



National Physical Laboratory

Design of the NPL Small Guarded Hot Plate

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Industrial Requirements

- Examples of Industrial Requirements:
 - Composites: including polymer composites for aerospace
 - Polymers: including oil pipeline insulation
 - Ceramics & glass: including energy generation applications
 - All becoming more demanding in terms of accuracy and conditions under which materials is tested
- NPL current service based on ASTM E1530 (-100 °C to 250 °C)
 - Not absolute, insufficient accuracy and flexibility
- NPL current service based on ISO 8302 (-20 °C to 70 °C)
 - Specimens too large and insufficient temperature range

Project Objectives

- Establish new National Facility for thermal conductivity measurements on composites, ceramics and polymers:

Guard Hot Plate (absolute and steady-state)

Temperature -100 °C to 250 °C

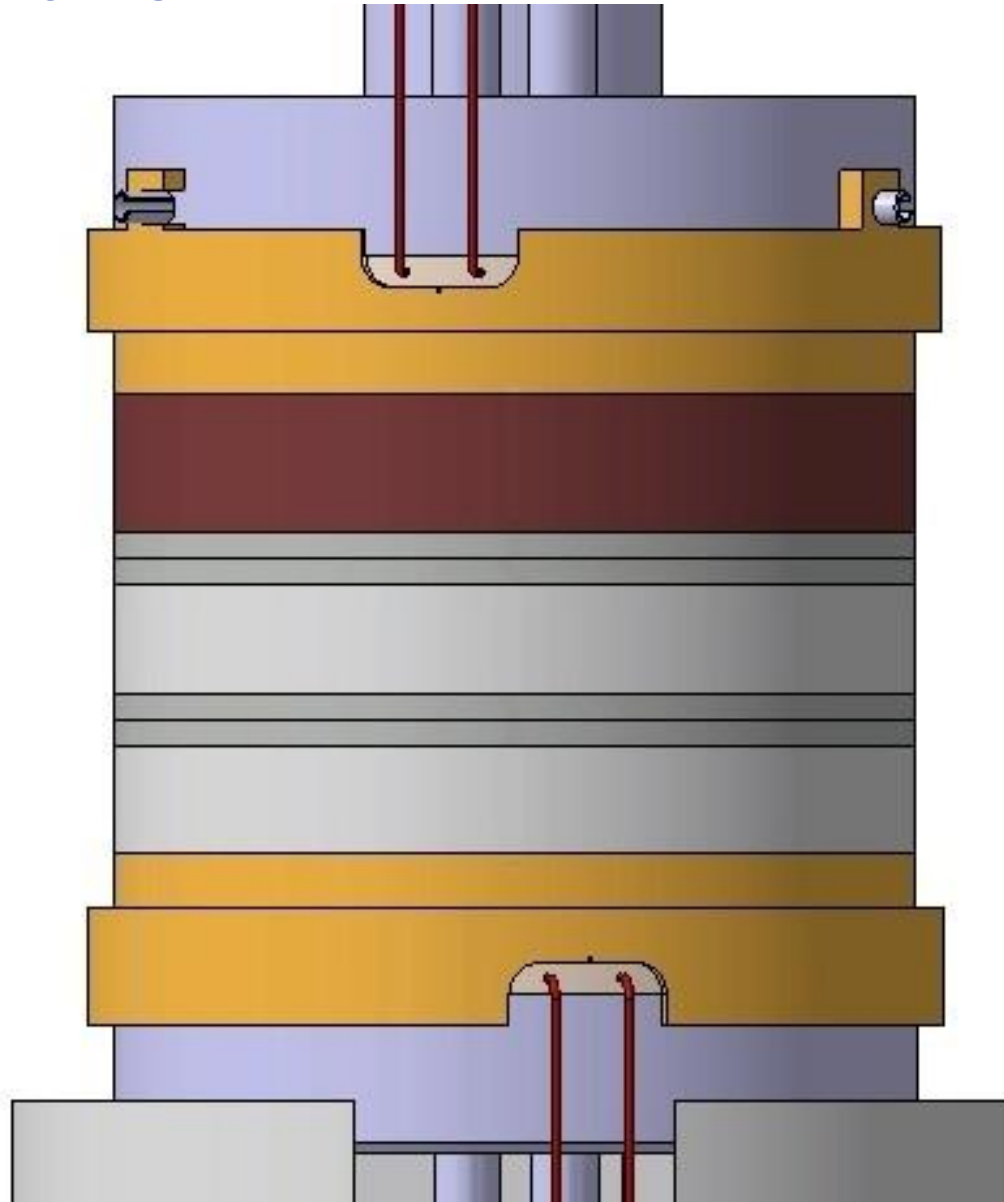
Thin specimens (below 5 mm)

Lowest available uncertainty (target $\pm 3\%$)

