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Recent Activities in Measurement Standards and Dosimetry at ARPANSA, 2011-2013

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1. INTRODUCTION

The Radiotherapy Section (previously Ionising Radiation Standards Section) at ARPANSA maintains the Australian standards of air kerma and absorbed dose. The section also develops techniques for radiation measurement and provides calibration services for medical therapy, diagnostic dosemeters and protection equipment.

The section was renamed during an ARPANSA-wide restructure in 2011. The new name was adopted to align the structure of the Medical Radiation Services branch with the areas of radiation use in medicine – diagnostic, nuclear medicine and radiotherapy.

The section recently acquired new staff: Andrew Cole, who provides technical support for the Elekta linear accelerator, and Nkem Anele who is acting for Viliami Takau. David Webb stepped down from his position as Section Manager in February 2012 and is now in a part time role as Senior Scientific Advisor. Duncan Butler is the new Section Manager. There section currently has eight staff.

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. The most commonly requested calibration is of thin window parallel plate chambers in air at 30 cm.

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 most commonly requested calibration is for Farmer-type chambers in air. The source-detector distance is restricted to around 1.3 m for practical reasons to do with the monitor chamber, filter wheel and shielding around the MEFAC.

The MEFAC is also used to provide dosimetry for the ISO Series of X-ray beam qualities which are used in our protection-level X-ray service. Due to the relatively small volume (5 cm^3) of the chamber the ionisation currents for the ISO Narrow Series are not large enough to achieve the same accuracy as for therapy calibrations.

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

2.2.1 ARPANSA therapy level ^{60}Co source

A 141 TBq (3820 Ci) source housed in an Eldorado 78 radiotherapy treatment head was installed in 2009. The head has been mounted vertically on a custom stand and only provides a horizontal beam of radiation suitable for calorimetry and calibration measurements (Figure 1). This source is used in the bulk of calibrations for hospital chambers. Of some 50 radiotherapy centres in Australia, nearly all have a reference chamber calibrated for absorbed dose to water traceable to the primary standard graphite calorimeter using this source.

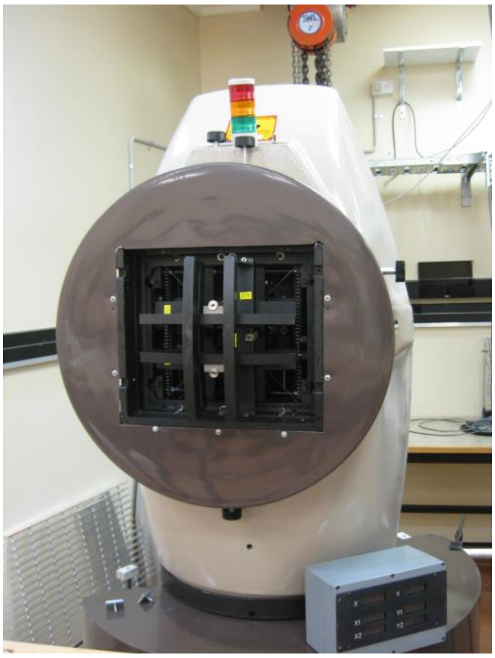

Figure 1. Eldorado 78 ^{60}Co therapy treatment head installed in 2009

2.2.2 ARPANSA therapy level ^{137}Cs source

ARPANSA continues to maintain a 50 TBq ^{137}Cs source which was installed in 1984, although we do not have primary standards for this beam. Instead, the response of a Farmer chamber calibrated in ^{60}Co and 250 kVp X-rays is interpolated to ^{137}Cs to provide a secondary standard of air kerma. This standard is transferred to protection-level sources and supports ARPANSA's calibration service for survey meters.

2.2.2 Air kerma standard at ^{60}Co

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). In June 2010, a new chamber was collected from the BIPM made to a more modern design. A year earlier, the components had been brought to Australia. The dimensions were accurately measured by coordinate measuring machines at the NMIA and the components returned to the BIPM for final assembly. This chamber is currently undergoing testing and evaluation with the intention that it will replace the earlier chamber as the Australian primary standard.

3 ABSORBED DOSE STANDARDS

3.1 The Australian primary standard for absorbed dose for photons

The Australian primary standard for absorbed dose is a graphite calorimeter based on Domen’s design and purchased from the ARCS in 1991. After repairs in early 2006 it was re-established as a primary standard for dose to water in the new El Dorado ^{60}Co source in 2009. The BIPM.RI(I)-K4 result based on the new determination in 2010 was published in 2012, with a result R_ARPANSA/BIPM = 0.9973. For this evaluation, ARPANSA changed the method of converting from graphite to water from the photon fluence scaling theorem to Monte Carlo calculation.

