Calibration of ARI QC Ionisation Chambers Using the Australian Secondary Standards for Activity

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SUMMARY The Secondary Standard Activity Laboratory (SSAL) in ANSTO routinely provides standardised radioactive sources, traceable activity measurements and custom source preparation services to customers. The most important activity carried out is the calibration of ionisation chambers located in the Quality Control (QC) section of Australian Radioisotopes (ARI). This ensures that their activity measurements are traceable to the Australian primary methods of standardisation.

ARI QC ionisation chambers are calibrated for ^{99m}Tc, ^{67}Ga, ^{131}I, ^{201}Tl and ^{153}Sm. The SSAL has a TPA ionisation chamber, which has been directly calibrated against a primary standard for a variety of radioactive nuclides. Calibration factors for this chamber were determined specifically for the actual volumes (5ml for ^{99m}Tc, ^{131}I, 2ml for ^{67}Ga, ^{201}Tl and 3 ml for ^{153}Sm) and types of vial (Wheaton) which are routinely used at ARI. These calibration factors can be used to accurately measure the activity of samples prepared by ARI. The samples can subsequently be used to calibrate the QC ionisation chambers. QC ionisation chambers are re-calibrated biannually.

1. INTRODUCTION

The National Measurement Act of 1960 requires that measurements made for any legal purpose should be traceable to Australian National standards of measurement. The CSIRO has been assigned the responsibility for maintaining Australia's national measurement standards. With regards to the standard for ionising radiation activity, the CSIRO has appointed the Australian Nuclear Science and Technology Organisation (ANSTO) as an agent.

Australian Radioisotopes (ARI), as a producer and supplier of radiopharmaceuticals, must be able to demonstrate traceability of their activity measurements to the National standard of measurement for ionising radiation activity. The Therapeutic Goods Administration (TGA) conducts regular inspections of ARI. Part of their requirements relates to the traceability of ARI's activity measurements. The Radiation Standards Project within the Physics Division at ANSTO maintains the Australian standard of measurement for radioactivity. A coincidence counting system is used to perform primary standardisations. The results of such standardisations may then be used to calibrate a secondary standard ionisation chamber. The secondary standard ionisation chamber or working standard ionisation chamber located in the SSAL is a "TPA" ionisation chamber which has been directly calibrated for a variety of radionuclides. For those nuclides for which the chamber has not been directly calibrated, it is possible to determine a calibration factor indirectly using the interpolation method. The results of primary standardisations may be compared with the results of other National standards institutes through the auspice of the Bureau International des Poids et Mesures (BIPM) via either full-scale international intercomparisons or the Internaional Reference Sysem (SIR).

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2. SAMPLE PREPARATION

The calibration of the working standard ionisation chamber against a primary standard requires careful handling of the radioactive solutions to ensure that all of the samples are gravimetrically related to the stock solution.

Radioactive stock solutions are usually supplied by ARI. Prior to dispensing, the solutions are mixed using an ultrasonic bath to ensure homogenity of the solutions. 1M HCl Diluent is used to prevent both

"plating – out" and precipitation of the nuclides. The solutions are diluted and then dispensed to provide five $4\pi\beta-\gamma$ counting sources to determine the activities of the solutions using the coincidence counting system. Five solutions are provided from the same stock in Wheaton vials and standard ampoules to calibrate the SSAL working standard ionisation chamber. Solutions in Wheaton vials will be used to calibrate QC's ionisation chambers. Standard ampoules may also be used for international comparison. All solutions are weighed before and after dispensing to determine the mass of solution added to each vial.

For the biannual re-calibration of QC ionisation chambers against the SSAL working standard ionisation chamber, only three solutions in Wheaton vials need to be dispensed from stock solution.

3. SECONDARY STANDARD IONISATION CHAMBER AND ITS CALIBRATION

The SSAL Ionisation chamber has characteristics of high sensitivity, long term stability, and simplicity of operation. Once calibrated it can be used to measure or calibrate further samples of the same radionuclide to give secondary standards at any later date.
The secondary standard ionisation chamber [1] shown in figure 1 provides an almost 4π geometry and is filled with argon to a pressure of about 20 atmospheres (~ 2026 kPa). Perspex holders have been made to allow source solutions to be introduced to the chamber.

