REPORT

On the interlaboratory comparison with relative humidity meter PT RH BMB Brcković 2017

Coordinator/Reference laboratory

University of Ljubljana, Faculty of Electrical Engineering
Laboratory of Metrology and Quality (MIRS/FE-LMK), Holder of the national standard for temperature and humidity
EURAMET Slovenian designated institute (DI) for thermometry and humidity
CMC entries in the BIPM KCDB http://kcdb.bipm.org/AppendixC/T/SI/T_SI.pdf
Accredited by Slovenian Accreditation (SA) LK – 002
Tržaška 25, SI-1000 Ljubljana, Slovenia

Drawn by: prof. dr. Igor Pušnik

Approved by: prof. dr. Janko Drnovšek, head of the laboratory

Issued by: University of Ljubljana, Faculty of Electrical Engineering, Laboratory of Metrology and Quality (MIRS/UL-FE-LMK)

Date of intercomparison: The measurements for this intercomparison were carried out in the period of June 2017 to July 2017 with one participating laboratory from Croatia. The reference laboratory specified above performed measurements before and after the participating laboratory.

Ljubljana, 17. July 2017

Copy holders: MIRS/UL-FE-LMK
Participant (BMB Brcković d.o.o., Croatia)

Drawn by: Approved by:

prof. dr. Igor Pušnik
quality manager (coordinator)

prof. dr. Janko Drnovšek
head of the laboratory

dr. Domen Hudoklin
responsible for hygrometry

CONTENTS

1. Introduction

The subject of this report is evaluation of the interlaboratory comparison in the field of measurement of relative humidity. The interlaboratory comparison was organized by the University of Ljubljana, Faculty of Electrical Engineering, Laboratory of Metrology and Quality, as the PT provider.

Interlaboratory comparison serves as a tool for comparison of measurement results carried out by accredited or non-accredited calibration laboratories in the relevant field of measurement. Participation in an interlaboratory comparison represents very effective mean to demonstrate technical competence of a participant and also serves as a technical base for accreditation. Furthermore, it is the most important element for monitoring of quality of measurement results as required by ISO/IEC 17025 standard for laboratories in paragraph 5.9. An extensive participation of accredited laboratories in interlaboratory comparisons/proficiency testing is required by ISO/IEC 17043:2010
Conformity assessment - General requirements for proficiency testing.

The interlaboratory comparison was organized by the University of Ljubljana, Faculty of Electrical Engineering, Laboratory of Metrology and Quality (MIRS/UL-FE/LMK), which is as a provider of proficiency testing/interlaboratory comparisons. Until 24th of May the LMK was accredited by the Dutch Accreditation Council (RvA) under the number R-014. The LMK withdrawn the accreditation due to financial restrictions but continues to provide the same service in complete accordance with previously accredited procedures. Technical supervision of this interlaboratory comparison was provided by dr. Igor Pušnik, as an expert in the field. The reference measurements have been performed by dr. Domen Hudoklin. The coordinating/reference laboratory MIRS/UL-FE/LMK provided reference values of the test item. MIRS/UL-FE/LMK is Slovenian national standard laboratory for thermodynamic temperature and humidity and accredited for calibration in the filed of humidity by the Slovenian Accreditation (LK-002). The MIRS/UL-FE/LMK, as a national laboratory for thermodynamic temperature and humidity, is a designated institute in the scope of EURAMET.

The test item was hand carried. The ILC was performed in accordance with expected time schedule.

This report was sent to the participating laboratory.

2. Specification of the interlaboratory comparison

The purpose of the proficiency test was to compare the results of the participating laboratory during calibration of a relative humidity meter.

The transfer standard was the probe Lufft, 8300.TFF, s/n 1.107.0814 with the measuring unit Lufft, 5900.00, s/n 006.0914.1001.002. The proficiency test included five measuring points in the range between 10 % r.h. and 90 % r.h. at temperatures 10 °C, 40 °C and 70 °C. The diameter of the probe is approximately 13 mm and it is 15 cm long. Resolution of the instrument is 0,01 % r.h.

It was recommended that the participant used its standard procedure during the relative humidity calibration and if possible avoid making extra time-consuming measurements, as described in the proficiency testing protocol. The reference measurements were executed using standards for which the traceability to (inter)national standards was demonstrated towards the SA.

The reported expanded uncertainty of measurement was stated as the standard uncertainty of measurement multiplied by the coverage factor k=2, which for the normal distribution corresponds to a coverage probability of approximately 95%. The standard uncertainty of measurement was determined in accordance with the publication EA-4/02.

Prior to the calibration, test measurement were performed in order to assess stability of the instrument. From the measurements of the reference laboratory, it has been concluded that the relative humidity meter was stable enough. The drift of the transfer standard was taken into account when calculations of the assigned values and its uncertainties were made.

Calibration was carried out at an ambient temperature of nominal 23 °C. The ambient temperature also had to be reported.

The results were reported electronically.

In the report form, the participants were also asked to fill in details about the applied method, equipment and traceability.

3. Participants

There was one participant in this intercomparison. Contact details are listed alphabetically:

Croatia
Participating laboratory: BMB Laboratorij Brcković
Contact person: Mr. Davor Matavulj
Address: BMB Laboratorij Brcković
Čulinečka cesta 87, 10040 Zagreb, Hrvatska
Phone: +385 01/2866-893, mob. +385 099/2866-892
Email: davor.matavulj@bmb-laboratorij.hr

3.1. Time schedule and deadlines

The deadline for the calibrations were determined on a basis of email agreement between the coordinator and participating laboratory. The participating laboratory took care about the transport between both laboratories.

Deadline for reporting the results was 2 weeks after the equipment has left the laboratory. If there were any problems or doubt regarding the results of the participant laboratory, the laboratory would be contacted immediately. Any suspicion that the equipment was defect or drifted, would lead to return of the equipment to the reference laboratory, which then would make an extra check and take an appropriate action.

4. Results and their uncertainties

4.1. The assigned values

As assigned values, measurement values with their corresponding uncertainties, measured by the coordinator during the course of the interlaboratory comparison were taken. The resulting assigned values were taken as the arithmetic mean value from those measurements.

All the measurements at the coordinator laboratory were made in combination with MBW 373 reference dew-point meter and Thunder Scientific 2500 humidity generator.

The assigned uncertainties were determined in accordance with calibration procedure of the coordinator (see below). It includes also the instability of the transfer standard.

Table 1A: Assigned reference values and their uncertainties at 10 °C

Set value % r.h.	Measured correction 7.6.2017 % r.h.	Measured correction 10.7.2017 % r.h.	Arithmetic mean correction, x_{ref} % r.h.	Expanded measurement uncertainty, U_{RV} % r.h.
10	1,3	-1,4	-0,05	2,1
30	1,7	0,2	0,95	1,9
50	1,6	1,0	1,30	1,9
70	1,1	1,0	1,05	1,9
90	0,1	0,2	0,15	1,9
50*	1,6	1,0	1,30	1,9

*repeated measurement for determination of the hysteresis

Table 1B: Assigned reference values and their uncertainties at 40 °C

Set value % r.h.	Measured correction 8.6.2017 % r.h.	Measured correction 11.7.2017 % r.h.	Arithmetic mean correction, x_{ref} % r.h.	Expanded measurement uncertainty, U_{RV} % r.h.
10	-1,0	-0,5	-0,75	0,9
30	0,1	0,0	0,05	0,9
50	0,6	0,2	0,40	0,9
70	0,5	0,1	0,30	0,9
90	-0,2	-0,2	-0,20	0,9
50	0,6	0,2	0,40	0,9

Table 1C: Assigned reference values and their uncertainties at 70 °C

Set value % r.h.	Measured correction 9.6.2017 % r.h.	Measured correction 13.7.2017 % r.h.	Arithmetic mean correction, x_{ref} % r.h.	Expanded measurement uncertainty, U_{RV} % r.h.
10	-0,5	-1,2	-0,85	1,5
30	0,9	-0,1	0,40	1,5
50	1,5	0,4	0,95	1,5
70	1,3	0,5	0,90	1,5
90	0,4	0,1	0,35	1,5
50	1,5	0,4	0,95	1,5

4.2. Uncertainty analysis

The uncertainty analysis was performed in accordance with the GUM (Guide to the Expression of the Uncertainty in Measurement). The following uncertainty contributions were taken into account:

1. The uncertainty of the reference equipment
   The measurements were done using MBW 373 reference dew-point meter in combination with Thunder Scientific 2500 LT humidity generator. The MBW 373 was calibrated with the primary humidity generator of MIRS/UL-FE/LMK, Ljubljana, Slovenia.
2. The uncertainty of the used humidity generator (stability and homogeneity)
   In both cases Thunder Scientific 2500 LT humidity generator was used. Its stability and homogeneity have been evaluated.
3. The stability of the measured relative humidity meter
   Determined drift of the measured relative humidity meter was added to the total measurement uncertainty assuming the rectangular distribution.

Table 1 show the total expanded uncertainty of the assigned reference values, U_{RV} (k=2).

4.3. Results of the participating laboratory

The measured corrections by the participating laboratory are presented in the Table 2.

Table 2: The measured corrections by the participant at 10 °C

Set	x_{lab} at 10 °C	x_{lab} at 40 °C	x_{lab} at 70 °C
% r.h.	% r.h.	% r.h.	% r.h.
10	0,47	-1,01	-0,48
30	0,62	-0,05	1,37
50	2,27	0,51	1,35
70	1,28	0,48	1,02
90	0,88	0,40	1,55
50	1,86	0,50	2,26

4.4. Uncertainties of the participating laboratory, U_{lab}

The expanded uncertainties U_{lab} submitted by the participant (with respect to CMCs) are presented in the Table 3.

