Recent Activities in Measurement Standards and Dosimetry at ARPANSA

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1.INTRODUCTION

The Ionising Radiation Standards Section continues to maintain Australian standards of air kerma and absorbed dose and to provide calibration services for therapy, diagnostic and protection equipment. Dr John F Boas who has run the Section for several years retired in May 2000, and its management has been taken over by Dr David V Webb. During last year, ARPANSA formally joined the Asia Pacific Metrology Program (APMP) and has participated in intercomparison activities of its Technical Committee for Ionising Radiation (TCRI). These and other activities of the IRS Section are discussed in this report.

2 EXPOSURE /AIR KERMA STANDARDS

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

The RT100 x-ray unit has been aligned and using various algorithms available in the literature *(see Section 2.3)*, spectra have been generated which give similar half-value layer information and air attenuation factors to that determined experimentally. These spectra have been used in conjunction with Monte-Carlo factors provided by D Burns (BIPM) to generate correction factors for electron scattering and photon losses for the low-energy primary standard chamber. The RT100 unit is in routine use for calibration of client equipment. The AEG50 unit is now in the process of being aligned.

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

Similarly, X-ray spectra have been generated for the Siefert Isovolt unit and we are in the process of re-evaluating the correction factors for the medium–energy free air chamber for our standard therapy and diagnostic quality beams, also using factors provided by D Burns. We are also re-evaluating the correction factors for the medium–energy free air chamber appropriate to the narrow and wide ISO protection level beams we offer our clients

We are still investigating discrepancies of the order 1-2% between the responses of the two free-air chambers. Some of this can be accounted for by more accurate distance measurements.

In addition, we are developing a method of rationalising the measured calibration factors for each type of frequently used ionisation chamber in order to significantly lower from twenty-five the number of beam qualities we offer clients. This is to be achieved by generating, in advance, a generic analytic curve shape which relates the chamber calibration factor to the half value layer of the beam over the available range of half-value layers. The calibration then consists of a minimal number of chamber measurements which normalise the curve parameters to the response of the specific chamber. These curve parameters will be presented to clients.

2.3 X-ray spectra characterisation

A Spectro-X Compton X-ray spectrometer has been used to measure the spectra from the ARPANSA primary x-ray tubes (RT100 and Seifert Isovolt). The advantage of this spectrometer is that spectra can be measured without having to attenuate the beam or reduce the tube current. We found that the measured spectra are qualitatively similar to theoretical spectra generated from a semi-empirical model using NIST mass-energy absorption coefficients. The algorithm is described in D M Tucker, G T Barnes, and D P Chakraborty, "Semiempirical model for generating tungsten target x-ray spectra", Med. Phys. 18, p211 (1991).

The measured spectra can be used to generate some derived quantities, such as the average energy. However, the derived quantities which depend on the calculation of exposure (such as half-value layer), are not in good agreement with the directly measured values. The reason for this appears to be the presence of small, but significant, levels of low-energy photons in the measured spectra. We suspect that such low-energy photons are an artefact of the spectral reconstruction process which is necessary in a Compton spectrometer.

The Compton spectrometer results have been compared with direct measurements in a small number of cases where such comparisons are possible, and reasonable agreement found. Both methods of spectrum measurement show unrealistic levels of low-energy photons. Attempts to correct for the response of the detector were successful only for narrow spectra.

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

2.4.1 A report of the comparison between ARPANSA and NPL in 1995/96 of air kerma standards for ^{60}Co is close to completion. As shown by the ratio of the transfer standard ionisation chamber calibration factors, the standards are in agreement to within 0.44%.

2.4.2 A draft report has been prepared covering a detailed review of correction factors for the carbon cavity chamber that is the primary standard.

2.4.3 An alignment laser system has been installed on the ARPANSA ^{137}Cs teletherapy source. This is an improved version of a similar system that has been in use on the ^{60}Co teletherapy source for many years. A radiographic image processing package in Matlab was used to define the radiation beam centre lines, and the laser beams were adjusted to match. Each teletherapy source can be oriented to produce either horizontal or vertical beams. A mylar mirror through which the radiation beam passes directs the laser beam along the radiation beam central axis in both orientations. The vertical radiation beam is normally used for air kerma calibrations, and also has a transverse laser beam to facilitate chamber positioning. The horizontal beam is normally used for absorbed dose calibrations, for which the phantom position is usually fixed and no transverse laser beam is needed.

2.5 International intercomparison activity

2.5.1 We have completed intercomparisons with the NRCC in 1997-1998 for the medium energy BIPM standard qualities, the 50 kV low energy standard qualities and for ^{60}Co. However we are still waiting for confirmation of provisional results provided by the NRCC. We also performed an intercomparison for the medium energy BIPM standard qualities with the INER (Taiwan) in 1999 but this has not been written up yet.

