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Thermometry

EURAMET Project N° 927

Comparison of blackbodies for calibration of infrared ear thermometers

Final report

(May 2010)

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1 Introduction

The EURAMET comparison was initiated during the EURAMET TC THERM meeting on 5./6. April 2005 in Vienna. MIRS/UL-FE (at the time MIRS/FE-LMK) was chosen to be the pilot laboratory. The procedures and instructions, which were given in the technical protocol, were agreed and followed by all participants. The objective of the intercomparison was to determine agreement of blackbodies in calibration of infrared ear thermometers (IRETs) among European national laboratories.

IRET is an instrument, which measures temperature of a human body. Despite all problems reported in the literature, more and more such thermometers are used not only in medical practice but also in home use. Therefore they shall meet certain requirements. Essential requirement is related to accuracy. There are several standards in the world, which describe requirements for IRETs. In the EU this is the standard EN 12470-5, which is a harmonised standard and supports the Medical Device Directive (MDD). Other standards are ASTM standard, Designation E 1965 – 98 and the Japan Industrial Standard. The basic requirement for accuracy in EN 12470-5 is that the maximum permissible error of IRET is ±0,2 °C in the range from 35,5 °C to 42,0 °C. The International Organization for Standardization (ISO) is developing a new standard for clinical thermometers, which will include also IRETs. To verify the accuracy of an IRET a suitable blackbody is needed. An example of a blackbody is presented in Annex C of the standard EN 12470-5. Such blackbody in a stirred water bath was provided for the comparison by the pilot laboratory.

The comparison was performed in one loop. Therefore the pilot laboratory provided the bath with the "EN-type" of a blackbody and the transfer IRET. The bath was rented from the manufacturer Kambič Laboratorijska oprema. Expenses related to renting of baths were covered by the pilot laboratory. The IRET and the bath were be calibrated in the pilot laboratory before and after comparison measurements in participating laboratories. The transfer calibration bath is shown in Figure 1. The transfer IRET is shown in Figure 2.

Figure 1: Transfer calibration bath with the EN-type of blackbody

Figure 2: Transfer IRET

The transfer IRET and the transfer bath are relatively robust but in any case transportation and handling should have been performed with extreme care. A suitable package was provided so that the transport was possible with the express courier. Each laboratory was responsible and covered expenses for transport of the devices to the following laboratory in the schedule.

Each participant laboratory calibrated at least the transfer IRET against the transfer blackbody and against a local blackbody. After calibration of the transfer IRET (and local IRET, if available) a laboratory reported the results in the Excel spreadsheet, which was provided by the pilot laboratory. This report should have been sent (within 1 month after measurements) to the pilot laboratory by E-mail.

2 Scheme of organization and schedule of comparison

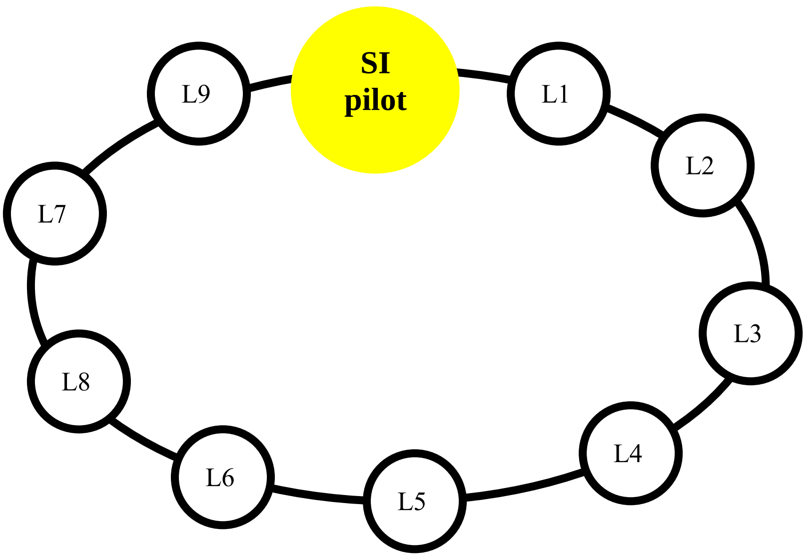

Figure 3: Organization of comparison

For a given laboratory, the time allowed for the measurements (calibration of IRET) was estimated to be less than 2 weeks. The transfer time between two laboratories was rated up to 2 weeks. Comparison measurements were performed according to the schedule except two modifications. The first modification was a 4-week delay due to complications in re-importing the equipment to the EU (Norway to Latvia). The second modification was a change in the schedule between the NMIs of United Kingdom and the Netherlands. The schedule of comparison is presented in Table 1. The scheme (loop) of comparison is presented in Figure 3.

Table 1: Schedule of comparison

	Country	Received	Sent
SI pilot	*SI	1. November 2007	3. December 2007
L1	****CH**	6. December 2007	14. January 2008
L2	****TR**	22. January 2008	Februar 2008
L3	****NO**	5. March 2008	26. March 2008
L4	*****LT**	15. April 2008	6. May 2008
L5	DK	13. May 2008	13. June 2008
L6	DE	16. June 2008	10. July 2008
L8	UK	15. July 2008	6. August 2008
L7	NL	7. August 2008	24. September 2008
L9	FR	29. September 2008	5. November 2008
SI pilot	SI	10. November 2008	

* ATA-carnet form must be filed at customs when **leaving** the country

** ATA-carnet form must be filed at customs when **entering and leaving** the country

*** ATA-carnet form must be filed at customs when **entering** the country

3 Participating laboratories

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4 Task of the pilot laboratory

The pilot laboratory provided:

- the transfer bath with the “EN-type” of blackbody and the transfer 4-wire PRT
- the transfer IRET as a transfer thermometer
- ATA carnet for countries outside the EU (Switzerland, Turkey, Norway)

The pilot laboratory calibrated both circulating thermometers (PRT and IRET) of the comparisons twice (at the beginning and at the end of the comparison), according to the instructions given in Chapter 6.

5 Requirements for participating laboratories

1. All participating laboratories should have had their own blackbody, which was capable of operation in the range from 35,5 °C to 42 °C and was used for calibration of IRETs.

2. All participating laboratories should have been able to measure the resistance of the 4-wire PRT, which was provided in the calibration bath with the blackbody to determine its temperature. The measuring current should have been 1 mA.

3. Additionally the participating laboratories may also had their own IRET, which was calibrated against the transfer blackbody and against a local blackbody.

6 Detailed instructions for participating laboratories

6.1 Description of package and the transfer bath with the blackbody

Upon receiving the bath with the blackbody and the IRET, the laboratory should have inspected received items for damage. The report of initial inspection should have been recorded in the form ”PACKAGE RECEIVED”, which was a part of the technical protocol and sent either by a fax or E-mail to the pilot laboratory. If there was any damage observed, the pilot laboratory should have been contacted to receive instructions on how to proceed.

If no damage was reported to the pilot laboratory, the laboratory should have left the equipment for one day in the laboratory conditions. The transfer bath with the blackbody (in the following text transfer BB) should have been positioned on a level surface, like in Figure 4.

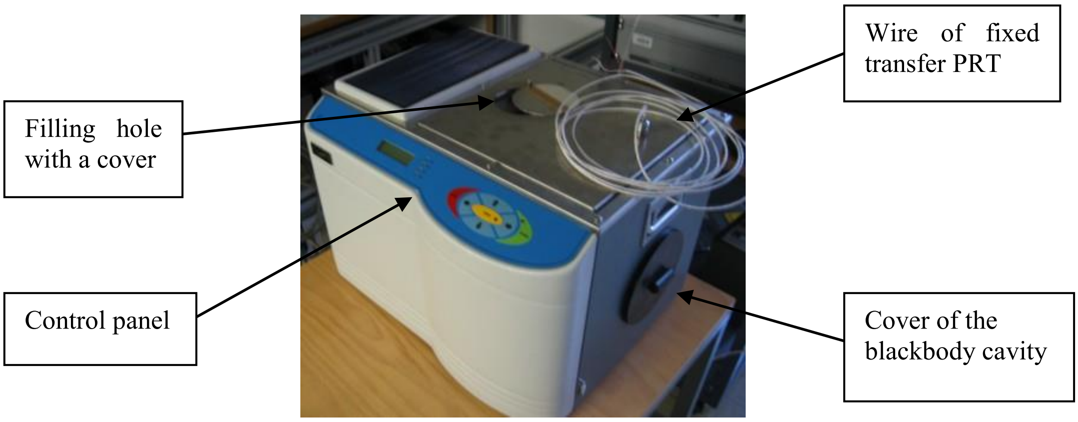

Figure 4: Transfer bath with the blackbody positioned on a level surface

The transfer bath with the blackbody should have been placed away from any direct air flow so that the blackbody was not affected by it. Transfer BB consisted of the blackbody of “EN-type” made of copper, the transfer PRT of nominal resistance 100 Ω, which was fixed and it could not be removed from the transfer bath, internal temperature sensor, two electric heaters of 100 W and 800 W power, the stirring system, the hole with mesh to prevent entry of other objects to the bath and the control panel to control the bath regulation (set point temperature, start and stop,..).

