peak output figures for this element were consistently lower and may be a result of coil variance.

The percentage energy returned as radiation at 100mm can be calculated from the Herschel data. The average figure for each element is shown in Table 3, below.

Table 3: Average percentage heat flux and associated error for Ceramicx and competitor's heaters

	Competitor	Ceramicx
Element 1	53.26±0.30	53.44±0.45
Element 2	53.04±0.67	
Element 3	53.17±0.24	

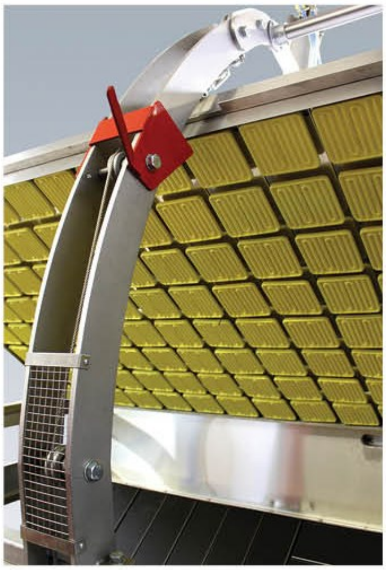
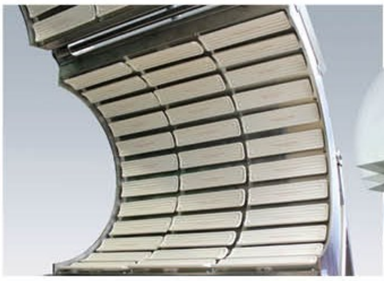
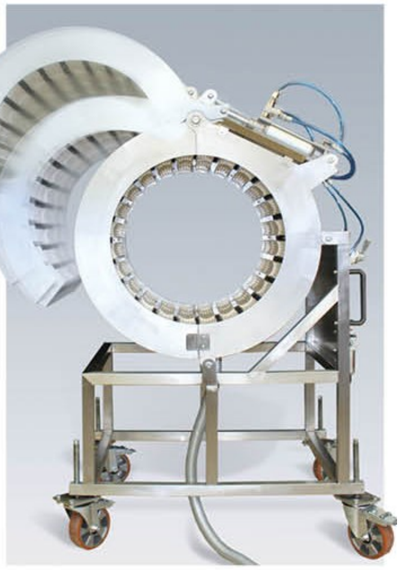
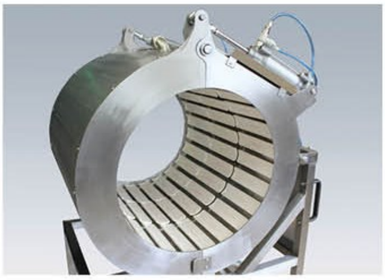
This shows that during general operation, Ceramicx material shows statistically identical performance characteristics to that of the competitor's material. Table 3 shows that, for competitor's element 3, the percentage energy returned as radiant heat flux is not influenced by the drop in peak heat flux for this element.

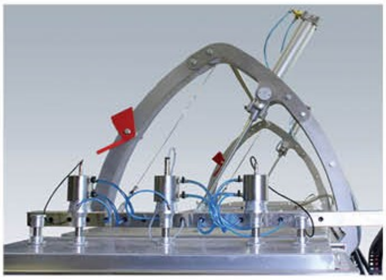
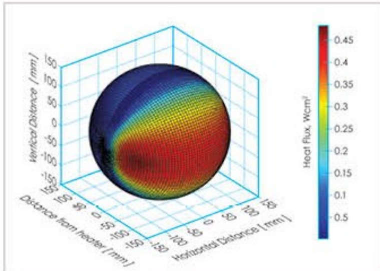
Conclusion

The exact reasons for the material degradation differences are unknown; however, this analysis shows that at elevated temperatures, the durability of the aluminised steel material used by Ceramicx is superior to that used by a leading competitor. The influence of the surface polishing of the Ceramicx material cannot be discounted, however quite how this influences the thermal durability is unknown.

The radiant performance of the elements made from the different materials is broadly identical and very consistent as indicated by the close grouping of the heat flux values.

Disclaimer



Vertical Distance [mm]
Distance from heater [mm]
Horizontal Distance [mm]
Heat Flux, Wcm²
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.5