Table 3: The expanded uncertainties submitted by the participant

Set	U_{lab} (95%) at 10 °C	U_{lab} (95%) at 40 °C	U_{lab} (95%) at 70 °C
% r.h.	% r.h.	% r.h.	% r.h.
10	1,01	1,01	1,01
30	1,13	1,13	1,13
50	1,25	1,25	1,25
70	1,37	1,37	1,37
90	1,49	1,49	1,50
50	1,25	1,25	1,25

5. Evaluation

5.1.Criteria for evaluation

The evaluation of the measurement results is made by the following criteria:

1. E_n number for each measured point:

$$|E_n| = \left| \frac{x_{lab} - x_{ref}}{\sqrt{U^2_{lab} + U^2_{RV}}} \right| \leq 1$$

2. CMCs, shown in table 3, in relation to uncertainties of the assigned expended reference value U_{RV}, shown in the table 1, must meet the following criteria for any measured point:

$$U_{lab} \geq U_{RV}$$

3. For each measured point:
   - if both criteria 1 and 2 are met, than the measurement result is deemed **adequate**
   - if criteria 1 is not met, than the measurement result is deemed **inadequate**
   - if only criteria 1 is met, while the criteria is not fulfilled, than the measurement result is deemed **conditionally adequate** with respect to the **increased CMC** (to U_{RV}), due to reduced comparability of the results

5.2.Results of evaluation

The E_n values are presented in Table 4.

Table 4: The E_n values

Set	$\|E_n\|$ at 10 °C	$\|E_n\|$ at 40 °C	$\|E_n\|$ at 70 °C
% r.h.	/	/	/
10	0,22	0,19	0,20
30	0,15	0,07	0,51
50	0,43	0,08	0,20
70	0,10	0,12	0,05
90	0,30	0,35	0,59
50	0,25	0,07	0,67

There were no results with E_n number larger than 1 or smaller than –1.

The summary of results of evaluation is presented in Table 5. The adequate CMCs are colored green, inadequate are colored red, while the conditionally adequate are colored orange with CMCs increased to U_{RV} (and reported CMCs stated in parenthesis).

Table 5: The E_n values

Set	CMC at 10 °C	CMC at 40 °C	CMC at 70 °C
% r.h.	% r.h.	% r.h.	% r.h.
10	2,1 (1,01)	1,01	1,5 (1,01)
30	1,9 (1,13)	1,13	1,5 (1,13)
50	1,9 (1,25)	1,25	1,5 (1,25)
70	1,9 (1,37)	1,37	1,5 (1,37)
90	1,9 (1,49)	1,49	1,5 (1,50)
50	1,9 (1,25)	1,25	1,5 (1,25)

Organization and evaluation of the ILC

The organization and evaluation of the ILC was made in accordance with the following documents:

ISO/IEC 17043:2010	Conformity assessment -- General requirements for proficiency testing

Annex A Proficiency testing protocol

The purpose of the proficiency test is to compare the results of the participating laboratories during calibration of a digital humidity meter.

The circulating item is a probe Lufft, 8300.TFF, s/n 1.107.0814 with the measuring unit Lufft, 5900.00, s/n 006.0914.1001.002. The proficiency test includes five measuring points in the range between 10 % r.h. and 90 % r.h. at temperatures 10 °C, 40 °C and 70 °C. The diameter of the probe is approximately 13 mm and it is 15 cm long. Resolution of the instrument is 0,01 % r.h.

It is recommended that the participant uses its standard procedure during the temperature calibration and if possible avoid making extra time-consuming measurements. The proficiency test is carried out in accordance with ISO/IEC 17043:2010.

Coordinator/Reference laboratory

University of Ljubljana, Faculty of Electrical Engineering
Laboratory of Metrology and Quality (MIRS/UL-FE/LMK),
Tržaška 25, SI-1000 Ljubljana, Slovenia

Contact persons in case of technical or administrative questions:
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Participant

There is one participant to this proficiency testing.
Croatia
Participating laboratory: BMB Laboratorij Brcković
Contact person: Mr. Davor Matavulj
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Phone: +385 01/2866-893, mob. +385 099/2866-892
Email: davor.matavulj@bmb-laboratorij.hr

Time schedule and deadlines

The participating laboratory has 4 weeks for calibration including transport to the coordinating laboratory.

If a participant anticipates difficulties in keeping the deadlines, the coordinator must be contacted immediately.

Deadline for reporting the result is 2 weeks after the equipment has left the laboratory. If there are any problems or doubt regarding the results of the participant laboratory, the laboratory will be contacted immediately. Any suspicion that the equipment is defected or drifted, will lead to return of the equipment to the coordinating laboratory, which then will make an extra check and take an appropriate action.

If deadlines are respected, the participant will receive the report of the proficiency test by 31. July 2017.

The first measurement in the laboratory BMB Brcković is expected to start in the mid-June 2017.

The equipment is expected to be returned to MIRS/UL-FE/LMK in the first week of July 2017.

Transportation of the equipment

The equipment is transported in person, on the expenses of the participant.
The equipment is unpacked and a visual inspection carried out. If the equipment has any visible damage due to transportation, this must be reported to the coordinator before the calibration begins. Please, attach digital photos to the potential damage report.

For transportation of the equipment back to the coordinator, the laboratory will inform coordinator that equipment is ready to be delivered. Please take care that everything is packed in the original packaging.

Description of the equipment

General

The laboratory receives the following equipment:

- Probe Lufft, 8300.TFF, s/n 1.107.0814
- measuring unit Lufft, 5900.00, s/n 006.0914.1001.002

In a case any of the above-mentioned equipment is missing at the receipt, the coordinator must be contacted.

Environmental conditions

Calibration is carried out at an air temperature of nominal 10 °C, 40 °C, and 70 °C. The ambient temperature shall be reported.

Handling

Packing and unpacking

Procedure for unpacking is as follows:

1. Inspect the transportation boxes for damage. If the boxes are damaged, the coordinator shall be contacted before continuing. Please, attach digital photos to the potential damage report.
2. Unpack the equipment and check that all equipment mentioned in the section “Description of equipment” is present.
3. If any equipment is missing, the coordinator shall be contacted.
4. Inspect the equipment. If any of the equipment shows visible signs of damage, the coordinator shall be contacted.

The packing procedure is as follows:

1. Check that all equipment mentioned in the section “Description of equipment” is packed before the equipment is transported to the next participant

Mounting

1. The relative humidity meter read-out unit is placed in such a way that it is kept free of obstructions.
2. The probe is connected to the read-out unit and carefully placed in the humidity generator/climatic chamber
3. The relative humidity meter is battery powered.

Precautions

- Circulation of air around relative humidity probe must be kept free
- Any contact of the probe with liquids, shall be avoided

Contact the coordinator in a case of doubt about the above-mentioned precautions.

Calibration/Test method

It is recommended that the participants use their standard procedure during humidity calibration and avoid making extra time-consuming measurements, if possible. For accredited laboratories it will be advantageous to apply the accredited procedures in preparation for later use of the report in relation with documentation to the accreditation body.
Details about the applied procedure can be stated in the report form.

Measuring points

The relative humidity meter is calibrated at increasing relative humidity in the following points (as close as possible to the nominal relative humidity points):
10 % r.h., 30 % r.h., 50 % r.h., 70 % r.h. and 90 % r.h., all relative humidity points at nominal temperatures of 10 °C, 40 °C, and 70 °C.
After 90 % r.h., repeat measurement at 50 % r.h.!

Reporting of results

The results are reported electronically in the forwarded Excel spreadsheet. The green fields of the spreadsheet should be filled in, if possible.
In the report form, the participants are also asked to fill in details about the applied method, equipment and traceability, if this information does not appear from an issued calibration certificate.

The laboratories which normally issue calibration certificates (e.g. the accredited laboratories), should send a standard certificate to the coordinator.
The results shall be sent to the coordinator no later than **2 weeks** after having finalized the calibration. Electronic reporting by e-mail is preferred.

Outline of statistical analysis

The assigned values are to be determined as the arithmetic mean of measurements made by the coordinator. Any outliers are detected by Cochran's test and Grubbs' test (ISO 5725-2, 7.3.3 and 7.3.4).

Information to be returned to participants

The participants will receive summary of all measurements, assigned values and uncertainties of assigned values, and evaluation of the performance. The evaluation of measurement results will be made on the basis of E_n number:

$$E_n = \frac{x_{lab} - x_{ref}}{\sqrt{U^2_{lab} + U^2_{ref}}}$$

where x_{lab} is the participant's result, x_{ref} is the assigned value, U_{lab} is the expanded (k=2) uncertainty of a participant's result and U_{ref} is the expanded (k=2) uncertainty of the reference laboratory's assigned value.

Criteria for performance evaluation will be based on statistical determination for E_n number:

$$|E_n| \leq 1 \quad = \quad \text{satisfactory}$$
$$|E_n| > 1 \quad = \quad \text{unsatisfactory}$$

Appendix A: Report form

Standard form for reporting of results and uncertainties.

The form has been forwarded electronically.

Results for 2017 PT 1 - H - Proficiency Test with relative humidity meter

Name of Laboratory:	

Equipment received (Date):	
Equipment calibrated (Date):	
Equipment shipped to next laboratory (Date):	

Calibration (according measurement instructions):

Set[1)]	Read relative humidity [2)]	Read air temperature[2)]	Reference relative humidity [3)]	Reference air temperature[4)]	Corr.[5)]	Corr.[6)]	*U (95%)*[7)]	*U (95%)*[7)]	CMC [8)]	CMC [8)]
% r.h.	% r.h.	°C	% r.h.	°C	% r.h.	°C	% r.h.	°C	% r.h.	°C
10,0					0	0				
30,0					0	0				
50,0					0	0				
70,0					0	0				
90,0					0	0				
50,0					0	0				

Ambient temperature		°C

Notes

1)	Set-value, typed in on the calibration medium
2)	Read-value, read on the relative humidity meter
3)	Reference realtive humidity, measured by the laboratory
4)	Reference temperature, measured by the laboratory
5)	Correction = reference relative humidity - relative humidity meter
6)	Correction = reference temperature - relative humidity meter
7)	Uncertainty on the correction (=uncertainty of the calibration)
8)	Calibration and measurement capability (only if the laboratory is accredited for the measurement)

