Australian Secondary Standards of Dosimetry

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Abstract

The Secondary Standard Dosimetry Laboratory (SSDL) is part of an international network of dosimetry laboratories established by the International Atomic Energy Agency (IAEA) and the World Health Organization (WHO). The Network provides a framework of international comparisons of the absorbed dose measurements that help to maintain consistency and accuracy particularly amongst the radiotherapy community. The SSDLs are designated by national laboratories (such as Primary Standard Dosimetry Laboratories, PSDLs) to provide national and international radiation dosimetry traceability for users in that country. Australia's national primary standard is the responsibility of the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA). The ANSTO SSDL has measurement traceability to ARPANSA; thus providing an interface between the primary standard and Australian hospitals, significantly reducing waiting time for instrument calibration. The ANSTO SSDL provides a calibration service, at cobalt-60, primarily to Australian hospital departments for radiotherapy level dosemeters and typically thimble ionization chamber types NE2561, NE2611A, NE2571 and NE2581. Other services include charge sensitivity and linearity tests of dosemeters and strontium-90 stability check source calibrations. This paper describes the facility and the available services to clients.

1. The ANSTO SSDL Facility

The ANSTO SSDL facility is comprised of a therapy level cobalt-60 source (currently 100TBq) mounted within a Theratronics-Eldorado-6 teletherapy unit, a series of standardized thimble ionization chambers, calibrated electrometers and strontium-90 stability check sources. ANSTO secondary standards are regularly calibrated against the primary standards provided by ARPANSA for exposure/air kerma and absorbed dose to water at cobalt-60. The facility has been designed to meet a national code of practice for the safe operation of radiation facilities [1], and is certified to ISO 9001:2000 for Quality Management Systems.

The source is controlled pneumatically along a cylindrical drawer. The chamber is positioned vertically (for horizontal beam) such that cross-hair lasers and the teletherapy field lamp can be used for alignment for air measurement and at 50mm depth in a water tank for absorbed dose measurement. The jig used to hold the chamber in place can be fixed onto a dual rail trolley, which can be moved for distance measurement from approximately 0.5 metres up to 6 metres. The reference distance for exposure / air kerma measurement is 1000mm from the geometric centre of the source to the chamber centre. The reference distance for absorbed dose to water measurement is 1050mm, including 50mm depth in water.

The water tank is a 30cm × 30cm perspex box 10mm thick with a 2mm thick window at the centre of the side facing the source. The water tank and chamber sleeves have been constructed to be as similar as possible to those used by ARPANSA to calibrate ANSTO chambers making corrections for different thicknesses negligible. An example of the absorbed dose to water measurement setup is shown in Figure 1.

Figure 1

2. Method of measurement

LabVIEW™ is used to communicate with a Programmable Logic Controller (PLC) to control the operation of the source. Figure 2 shows the response of a chamber as the source moves from its shielded position at $\mathbf{t_0}$ to when it starts to retract at $\mathbf{t_2}$.

