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CALIBRATING COMMERCIAL RADIATION THERMOMETERS AGAINST FIXED POINT BALCKBODIES.

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Abstract – ITS-90 Radiation temperature Scale is defined only above the freezing point of silver. However, the need of calibration of radiation thermometers below this temperature is also important because many industries such as paper, cement, rubber makes use of the radiation thermometry for temperature measurements. Besides the temperature range of many radiation thermometers cover below and above freezing point of silver.
This work will describe the radiometric calibration of a commercial thermometer at the fixed points.

Keywords: Radiation thermometer, fixed points, calibration.

1. BASIC INFORMATION

ITS-90 defines the radiation temperature scale only above the temperature of freezing point of silver (961,78°C) [1].

However, there are increasing usage of radiation thermometers below this temperature in various industries.

In Turkey, glass, cement, food, paper industries uses radiation thermometers in various points in their production line.

All these radiance temperature measurements require traceability to national institute standards, therefore the instruments - radiation thermometers require calibration against the national primary standards. In Turkey primary level calibrations are realized by the National Metrology Institute (UME).

ITS-90 defines the radiation temperature scale making use of the Planck's radiation law that requires reasonably monochromatic radiation thermometers.

Due to logarithmic nature of the Planck's law, at lower temperatures (i.e. below 961.78 °C) amount of radiation reaching to the thermometer drops down logarithmically, making the monochromatic thermometers unsuitable, to be used in this temperature range.

Therefore band thermometers are used, and different calibration scheme is required.

Generally, below freezing point of silver, traceability of radiance temperature scale is maintained through contact thermometry. This requires a very uniform furnace and close to ideal cavity design in order to overcome the many difficult aspects of the radiance temperature measurement such as emissivity, temperature-coupling problems with contact thermometer, etc.

Another difficulty of calibrating industrial radiation thermometers originates from the fact that almost all commercially available thermometers are linearized in terms of temperature; therefore their calibration is impossible following the ITS-90 scheme even above the Silver point. However, some commercial thermometers can be calibrated radiometrically provided that suitable blackbodies are available. The main criteria for radiometric calibration of commercial radiation thermometers against fixed-point blackbodies are the minimum target size and small size-of-source effect (SSE). In this paper, the calibration of commercial radiation thermometer between Sn-point and Cu-point using ITS-90 fixed-point blackbodies will be described.

2. CALIBRATION PROCEDURE

2.1. Calibration systems

The technical specifications of the thermometer [2] and fixed-point blackbodies [3] that have been used in this work are given in tables 1 and 2 respectively. This thermometer is being used in industrial calibrations routinely as a working standard. It has linearized temperature output of a 0.1° C resolution.

Normally it has target diameter larger than aperture opening of fixed-point cavities however it is possible to reduce the minimum target size by using a set of close up lenses.

Therefore, in order to reduce the measurable minimum target size of thermometer, a close up lens was placed in front of radiation thermometer during the fixed-point measurements. In this case the focal distance of radiation thermometer also changed and reduced. The thermometer was checked for the distance effect with and without close-up lenses and calibration was made in flat part of the focal distance effect. The scale was constructed using the lens-on measurements.

How ever radiation thermometer has been used as a reference for industrial calibrations without a close-up lens. In order to acquire the equivalence of measurements with and without a close up lens a simple set of measurements has been performed.

In these set of measurements, radiation thermometer has been checked with large area high stability variable

temperature black body, calibrated using the UME transfer standard radiation thermometer. Measurements have been performed with close up lens and at the focal distance required by the lens, and also at the same temperature at a longer focal distance without a lens at all.
The emissivity setting of the radiation thermometer has been adjusted to obtain the same readings at the shorter distance with a close-up lens. Differences read due to aperture settings (due to SSE with and without close-up lens) at different temperatures have been treated as a correction in the industrial calibrations.

The SSE of the thermometer is shown in Fig.1. The SSE measurements were carried out using indirect method and without close-up lenses.

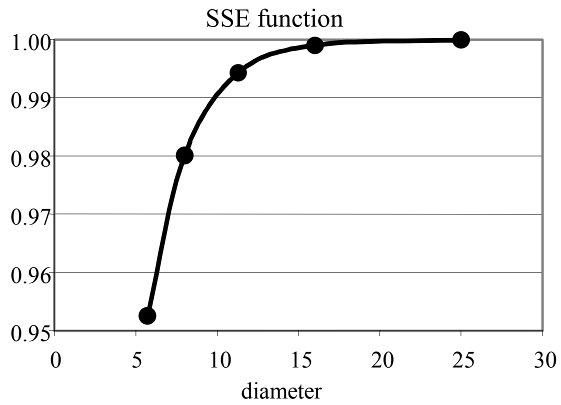

Fig.1. SSE of the radiation thermometer without close up lens.

