IAMFTF: Airbus VFP presentation 23092024

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Agenda

- **Airbus presentation 2023**
- **Heat flux mapping**
  - Mapping (“gradient”) of different VFPs in Airbus laboratory
  - Normalization of heat flux mapping from experiments and from theory
- **Temperature distribution mapping**
  - Aluminium plates painted with high emissivity paint and temperature visualized with IR thermal camera for both VFP1 and VFP2
- **Heater shape study**

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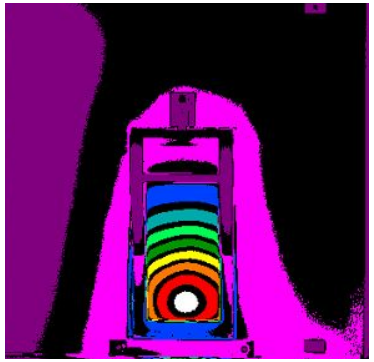
Introduction

- In 2023, Airbus presented a study that showed the state of its two VFP machines (Marlin, Deatak)
  - Non-conformances to dimensions laid out in the Handbook draft
  - Manufacturing issues (e.g. fitting the door to the frame)
  - Burners out of spec and corroding
  - Heaters out of spec (deformed) and failing after a relatively short use time
  - MFC calibration: analogue vs digital → calibration still unclear for digital MFCs

- Furthermore, Airbus proposed tightening the specifications in the Handbook
  - Tolerances
  - Window positions
  - Harmonisation of HF gauge fitting
- Airbus also presented two approaches to quantitatively compare the output of the heaters
  - Melt patterns on polyethylene foam
  - IR camera images of thin aluminum plates subjected to the heaters' radiation



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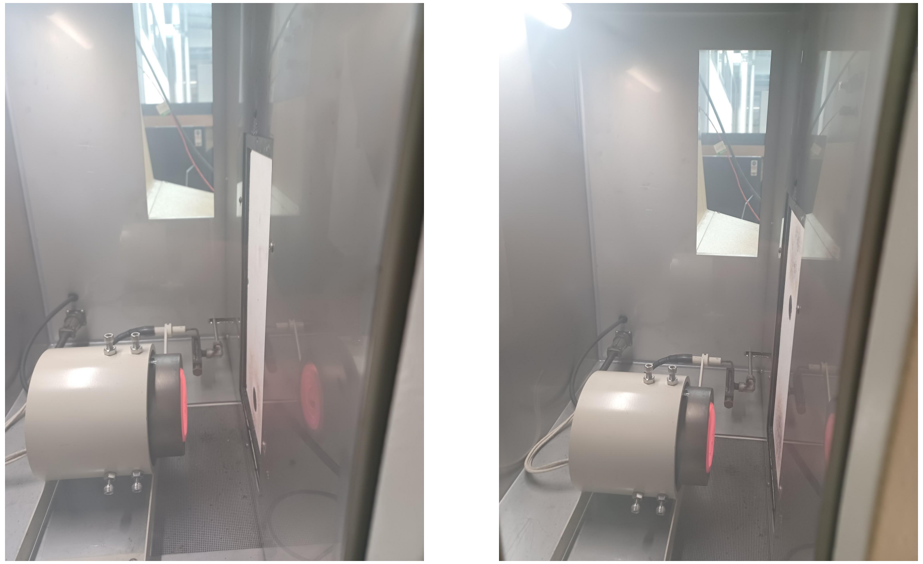
Heat flux mapping

Heat flux mapping

- **Methodology**
  - VFP1 (ME) and VFP2 (Deatek) are initially calibrated at the original position within the target 1.8 ± 0.05 W cm^{-2}
  - The heat flux mapping is followed as indicated by FAA. For each position, the gauge remains 300 s in position until stabilization and then data recorded and the mean value determined during the next 300 s.



Gardon gauge inserted in different position for the heat flux mapping in VFP1.

- **The objective is to identify…**
  - Variability in results from same type of heater in different VFP benches (VFP1 and VFP2).
  - Whether the requirement shall be recommended to be expressed in absolute or normalised terms.
  - Whether the type of insulation may affect the gradient reading significantly.

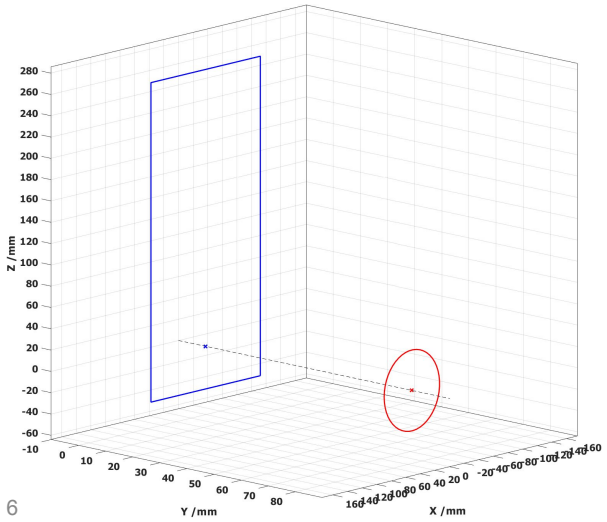
Gardon gauge inserted in a refractory standard board (left) and a Superwool board (right).

