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Recent Activities in Measurement Standards and Dosimetry at ARPANSA, 2005-2007

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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 is a small group of five permanent staff including three scientists. In February 2006, Dr Ganesan Ramanathan joined ARPANSA on a 12 month appointment to work on graphite calorimetry.

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 mentioned, the status of the LEFAC was downgraded to that of a secondary standard in April 2003 with calibration factors determined by an interpolation of results obtained from the BIPM comparison and from the ARPANSA medium energy free-air chamber.

In 2005, collaboration began with the University of Wollongong in New South Wales to model the response of the LEFAC with several Monte Carlo codes including EGSnrc and Penelope. Preliminary results indicate that correction factors are similar to those provided by D Burns and further study is required.

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. Our participation in the Euromet 545 intercomparison has forced a review of the methods by which this dosimetry is achieved (see Section 4.2.1). 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.

2.2 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). Monitoring of the chamber since the repair of its central electrode in 2003, has yielded good agreement with measurements by Huntley in 1999. However a small but statistically visible difference seems to be emerging that may require verification of several parameters related to the chamber volume.

3 ABSORBED DOSE STANDARDS

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

ARPANSA does not hold primary standards of absorbed dose for the kilovoltage x-rays. In order to adopt TRS-398, an air kerma calibration must be converted into an absorbed dose to water calibration. For the low energy region, a measurement of the chamber response in a phantom is required if the conversion is to be done at ARPANSA. If the conversion is done in the clinic, measurements in air can be used to find the air kerma rate in the clinic beam, and this rate then converted to absorbed dose to water.

TRS-398 specifies that the clinic and ARPANSA beams should have the same geometry (radius and focal distance) in which case there would be no difference between these two methods. However, in practice this is not always the case. We are investigating the uncertainty introduced into the clinical beam calibration by the fact that the beams have different geometry. The results suggest that the conversion to absorbed dose is more accurate if done in the clinic, since the transfer is done using calibrations in air, which are less sensitive to beam size variations. Measurements of the ratio of the response of a PTW 23342 chamber in air and in a Perspex phantom for a range of energies and beam sizes are used to predict a maximum difference of 3% between these two methods.

3.2 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. The progressive failure of thermistors mounted on the jacket surrounding the core, led to an initial attempt to replace these thermistors in 2005 which was unsuccessful, with shorts to the graphite and between wires occurring. The thermistors were replaced successfully in early 2006, but the calorimeter has required modifications to the electronic control system as a result of the different lead resistances of the new thermistors. To facilitate more sensitive measurement, the chart recorder output has been replaced by a digital voltmeter read by Labview software on a PC.

A similar calorimeter has been on loan from the IAEA, intended to be used as a temporary standard while repairs were being made. What appeared to be a faulty thermistor, in a similar jacket location to those in the ARPANSA calorimeter, was a faulty solder joint on the connector ring at the head of the shield assembly.

Both calorimeters have been operated over the past year in the ARPANSA ^{60}Co beam and their performance has been compared. The calorimeters are similar dimensionally but are made of graphite of different density so that the responses will differ proportional to the masses in each case. Being from different construction series (the IAEA calorimeter is somewhat older) there are differences in the electronic control and measurement circuits. In particular the heating power of all sections of the ARPANSA calorimeter is about 3 times higher than in the IAEA calorimeter.

Both calorimeters have similar short term drifts in the core of about 30 nK/sec which is sufficiently small for the dose rates around 3.15 mGy/sec that are being used. The temperature stabilised outer shell (referred to as the “Medium”) seems slightly more sensitive in the case of the ARPANSA calorimeter to ambient variations. This is not so important since 24-hour air conditioning was implemented in mid-2006 capable of maintaining the room temperature around 22 ± 0.2 C.