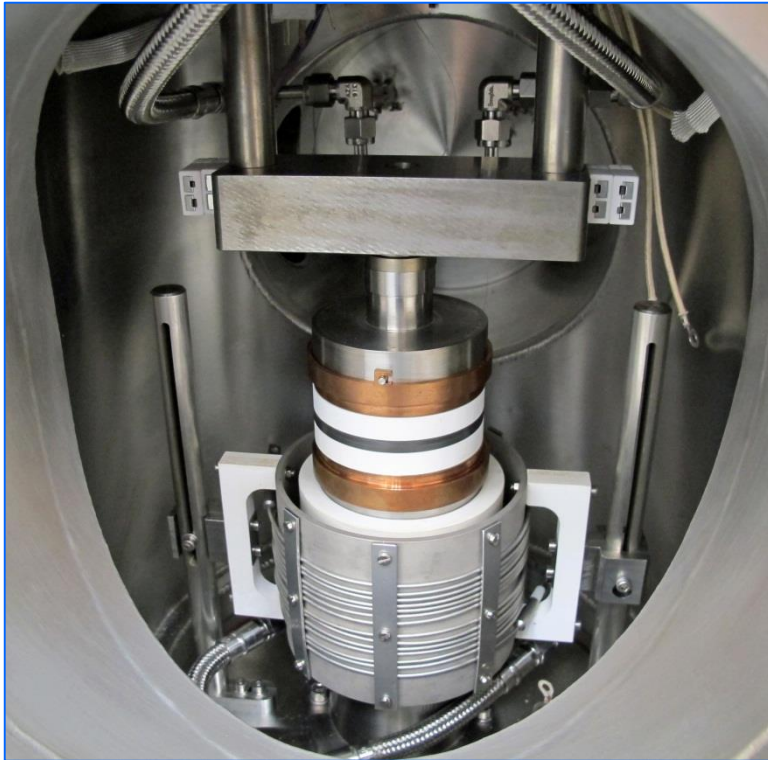
Flexibility in environmental conditions

Measurements under high compressive loads (up to 9 MPa)

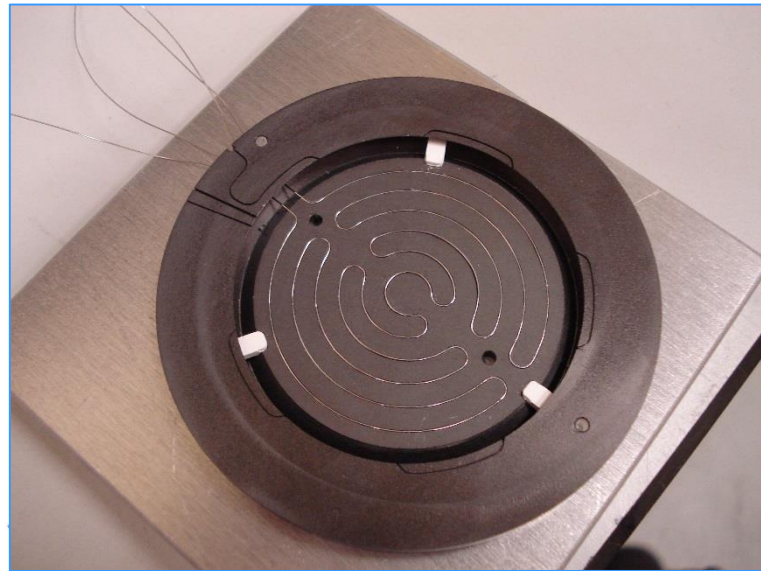
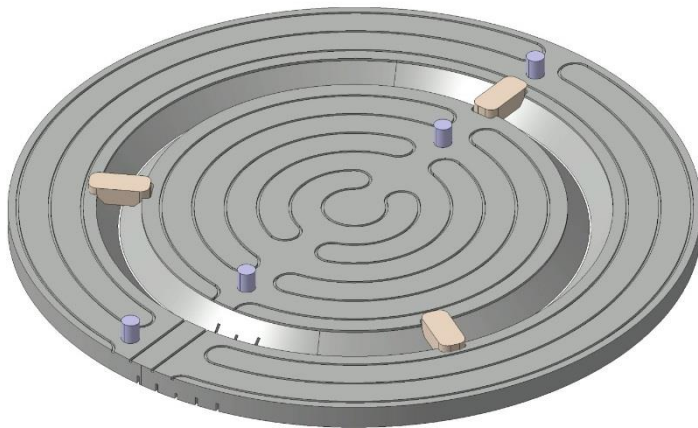
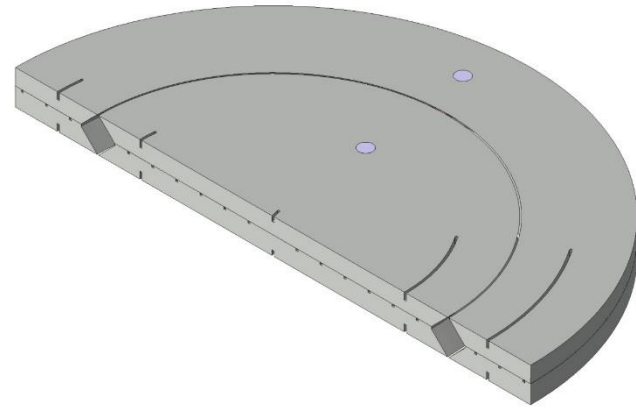
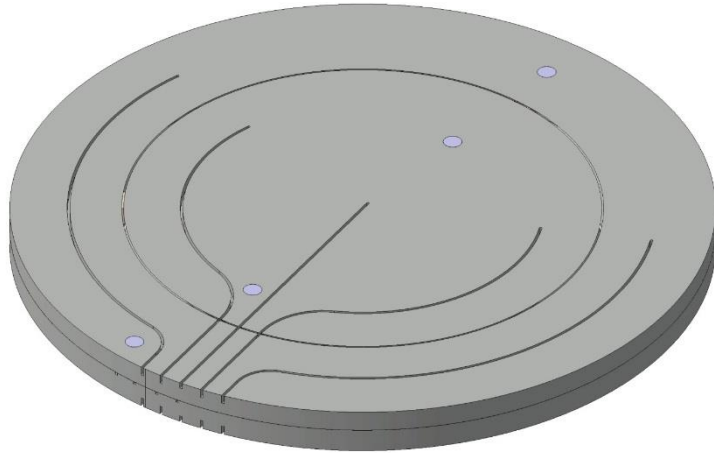
Configuration