Heat flux mapping

Feasibility assessment for a “simple” theoretical approach for tolerance definition

- In addition to the empirical determination of heat fluxes using a Gardon gauge in VFP1&2, a **theoretical approach is applied to identify the trend of radiative heat flux on the sample**.
- The approach consists of determining the view factor (F) between two surfaces and assume (i) a constant temperature of both heater and sample and (ii) a negligible convection.
- These assumptions allow using the **view factor as a surrogate variable to compare the heat flux distribution** with experiments after normalization with the maximum value (original position).

$$\dot{q}''_{tot} = \dot{q}''_{rad} + \dot{q}''_{conv} = \epsilon \cdot F \cdot \left(T^4_{heater} - T^4_{sample}\right) + h_c(T_{gas} - T_{sample})$$



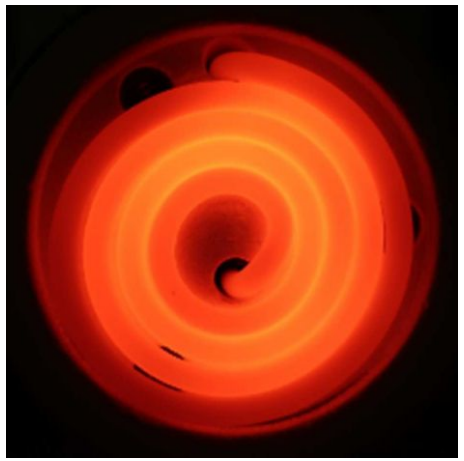
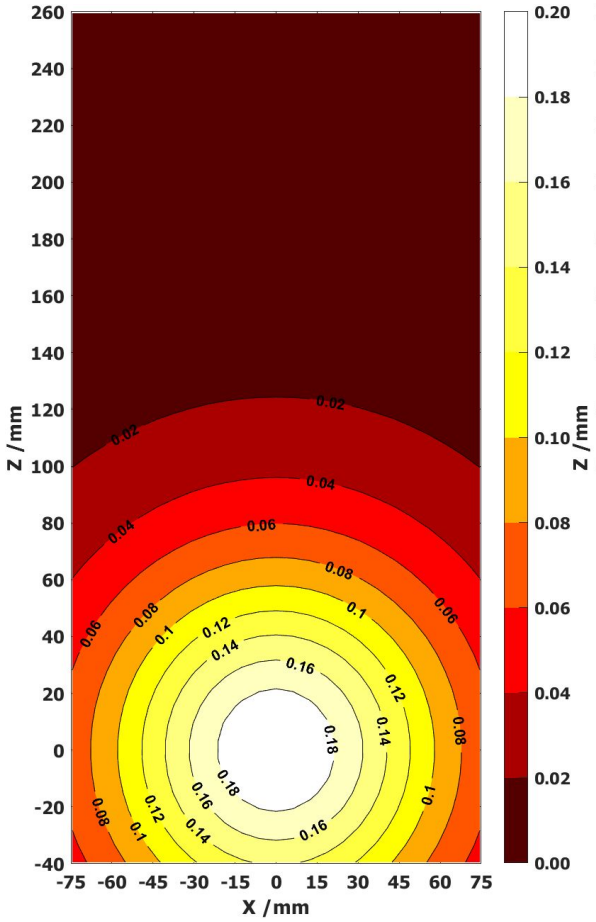
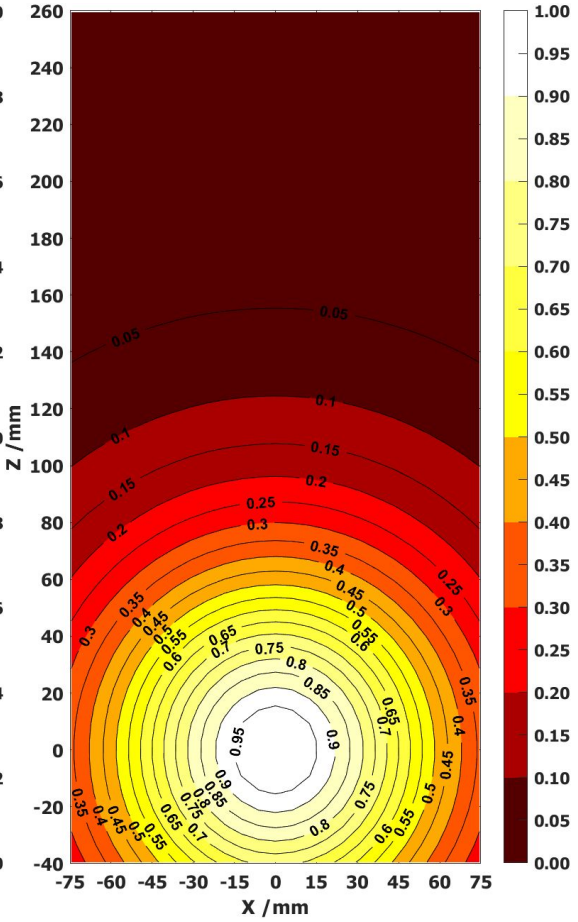


Image of actual heater showing not uniform temperature over the circle shape



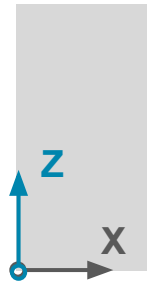
View factor distribution (F) between a 300 mm x 150 mm plate (blue) and a circular heater of 76 radius horizontally separated 76 mm