Additional information

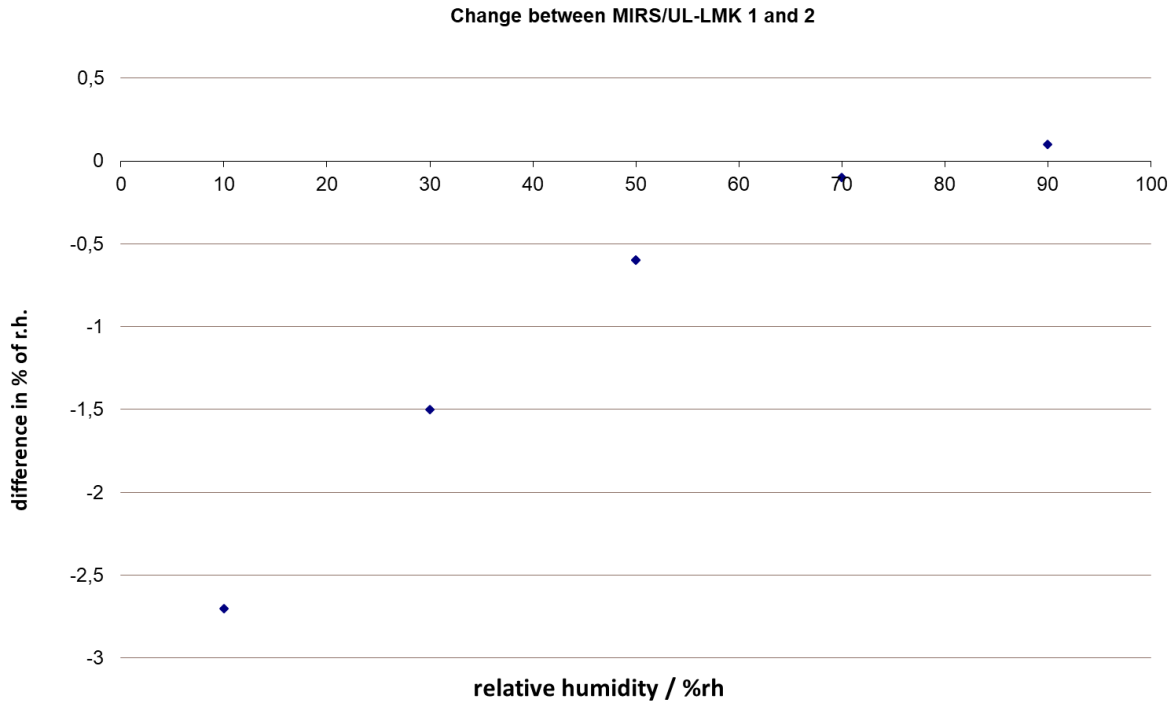
State, if required, details concerning the used calibration procedure

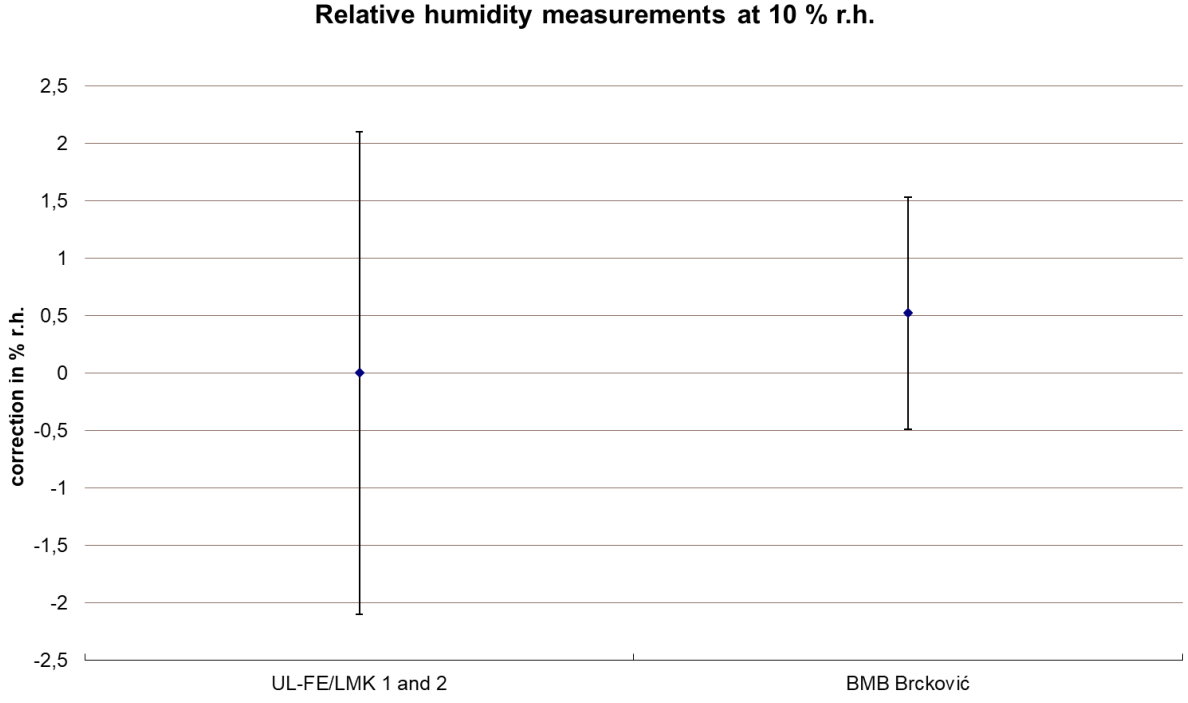
Used reference standards and traceability