Environmental Chamber



Heater Plate



Specimen Surface Temperature

- Measurement Issues:
 - Thermal contact resistance
 - Differential expansion
 - Transducer dimensions compared to thin specimen
- Measurement Solutions:
 - Surface mounted thermocouples (butt-welded, 0.075 mm)
 - Thermal interface materials
 - Thin films (centre-guard gap & absorbent specimens)

Initial Validation

- Perspex (PMMA) NPL reference material batch 05/01
- Thickness: 10 mm
- Uncertainty of reference values: $\pm 4\%$
- Thermal conductivity: $0.189 \text{ W}\cdot\text{m}^{-1}\cdot\text{K}^{-1}$

- Agreement: SGHP measurements 2% higher than reference
- Combined uncertainty: $\pm 5\%$ (based on SGHP target of $\pm 3\%$)

- Further validation to be carried out with:
 - BCR-039 (Pyrex glass)
 - BCR-724 (Pyroceram 9606)

Progress since D1.5.3 Report

- Paper published in 32nd International Thermal Conductivity Conference (Oct 2015 – 56 downloads)
- Chamber insulated
 - Flexible foamed polyimide
 - Aluminium foil
- LVDTs commissioned
- Single heater/chiller not adequate and valves failed:
 - Upgrading plumbing
 - Additional heater/chiller
- Measurements on proposed polymer composite reference material

Measurements on Composite

Unidirectional Carbon Fibre (T700) Epoxy (SE84) System

| Temperature (°C) | Difference between SGHP & ASTM E1530 |
|------------------|--------------------------------------|
| 19.5 | -4.4% |
| 39.9 | -5.5% |
| 59.7 | -6.7% |
| 79.6 | -8.6% |
| 99.6 | -9.3% |

Note 1: 50GHFM – four samples with 2.3% spread and uncertainty of $\pm 7.5\%$

Note 2: Estimated combined uncertainty: 8.4% (based on SGHP target of $\pm 3\%$)

Future Plans

- Further performance evaluation, optimisation & validation
- Further investigation into minimisation of contact resistance
- Measurement Services and materials R&D projects
- Extend range of NPL reference materials
- Measurements of thermal conductivity and contact resistance under high compressive loads (9 MPa)



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Euramet EMRP

- EMRP supports the collaboration of European metrology institutes, industrial organisations and academia through Joint Research Projects (JRPs). It is structured around European Grand Challenges in such areas as Health, Energy, the Environment & New Technologies.
- This presentation is one of 17 presentations, 5 posters and 2 workshops at this conference supported by the European Metrology Programme, implemented by EURAMET.
- The last call for EMRP proposals has just closed – but we look forward to its successor - EMPIR. See www.euramet.org for more details.



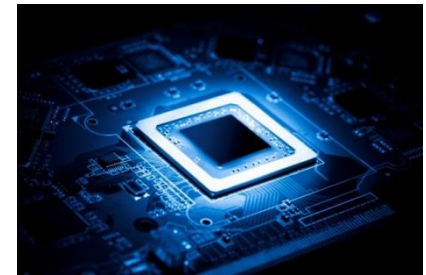
SI Units (2011 & 2012)



Environment (2010 & 2013)



Energy (2009 & 2013)



New Technologies (2011)



Health (2011)



Industry (2010 & 2012)