Each device has been operated in both quasi-adiabatic and quasi-isothermal modes. While the most accurate measurement will be obtained with the quasi-isothermal mode as it less dependent on the intrinsic drift rates, the two modes agree in the measurement of the mean absorbed dose rate to better than 0.1% for both calorimeters. The mean ^{60}Co dose rate measured by the ARPANSA calorimeter over four months in late 2006, and corrected to the dose rate measured on 15 March 1997, is found to deviate from the expected value by 0.12 ± 0.12 %. The dose rate in 1997 was established through an intercomparison with the BIPM. At the present time, the IAEA calorimeter appears to give a lower estimate of the absorbed dose-rate by about 0.2% but this is also within the uncertainty.

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 and a new supplier is being sought. It is noted that it has been at least 10 years since the comparison of both air kerma and absorbed dose standards was made with the BIPM and a new comparison is due, particularly since the repairs made to the ARPANSA calorimeter and also to the pancake cavity chamber, air kerma standard. However it seems sensible to wait until the source is refurbished with a higher dose rate although this may have some consequence for traceability as a linking laboratory for regional key comparisons.

3.4 Mega-voltage X-ray and electron beams

The linear accelerator is used primarily to support absorbed dose standards at therapy energies. As noted previously, the unavailability of the ARPANSA graphite calorimeter has prevented the program from producing kQ values for reference megavoltage x-ray beams. Furthermore the reproducibility of these beams has been difficult to establish with the existing rf structure and beam line configuration.

3.5 A primary standard for electrons

A graphite electron calorimeter was purchased from the NPL several years ago. The instrumentation of this device has been undertaken and initial calibration of thermistors has been done. Construction of the bridge circuits has started.

3.6 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. These results have been published in 2005 in the Australasian Physical and Engineering Sciences in Medicine journal.

4 INTERNATIONAL COMPARISON ACTIVITY

4.1 Key comparisons

4.1.1 APMP.RI(I)-K3: The Draft B report is being prepared for the APMP air kerma intercomparison for medium energy kilovoltage x-rays, which was completed in June 2003.

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 the linking laboratories along with BARC and more recently 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 and Draft A report were distributed in December 2006. For the 30 cm^3 chamber, ARPANSA was within 2% of the mean of the participants for most of the beams but showed a 4% deviation for the highest energy beam (N-300). Our tentative explanation is uncertainty in the electron loss correction factor for the free-air chamber. The standard uncertainty in our measurements was estimated at 1-1.5 %.

The results were reasonable given the use of a free-air chamber designed for therapy beams at these protection levels. The agreement for the larger chambers which had to be calibrated using larger beams at greater distances was just outside the uncertainty of the measurements. We suspect that in these cases our uncertainties should be revised to include the effect of beam non-uniformities and scatter that have not been fully quantified for these beams.

4.3 Bilateral comparisons

4.3.1 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. The laboratory was re-audited in June 2006 extending the scope to our X- or gamma-ray based protection level services and diagnostic and therapy level services. The audit report confirmed the protection level accreditation and noted several actions to fulfil the requirements for the extended scope, notably the completeness of the uncertainty budgets. Our response will be sent to NATA in May 2007.

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 will continue.

6.2 National therapy dosimetry audit

Preparations for the recommencement of the mailed MV photon TLD audit program have involved a number of measurements and calculations performed in 2006 and these are currently continuing. Three different therapy centres have been visited and

TLD measurements on multiple MV photon beams at each centre have been made to determine the energy correction of the LiF-100 powder which will be used in the audit program. The results obtained are in agreement with energy correction data published by the IAEA for the LiF-100 used in their audit program.

Holder correction measurements have also been made while visiting the therapy centres. This is to correct for the non water equivalence of the PMMA holder which is used to position the TLD capsule at the correct depth in the water phantom. This is important for beam quality measurements where up to 15 cm of the PMMA tube lies upstream of the TLD capsule. Preliminary results are in agreement with previously published work. Further measurements of the holder correction are being computationally simulated using the Monte Carlo codes EGSnrc and BEAMnrc. Results are pending.

7. PUBLICATIONS

Shortt K R, Huntley R B, Kotler L H, Boas J F and Webb D V, *A comparison of Australian and Canadian calibration coefficients for air kerma and absorbed dose to water for* ^{60}*Co γ radiation*, Aust. Phys. Eng. Sci. Med. **29,** No. 2 (2006) 207-215.

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