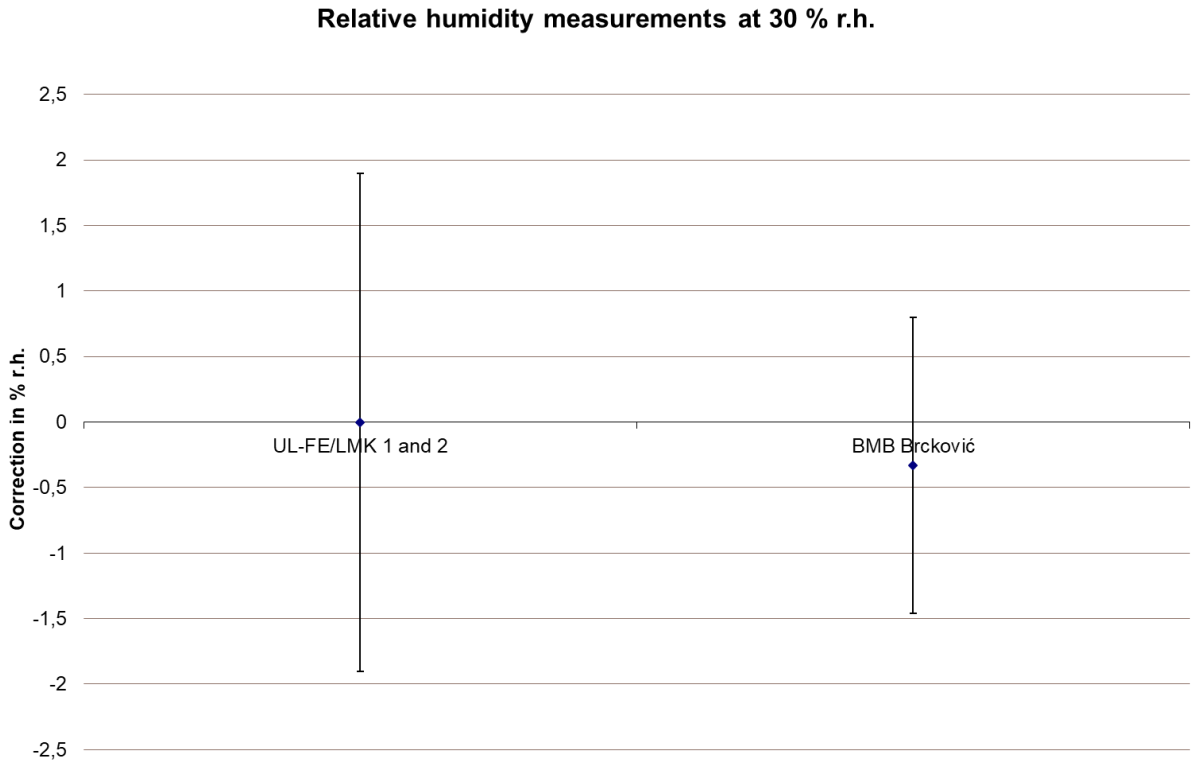
Standards	Traceability

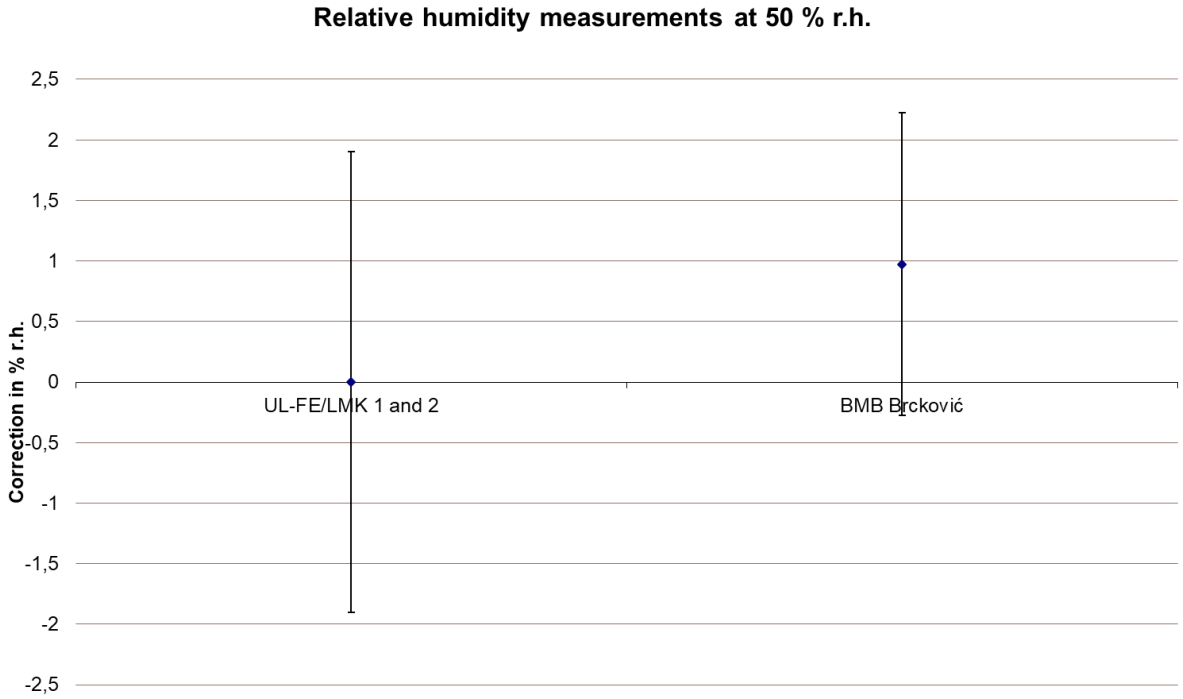
Annex B Results graphs

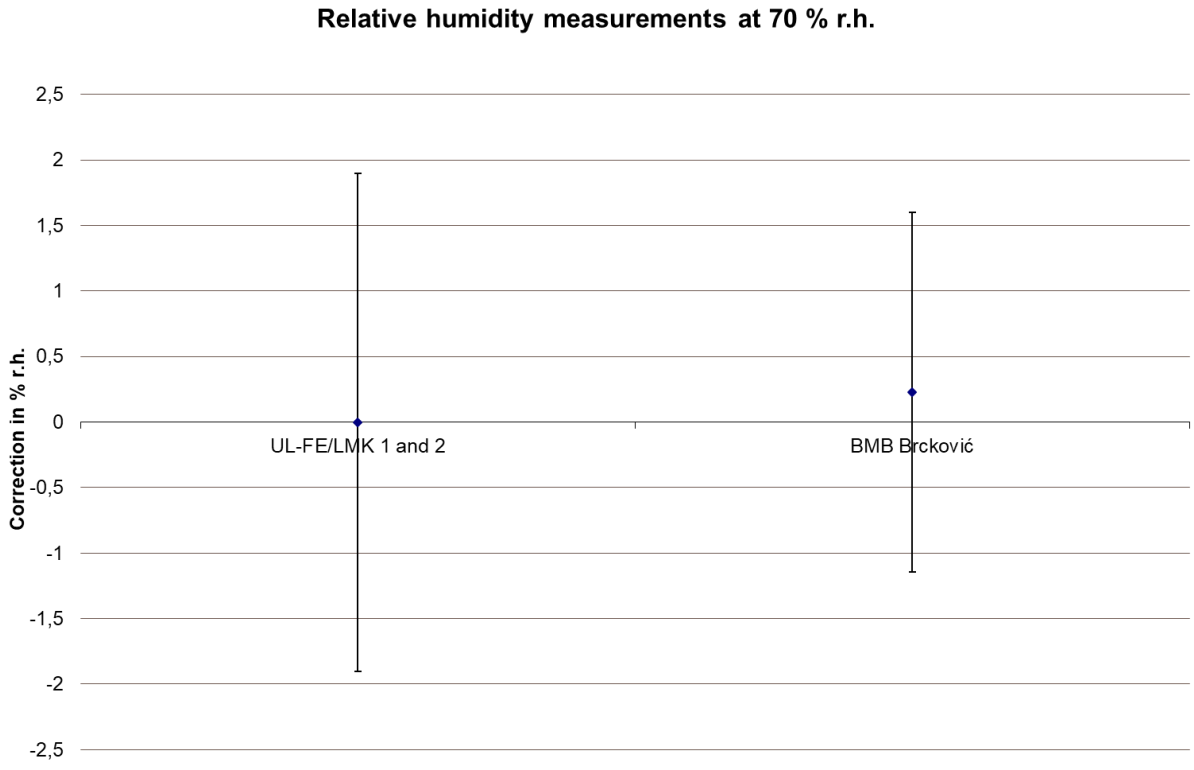
1. At temperature 10 °C

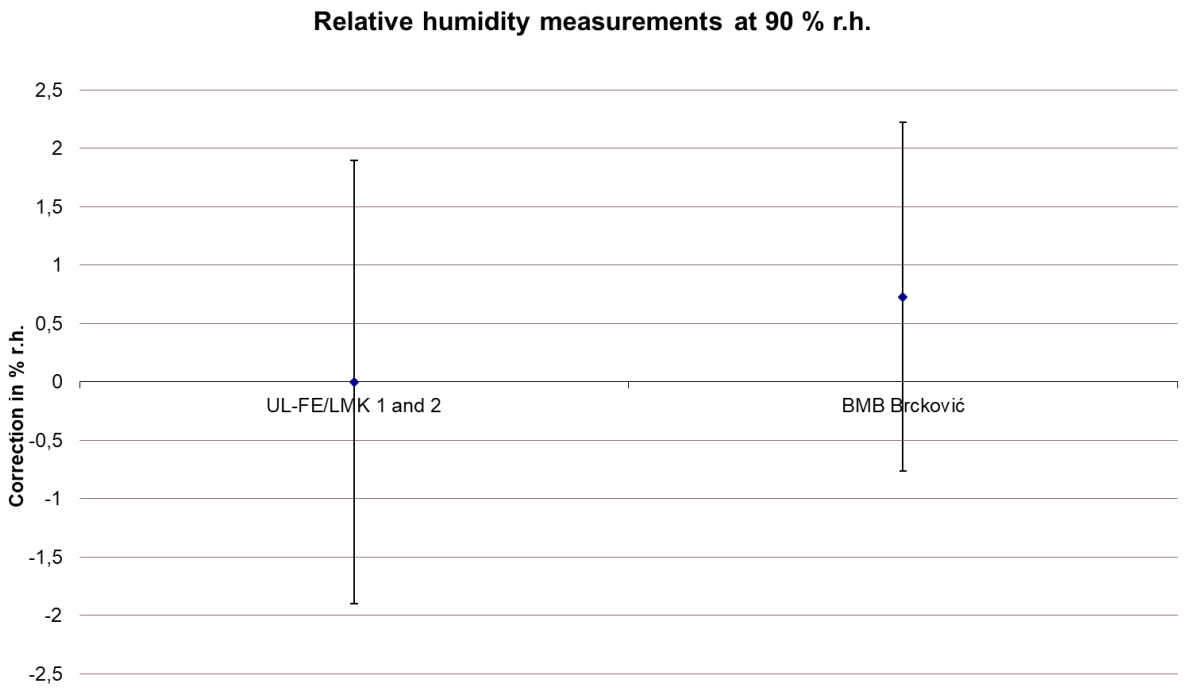


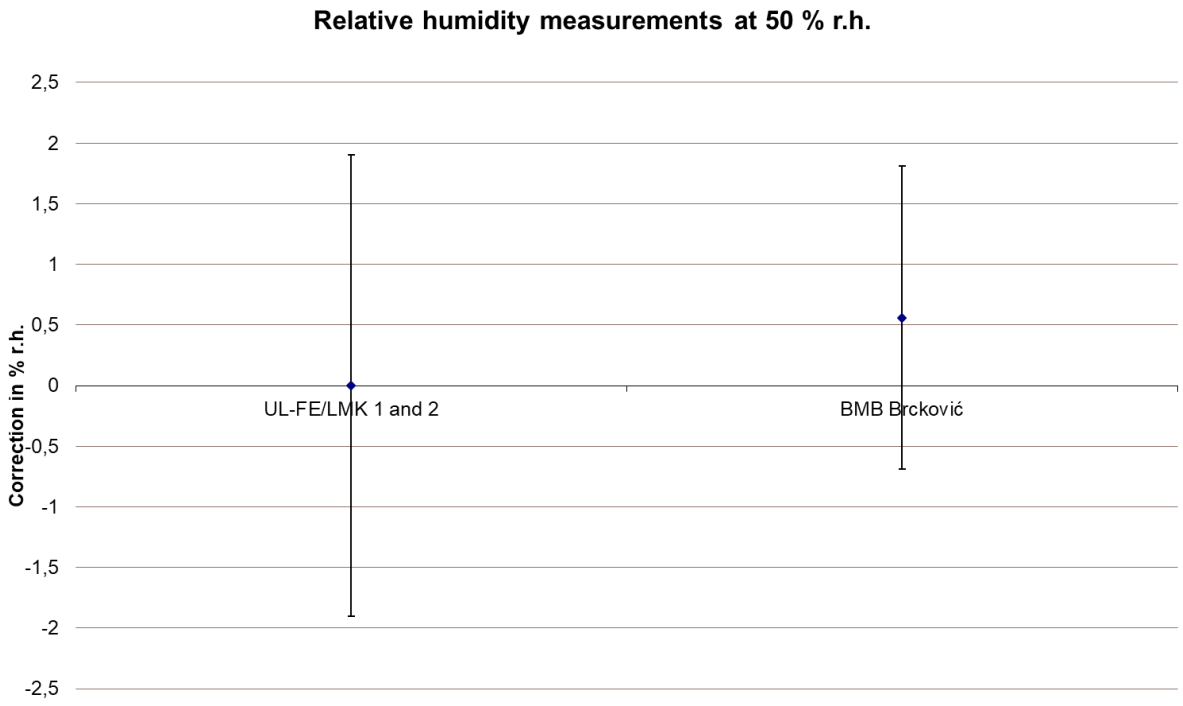



Relative humidity measurements at 30 % r.h.
Correction in % r.h.
2,5
2
1,5
1
0,5
0
-0,5
-1
-1,5
-2
-2,5
UL-FE/LMK 1 and 2
BMB Brcković

