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Intercomparison of Temperature Block Calibrators

H.-G. Behnke · S. Friederici · S. Rudtsch

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Abstract In 2008/2009 an intercomparison of temperature block calibrators (TBCs) was carried out among 17 DKD accredited laboratories with Physikalisch-Technische Bundesanstalt (PTB) as the pilot laboratory. Within the framework of this intercomparison, different types of block calibrators were investigated in the temperature range between −24 °C and 600 °C. It was discovered that the devices have become significantly better during the past 10 years. As an example, the axial temperature distribution of the actual generation of TBCs is about ten times better than during the intercomparison of 1998. The results were improved in the same level and demonstrate the present capabilities of accredited laboratories in Germany.

Keywords Dry block calibrator · Inter comparison · Temperature block calibrator

1 Introduction

During recent years, temperature block calibrators (TBCs) have become increasingly popular for thermometer calibrations in industrial calibration laboratories and also for specific tasks at national metrological institutes (NMIs). With the publication of the calibration guideline EURAMET/cg-13/v.01 [1], users of TBCs have access to an agreed procedure to quantify different sources of uncertainty and to validate calibrations by means of block calibrators. Moreover, manufacturers of block calibrators now have the advantage of transparent and uniform assessment criteria of their products and a better basis for further developments. As a result, considerable improvements of the actual generation of TBCs were reported within the temperature community, and as

H.-G. Behnke (✉) · S. Friederici · S. Rudtsch
Physikalisch-Technische Bundesanstalt, PTB, Berlin, Germany
e-mail: heinz-guenther.behnke@ptb.de

a consequence, lower measurement uncertainties were claimed within the framework of accreditation within the German calibration services (DKD).

Most industrial thermometer calibrations are performed with TBCs, often also called dry block calibrators. To perform traceable calibration, these TBCs also have to be calibrated, preferably by calibration laboratories accredited for this service. The German calibration service (DKD) organized its first interlaboratory comparison among such accredited laboratories about a decade ago [2]. Commercial proficiency tests for laboratories have been offered in the meantime by at least two organizations: the Danish Technological Institute (DTI) [3] and the NMi Van Swinden Laboratory B.V. [4]. A new intercomparison among all the DKD laboratories accredited for the calibration of TBCs was carried out from April 2008 to December 2008. A calibrated SPRT was used to measure the temperature in one boring of the insert of the TBC, and to compare this measured value with the indicated value on the display of the TBC. As a result, a correction of the indicated temperatures was determined.

The aims were:

(1) to prove the ability of the accredited laboratories to calibrate TBCs and to verify their accredited uncertainties (Sect. 3.1),
(This includes also the characterization of the properties of the TBCs which is needed for the estimation of the uncertainty (Sects. 3.1/3.2).)
(2) to demonstrate the capabilities of modern TBCs (Sects. 3.2/3.3), and
(3) to demonstrate the applicability of the EURAMET/cg-13/v.01 (Sects. 3.3/4).

Seventeen DKD laboratories from Germany took part in the intercomparison. To minimize the time for the comparison, two loops were started. In the first loop, two TBCs manufactured by Ametek (Types ATC 156B and ATC 650B) were measured and in the second loop two TBCs manufactured by Fluke (Types 9171 and 9173) were measured. Each laboratory calibrated two TBCs, the first one in the temperature range between −24 °C and 140 °C and the second one in the temperature range between 50 °C and 600 °C. Three DKD laboratories calibrated all four TBCs of both manufacturers. The measurement time for each laboratory was 2 weeks including the time for transport to the next participant of the intercomparison. Every participant performed a calibration and determined the properties of each device according to EURAMET/cg-13/v.01. The investigated properties were: temperature stability with time, the axial temperature homogeneity along the boring in the measurement zone, temperature differences between the borings, and the influence of different loading upon the temperature in the measurement zone (heat sink or load). Each laboratory received a short guide for measuring and handling the TBC. After the comparison, all the participants received a report including their own results and an anonymous overview of the results of all the participants.