Diameter of the aperture of the transfer blackbody cavity was 20 mm. Figure 5 shows technical drawing of the transfer blackbody cavity and the position of transfer PRT.

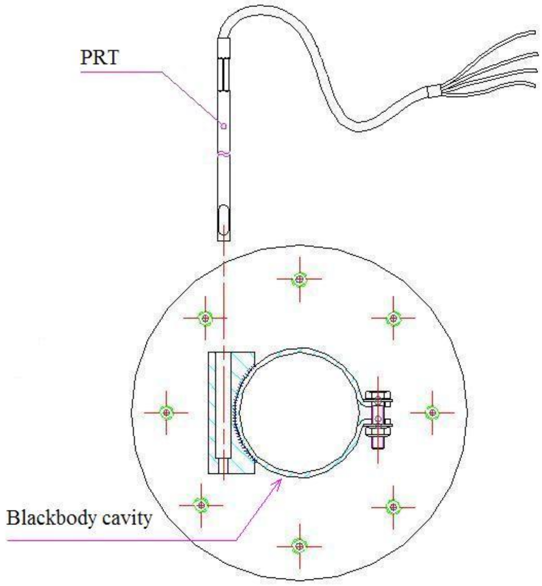

Figure 5: Position of the transfer PRT in the transfer BB

6.2 Preparation of transfer bath with the blackbody for use

After the transfer BB had been positioned, it had to be filled with distilled or demineralized water. Before filling the bath with water, the drain valve of the bath has to be checked and closed. Figure 6 shows a closed drain valve, two connections for cooling water, main switch and power cable of the bath. Power cable should have had appropriate connection for the socket. Originally it was equipped with the EU standard plug. Wherever necessary (UK for example), a laboratory should have used an appropriate adaptor or cable.

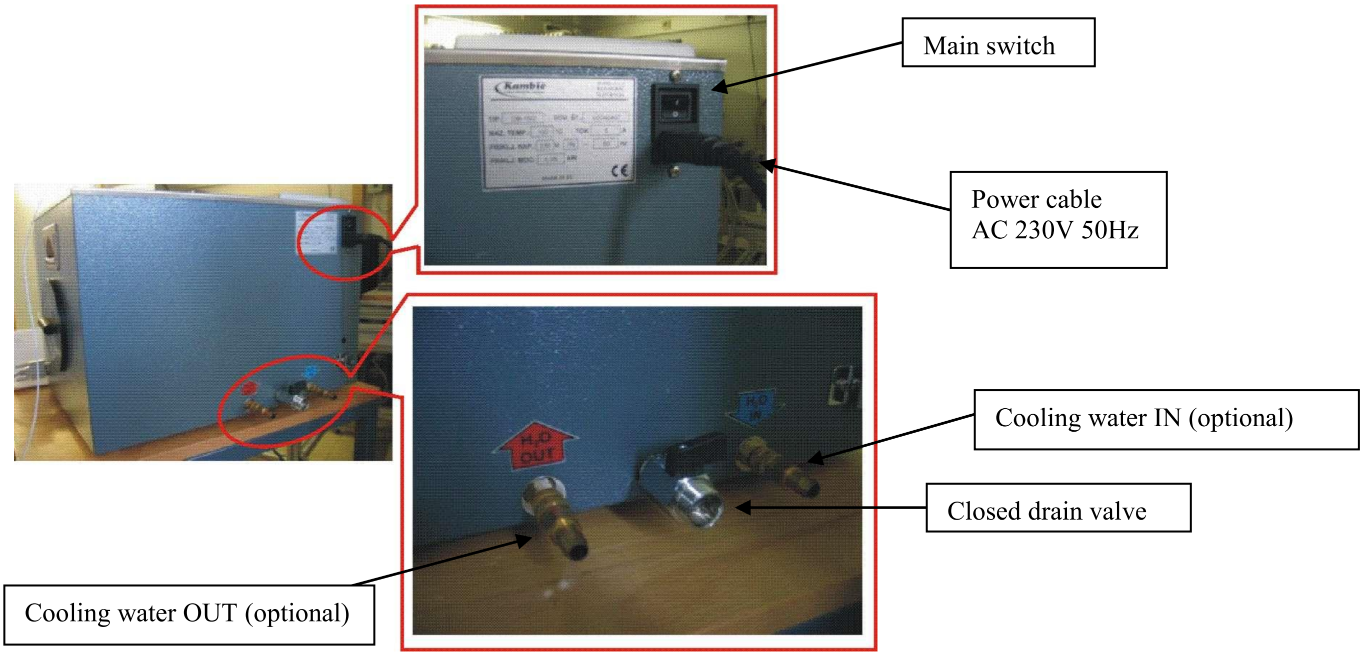

Figure 6: Back side of the transfer BB

Figure 7 shows the hole with a mesh through which the bath was filled. First of all the cover of filling hole had to be opened and then water was poured into the bath through this hole. The volume of water filled should have been approximately 15,2 liters and it should have been either distilled or demineralized. Water should have reached at least the wire mesh or it should have been 1 mm above the mesh. If it was higher than 1 mm above the mesh, it had to be removed through the drain valve. The water level in bath increased after the bath and stirring system has been switched on.

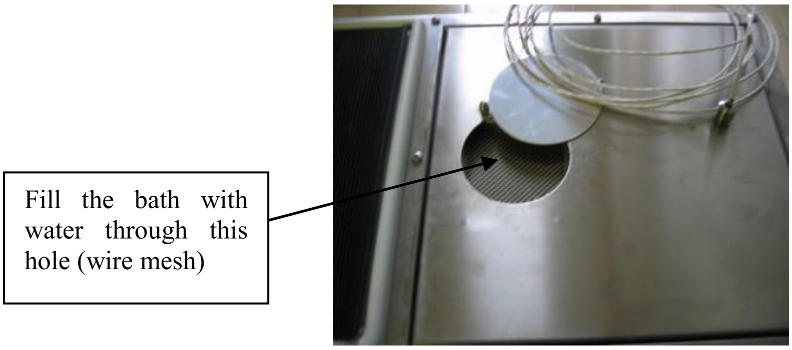

Figure 7: Filling hole with mesh

Measurements of the transfer IRET and of eventual local IRET should have been performed against the transfer bath with "EN-type" of blackbody and against a local bath with a blackbody at the following set of temperatures 35,5 °C, 38,0 °C and 41,0 °C. It was important to start measurements with a set temperature of the transfer bath at temperature 35,5 °C and then continue with 38,0 °C and 41,0 °C and not vice versa, because the bath cools down very slowly. If cooling was needed, the fastest way was to switch off the regulation of bath temperature (described further). When the regulation is switched off heaters and stirrer don't work. Stirrer motor contributes to heating of the bath water, when the stirrer is running.

It was possible to cool the bath temperature with cooling water using appropriate connections in Figure 6. During the bath operation, the cooling water could be used, but it was not recommended. If it was used, the water flow should have been moderate and LED (light-emitting diode) L1 (see Figure 8) should have been pulsing with approximately 50% duty cycle. When led L1 was switched on it meant that the 100 W electric heater was switched on. Led L2 (800 W electric heater) should have been switched off after the bath reached the stable temperature. In the case when both LEDs were switched off, the water flow should have increased. In a case when both LEDs were switched on or L2 was pulsing the water flow should have decreased.

The transfer PRT was mounted in such a way that it was in a contact with the blackbody cavity (see Figure 5) and directly measured temperature of the blackbody. The transfer PRT should have been connected to a resistance measuring system (bridge or multimeter).