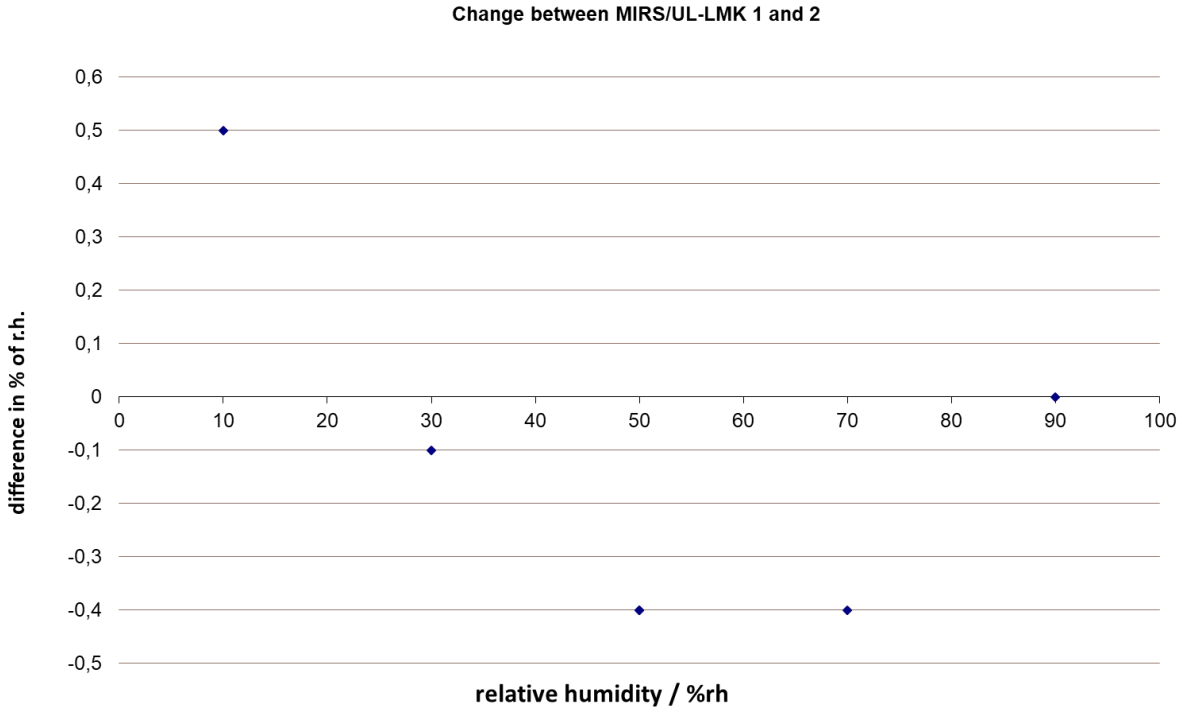

Relative humidity measurements at 50 % r.h.
Correction in % r.h.
2,5
2
1,5
1
0,5
0
-0,5
-1
-1,5
-2
-2,5
UL-FE/LMK 1 and 2
BMB Brcković

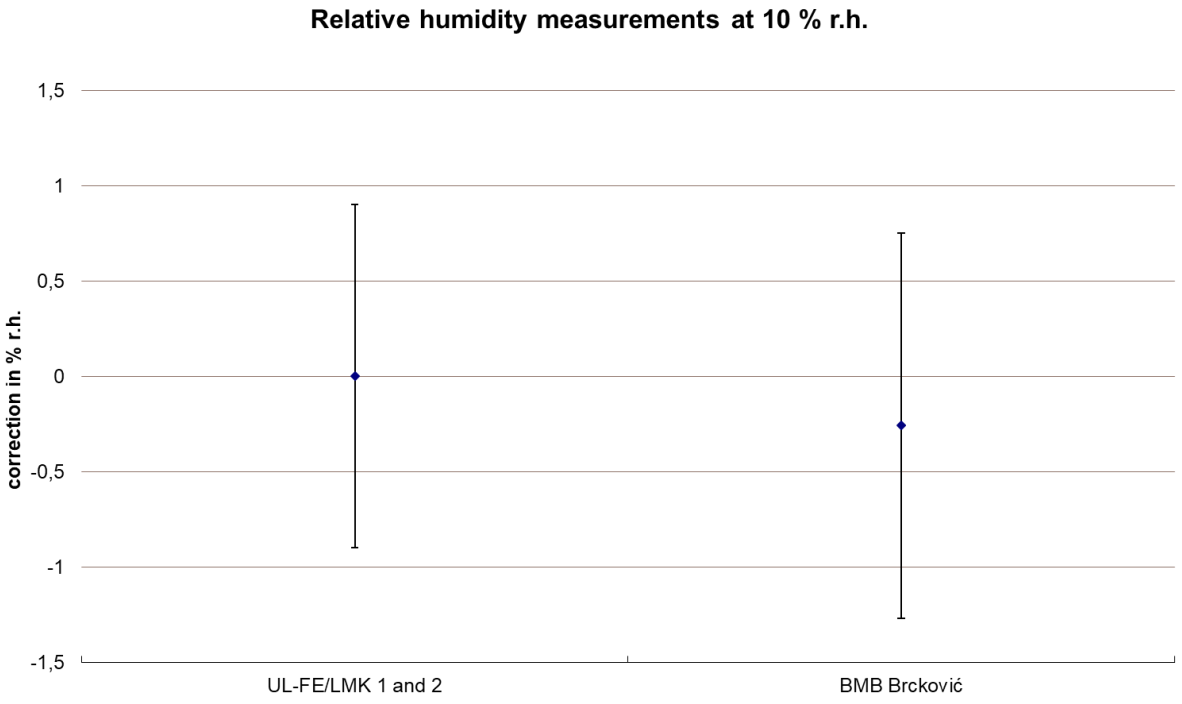

Relative humidity measurements at 70 % r.h.
Correction in % r.h.
2,5
2
1,5
1
0,5
0
-0,5
-1
-1,5
-2
-2,5
UL-FE/LMK 1 and 2
BMB Brcković

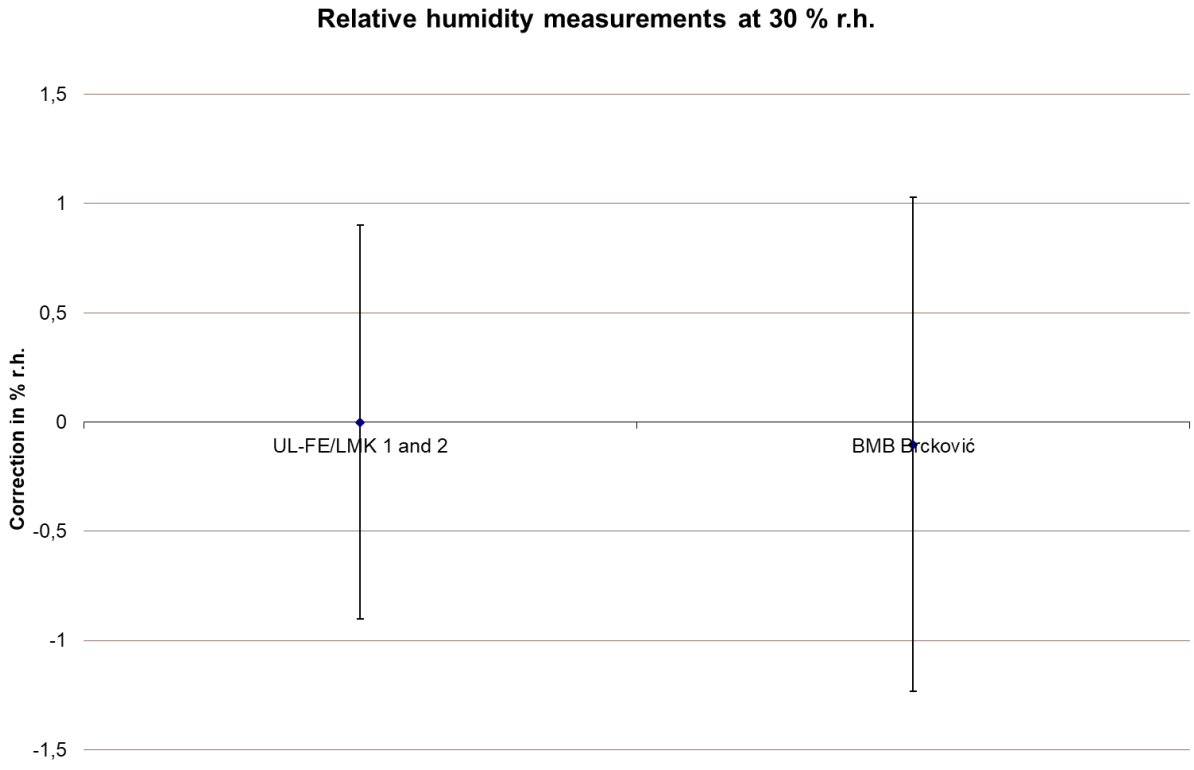

Relative humidity measurements at 90 % r.h.
Correction in % r.h.
2,5
2
1,5
1
0,5
0
-0,5
-1
-1,5
-2
-2,5
UL-FE/LMK 1 and 2
BMB Brcković

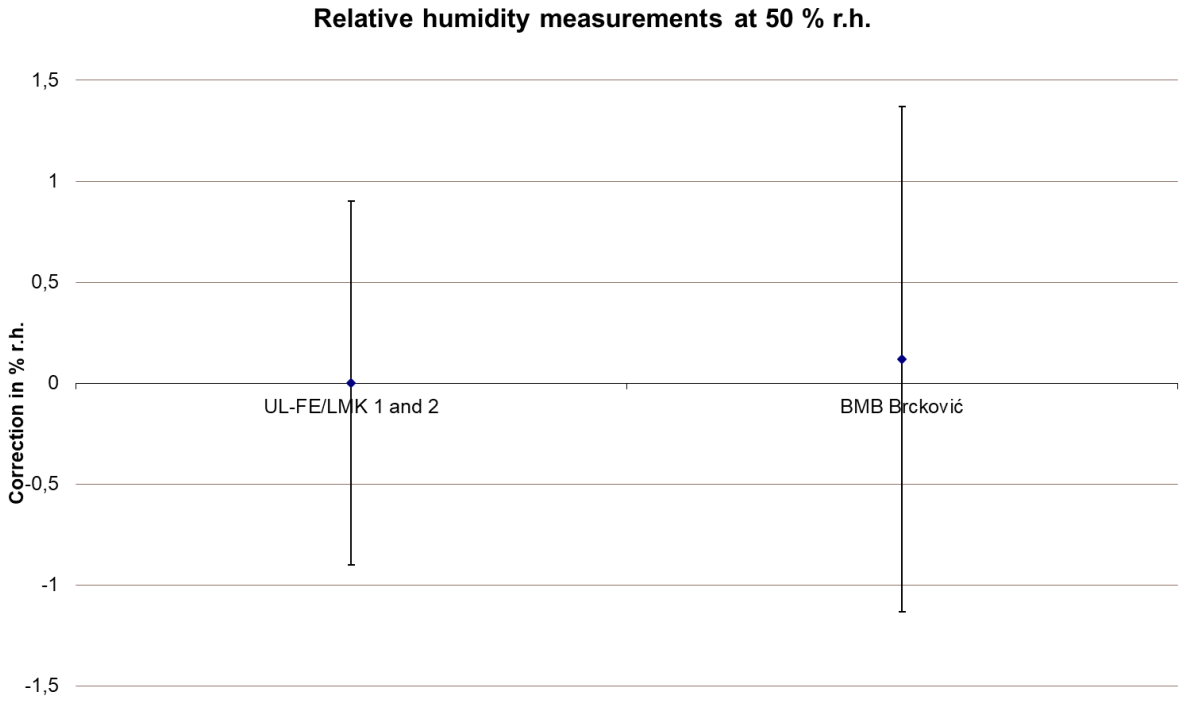

Relative humidity measurements at 50 % r.h.
Correction in % r.h.
2,5
2
1,5
1
0,5
0
-0,5
-1
-1,5
-2
-2,5
UL-FE/LMK 1 and 2
BMB Brcković

