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Recent Activities in Measurement Standards and Dosimetry at ARPANSA, 2003-2005

David Webb, Duncan Butler and Chris Oliver

Ionizing Radiation Standards Section, Medical Radiation Branch

Australian Radiation Protection & Nuclear Safety Agency (Melbourne)
619 Lower Plenty Road, Yallambie, Victoria 3085, Australia
Telephone: +61 3 9433 2211, Facsimile: +61 3 9432 1835
E-mail: info@arpansa.gov.au, Website: http://www.arpansa.gov.au

1. INTRODUCTION

The Ionising Radiation Standards Section continues to maintain Australian standards of air kerma and absorbed dose and to provide calibration services for medical therapy and diagnostic dosemeters and for protection equipment. Considerable staff changes have occurred since the previous meeting of the CCRI(I) in 2003, and directions of interest have been continued to be affected by the need to support the regulatory functions of ARPANSA. More emphasis has been placed on the security of sources and the implementation of a quality system.

Mr Robert Huntley retired at the end of December 2003 and Mr Lew Kotler retired at the end of March 2004. This has removed a considerable amount of experience from the Section which has affected programmes supporting the measurement standards. New staff are being recruited and Dr Chris Oliver joined us in November 2004.

2 EXPOSURE /AIR KERMA STANDARDS

2.1 Kilovoltage X-rays

2.1.1 Low energy X-rays (10-50 kV)

Previously ARPANSA has maintained two standards of air kerma for kilovoltage X-rays. A medium-energy free air chamber (MEFAC) used for the measurement of beams generated by tube potentials in the range 50 – 300 kV, and a low-energy free-air chamber (LEFAC) is used in the range 20 – 70 kV. These chambers have been known to differ by approximately 2% when they are compared using beams in the overlap region of their energy ranges. The magnitude of the difference is significant but is comparable to the combined uncertainties of the two free-air chambers (typical standard uncertainties are 0.5% for the MEFAC and 1.5% for the LEFAC).

In 2002 these standards were compared with the BIPM in Paris. The results showed that the MEFAC was in good agreement with the international primary standard, and confirmed the difference between the MEFAC and LEFAC. Using the results of the intercomparison and the results of previous comparisons between the two ARPANSA chambers, calibration factors were determined for the LEFAC. In April 2003 the status of the LEFAC was downgraded to that of a secondary standard. The LEFAC

response is now determined by an interpolation of results obtained against the BIPM and the ARPANSA MEFAC. The results can be traced to the ARPANSA standard through the known relationship between the MEFAC and LEFAC for beams from the RT100 generator.

An ARPANSA Fact Sheet (see Section 7) has been published on the ARPANSA website to inform Australian hospitals of correction factors that may apply to calibrations of their equipment prior to April 2003.

2.1.2 Medium energy X-rays (50-300 kV)

The medium-energy free-air chamber continues to support calibrations for therapy dosimeters for orthovoltage X-rays. The chamber is also used to provide dosimetry for the ISO Series of X-ray beam qualities at ARPANSA and our protection-level service. Our participation in the Euromet 545 intercomparison has forced a review of the methods by which this dosimetry is achieved. The free-air chamber is designed to work at therapy dose rates, and the transfer of this standard to the very low dose rates of some of the ISO beams entails large uncertainties.

2.1.3 Provision of absorbed dose calibrations at kilovoltage X-ray qualities

Australian radiotherapy centres are in the process of adopting TRS-398 for megavoltage photons and electrons. For low and medium energy kilovoltage X-rays, however, ARPANSA cannot provide direct calibrations for absorbed dose to water. We are involved in collaboration with a local dosimetry centre to investigate the alternative method suggested by TRS-398 by which an air kerma calibration is converted to an absorbed dose to water calibration at the primary standards laboratory.

For the present the only calibration available for kilovoltage X-ray qualities remains air kerma, free in air.

2.1.4 Determination of beam uniformities

The ^{60}Co teletherapy beam uniformity has been verified at routinely used source to detector distances. This information also enabled the determination of the offset between a central positioning laser and the true centre of the beam at these distances.

We also have measured the beam uniformity and inverse square law behaviour of the beams from our ^{241}Am, ^{137}Cs and ^{60}Co protection-level sources to verify that they lie within the accepted bounds for their use dictated by the ISO 4037 standard.