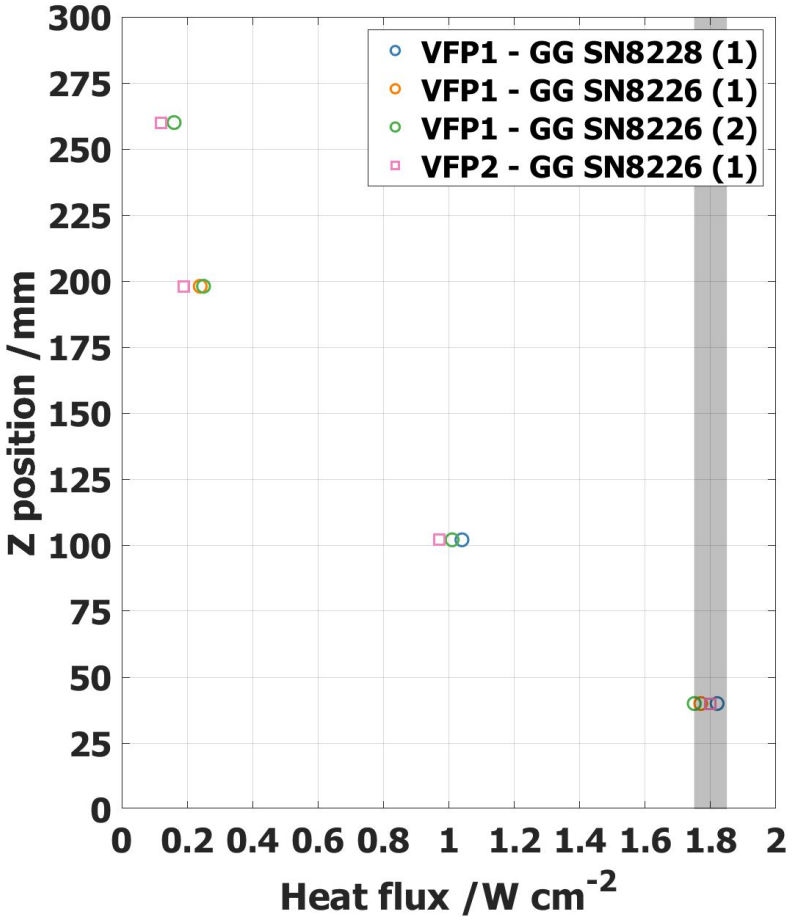
Normalised view factor by maximum value

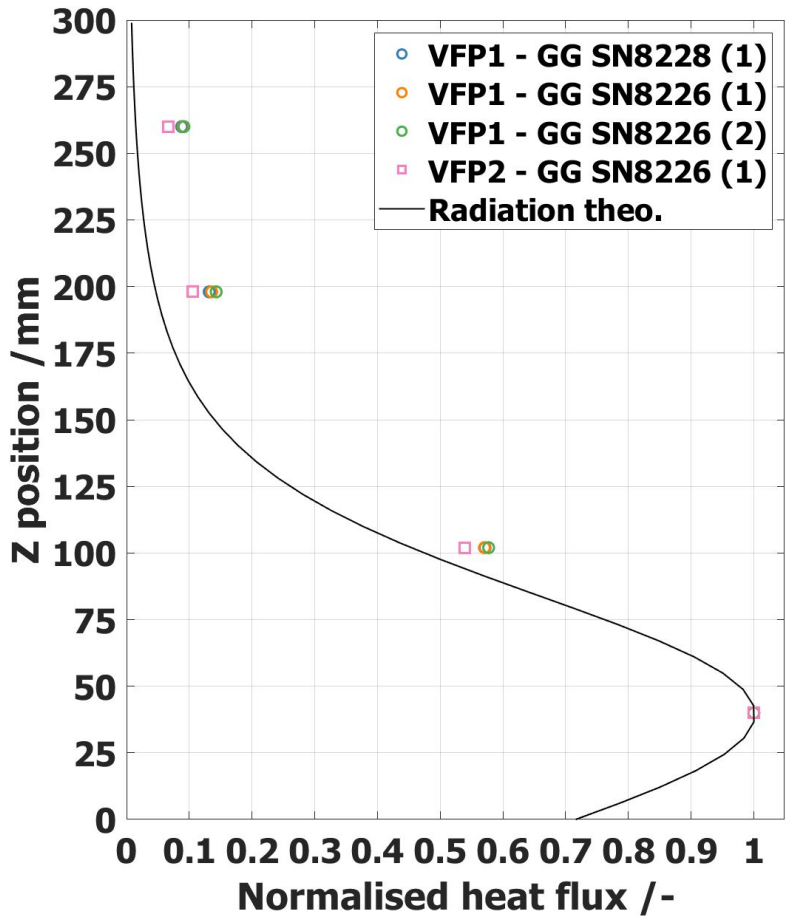
Heat flux mapping

Vertical gradient



- **Left plot:** absolute values in W cm^{-2}
  Right plot: normalized heat flux values with maximum heat flux at the original calibration position
- **Main outcomes:**
  (i) When calibrated within 1.8 ± 0.05 W cm^{-2}, higher heat fluxes are obtained in upper regions for VFP1. These differences are however minor.
  (ii) A better collapse of the data is obtained when using a normalized approach. This suggests tolerances may be defined more consistently in relative terms.
- **Theoretical normalization:** the normalized plot includes a theoretical trend line for the radiative heat flux expected when assuming a rectangular sample and a circular heater at uniform temperature. The larger experimental values highlight the role of convection measured by the Gardon gauge.