6.3 Instructions for use of the transfer bath with the blackbody

To start operation of the transfer BB the main switch (see Figure 6) should have been turned on. Figure 8 shows the control panel of the bath. The LCD displays current temperature of water in the bath, date and time (see Figure 9). Current temperature is read by the internal temperature sensor which is needed for bath regulation.

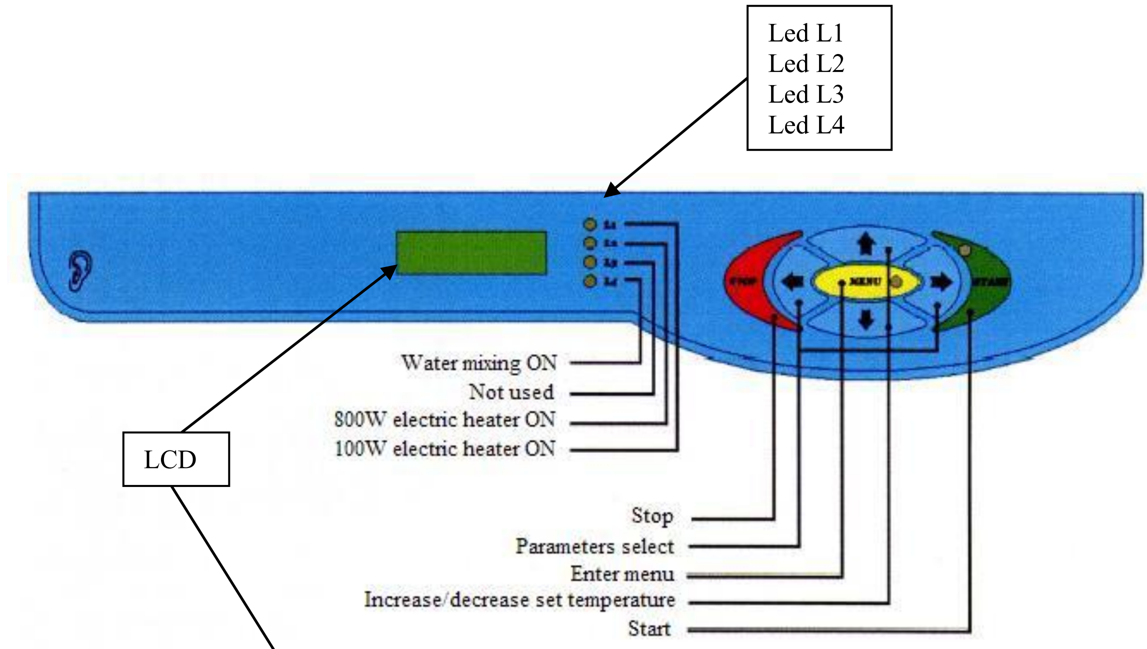

Figure 8: Control panel of the bath

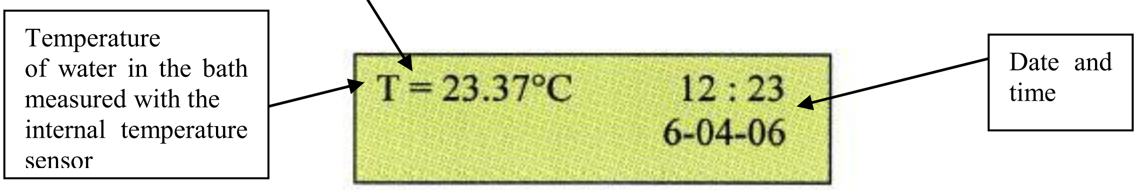

Figure 9: Temperature of water in the bath, date and time

Before starting the transfer BB regulation it should have been set to a desired temperature of the blackbody (bath). The first temperature to be set was 35,5 °C. On the control panel of the bath, button “**MENU**” had to be pressed. The yellow led in button “**MENU**” would turn on. The LCD displayed previous set temperature (for example 35,0 °C or something else, probably 35,5 °C, 38,0 °C or 41,0 °C):

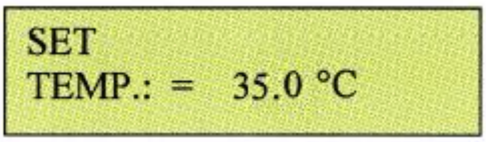

Figure 10: Set temperature

To change the settings use  up or  down buttons. Set temperature value to 35,5 °C and enter it with “**MENU**” button, the yellow led would turn off. The LCD would display:

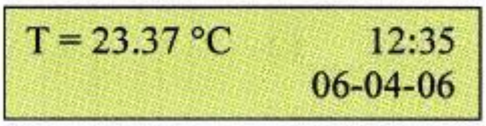

Figure 11: Current temperature of water in the bath, date and time

To initiate bath regulation the “**START**” button had to be pressed. After the “**START**” button had been pressed, electric heaters and stirrer motor would automatically turn on and the bath water would begin circulating and heating. The LCD would display:

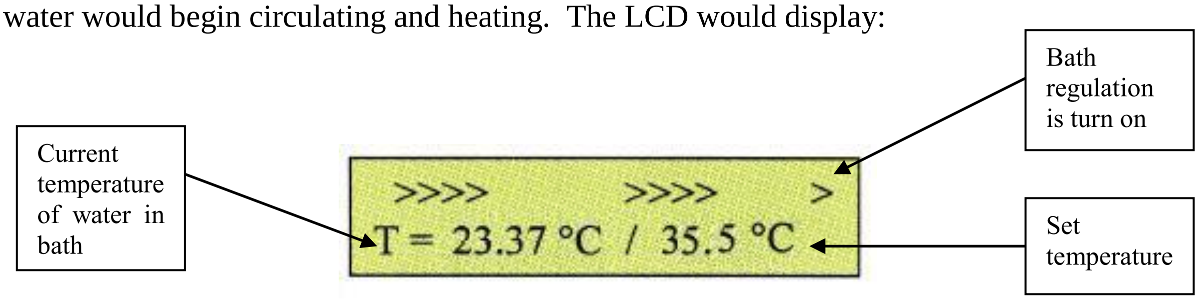

Figure 12: Regulation of water temperature in the bath

It should have been checked that the water was circulating properly and that the stirrer was running smoothly and silently. During the regulation it was possible to change the set temperature simply by pressing the “**MENU**” button. The LCD would have displayed like in Figure 10. Simply change *set temperature* value by pressing up or down buttons. Set temperature would have been automatically accepted when the button up (increase) or down (decrease) was pressed. For exit the set temperature menu the “**MENU**” button had to be pressed.

The bath regulation could have been stopped at any time. To stop regulation, the “**STOP**” button had to be pressed and held for 3 seconds. The LCD would have displayed:

Figure 13: Regulation of the bath was stopped

Before turning off the main switch, the state of LCD should be like in Figure 9. The “**MENU**” button had to be pressed two times. After the first set point 35,5 °C (the second was 38,0 °C and the third was 41,0 °C) had been set and regulation had been started the cover of blackbody cavity had to be opened (see Figure 14). Before taking measurements wait for the bath temperature to stabilize. This was possible by measuring a resistance of the transfer PRT, which was mounted in the bath. It was in a contact with the blackbody cavity. During measurements with IRET **the cavity had to remain open** to keep the temperature stability of the blackbody and the filling hole should have remained open too (it was easier to control the water level in bath and keep the temperature stability).

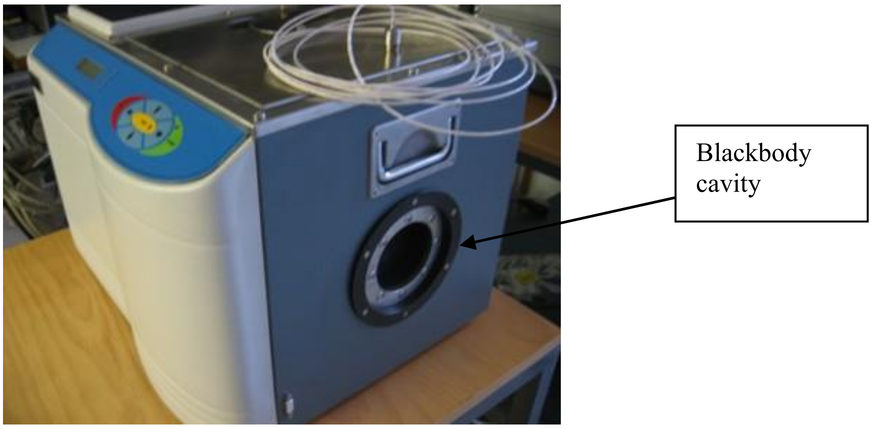

Figure 14: Opened blackbody cavity

6.4 Description of the transfer IRET with instructions for use

The transfer IRET has two modes of operation. These are the normal and the calibration mode. It had to be set in the calibration mode. In the calibration mode “CAL mode” it is possible to display temperature with a resolution of a hundredth of degree Celsius (0,01 °C) and the instrumental emissivity is set to one (which is not possible in the normal mode). To enter the “CAL mode” the following steps have to be performed:

- Wait until the thermometer is in standby mode (it switches off)
- Press and hold the On/Mem button (see Figure 15)
- Then as soon as possible press and hold down the Activation button
- When the “CAL” is displayed and flashing, release all buttons (see Figure 16)

IRET is now ready to take measurements.