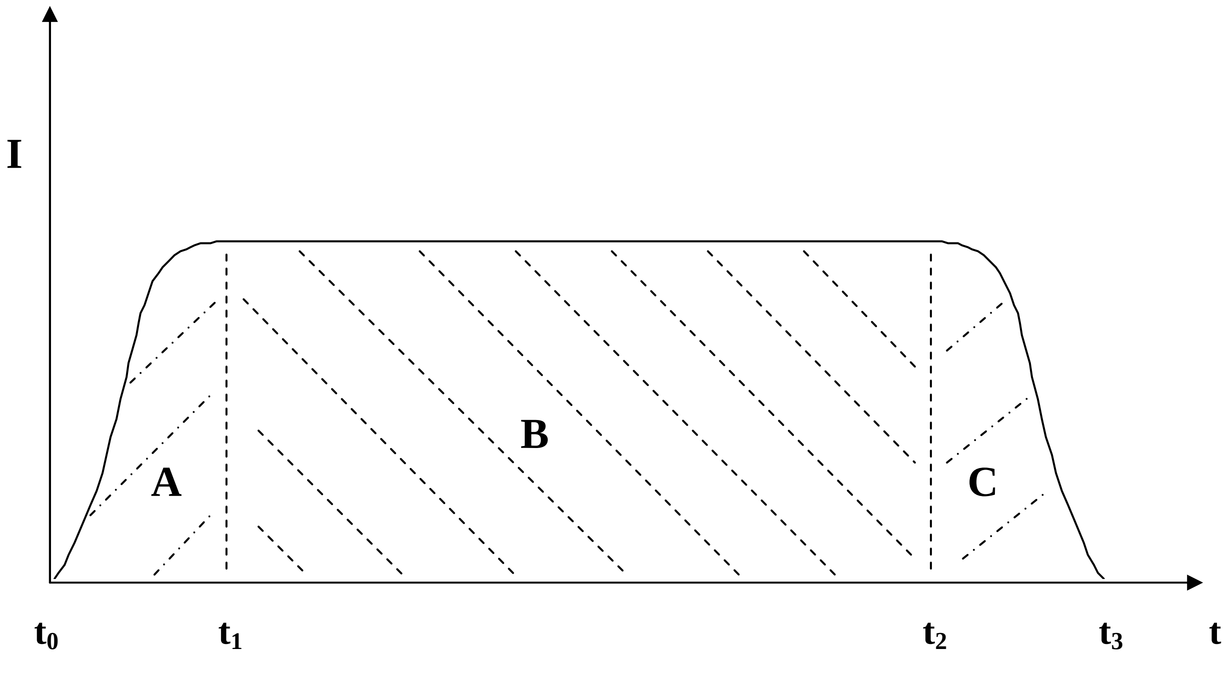

Figure 2

Three independent programs have been written to measure different aspects of ion chamber response. The first records chamber response for regions **A** + **B**. The second measures the response for region **B** only. That is, a reading of charge and time is taken only after the source has been fully exposed. A second reading of charge and time is taken before the source is retracted, giving the measured current as $\Delta Q/\Delta t$, thus eliminating the need for transit time corrections. This method is used to calculate dose rates. It is these reference values of exposure / air kerma and absorbed dose to water that are used to calibrate a test chamber. The third measures the response for regions **A + B + C**. This becomes convenient for measuring the absorbed dose to other dosimeters such as thermoluminescent dosimeters (TLDs).

Ionization chambers set up for measurement are allowed to stabilize for at least one hour prior to radiation exposure. For reproducibility, the chamber is positioned so that a reference mark, for example, the breather hole, always faces the source. Every reading is corrected to reference conditions of temperature 20°C and pressure 760mmHg. The electronic devices used to measure temperature and pressure are regularly calibrated against mercury thermometers and a mercury barometer, respectively, which have measurement traceability to the relevant national standards. Corrections for relative humidity are considered negligible; however, readings are rarely outside the range of 30% to 70%.

For a typical measurement 100 readings are recorded with the raw data collected saved as a comma separated variable file. The raw data is checked for constancy before a series of spreadsheets are used to automate all measurement calculations. The calculated dose rate is collated with past measurements to determine a mean reference value. To date the values of exposure, air kerma and absorbed dose rates, under the conditions described above, are 0.759 ± 0.008 R/sec, 6.67 ± 0.07 mGy/sec and 6.095 ± 0.054 mGy/sec, respectively, corrected for the decay of cobalt-60 to 1/7/2003 at 12:00. The uncertainties here are the expanded uncertainties to a level of confidence of approximately 95% (coverage factor k = 2) taking into account the standard uncertainties of all influence quantities. The SSDL follows the ISO Guide [2] for the expression of uncertainty in measurements.