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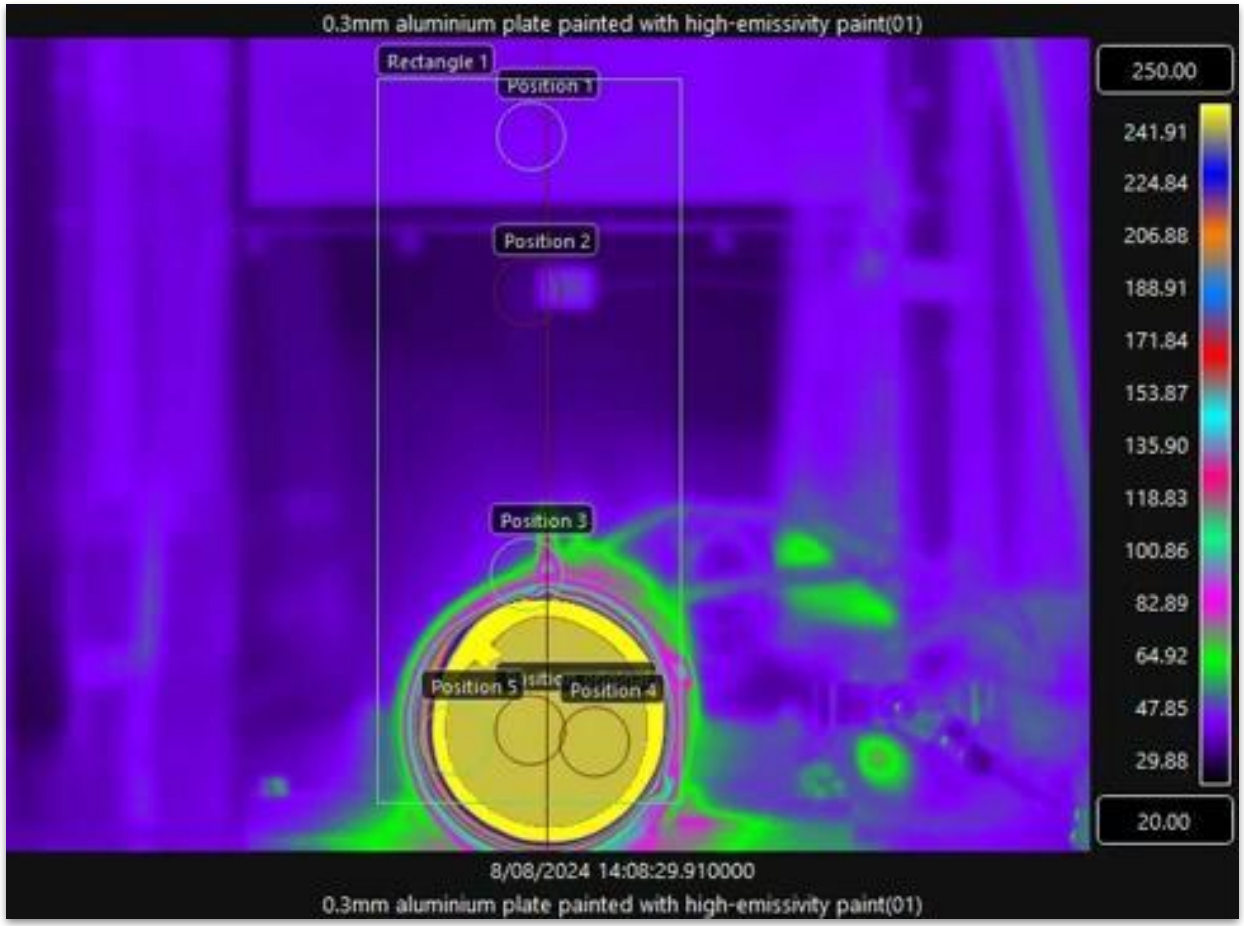
Temperature mapping

An alternative methodology to assess the heat flux distribution on the sample but with a larger resolution

Temperature mapping

Methodology

- **Samples:** Two aluminium plates of 0.3 mm and 0.8 mm painted with high emissivity paint are used as surrogate samples.
- **Frame:** An insulation frame is used to hold the sample and an IR camera (FLIR A655c) is used to measure the back face temperature of the plates (area exposed 110 mm x 265 mm).
- **Exposure:** The samples are exposed to the heating from the coil that has been calibrated at 1.8 ± 0.05 W cm^{-2} in the original position. The samples are exposed for 600 seconds and then temperature is processed at this time with latest steady-state value.
- **Repetitions:** 6 repetitions are carried out to complete an analysis of the repeatability of the heating produced by the coils.



