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Development of High- and Medium-Temperature Fixed Point Cells for Use in Radiometry and Thermometry

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Your measure of excellence

A project for realising high-temperature fixed points on the basis of M-C and MC-C eutectics was initiated at the CSIR National Metrology Laboratory (South Africa) in January 2006.

Motivation of the Project:

- *The uncertainty of the temperature measurement makes the most significant contribution to the uncertainty of realising the spectral irradiance scale.*
- *High temperature fixed points, above the copper point (1085 °C) , are required to improve these uncertainties.*
- *In 1996, the joint working group of the CCPR and the CCT encouraged NMIs to develop high temperature fixed points above 2 300 K with a reproducibility better than 100 mK.*
- *Since then, many NMIs have initiated cooperative projects and comparisons to characterise these points in order to reach a consensus on the transition temperatures and implementation procedures.*
- *In order to be accepted as a Secondary Reference Point (SRP), a eutectic point must be highly reproducible.*
- *Some metal-carbon eutectic points, such as Re-C, have reached such a level of confidence. Other fixed points, such as the δ(MoC)-C fixed point for radiometry applications, still require further study before temperatures can be assigned to it with acceptable uncertainties. Future research and comparisons between NMIs will refine the knowledge of these fixed points.*

Importance

- Metal-carbon eutectic fixed point (FP) cells:
  - Medium-temperature (MT) eutectics above 1085℃ (around 1300℃ and 1500℃): will improve accuracy of thermocouple and radiation thermometer calibrations, by increasing number of available temperature fixed points.
  - High-temperature (HT) eutectics (around 2500℃ and 2600℃): will improve accuracy of temperature measurement of variable-temperature blackbody (to be used as the primary source for realisation of spectral units), by providing very stable sources for calibration and drift checks.

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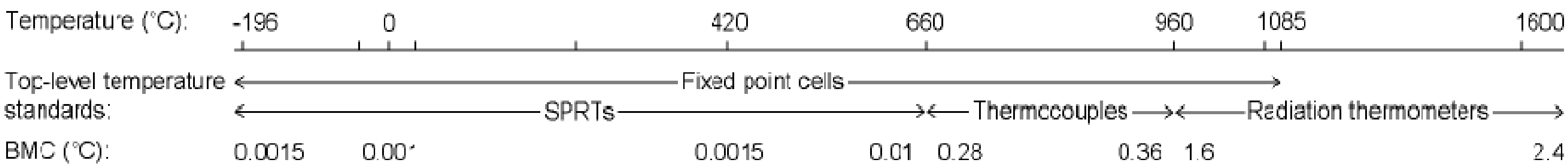
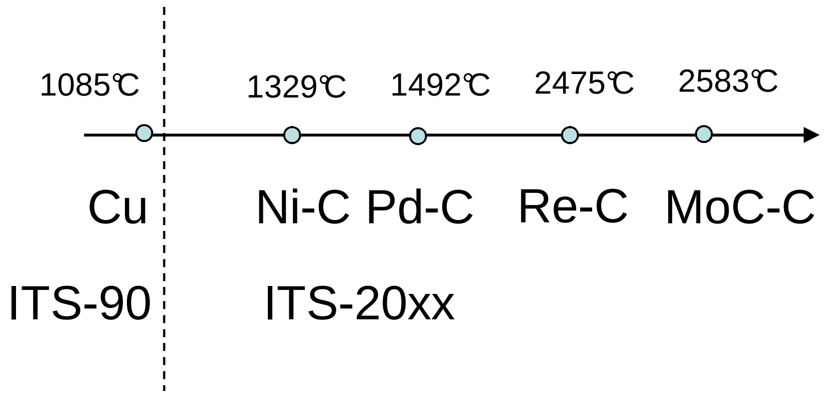
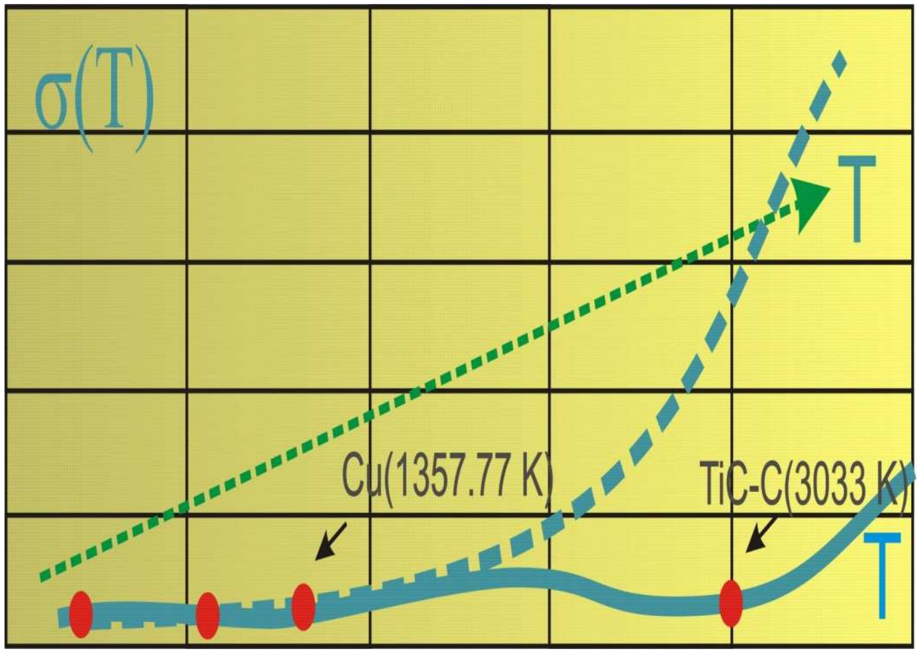
International (Practical) Temperature Scale







