

**Bilateral Comparison of Relative Humidity
Calibration**

Technical protocol

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1. INTRODUCTION

- 1.1 This comparison is aimed at establishing the degree of equivalence between relative humidity calibration in the range from 10 %RH to 95 %RH and the ambient temperature range +1 °C to +50 °C among the participating national metrology institutes.
- 1.2 In the framework of Phare project BG 2005/017-353.02.02, LOT 1, it was decided that a key comparison of relative humidity measurements shall be carried out, between the laboratory of NCM (Bulgaria) acting as organizing laboratory and NMI-VSL acting as reference laboratory.
- 1.3 The procedures outlined in this document cover the technical procedure to be followed during measurement of the travelling standards.

2. ORGANIZATION

2.1 Participants

- 2.1.1 NMI van Swinden Laboratorium, Delft, Netherlands, NCM, Sofia, Bulgaria
- 2.1.2 Reference laboratory - NMI van Swinden Laboratorium
- 2.1.3 By their declared intention to participate in this bilateral comparison, the laboratories accept the general instructions and the technical protocol written down in this document and commit themselves to follow strictly the procedures of this protocol.
- 2.1.4 Once the protocol and list of participants have been approved, no change to the protocol or list of participants may be made without prior agreement of participants.
- 2.1.5 The participants must be able to submit an uncertainty budget of their humidity standards.

2.2 Method of comparison

- 2.2.1 The bilateral comparison is a comparison of relative humidity calibration at the participating national institutes.
- 2.2.2 The comparison will be made by calibration of transfer standard. The laboratory will calibrate 1 digital hygrometer Testo 645 with two measuring probes, property of NCM, Bulgaria. Each measuring probe will independently measure the relative humidity of a sample of moist gas produced by a participant's standard generator using the same measuring process.
- 2.2.3 Simultaneous measurements using a pair of standards gives information about the within-laboratory consistency of the measurements, the reproducibility of the instrument performance, and continuous feedback about the successful transport of the instruments without any major shift in performance.

2.3 Handling of artefacts

- 2.3.1 The artefacts should be examined immediately upon receipt at the laboratory. The participants are expected to follow all instructions in the operator's manual provided by the instrument manufacturers for proper unpacking, subsequent packing and shipping to the next participant. During packing and unpacking, the participants should check the contents with the packing list including the operator's manual.
- 2.3.2 The travelling standards should only be handled by authorized persons and stored in such a way as to prevent damage.
- 2.3.3 During operation of the travelling standards, if there is any unusual occurrence, the other laboratory should be notified immediately before proceeding.

2.4 Transport of artefacts

- 2.4.1 The transportation process begins when the artefact leaves the sending laboratory and does not end until it reaches the destination laboratory. All participants should follow the following general guidelines:
- (1) Plan the shipment well in advance. The recipient should be aware of any customs issues in their country that would delay the testing schedule. The shipping laboratory must be aware of any national regulations covering the travelling standard to be exported;
 - (2) Determine the best way to ship the travelling standard to the next participant;
 - (4) Obtain the recipient's exact shipping address. If possible, have it shipped directly to the laboratory;
 - (5) Coordinate the shipping schedule with the recipient. The sending laboratory should provide the recipient with the carrier, the exact travel mode, and the estimated time of arrival;
 - (6) Instruct the recipient to confirm receipt and condition upon arrival to the sender and the pilot.
- 2.4.2 Each travelling standard is supplied with its shipping container, which is sufficiently robust to ensure safe transportation.

2.5. Timetable

Table 1

Period	Task	Lab.
October 2008	Calibration of transfer standard	NCM
November 2008	Calibration of transfer standard	NMi VSL
December 2008	Calibration of transfer standard	NCM

3. DESCRIPTION OF THE TRAVELLING STANDARDS

3.1. Artefacts

3.1.1 Travelling standard is digital hygrometer Testo 645 with two measuring probes, type 12s property of NCM, Bulgaria.

3.1.2 Details of travelling standards:

Model:	Testo 645
Size (in packing case):	58 x 51 x 24 cm
Weight (in packing case):	4,5 kg
Manufacturer:	Testo GMBH
Owner:	NCM, Bulgaria
Electrical supply:	230 V / 50 Hz, AC/DC Adapter 9,7 VA
Accessories:	Two measuring cables
Approximate value for insurance and customs declaration:	3 500 EUR

Serial numbers of the instruments are:

Testo 645	01133442
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Measuring probes:	20142598 20142601
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4. MEASUREMENT INSTRUCTIONS

4.1. Measurement process

4.1.1 The participants should refer to the operating manuals for instructions and precautions for using the travelling standards. Participants may perform any initial checks of the operation of the hygrometers that would be performed for a normal calibration. In the case of an unexpected instrument failure at a participant institute, the owner should be informed.

4.1.2 Sample gas generated by a participant's standard generator, is introduced into travelling standard hygrometer probes.

4.1.3 Each laboratory should follow its normal practice when calibrate digital hygrometers.

4.1.4 Each measurement should be conducted with the instruments measuring nominally simultaneously.

4.1.5 Three repeated full set of measurements are carried out, i.e. each nominal of relative humidity and temperature should be separately repeated (reproduced) three times to reduce the effect of any irreproducibility of the travelling standards.

- 4.1.6 Participants should avoid lengthy additional measurements, except those necessary to give confidence in the results of this comparison.
- 4.1.7 The travelling standards used in this comparison must not be modified, adjusted, or used for any purpose other than described in this document, nor given to any party other than the participants in the comparison.
- 4.1.8 NCM laboratory will make an assessment of any drift in the travelling standards during the comparison, based on measurements at the beginning and end of the comparison period. If drift is found, this will be taken into account in the final analysis of the comparison results.
- 4.1.9 If poor performance or failure of a travelling standard is detected, the owner will propose a course of action, subject to agreement of the participants.