TABLE I. Technical specification of radiation thermometer with close up lens.

Type size	Use for
Main wavelength	1,6 µm
Temperature-Range	200°C-1600°C
Min. target diameter	3,6mm
Focal length	220mm

TABLE II. Technical specification of BB's.

BB	Sn	Zn	Al	Cu
T/°C	231,928	419,527	660,323	1084,62
Aperture/mm	9			
Volume/cm^3	48			
Mass/g	342	332	120	420
Purity	99.9999%	99.999%	99.9999%	99.999%
Emissivity	0.99957±0.00009			
Material	High density graphite			

2.2 Calibration results

Calibration consists of realizing the fixed point and measuring the temperature signal of the thermometer.

Thermometer signal obtained at the freezing point of Cupper and Tin points are shown in Fig.2. and Fig.3.

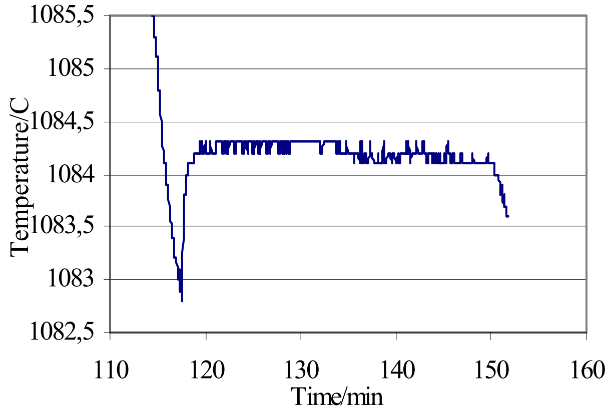

Fig. 2. Freezing curve at Cu-point.

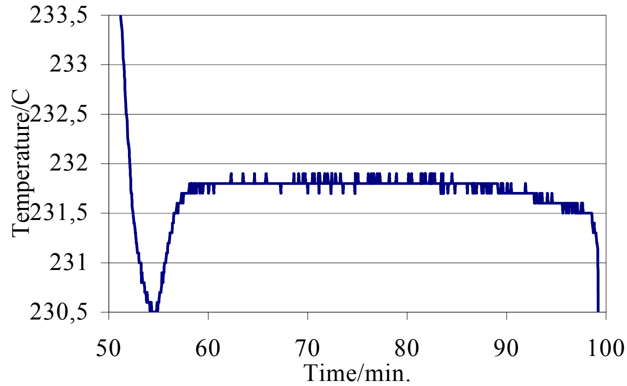

Fig 3. Freezing curve at Zn-point

Table 3 shows the average thermometers signal and uncertainty, associated with at Sn (231.928°C), Zn (419.527°C), Al (660.323°C) and Cu (1084.62 °C) fixed points.

TABLE III. Results of calibration at Fixed-points

Thermometer Reading °C	**Fixed Point Temperature °C**	**u (k=1) °C**
231.8	231.928	0.06
419.3	419.527	0.07
660.2	660.323	0.10
1084.2	1084.62	0.22

The calibration equation of the thermometer has been obtained by fitting a third degree polynomial equation to the values in table 3.

2.3 Uncertainties.

The following uncertainty components taken into consideration in calculating the final uncertainty of the scale, which was carried and disseminated by the radiation thermometer:

- Uncertainty due to reference Blackbodies
- Uncertainty due to instrument under calibration, namely UME working standard radiation thermometer which includes
- Size of Source effect
- Temperature resolution.
- Uncertainty due to calibration equation.
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We must note the long-term stability of the working standard radiation thermometer has been quite satisfactory, results of calibrations using this scheme in 4 years of time have shown no significant drift in the temperature indication of the thermometer at the fixed points.

One additional note for the uncertainties given to the industrial radiation thermometers calibrated at UME, much larger uncertainties are assigned mainly due to the larger uncertainty component originating from the test thermometer itself and also the uncertainty components due to radiating source namely UME variable temperature black bodies used in the calibrations of the industrial radiation thermometers.

3. CONCLUSION

This procedure has been formally tested in the EUROMET Comparison TRIRAT [4]. “Intercomparison of local medium-temperature scales where three transfer standards an infrared thermometer supplied by IMGC and denominated TRT1 [5], an infrared thermometer supplied by Heitronics and denominated TRT2 and a Zn-point blackbody and furnace supplied by IMGC [3] were circulated among the partners according to the protocol.

