INDUSTRIAL THERMAL RADIATION SOURCE FOR HIGH TEMPERATURE INFRARED THERMOMETER CALIBRATION

Frank Liebmann, Tom Kolat
Fluke Calibration
799 E Utah Valley Dr, American Fork, Utah, EEUU
+1 801-847-1154, frank.liebmann@flukecal.com

Abstract: Industrial level infrared thermometers are being increasingly designed to measure temperatures above 500 °C. A thermal radiation source is needed to calibrate these instruments. The infrared thermometers designed to measure these temperatures generally measure with a smaller field-of-view. This means there is a possibility of using a blackbody cavity as the thermal radiation source. This paper discuses an attempt to mount a cavity inside a thermocouple furnace. It discusses the measurements made to verify the emissivity of the cavity using radiation thermometers.

1. INTRODUCTION

In 2008, Fluke Calibration released a series of flat plate infrared calibrators with a temperature range of up to 500 °C. Since the release of these products, there has been increased demand for a calibrator to cover a higher temperature range. Recently Fluke Calibration has come out with a new thermocouple calibration furnace that with modification may serve as a solution for higher temperatures.

2. THEORY

The cavity installed in the furnace is of a cylindro-conical design with an apex angle of 120° with a diameter of 50 mm [1]. The cavity design uses a contact thermometer for traceability placing the thermometer as close as possible to the conical apex of the cavity bottom. The reason for this is to minimize temperature measurement error due to heat transfer between the probe's sensor and the cavity bottom surface [2].

The cavity bottom uniformity was measured by scanning the cavity bottom using a precision radiation thermometer with a small field of view. The contribution to the cavity measurement uncertainty was included in the uncertainty analysis. In order to calculate data needed for the blackbody emissivity model and to estimate uncertainty due to cavity bottom heat exchange, temperature gradient was measured along the cavity axis.

The cavity was modeled for emissivity using STEEP3 [3]. The results of this modeling are shown in Table 1.

Table 1. Results of STEEP3 modeling.

Temp (°C)	Isothermal		Non-Isothermal	
	3.9 µm	8 – 14 µm	3.9 µm	8 – 14 µm
300			0.9983	0.9997
660	0.9998	0.9991	0.9987	0.9998
960			0.9986	0.9997

In order to test the cavity design, measurements were made on the cavity. These measurements involved comparing the traceable readout temperature of a contact thermometer used in the furnace cavity. The radiation thermometers used for the comparison were precision radiation thermometers with pyroelectric detectors [4]. The contact thermometry data was taken with either a rhodium versus platinum standards thermocouple (TC) or platinum resistance thermometer (PRT). In all measurements, two chains of traceability to the *Système International d'Unités* (International System of Units or SI) were maintained, and the two measurements were compared using normal equivalence (E_n) [5][6]. Two different wavelengths were used for measurements at each temperature serving to reduce any doubts about the emissivity estimation due to the various influences of effective emissivity [3].

The traceability of the contact measurements came through the American Fork Primary Temperature Laboratory (AFL), through the National Institute of Science and Technology (NIST), to the SI. The traceability for the radiation thermometry measurements came through AFL, through NIST to the SI or through the *Physikalisch-Technische Bundesanstalt* (PTB). In all cases, there is always a contact measurement compared to a non-contact measurement for the determination of normal equivalence, both measurements being traceable.

3. RESULTS

The measurements were divided into four sets for organizational purposes. Only a portion of the results are reported in this paper due to the sheer number of tests. Data Set 1 and Data Set 2 compare the AFL bath cavity temperature to the furnace cavity temperature using the TC as a reference. Data Set 3 compare PTB data to the furnace data using the TC as the furnace reference. Data Set 4 compares the AFL bath cavity temperature to the furnace cavity temperature using the PRT as a reference. It should be noted that the measurements using a PRT showed larger uncertainty than those using a thermocouple as a reference. This was due mainly the cavity bottom heat exchange uncertainty [2]. This was a result of the length of the PRT sensor and the heat flow mentioned previously. The results of this testing are summarized in Table 2.

4. DISCUSSION

In all cases the normal equivalence was well below unity. This validated two things. First, it shows a valid emissivity model of the cavity. Second, it showed that with the experimental uncertainties the reference probe provides sufficient traceability in the spectral bandwidths tested.

5. CONCLUSIONS

Based on the positive outcome of the results, AFL has added the furnace blackbody to their calibration capabilities in their scope of accreditation increasing the upper range of their capability to 1000 °C.

REFERENCES

[1] DeWitt, D., Nutter, G., Editors, Theory and Practice of Radiation Thermometry, pp. 602 – 603, 658 – 661, 695 – 705, (Wiley Interscience, New York, 1988).

[2] J. Fischer, et. al., Uncertainty budgets for calibration of radiation thermometers below the silver point, CCT-WG5 working document CCT-WG508-03, (BIPM, Sèvres, France, 2008).

[3] Prokhorov, A., Monte Carlo Method in Optical Radiometry, Metrologia, Vol. 35, pp. 465-471, (BIPM, Sèvres, France, 1998) doi: 10.1088/0026-1394/35/4/44.

[4] VDI/VDE Guideline 3511 Blatt 4: Temperature Measurement in Industry – Radiation Thermometry, (VDI, Düsseldorf, 2011).

[5] ISO/IEC 17043:2010 Conformity assessment — General requirements for proficiency testing, 2010, (ISO, Geneva, 2010).

[6] ILAC-G22:2004 Use of proficiency testing as a tool for accreditation in testing, (ILAC, Rhodes, Australia, 2004).

Table 2: Results of radiation thermometer comparisons.

Data Set	λ / µm	LAB / °C	FURN / °C	Diff / °C	U_{LAB} / K	U_{FURN} / K	E_n
Set 1	8 - 14	300.00	299.97	-0.03	0.20	0.45	-0.05
Set 1	8 - 14	500.00	499.61	-0.39	0.34	0.52	-0.62
Set 2	3.9	300.00	300.05	0.05	0.42	0.45	0.08
Set 2	3.9	420.00	420.21	0.21	0.60	0.48	0.27
Set 2	3.9	500.00	500.39	0.39	0.85	0.52	0.39
Set 2	3.9	300.00	300.14	0.14	0.42	0.60	0.19
Set 2	3.9	420.00	420.38	0.38	0.60	0.80	0.38
Set 2	3.9	500.00	500.45	0.45	0.85	1.04	0.34
Set 3	8 - 14	660.00	659.83	-0.17	0.24	0.60	-0.27
Set 3	8 - 14	810.00	810.02	0.02	0.31	0.80	0.02
Set 3	8 - 14	960.00	960.27	0.27	0.37	1.04	0.24
Set 3	3.9	660.00	659.90	-0.10	0.14	0.83	-0.12
Set 3	3.9	810.00	809.84	-0.16	0.19	1.15	-0.14
Set 3	3.9	960.00	959.67	-0.33	0.25	1.48	-0.22
Set 4	8 - 14	300.00	299.61	-0.39	0.20	0.65	-0.58
Set 4	8 - 14	500.00	499.72	-0.28	0.34	0.75	-0.34