2.5.2 At present we are performing an intercomparison with NRL (New Zealand) for BIPM medium energy qualities, BIPM low energy qualities at 30 and 50 kV and for some ISO protection level qualities. The low energy qualities will be standardised against both the low and medium energy primary chambers.

2.5.3 We hope to perform an intercomparison with BIPM for low and medium energy qualities within the year. We will be taking part in the APMP medium energy and low energy intercomparison program.

3 ABSORBED DOSE STANDARDS

3.1 The Australian primary standard for photons

Temperature control of the ARCS graphite calorimeter that is used to maintain the Australian primary standard for absorbed dose, has been improved to make the device less susceptible to ambient temperature fluctuations. Cycling of the air conditioning system can result in swings of up 2^{o}C in the room temperature.

3.2 APMP/TCRI WG5 comparison

The APMP/TCRI WG5 comparison of absorbed dose to water standards at ^{60}Co was coordinated by BARC in 2000. ARPANSA participated as a link laboratory. Each participant was asked to supply a single transfer standard chamber - ARPANSA supplied two chambers. The two ARPANSA chambers were returned packed in dessicant to cope with high humidity conditions in India. One of the chambers became jammed in the dessicant filled container and was only extracted with some difficulty. Some of the dessicant had become finely powdered and there was a concern that the chamber may have become contaminated. While carrying out routine ^{90}Sr check source measurements as part of the “on return” calibration of the two chambers used in WG5, one of the chambers left its cap behind in the ^{90}Sr source. Fortunately the “on return” calibrations had been otherwise completed and were in agreement with the “before” calibrations. The final report from BARC was submitted to the APMP without the participants being given the opportunity to comment or to make any corrections.

3.3 BIPM Star comparison

Dr David Burns from BIPM visited ARPANSA in February 2000 to spend a two weeks at the Laboratory bringing with him three different types of transfer standard (cavity ionisation chamber types: NE2611A, NE2571 and OMH/ND1006). We calibrated all three for absorbed dose to water at ^{60}Co. Air kerma measurements were carried out at the same time. Two ARPANSA secondary standard ionisation chambers were used for purposes of quality assurance. We also discussed the finalisation of the ARPANSA/BIPM absorbed dose to water comparison report (BIPM 99/17).

3.4 A primary standard for electrons

In January 2001 we purchased from the NPL a graphite calorimeter suitable for establishing a primary standard of absorbed dose for electron beams. The instrumentation will be developed and the device implemented in suitable electron beams from the ARPANSA linear accelerator later this year.

4 ELECTRICAL AND SUPPORTING STANDARDS

The IRS Section maintains subsidiary standards of various quantities to support our primary standards. These include temperature, pressure, relative humidity, dc voltage and current, resistance, capacitance, time and length.

Recently, our dc voltage, current and resistance standards have been greatly improved by the acquisition of a Fluke 5720A calibrator and associated Hewlett Packard 3458A long scale multimeter. Baseline stability checks have been made over a period of 6 months. The multimeter will now be sent to the NML for calibration against Australian standards of dc and ac voltage, current and resistance. NATA accreditation of this system will be sought when stability checks have been repeated after its return from calibration. It will then become a commercially viable calibration facility for all digital multimeters.

5 APPLICATIONS OF DOSIMETRY STANDARDS

5.1 ESR alanine dosimetry for high dose irradiations

A Bruker Model 200D-SRC ESR spectrometer has been brought back into service and a Labview interface developed to replace the analogue graphical display that will facilitate the measurement of absorbed dose in l-alanine at therapy levels and higher up to 100 kGy. Reference quantities are being established.

5.2 IAEA PSDL and SSDL activities

We will be providing standard exposures for the third IAEA/RCA intercomparison for individual monitoring for occupational exposures. The next round will be in July this year.

5.3 SiO_2 beta/gamma radio-dating

A research project with geophysicists from a local university has led us to develop a technique to deliver accurate doses to single grains of sand (SiO_2) using the photon fluence-scaling theorem. As aluminium has very similar radiation interaction coefficients to SiO_2, an aluminium phantom was constructed. Individual sand grains were loaded onto aluminium discs, which were then stacked inside a cylindrical aluminium holder. The holder was inserted into a diametrical hole in the cylindrical phantom and centred. An ionisation chamber calibrated in absorbed dose to graphite was then used in a graphite phantom at the appropriate scaled distance, to provide absorbed dose to aluminium. Only minor corrections were then required to obtain the absorbed dose to SiO_2.

5.4 Accident dosimetry and dose reconstruction

A current project is the delivery of large absorbed doses to plastic buttons and human teeth, as part of an investigation of ESR methods for accident dosimetry. These are currently being irradiated at about 10 Gy/h in our ^{60}Co water phantom. We are considering the use of alanine to calibrate a special irradiation device that can hold small samples very close to our high activity ^{137}Cs source. The dose rate there is expected to be over 10 kGy/h.