Asia Pacific Laboratory Accreditation Cooperation

# RELATIVE HUMIDITY MEASUREMENT

INTERLABORATORY COMPARISON
APLAC M023

Final Report
April 2010

**ACKNOWLEDGEMENTS**

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**CONTENTS**

## 1. INTRODUCTION

This report summarises the results of an interlaboratory comparison on relative humidity calibration by laboratories accredited by bodies that are members of the Asia Pacific Laboratory Accreditation Cooperation (APLAC). The identification code number of this programme is M023. This programme was coordinated by the STANDARDS MALAYSIA.

## 2. AIM OF THE PROGRAM

One of the APLAC's main aims is to build up and maintain mutual confidence in the technical competence of APLAC members. Interlaboratory comparisons provide objective evidence that laboratories are competent and that they can achieve the level of accuracy for which they are accredited. They also provide means for improving the quality and performance of laboratories throughout the region.

APLAC M023 relative humidity programme was designed to test the participant's ability to perform calibration of a relative humidity using a relative humidity and temperature transmitter over a specified range and to obtain values within their accredited uncertainties of measurement. Secondary aim is to assess the participant's ability to estimate their uncertainty of measurement.

## 3. DESIGN OF THE PROGRAMME

This interlaboratory comparison involved the circulation of relative humidity and temperature transmitter with digital indicator around two schemes of participating laboratories, designated as Scheme A and Scheme B. The measurement artefacts comprised of two Vaisala relative humidity and temperature transmitter with digital indicator. The artefacts were identified as Artefact A and Artefact B and were circulated to Scheme A and Scheme B respectively.

National Metrology Laboratory (NML) of SIRIM, Malaysia acted as the Reference Laboratory, deriving values from a series of calibrations of the measurement artefacts at the beginning and the end of the program and at the intervals throughout.

The selected instrument needed to have sufficient resolution, repeatability and stability to be suitable for laboratories.

Participants were required to carry out calibration from 10 %rh to 90 %rh at nominal temperature of 23 °C. Participants were allowed to use their own measurement methods. A copy of the *Instructions to Laboratories* appears in Appendix A.

## 4. PARTICIPANTS

21 laboratories from 10 accreditation bodies participated in the programme. These laboratories are accredited for various levels of accuracy as defined in their scope of accreditation which lists their least uncertainties of measurement. During the circulation of the programme three laboratories withdrawn their participation.

In order to keep with the schedule, all the accreditation bodies were asked to strictly follow the circulation period given to all laboratories before starting the programme. However the circulation delayed for a few laboratories due to custom regulation for that particular country. Appendix B illustrated the circulation schedule for each laboratories.

To maintain confidentiality, participating laboratories were assigned random Lab Code numbers and these numbers are used in the report.

## 5. CIRCULATION DELAYS

There were delays in the circulation of artefacts. Most delays were only for a few weeks. The delays were due to the custom regulation in various countries.

## 6. REPORTING BY PARTICIPANTS

Laboratories were requested to report their test results on a pro-forma *Results Sheet* (refer to Appendix A). The participating laboratories shall report the calibration uncertainties at 95% confidence levels.

## 7. REFERENCE VALUES AND STABILITY OF THE ARTEFACTS

### *7.1 Assignment of Reference Values*

Before and after each round of circulation, the reference laboratory carried out a series of calibration of the artefacts. The reference values obtained from the calibration of the artefacts are in terms of correction to the readings at nominal value. Assignment of reference values for each laboratory is the average of readings before and after each round of circulation. Each loop had been assigned with different reference value. The results obtained by the reference laboratory appear in Appendix C.

The calibrations performed by the reference laboratory before and after the circulation showed that drift occurred for both artefacts for all ranges. Referring to APLAC PT001 *Calibration Interlaboratory,* where drift had occurred significantly during the circulation, different reference value may be specified for different laboratories. Therefore no laboratory is unfairly disadvantages. The transportation drift value was included in the uncertainty calculation for the reference value. Appendix E explained how and where drift was included in uncertainty calculation. The method used by the reference laboratory for uncertainty calculation was based on the method described in the ISO /IEC Guide 98-3, *Uncertainty of Measurement*.

*7.2 Performance of Artefacts*

Laboratories were asked to carry out measurement at 50 %rh before start calibration and after completed calibration in order to ensure that artefacts perform satisfactorily for the entire programme. Appendix D provides results of the measurement fluctuated within ± 2.0 %rh at 50 %rh. Therefore both artefact performed well during the programme.

## 8. INTERIM REPORTS

Upon receiving the calibration reports from the participating laboratories and completion of measurement of the reference value, interim reports were issued to the participating laboratories.

## 9. SUMMARY OF RESULTS

In accordance with the international practice, measurement performance has been assessed on the basis of an $E_n$ ratio for each measurement. The $E_n$ ratios are calculated using a standard statistical technique for comparing values and are derived from the following expression:

$$E_n = \frac{LAB - REF}{\sqrt{U_{LAB}{}^2 + U_{REF}{}^2}}$$

where:

*LAB* is the correction at nominal value measured by the participating laboratory.

*REF* is the average of correction at nominal value determined from measured correction value made before and after the circulations round by the reference laboratory.

$U_{LAB}$ is the expanded uncertainties of the correction provided by the participating laboratories.

$U_{REF}$ is the expanded uncertainties of the correction evaluated by the reference laboratory and the transportation drift.

For the results to be acceptable, values of $|E_n| \leq 1$ are required. Values of $|E_n| > 1$ require investigation and corrective action by both the laboratory concerned and its accreditation body.

A summary of results for every participating laboratories are summarized in Tables 1 to 2 along with the $|E_n|$ values. The graphs in Figures 1 to 10 illustrate the correction values corrected to nominal values reported by each laboratory together with its associated uncertainty.

**Table 1 – Summary of Reported Results Artefact A**

Relative humidity: 10 %rh at 23 °C

| Lab Code | Unit | **214** | **217** | **237** | **239** | **253** | **273** | **278** | **296** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Correction at nominal for *Lab* | %rh | 0.19 | 0.33 | -0.57 | 0.13 | -0.21 | -0.20 | -0.65 | 0.13 | | | |
| Correction at nominal for *Ref* | %rh | 0.36 | 0.86 | 0.36 | 0.36 | -0.13 | -0.13 | -0.13 | -0.13 | | | |
| *LAB-REF* | | -0.17 | -0.52 | -0.93 | -0.23 | -0.08 | -0.07 | -0.51 | 0.26 | | | |
| $U_{Lab}$ | %rh | 0.4 | 1.7 | 0.2 | 0.2 | 2.1 | 1.1 | 2.3 | 1.7 | | | |
| $U_{Ref}$ | %rh | 1.1 | 1.6 | 1.1 | 1.1 | 2.0 | 2.0 | 2.0 | 2.0 | | | |
| Coverage Factor: $k$ | - | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | | | |
| $\|E_n\|$ | - | 0.14 | 0.22 | 0.81 | 0.20 | 0.03 | 0.03 | 0.17 | 0.10 | | | |

Relative humidity: 30 %rh at 23 °C

| Lab Code | Unit | **214** | **215** | **217** | **237** | **239** | **251** | **253** | **257** | **273** | **278** | **293** | **296** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Correction at nominal for *Lab* | %rh | 0.78 | 1.13 | 0.60 | 0.59 | 0.84 | 1.3 | 0.54 | 0.21 | 0.85 | 0.88 | 1.90 | 0.06 |
| Correction at nominal for *Ref* | %rh | 0.92 | 0.79 | 0.79 | 0.92 | 0.92 | 0.8 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 |
| *LAB-REF* | | -0.14 | 0.34 | -0.19 | -0.34 | -0.08 | 0.54 | 0.32 | -0.00 | 0.63 | 0.66 | 1.68 | -0.15 |
| $U_{Lab}$ | %rh | 0.7 | 1.3 | 2.0 | 0.2 | 0.3 | 3.2 | 2.1 | 3.5 | 1.1 | 2.3 | 2.3 | 1.7 |
| $U_{Ref}$ | %rh | 1.2 | 1.6 | 1.6 | 1.2 | 1.2 | 1.6 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| Coverage Factor: $k$ | - | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| $\|E_n\|$ | - | 0.10 | 0.17 | 0.07 | 0.28 | 0.07 | 0.15 | 0.11 | 0.00 | 0.28 | 0.22 | 0.55 | 0.06 |

Relative humidity: 50 %rh at 23 °C

| Lab Code | Unit | **214** | **215** | **217** | **237** | **239** | **251** | **253** | **257** | **273** | **278** | **293** | **296** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Correction at nominal for *Lab* | %rh | 1.94 | 2.57 | 1.72 | 1.62 | 1.71 | 2.4 | 1.55 | 1.03 | 2.40 | 2.45 | 3.41 | 0.35 |
| Correction at nominal for *Ref* | %rh | 1.86 | 1.73 | 1.73 | 1.86 | 1.86 | 1.73 | 1.27 | 1.27 | 1.27 | 1.27 | 1.27 | 1.27 |
| *LAB-REF* | | 0.08 | 0.84 | -0.02 | -0.24 | -0.15 | 0.69 | 0.28 | -0.24 | 1.13 | 1.18 | 2.14 | -0.92 |
| $U_{Lab}$ | %rh | 1.1 | 1.5 | 2.3 | 0.2 | 0.5 | 2.9 | 2.1 | 3.5 | 1.1 | 2.3 | 2.3 | 1.7 |
| $U_{Ref}$ | %rh | 1.3 | 1.7 | 1.7 | 1.3 | 1.3 | 1.7 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 |
| Coverage Factor: $k$ | - | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| $\|E_n\|$ | - | 0.05 | 0.37 | 0.01 | 0.19 | 0.11 | 0.21 | 0.10 | 0.06 | 0.48 | 0.38 | 0.69 | 0.34 |

Relative humidity: 70 %rh at 23 °C

| Lab Code | Unit | **214** | **215** | **217** | **237** | **239** | **251** | **253** | **257** | **273** | **278** | **293** | **296** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Correction at nominal for *Lab* | %rh | 3.04 | 3.33 | 2.96 | 2.24 | 2.50 | 3.4 | 2.32 | 1.72 | 3.82 | 3.82 | 5.52 | 0.93 |
| Correction at nominal for *Ref* | %rh | 2.73 | 2.87 | 2.87 | 2.73 | 2.73 | 2.9 | 2.32 | 2.32 | 2.32 | 2.32 | 2.32 | 2.32 |
| *LAB-REF* | | 0.30 | 0.46 | 0.10 | -0.49 | -0.24 | 0.57 | 0.00 | -0.60 | 1.50 | 1.50 | 3.20 | -1.40 |
| $U_{Lab}$ | %rh | 1.5 | 1.7 | 2.7 | 0.2 | 0.7 | 2.9 | 2.5 | 3.5 | 1.1 | 2.3 | 2.3 | 2.0 |
| $U_{Ref}$ | %rh | 1.4 | 1.8 | 1.8 | 1.4 | 1.4 | 1.8 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 |
| Coverage Factor: $k$ | - | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| $\|E_n\|$ | - | 0.15 | 0.19 | 0.03 | 0.34 | 0.15 | 0.17 | 0.00 | 0.15 | 0.61 | 0.47 | 1.01 | 0.47 |