Figure 3 shows absorbed dose to water measurements over a 15 month period. Each colour represents a different ion chamber. The red line indicates a moving average. The average of the set as shown is then the reference value. The standard deviation represented indicates the precision (Type A uncertainty) of the measurements.

3. Ion Chamber Calibration

During calibration an SSDL chamber of similar type as the test chamber is used for quality assurance as verification of accurate dose rate measurement. The test chamber is placed under the same conditions as described above and where a dosemeter is supplied the chamber and meter are measured together as one unit. The ratio of the SSDL reference value to the nominal measurement rate from the test unit determines the calibration coefficient. If a dosemeter is not supplied an SSDL electrometer is used and the calibration coefficient is reported in units of (R or mGy)/nC.

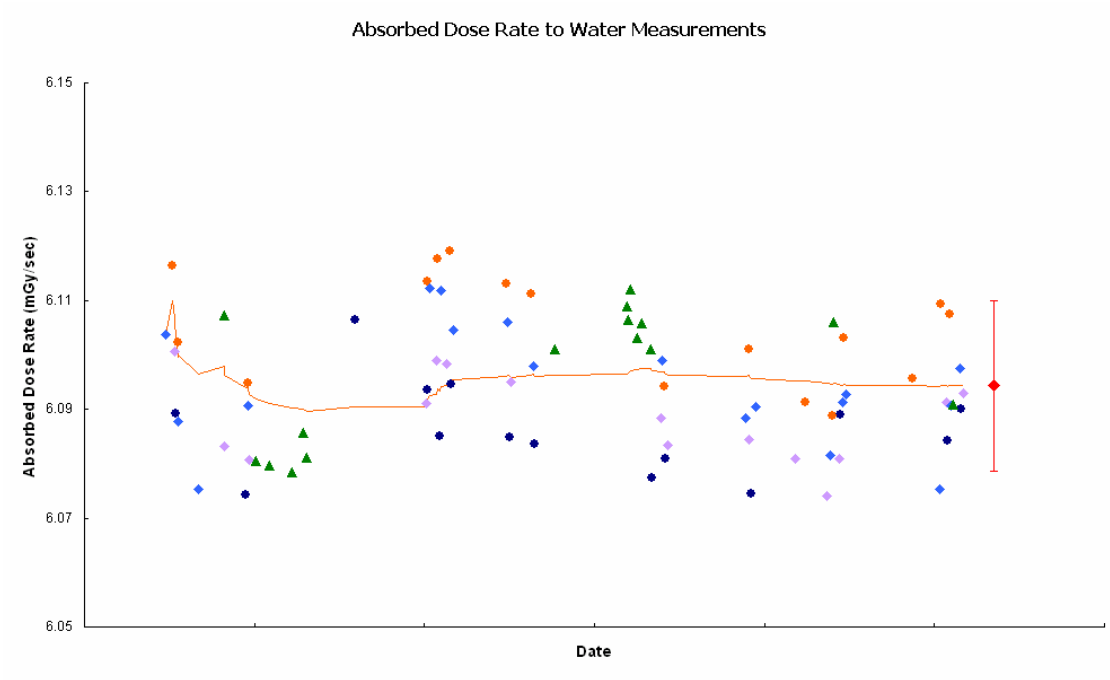

Figure 3

4. TLD irradiations

Part of ANSTO's obligation as a member of the IAEA/WHO SSDL Network is to participate in annual TLD postal dose quality audits. Since the facility's construction in 1999, the SSDL has demonstrated results to within 1% of the IAEA TLD measurement. As mentioned in section 0, the dose delivered to the TLD is measured for regions **A** + **B** + **C** with an ion chamber. A significant component of uncertainty in this measurement is attributed to the variation in the source transit time. The source transit time for this unit is typically of the order of 3 seconds and can vary by as much as 0.5 seconds.