2 Measurements

2.1 Measurements at PTB

The pilot laboratory performed three calibrations of each TBC. The reference values were calculated by the arithmetic mean of these results. Two calibrations were carried

Table 1 Results of the pilot laboratory for loop 1 and loop 2

Loop	Calibrator Type	Nominal value (°C)	Measured correction 2008-04-10 (mK)	Measured correction 2008-05-14 (mK)	Measured correction 2008-12-10 (mK)	Mean correction[a] (mK)	Expanded uncertainty ($k = 2$) (mK)
1	156B	−24	1	11	15	9	52
1	156B	23	0	13	18	10	28
1	156B	140	26	36	43	35	50
1	650B	50	7	1	−7	0	25
1	650B	300	35	21	17	24	88
1	650B	600	73	51	43	56	172
2	9171	−24	−18	−12	12	−6	45
2	9171	23	39	42	60	47	28
2	9171	140	27	28	81	45	92
2	9173	50	−76	−83	−62	−74	27
2	9173	300	26	35	59	40	56
2	9173	600	−3	32	28	19	77

[a] Reference value

out in a period of 1 month before a loop was started, and a final calibration took place at the end of each loop. For the calibration, the pilot used an SPRT type Goodrich/Rosemount Model 162CE. Each TBC of loop 1 had an external sensor included, which was directly connected with the readout on the display of the TBC. The results are shown in Table 1.

2.2 Measurements of Participants of the Intercomparison

The participants used their equipment and procedures of accreditation to calibrate the TBC. The recommended basic document was the calibration guideline EURAMET/cg-13/v.01.

3 Results

3.1 Comparisons of the Calibration Results of the Participants

The results of the comparison at selected temperatures are presented in Figs. 1, 2, and 3.

The figures show the deviation of each participant from the reference value of the pilot laboratory including the associated uncertainty at selected temperatures. The identification number of the laboratory (ID) 21 presents the mean of the results of the pilot laboratory. ID 22-27 indicates all the measurements of the pilot laboratory. IDs 2, 9, 11, 13-20, and 22-24 indicate the measurements of loop 1. IDs 1, 3-8, 10, 12, and 25-27 indicate the measurements of loop 2. The dashed lines represent the expanded ($k = 2$) uncertainty of the results of the pilot laboratory (PTB). All error bars

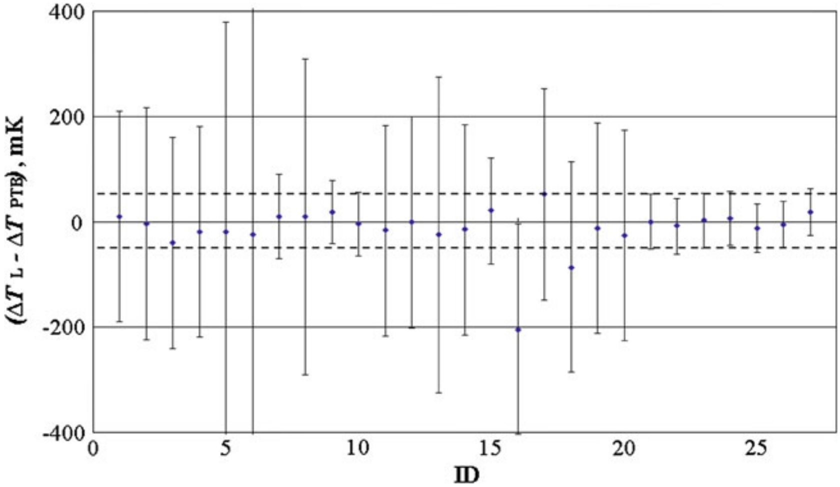

Fig. 1 Deviations between corrections of the laboratory to corrections of the pilot at −24 °C. *Dashed lines* represent the expanded ($k = 2$) uncertainty of the results of the pilot laboratory (PTB). All *error bars* correspond to expanded ($k = 2$) uncertainties