Relative humidity: 90 %rh at 23 °C

| Lab Code | Unit | **214** | **215** | **217** | **237** | **239** | **251** | **253** | **257** | **273** | **278** | **293** | **296** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Correction at nominal for *Lab* | %rh | 3.44 | 3.41 | 3.62 | 2.21 | 2.98 | 4.4 | 2.32 | 1.74 | 4.48 | 4.73 | 2.81 | 1.72 |
| Correction at nominal for *Ref* | %rh | 3.12 | 3.38 | 3.38 | 3.12 | 3.12 | 3.4 | 2.64 | 2.64 | 2.64 | 2.64 | 2.64 | 2.64 |
| *LAB-REF* | | 0.32 | 0.04 | 0.24 | -0.91 | -0.14 | 0.98 | -0.32 | -0.90 | 1.84 | 2.09 | 0.17 | -0.92 |
| $U_{Lab}$ | %rh | 1.8 | 2.0 | 3.0 | 0.2 | 0.9 | 2.9 | 2.5 | 3.5 | 1.1 | 2.3 | 2.3 | 2.6 |
| $U_{Ref}$ | %rh | 1.6 | 1.9 | 1.9 | 1.6 | 1.6 | 1.9 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 |
| Coverage Factor: $k$ | - | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| $\|E_n\|$ | - | 0.14 | 0.01 | 0.07 | 0.57 | 0.08 | 0.29 | 0.09 | 0.21 | 0.70 | 0.63 | 0.05 | 0.26 |

**Table 2 – Summary of Reported Results Artefact B**

Relative humidity: 10 %rh at 23 °C

| Lab Code | Unit | **224** | **260** | **266** | **275** | **279** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Correction at nominal for *Lab* | %rh | 0.7 | 0.23 | 0.23 | 0.4 | 0.2 | | | | |
| Correction at nominal for *Ref* | %rh | -0.1 | -0.34 | -0.34 | -0.1 | -0.1 | | | | |
| *LAB-REF* | | 0.75 | 0.57 | 0.58 | 0.51 | 0.34 | | | | |
| $U_{Lab}$ | %rh | 0.5 | 0.4 | 0.4 | 1.2 | 0.3 | | | | |
| $U_{Ref}$ | %rh | 1.4 | 1.2 | 1.2 | 1.4 | 1.4 | | | | |
| Coverage Factor: *k* | - | 2 | 2 | 2 | 2 | 2 | | | | |
| $\|E_n\|$ | - | 0.50 | 0.45 | 0.46 | 0.28 | 0.24 | | | | |

Relative humidity: 30 %rh at 23 °C

| Lab Code | Unit | **224** | **260** | **263** | **266** | **267** | **271** | **275** | **279** | |
|---|---|---|---|---|---|---|---|---|---|---|
| Correction at nominal for *Lab* | %rh | 1.6 | 0.60 | 1.4 | 0.56 | -0.11 | 0.8 | 1.1 | 1.1 | |
| Correction at nominal for *Ref* | %rh | 1.0 | 0.40 | 0.9 | 0.40 | 0.40 | 0.9 | 1.0 | 1.0 | |
| *LAB-REF* | | 0.67 | 0.21 | 0.50 | 0.16 | -0.50 | -0.13 | 0.15 | 0.11 | |
| $U_{Lab}$ | %rh | 0.5 | 0.5 | 4.9 | 1.5 | 2.3 | 2.3 | 1.2 | 0.3 | |
| $U_{Ref}$ | %rh | 1.5 | 1.3 | 1.7 | 1.3 | 1.3 | 1.7 | 1.5 | 1.5 | |
| Coverage Factor: $k$ | - | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | |
| $\|E_n\|$ | - | 0.42 | 0.15 | 0.10 | 0.08 | 0.19 | 0.05 | 0.08 | 0.07 | |

Relative humidity: 50 %rh at 23 °C

| Lab Code | Unit | **224** | **260** | **261** | **263** | **266** | **267** | **271** | **275** | **279** |
|---|---|---|---|---|---|---|---|---|---|---|
| Correction at nominal for *Lab* | %rh | 2.9 | 1.85 | 1.13 | -1.4 | 1.30 | 1.45 | 2.3 | 2.3 | 2.3 |
| Correction at nominal for *Ref* | %rh | 2.2 | 1.42 | 1.42 | 2.3 | 1.42 | 1.42 | 2.3 | 2.2 | 2.2 |
| *LAB-REF* | | 0.76 | 0.43 | -0.29 | -3.7 | -0.12 | 0.03 | -0.04 | 0.12 | 0.14 |
| $U_{Lab}$ | %rh | 0.5 | 0.6 | 2.4 | 4.9 | 2.0 | 2.4 | 2.3 | 1.2 | 0.3 |
| $U_{Ref}$ | %rh | 1.6 | 1.4 | 1.4 | 1.7 | 1.4 | 1.4 | 1.7 | 1.6 | 1.6 |
| Coverage Factor: $k$ | - | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| $\|E_n\|$ | - | 0.45 | 0.28 | 0.10 | 0.7 | 0.05 | 0.01 | 0.02 | 0.06 | 0.08 |

Relative humidity: 70 %rh at 23 °C

| Lab Code | Unit | **224** | **260** | **261** | **263** | **266** | **267** | **271** | **275** | **279** |
|---|---|---|---|---|---|---|---|---|---|---|
| Correction at nominal for *Lab* | %rh | 3.9 | 2.92 | 1.83 | -1.3 | 2.94 | 2.23 | 3.5 | 3.4 | 3.4 |
| Correction at nominal for *Ref* | %rh | 3.2 | 2.38 | 2.38 | 3.5 | 2.38 | 2.38 | 3.5 | 3.2 | 3.2 |
| *LAB-REF* | | 0.73 | 0.54 | -0.55 | -4.9 | 0.56 | -0.15 | 0.00 | 0.19 | 0.21 |
| $U_{Lab}$ | %rh | 0.5 | 0.8 | 2.4 | 4.9 | 2.8 | 2.4 | 2.3 | 1.2 | 0.3 |
| $U_{Ref}$ | %rh | 1.7 | 1.6 | 1.6 | 1.8 | 1.6 | 1.6 | 1.8 | 1.7 | 1.7 |
| Coverage Factor: $k$ | - | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| $\|E_n\|$ | - | 0.41 | 0.30 | 0.19 | 0.9 | 0.17 | 0.05 | 0.00 | 0.09 | 0.12 |

Relative humidity: 90 %rh at 23 °C

| Lab Code | Unit | **224** | **260** | **263** | **266** | **267** | **271** | **275** | **279** |
|---|---|---|---|---|---|---|---|---|---|
| Correction at nominal for *Lab* | %rh | 4.0 | 2.76 | -1.8 | 5.98 | 3.11 | 4.6 | 3.8 | 3.8 |
| Correction at nominal for *Ref* | %rh | 3.7 | 2.95 | 4.1 | 2.95 | 2.95 | 4.1 | 3.7 | 3.7 |
| *LAB-REF* | | 0.28 | -0.20 | -5.9 | 3.02 | 0.16 | 0.42 | 0.13 | 0.08 |
| $U_{Lab}$ | %rh | 1.0 | 0.9 | 4.9 | 4.2 | 2.6 | 2.3 | 1.2 | 0.3 |
| $U_{Ref}$ | %rh | 1.9 | 1.8 | 1.9 | 1.8 | 1.8 | 1.9 | 1.9 | 1.9 |
| Coverage Factor: $k$ | - | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| $\|E_n\|$ | - | 0.13 | 0.10 | 1.1 | 0.66 | 0.05 | 0.14 | 0.06 | 0.04 |

