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Recent Activities in Measurement Standards and Dosimetry at ARPANSA, 2007-2009

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1. INTRODUCTION

The Ionising Radiation Standards Section maintains Australian standards of air kerma and absorbed dose, develops techniques for radiation measurement and provides calibration services for medical therapy and diagnostic dosemeters and for protection equipment. Directions of interest are affected by the need to support the regulatory functions of ARPANSA and emphasis has been placed recently on the security of sources and the implementation of a quality system.

The Section has six scientific staff and one technical officer. In September 2008, Dr Ganesan Ramanathan permanently rejoined ARPANSA after a temporary 12 month appointment in 2006-7. Other new staff include Dr Jessica Lye (December 2007) and Dr Peter Harty (December 2008).

2 EXPOSURE /AIR KERMA STANDARDS

2.1 Kilovoltage X-rays

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

ARPANSA maintains a low-energy free-air chamber (LEFAC) which is used in the range 20 to 70 kV. As previously reported, the status of the LEFAC was downgraded to that of a secondary standard in April 2003 after an international comparison in 2002 indicated discrepancies in its response. In May 2008, the anomalous behaviour was resolved when the reference distance was changed, the chamber corrections were re-calculated using the EGSnrc Monte Carlo system, and some misalignment was corrected. In late October, several transfer standards were sent to the BIPM for an intensive comparison. Preliminary results suggest that it will be possible to re-instate the standard.

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

The medium-energy free-air chamber (MEFAC) 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. A new Monte Carlo model calculation has recently attributed the origin of a discrepancy in the higher energy beams, observed in the EUROMET 545 comparison, to an incorrect assessment of the transmission through the aperture at those energies.

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). Extensive Monte Carlo simulations have been recently been performed to recalculate the correction factors needed to determine the air kerma rate with this chamber. Excellent agreement has been reached when comparing with published Monte Carlo correction values for similar graphite chambers. This work is getting close to completion with the standard to be re-established in the near future.

3 ABSORBED DOSE STANDARDS

3.1 The Australian primary standard for photons

The Australian primary standard for absorbed dose is maintained by a graphite calorimeter based on Domen's design and purchased from the ARCS in 1991. It was repaired in early 2006 and the electronic control system has been upgraded.

The IAEA calorimeter was obtained on loan in 2006 to use as an interim standard while the ARPANSA calorimeter was being repaired. However it also required repair of electrical connections and has been used as a performance comparator in ARPANSA's ^{60}Co beam. Testing over 2006-7 indicated similar short-term drifts and the responses of the two calorimeters confirmed the Australian absorbed dose standard for ^{60}Co.

Recent electrical calibrations performed for both the ARPANSA and IAEA photon calorimeters over a two month period to test for long-term stability have resulted in consistent calibration factors indicating a high level of stability. The spread in the values was found to have a standard deviation of 0.5% and it compares well with similar results published by BEV, Austria for similar calorimeters.

The performance of the medium heater control in the ARPANSA calorimeter has been improved to reduce drifts to less than 5 mK over 24 hours. New digital single phase lock-in amplifiers have been procured and are being tested as possible replacements to the earlier analogue lock-in-amplifiers. Programs for the analysis of calorimetry data have been written in Matlab.

The IAEA calorimeter has been mounted in the beam line of the ARPANSA medical standards linac and drifts are being evaluated under operational conditions.

3.2 A primary absorbed dose standard for electrons

The graphite electron calorimeter procured earlier from NPL has had thermistors mounted and connected to a simple DC Wheatstone bridge circuit. The thermistor response was obtained by combining the bridge with a digital lock-in amplifier and a nanovoltmeter. The thermistors in this configuration have been calibrated against a platinum resistance thermometer over the range 18 °C to 27 °C so that the bridge output can be accurately established in terms of temperature. It was observed that for this thermistor calibration, using a quadratic polynomial fit gave more accurate interpolated values for the measured resistances than a linear fit. The calorimeter is being readied for measurements in electron beams.

3.3 Refurbishment of the ARPANSA therapy level ^{60}Co source

The cobalt source used in the calorimetry activity is aging and the dose rates are just sufficient to obtain satisfactory accuracy. The source was purchased in 1995 from the Australian Nuclear Science and Technology Organisation (ANSTO) but they no longer have fabrication facilities. A 130 TBq source was ordered in June 2008 from an overseas supplier but it is expected to be delivered in the next few months. An Eldorado 78 therapy head will replace the previous container/collimator made in-house in the 1970's. It is noted that the comparisons of both air kerma and absorbed dose standards were made over 10 years ago. New comparisons will be sought when the new source is installed and is fully characterised.