Reduction of uncertainties in radiation thermometer calibration by using multiple fixed points

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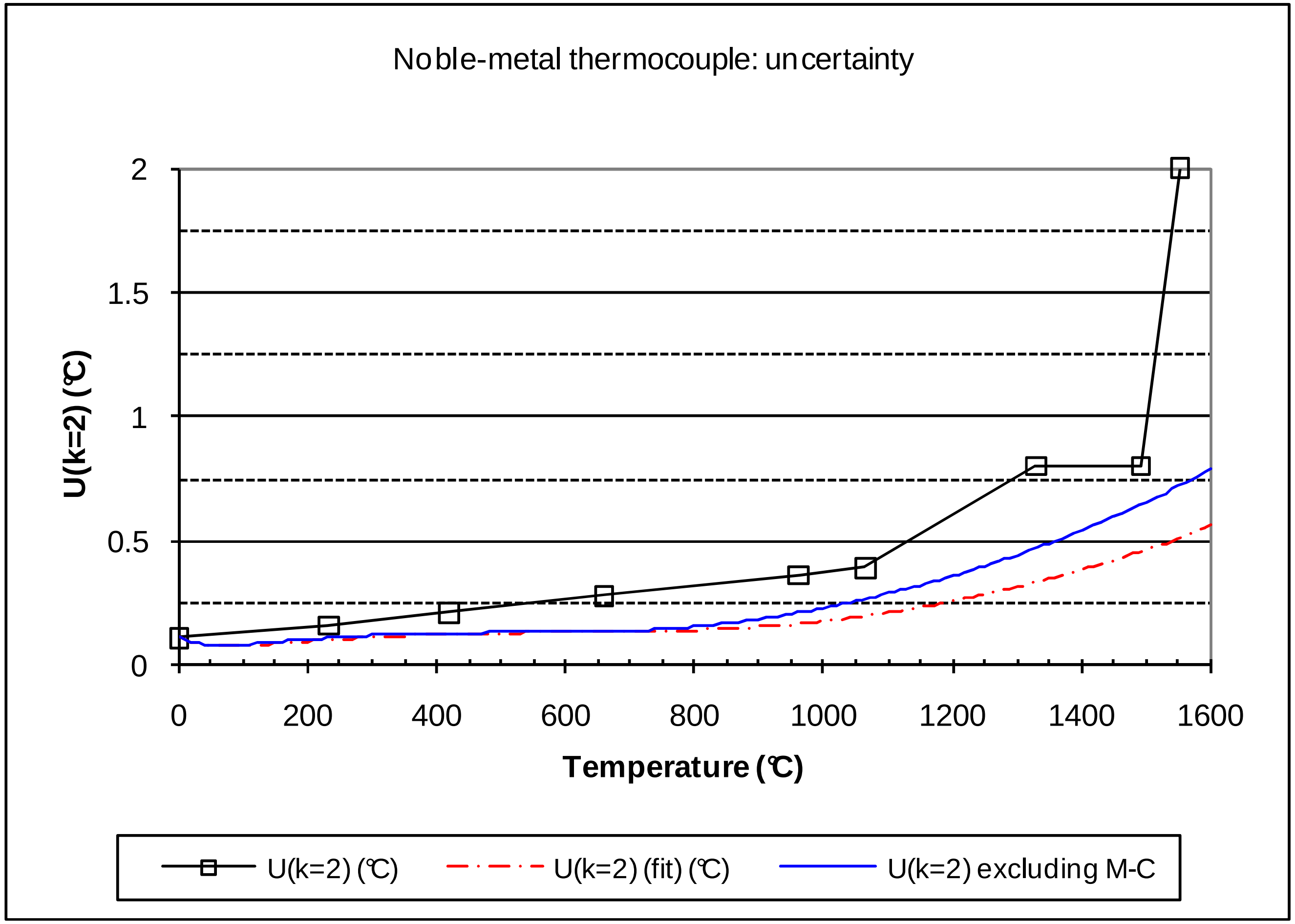
Uncertainties in noble-metal thermocouple calibrations



- Present fixed points: Cu (1085 ℃): ±0.4 K, Pd (1554 ℃) by wire-bridge method: ±2 K
- Planned: Ni-C (1329 ℃) and Pd-C (1492 ℃): ±0.8 K
- Result: reduce uncertainty of fitted curve (red dashed line).