2.2 Gamma-rays from ^{60}Co and ^{137}Cs

2.2.1 Standard chamber

The Australian primary standard of exposure or air kerma for ^{60}Co radiation is a thick-walled pancake graphite cavity chamber similar in design to that described by Boutillon and Niatel (1973). As well as comparisons with the BIPM, Australian standards of air kerma have been compared with a number of other National standards. A recent ARPANSA technical report documents the status of the physical constants, correction factors and their uncertainties as of January 1, 2001, as used in

the determination of the air kerma rate at ARPANSA to that date. Recently, in the regular exercise of the standard, the central electrode of the chamber was found to be detached. Satisfactory repairs have been made and in subsequent testing the results are in good agreement with measurements by Huntley in 2002.

3 ABSORBED DOSE STANDARDS

3.1 The Australian primary standard for photons

Two thermistor failures occurred in the first jacket of the ARCS graphite calorimeter that is used to maintain the Australian primary standard for absorbed dose. These have been replaced, but the calorimeter requires modifications to the electronic control system as a result of the different lead resistances of the new thermistors.

A similar calorimeter has been on loan from the IAEA, intended to be used as a temporary standard while repairs were being made. It has developed a faulty thermistor in a similar location to those in the ARPANSA calorimeter. The thermistor can be readily replaced with the same technique learned previously but the associated control system will need adjustment also.

3.2 A primary standard for electrons

This project is awaiting the allocation of staff. It may be advanced as a postgraduate project with a local institute. A graphite electron calorimeter has been purchased from the NPL.

3.3 Mega-voltage X-ray and electron beams

The linear accelerator is used primarily to support absorbed dose standards at therapy energies. After X-ray beams were re-established in April 2002, the development and characterisation of standard beams from 8 to 20 MV has continued. The unavailability of the ARPANSA graphite calorimeter has prevented the program from producing kQ values for these beams. Without these values, we were forced to withdraw from the Euromet 605 project investigating the beam quality specification of high-energy photon beams.

Following discussions during the AbsDos2003 Workshop, NPL loaned ARPANSA a dual dosemeter PMMA phantom in order that we could carefully assess the relative performance of the NE2561 and NE 2611A cavity chambers. In a previous comparison with NPL we had consistently noticed behaviour that indicated that they may not be as identical as supposed, but which could not be confirmed by NPL. We have developed procedures to take simultaneous measurements while traversing the MV photon beam to remove non-uniformity effects. The results to date are not conclusive but are not inconsistent with a possible difference of 0.5% at 16 MV and further measurements are necessary.

The linear accelerator maintains a pulse radiolysis facility on behalf of the Australian Institute of Nuclear Science and Engineering and is used by several universities throughout Australia.

3.4 Absorbed dose workshop - AbsDos2003

ARPANSA convened a three day workshop on "Recent Advances in Absorbed Dose Standards" held in Melbourne, Australia over August 19 to 21, 2003. The workshop preceded the 2003 World Congress of Medical Physics in Sydney, August 24-29, 2003. The proceedings are being assembled for publication on the ARPANSA website. Seventeen papers (14 presentations and 3 posters) have been published thus far. Five papers are outstanding.

2.2.2 Clinical dosimetry differences in changing to a TRS-398 based protocol

Australian radiotherapy centres are in the process of adopting TRS-398 for linac calibrations. We have calculated the expected change in a linac calibration to be between 0.1 - 1.0% when changing from the currently used air kerma based protocol (an adaptation of TRS-277) to the TRS-398 protocol based on ^{60}Co absorbed dose to water. The shift is primarily due to the change in the relevant primary standards at ARPANSA. A paper is being drafted.

4 INTERNATIONAL INTERCOMPARISON ACTIVITY

4.1 Key comparisons

A. APMP.RI(I)-K3: The APMP air kerma intercomparison for medium energy kilovoltage x-rays, which was coordinated by INER (Taiwan), started in July 2000 and was completed in June 2003. Eleven laboratories participated. A draft report was completed in 2004.

B. APMP.RI(I)-K1: The comparison of air kerma standards at ^{60}Co is being coordinated by KRISS (Korea). Two NE2571 chambers from ARPANSA and one from INER were provided to the pilot laboratory. One of the ARPANSA chambers was damaged after shipment to Korea and replaced with a chamber from KRISS. ARPANSA, AIST/NMIJ and BARC provide links to the BIPM. The exercise commenced in September 2004.

4.2 Regional comparisons

A. EUROMET 545: We have participated in the comparison of air kerma standards for the ISO 4037 narrow series of X-ray spectra. Measurements with three large-volume chambers sent from the PTB were completed at ARPANSA in August 2004. The comparison is due to be completed in August 2005.