UME, the National Metrological Institute of Turkey, that was involved in an extension of the TRIRAT Project, carried out as EUROMET Project no. 453. Two different schemes were available for the calibration of the thermometers:

- **Scheme I**: calibration of the thermometers at the fixed points of In, Sn, Zn, Al and Ag.
- **Scheme II**: calibration with continuously variable blackbody cavities at nine temperatures (156.599 °C, 200 °C, 231.928 °C, 327.462 °C, 419.527 °C, 550 °C, 660.323 °C, 730 °C, 800 °C). Points at 880 °C and 961.78 °C were optional.

UME calibrated both thermometers with scheme I and scheme II, but only calibrations with scheme II will be reported here since the reference instrument used for scheme two was the thermometer which is subject to present paper.

In the EUROMET project two variable temperature blackbodies have been employed as a radiance source The calibration results of two circulating thermometers are shown in Fig.4 and Fig. 5.

TABLE IV. Description of variable temperature black bodies

	BB #1	BB#2
Range	50°C-750°C	150°C-1100°C
Material	-	Ni-Cr
Size	Spherical (no information available for size and material)	Cylindrical cavity inner diameter 90 mm and 450 mm long slanted by 30° at the bottom.
Aperture	25 mm	60 mm
Emissivity	0.999 ±0.0005	0.99 ±0.003

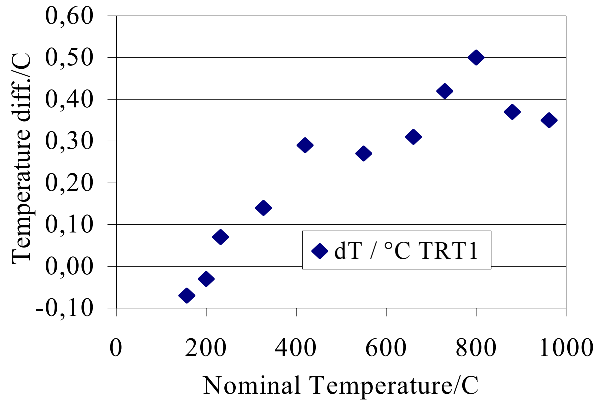

Fig. 4. Calibration results of EUROMET circulating thermometer TRT1.

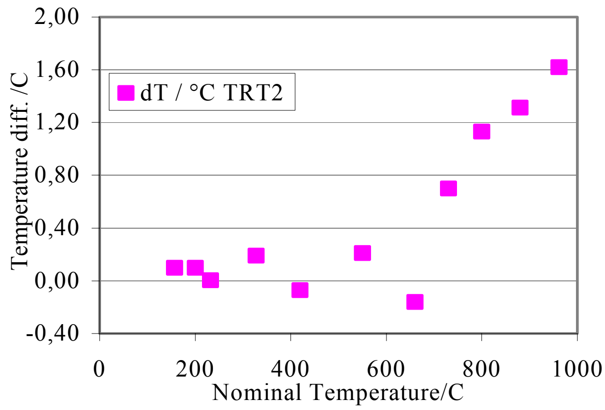

Fig. 5. Calibration results of EUROMET circulating thermometer TRT2

As seen in the figure 5 deviation from the mean temperature is larger for temperatures 800°C, 880°C, and 961,78°C, at these three points BB2 variable temperature black body has been used as a radiance source. As also see in table IV its uniformity, stability and emissivity characteristics is not as good as the lower temperature black body BB1.

But the calibration of TRT1 where the thermometer has analogue signal output and smaller size of source effect, against the same blackbodies yielded considerably better results.

This work has shown that it is possible and also quite convenient to calibrate industrial radiation thermometers and obtain relatively smaller uncertainties using fixed points

It also shows that in order to obtain satisfactory results for radiance temperature calibrations variable temperature black bodies with uniform cavity and high emissivity required as well as the thermometers with non-linearized analogue outputs, smaller size of source effect. Then uncertainties better than 1°C is attainable following the fixed point scheme described in this paper.

REFERENCES

[1] H.Preston Thomas, ”The International Temperature Scale of 1990 (ITS-90)”, *Metrologia*, vol. 27, pp. 3-10, 1990.

[2] MIKRON M190 Operating Instructions, MIKRON Instruments Company Inc.

[3] F. Girard,.T. Ricolfi, ”A transportable blackbody furnace for the accurate realization of the fixed points of indium, tin and zinc", Meas. Sci. Technol., vol.9, n.8, pp. 1215-1218, 1998.

[4] M. Battuello, at all, “The European Project TRIRAT” to be published in the proceedings of the 8th Temperature Symposium, 2002.

[5] T Ricolfi., F. Girard., “A transfer standard infrared thermometer for the temperature range 150 °C to 1000 °C”, Proceedings of TEMPMEKO ’99, edited by J. Dubbeldam and M. de Groot, IMEKO TC12/Nmi-VSL, Delft, 1999, pp 593-598.

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