Screenshot of video of insulated plate with gauge hole in different positions

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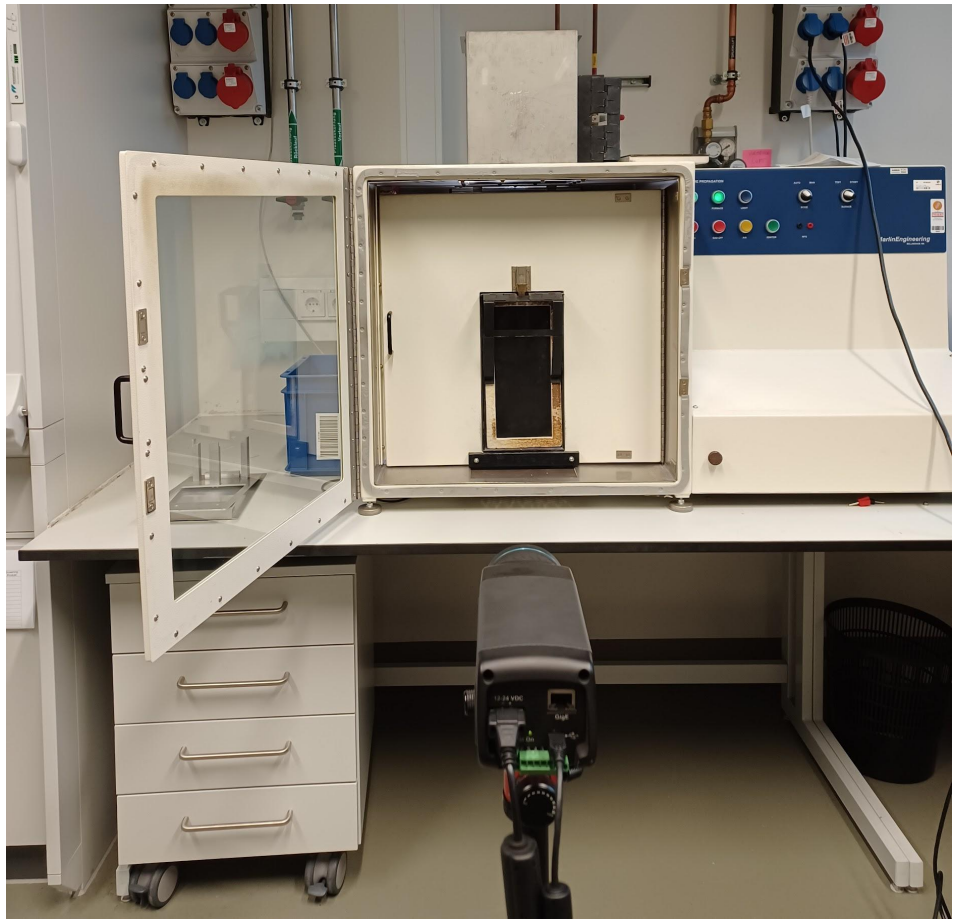
Temperature mapping

Methodology



FLIR A655sc in front of the aluminium plate placed on VFP1's sample holder.

Painted aluminium plate on VFP1 sample holder with Superwool Plus H around the edges.

Painted aluminium plate on VFP2 sample holder with Superwool Plus H around the edges.

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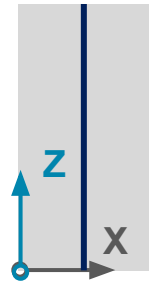
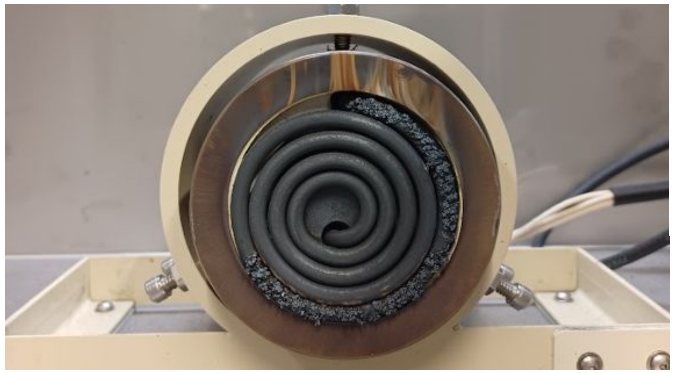
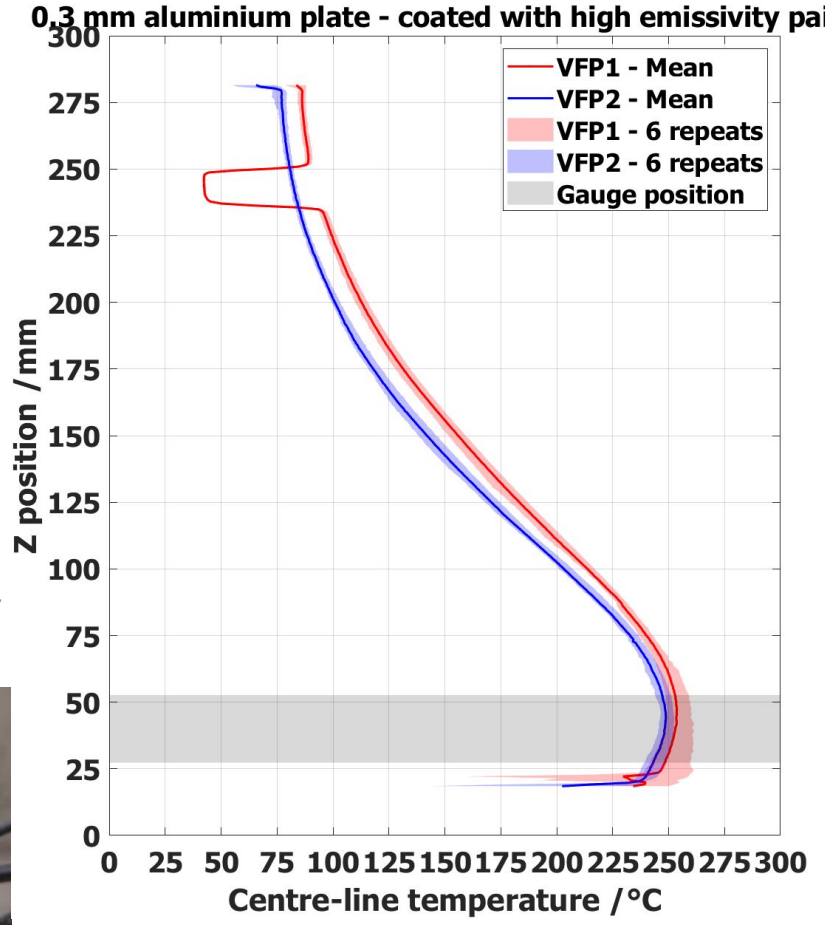
Temperature mapping