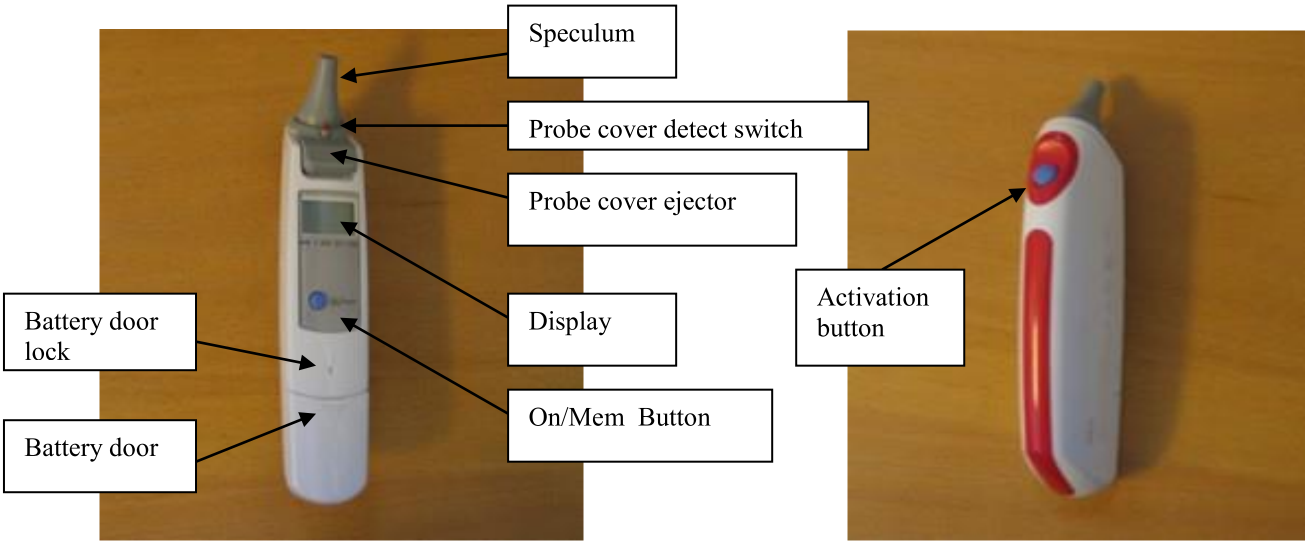

Figure 15: Transfer IRET; front and back view

CAL symbol
flashing

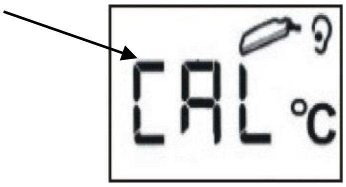

Figure 16: Display – calibration mode

To measure temperature of the blackbody the IRET had to be positioned like in Figure 17. It had to be placed as deep as possible in the blackbody cavity, but not touching the edges of the cavity.

- Then press and hold the Activation button until the beep is heard (temperature has been read).
- After having performed a temperature reading, take the IRET out of the blackbody cavity, turn it around to read the LCD and then press the On/Mem button. As long as this button is pressed the internal sensor temperature will be indicated on display.
- Release the On/Mem button. The display will switch to an indication, where three figures without decimal point and without the unit indication are displayed. The meaning of the figures are :

First digit: last part of the integer part of the measured temperature
Second digit: tenth of degree of the measured temperature
Third digit: hundredth of degree of the measured temperature

For example: If the set point temperature of bath was 35.5 °C and the numbers indicated on the display were 551, it meant that the measured temperature was 3**5.51** °C.

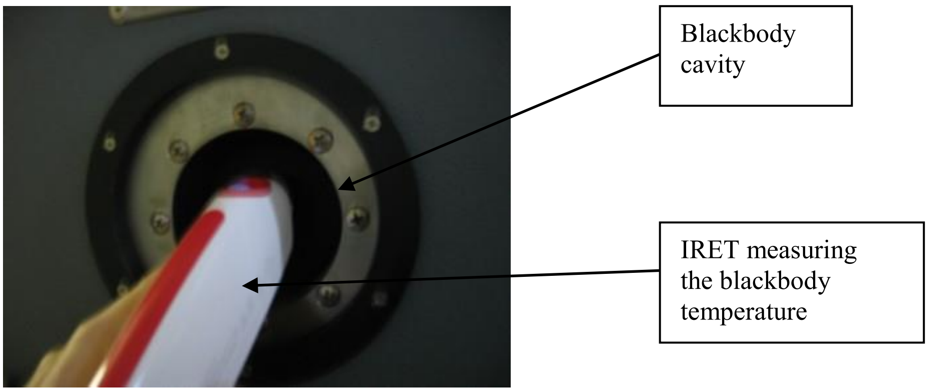

Figure 17: Measuring temperature of the blackbody

- After the first reading has been taken, repeat the procedure for other readings (place the IRET like in Figure 17, then press and hold the Activation button…), third...
- The calibration mode "CAL mode" will be canceled automatically, when the thermometer enters, the standby mode (it switches off).
- The IRET switches off automatically.

Some IRETs might exhibit higher readings of temperature due to their heating by hand. That will be observed by the temperature curve of subsequent readings during the measurement.

6.5 Measurements

Measurements with the transfer IRET should have been performed against the transfer bath with the "EN-type" of blackbody and against the local bath with the blackbody.

After stabilization of temperature in both the transfer bath and the local bath, **the first** series of measurements had to be taken. In the first series the transfer IRET was **without the attached probe cover.** Probe covers are shown in Figure 18. Figure 19 shows how to attach or detach a probe cover. In the calibration mode the transfer IRET allows measuring even, if there is no probe cover installed. The transfer IRET automatically detects that a probe cover is not attached (symbol of probe cover is displayed flashing). Readings with the transfer IRET, which was set to the calibration mode - "CAL mode", had to be taken directly alternating between the transfer BB and local BB. The first cycle of measurements had to be taken with the transfer IRET against the transfer BB plus the reading of the transfer PRT resistance, and immediately after that against the local BB plus the reading of temperature of the local BB, determined by the local calibrated thermometer. This cycle had to be repeated 20 times. Thus in the first series 80 measurements had to be taken.

In **the second** series of measurements the procedure remained the same, the only difference was that the IRET was used **with the attached probe cover** which was marked as "1**"**.

Figure 18: Three probe covers

All readings had to be taken in approximately 20 second interval. After the probe cover was damaged (top of the cover was torn, problems with attaching, ...) for any reason, the laboratory had to clearly mark the measurement results made by the consecutive reserve probe cover, which was marked as "2" or "3". Series of measurements with the same probe cover would enable us to determine the influence of a probe cover.

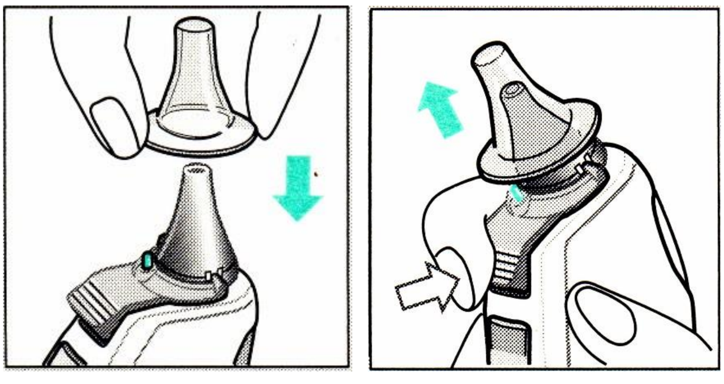

Figure 19: Attaching/detaching probe cover

If the laboratory had its own IRET, measurements of the local IRET should have been performed against the transfer bath with the “EN-type” of blackbody and against the local bath with the blackbody in the same way as with the transfer IRET. This means that a laboratory should have tried to perform measurements with the local IRET without the probe cover even, if it was not designed for such application.