3.4 Mega-voltage X-ray and electron beams

The research linear accelerator has been used primarily to support absorbed dose standards at therapy energies. However the reproducibility of those beams has been difficult to establish with the existing RF structure and beam line configuration. In October 2007, a tender was released for the supply and installation of a medical linear accelerator suitable for the maintenance of radiation measurement standards. Elekta was the successful vendor and, on 13 October 2008, delivered a Synergy Platform System to ARPANSA in a configuration very close to that installed at the NPL(UK).

The linac consists of:

a) A beam generator capable of generating a range of photon beams between 4 MV and 25 MV and a range of electron beams between 4 MV and 25 MV. Seven photon energies are distributed over 4 "handbags" of which one will include a set of 3 energies appropriate to the calibration of clinical accelerators in Australia and another will have the 3 energies proposed in the BIPM K6 protocol. Beams not used for calibration of clinical linacs will be matched to those on the NPL linac.
b) A treatment head comprising of multi-leaf collimator, jaws, filters and wedging on a gantry with full 360^{o} rotation.
c) An electronic portal imaging device (EPID).
d) Record and verify treatment sequencing software.
e) The patient treatment table is replaced with a height-adjustable measurement table supplied by ARPANSA for calorimetry and reference measurements.

Installation occurred over the following 4 to 5 weeks and a preliminary 6 MV photon beam was achieved in early November 2008. Commissioning and acceptance testing continued through January into February 2009 and sign-off was achieved on February 10. J Lye visited the NPL in early November to gain and share experience on the

installation and acceptance testing by NPL of their Elekta “twin” medical linac for megavoltage dosimetry and was present for the opening of the NPL facility. A similar launch for the ARPANSA linac occurred on February 13.

4 INTERNATIONAL INTERCOMPARISON ACTIVITY

4.1 Key comparisons

4.1.1 APMP.RI(I)-K2: ARPANSA is participating in the APMP air kerma comparison for low energy kilovoltage x-rays. There are 10 participating laboratories. NMIJ (Japan) has provided 3 ionization chambers to ARPANSA for measurement in April 2009. These measurements have been completed and the equipment will be returned to NMIJ shortly. Some difficulty was experienced with the measurement reference distance at 100 cm rather than at the BIPM distance of 50 cm. The shorter distance is more clinically relevant and ARPANSA normally calibrates at a distance of 30 cm to match hospital conditions.

APMP.RI(I)-K3: Measurements for the APMP air kerma intercomparison for medium energy kilovoltage x-rays, were completed in June 2003 and the report was recently published in February 2008. ARPANSA was a link laboratory even though its Degree of Equivalence is old (1988) however a more recent comparison with the BIPM in 2002 has not yet been published.

4.1.2 APMP.RI(I)-K1: ARPANSA participated in the comparison of air kerma standards at ^{60}Co which commenced in September 2004. Measurements were completed in June 2006 and a report is being prepared by the coordinating laboratory KRISS (Korea). Ten laboratories participated. ARPANSA is one of two linking laboratories along with NMIJ.

4.2 Regional comparisons

4.2.1 EUROMET 545: In 2004 we participated in the comparison of air kerma standards for the ISO 4037 narrow series of X-ray spectra. The results were generally within the stated uncertainty with the notable exception of the 300 kV beam. A new Monte Carlo model has since attributed the origin of this discrepancy) to an incorrect assessment of the transmission through the aperture at this energy.

4.3 Bilateral intercomparisons

4.3.1 BIPM.RI(I)-K2 As a result of the rehabilitation of the ARPANSA low energy kV free air chamber, a comparison with the BIPM was arranged. Measurements at the BIPM were undertaken in October 2008. The equipment was returned to ARPANSA in March this year and final measurements are in progress.

4.3.2 Between May and October 2001, ARPANSA and the Federal Office of Metrology (METAS) undertook a comparison of the Australian and Swiss standards of air kerma and absorbed dose to water has been carried out in ^{60}Co gamma radiation. The comparison was made using two transfer standard ionization chambers belonging to ARPANSA. The analysis was completed recently and a paper is being prepared for publication.