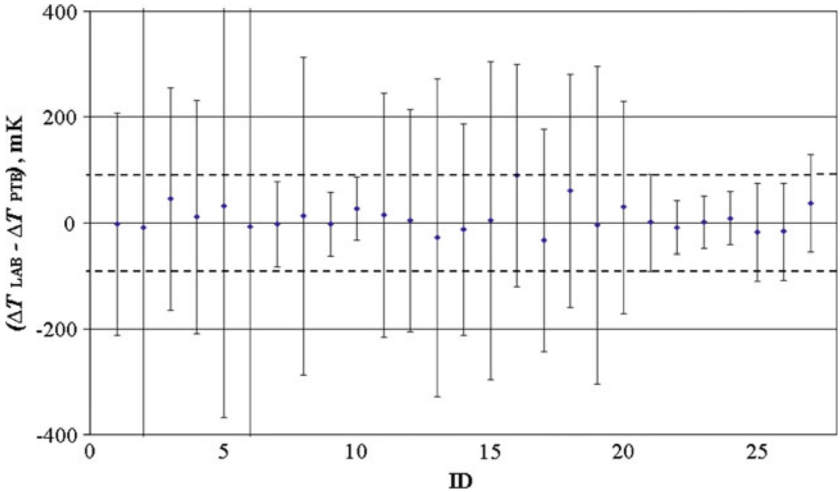

Fig. 2 Deviations between corrections of the laboratory to corrections of the pilot at 140 °C. *Dashed lines* represent the expanded ($k = 2$) uncertainty of the results of the pilot laboratory (PTB). All *error bars* correspond to expanded ($k = 2$) uncertainties

correspond to expanded ($k = 2$) uncertainties. The results prove that all the laboratories have good consistency related to their stated uncertainties. Only one laboratory deviated in its results more than the combined uncertainty ($k = 2$) from the result of the pilot laboratory at 600 °C. It was discovered that this laboratory used an unsuitable thermometer during the period of comparison. The diameter of the thermometer was too small for the boring of the TBC. Most of the stated uncertainties of the participating laboratories were fairly large related to the good agreement of the vast majority of the

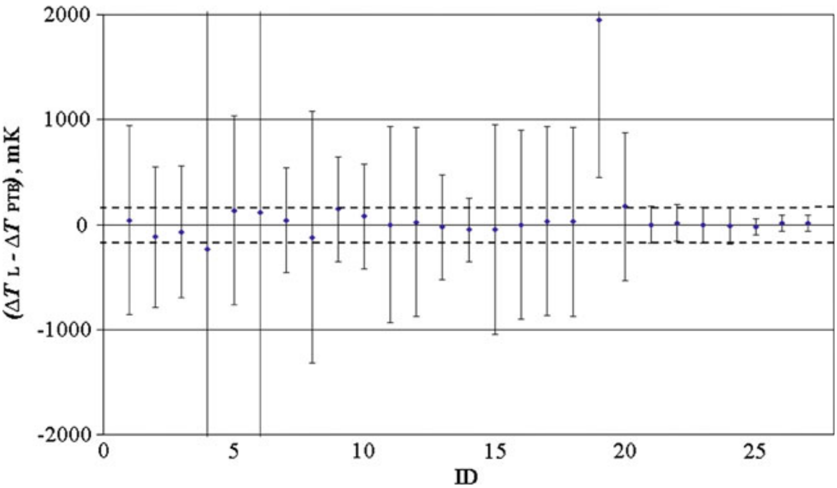

Fig. 3 Deviations between corrections of the laboratory to corrections of the pilot at 600 °C. *Dashed lines* represent the expanded ($k = 2$) uncertainty of the results of the pilot laboratory (PTB). All *error bars* correspond to expanded ($k = 2$) uncertainties

results. This was caused mainly by "old" DKD accreditations with larger uncertainties from 10 years ago and the inferior capabilities of the TBCs at that time.

3.2 Properties of the Temperature Block Calibrators

The properties determined are listed in Sect. 1 and specified in detail in the corresponding EURAMET guideline. Every participant had to examine all the corresponding properties of each TBC. Presenting all the results would go far beyond the scope of this article. However, three distinct tendencies can be stated as follows:

- The more pronounced an effect or property of a temperature block calibrator appears at a specific temperature, the more differences occur between the participants. (For example, larger differences occur at the measured axial temperature distribution at high temperatures and smaller differences at the measured temperature stability close to ambient temperature.)
- The spread of the results of every property of nearly all the participants is well covered by the accredited uncertainties.
- Mostly the axial temperature inhomogeneity is the largest contribution to the uncertainty.

As an example, the results of the measured properties of the pilot are presented in Table 2. Figure 4 shows a typical example of the axial temperature distribution for a TBC measured at −24 °C.

The different results at the radial distribution were mainly caused by the regulation of the TBC due to the change of the location of the two thermometers. These portray no real differences of the temperatures between the borings. All the participants measured similar effects. More details are given in an internal final report of this intercomparison.