**Corrections at nominal values with its associated uncertainty for Artefact A: C4510044**

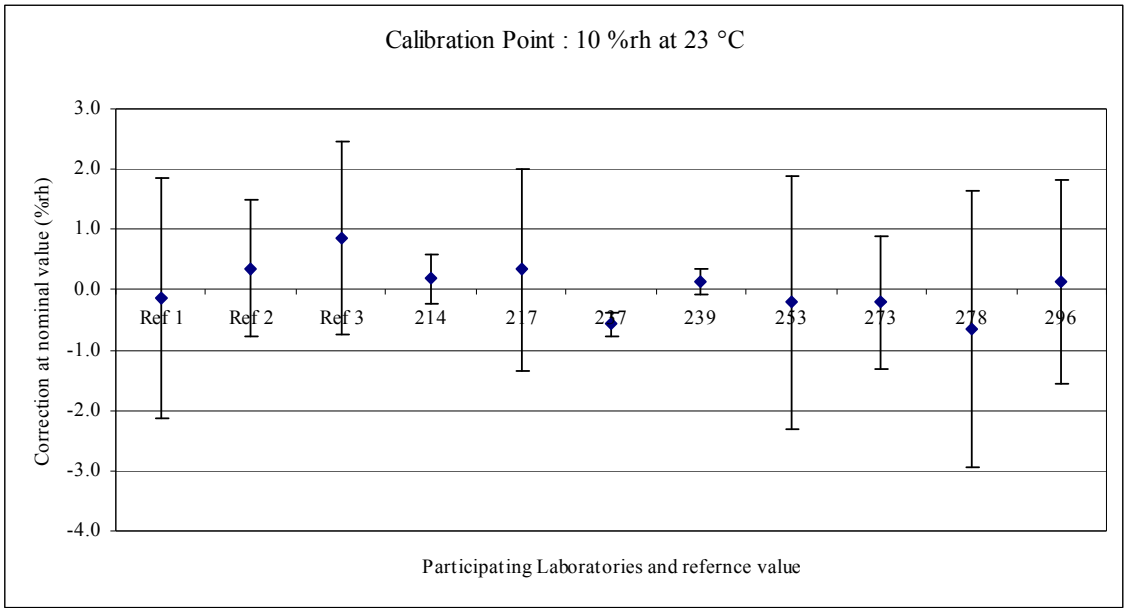



Figure 1: Calibration at 10 %rh at 23 °C

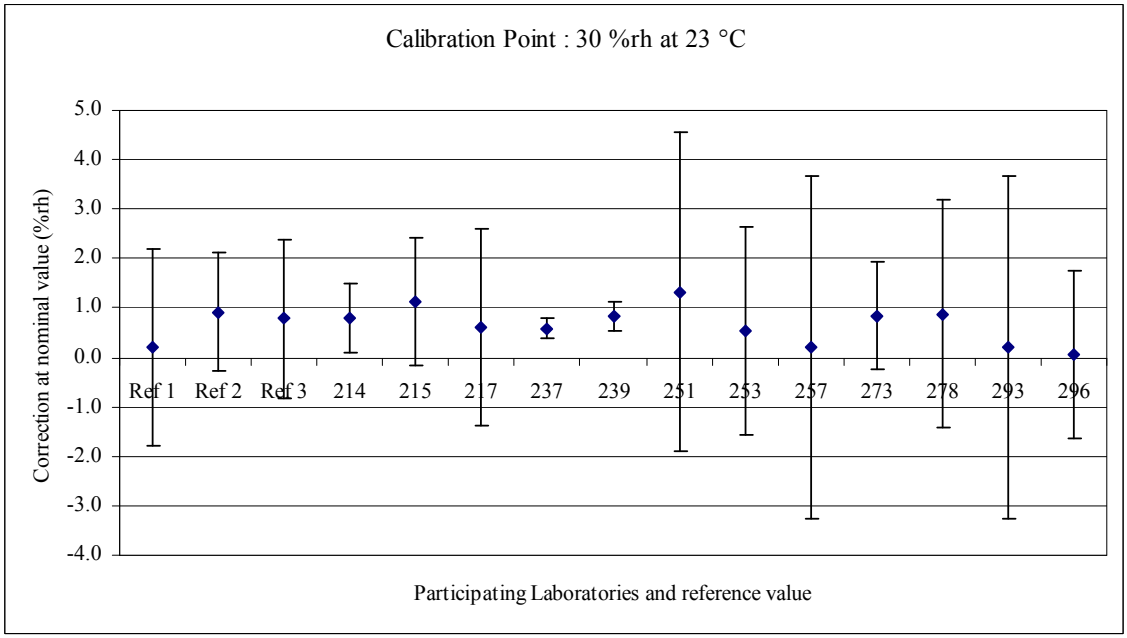



Figure 2: Calibration at 30 %rh at 23 °C

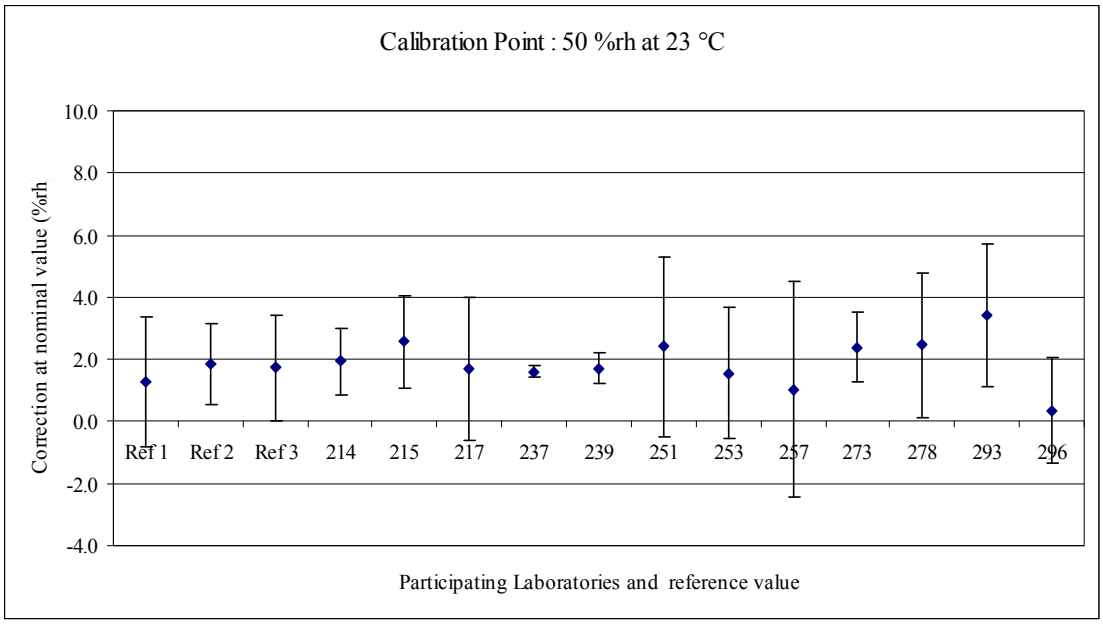



Figure 3: Calibration at 50 %rh at 23 °C

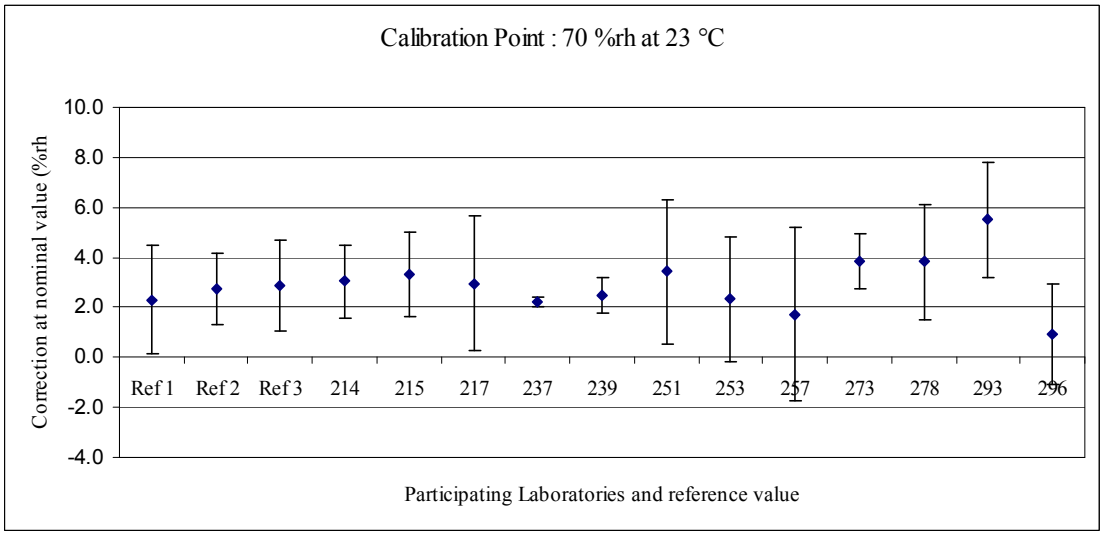



Figure 4: Calibration at 70 %rh at 23 °C

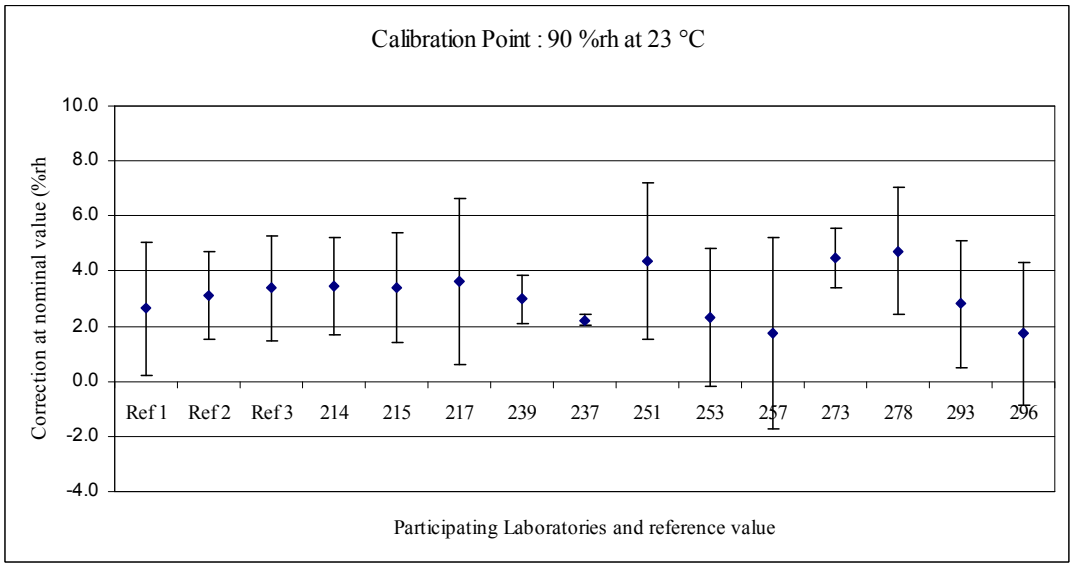



Figure 5: Calibration at 90 %rh at 23 °C

**Corrections at nominal values with its associated uncertainty for Artefact B : C4510045**

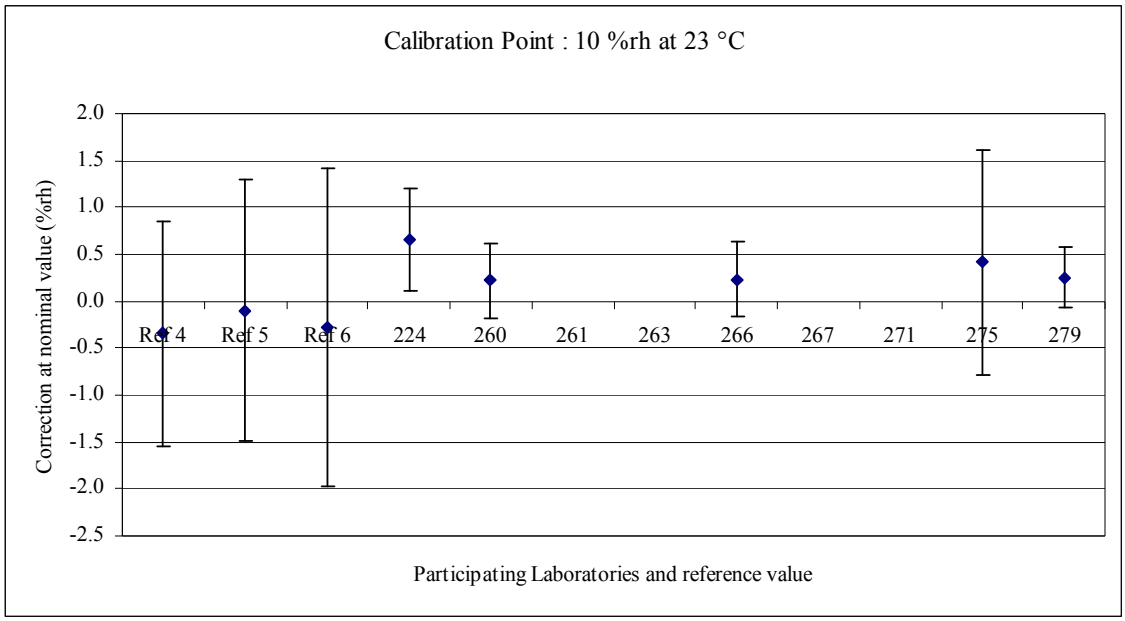



Figure 6: Calibration at 10 %rh at 23 °C

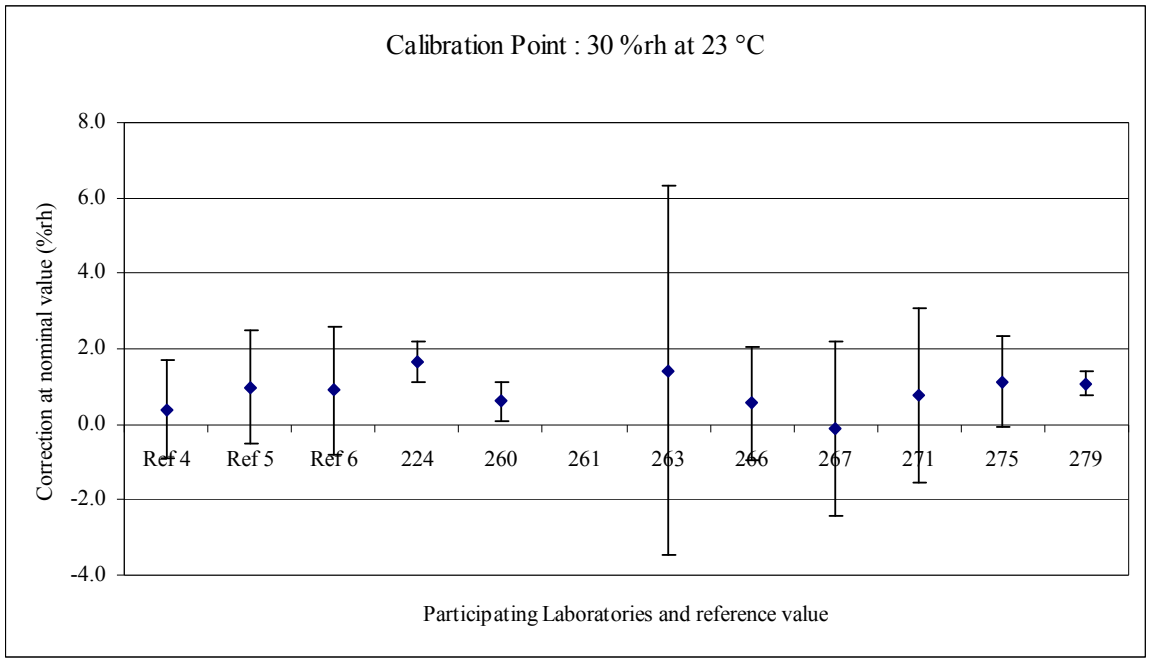



Figure 7: Calibration at 30 %rh at 23 °C

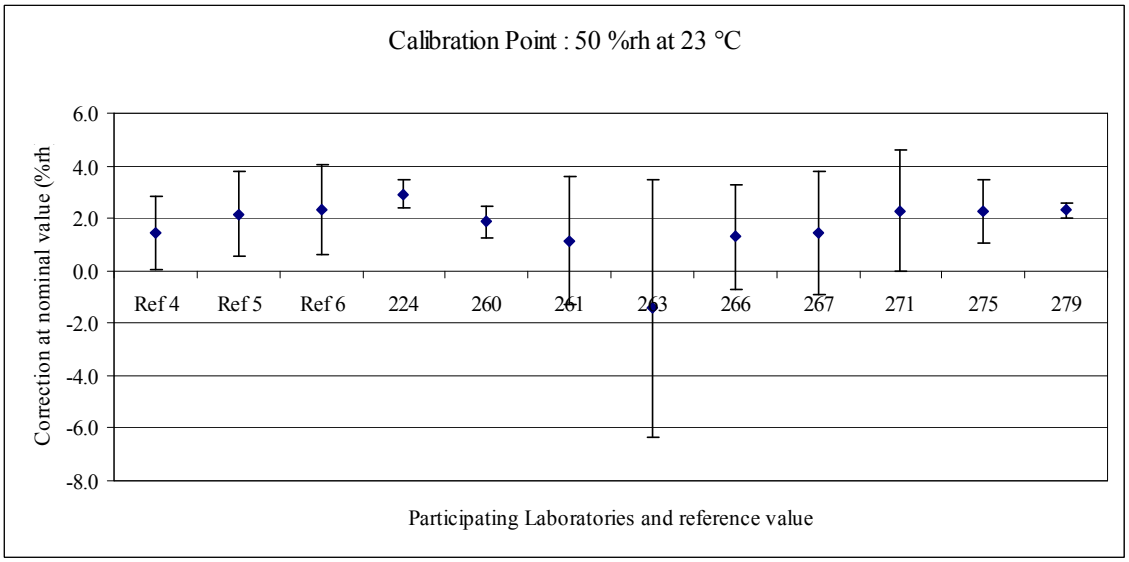



Figure 8: Calibration at 50 %rh at 23 °C

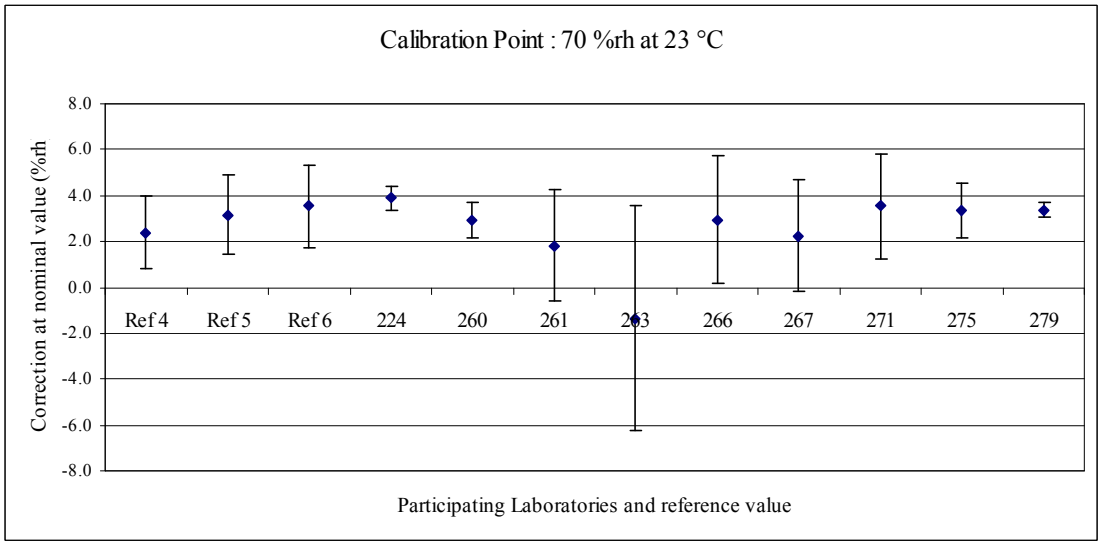



Figure 9: Calibration at 70 %rh at 23 °C

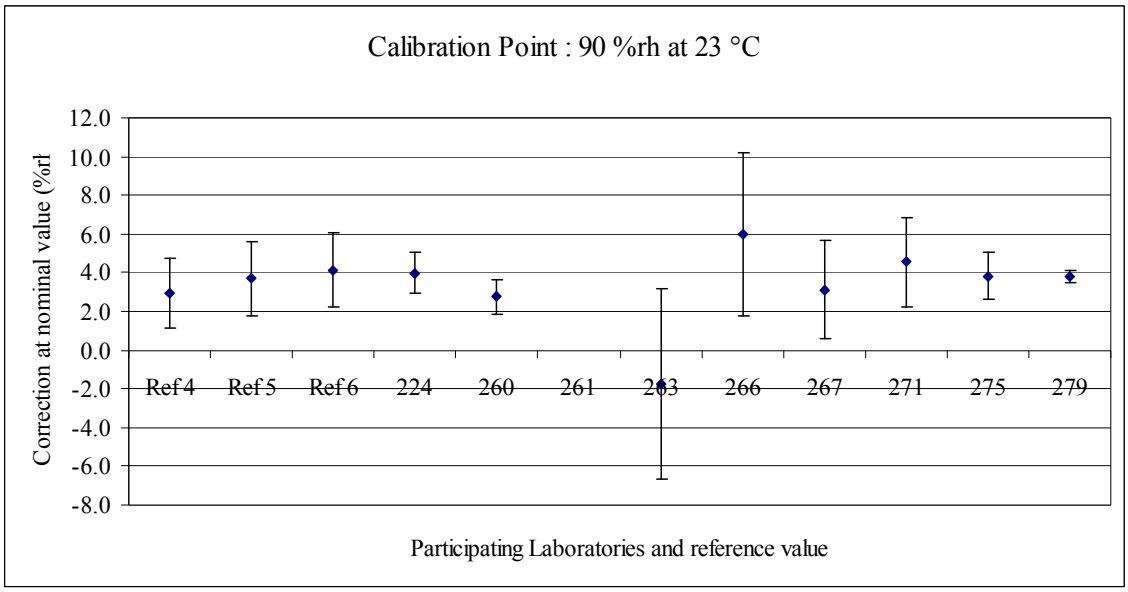



Figure 10: Calibration at 90 %rh at 23 °C

## 10. PERFORMANCE OF PARTICIPANTS

Tables 1 and 2 for the $|E_n|$ ratios show an overall good performance by the majority of the participating laboratories. The following is the summary of performance of participating laboratories.

### *10.1 Circulation of Scheme A*

Twelve (12) laboratories registered in measurement for Scheme A. For measurement at 10 %rh, 30 %rh, 50 %rh, and 90 %rh, the performance of all participating laboratories was excellent as indicated by the fact that no laboratory had an $|E_n|$ value greater than 1. For measurement at 70 %rh, Lab Code 293 had one result with an $|E_n|$ values exceeded 1.

Only eight (8) laboratories were able to perform measurement at 10 %rh. All twelve (12) laboratories were able to perform measurement from 30 %rh to 90 % rh.