If possible, the local IRET should have been measured in the calibration mode also. If the calibration mode was not available, the operation mode of IRET as it was used during comparison had to be recorded. Also the local IRET should have had a dedicated probe cover for the measurements with suitable marking and a reserve probe cover. If a reserve probe cover had to be used, the laboratory had to clearly mark the related measurement results. If possible, the laboratory should have performed also one set of measurements with the local IRET without the probe cover.

After completion of comparison measurements, bath regulation had to be stopped. To stop the bath regulation the “**STOP**” button should have been pressed and held for 3 seconds and then “**MENU**” button had to be pressed two times to enter the LCD like in Figure 9. After that the main switch should have been turned off.

After 5 to 7 days the complete set of measurements had to be repeated once again. The second set of measurements had been used for estimation of the short-term stability of IRETs.

6.6 Preparing the package for transport to the following laboratory

Before packing the bath again water from the bath had to be completely poured out through the drain valve. At the end of measurements the bath and the IRET should have been packed securely to the original package and transport to the next participant should have been organized. After sending the package, also a signed form “PACKAGE SHIPPED” should have been sent to the coordinator via fax or e-mail.

The procedures required by the Department of Customs of various countries should have been strictly obeyed when the devices were shipped outside the EU. In these cases, the ATA Carnet forms should have been carefully and accurately completed. **It was responsibility of the laboratory organising the transfer to the next laboratory to present the ATA Carnet to the Customs, when leaving the country and upon arrival in the country of destination.** Usually only express couriers (e.g. DHL) perform appropriate customs procedure. Nevertheless, any courier should have been informed about the ATA carnet forms and procedure, when the transport went outside or back to the EU and between countries, which were not members of the EU. The pilot laboratory provided suitable ATA carnet forms for participants outside the EU. The ATA carnet forms accompanied the package.

If the equipment was not received according to the schedule the pilot laboratory should have been immediately informed. The responsibility of the pilot laboratory was to deal with any problem, to find appropriate solutions with relevant participants, and to inform other participants about the status of the comparison. The timetable was revised accordingly.

7 Reporting the results

The participating laboratories should have filled the Excel spreadsheet provided by the pilot laboratory. The spreadsheet was sent to a participating laboratory via E-mail after a participating laboratory confirmed a receipt of the package.
The file named “EURAMET 927 XX first set.xls” contained four spreadsheets. Every participating laboratory had to fill the "Instrument details" spreadsheet first. Other three spreadsheets were prepared for filling the measurement results, separately for each set temperature. A participating laboratory had to rename the file and replace XX with its country code. For the second set of measurements a laboratory had to rename the file to “EURAMET 927 XX second set.xls”.

7.1 Details of instrumentation of participating laboratories

Participating laboratories had to report to the pilot laboratory the following details of their instrumentation used in the comparison:

Blackbody details

- Manufacturer, model and serial number
- Heating power (AC or DC)
- Temperature uniformity along the blackbody cavity measured with at least two thermometers.
- Temperature stability at 41 °C over 1 hour presented as a graph and standard deviation of the sample (not standard deviation of mean).
- Emissivity and its uncertainty (either calculation or estimation) with brief explanation, how it was determined.

Local IRET details

- Manufacturer, model and serial number
- Available operating modes
- Resolution
- Additional data, if available (e.g. spectral response, field of view, etc.)

Local reference (contact) thermometer details

- Manufacturer, model and serial number
- Uncertainty
- Drift

Details of instrument for measuring the resistance

- Bridge (AC or DC) or other instrument
- Manufacturer, model and serial number
- Frequency (if applicable)
- Bandwidth (if applicable)
- Accuracy (ppm)

Reference resistor (if applicable)

- Manufacturer, model and serial number
- Temperature coefficient of the reference resistor (Ω/°C)
- Uncertainty and drift (ppm)
- Maintained: air, temperature stabilized oven, temperature stabilized (water, oil) bath
- Temperature of maintenance (°C)
- Temperature stability of the air, oven or bath (°C)

7.2 Uncertainty budget

Uncertainty budget in calibration of an IRET consisted of the following uncertainty contributions at least:

Type A

- $u_{\text{IRET, std}}$ standard deviation of a sample of IRET measurements at each temperature point

Type B

- $u_{\text{BBR, temp. stab.}}$ uncertainty of a blackbody radiator (stability of temperature measured as a standard deviation of a transfer PRTs during the measurement of IRETs)
- $u_{\text{BBR, temp. hom.}}$ uncertainty of a blackbody radiator (homogeneity or uniformity of temperature along the blackbody cavity). Uniformity for the transfer blackbody is given by the pilot laboratory.
- $u_{\text{BBR, emis.}}$ uncertainty of a blackbody radiator temperature due to emissivity less than unity. Uncertainty of the transfer blackbody radiator temperature due to emissivity is given by the pilot laboratory.
- $u_{\text{ref. term.}}$ uncertainty of the reference termometer (including drift). Uncertainty for the transfer PRT is given by the pilot laboratory.
- $u_{\text{resistance}}$ uncertainty of a measuring instrument for resistance (if a resistance bridge was used a participating laboratory has to state also the uncertainty of a reference resistor used in combination with the bridge, and drift of the reference resistor).
- $u_{\text{IRET, resol.}}$ uncertainty of an IRET resolution.
- $u_{\text{add.}}$ any other additional uncertainty component given and described by a participating laboratory

7.3 Analysis of results

All participating laboratories but the laboratory from Latvia sent their results. Because after several interventions of the coordinator and no response from the Latvian laboratory it was decide during the EURAMET TC Thermometery meeting on 3$^{\text{rd}}$ of April 2009 that Latvian laboratory was excluded from the intercomparison.

On 5$^{\text{th}}$ of January 2009 all participating laboratories received analyzed results of their own measurements only. At this stage participants couldn't see the results of other participating laboratories. Measured resistance of the transfer PRT was calculated to temperature based on coefficients provided by the pilot laboratory. Coefficients used in analysis were determined prior circulation of the transfer blackbody and transfer IRET. Participants had to check the entries and state relevant uncertainties to the table, which was provided and send their consent or corrections to the coordinator. By the end of April all the entries were confirmed.

On 3$^{\text{rd}}$ of July 2009 the participants received two files with results of all measurements. In the first file the results of transfer IRET were analyzed while in the second file the results of local IRET were analyzed. Participant received also the file in which the drift of the transfer PRT was analyzed.

By May 2010 the analyses were concluded and the project was presented in the TEMPMEKO&ISHM 2010 conference. The article on the comparison was published in the International Journal of Thermophysics http://www.springerlink.com/content/f6107730386w65v8/.

In general, the results showed good agreement between the blackbodies for calibration of IRETs at majority of participating NMIs. The results agreed better, if measurements of IRETs without a probe cover were taken into account. The results could be used in the process of reviewing calibration measurement capabilities (CMC) in the field of radiation thermometry.

The new ISO standard for clinical thermometers (IEC ISO 80601-2-56, Medical electrical equipment — Part 2-56: Particular requirements for basic safety and essential performance of clinical thermometers for body temperature measurement) states that the BB used for laboratory calibration of IRETs must have an uncertainty of no greater than 0.07 °C (k = 2). The comparison results show that the majority of the BBs agree within the requirements of the standard, especially taking into account the comparison measurement uncertainties, such as the repeatability of the measurements, the positioning of the probe cover and placement of the probe within the blackbody aperture etc. The agreement was better if an IRET (transfer and local) was used without a probe cover and the agreement was worse, if an IRET was used with a probe cover. Results were better in comparison of BBs with the help of local IRETs, but not all laboratories had them (Denmark, The Netherlands). The obvious deviation was observed in Turkey, where some problems exist with the local BB, which needs further investigation.

It can be seen that the differences (transfer blackbody – local blackbody) are generally negative; i.e. the local BB gave a consistently higher temperature, as measured by the IRET, than the transfer BB. The differences are more negative still for the measurements when the IRETs were used with the probe cover. This suggests that there are some systematic effects that are not being taken into account.