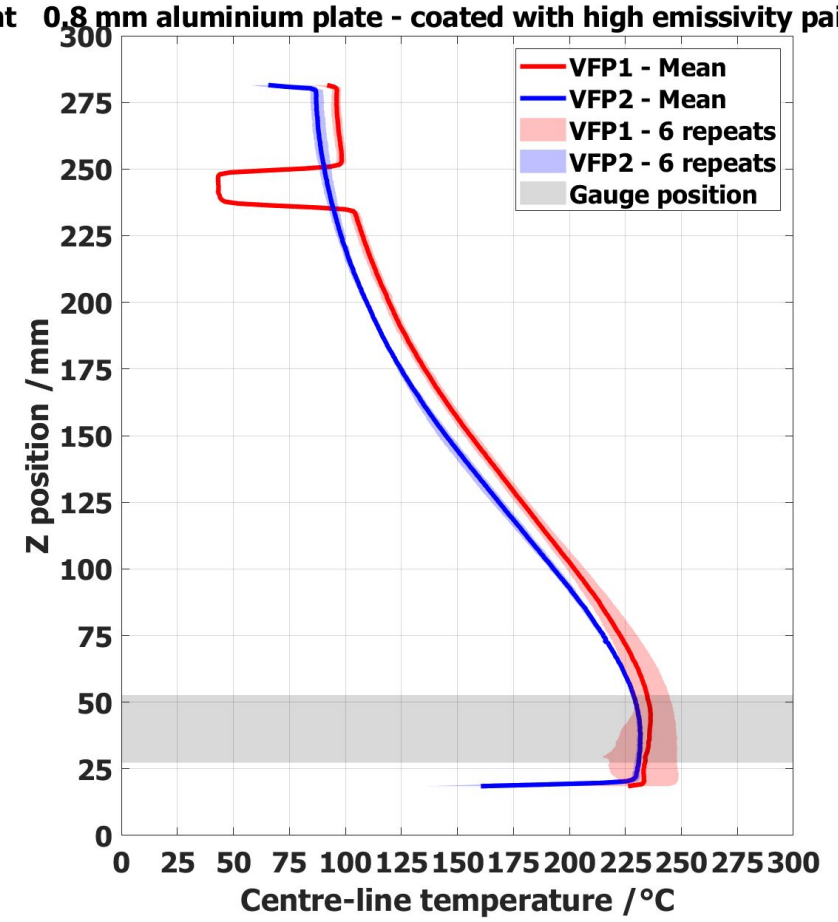
Vertical gradient



- **Left & right plot:** 0.3 and 0.8 mm aluminium plates:
  Solid line = mean value of six repetitions
  Shade = maximum and minimum envelope of six repetitions.
- **Main outcomes:**
  (i) When calibrated within 1.8 ± 0.05 W cm^{-2}, higher temperatures are obtained in upper regions for VFP1. This is consistent with the heat flux mapping results.
  (ii) Repeatability from heater in VFP1 is not good compared to heater in VFP2. The heater failed next day of use, possibly indicating anomalous function behaviour.







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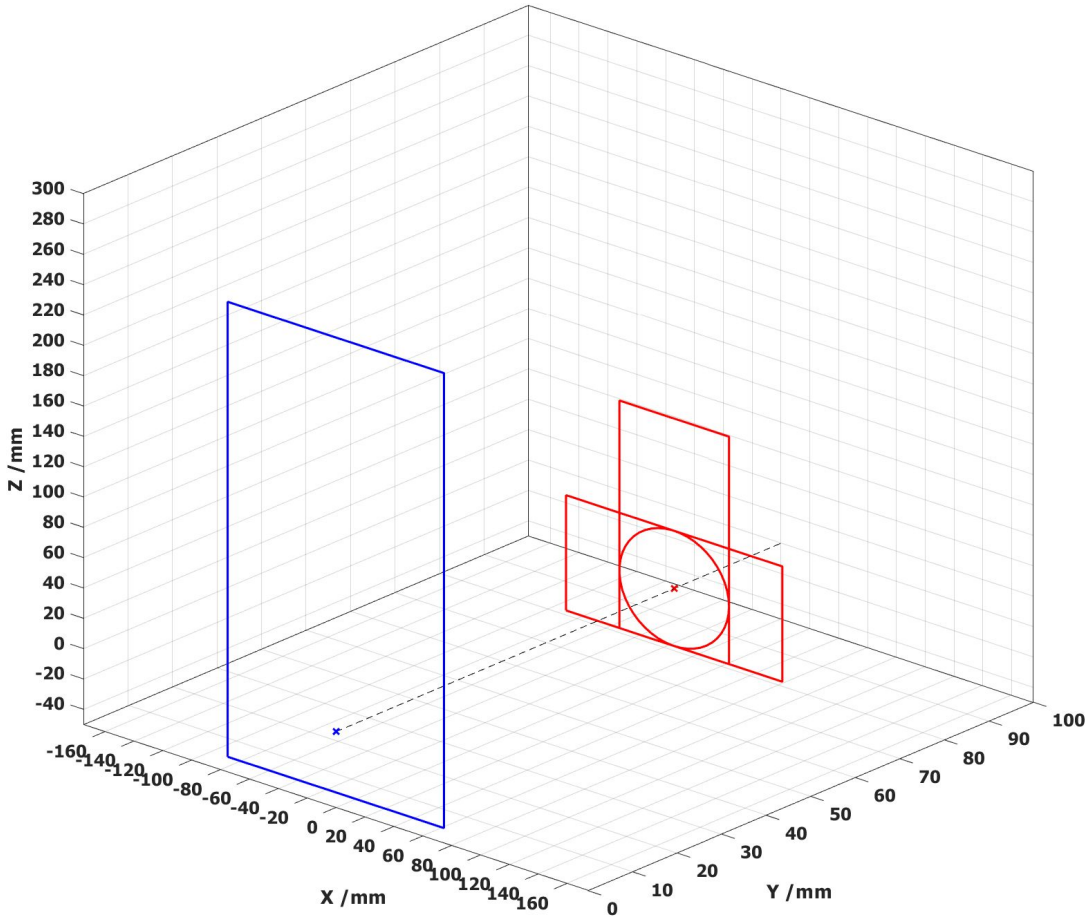
How feasible is to use other heater shapes and meet the requirement?