Relevance to Radiometry

• Dominant uncertainty: temperature of source (3K at 3000 K), equivalent to approx. 1% in spectral irradiance units (in visible region of spectrum).

• Eutectics provide very reproducible, stable temperature sources

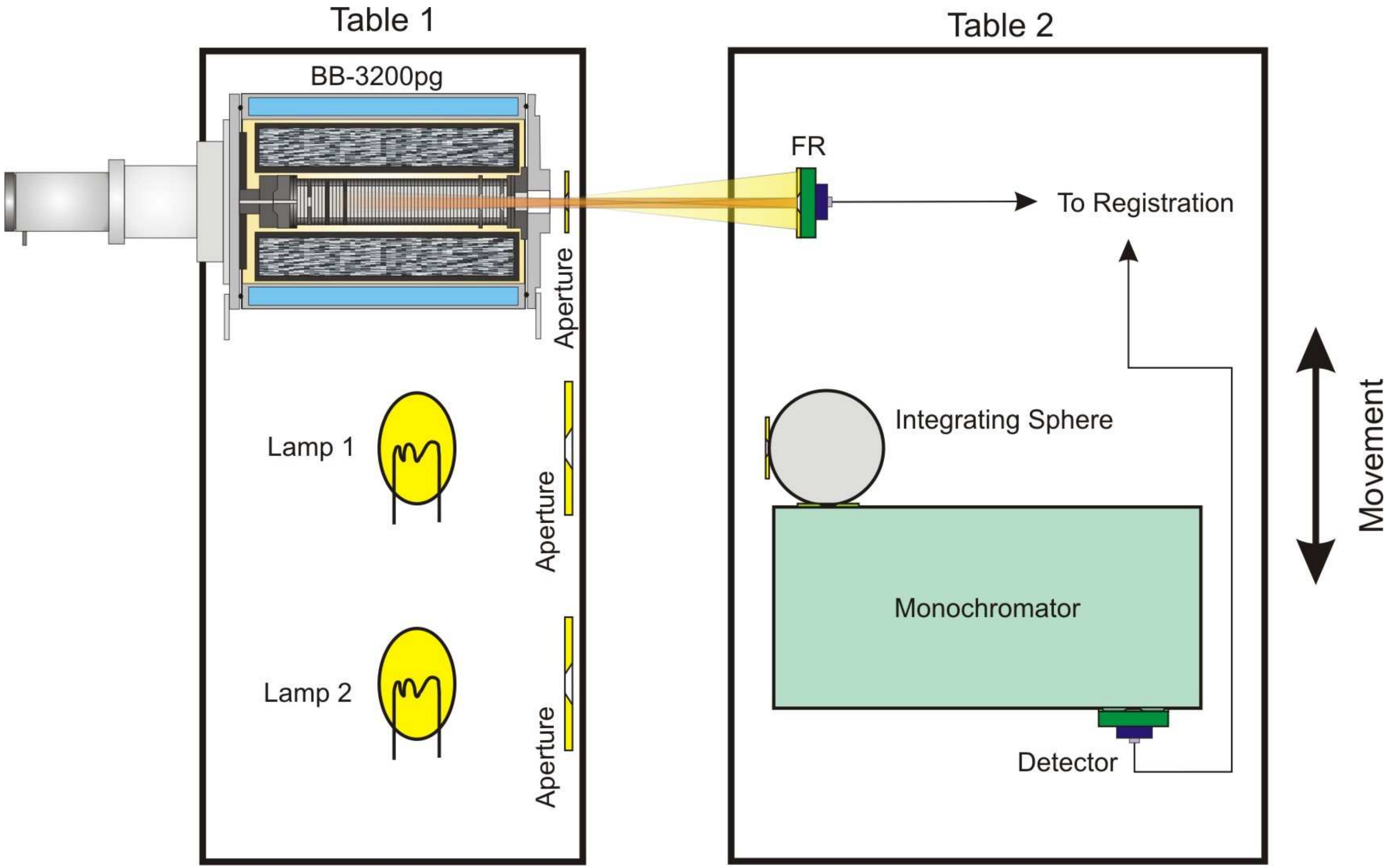
⇒ control drift in realisation of spectral units

⇒ reducing uncertainty of source temperature by a factor of two leads to reduction of uncertainty of realisation of spectral units (spectral radiance, spectral irradiance) by approximately the same factor

Immediate benefit: greatly improved stability and long-term reproducibility (decades) of scale. Facilitate preservation and reconstruction (if necessary) of scale.