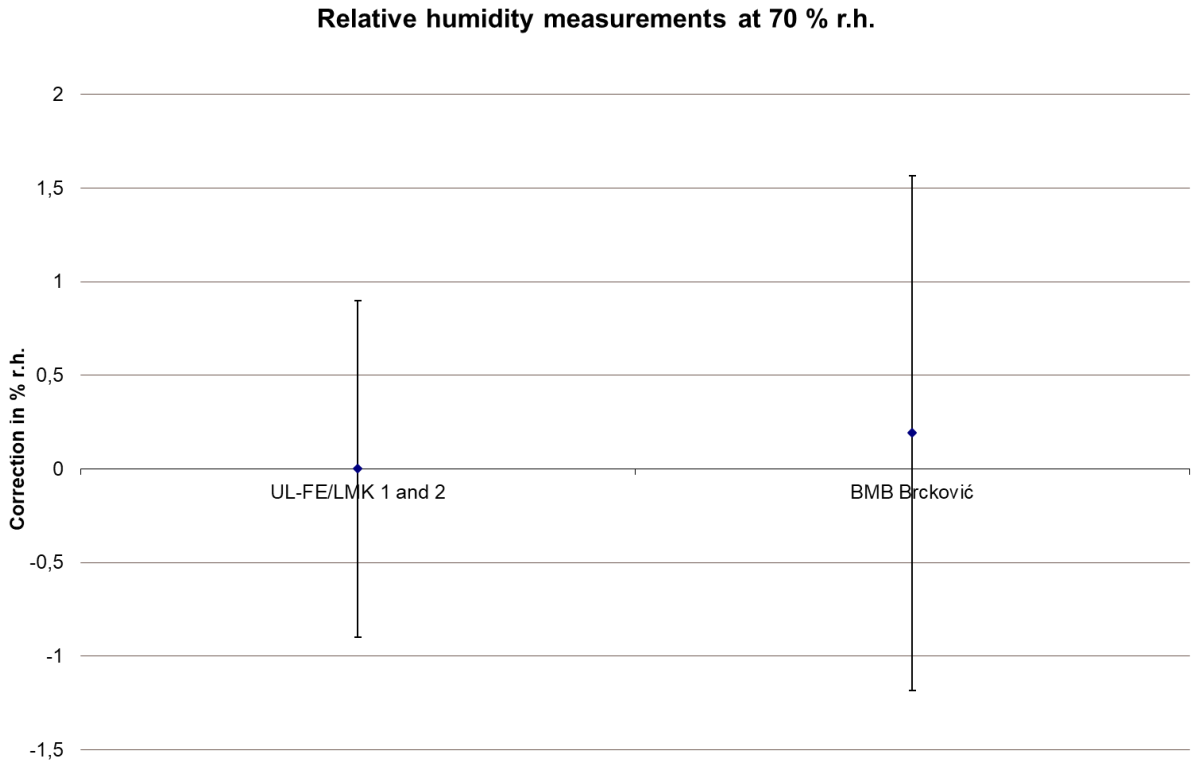
2. At temperature 40 °C

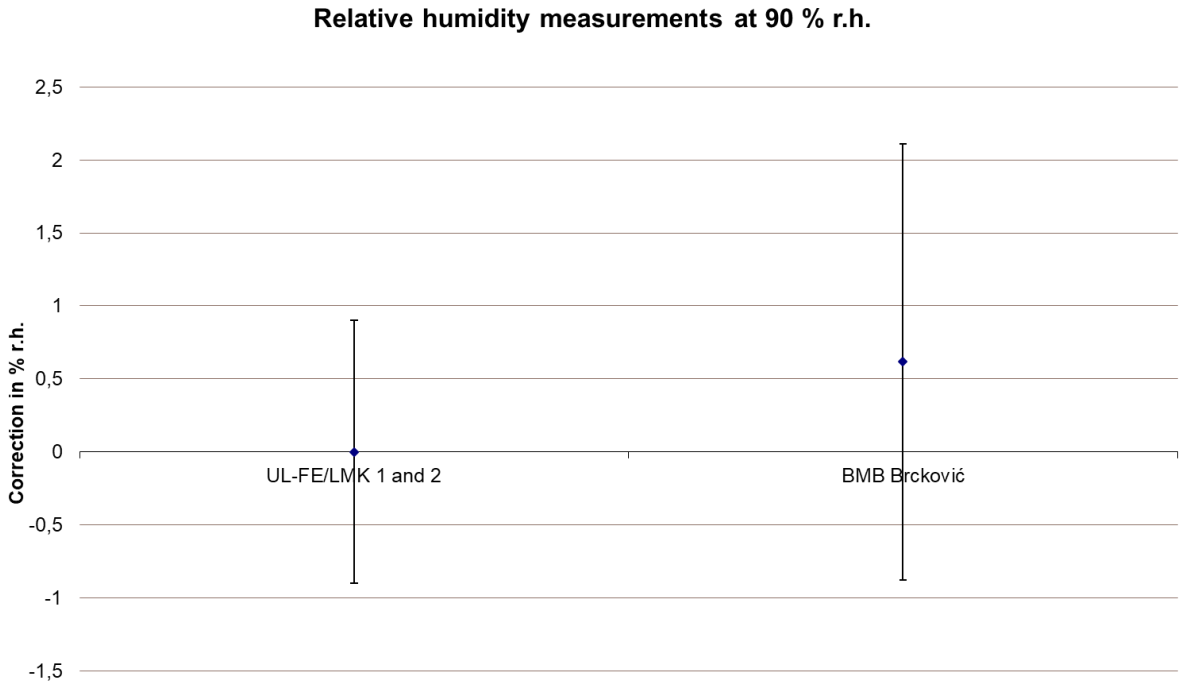


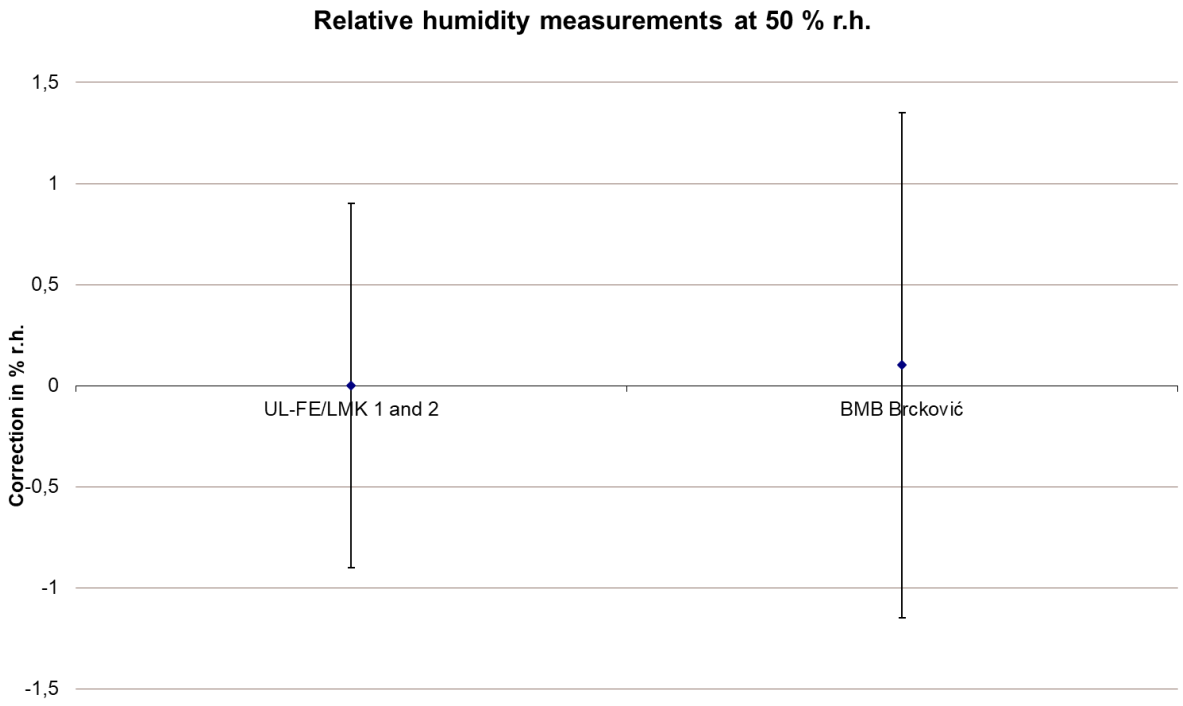



Relative humidity measurements at 30 % r.h.
1,5
1
0,5
0
-0,5
-1
-1,5
Correction in % r.h.
UL-FE/LMK 1 and 2
BMB Brcković