5. ANSTO SSDL Services

The ANSTO SSDL provides a calibration service, at cobalt-60, primarily to Australian hospital departments for radiotherapy level dosemeters and typically chamber types NE2561, NE2611A, NE2571 and NE2581. Other services include charge sensitivity for electrometers measuring nano-coulombs. Using an ion chamber as an arbitrary current source, a comparison is done between the response of a calibrated SSDL electrometer to that of the test electrometer. The SSDL electrometer has charge measurement traceability to the Australian standard via ARPANSA. Plotting charge (corrected for environmental conditions and decay) against exposure time for each range of the electrometer determines the calibration applicable for the device.

For devices not measuring nano-coulombs two types of linearity tests are done. They are measurement reading against increasing exposure time, or measurement rate against the inverse square of the distance. The facility also has the capability to calibrate the customer's strontium-90 stability check source. This is done by measurement of the ratio of an ion chamber response to an SSDL reference source of the same type.

6. References

[1] **National Health and Medical Research Council**, *Code of Practice for the Design and Safe Operation of Non-Medical Irradiation Facilities*. NH&MRC (1988).

[2] **International Organization for Standardization**, *Guide to the Expression of Uncertainty in Measurement* (1993).

Discussion

Tony Aalbers – How do you provide for the charge calibrations of the electrometers?

Justin Davies – Every year we send our reference Keithley down to ARPANSA here for calibration, and they have a working standard which is traceable to the national standard, so the way we would do it is to measure a reference current directly from an ion chamber as an arbitrary current source, and compare that response to another electrometer.

Malcolm McEwen – In that graph where you've got the A, B and C regions, what time would you use to give you the dose rate, do you use the internal timer?

Justin Davies – Approximately 50 seconds per measurement for region B, using the time from the Keithley.

Malcolm McEwen – OK you use the Keithley clock.

Justin Davies – The readings of charge and time are taken directly from the Keithley.

Malcolm McEwen – Do you calibrate that timer at all, or ...

Justin Davies – No. We do rely on it.

Frank Pernicka – You mentioned you calibrate therapy dosemeters, are you planning to extend it for protection?

Justin Davies – At the moment the dose rate of the source is too high, even at the maximum distance from the source.

Tony Aalbers – On one of the slides I saw that you showed five chambers, but four of them were I think this NPL 2611, and I saw a Farmer type. Do you employ also Farmer type chambers?

Justin Davies – 2571.

Tony Aalbers – OK, that was the one I saw then.

Simon Duane – I looked closely and I thought you had two of the old type and two of the new type.

Justin Davies – Yes, two 2561, two 2611A.

Simon Duane – And one of the 2571s.

Justin Davies – That's right.

Rashmi Gupta – There's no collimator inside the therapy head?

Justin Davies – There is a jaw collimator, its base is made of depleted Uranium, the rest are lead jaws.

Rashmi Gupta – You have the extra pair of collimators on the outside?

Simon Duane – Trimmer bars on the outside.

Justin Davies – Yes.

Rashmi Gupta – Why do you need trimmer bars?

Justin Davies – It just helps to keep the beam uniform ...

Malcolm McEwen – NPL takes its trimmer bars off.

Simon Duane – We judge that for our measurements on the central axis, that it didn't matter if we had a rather broad penumbra at the edge of the field, but I understood that for treatments it was important to have a sharp definition and that's what the trimmer bars are there for, but I don't think it makes much difference.

Malcolm McEwen – Yes for standards work it's not ...

Simon Duane – Our trimmer bars are depleted Uranium, so we have put those away. I have one question, you showed a graph of the overall stability and consistency, and I think mentioned a figure for the percent deviation. Do you find a greater consistency over the short term, for instance over a series of measurements with one set-up, or is that standard deviation typical ...

Justin Davies – That's for a single set-up, that's the only way we can collate all those readings.

Tony Aalbers – What is your calibration frequency to ARPANSA?

Justin Davies – We try and send each chamber down between two and three years on a rotating cycle.