4.2. Data collection

- 4.2.1 Travelling standard has two probes for relative humidity measurement.
- 4.2.2 Participants may apply their own criteria of stability for acceptance of measurements.
- 4.2.3 The data reported for the pair of probes should be for simultaneous or near-simultaneous measurement of the same applied condition.
- 4.2.4 The measurement points are given in Table 2.

Table 2

Temperature °C	Relative humidity %RH		Temperature °C	Relative humidity %RH
1	10		25	10
1	30		25	30
1	60		25	60
1	95		25	95
50	10		50	90

5. REPORTING OF MEASUREMENT RESULTS

After NCM has completed its measurements, NCM will send its measurement report to NMI van Swinden Laboratorium. When NMI laboratory has received this measurement report, NCM is no longer allowed to make any changes in its results or in its uncertainties. When NMI has completed its measurements they will also make a measurement report of its results. When all measurements reports have been completed, they will be sent to NCM who will do the data analysis and write the comparison report.

- 5.1 Participants must report their measurement results of three repeated experiments, within four weeks of completing their measurements.

- 5.2 The parameter to be compared between the laboratories in this comparison is the difference found between the travelling standards and the laboratory relative humidity standard. The travelling standards are used simply as comparators.
- 5.3 Participants should report results to the NMi VSL in terms of relative humidity. The main measurement results comprise:
- values of relative humidity applied to the travelling standards, and associated standard uncertainty
 - values measured using both travelling standards simultaneously (and their associated uncertainties derived from standard deviation of the set of readings)
 - values of difference between applied relative humidity and measured relative humidity.
- 5.4 From the data measured by each participant, results will be analysed in terms of differences between applied and measured relative humidity. In each case, the difference will be taken between the applied (realised) value and the mean (mid-point) between the two hygrometer values.
- 5.5 In addition, the difference between the two hygrometer readings on all occasions will be analysed and will serve as a check of consistency.

6. UNCERTAINTY OF MEASUREMENT

- 6.1 The uncertainty of the bilateral comparison results will be derived from:
- the quoted uncertainty of the relative humidity realisation (applied relative humidity)
 - the estimated uncertainty relating to the short-term stability of the travelling standard at the time of measurement
 - the estimated uncertainty due to any drift of the travelling standard over the period of the comparison (estimated by the NCM)
 - the estimated uncertainty in mean values due to dispersion of repeated results (reflecting the combined reproducibility of laboratory standard and travelling standards)
 - the estimated uncertainty due to non-linearity of the travelling standards in any case where measurements are significantly away from the agreed nominal value
 - the estimated covariance between applied (laboratory standard) and measured (travelling standard) values of relative humidity (if found significant)
 - any other components of uncertainty that are thought to be significant
- 6.2 Participants are required to submit detailed analyses of uncertainty for their relative humidity standards. Uncertainty analysis should be according to the approach given in the ISO Guide to the Expression of Uncertainty of Measurement. A list of the all significant components of the uncertainty budget should be evaluated, and should support the quoted uncertainties. Type B estimates of uncertainty may be regarded as having infinite degrees of freedom, or an alternative estimate of the number of degrees of freedom may be made following the methods in the ISO Guide. Individual institutes may add to the template any additional uncertainties they consider relevant.
- 6.3 The pilot laboratory will collect draft uncertainty budgets as background information to the uncertainties quoted by participants for the comparison measurements. The Pilot will review the uncertainty budgets for consistency among participants.

6.4 The uncertainty budget stated by the participating laboratory should be referenced to an internal report and/or a published article.

7. DETERMINATION OF THE BILATERAL COMPARISON REFERENCE VALUE

7.1 The outputs of the bilateral comparison are expected to be:

- Results of individual participants for comparison of the hygrometers against their relative humidity reference in terms of mean values for each hygrometer at each measured value, estimated standard uncertainty of each mean result and estimated standard uncertainty of comparison process (e.g. effect of long-term stability and non-linearity of the travelling standards) if necessary.
- Estimates of bilateral equivalence between the pair of participants at each measured relative humidity.
- A bilateral comparison reference value (BCRV) for each nominal value of relative humidity in the comparison. The BCRV might be calculated as the mean of all valid results of reference laboratory.
- Estimates of equivalence of each participant to the BCRV. This might be expressed in terms of the Degree of Equivalence (DOE) given as a difference and its uncertainty ($\Delta \pm U$), in %RH.

7.2 The NCM lab will make an assessment of any drift in the travelling standards during the comparison. The assessment will be based on initial and final measurements done by the NCM. If drift is found, this will be taken into account in the final analysis of the comparison results. If the drift is small compared with uncertainty values reported by the participants, an estimate for the drift may be set to zero with a standard uncertainty calculated according to the ISO Guide. In a case of a significant drift, the effect is taken into account by assigning a time-dependent value to BCRV, or by other suitable method so that the estimates of equivalence can be meaningfully calculated between results taken at different times.

APPENDIX 1. DETAILS OF PARTICIPATING INSTITUTES

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APPENDIX 2. PROVISIONAL TEMPLATE FOR DOCUMENTATION OF UNCERTAINTIES

Refer to Sheet “Uncert of standard” in accompanying MS Excel file “Appendices2to3_2008_10.xls”.

APPENDIX 3. PROVISIONAL TEMPLATE FOR REPORTING OF RESULTS

Refer to Sheet “Measurement results and inserts” in accompanying MS Excel file “Appendices2to3_2008_10.xls”.