Good agreement between the IRET BBs of different laboratories is necessary for further dissemination of the temperature scale to IRETs, which is one of essential requirements in the international standard for clinical thermometers. The requirement for the laboratory accuracy of an IRET is ±0.2 °C and was simply adopted from the other standards of clinical thermometers. In the past clinical thermometers were only contact thermometers and achieving of such laboratory accuracy was not a problem. With the infrared technology achieving of such accuracy is a challenge even in the laboratory conditions. Further development in this field is in line with the overal development strategy in thermal metrology.

7.3.1 Analysis of results of BBRs via the transfer IRET

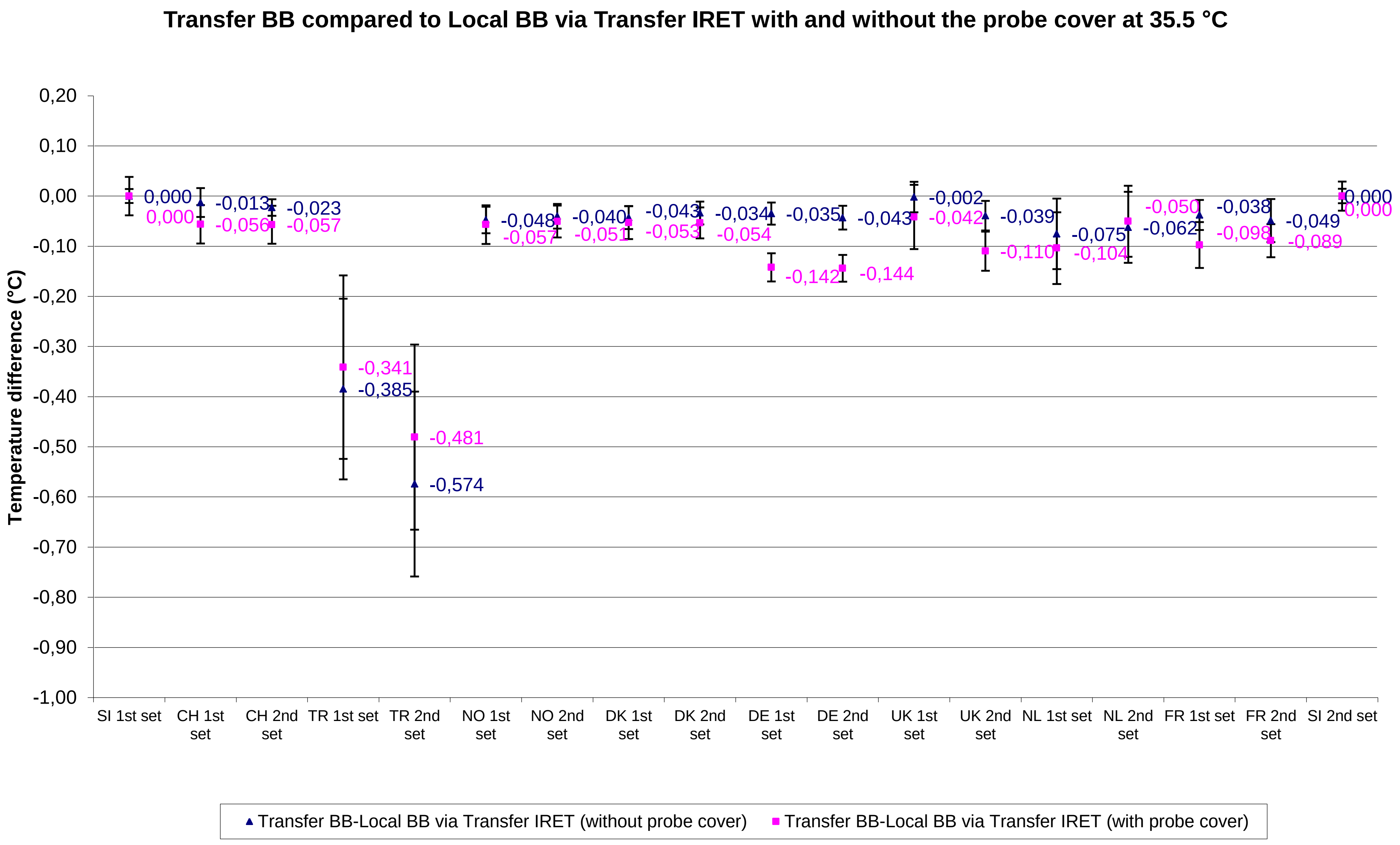

Figure 1: Transfer BB compared to Local BB via Transfer IRET with and without the probe cover at 35.5 °C

Transfer BB compared to Local BB via Transfer IRET with and without the probe cover at 38.0 °C

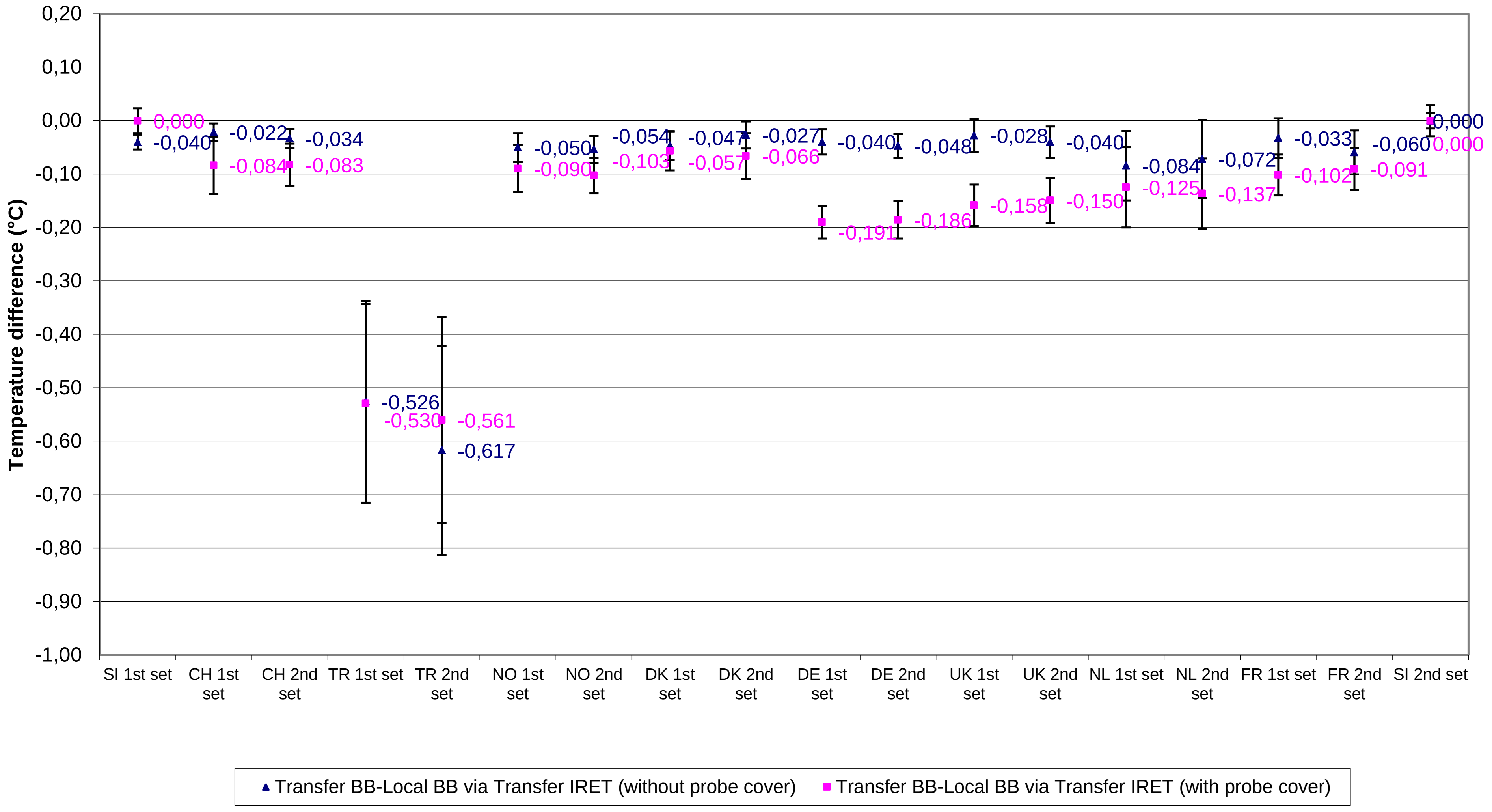

Figure 2: Transfer BB compared to Local BB via Transfer IRET with and without the probe cover at 38.0 °C

