

# Overview of measurements capabilities in radiation thermometry at CEM (Spain)

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**Abstract.** CEM (Spanish National Institute of Metrology) is responsible for the maintenance and dissemination of the temperature national standards. Nowadays, the CEM Radiation Thermometry Laboratory disseminates and maintains the International Temperature Scale of 1990 (ITS-90) from the Ag fixed point (961.78 °C) to 2800 °C, using Ag or Cu fixed points as reference and standard radiation thermometers (RTs) working at a wavelength of 650 nm. CEM is also able to provide traceability to the new definition of the kelvin and to perform measurements of thermodynamic temperature from 400 °C to 2800 °C with different RTs (wavelengths of 650 nm, 900 nm and 1550 nm) using absolute and relative primary radiation thermometry. In addition the Radiation Thermometry laboratory performs calibration of RTs working in the usual infrared ranges (1 μm and 10 μm) from – 40 °C to 1600 °C.

## 1 Introduction

The CEM Temperature Division is responsible for the development, maintenance and dissemination of the thermodynamic temperature unit: the.

The Radiation Thermometry Laboratory is long experienced in the dissemination and maintenance of the ITS-90 from the silver fixed point (961.78 °C) to 2800 °C. Recently, CEM has participated in the assignment of –the thermodynamic temperature to the Cu, Co-C, Pt-C and Re-C fixed points in the frame of the InK EMRP project and has performed measurements of the difference between the thermodynamic temperature  $t$  and the temperature defined by the ITS-90,  $t_{90}$  (from 420 °C to 1100 °C) in the frame of the InK2 EMPIR Project [1], [2].

In addition, CEM has secondary radiation thermometry facilities to perform calibrations of infrared radiation thermometers from – 40 °C to 1600 °C.

## 2 Description

### 2.1 $t_{90}$ measurements and dissemination from Ag to 2800 °C

A picture of the equipment used to measure high temperatures traceable to the ITS-90 is shown in figure 1. The standard RTs used are a KE LP4 and a KE LP2. The thermometers can be referred to a Cu fixed point (FP) or a Ag FP. The  $t_{90}$  is obtained by extrapolation using the relative spectral response of the thermometer, that is measured using a calibrated monochromator model SPEX 750.

The RTs are characterized in linearity and in size of source effect (SSE) using the double flux method and the indirect method, respectively. Variable temperature blackbodies (VTBBs) or high stability lamps are used as sources to measure linearity. An integrating sphere and different spots and apertures are used to measure SSE.

The variable temperature blackbodies available at the laboratory are:

- In the range from 960 °C to 2200 °C: CHINO IR-R80 furnace (10 mm diameter aperture).
- In the range of 2000 °C to 2800 °C a BB3200 furnace (12 mm diameter aperture).

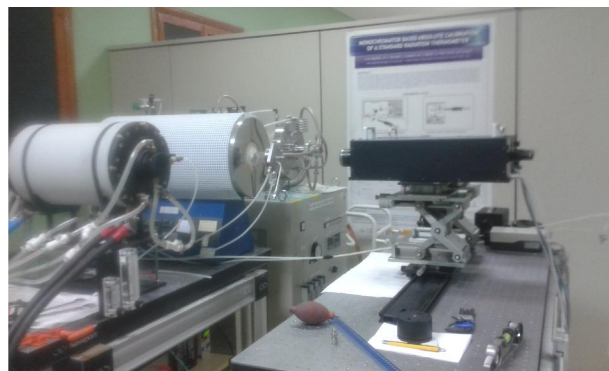


Fig. 1. ITS-90 measurements setup.

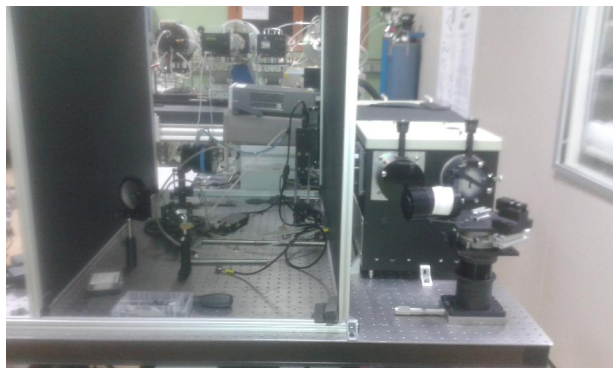
### 2.2 $t$ measurements and dissemination from 400 °C to 2800 °C

In the last years, CEM, in collaboration with Instituto de Optica of Consejo Superior de Investigaciones Científicas (IO-CSIC), has developed a setup for absolute calibration of standard radiation thermometers

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using the radiance method at 650 nm [3]. The aim is twofold: to realise and disseminate the new definition of the kelvin and to perform the assignment of the thermodynamic temperature to fixed points [4].