4.3 Bilateral intercomparisons

A. In 2003, we performed a bilateral comparison of ^{60}Co absorbed dose to water standards with INER (Taiwan) after INER recently improved their ionometric standard with a redesigned carbon cavity chamber for their water phantom. Three NE2571 chambers were used as transfer standards. The report has been accepted for publication later this year in Radiation Measurements. At the same time, a comparison of 60Co air kerma standards was made using the same set of transfer

chambers. While ARPANSA's standard is a pancake carbon cavity chamber, INER uses 8 spherical graphite cavity chambers to maintain their standard.

B. Reports are being prepared for air kerma comparisons performed in June 2002 made at the NPL (UK) for four IEC diagnostic level qualities in the range 40 to 90 kV, four ISO protection level qualities in the range 60 to 300 kV, plus ^{241}Am at protection levels, and a comparison performed in late 2002 with NRL (New Zealand) for BIPM medium energy kilo-voltage qualities, BIPM low energy qualities at 30 and 50 kV and for three ISO protection level qualities in the range 30 to 200 kV, plus ^{137}Cs at protection levels.

C. In 2001, we participated in a multi-lateral comparison of the air kerma standards for BIPM medium energy kilovoltage x-rays at INER, PTB and ARPANSA. The comparison was coordinated by INER after they had modified their standard free air chamber. The report was published in March 2004 in Radiation Measurements.

D. A bilateral air kerma comparison with the NRCC was completed in 1997-1998 for the medium energy X-ray BIPM standard qualities and the 50 kV low energy standard quality. The report has not yet been finalised.

5 QUALITY SYSTEMS

5.1 Accreditation

Our source-based protection level calibration services (^{137}Cs, ^{60}Co and ^{241}Am) have been submitted for accreditation from the Australian National Association of Testing Authorities (NATA). The laboratory was audited in February 2004 and the audit report noted 12 conditions and 11 minor conditions which must be rectified before accreditation. Our response to this audit will be sent to NATA in April 2005.

Accreditation is being sought progressively over the next year for our X- or gamma-ray based protection level services and diagnostic and radiotherapy level services.

5.2 National primary standards and NSC Verifying Authority status

Our primary standards of exposure and absorbed dose have been assessed by the Australian National Standards Commission (NSC) and resulted in an interim Verifying Authority status. In Australia, this legally entitles ARPANSA under the Australian National Measurement Act to issue certificates needed to give legally traceable calibrations to third parties. In July 2003, the NSC was merged with the CSIRO/National Measurement Laboratory and the Australian Government Analytical laboratory to form the National Measurement Institute (NMI). New authorisations are needed to enable ARPANSA to continue to maintain National dosimetry measurement standards and to retain the Verifying Authority status.

6 APPLICATIONS OF DOSIMETRY STANDARDS

6.1 IAEA PSDL and SSDL activities

We provided standard exposures in July 2003 for the third IAEA/RCA intercomparison for individual monitoring for occupational exposures.

As a reference laboratory for the IAEA TLD QA service for radiotherapy dosimetry, ARPANSA has provided annual reference irradiations of control capsules in December for the last two years. This activity will continue.

6.2 National therapy dosimetry audit

In November 2004, ARPANSA completed the first round of a national TLD radiotherapy QA service. Seventeen centres participated, and 36 beams were surveyed. Good results were obtained for the dose at 5 cm depth in water with most reported doses within 3% of the assessed value.

7. PUBLICATIONS

Jeng-Hung Lee; Lew H Kotler, Ludwig Buermann, Wen-Song Hwang, Jih-Hung Chiu and Chu-Fang Wang, *The performance of the INER improved free-air ionization chamber in the comparison of air kerma calibration coefficients for medium-energy X-rays*, Radiation Measurements **39,** Issue 1 (January 2005) 1-10.

John F Boas, Robert B Huntley and David V Webb, *The relative response of NE2561 and NE2611A ionization chambers in megavoltage x-ray beams*, Phys. Med. Biol. **46**, (2001) 3259-3267.

J.H. Lee, C.Y. Lin, C.F. Wang, D.J. Butler, D.V. Webb, C.Y. Yeh and W.S. Hwang, *Performance evaluation of graphite pancake ionization chamber by comparing the absorbed dose to water calibration*, Radiation Measurements, Article in Press (February 2005)

D J Butler, *Interim changes to the Australian low-energy x-ray standard*, ARPANSA Fact Sheet (February 2005) http://www.arpansa.gov.au/xraystnd.htm.