Postal audit for all high dose-rate brachytherapy centres in Australia & New Zealand: lessons learned

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• CONFERENCE 2022 •

Disclosure

The presenter has advised that the following presentation is subject to **no** conflicts of interest and has **nothing** to disclose. The work has primarily been completed by **Emily Simpson-Page** who unfortunately couldn’t attend EPSM (busy passing TEAP exams!)

Some aspects of this work (e.g., design of the jig) have been presented previously at other events.

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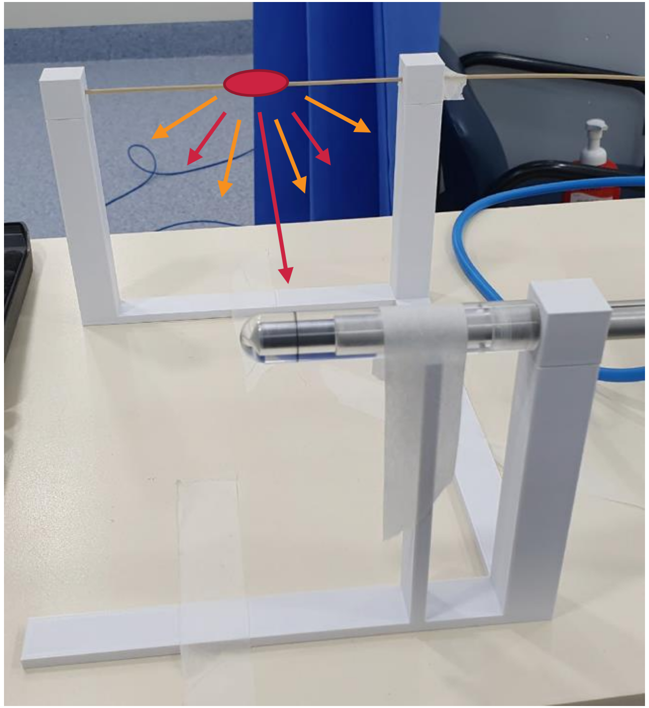
Introduction

High dose-rate (HDR) brachytherapy sources can be calibrated using an in-air method with a Farmer chamber, as an alternative to the ACPSEM recommended well chamber measurement.

This can be used as an independent check, a backup device, or for traceability to the national dosimetry standard.

The ability to use a cylindrical chamber relies on a robust, reproducible set up, a calibrated Farmer chamber and an understanding of the IAEA calibration requirements.



Introduction

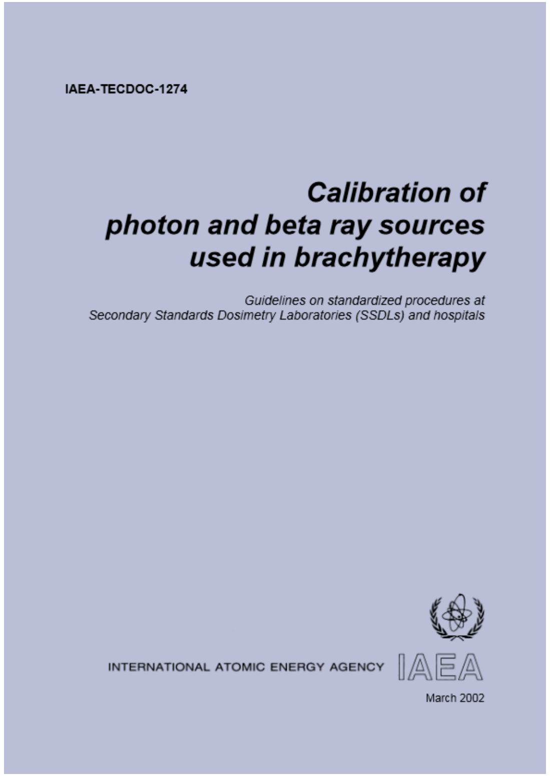
Refresher on in-air reference air kerma rates:

$$K_R = N_{K,\mathrm{Ir}} \frac{M_u}{t} k_{\mathrm{air}} k_{\mathrm{scatt}} k_n \left(\frac{d}{d_{\mathrm{ref}}}\right)^2$$

From ARPANSA calibration:

$$N_{K,\mathrm{Ir}} = \frac{\left(0.8A_{w,250\mathrm{kVp}} N_{K,250\mathrm{kVp}} + 0.2A_{w,\mathrm{Co-60}} N_{K,\mathrm{Co-60}}\right)}{A_{w,\mathrm{Ir}}}$$

From multi-distance measurements, shadow shielding or empirically calculated from room dimensions.