3.2 Mega-voltage X-ray beams

The Elekta Synergy medical standards linear accelerator has now been installed for 3 years. A program of routine QA has been implemented using a Daily QA. An external monitor chamber has been commissioned which allows even greater short-term reproducibility than using the internal monitor chamber. After the BIPM.RI(I)-K6 comparison in September 2012, an external thimble chamber monitor was also installed to account for day-to-day variations in output.

During the period 2009-2012 the primary standard graphite calorimeter was commissioned on the MV photon beams. This process required considerable changes to the mode of operation as currently used on the ^{60}Co source. A Monte Carlo method of calculating the absorbed dose to water was implemented, in conjunction with a method for estimating the uncertainty in this calculation which makes use of the depth dose profiles measured in water and graphite.

The results of calibration coefficients for Farmer chambers using this method are currently within 2 standard uncertainties of the expected values. See the section 4.3.2 BIPM.RI(I)-K6 for more information.

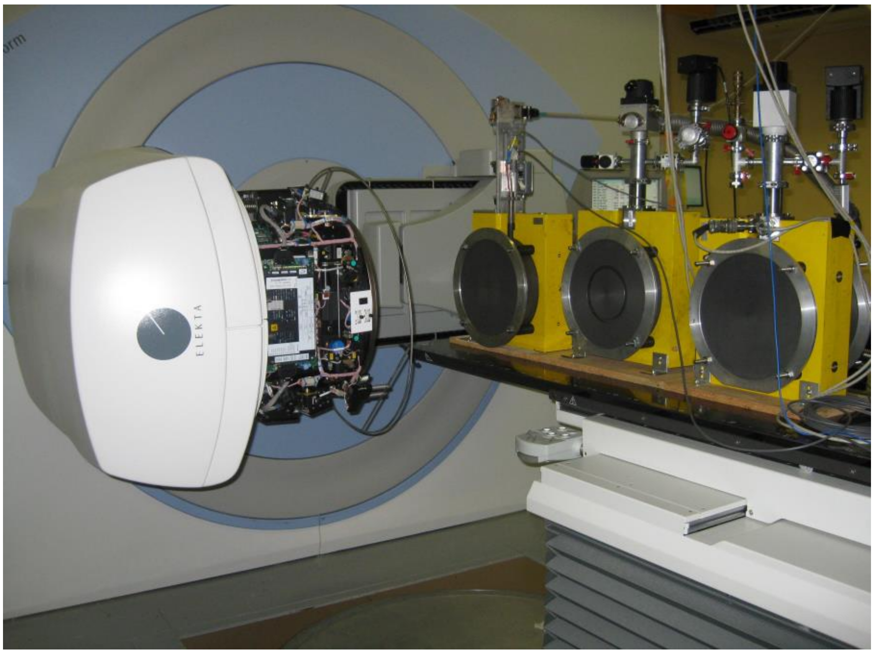

Figure 2. The ARPANSA and IAEA calorimeters on the patient support table at the measurement distance from the therapy head. The third device on the table at far left is a graphite phantom holding a thimble chamber.

3.2 A primary absorbed dose standard for electrons

Plans to implement the ARPANSA calorimeter for electron beams have been put on hold until the BIPM.RI(I)-K6 comparison results have been finalised.

3.3 Vickers research linear accelerator

A decision was made in 2012 to no longer support the research linac. This linac is in the process of being decommissioned.

4 INTERNATIONAL COMPARISON ACTIVITY

4.1 APMP Key comparisons

4.1.1 APMP.RI(I)-K2: ARPANSA participated in the APMP air kerma comparison for low energy kilovoltage x-rays. The measurements have been completed and a Draft A report has been produced by the pilot laboratory NMIJ.

4.1.2 APMP.RI(I)-K1: ARPANSA participated in the comparison of air kerma standards at ^{60}Co which ran between 2004 and 2006. Ten laboratories participated. The Draft B report is available.

4.1.3 APMP.RI(I)-K4: INER (Taiwan) is coordinating the comparison after the attempt in 2000 was abandoned. Measurements have begun.

4.1.4 APMP.RI(I)-K1.1: This is an extension of APMP.RI(I)-K1 to several laboratories not able to participate in the earlier comparison. It has been coordinated by ARPANSA using the APMP.RI(I)-K4 circulation. Measurements are complete.

4.2 Other Regional comparisons

4.2.1 APMP.RI(III)-S1 comparison of ambient dose equivalent meters in ISO neutron reference fields. ARPANSA measured the two transfer artefacts in Am/Be neutrons in 2012.

4.2.2 APMP.RI(I)-S3 comparison of ISO Wide and Narrow Series X-ray beams air kerma. ARPANSA is the pilot laboratory. The protocol for the comparison was agreed by the APMP in January 2013. The transfer artefacts will be sent to the first laboratory in June 2013.