### *10.2 Circulation of Scheme B*

Nine (9) laboratories registered in measurement for Scheme A. For measurement at 10 %rh, 30 %rh, 50 %rh, and 70 %rh, the performance of all participating laboratories was excellent as indicated by the fact that no laboratory had an $|E_n|$ value greater than 1. For measurement at 90 %rh, Lab Code 263 had one result with an $|E_n|$ values exceeded 1.

Only five (5) laboratories were able to perform measurement at 10 %rh. Eight (8) laboratories were able to performed measurement at 30 %rh. All nine (9) laboratories were able to perform measurement from 50 %rh to 70 % rh. Finally eight (8) laboratories were able to performed measurement at 90 %rh.

As shown in Figure 11 for 95 reported results, 98% were in agreement with the reference laboratory and 2% were outliers.

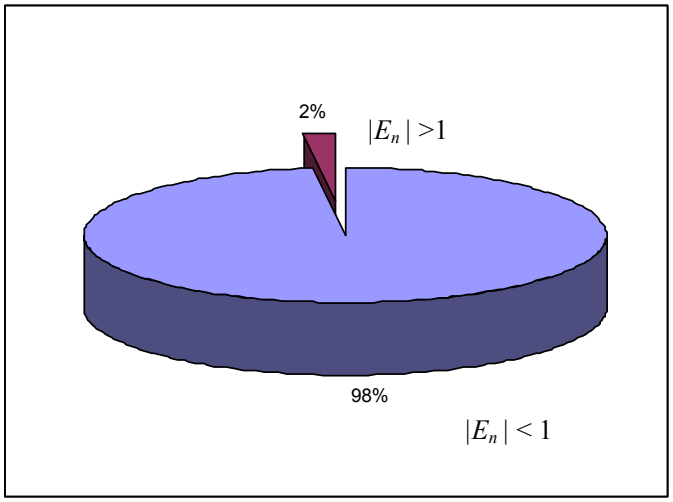



Figure 11 – Summary of 95 Reported Results

Figure 12 shows that 91% of the participating laboratories obtained an excellent performance with an $|E_n|$ value of less than unity for all the measurements, 9% of the participating laboratories each had one result with an $|E_n|$ value exceeded 1.

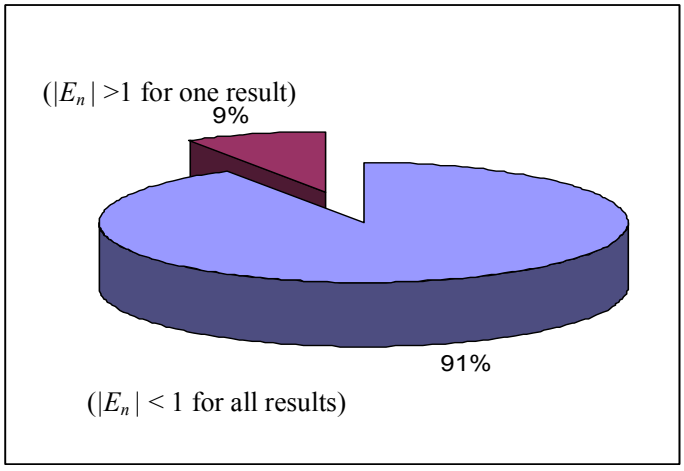



Figure 12 - Summary of 21 Participating Laboratories

## 11. UNCERTAINTIES OF MEASUREMENT

Uncertainty calculations were generally adequate and covered the major sources of uncertainty. Uncertainty calculation for reference value seems to be quite large compared to a few participating laboratories. This is due to the effect of transportation drift for each artefact. Five (5) laboratories reported uncertainty value of less than 1 %rh. Most of the laboratories reported uncertainty values between 1 .0 %rh to 3.0 %rh. However, Lab code 257 and 263 reported large values of expanded uncertainty (more then 3.0 %rh) compare to others laboratories.