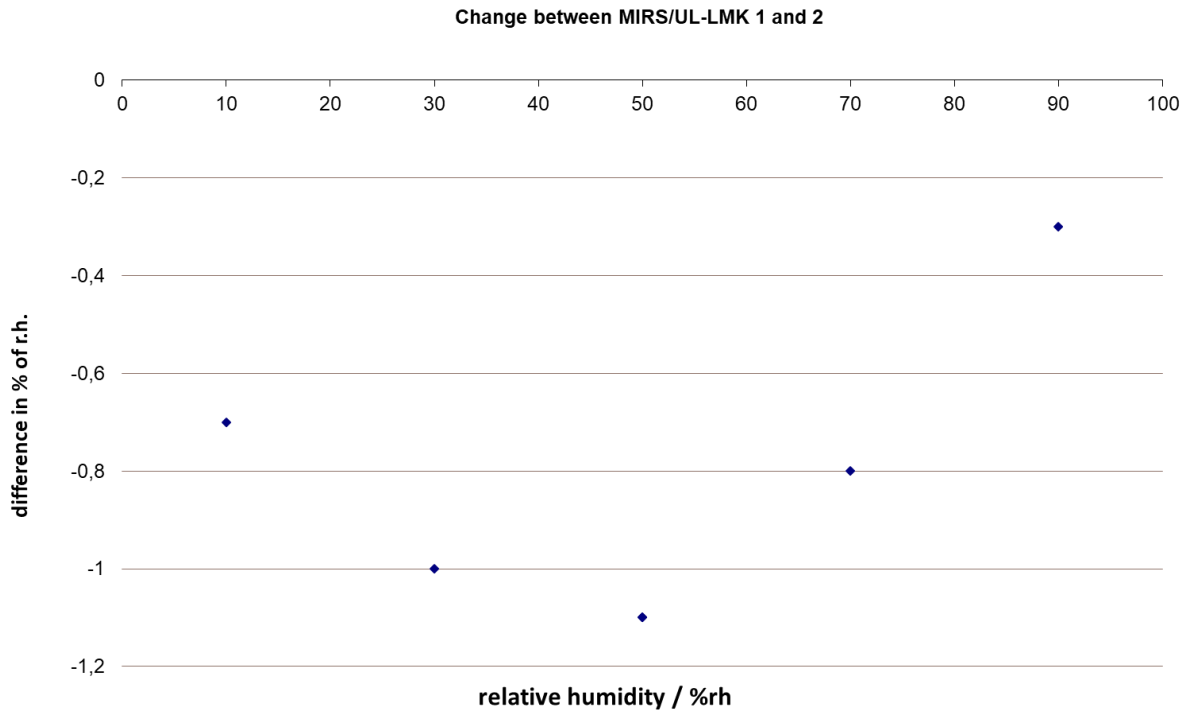

Relative humidity measurements at 50 % r.h.
1,5
1
0,5
0
-0,5
-1
-1,5
Correction in % r.h.
UL-FE/LMK 1 and 2
BMB Brcković

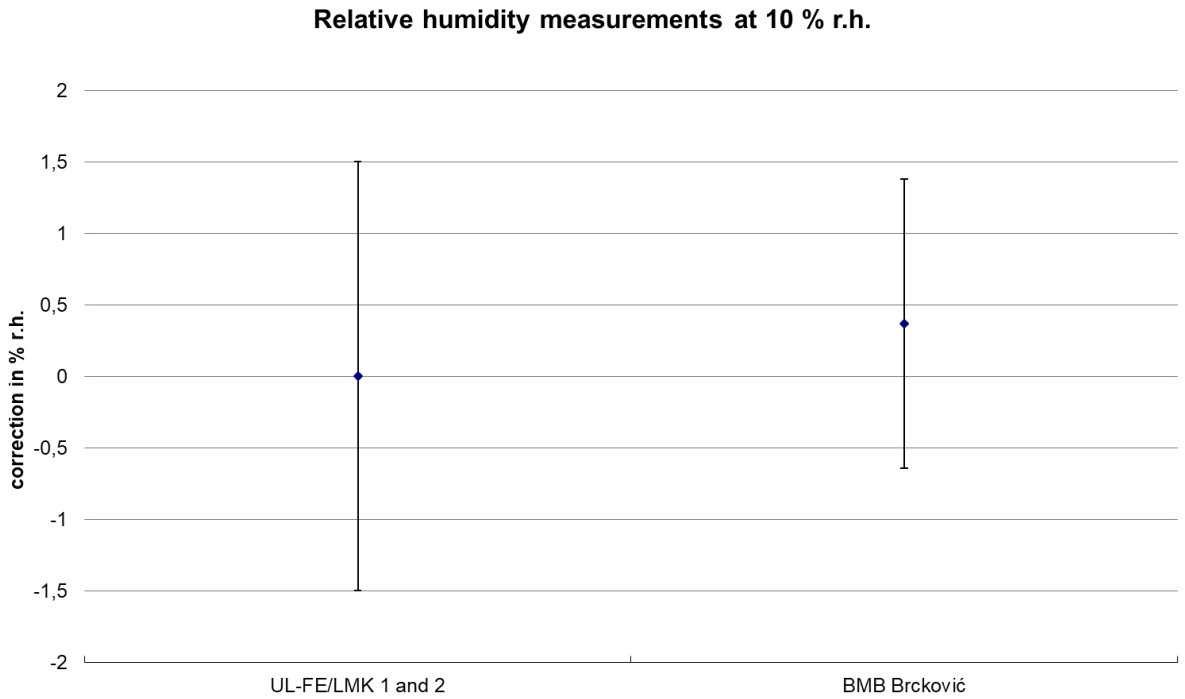

Relative humidity measurements at 70 % r.h.
Correction in % r.h.
2
1,5
1
0,5
0
-0,5
-1
-1,5
UL-FE/LMK 1 and 2
BMB Brcković

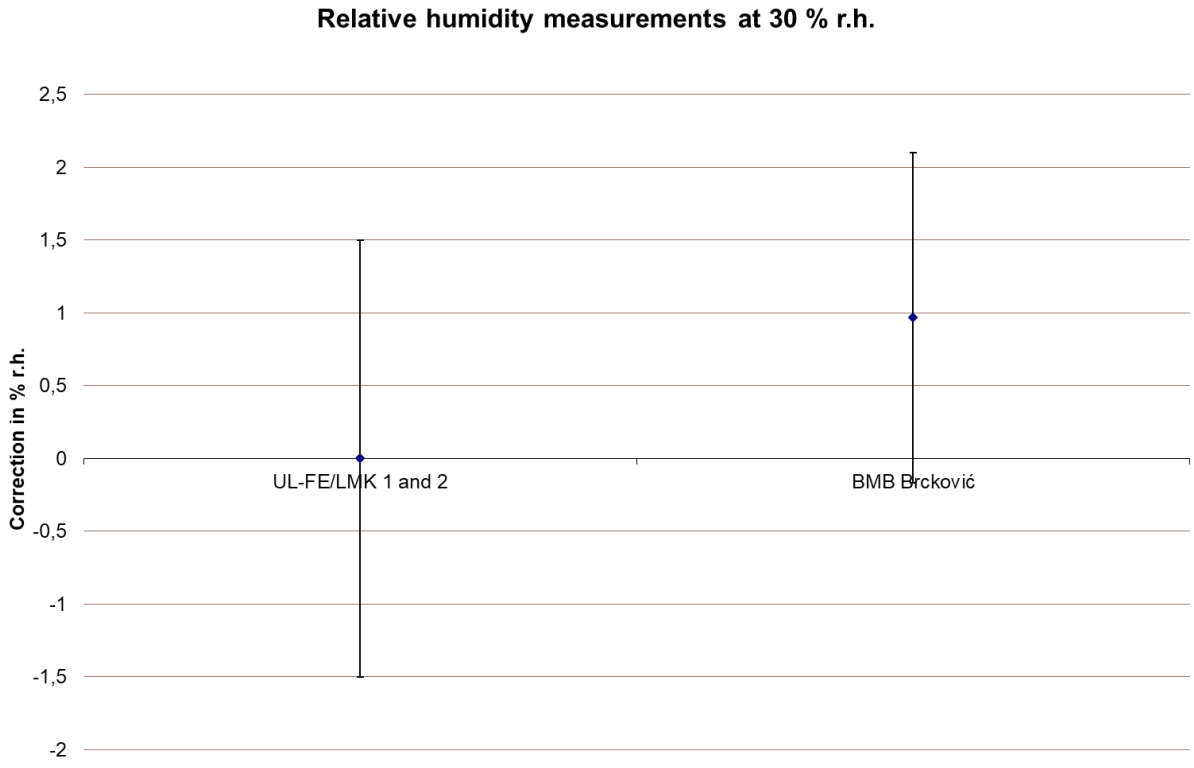

Relative humidity measurements at 90 % r.h.
Correction in % r.h.
2,5
2
1,5
1
0,5
0
-0,5
-1
-1,5
UL-FE/LMK 1 and 2
BMB Brcković

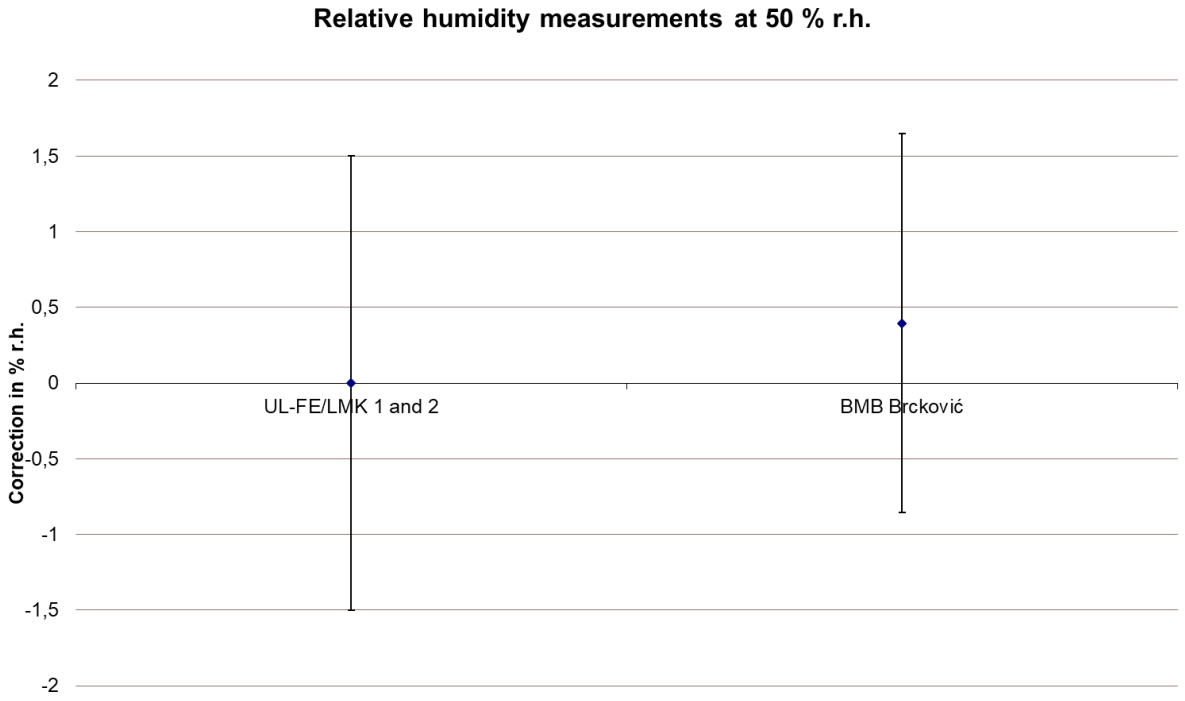

Relative humidity measurements at 50 % r.h.
Correction in % r.h.
1,5
1
0,5
0
-0,5
-1
-1,5
UL-FE/LMK 1 and 2
BMB Brcković