4.3 Bilateral intercomparisons

4.3.1 BIPM.RI(I)-K1, -K3 and –K4: Comparisons were undertaken by ARPANSA and the BIPM in May 2010. Results have now been published and degrees of equivalence approved for all three key comparisons.

4.3.2 BIPM.RI(I)-K6. In September 2012 the BIPM brought their calorimeter to ARPANSA for a direct comparison of absorbed dose to water in MV photon beams (Fig. 3). The absorbed dose to water was determined by the BIPM for the 6, 10 and 18 MV beams on the Elekta Synergy Linac. Two NE 2571 chambers previously calibrated against the ARPANSA calorimeter on these beams were used for the ARPANSA determination of dose to water, and these quantities were compared. The combined standard uncertainty in the comparison ratio is likely to be of the order of 0.6% for all three energies.

Preliminary results of the comparison indicated a consistent difference between the two primary standards at the 2 sigma level. The ARPANSA has since spent some time investigating possible sources of the discrepancy. When radiographs of the ARPANSA calorimeter are used to determine the internal geometry of the calorimeter, a difference of approximately 0.45% is obtained compared to the dose determined using geometry derived from the original specifications. Investigations continue.

Figure 3: BIPM staff Philippe Roger (left), Susanne Piccard and David Burns installing the BIPM calorimeter on the Elekta Synergy Linac at ARPANSA.

5 QUALITY SYSTEMS

5.1 Accreditation

Calibration services are accredited by NATA to the ISO 17025 standard for calibration and testing services. As a part of the accreditation, the quality system is reviewed every 1.5 years, and an international technical assessor accompanies the NATA assessor every second audit (every 3 years).

5.2 National primary standards and NSC Verifying Authority status

The National Measurement Institute of Australia (NMIA) authorised ARPANSA to maintain the Australian primary standards for radiation dosimetry. This authorisation was re-issued in 2012. ARPANSA as designated by NMIA as a Verifying Authority to issue certificates needed to give legally traceable calibrations to third parties. This designation covers the scope of the NATA accreditation.

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

For many years ARPANSA provided a postal TLD audit of megavoltage therapy beams for Australian radiotherapy centres. This service was a copy of the IAEA service. With the establishment of the Australian Clinical Dosimetry Service (ACDS) pilot project (see 6.3), the TLD audit was continued as a part of that project until it was replaced with an OSLD service. ARPANSA retains the ability to perform the audit in case the ACDS pilot is not continued, but TLD audits no longer occur.

6.3 Australian Clinical Dosimetry Service (ACDS)

In a 3 year program, an ACDS pilot has been established as a new section in ARPANSA to provide clinical dosimetry assessments for radiotherapy facilities across Australia. The ACDS consists of 5 staff and operates alongside the Radiotherapy Section. The ACDS has developed the following dosimetry tests:

Level I: Linear accelerator output check for MV photons
The ACDS commissioned a new OSLD system [Inlight®InLight® nanoDot OSLD reader from Landauer (Landauer, Inc., Glenwood, IL)] – similar to that deployed by the Radiological Physics Centre (Houston, USA) – to replace the ARPANSA TLD audit. The new system is faster and more accurate, and better suited to bulk measurements. To date they have measured the output on more than 70% of the linacs in Australia. The repeatability of doses measured by the OSLD system is 1.3 % at 1 sigma. They also have a version of the audit for photons and electrons conducted on-site with an ionisation chamber.

Level II: Linear accelerator beam integrity check
A synthetic CT dataset of a block phantom is sent to the facility and used to plan a number of radiations following a protocol based on IAEA TECDOC 1583. An ion chamber array in solid water is used to measure the beam profiles which are compared to the planning system predictions and the outcome is scored. Commissioning has just been completed and the audit commenced in March 2013.

Level III: Linear accelerator radiotherapy treatment check
The ACDS also developed an on-site anthropomorphic phantom test, based on the CIRS thorax phantom and IAEA TECDOC 1583. The facility scans the phantom and sends the CT data to the local planning system. Three radiation plans are developed by the facility and transferred by the local data network to the linear accelerator. Measurements are performed by the ACDS on-site and compared with the planning system. This audit has been performed on 12 radiotherapy facilities covering 28 linear accelerators to date.

The service is now in its final year before it is assessed and a decision about its future made. The ACDS is an initiative between the Department of Health and Ageing and the ARPANSA.

7 PUBLICATIONS 2011-2013

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Comparison of TLD calibration methods for ^{192}Ir dosimetry, Annette Haworth, Duncan J. Butler, Lisa Wilfert, Martin A. Ebert, Stephen P. Todd, Anna J.M. Hayton, Tomas Kron Journal of Applied Clinical Medical Physics, **14** No 1, p258-272, 2013

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