## 12. CORRECTIVE ACTIONS

Details of corrective action are not included in this report. The respective accreditation bodies (ABs) have to ensure that any outlier under their purview has the problem rectified and procedures to prevent recurrence have been put in place.

## 13. REFERENCES

1. APLAC PT001 Calibration Interlaboratory Comparisons Issue No. 5
2. ISO /IEC Guide 98-3, Uncertainty of Measurement – Part 3: Guide to the Expression of Uncertainty in Measurement.
4. Guide to calculate uncertainty in humidity measurement by NPL, UK.
5. ISO/IEC 17025 General requirements for the competence of testing and calibration laboratories.

Asia Pacific Laboratory Accreditation Cooperation

# APPENDIX A

# APLAC M023 RELATIVE HUMIDITY MEASUREMENT PROFICIENCY TESTING PROGRAMME

## CALIBRATION OF RELATIVE HUMIDITY 10 %rh TO 90 %rh AT NOMINAL TEMPERATURE OF 23 °C

# MEASUREMENT INSTRUCTIONS

## October 2008

# APLAC PROFICIENCY TESTING PROGRAMME M023

# APLAC M023 CALIBRATION OF RELATIVE HUMIDITY 10 %rh TO 90 %rh AT NOMINAL TEMPERATURE OF 23 °C

## 1. Introduction

The purpose of APLAC M023 Relative Humidity Measurement Proficiency Testing Programme is to compare the calibration results of accredited laboratories within APLAC in the field of Relative Humidity measurement. Two different relative humidity and temperature sensor of the same model will be used in a circulation, among the accredited laboratories of the APLAC members.

## 2. Coordinator

The coordinator of this PT Programme is the Department of Standards Malaysia. The complete information is as follows:

STANDARDS MALAYSIA
Century Square,
Level 1 & 2, Block 2300,
Jalan Usahawan,
63000 Cyberjaya, Selangor
MALAYSIA

***Contact person for***
Department of Standards Malaysia

Mr. Ahmad Razif Bin Abd. Rahim
Tel : +60 3 8319 1400
Fax : +60 3 8318 9339
E-mail : razif@standardsmalaysia.gov.my

## 3. Reference Laboratory

The reference values for the Relative Humidity measurement will be provided by the National Metrology Laboratory, SIRIM Berhad, (NML-SIRIM), Malaysia. Complete information on NML-SIRIM is as follows:

National Metrology Laboratory
SIRIM Berhad
Lot PT 4803, Bandar Baru Salak Tinggi
43900 Sepang
MALAYSIA

***Contact person for NML-SIRIM*** Ms. Faridah Hussain
Tel: +60 3 8778 1735
Fax : +60 3 8778 1661
E-mail: faridah_hussain@sirim.my

## 4. Artefact

Each accredited laboratories will be provided with one relative humidity and temperature transmitter with digital indicator. Each device comes with one sensor, each measuring temperature and relative humidity. It will be shipped together with an operation manual. Details of the artefact are as below:

| Artefact | Measurement Temperature (°C) | Manufacturer | Model | Serial Number |
|---|---|---|---|---|
| A | 23 °C | Vaisala | HMT330 | C4510044 |
| B | 23 °C | Vaisala | HMT330 | C4510045 |

## 5. Calibration Procedure

During the calibration, the artefacts should be supplied with 240 V ± 10%, 50 Hz. Measurements will be performed using the Laboratory's own procedures, within the following constraints:

All laboratories should refer to the operating manuals for instructions and precautions for using the artefacts. These instructions shall be read in full and if in doubt on any of the aspects, the laboratory shall contact the reference laboratory. In the case of any unexpected instrument failure at a participant laboratory, the reference laboratory should be informed in order to revise the schedule, if necessary, as early as possible.

- Measurements shall be performed for increasing values of relative humidity.

- No adjustments shall be performed on the artefacts.
- The artefact used in this comparison must **not be** modified, adjusted, or used for any purpose other then described in this document, nor given to any party other then the participants in the comparison.

## 5.1 Measurement at 23 °C

**Equipment:**

a) Artefact A or B
b) Laboratory relative humidity and temperature standard
c) Laboratory relative humidity and temperature calibration chamber

1. The artefact shall be left in the nominal ambient conditions of the laboratory for a minimum period of 3 hours before taking any measurement.

2. Place the sensor of the artefact in a relative humidity and temperature calibration chamber together with the laboratory relative humidity and temperature standards. Refer to Set-up diagram in Figure 1.

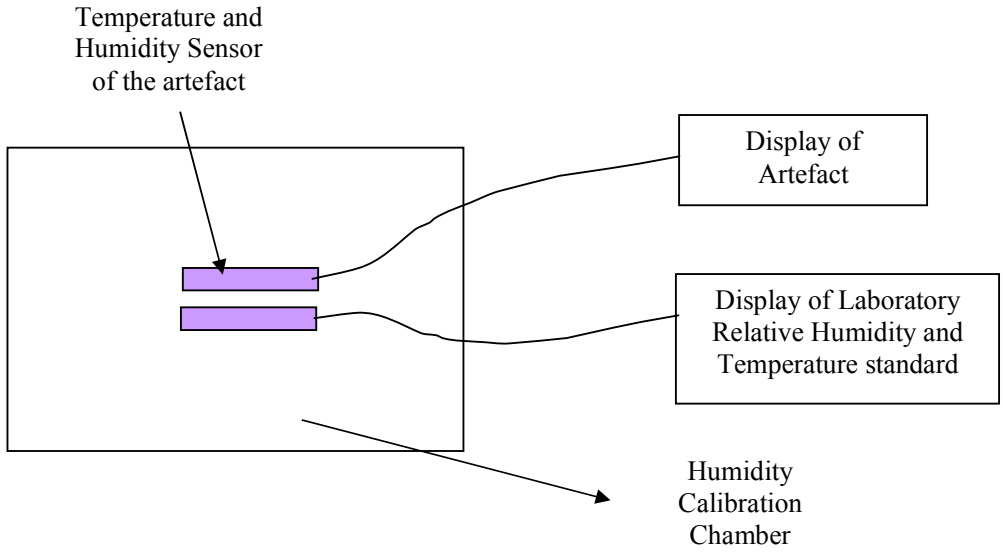



Figure 1: Schematic diagram set-up for calibration

3. For checking purposes of the artefact before calibration, set the relative humidity and temperature calibration chamber to **50 %rh** at **23 °C**. Take the measured data for standard used and the artefact using **Appendix F1**.

4. Then perform measurement at the nominal value within the Laboratory's scope of accreditation at nominal temperature of **23 °C**.

5. Nominal values to be measured: **10 %rh, 30 %rh, 50 %rh, 70 %rh** and **90 %rh**. Measurement should be made in **rising order** of relative humidity.

6. At each generated condition a time of not less than 60 minutes should be allowed for the relative humidity to equilibrate. A set of **10** readings at **1 minute interval** should be recorded from the laboratory standard and artefact.

7. Once again after completed all measurement points, set the relative humidity and temperature calibration chamber to **50 %rh** at **23 °C**. Take the measured data for standard used and the artefact using **Appendix F2**.

## 6. Environmental Conditions

Assure that the calibration ambient temperature is stable and within 18 °C to 28 °C and the ambient relative humidity is less than 80 %.

The actual environmental conditions during calibration should be reported.

## 7. Reporting of calibration results

Please refer to the table below for the details of results submission.

| Document | When to be submitted | Submitted to whom |
|---|---|---|
| Completed proforma result sheets (Appendix F1-7) | **Within 2 weeks after completing the calibration** | Participating Laboratory Accreditation Body (AB) for forwarding to STANDARDS MALAYSIA |
| Completed laboratory's budgets for estimating the uncertainty of measurement. Please refer to Appendix G for the template of estimating uncertainty of measurement. | | |

## 8. Analysis of results

The reference laboratory will analyze the results and produce interim and final reports in consultation with the STANDARDS MALAYSIA.

# Appendix A
# Instructions to Accreditation Bodies

**APLAC PROFICIENCY TESTING PROGRAMME M023**
**– RELATIVE HUMIDITY MEASUREMENT**

## 1. EQUIPMENT

On receipt, unpack the audit pack and inspect the artefact for any defects. *List other specific checks.*
Complete the attached "*RECEIPT FORM*" and fax to STANDARDS MALAYSIA.

## 2. TRANSPORT

The artefacts can be carried by hand, car or by plane, whatever means of transportation considered as safe.

## 3. CUSTOMS

**NO** ATA Carnet is provided with these artefacts. A *Declaration to Customs Officials and Shipping Agents* is enclosed in the plastic envelope attached to the outside of the box. Please make sure it is in place before dispatching to the next country otherwise it will not pass through their Customs authorities. Please attach 3 extra photocopies of the *Declaration*.

## 4. MEASUREMENTS TO BE CARRIED OUT

Please refer to *MEASUREMENT INSTRUCTIONS* enclosed. If necessary, these should be translated into the appropriate language by the accreditation body.

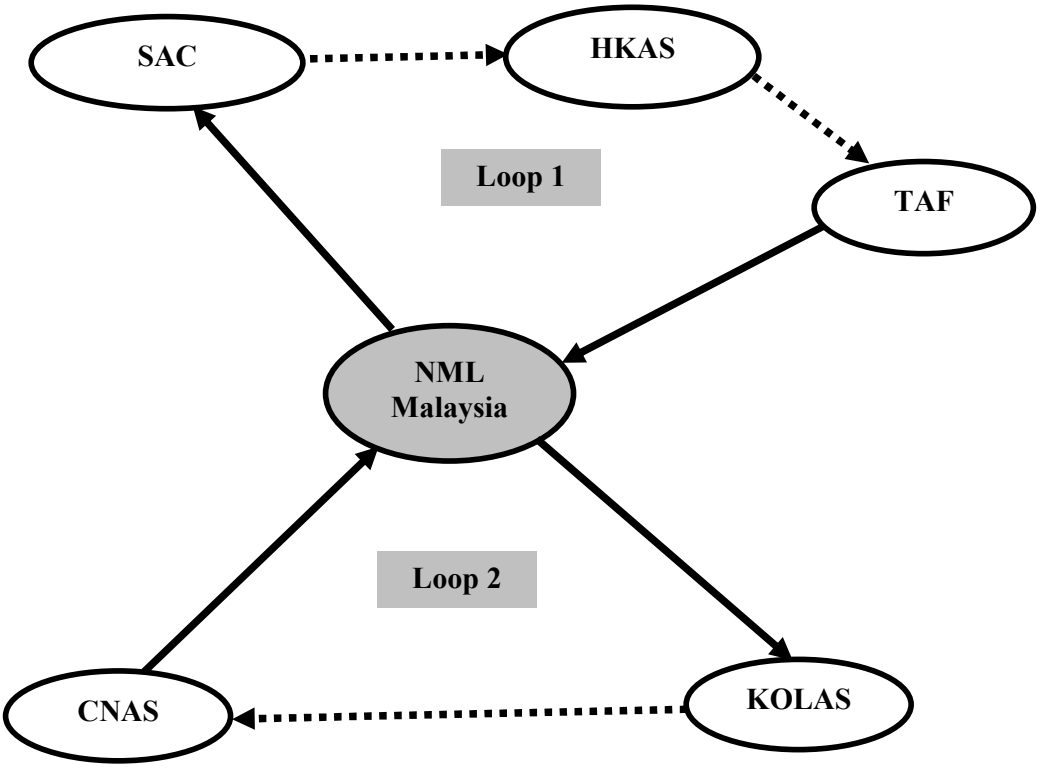
## 5. CIRCULATION SCHEME

At the beginning, middle and at the end of the circulation scheme, measurements will be performed by the reference laboratory, National Metrology Laboratory, Malaysia. Two (2) units of artefact; A and B will be used to cover two (2) parallel scheme ; scheme A and scheme B.