Influence of heater shape

Methodology

- **Theoretical analysis** to identify the influence of heater shape on the heat flux distribution on the sample.
  - Four different **heaters (red shapes)** of different shapes are used, located 76 mm away from the **sample**:
    - Circular heater of diameter 76 mm.
    - Squared heater of width & height 76 mm.
    - Horizontal rectangular heater of width 150 mm and height 76 mm.
    - Vertical rectangular heater of width 76 mm and height 150 mm.
    - Sample: 150 mm wide, 300 mm tall
- **Methodology assumption:**
  - The heater and sample remain at constant temperature. Then the radiative heat flux is determined by the view factor between the two surfaces (i.e. the fraction of radiation that leaves a surface and strikes the other surface).
  - The convection on the sample is neglected.



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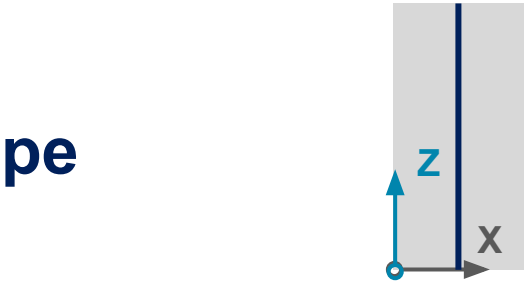
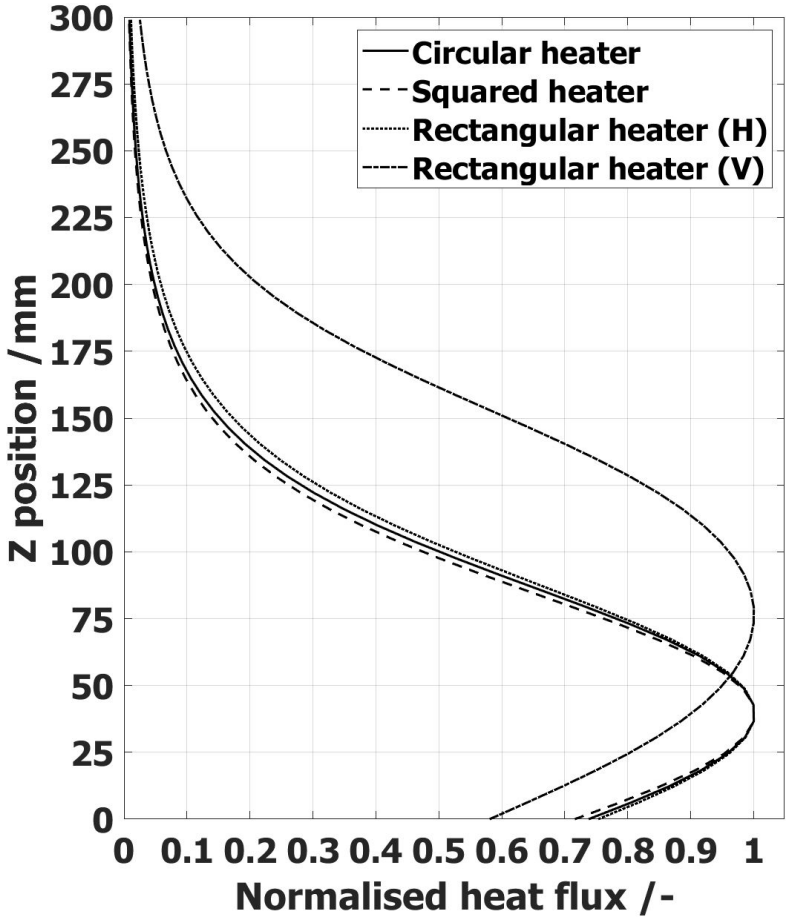
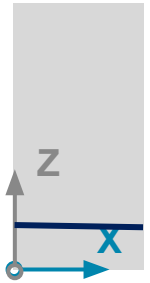
Influence of heater shape

