**Technical protocol for the APMP key comparison of air kerma standards in mammography X-rays, APMP.RI(I)-K7**

1. **Introduction**

Breast cancer is the most common cancer diagnosed in women. Mammography, a special x-ray of the breast, is the mean test to screen for possible tumours. It can help reduce the number of deaths from breast cancer among women ages from 40 to 70. So there are a great deal of mammography machines in the Asia-Pacific region. However, it exposes the people to X-ray radiation and measurements of radiation dose are important.

The APMP Key Comparison of air kerma standards in mammography X-rays, APMP.RI(I)-K7, will compare regional standards laboratories’ measurements of air kerma in Mo/Mo mammography beams in the X-ray range from 25 kV to 35 kV, to establish the degrees of equivalence in APMP.

NIM and NMIJ will be the pilot laboratory, NIM and NMIJ will be the linking laboratories. The comparison will be linked to the BIPM.RI(I)-K7 Key Comparison in which NIM participated in 2018 and NMIJ in 2009.

1. **Participants**

The participants are listed in Table 1.

**Table 1. Participants in the comparison**

|  |  |  |  |
| --- | --- | --- | --- |
| Participant | Institute | Economic | Contact person (E-mail) |
| 1 | NMIJ | Japan | Takahiro Tanaka (takahiro-tanaka@aist.go.jp) |
| 2 | NIS | Egypt | Eman Sayed Abdel Fattah (eman\_sayed\_a@yahoo.com) |
| 3 | INER | Chinese Taipei | Huang, Tseng-Te (huangtt@iner.gov.tw) |
| 4 | NMISA | South Africa | Sibusiso Jozela (sjozela@nmisa.org) |
| 5 | OAP | Thailand | Vithit Pungkun (vithit.p@oap.go.th) |
| 6 | NIM | China | GUO Siming (gsm@nim.ac.cn) |

1. **Comparison procedure**
   1. **Transfer chambers**

Two ionization chambers will be used as transfer standards. These chambers will be calibrated by each of the participating laboratories for a number of previously selected radiation qualities. The transfer instruments are used for this comparison: RC6M(10164), RC6M(10257), TW23344(001021).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Supplier | Model | Serial number | Volume/(cm3) | HV/(V) | Cable length/(m) | Cable connection |
| NIM | RC6M | 10164 | 6 | +300 | 10 | TNC |
| NIM | RC6M | 10257 | 6 | +300 | 10 | TNC |
| NIM | 23344 | 001021 | 0.2 | +400 | 10 | TNC |

**Table 2. Main characteristics of the transfer chamber**

* 1. **Reference conditions**

The reference conditions for the chamber calibrations are as follows:

1). **Distance** from the focal spot to the reference plane (the positioning mark surface of the chamber): **600 mm.**

2). **Field size** at the reference plane: **8 cm in diameter**.

3)**. Air temperature, pressure and relative humidity** of *T* = 293.15 K, *P* = 1013.25 hPa and *h* = 50%.

4). The calibration coefficients for the transfer chambers should be given in terms of air kerma per charge, in units of GyC-1.

The air-kerma calibration coefficient NK for the chamber is given by the equation

(1)

Where

1） is the air-kerma rate determined by the standard.

2) is the ionization current measured by RC6M or the signal measured by transfer chamber.

3) is the calibration coefficients.

Note: For RC6M the current should be corrected to the reference conditions of ambient air temperature, pressure and relative humidity chosen for the comparison(T=293.15K, P=101.325 kPa and h= 30%-70%).

* 1. **Radiation qualities**

The radiation qualities to be used for the comparison are the reference conditions recommended by the CCRI for the Mammography x-rays range (25 kV, 28 kV, 30 kV, 35 kV).

**Table 4. The radiation qualities for calibration**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Radiation qualities | Mo-25 | Mo-28 | Mo-30 | Mo-35 |
| Generating potential / kV | 25 | 28 | 30 | 35 |
| Additional filtration | 30 μmMo | | | |
| Reference distance / mm | 600 | | | |

* 1. **Course of measurement**

There will be a petal-shaped circulation of the transfer chambers between the NIM and the participants. **Each participant will pay for the transport of the chambers to the next participant.** The chambers should stay at the participants’ site for **no longer than 3 weeks.**

Measurements at NIM throughout the comparison will form the basis of the uncertainty estimate for chamber stability entering in the data analysis.

* 1. **Schedule**

The comparison is scheduled to commence at the beginning of 2021 and expected to be completed within 1 year. The proposed schedule is shown in Table 5.