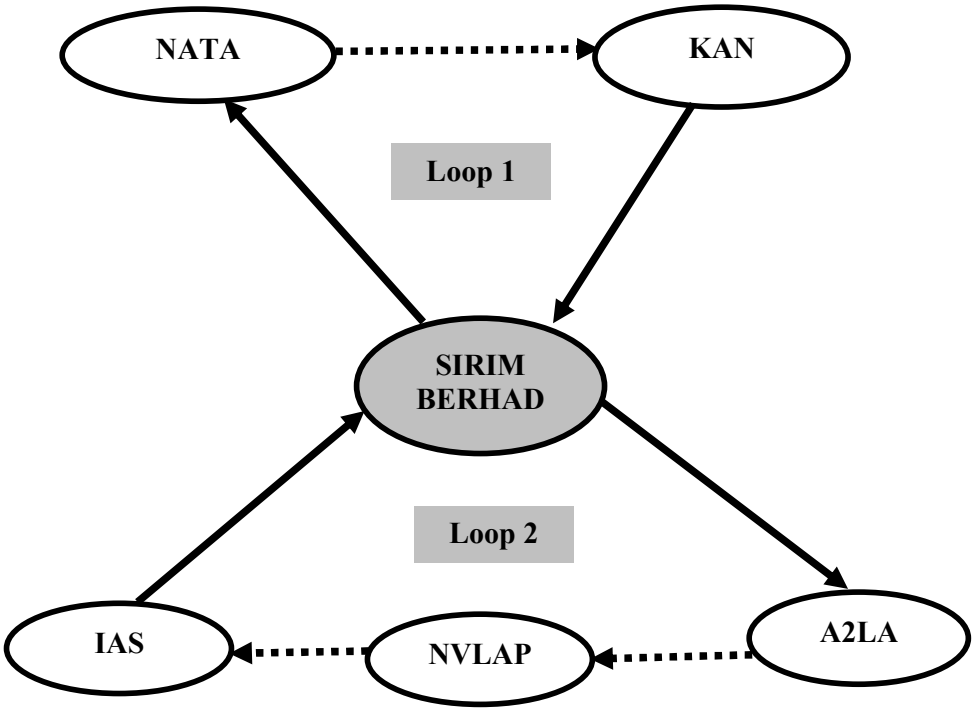
Each laboratory will be given 1(one) weeks to perform measurement. It is the responsibility of the accreditation body to make sure that the artefact is dispatched to the next participant by the date specified. One week have been allowed for each international transport and customs clearance. If a delay occurs with one laboratory, STANDARD MALAYSIA shall be informed. When ready for dispatch, fill in the attached *DISPATCH FORM* and fax to the next participant and to STANDARD MALAYSIA.

**CIRCULATION SCHEME FOR TRAVELLING ARTEFACT**

# SCHEME A
# ARTEFACT A



# SCHEME B
# ARTEFACT B



## 6. DOCUMENTS TO BE SUBMITTED

Within two week of the completion of the measurements, participating laboratories are required to fax or send the *Result Sheet* together with their formal calibration report to their accreditation body. The accreditation body is required to ensure that the *Result Sheet* has been filled in correctly and completely. The accreditation body should provide details of any problems that their laboratories had. The accreditation body is required to fax the documentation to the organising body within two weeks of dispatching the artefact.

On receipt of the information, the organising body for this APLAC proficiency testing programme will prepare interim reports on each laboratory which are then sent back to the national accreditation body. A final report will be issued at the end of the program with each laboratory only identified by a **confidential** code number.

## 7. GENERAL INFORMATION

For general queries, please contact:


STANDARDS MALAYSIA
Century Square,
Level 1 & 2, Block 2300,
Jalan Usahawan,
63000 Cyberjaya, Selangor
MALAYSIA

***Attention:*** Mr. Ahmad Razif Bin Abd. Rahim
Fax : +60 3 8318 9339
E-mail : razif@standardsmalaysia.gov.my

# Appendix B
# Receipt Form

**APLAC PROFICIENCY TESTING PROGRAMME M023**
**– RELATIVE HUMIDITY MEASUREMENT**

In order to monitor the progress of the PT Programme, we kindly ask each accreditation body, on receipt of the artefact, to fill in this RECEIPT FORM and fax it to:

STANDARDS MALAYSIA
Century Square,
Level 1 & 2, Block 2300,
Jalan Usahawan,
63000 Cyberjaya, Selangor
MALAYSIA

***Attention:*** Mr. Ahmad Razif Bin Abd. Rahim
Fax : +60 3 8318 9339
E-mail : razif@standardsmalaysia.gov.my

Thank you in advance for your cooperation.

The M023 artefact, serial number _____ was received on:_____ (*date*)

After inspection, are the contents damaged? _____
*(yes/no)*

If yes, is this serious? _____
*(yes/no)*

Are the contents still suitable for use? _____
*(yes/no)*

Was there a "*Declaration to Customs Officials and Shipping Agents*" enclosed in the plastic envelope attached to the outside of the case?

_____
*(yes/no)*

Remarks: _____

_____

Participating Accreditation Body: _____

Contact Person: _____ Fax: _____

e-mail: _____ Tel: _____

# Appendix C
# Dispatch Form

**APLAC PROFICIENCY TESTING PROGRAMME M023**
**– RELATIVE HUMIDITY MEASUREMENT**

In order to monitor the progress of the PT Programme, we kindly ask each accreditation body, on dispatch of the artefact, to fill in this DISPATCH FORM and fax it to:

STANDARDS MALAYSIA
Century Square,
Level 1 & 2, Block 2300,
Jalan Usahawan,
63000 Cyberjaya, Selangor
MALAYSIA

***Attention:*** Mr. Ahmad Razif Bin Abd. Rahim
Fax : +60 3 8318 9339
E-mail : razif@standardsmalaysia.gov.my

and **also** fax it to the next participating accreditation body :-

Please ensure that the "*Declaration to Customs Officials and Shipping Agents*" is attached to the outside of the case. Thank you in advance for your cooperation.

The M023 artefact, serial number _____ was dispatched on: _____
*(date)*

The artefact has been inspected after return from our laboratories and were found to be in good condition. _____ *(yes/no)*
Please give details of any problems:-

---

Shipping agent: _____ Phone: _____ Fax: _____

Airwaybill no. (or consignment note no.): _____

Your accreditation body: _____

Contact person: _____ Fax: _____

e-mail: _____ Tel: _____

# Appendix D
# Instructions to Laboratories

**APLAC PROFICIENCY TESTING PROGRAMME M023**
**– RELATIVE HUMIDITY MEASUREMENT**

## 1. Equipment

The contents of the audit pack are as follows:

| Item No. | Unit | Description |
|---|---|---|
| 1. | One (1) | Temperature and Humidity Transmitter,<br>Brand Vaisala, Model HMT330, S/No.C4510044 or C4510045 |
| 2. | One (1) | User's Guide<br>* Please put back the User's Guide in the transportation box before sending to another laboratory |


**Figure 2:** Photo of the artefact

## 2. On Receipt

On receipt, unpack the audit pack and inspect the artefact for any defects.

Read the following instructions before starting the measurement.

1. Please handle artefact with care.
2. Do not tamper with or adjust the test artefact.
3. Notify the local AB of any damage or erratic operation of the test artefact as soon as possible.

## 3. Measurement Considerations for the Artefact

Power up the artefact using 240 VAC, 50 Hz supply from the mains.

Refer to **Measurement Instructions** for the details of measurement to be performed.

## 4. Completion of measurements

Upon completion of required measurement, the laboratories are required to inform the respective accreditation body in the country.

## 5. Documents to be submitted

Within two weeks of the completion of the measurements, participating laboratories are required to send the attached *Result Sheet* (**Appendix A, B, C, D, E, F1 to F7, G**) and the calibration report to the respective accreditation body. Laboratories are strongly advised to make a copy of the *Result Sheet* for record keeping and future reference purposes.

In addition to the above, participating laboratories are required to submit uncertainty budgets which are prepared in accordance with the ISO *Guide to the Expression of Uncertainty in Measurement.* See **Appendix G** for the template of the uncertainty budget table. **Participating laboratories are required to prepare uncertainty budget table for each calibration point.**

A final report will be issued at the end of the program with each laboratory which is identified by a confidential code number.

## 6. General Information

For general queries, please contact your accreditation body. Additional information may be obtained from :

STANDARDS MALAYSIA
Century Square,
Level 1 & 2, Block 2300,
Jalan Usahawan,
63000 Cyberjaya, Selangor
MALAYSIA

Attention: Mr. Ahmad Razif Bin Abd. Rahim
Tel : +60 3 8319 1400
Fax : +60 3 8318 9339
E-mail : razif@standardsmalaysia.gov.my

**Appendix E**

## LABORATORY DETAILS

**M023** ☐☐☐☐
For official use only

| | |
|---|---|
| Name of laboratory | |
| Measurement Date | From _____ to _____ |
| Mains Power Supply | _____ VAC ± _____ VAC, _____ Hz |
| Ambient Temperature (°C) | _____ °C ± _____ °C |
| Ambient Relative Humidity (%) | _____ % ± _____% |
| Laboratory Reference Standard | Description:<br>Maker:<br>Model:<br>Serial no.:<br>Calibration due date : |
| Laboratory Humidity calibration chamber | Description:<br>Maker:<br>Model:<br>Serial no.: |

**Appendix F1**

**RESULT SHEET**

**Measurement point: 50 %rh at 23 °C**

**BEFORE CALIBRATION**

| | Corrected value of Laboratory Standard (%rh) | Corrected value of Laboratory Standard t, (°C) | Indicated value of Artefact _____ (%rh) | Indicated value of Artefact _____ t, (°C) |
|---|---|---|---|---|
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 5 | | | | |
| 6 | | | | |
| 7 | | | | |
| 8 | | | | |
| 9 | | | | |
| 10 | | | | |
| Average | | | | |
| Std dev. | | | | |