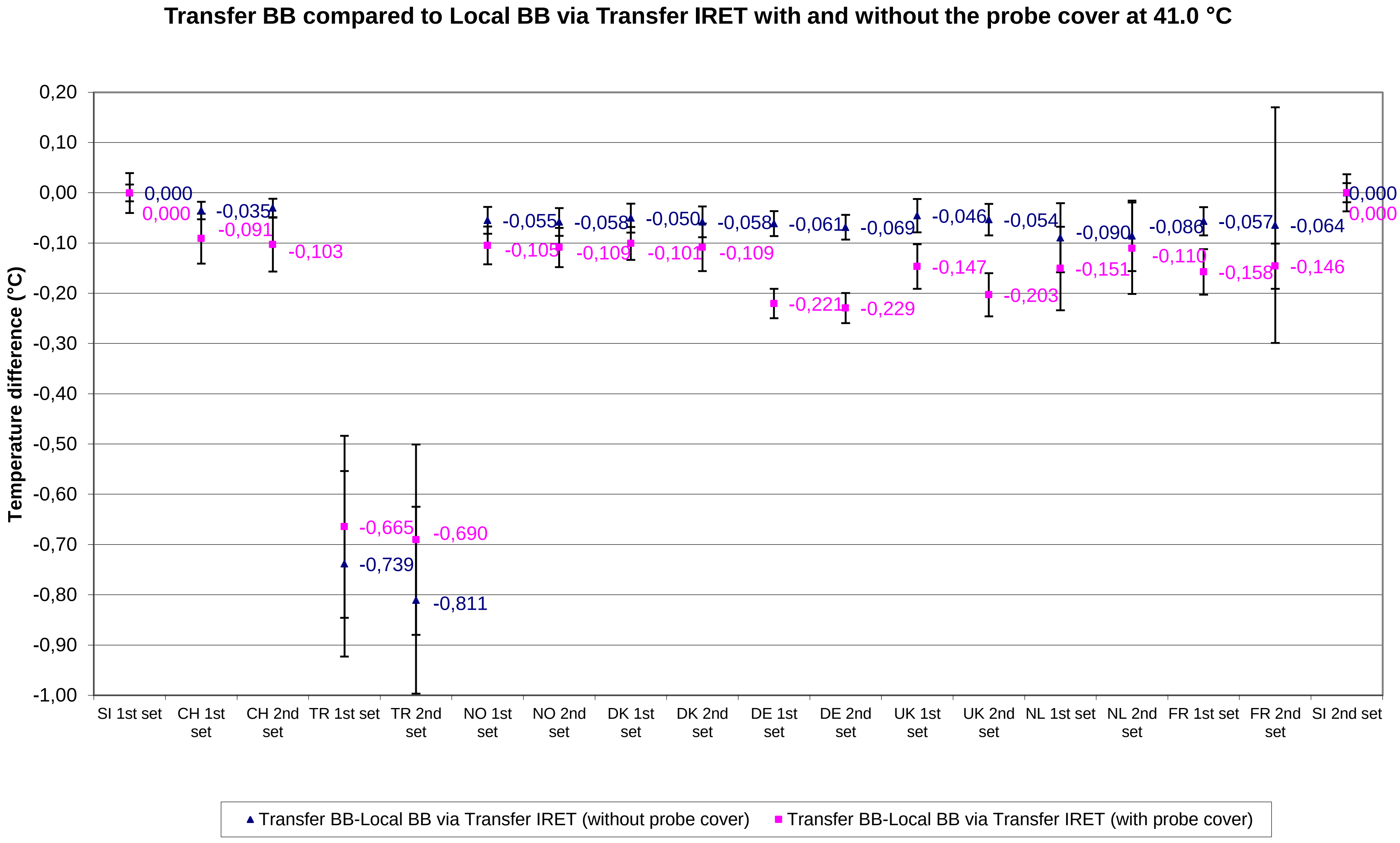

Figure 3: Transfer BB compared to Local BB via Transfer IRET with and without the probe cover at 41.0 °C

7.3.2 Analysis of results of BBRs via a local IRET

Not all participants had a local IRET. The transfer blackbody and the transfer IRET were considered also as the local instruments for Slovenia. Other laboratories, which participated with their local IRET were Switzerland, Turkey, Norway, Germany, United Kingdom and France.

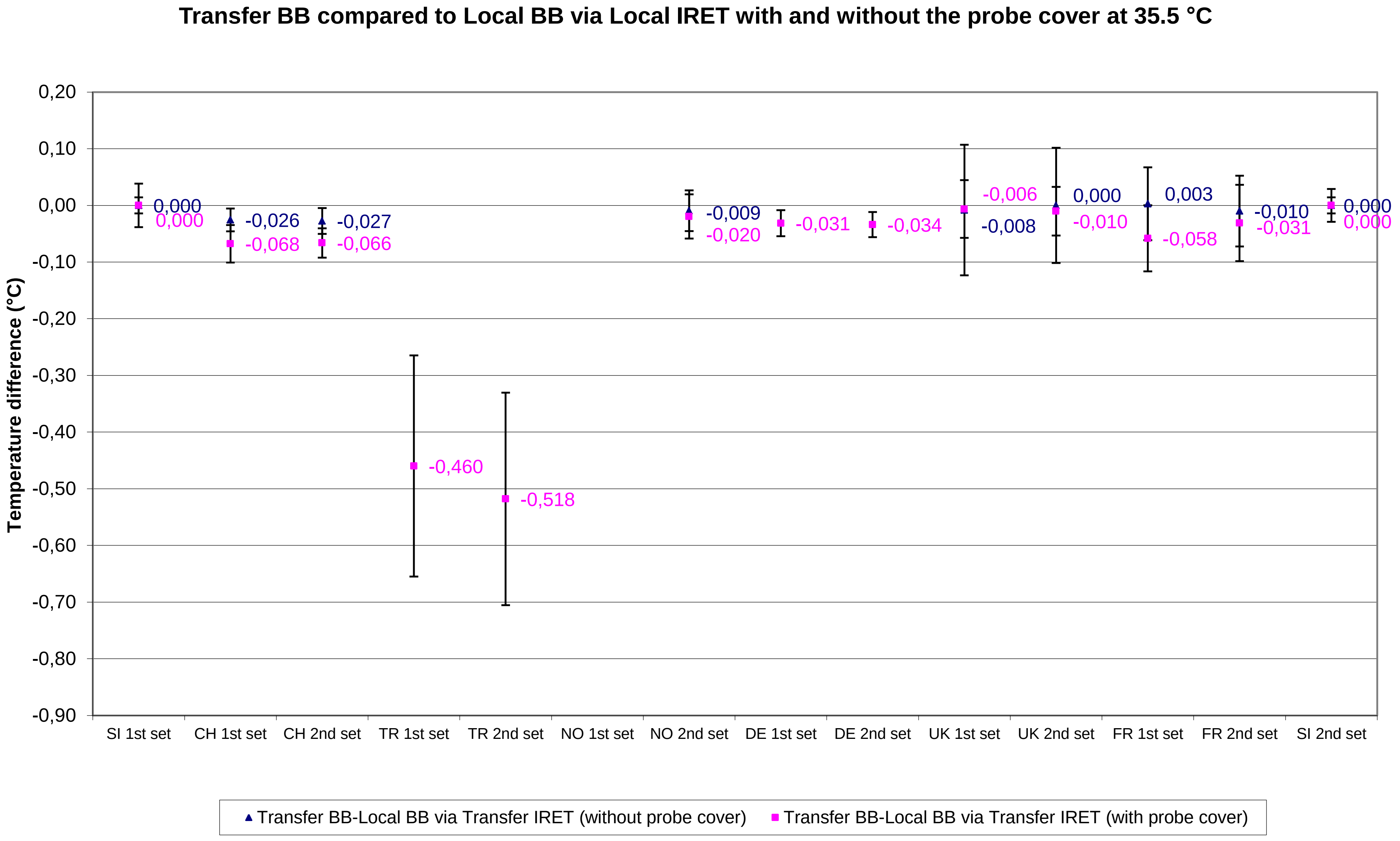

Figure 4: Transfer BB compared to Local BB via Local IRET with and without the probe cover at 35.5 °C