IAEA-TECDOC-1274

Calibration of photon and beta ray sources used in brachytherapy

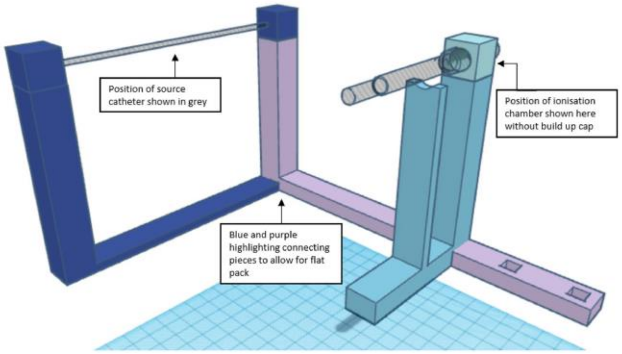
Guidelines on standardized procedures at Secondary Standards Dosimetry Laboratories (SSDLs) and hospitals

INTERNATIONAL ATOMIC ENERGY AGENCY IAEA

March 2002

Introduction

3D printed jigs can provide a cheap, easy way to set up in air measurements for HDR sources. Such a jig was designed, fabricated, and then tested across four systems in three departments in 2020. This experience was published in 2021, DOI: [10.1007/s13246-021-01050-x](https://doi.org/10.1007/s13246-021-01050-x)



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SCIENTIFIC PAPER

3D printed brachytherapy jig for Reference Air Kerma Rate calibration

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Abstract
3D printing in modern radiotherapy allows users the ability to create custom devices which can be a valuable tool for use in brachytherapy source calibration. Radiotherapy centres may verify their brachytherapy source activity with a calibrated Farmer chamber. For this purpose, a jig was designed, 3D printed and commissioned for in-air source strength calibration. Measurements on four afterloaders with varied equipment and environments were completed. A full uncertainty budget was developed and measurements with the in-air jig were consistently within 3% of the certificate source strength, and within the 4.1% combined uncertainty for comparing a well chamber measurement (1.7%) with the in air jig (3.75%). By creating a jig that is able to be customised to multiple catheter sizes and cylindrical chamber designs, centres can be provided with the option of independently checking their source strength with ease and for little cost.

Keywords Radiation therapy · Iridium-192 · Additive manufacture · Fused deposition modelling

Introduction

Radiotherapy centres that provide brachytherapy treatments should have the ability to independently verify the source strength, frequently specified as the Reference Air Kerma Rate (RAKR) and Apparent Activity, provided by the manufacturer [1]. The International Atomic Energy Agency (IAEA) recommends this verification use RAKR to specify the activity of gamma sources [2]. A number of different detector types are able to undertake this calibration though most often a well chamber is used [3, 4]. In many countries, centres are required to ship well chambers overseas for calibration, since not all local standards laboratories maintain a brachytherapy standard or provide a well chamber calibration service [5].

Because the RAKR is directly related to the dose received by a patient it is prudent to have an independent dosimetry system to check against and verify the primary method for calibration. Further to this, having an independent dosimetry system for a brachytherapy source can aid with establishing a mean ratio between the locally measured and vendor specified RAKR which can function as an early indication of problems with the calibration system [6]. Moreover, when sending well chambers overseas for calibration, centres may experience a period of time where they do not have a dosimetry system for calibrating brachytherapy sources. The ability to use a traceable calibrated Farmer chamber provides an easy solution to both challenges; the Farmer chamber can be used both to verify the well chamber measurement and to provide source calibration checks when the well chamber is not available. This method is in accordance with IAEA recommendations for using a cylindrical chamber, such as a Farmer chamber, to calibrate a brachytherapy source [2].

Where primary standards laboratories are able to calibrate cylindrical chambers at energies either side of the Ir-192 mean energy, a correction factor can be produced

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Objectives

One of the benefits of the design of this jig was that it could be easily shared by flat pack shipping or 3D printing within the local department, and if necessary could be adapted for different applicators or detectors.

Hence we decided to conduct an audit!