Name of the Laboratory : _____

Date of Measurement : _____

Environment of the Laboratory : Temperature : (_____ ±_____) ℃

Humidity : (_____ ±_____) %rh

**Appendix F2**

**RESULT SHEET**

**Measurement point: 50 %rh at 23 °C**

**AFTER CALIBRATION**

| | Corrected value of Laboratory Standard (%rh) | Corrected value of Laboratory Standard t, (°C) | Indicated value of Artefact _____ (%rh) | Indicated value of Artefact _____ t, (°C) |
|---|---|---|---|---|
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 5 | | | | |
| 6 | | | | |
| 7 | | | | |
| 8 | | | | |
| 9 | | | | |
| 10 | | | | |
| Average | | | | |
| Std dev. | | | | |

Name of the Laboratory : _____

Date of Measurement : _____

Environment of the Laboratory : Temperature : (_____ ±_____) °C

Humidity : (_____ ±_____) %rh

**Appendix F3**

**RESULT SHEET**

**ARTEFACT _____**

**Measurement point: 10 %rh at 23 °C**

| Nominal value 10% | Corrected value of Laboratory Standard (%rh) | Corrected value of Laboratory Standard t, (°C) | Indicated value of Artefact (%rh) | Indicated value of Artefact t, (°C) |
|---|---|---|---|---|
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 5 | | | | |
| 6 | | | | |
| 7 | | | | |
| 8 | | | | |
| 9 | | | | |
| 10 | | | | |
| Average | | | | |
| Std dev | | | | |

Calibrated By: Checked By:

Date: Date:

**Appendix F4**

**RESULT SHEET**

**ARTEFACT _____**

**Measurement point: 30 %rh at 23 °C**

| Nominal value 30% | Corrected value of Laboratory Standard (%rh) | Corrected value of Laboratory Standard t, (°C) | Indicated value of Artefact (%rh) | Indicated value of Artefact t, (°C) |
|---|---|---|---|---|
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 5 | | | | |
| 6 | | | | |
| 7 | | | | |
| 8 | | | | |
| 9 | | | | |
| 10 | | | | |
| Average | | | | |
| Std dev | | | | |

Calibrated By: Checked By:

Date: Date:

**Appendix F5**

**RESULT SHEET**

**ARTEFACT _____**

**Measurement point: 50 %rh at 23 °C**

| Nominal value 50% | Corrected value of Laboratory Standard (%rh) | Corrected value of Laboratory Standard t, (°C) | Indicated value of Artefact (%rh) | Indicated value of Artefact t, (°C) |
|---|---|---|---|---|
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 5 | | | | |
| 6 | | | | |
| 7 | | | | |
| 8 | | | | |
| 9 | | | | |
| 10 | | | | |
| Average | | | | |
| Std dev | | | | |

Calibrated By: Checked By:

Date: Date:

**Appendix F6**

**RESULT SHEET**

**ARTEFACT _____**

**Measurement point: 70 %rh at 23 °C**

| Nominal value 70% | Corrected value of Laboratory Standard (%rh) | Corrected value of Laboratory Standard t, (°C) | Indicated value of Artefact (%rh) | Indicated value of Artefact t, (°C) |
|---|---|---|---|---|
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 5 | | | | |
| 6 | | | | |
| 7 | | | | |
| 8 | | | | |
| 9 | | | | |
| 10 | | | | |
| Average | | | | |
| Std dev | | | | |

Calibrated By: Checked By:

Date: Date:

**Appendix F7**

**RESULT SHEET**

**ARTEFACT _____**

**Measurement point: 90 %rh at 23 °C**

| Nominal value 90% | Corrected value of Laboratory Standard (%rh) | Corrected value of Laboratory Standard t, (°C) | Indicated value of Artefact (%rh) | Indicated value of Artefact t, (°C) |
|---|---|---|---|---|
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 5 | | | | |
| 6 | | | | |
| 7 | | | | |
| 8 | | | | |
| 9 | | | | |
| 10 | | | | |
| Average | | | | |
| Std dev | | | | |

Calibrated By: Checked By:

Date: Date:

# Appendix G

## Template for Uncertainty Budget Table

Calibration Point: ……

| Quantity | Value | Divisor | Standard Uncertainty | Probability Distribution | Degree of Freedom | Sensitivity Coefficient | Uncertainty Contribution |
|---|---|---|---|---|---|---|---|
| $X_i$ | $x_i$ | | $u(x_i)$ | | $\nu_i$ | $c_i$ | $u_i(y)$ |
| | | | | | | | |

**Result**

Average Value = _____ %rh

Relative Humidity Combined Uncertainty, $u_c(y)$ = _____ %rh

Effective degrees of freedom, $\nu_{eff}$ = _____

Coverage factor, $k$ = _____

Relative Humidity Expanded Uncertainty, $k \times u_c(y)$ = _____ %rh

Notes:
1. (Add any comments here)

# APPENDIX B

# CIRCULATION SCHEDULE

Table 1 – Circulation schedule for Artefact A

| Economy | Accreditation Body | No. of Lab | Receipt | Dispatch |
|---|---|---|---|---|
| Malaysia | NML (Ref Lab) | 1 | - | 30 Sept 08 |
| Singapore | Singapore Accreditation Council | 2 | 2 Oct 08 | 20 Oct 08 |
| Hong Kong | Hong Kong Accreditation Service (HKAS) | 2 | 22 Oct 08 | 10 Nov 08 |
| Taiwan | Taiwan Accreditation Foundation (TAF) | 2 | 12 Nov 08 | 2 Dec 08 |
| Malaysia | NML (Ref Lab) | 1 | 6 Dec 08 | 29 Dec 08 |
| Korea | KOLAS | 1 | 31 Dec 08 | no info |
| China | China National Accreditation Service for Conformity Assessment (CNAS) | 2 | 16 Jan 09 | 6 Feb 09 |
| Malaysia | NML (Ref Lab) | 1 | 10 Feb 09 | 20 March 09 |
| Malaysia | STANDARDS MALAYSIA | 3 | 23 March 09 | 12 April 09 |
| Malaysia | NML (Ref Lab) | 1 | 12 April 09 | - |

Table 2 – Circulation schedule for Artefact B

| Economy | Accreditation Body | No. of Lab | Receipt | Dispatch |
|---|---|---|---|---|
| Malaysia | NML (Ref Lab) | 1 | - | 30 Sept 08 |
| Australia | National Association of Testing Authorities (NATA) | 2 | 2 Oct 08 | 24 Oct 08 |
| Indonesia | KOMITE AKREDITASI NASIONAL | 2 | 4 Nov 08 | 25 Nov 08 |
| Malaysia | NML (Ref Lab) | 1 | 30 Nov 08 | 5 Dec 08 |
| USA | American Association for Laboratory Accreditation (A2LA) | 2 | 18 Dec 08 | no info |
| USA | National Voluntary Laboratory Accreditation Program | 2 | no info | no info |
| USA | International Accreditation Service | 2 | no info | 29 May 09 |
| Malaysia | NML (Ref Lab) | 1 | 22 Jun 09 | 31 July 09 |
| Malaysia | STANDARDS MALAYSIA | 2 | 31 July 09 | 28 Aug 09 |
| Malaysia | NML (Ref Lab) | 1 | 30 Aug 09 | - |

# APPENDIX C

# REFERENCE VALUE

Table 1 – Reference value 1 for Artefact A

Lab Code: 253, 257, 296, 293, 278, 273
Maximum drift is 1.63 %rh.

| **Relative Humidity at Nominal (%rh)** | **Reference Value 1** | $U_{Ref}$ **without drift** | $U_{REF}$ **with drift** |
|---|---|---|---|
| 10 | -0.13 | 0.7 | 2.0 |
| 30 | 0.21 | 0.8 | 2.0 |
| 50 | 1.27 | 1.0 | 2.1 |
| 70 | 2.32 | 1.2 | 2.2 |
| 90 | 2.64 | 1.4 | 2.4 |

Table 2 – Reference value 2 for Artefact A

Lab Code: 237, 239, 214
Maximum drift is 0.78 %rh

| **Relative Humidity at Nominal (%rh)** | **Reference Value 2** | $U_{Ref}$ **without drift** | $U_{REF}$ **with drift** |
|---|---|---|---|
| 10 | 0.36 | 0.7 | 1.1 |
| 30 | 0.92 | 0.8 | 1.2 |
| 50 | 1.86 | 1 | 1.3 |
| 70 | 2.73 | 1.2 | 1.4 |
| 90 | 3.12 | 1.4 | 1.6 |

Table 3 – Reference value 3 for Artefact A

Lab Code: 215, 217, 251
Maximum drift is 1.22 %rh

| **Relative Humidity at Nominal (%rh)** | **Reference Value 3** | $U_{Ref}$ **without drift** | $U_{REF}$ **with drift** |
|---|---|---|---|
| 10 | 0.86 | 0.7 | 1.6 |
| 30 | 0.79 | 0.8 | 1.6 |
| 50 | 1.73 | 1 | 1.7 |
| 70 | 2.87 | 1.2 | 1.8 |
| 90 | 3.38 | 1.4 | 1.9 |

Table 4 – Reference value 4 for Artefact B

Lab Code: 266, 260, 267, 261
Maximum drift is 0.86 %rh

| Relative Humidity at Nominal (%rh) | Reference Value 4 | $U_{Ref}$ without drift | $U_{REF}$ with drift |
|---|---|---|---|
| 10 | -0.34 | 0.7 | 1.2 |
| 30 | 0.40 | 0.8 | 1.3 |
| 50 | 1.42 | 1 | 1.4 |
| 70 | 2.38 | 1.2 | 1.6 |
| 90 | 2.95 | 1.4 | 1.8 |

Table 5 – Reference value 5 for Artefact B

Lab Code: 275, 279, 224
Maximum drift is 1.09 %rh

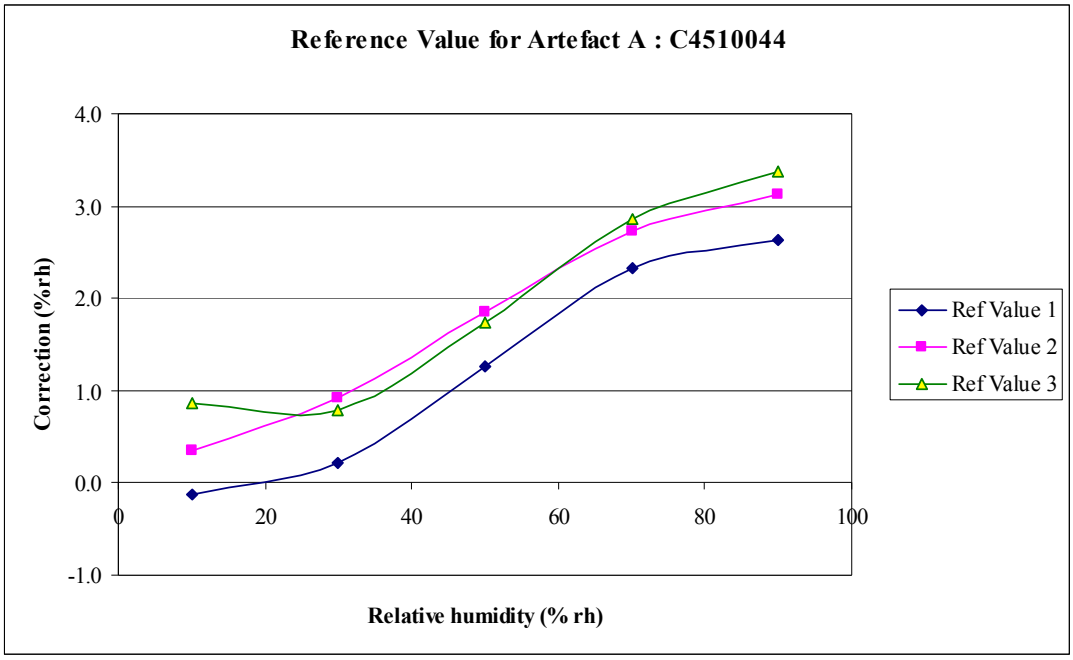
| Relative Humidity at Nominal (%rh) | Reference Value 5 | $U_{Ref}$ without drift | $U_{REF}$ with drift |
|---|---|---|---|
| 10 | -0.1 | 0.7 | 1.4 |
| 30 | 1.0 | 0.8 | 1.5 |
| 50 | 2.2 | 1.0 | 1.6 |
| 70 | 3.2 | 1.2 | 1.7 |
| 90 | 3.7 | 1.4 | 1.9 |