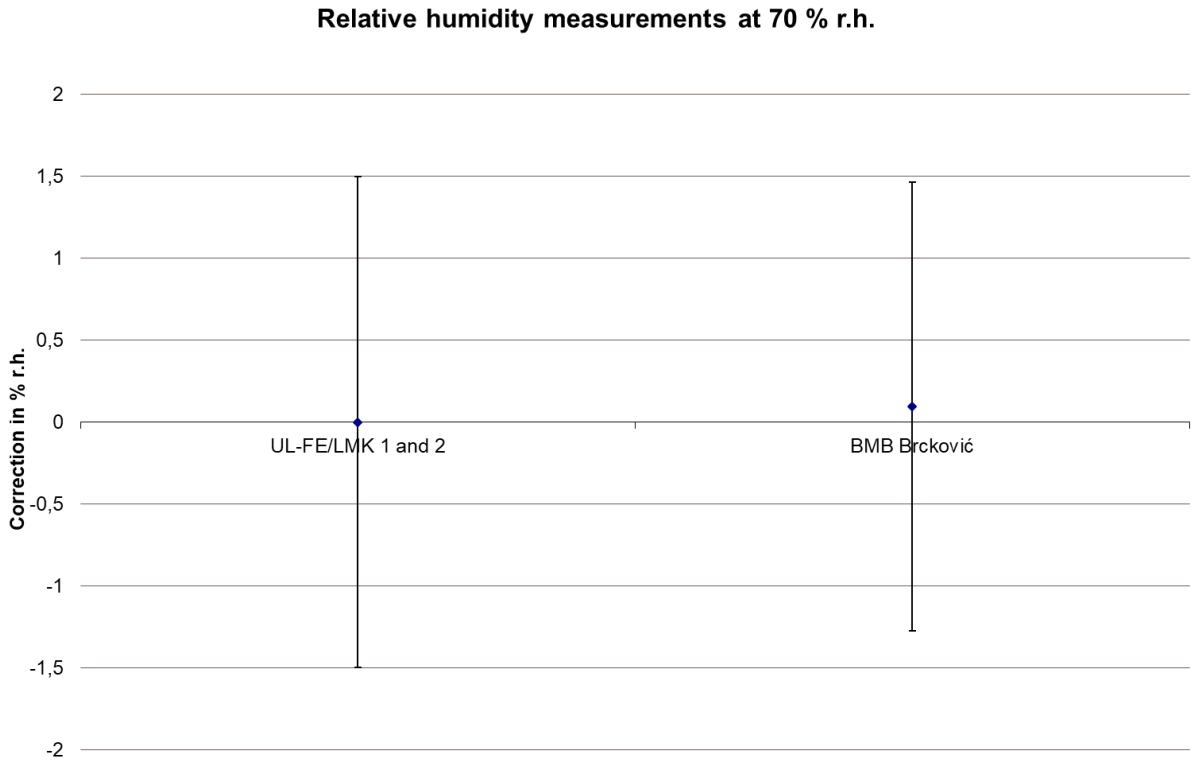
3. At temperature 70 °C

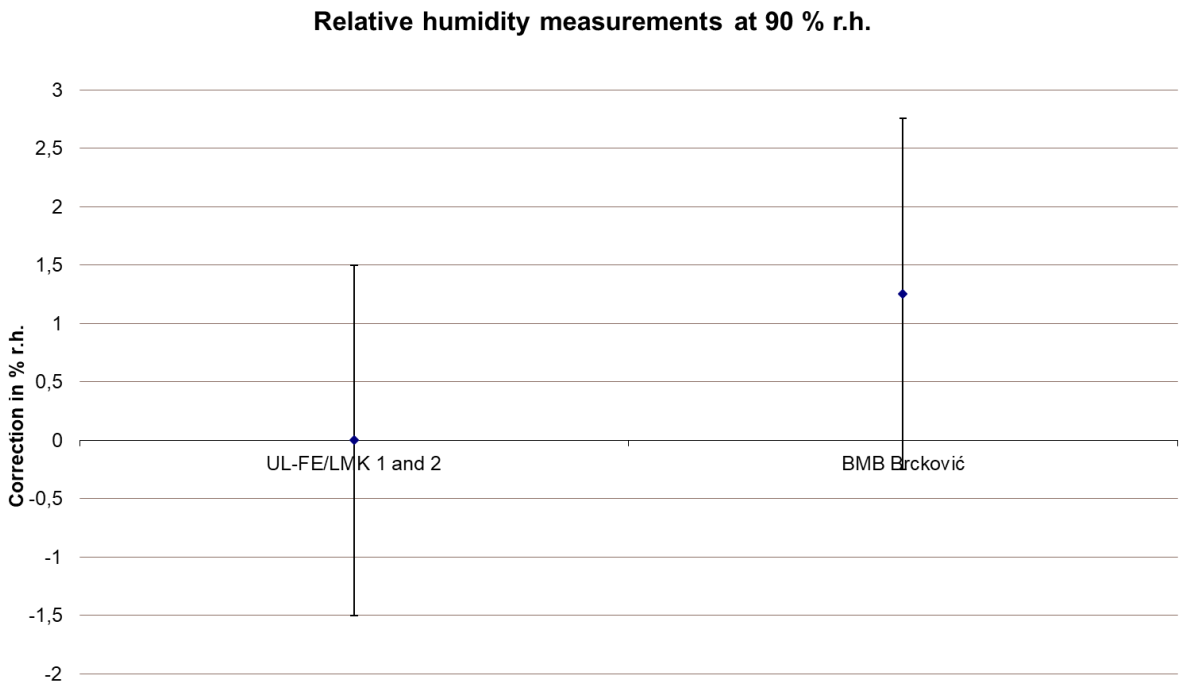


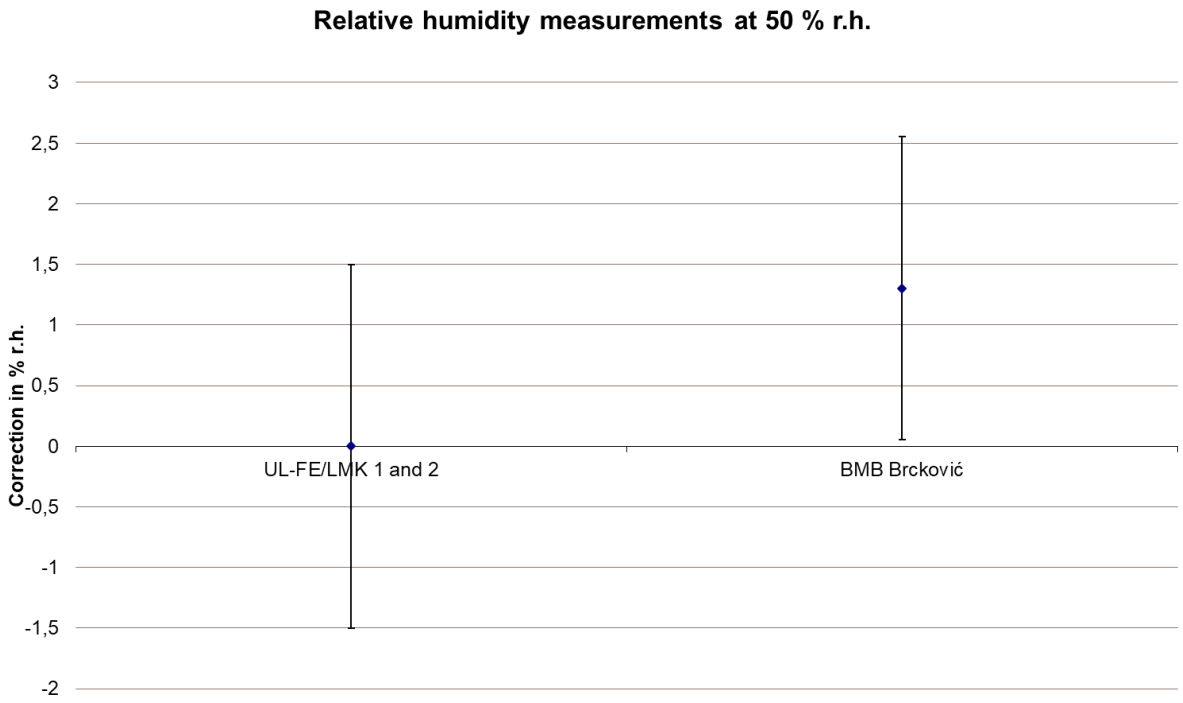



Relative humidity measurements at 30 % r.h.
Correction in % r.h.
2,5
2
1,5
1
0,5
0
-0,5
-1
-1,5
-2
UL-FE/LMK 1 and 2
BMB Brcković


Relative humidity measurements at 50 % r.h.
Correction in % r.h.
2
1,5
1
0,5
0
-0,5
-1
-1,5
-2
UL-FE/LMK 1 and 2
BMB Brcković


Relative humidity measurements at 70 % r.h.
Correction in % r.h.
2
1,5
1
0,5
0
-0,5
-1
-1,5
-2
UL-FE/LMK 1 and 2
BMB Brcković


Relative humidity measurements at 90 % r.h.
Correction in % r.h.
3
2,5
2
1,5
1
0,5
0
-0,5
-1
-1,5
-2
UL-FE/LMK 1 and 2
BMB Brcković


Relative humidity measurements at 50 % r.h.
Correction in % r.h.
3
2,5
2
1,5
1
0,5
0
-0,5
-1
-1,5
-2
UL-FE/LMK 1 and 2
BMB Brcković