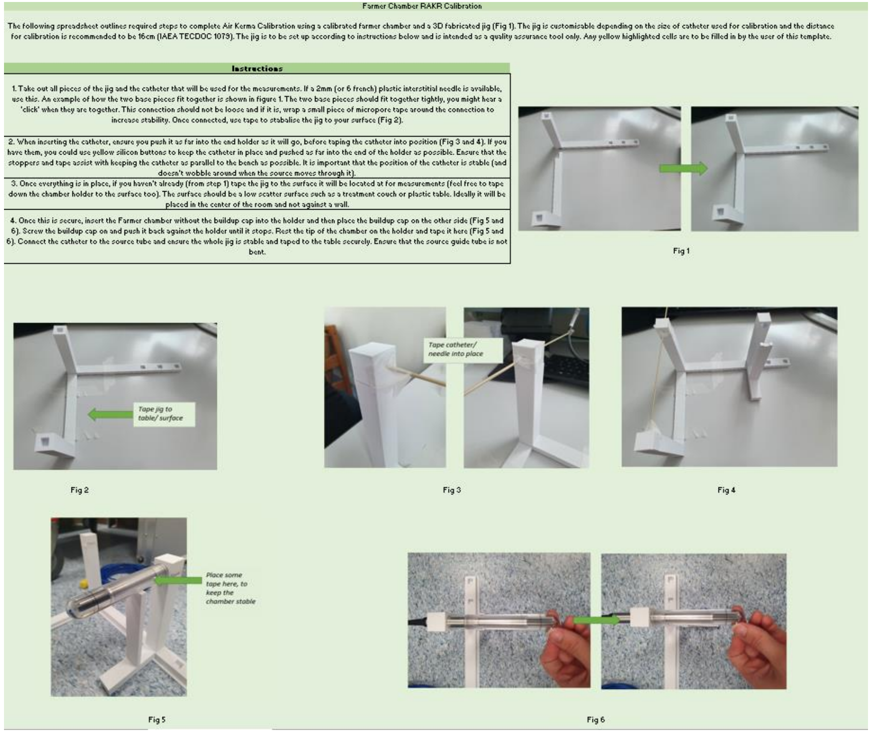
- We invited 24 Australian and New Zealand radiation oncology departments with HDR systems.
- To compare reference air-kerma rates measured using the jig and local calibrated Farmer chamber, against local Well chamber and certificate values.
- By completion of a shared audit spreadsheet, for control of methods used.

Measurements

An audit spreadsheet and 3D printed jig was distributed to departments, identified through personal networks.

Sheet included introduction and description of setup (with photos), and worksheets for:

- Determining appropriate dwell pos.
- Determining chamber corrections.
- Determining air and room scatter corrections
- Measurement of RAKR at three distances, and using Well chamber.
- Inclusion of user certificates.


Farmer Chamber RAKR Calibration

The following spreadsheet outlines required steps to complete Air Kerma Calibration using a calibrated farmer chamber and a 3D fabricated jig (Fig 1). The jig is customisable depending on the size of catheter used for calibration and the distance for calibration is recommended to be 16cm (IAEA TECDOC 1079). The jig is to be set up according to instructions below and is intended as a quality assurance tool only. Any yellow highlighted cells are to be filled in by the user of this template.

Instructions

1. Take out all pieces of the jig and the catheter that will be used for the measurements. If a 2mm (or 6 french) plastic interstitial needle is available, use this. An example of how the two base pieces fit together is shown in figure 1. The two base pieces should fit together tightly, you might hear a 'click' when they are together. This connection should not be loose and if it is, wrap a small piece of micropore tape around the connection to increase stability. Once connected, use tape to stabalise the jig to your surface (Fig 2).

2. When inserting the catheter, ensure you push it as far into the end holder as it will go, before taping the catheter into position (Fig 3 and 4). If you have them, you could use yellow silicon buttons to keep the catheter in place and pushed as far into the end of the holder as possible. Ensure that the stoppers and tape assist with keeping the catheter as parallel to the bench as possible. It is important that the position of the catheter is stable (and doesn't wobble around when the source moves through it).

3. Once everything is in place, if you haven't already (from step 1) tape the jig to the surface it will be located at for measurements (feel free to tape down the chamber holder to the surface too). The surface should be a low scatter surface such as a treatment couch or plastic table. Ideally it will be placed in the center of the room and not against a wall.

4. Once this is secure, insert the Farmer chamber without the buildup cap into the holder and then place the buildup cap on the other side (Fig 5 and 6). Screw the buildup cap on and push it back against the holder until it stops. Rest the tip of the chamber on the holder and tape it here (Fig 5 and 6). Connect the catheter to the source tube and ensure the whole jig is stable and taped to the table securely. Ensure that the source guide tube is not bent.