Table 2 Properties of the temperature block calibrators, typical mean results of the pilot laboratory

Calibrator type (mK)	Nominal value (°C)	Stability with time[a]	Axial distribution[b] 0 mm to 20 mm (mK)	Axial distribution[b] 0 mm to 40 mm (mK)	Radial distribution[c] (mK)	Effect of Loading[d] (mK)
156B	−24	15	61	256	14	26
9171	−24	5	10	21	4	12
156B	140	18	−12	−79	6	40
9171	140	12	−21	−38	6	12
650B	600	22	−115	−76	49	8
9173	600	19	35	32	8	24

[a] Stability with time over 30 min (difference between maximum and minimum temperature)
[b] Axial distribution of the temperature along the boring at a distance of 20 mm or, respectively, 40 mm over the bottom for a thermometer with a short sensor (length about 10 mm)
[c] Absolute value of the radial distribution of the temperature between two borings which lay opposite each other
[d] Absolute value of the temperature difference with and without heat sink or load (additional thermometer or metal rod)

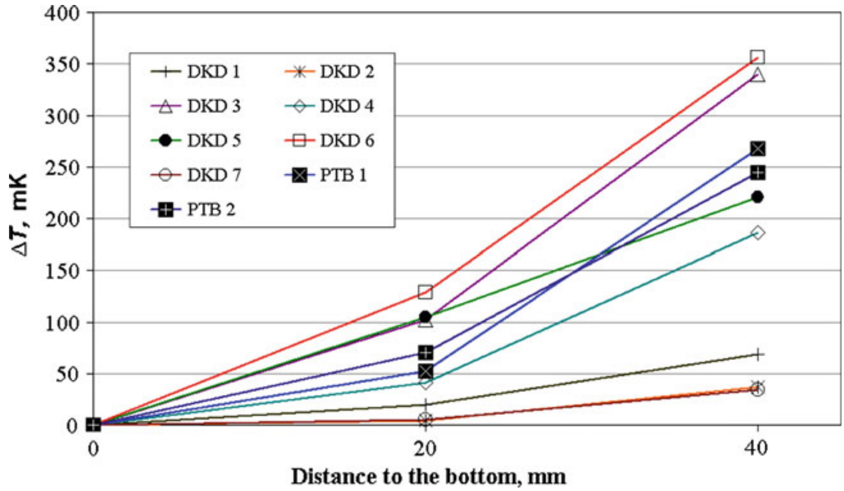

Fig. 4 Typical results of measurements of the axial temperature distribution at −24 °C

3.3 Discussion of the Results

Comparing the results of this intercomparison with those of the first round of the national DKD laboratory intercomparison with TBCs (10 years ago) leads to some major differences. The results are shown in Table 3. Only comparable results (similar temperatures and measurement procedures) are listed. Both intercomparisons used TBCs which were state of the art at their time. Of the two loops of the "2008 intercomparison," only the bigger values (of the "inferior" devices) are listed. It was found that the devices have become significantly better during the last 10 years. As an example,

Table 3 Approximate values of two DKD intercomparisons of TBCs (significant results only)

Year of intercomparison	1998/1999	2008
600 °C, correction (result), PTB[a]	1.3 K	<0.08 K
600 °C, axial temp. distrib., 40 mm, PTB[a]	1.0 K	<0.1 K
600 °C, temp. stability, PTB/DKD[a]	0.10 K	<0.03 K
−24 °C[b], correction (result), PTB[a]	0.15 K	<0.02 K
−24 °C[b], axial temp. distrib., 40 mm, PTB[a]	0.6 K	<0.3 K
−24 °C[b], temp. stability, PTB[a]	<0.02 K	<0.02 K

[a] Approximate measurement result(s) of PTB (and DKD, where indicated)
[b] 1998/1999 intercomparison was realized at −25 °C

the axial temperature distribution of the new generation of TBCs is about ten times better than in 1998. The mentioned guideline and its previous (international and national) versions might have inspired the manufacturer to improve their devices.

4 Conclusion

The accreditation of calibration services requires the verification of the capabilities of the laboratories. This is carried out by means of intercomparison measurements at regular time intervals. Seventeen DKD calibration laboratories carried out intercomparisons at six temperatures in the temperature range between −24 °C and 600 °C. The TBCs were characterized according to the calibration guidelines of EURAMET/cg-13/v.01. The agreement of the measurement results is considerably better than expected. The main reasons are the improved performance of the new generation of TBCs and the experience and competence of the participating laboratories. The stated uncertainties were based on the accreditation which was supported by the intercomparison 10 years ago. The intercomparison results show clearly that most of the calibration laboratories have fulfilled the requirements for reducing their measurement uncertainties.

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