**Table 5. Proposed schedule for the comparison**

|  |  |  |
| --- | --- | --- |
| Participant | Measurement period at the laboratory | Date of chambers leaving participant for next participant |
| Pilot(NIM) | 21-Nov-2021 to 9-Dec-2021 | 10-Dec-2021 |
| NIS | 10-Jan-2022 to 1-Feb-2022 | 2-Feb-2022 |
| NMISA | 1-Mar-2022 to 20-Mar-2022 | 21-Mar-2022 |
| Pilot(NIM) | 19-Apr-2022 to 10-May-2022 | 11-May-2022 |
| NMIJ | 10-Jun-2022 to 1-Jul-2022 | 2-Jul-2022 |
| OAP | 1-Aug-2022 to 20-Aug-2022 | 21-Aug-2022 |
| INER | 21-Sept-2022 to 11-Oct-2022 | 12-Oct-2022 |
| Pilot(NIM) | 9-Nov-2022 to 29-Nov-2022 |  |

NOTES:

1. The time allowed for measurements for each participant is about three weeks.
2. Allowance is made for a transportation time for the chambers of about three weeks.
3. The time allowed for constancy measurements at the NIM is about three weeks.
   1. **Submission of the results**

It is expected that all participating laboratories will submit their calibration results **within 6 weeks** of calibration. An **MS-Excel sheet** will be provided by the pilot laboratory in which information on the participants’ radiation qualities, primary standards and calibration results can be submitted.

* 1. **Evaluation of measurement uncertainty**

All participating laboratories are required to evaluate the uncertainty of their calibration coefficients as Type A and Type B according to the criteria given in the “Guide to The Expression of Uncertainty in Measurement” issued by the International Organization for Standardization (ISO) in 1995.

The Type A uncertainty is obtained by the statistical analysis of a series of observations; the Type B uncertainty is obtained by means other than the statistical analysis of series’ of observations.

An **MS-Excel sheet** will be provided by the pilot laboratory in which the participants can detail the uncertainty. The sheet should be submitted together with the calibration results.

* 1. **Comparison Report**

The pilot laboratory will prepare a draft report for circulation to all participants for comments and discussion of the results. A revised final report will be submitted to the APMP/TCRI Chairman. After the agreement of the APMP and the CCRI(I), the report will be published as the Technical Supplement in *Metrologia*. In addition, the comparison results will be sent to the BIPM for inclusion in the key comparison database (KCDB).

1. **Linking of regional comparisons to international comparisons**

To link the APMP/TCRI comparison (a regional comparison) to the results of the international comparison at the BIPM, two participating laboratories (NIM[1] and NMIJ[2]) that have made a key comparison with the BIPM for the measurement of air kerma in mammography X-rays is used as a “linking laboratory.” Then, through the following equation, the measured calibration coefficients for each laboratory, and for each of the CCRI reference radiation qualities, will be converted to ratios relative to the BIPM. The ratio of the calibration coefficient reported by the *i*-th participating laboratory to the KCRV[3], *Ri*, was determined as[4]:

(2)

where *N*K,*i* (or LINK) is the air kerma calibration coefficient reported by the *i*-th participating laboratory (or the LINK); *R*LINK,BIPM represents the result of the LINK in the BIPM international comparison BIPM.RI(I)-K7. In this study, the NIM and the NMIJ played the role of the linking laboratories. They made direct comparisons of their standards for air kerma with the BIPM respectively. *R*LINK,BIPM of each LINK was calculated as:

(3)

where is the air kerma rate reported by the LINK in the BIPM.RI(I)-K7. In this case (with two links laboratories), equation (2) gives rise to two values of *Ri* for each participating laboratory *i* = 1 to (*n*-2), not acting as a link laboratory. Denoting these values as *Ri*,NIM and *Ri*,NMIJ, the *Ri* values for these laboratories were calculated as[4]:

(4)

1. **References**
2. Key comparison BIPM.RI(I)-K7 of the air-kerma standards of the NIM, China and the BIPM in mammography x-rays[J]. Metrologia, 2020, 57(1A):06007-06007.
3. Kessler C , Burns D T , Tanaka T , et al. Key comparison BIPM.RI(I)-K7 of the air-kerma standards of the NMIJ, Japan and the BIPM in mammography x-rays[J]. Metrologia, 2010, 47(1A):6024-06024.
4. P.J. Allisy, D.T. Burns and P. Andreo, “International framework of traceability for radiation dosimetry quantities,” Metrologia, 46, S1-S8 (2009).
5. D.T. Burns and D. Butler, “Updated report on the evaluation of degree of equivalence in regional dosimetry comparisons”, CCRI(I)/17-09 (2017).

**APPENDIX A. Participants Data**

* 1. Pilot laboratory
     1. **NIM**

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**APPENDIX B. Transfer Chambers**



RC6M&TW23344