Fig 1

Tape jig to table/ surface

Fig 2

Tape catheter/ needle into place

Fig 3

Fig 4

Place some tape here, to keep the chamber stable

Fig 5

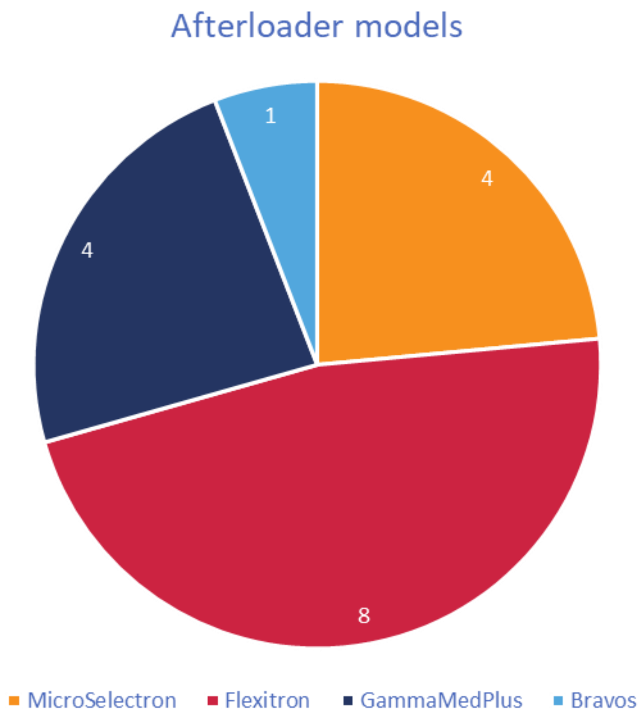
Fig 6

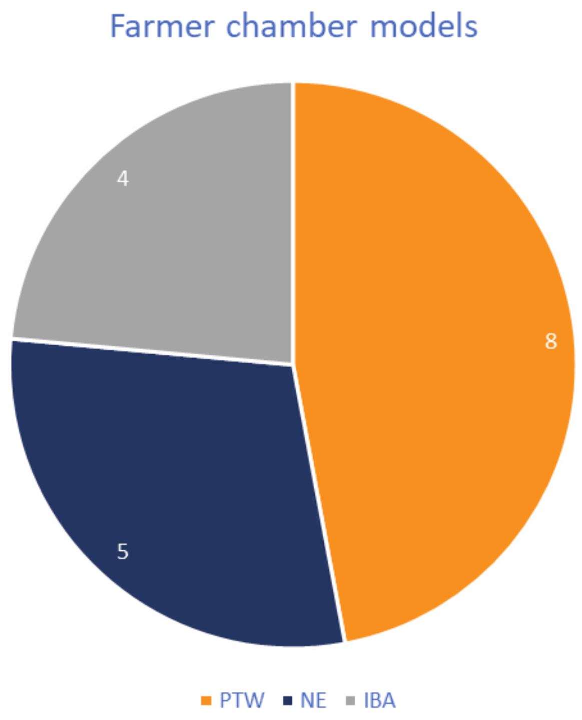
Audit results

As of October 2022, 17 Australian and New Zealand departments had completed the audit and provided results. A further 5 departments had been sent the jig. 2 others had not agreed to participate. Overall, the audit ran for around 14 months – Emily has no longer been actively following up the remaining sites.

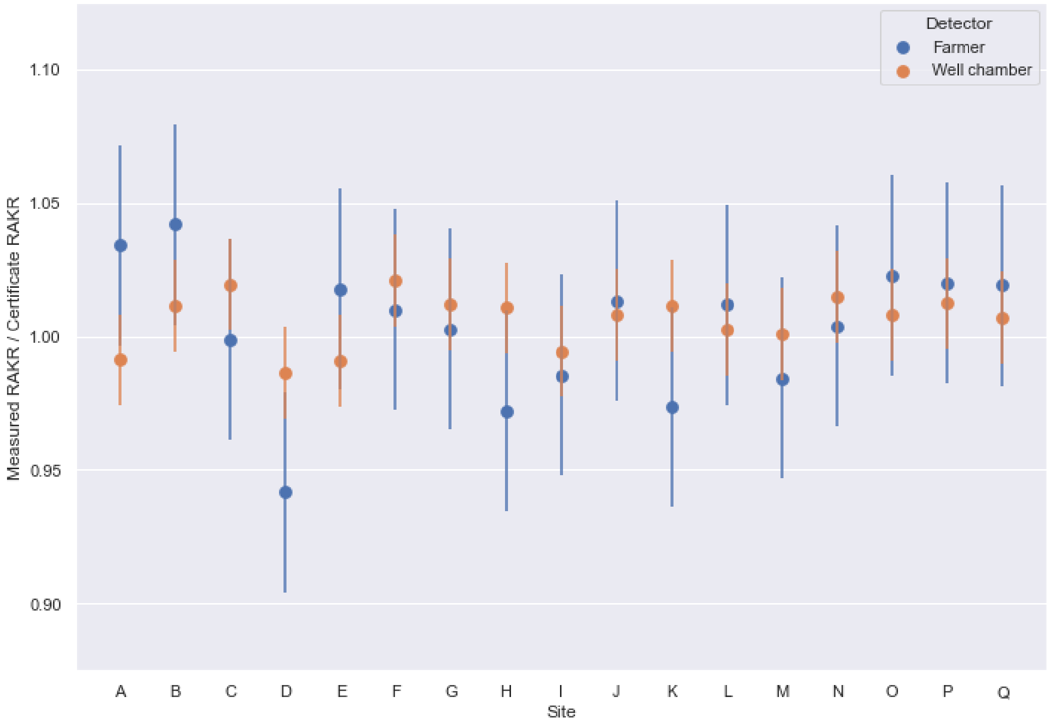
The audit was a joy to manage! Everyone who I reached out to responded positively, and it was a great way to show how collaborative and helpful the Australia & New Zealand Medical Physics workforce is.