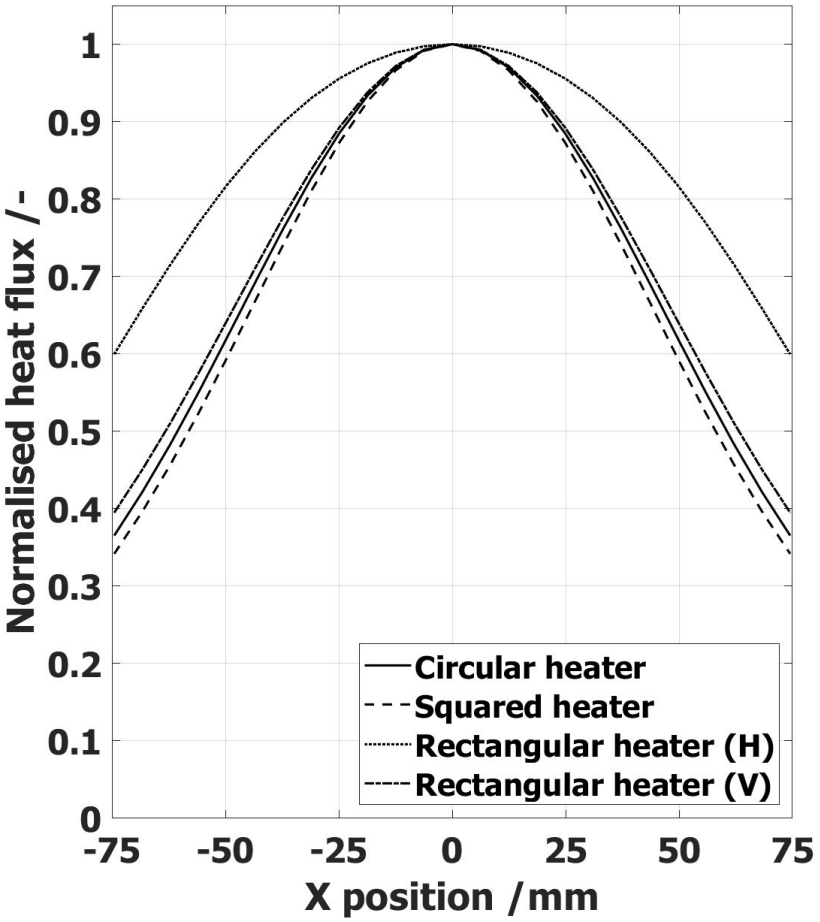
Vertical and horizontal gradient

- **Left plot:** normalized vertical heat flux
  Right plot: normalized horizontal heat flux
- **Main outcomes:**
  (i) Minor deviations are observed on the vertical and a horizontal gradient when a squared heater is used.
  (ii) The rectangular heater would result in minor deviations only in one axis: The horizontally-laid results in minor deviations in the vertical gradient but not the horizontal gradient, and vice versa for the vertically-laid rectangular heater.









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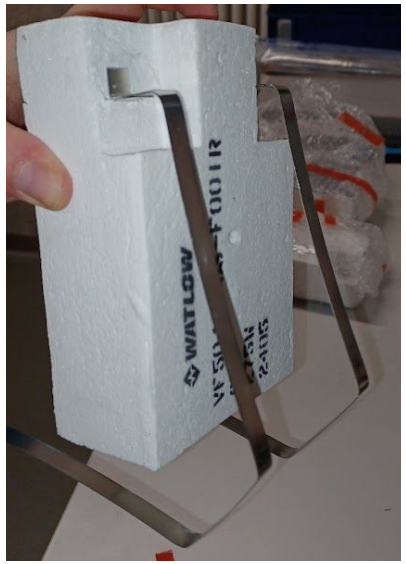
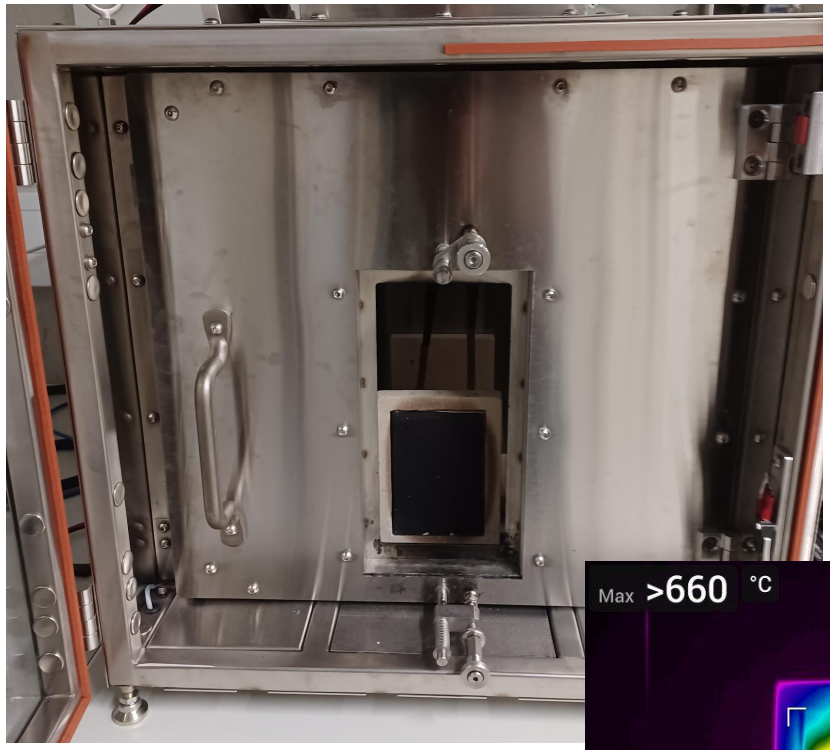
Influence of heater shape

Next step

- For research purposes, a different type of heater has been procured from Watlow and the empirical part of the feasibility assessment for using other type of heater is underway, complementing the theoretical analysis.
- The currently available heater is:
  - A flat ceramic fibre heater 4in x 6in with a coil embedded beneath the surface. The surface is coated with a high emissivity coating.
  - The heater is manufactured using molding, so the geometry has some level of imperfection not compatible with potentially strict geometrical tolerances.
  - The heater is to be supplied with DC current and reaches higher temperatures as the power supply is increased.





Temporary fixation of heater in VFP2 exemplifying the assessment to identify the influence of heater on heat flux distribution.

IR camera imaging to:
(i) assess temperature of heater as a function of power supply
(ii) assess uniformity of temperature across the surface.

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Thank you

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