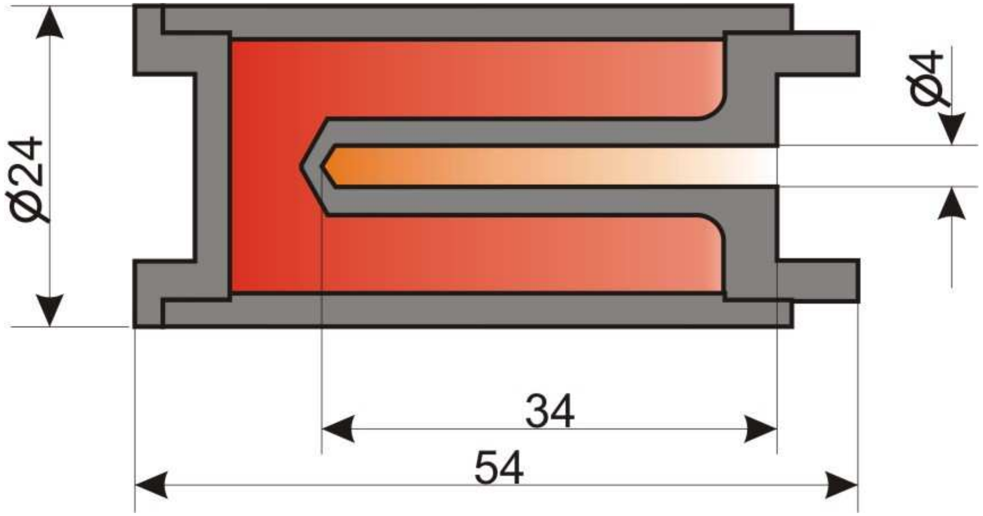
Future benefit: global efforts to reduce uncertainty of fixed point temperatures will allow reduction in uncertainty of local scale.

Schematic view of the Primary Spectral Irradiance Facility being developed at the NMISA

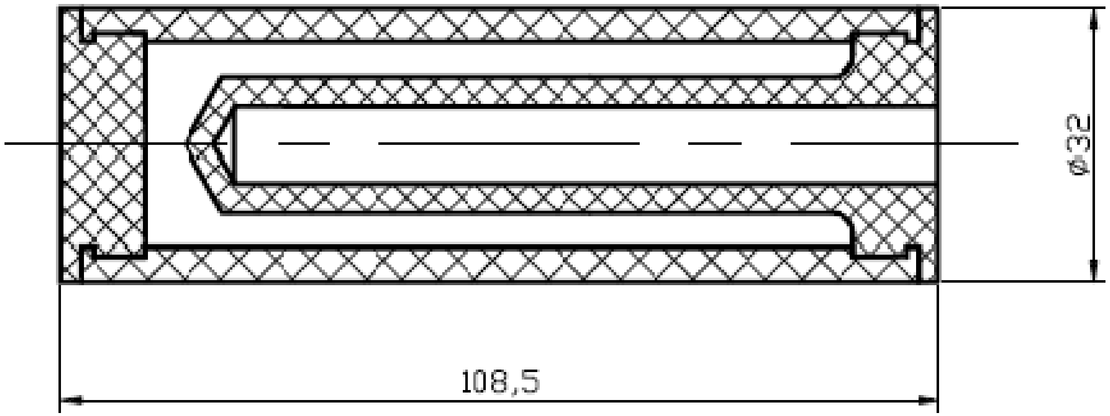


The Cells

Cell for radiometers and radiation thermometers:



For thermocouples, a larger (9 mm) well is needed:



The Cells (continued)

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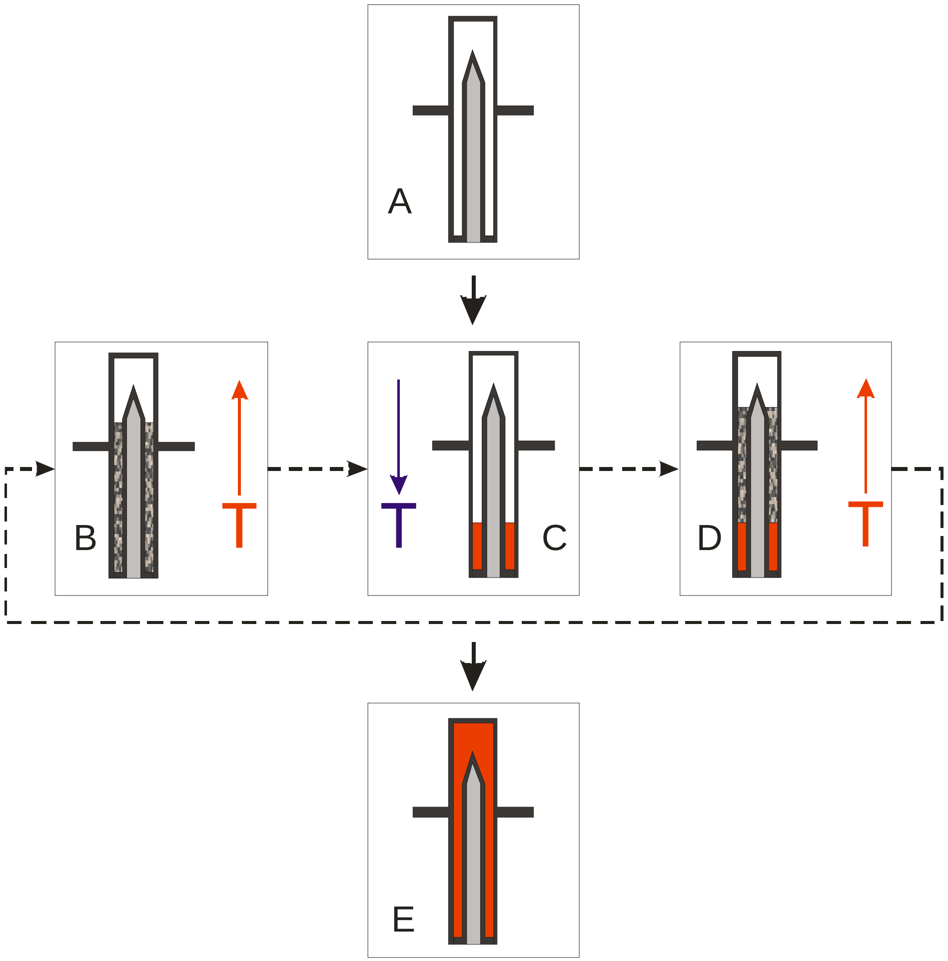
The filling procedure