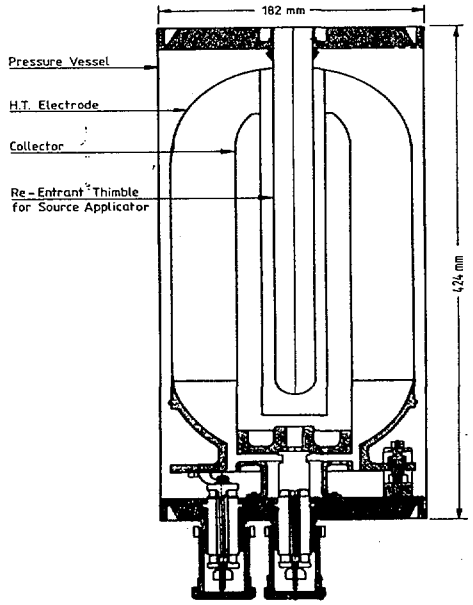

Figure 1. TPA ionisation chamber [1]

When a radioactive sample is inserted into the chamber, ion pairs will be generated within the gas. When there is no voltage, the ion pairs will re-combine and as a result no current will flow between the electrodes. However, applying a voltage will cause the positive and negative ions to drift in opposite directions toward their respective electrodes. This results in an electrical current being produced [2]. If the voltage is further increased, a saturation voltage will be reached at which all of the ion pairs are collected at the electrodes. As long as the charged particles lose all of their energy within the gas volume, the number of ion pairs produce will be proportional to the kinetic energy of the charged particles.

For a particular nuclide , for which the activity has been determined using one of the Australian primary methods of standardisation, the specific ionisation current (or calibration factor) i_c is given by

$$i_c = \frac{I_m - I_b}{A_m} \qquad (1)$$

where I_m is the ionisation current of the standard solution for that nuclide, I_b is the current due to background radiation, A_m is the activity of the solution which has been determined using primary standardisation and corrected for radioactive decay. To estimate the activity of this nuclide a long time after the chamber calibration, the stability of the chamber needs to be verified by comparing the ionisation current from a radium reference source at sample measurement time t_m with the current predicted based on measurements made at calibration time t_c.

Calibration factors for the working standard ionisation chamber, which were determined for the ARI calibration program are listed in table 1.

Table 1. Calibration factors for working standard ion chamber

Nuclide	Volume (ml)	Factor i_C (pA/MBq)
^{67}Ga	2	6.24 ± 1%
^{99m}Tc	5	5.68 ± 1%
^{131}I	5	11.48 ± 1%
^{201}Tl	2	4.693 ± 1%
^{153}Sm	3	2.03 ± 1.5%

4. CALIBRATION OF ARI QC IONISATION CHAMBERS

ARI QC has two ionisation chambers, a Vinten and a TPA chamber. They work on the same principle as the standard ionisation chambers described above.

Solutions were repeatedly measured in both the ARI TPA and Vinten chambers to obtain ionisation currents for each sample. Then the solutions were transported to the SSAL where their activities were determined in the standard TPA ionisation chamber.

The decay corrected activities were then used to calibrate ARI ionisation chamber using equation (1). Calibration factors for the ARI Vinten and TPA chambers are list in table 2.

Table 2. Calibration factors for the ARI ion chambers

Nuclide	Volume (ml)	Factor i_C (pA/MBq)	
		ARI TPA	ARI Vinten
^{67}Ga	2	5.12 ± 2%	1.55 ± 2%
^{99m}Tc	5	4.69 ± 2%	1.216 ± 2%
^{131}I	5	9.37 ± 2%	3.894 ± 2%
^{201}Tl	2	3.93 ± 2%	0.845 ± 2%
^{153}Sm	3	-	0.54 ± 3.7%

Once the calibration factors for the ARI chambers are determined, the bi-annual re-calibration is conducted by measuring the activities of 'standard' sources using the ARI chambers and comparing these measurements with the activities determined using the SSAL working standard.

5. CONCLUSION

The ARI QC ionisation chambers has been calibrated for the actual volumes (5ml for ^{99m}Tc, ^{131}I, 2ml for ^{67}Ga, ^{201}Tl and 3 ml for ^{153}Sm) and types of vial (Wheaton) which are routinely used at ARI. The calibration factors can be found in table 2. The activity measurements on these nuclides are traceable to the Australia primary methods of standardisation.

ACKNOWLEDGMENTS

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REFERENCE

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[2] NCRP., (1985) A handbook of radioactivity measurements procedures, *NCRP Report No. 58, second edition.*