Table 6 – Reference value 6 for Artefact B

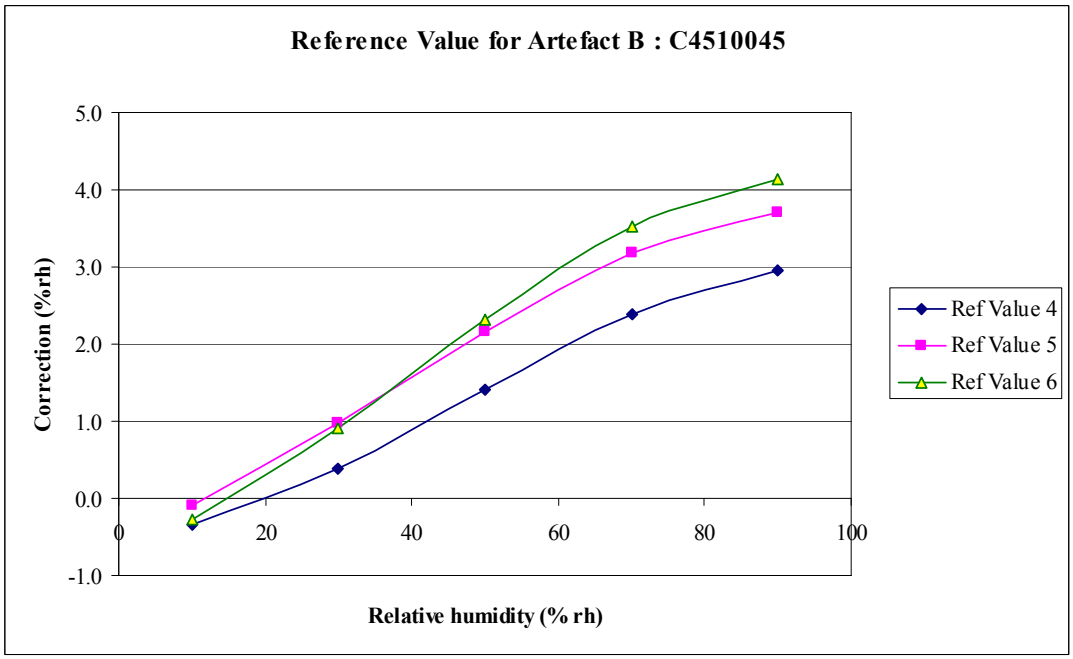
Lab Code: 271, 263
Maximum drift is 1.3 %rh

| Relative Humidity at Nominal (%rh) | Reference Value 6 | $U_{Ref}$ without drift | $U_{REF}$ with drift |
|---|---|---|---|
| 30 | 0.9 | 0.7 | 1.7 |
| 50 | 2.3 | 0.9 | 1.7 |
| 70 | 3.5 | 1.0 | 1.8 |
| 90 | 4.1 | 1.2 | 1.9 |

Graph 1: Reference Value for Artefact A




Graph 2: Reference Value for Artefact B



# APPENDIX D

# PERFORMANCE OF ARTEFACTS BEFORE AND AFTER EACH CALIBRATION

Table 1 – Performance of Artefact A before and after each calibration

| Bil | Laboratory Code | Before (%rh) | After (%rh) | Difference (%rh) |
|---|---|---|---|---|
| 1 | 214 | 49.9 | 49.8 | 0.1 |
| 2 | 215 | 50.2 | 50.2 | 0.0 |
| 3 | 217 | 51.0 | 50.2 | 0.8 |
| 4 | 237 | 50.2 | 50.2 | 0.0 |
| 5 | 239 | 51.4 | 51.2 | 0.2 |
| 6 | 251 | 51.1 | 50.4 | 0.7 |
| 7 | 253 | 51.2 | 49.0 | 2.2 |
| 8 | 257 | 51.2 | 49.0 | 2.2 |
| 9 | 273 | 50.0 | 50.0 | 0.0 |
| 10 | 278 | 50.0 | 50.0 | 0.0 |
| 11 | 293 | 49.9 | 50.0 | -0.1 |
| 12 | 296 | 48.6 | 48.6 | 0.0 |
| 13 | Reference Value 1 | 49.7 | 49.6 | 0.1 |
| 14 | Reference Value 2 | 49.9 | 49.9 | 0.0 |
| 15 | Reference Value 3 | 49.6 | 49.7 | -0.1 |

Table 1 – Performance of Artefact B before and after each calibration

| Bil | Laboratory Code | Before (%rh) | After (%rh) | Difference (%rh) |
|---|---|---|---|---|
| 1 | 224 | 50.1 | 50.0 | 0.1 |
| 2 | 260 | 49.3 | 50.4 | -1.1 |
| 3 | 261 | 50.6 | 50.5 | 0.1 |
| 4 | 263 | 49.8 | 48.3 | 1.5 |
| 5 | 266 | 50.0 | 50.9 | -1.0 |
| 6 | 267 | 49.9 | 50.1 | -0.2 |
| 7 | 271 | 51.1 | 49.1 | 2.0 |
| 8 | 275 | 50.0 | 50.0 | 0.0 |
| 9 | 279 | 50.0 | 50.0 | 0.0 |
| 10 | Reference Value 4 | 49.8 | 50.2 | -0.4 |
| 11 | Reference Value 5 | 49.3 | 50.0 | -0.7 |
| 12 | Reference Value 6 | 49.6 | 49.6 | 0.0 |

# APPENDIX E

# EXAMPLE OF
# UNCERTAINTY BUDGET TABLE

**CALIBRATION OF RELATIVE HUMIDITY TRANSMITTER**

The measurement involves the calibration of Relative Humidity transmitter by comparison method with humidity standard. The measurement was done at nominal values 10 %rh, 30 %rh, 50 %rh, 70 %rh and 90 %rh. at nominal temperature of 23 °C. At each generated condition a time of not less than 60 minutes was be allowed for the relative humidity to equilibrate. A set of 10 readings at 1 minute interval were recorded from the laboratory standard and artefact.

Example for uncertainty components and calculation at 90 %rh is shown in Tables 1.

Table 1 : Uncertainty Budget and Sources of Uncertainty

| Symbol | Standard Dew Point Hygrometer | Type | Value | Distribution | Divisor | Std U | Dof |
|---|---|---|---|---|---|---|---|
| $U_a$ | Calibration | B | 0.04 | normal | 2 | 0.0200 | 100000000 |
| $U_b$ | Long term drift | B | 0.05 | rectangular | 1.732 | 0.0289 | 100000000 |
| $U_c$ | Reproducibility | B | 0.050 | normal | 1 | 0.0500 | 49 |
| $U_d$ | Short term stability | A | 0.0045 | normal | 1 | 0.0045 | 9 |
| $U_e$ | Non-linearity | B | 0.016 | rectangular | 1.732 | 0.0092 | 100000000 |
| $U_f$ | Settling time to final value | B | 0.01 | rectangular | 1.732 | 0.0058 | 100000000 |
| $U_g$ | Resolution | B | 0.005 | rectangular | 1.732 | 0.0029 | 100000000 |
| $U_h$ | Effect of pressure difference | B | 0.05 | rectangular | 1.732 | 0.0289 | 100000000 |
| $U_i$ | Error due to condition different from calibration | B | 0.05 | rectangular | 1.732 | 0.0289 | 100000000 |
| $U_j$ | Hysterisis | B | 0.05 | rectangular | 1.732 | 0.0289 | 100000000 |
| $U_k$ | Contamination | B | 0.05 | rectangular | 1.732 | 0.0289 | 100000000 |
| | | | | | | | |
| | Combined uncertainty in dew point | | | | | 0.0849 | 408 |
| $U_{dp}$ | Combined uncertainty in Relative Humidity | | | | | -0.4700 | |
| | | | | | | | |
| | **Temperature Standard** | | | | | | |
| | **NML-356/05** | | | | | | |
| $U_a$ | Calibration | B | 0.01 | normal | 2 | 0.0050 | 100000000 |
| $U_b$ | Long term drift | B | 0 | rectangular | 1.732 | 0.0000 | 100000000 |
| $U_c$ | Reproducibility | B | 0.05 | normal | 1 | 0.0500 | 49 |
| $U_d$ | Short term stability | A | 0.0016 | normal | 1 | 0.0016 | 9 |
| $U_e$ | Non-linearity | B | 0.008 | rectangular | 1.732 | 0.0046 | 100000000 |
| $U_f$ | Self Heating effect | B | 0.025 | rectangular | 1.732 | 0.0144 | 100000000 |
| $U_g$ | Hysterisis | B | 0.0000 | rectangular | 1.732 | 0.0000 | 100000000 |
| $U_h$ | Stem Conduction | B | 0.01 | rectangular | 1.732 | 0.0058 | 100000000 |
| $U_i$ | Resolution | B | 0.005 | rectangular | 1.732 | 0.0029 | 100000000 |
| | | | | | | | |
| | Combined uncertainty in temperature | | | | | 0.0529 | 61 |
| $U_t$ | Combined uncertainty in Relative Humidity | | | | | 0.2900 | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Chamber** | | | | | | |
| $U_a$ | RH uniformity | | 0.2 | rectangular | 1.732 | 0.1155 | 100000000 |
| $U_b$ | RH stability | | 0.0218 | normal | 1 | 0.0218 | 9 |
| $U_c$ | Incomplete settling to final rh value | | 0.2 | rectangular | 1.732 | 0.1155 | 100000000 |
| | | | | | | | |
| $U_{chamber}$ | Combined uncertainty | | | | | 0.1648 | 29361 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| | **Artefact A** | | | | | | |
| $U_a$ | Standard deviation | | 0.0000 | normal | 1 | 0.0000 | 9 |
| $U_b$ | Resolution | | 0.05 | rectangular | 1.732 | 0.0289 | 100000000 |
| $U_c$ | Incomplete settling to final rh value | | 0.5 | rectangular | 1.732 | 0.2887 | 100000000 |
| $Ud$ | Transpotation drift | | 1.22 | rectangular | 1.732 | 0.7044 | 100000000 |
| $U_{UUT}$ | Combined uncertainty | | | | | 0.7618 | 133052880 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| $U_c$ | Combined Uncertainty of calibration | | | | | 0.9552 | 6960 |
| $k$ | Expanded uncertainty %rh | | | normal | **2** | **1.9105** | infiniti |

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