The filling procedure (continued)

A schematic view of the filling procedure:



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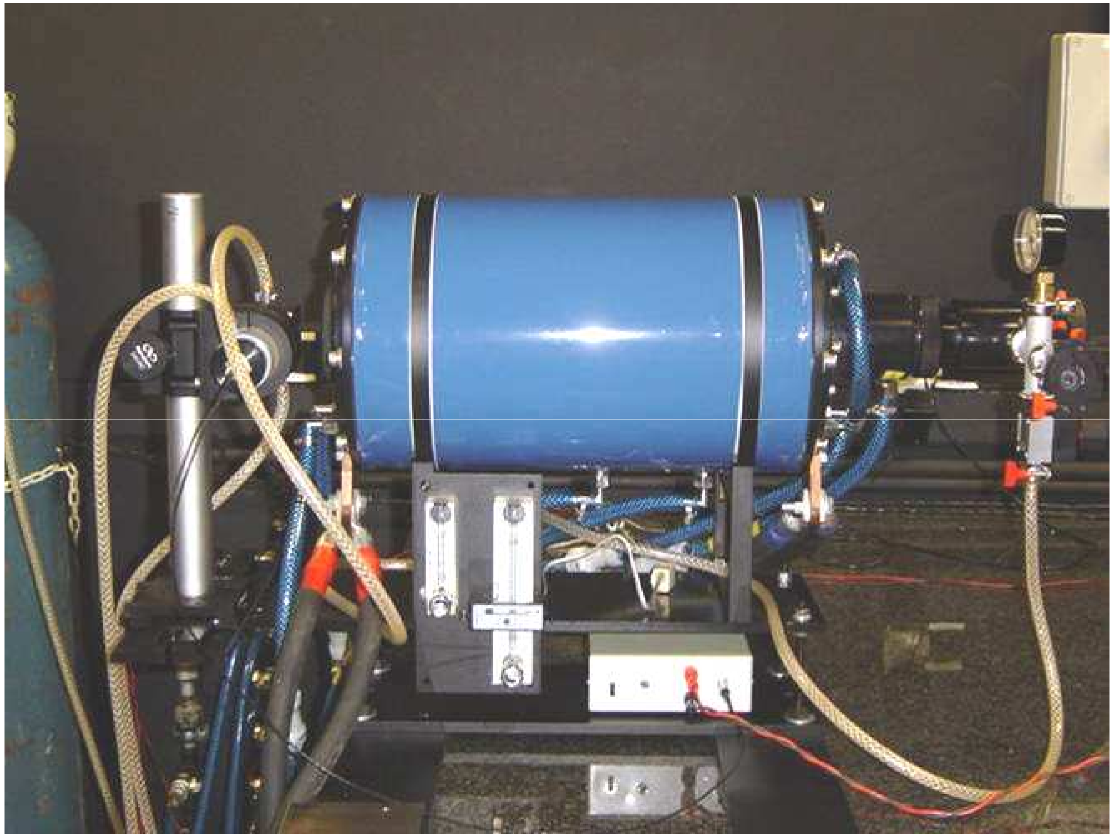
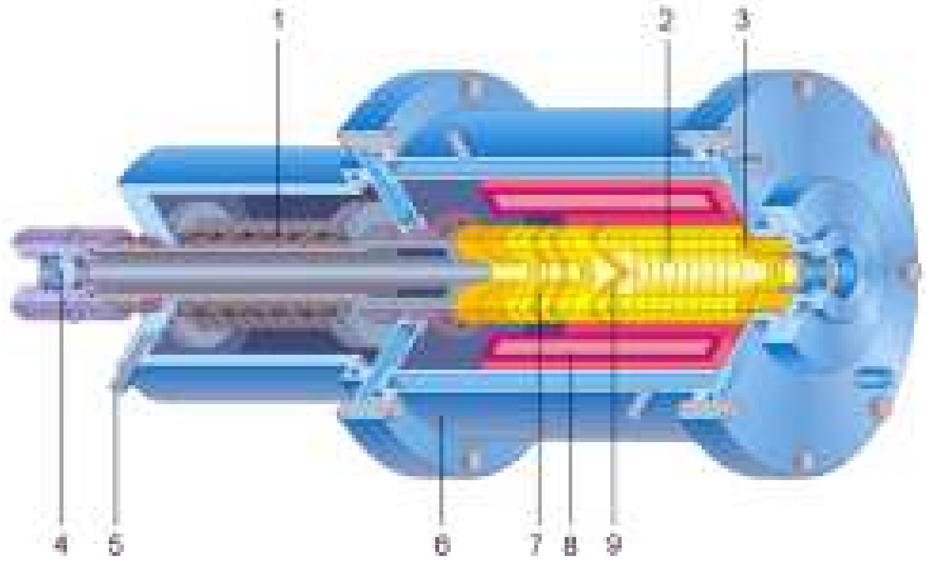
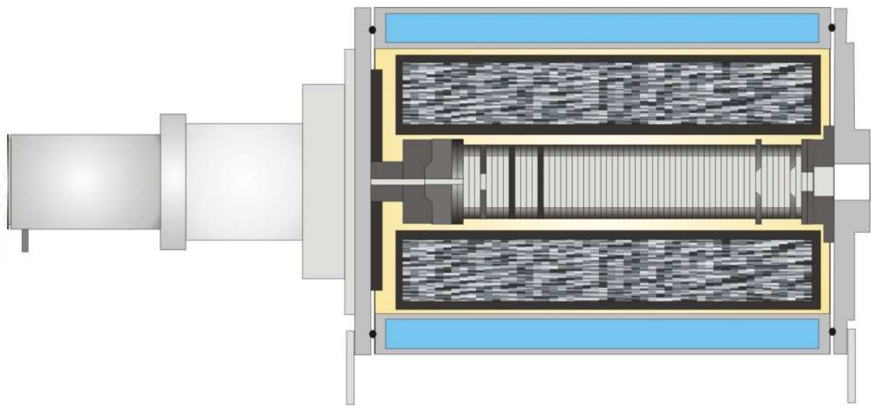
The Furnace