In order to carry out these measurements a system based in a monochromator or/and a laser and an integrating-sphere is used to calibrate the CEM standard RTs (KE-LP2 and LP4) [3]. The setup is shown in figure 2.



**Fig. 2.** RTs absolute calibration setup.

In addition to the absolute primary radiation thermometry, relative primary radiation thermometry are also available allowing  $t$  measurements below the Ag FP temperature. Both a KE LP4 at 900 nm and a KE LP5 at 1550 nm can be used to calculate  $t$  by extrapolation from the  $t$  Ag FP value (assigned with a KE LP2 or KE LP4 thermometer at 650 nm). The range covered by the relative primary radiation thermometry is 400 °C to the Ag FP temperature [5].

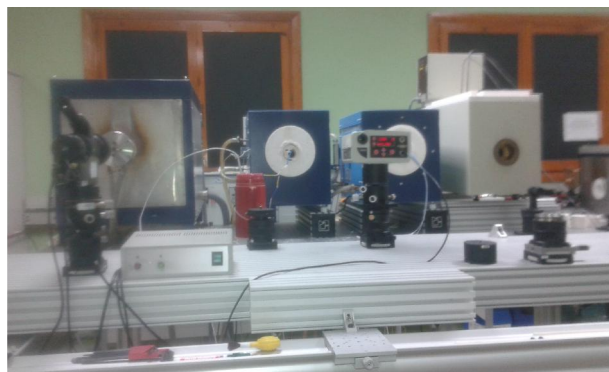
### 2.3 $t_{90}$ measurements and dissemination from – 40 °C to 1600 °C

A picture of the equipment used to measure radiation temperature from – 40 °C to 1600 °C at CEM is shown in figure 3. Different VTBBs are used: an ethanol bath (– 40 °C to 30 °C), an oil bath (50 °C to 180 °C), a Cs heat pipe (200 °C to 500 °C), a Na heat pipe (600 °C to 950 °C) and a three zone furnace (950 °C to 1600 °C).

The maximum diameter of the VTBB's apertures are 70 mm (–40 °C to 180 °C), 30 mm (200 °C to 950 °C) and 10 mm (950 °C to 1600 °C).

The standards used to measure the VTBB's temperature are:

- Up to 180 °C, Pt100, calibrated by comparison, immersed in the bath liquid touching the cavity.
- From 200 °C to 950 °C, home-made Au/Pt thermocouples calibrated in fixed points and inserted in a boring in the heat pipe parallel to the cavity.
- From 950 °C to 1600 °C, a VEGA TRTII (900 nm) calibrated as in 2.1.



**Fig. 3.** Secondary radiation thermometry facilities.

## 3 Results

The uncertainties of radiation thermometry measurements capabilities at CEM are:

- $t_{90}$  (from Ag to 2800 °C, 650 nm): from 0.2 °C to 1.8 °C [6]
- $t$  (from Ag to 2800 °C, 650 nm): 0.2 °C to 1.5 °C [7]
- $t$  (from 400 °C to Ag, 900 nm and 1550 nm): from 0.1 °C to 0.2 °C [5]
- $t_{90}$  radiation temperature (–40 °C to 1600 °C, 1  $\mu$ m and 10  $\mu$ m): 0.5 °C to 1 °C [8]

## 4 Conclusions

CEM Radiation Thermometry Laboratory can measure and disseminate both  $t_{90}$  and  $t$  at different ranges using RTs at different wavelengths. The best uncertainties range from 0.2 °C to 1.5 °C from Ag temperature to 2800 °C.

CEM radiation thermometry secondary facilities can supply traceability to infrared RTs from – 40 °C to 1600 °C, with uncertainties ranging from 0.5 °C to 1 °C.

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