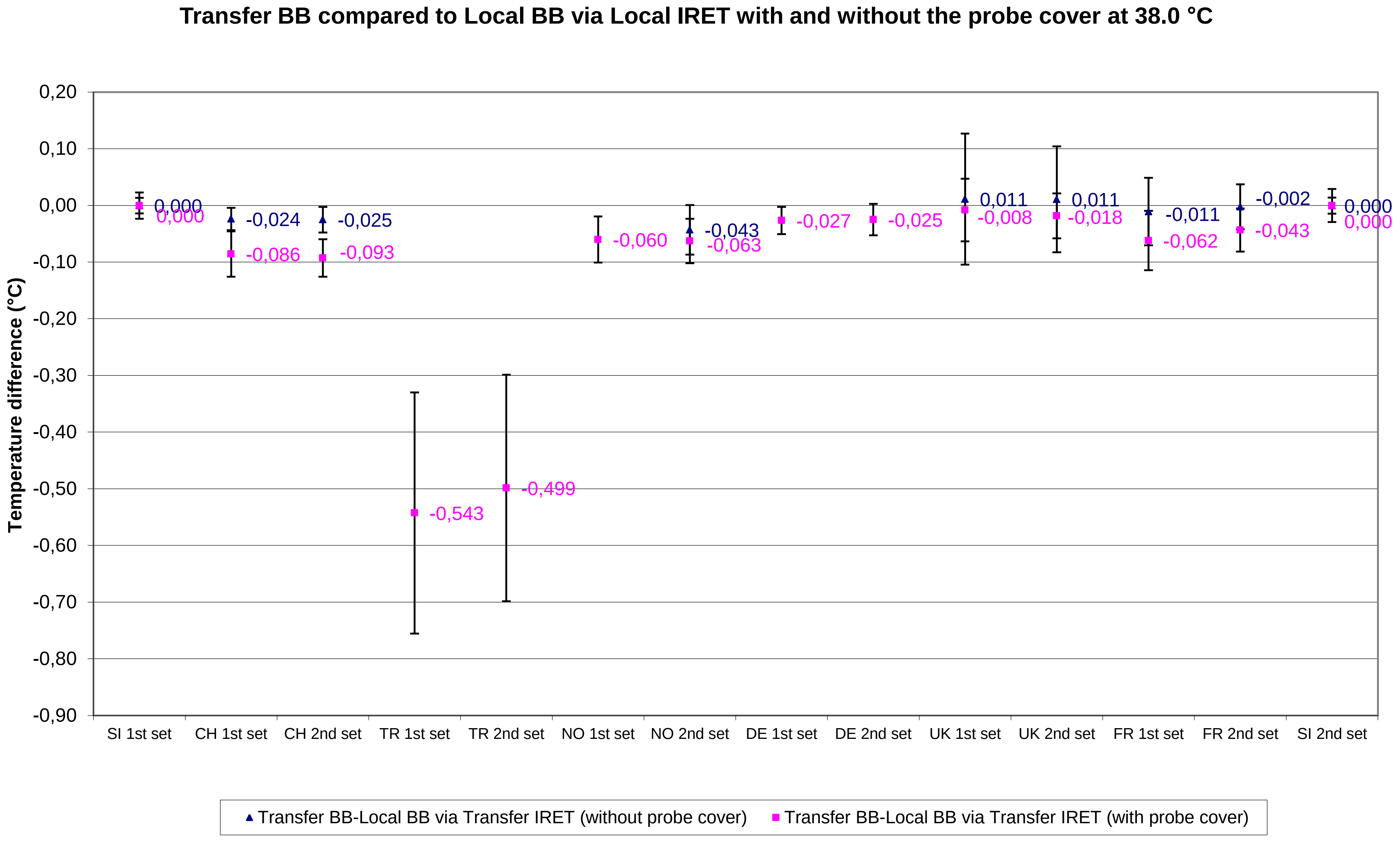

Figure 5: Transfer BB compared to Local BB via Local IRET with and without the probe cover at 38.0 °C

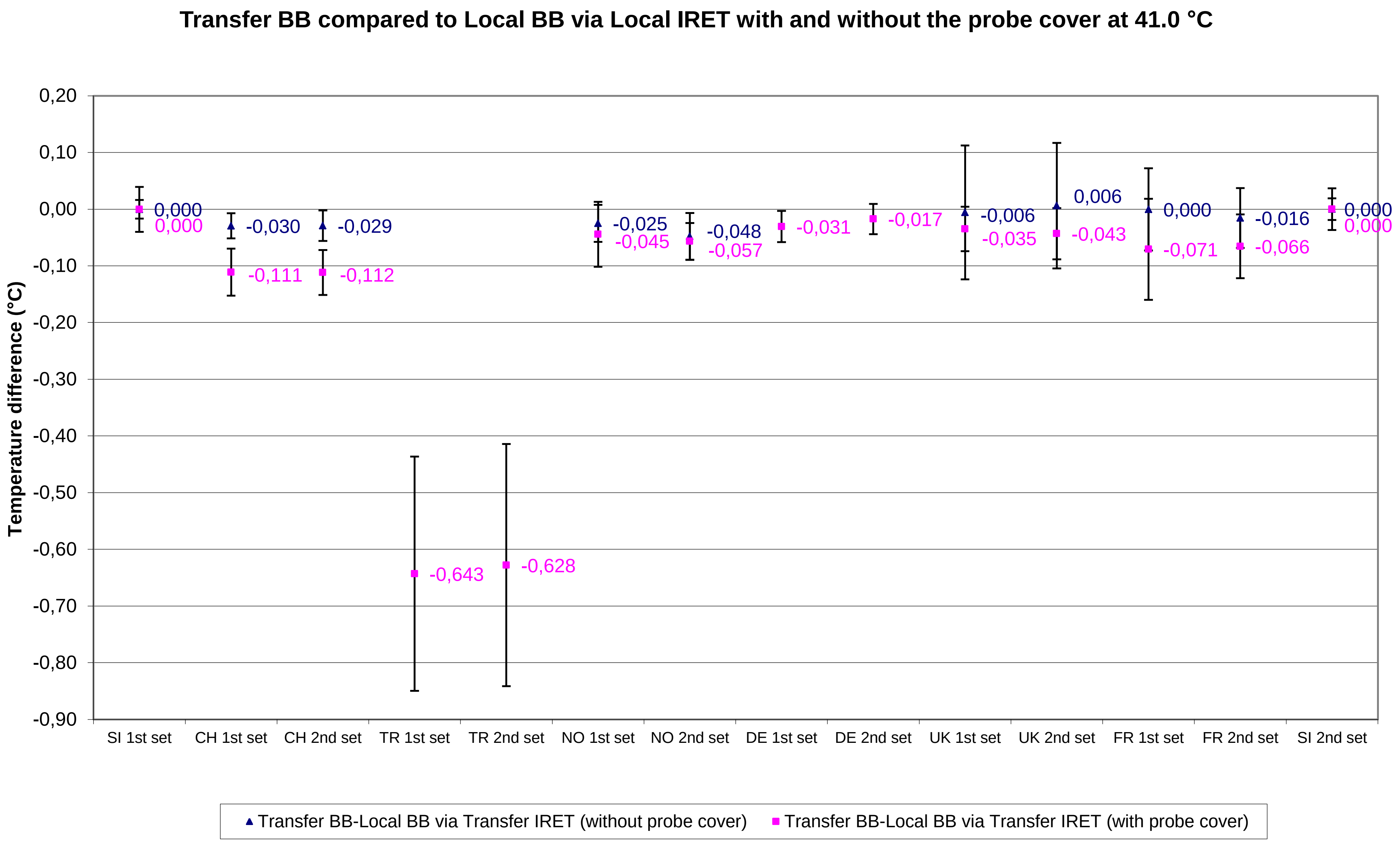

Figure 6: Transfer BB compared to Local BB via Local IRET with and without the probe cover at 41.0 °C

8 Enclosures

8.1 Technical protocol

The technical protocol is enclosed in the file *EUROMET 927 protocol.doc*.

8.2 Analysis of results of BBRs via the transfer IRET

Analysis of results of BBRs via the transfer IRET is enclosed in the file *EURAMET 927 results of transfer IRET V6C.xls*.

8.3 Analysis of results of BBRs via a local IRET

Analysis of results of BBRs via a local IRET is enclosed in the file *EURAMET 927 results of local IRET V6E.xls*.