High-temperature pyrolitic graphite blackbody BB3200pg





1. Clamping Spring 2. Radiating Cavity 3. Cavity Opening 4. Rear Quartz Window 5. Inert Gas Purge Inlet
6. Water-cooled Chamber 7. Radiation Shields 8. Thermal Insulation Unit 9. Cavity Inner Conical Bottom

Specifications	**Effective Emissivity at 500 nm, greater than 0.999**
Temperature Range, K 1300-3200	**Maximum Current, A 700**
Cavity Diameter, mm 37	**Maximum Voltage (DC), V 30**
Cavity Opening Diameter, mm 22	**Service life, hrs**
Cavity Length, mm 200	**at 3200 K 150**
Optional External Aperture Dia., 15 mm	**at 2800 K 500**

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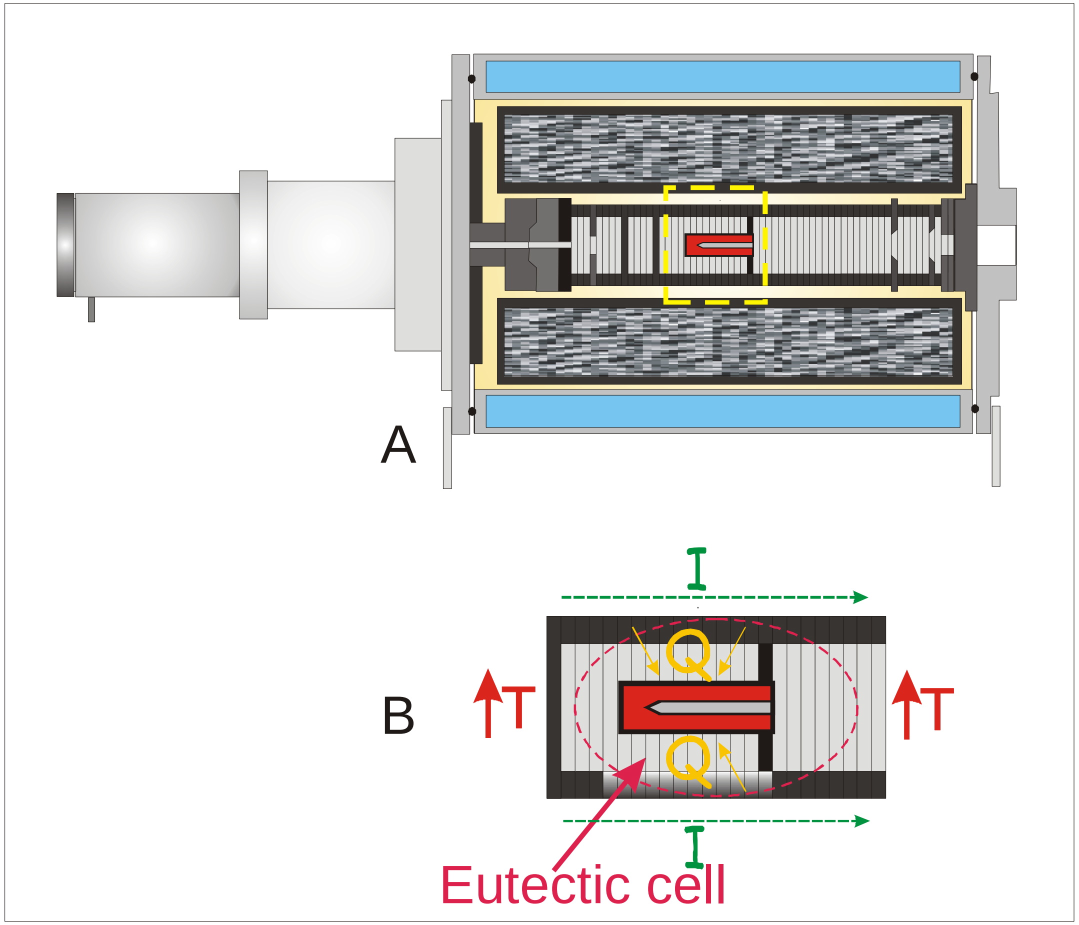
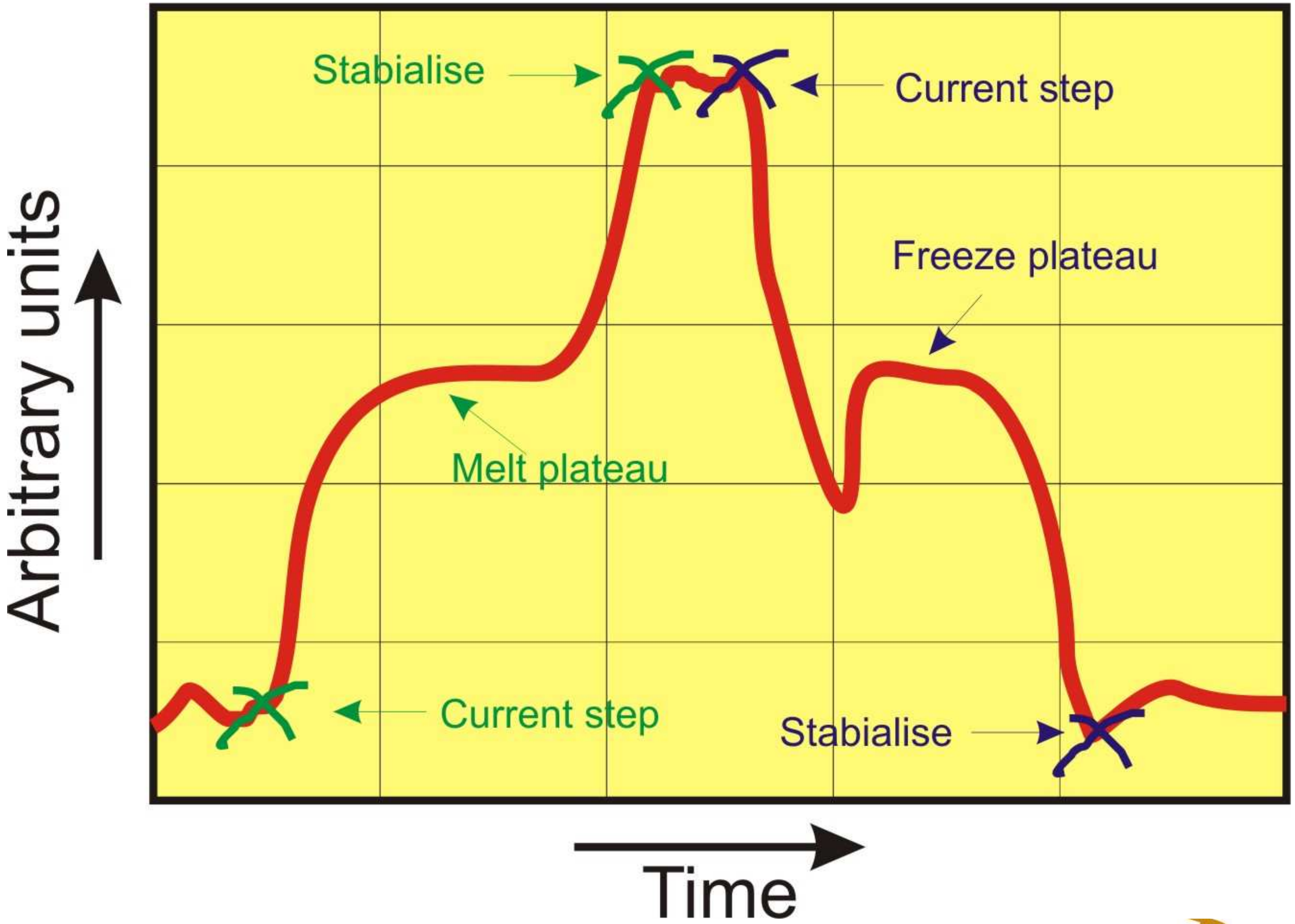
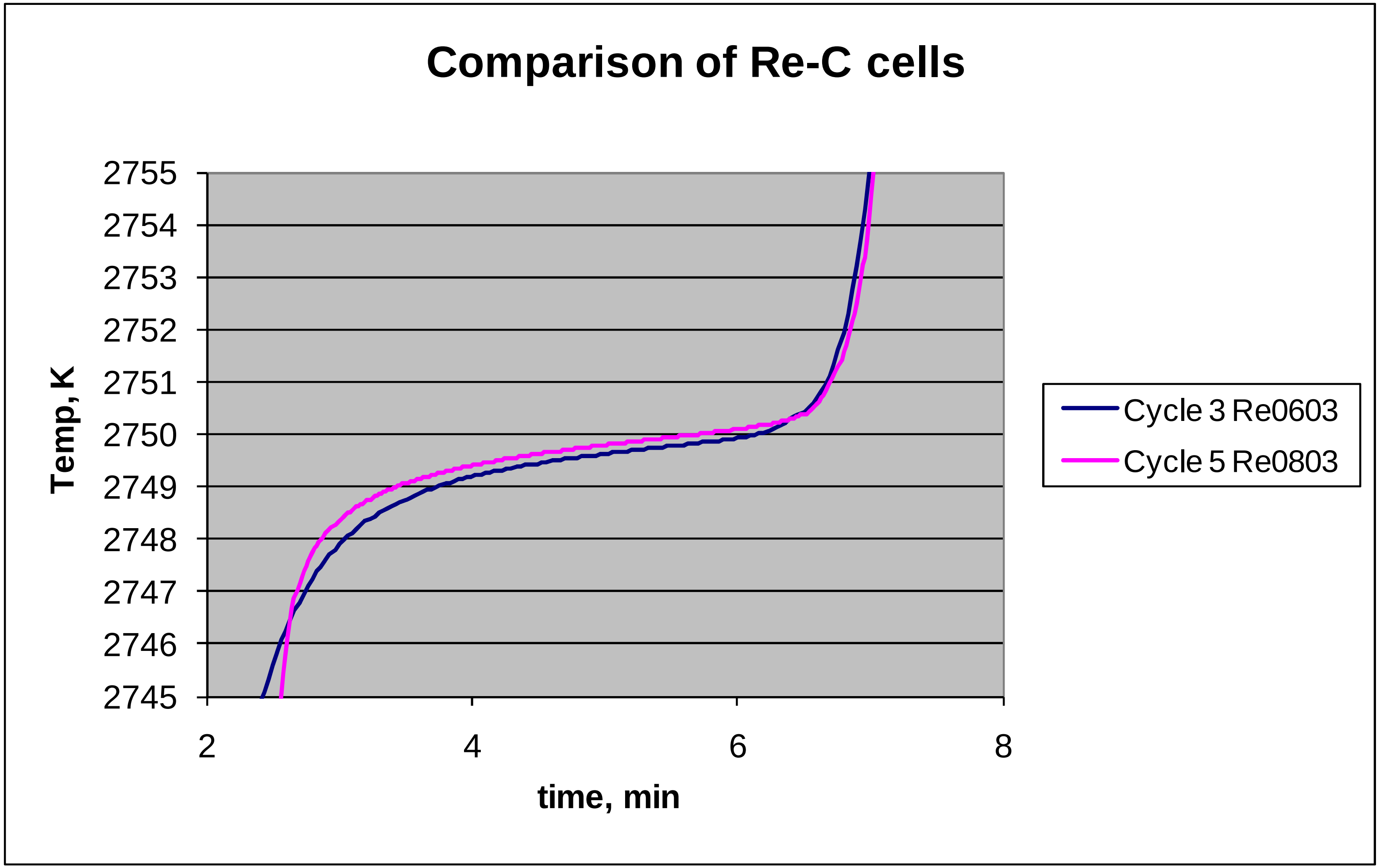
High Temperature Black Body with Eutectic Cell



Measurement process



Melts of two “small” Re-C cells



Literature value: 2747 K [Woolliams, Metrologia 43 2006 R11-R25]

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Typical spread of melting temperatures

Eutectic	T, ℃	Spread of reported temperatures, K
Co-C	1324	0.7
Pd-C	1492	0.8
Pt-C	1738	1.3
Ru-C	1954	1.6
Re-C	2474	2.0

References:

Sadli, Tempmeko 2004
Anhalt, Metrologia 2006

Conclusions

- Re-C (2474 °C) and δ(MoC)-C (2583 °C): plateau shapes and standard deviations of the melt and freeze temperatures compare well to results reported by other NMIs.
- Future plans:
  - Construct larger cells of Ni-C and Pd-C, for use with thermocouples and radiation thermometers.
  - Since it was noticed that the shape of the phase transition plateaus depends on the temperature uniformity (distribution) of the furnace cavity, the uniformity of the furnace should be characterised and further improved.
  - The long term stability of these eutectics should be tested over time and compared to the characteristics of eutectics produced by other NMIs.