Audit results





Audit results



Uncertainties estimated based on published RBWH data (k=2)

- Farmer: 3.8%
- Well chamber: 1.7%

Mean absolute errors:

- Farmer: 2.0%
- Well chamber: 1.0%

Generally consistent, though one Farmer measurement differed by >5% from certificate.

User feedback

Efficiency could have been improved by requesting fewer measurements (e.g. k_{pol} and k_s were requested although not applied for MEX and Co-60 ARPANSA calibrations).

Users had mixed opinions on measurement of transit dose, some feeling that it was good to characterise it, but others suggesting a measurement with source in place.

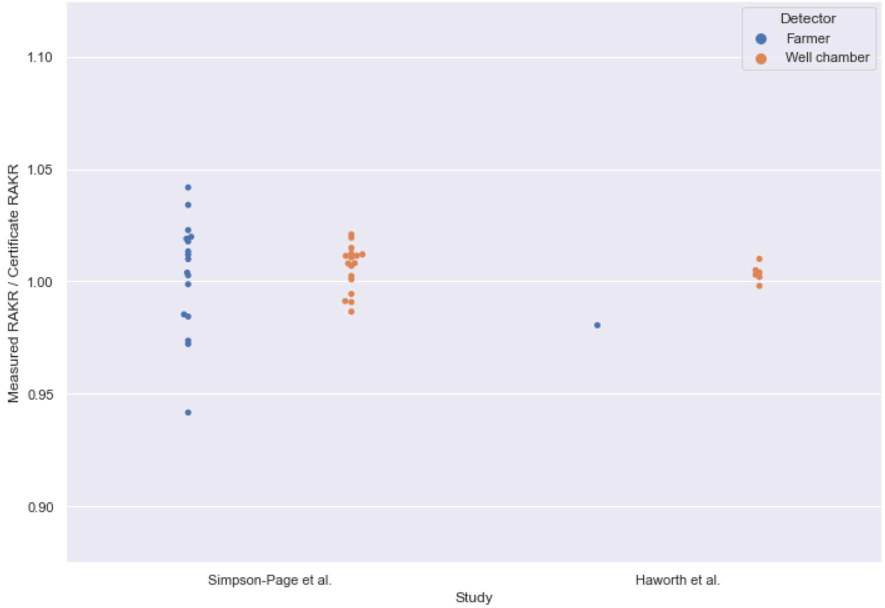
Issues with jig stability and fitting NE2571 chamber (jig designed for PTW).

If I could go back and start again, I would make the spreadsheet even more robust and have it go through more user testing before sending it out, as some of this was done 'on the fly' as user feedback came back

Discussion

The results observed in this study were reasonably consistent with Haworth et al.'s 2013 audit, where:

- The mean absolute error for Well chamber measurements compared to calibration certificates was 0.6%
- The single Farmer chamber measurement had increased disagreement from certificate.



Conclusion

Farmer chamber measurements provide an independent check of Well chamber measurements, traceable to the Co-60 and MEX standards at ARPANSA, albeit with a greater uncertainty.

The increased uncertainty manifests as an increased mean absolute error from calibration certificate values.

Future work will include k_{scatt} evaluation against multiple distance calculations.

The feedback received from the volunteer centres can be used to optimise the jig and measurement process. There is potential for use of the jig in further postal audits and dosimetry intercomparisons.

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