5 QUALITY SYSTEMS

5.1 Accreditation

Our source-based protection level calibration services (^{137}Cs, ^{60}Co and ^{241}Am) were accredited by the Australian National Association of Testing Authorities (NATA) in July 2005. A review in June 2006 led to the accreditation being extended in January 2008 to include the calibration of therapy level dosemeters at kV x-ray and gamma-ray qualities up to ^{60}Co.

5.2 National primary standards and NSC Verifying Authority status

The National Measurement Institute of Australia (NMIA) was formed from the merger of CSIRO/National Measurement Laboratory (NML), the Australian National Standards Commission (NSC) and the Australian Government Analytical laboratory (AGAL). It is implementing new authorisations to enable ARPANSA to continue to maintain national standards of exposure and absorbed dose. It is also designating ARPANSA as a Verifying Authority which in Australia, entitles ARPANSA to issue certificates needed to give legally traceable calibrations to third parties. This status is contingent on full accreditation of the calibration services.

6 APPLICATIONS OF DOSIMETRY STANDARDS

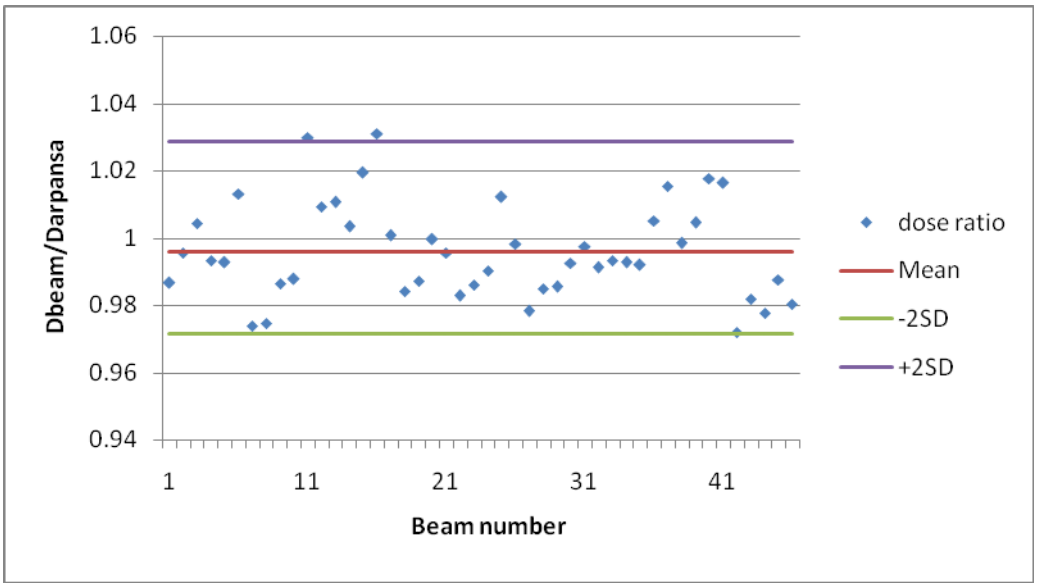
6.1 IAEA PSDL and SSDL activities

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 several years. This activity has continued.

6.2 National therapy dosimetry audit

ARPANSA provides a postal TLD audit of megavoltage therapy beams for Australian radiotherapy centres. Jigs and capsules similar to those used by the IAEA are employed. Energy response and capsule holder correction factors for the LiF-100 TLD powder were established by measurements made at several clinics. Monte Carlo simulations have also been performed to calculate correction factors due to the presence of the PMMA TLD holder. The results compare favourably with published holder correction values.

Centres are sent TLD material and a jig for their quality assurance water phantom. Exposures are scheduled to coincide with ^{60}Co normalisation exposures at ARPANSA. As of April 2009, 46 beams from 24 accelerators have been audited (approximately 1/6th of the number of clinical accelerators in Australia). The results to date have generally been within a 3.5% criterion



7. PUBLICATIONS

L Buermann, M O;Brien, D Butler, I Csete, F Gabris, A Harkanen, J-H Lee, M Palmer, N Saito and W de Vries, *Comparison of national air kerma standards for ISO 4037 narrow spectrum series in the range 30 kV to 300 kV*, EUROMET.RI(I)-S3 Final Report, Metrologia Tech. Suppl **45**. 06013 (2008) 48 pages.

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Kadni, N Takata and Z Msimang, *APMP/TCRI key comparison report of measurement of air kerma for medium-energy x-rays (APMP.RI(I)-K3),* Metrologia Tech. Suppl. **45** 06012 (2008).

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