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# The Australian MRI-Linac Program: measuring profiles and PDD in a horizontal beam

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# The Australian MRI-Linac Program: measuring profiles and PDD in a horizontal beam

## Abstract

The Australian MRI-Linac consists of a fixed horizontal photon beam combined with a MRI. Commissioning required PDD and profiles measured in a horizontal set-up using a combination of water tank measurements and gafchromic film. To validate the methodology, measurements were performed comparing PDD and profiles measured with the gantry angle set to 0 and 90° on a conventional linac. Results showed agreement to within 2.0% for PDD measured using both film and the water tank at gantry 90° relative to PDD acquired using gantry 0°. Profiles acquired using a water tank at both gantry 0 and 90° showed agreement in FWHM to within 1 mm. The agreement for both PDD and profiles measured at gantry 90° relative to gantry 0° curves indicates that the methodology described can be used to acquire the necessary beam data for horizontal beam lines and in particular, commissioning the Australian MRI-linac.

## Keywords

pdd, beam, profiles, horizontal, measuring, program:, mri-linac, australian

## Disciplines

Engineering | Science and Technology Studies

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# The Australian MRI-Linac Program: measuring profiles and PDD in a horizontal beam

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**Abstract.** The Australian MRI-Linac consists of a fixed horizontal photon beam combined with a MRI. Commissioning required PDD and profiles measured in a horizontal set-up using a combination of water tank measurements and gafchromic film. To validate the methodology, measurements were performed comparing PDD and profiles measured with the gantry angle set to 0 and 90° on a conventional linac. Results showed agreement to within 2.0% for PDD measured using both film and the water tank at gantry 90° relative to PDD acquired using gantry 0°. Profiles acquired using a water tank at both gantry 0 and 90° showed agreement in FWHM to within 1 mm. The agreement for both PDD and profiles measured at gantry 90° relative to gantry 0° curves indicates that the methodology described can be used to acquire the necessary beam data for horizontal beam lines and in particular, commissioning the Australian MRI-linac.

## 1. Introduction

The Australian MRI-Linac Program [1] is developing a 1 T split-bore MRI/6 MV linac using a Varian Linatron-MP (Palo Alto, USA) horizontal 6 MV beam. The design of the system permits the beam orientation to be either perpendicular or parallel to the main magnetic field but operating in a fixed horizontal axis. The fixed horizontal beam presents a challenge for beam data collection in the Scanditronix Wellhofer Blue Water Tank Phantom (IBA-Dosimetry, Germany, herein referred to as the water tank). This work presents the methodology used to measure large field profiles and PDDs for a horizontal beam. The methodology was validated by comparing beam data from an Elekta Synergy (Stockholm, Sweden) measured at gantry 0 and 90°.

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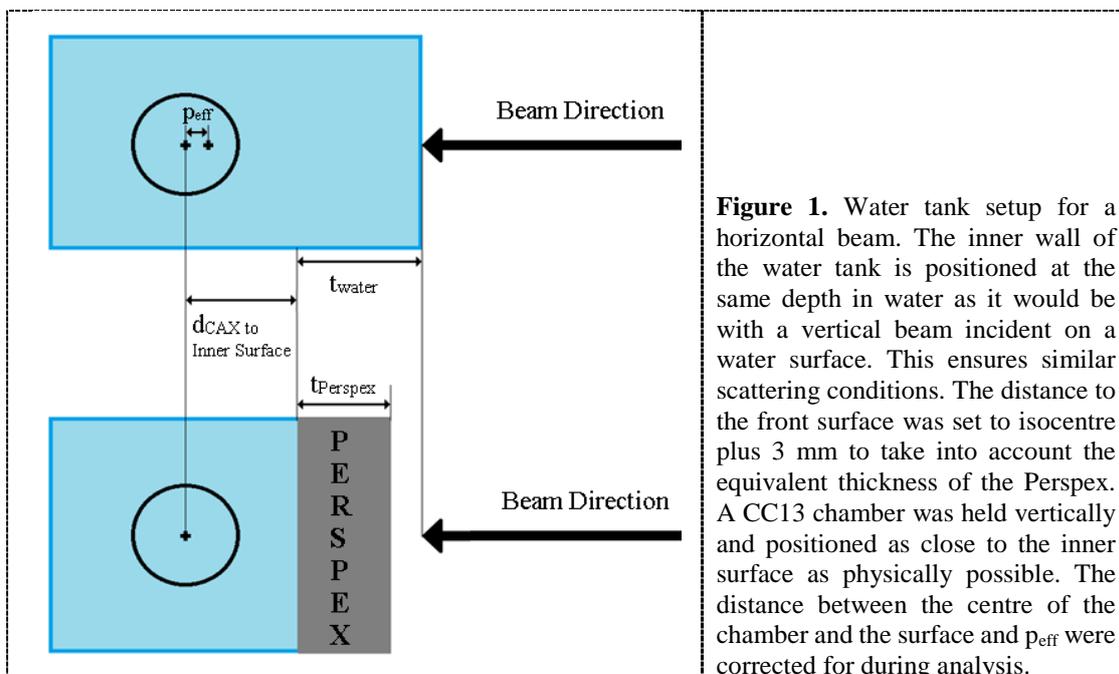


## 2. Method

To validate measurements made in a horizontal geometry, a CC13 ionisation chamber was used to compare PDD and profiles measured at gantry 0 and 90°. The long axis of the chamber was orthogonal to the radiation beam axis for both geometries. For gantry 0° measurements, the water tank was set-up following standard procedures [2] and effective point of measurement,  $P_{eff}$  [3], corrections applied in software.

For gantry 90° measurements, the water tank was aligned to the origin markings using lateral room lasers and the level of the tank and rails adjusted until level. The outer tank surface was set up at the isocentre distance plus 3 mm to take into account the effective wall thickness of the tank ( $t_{Perspex} = 15$  mm equivalent to 17.9 mm water)(figure 1). A CC13 chamber (IBA-Dosimetry, Germany, s/n: 11261) was held vertically using an in-house built chamber holder and the software origin position set as close to the inside surface of the tank as possible. An identical reference chamber (s/n: 11262) was placed on the outside of the tank. An alignment cap was used to check the coincidence of the ion chamber with lasers along both the inplane and crossplane axes. The distance between the central axis of the chamber and the inside surface of the wall was measured ( $d_{CAX\ to\ Inner\ Surface}$ ). Corrections for the wall thickness, central axis offset from the inside of the window and effective point of measurement in the chamber ( $p_{eff} = 1.8$  mm) were applied post acquisition. An analysis of the uncertainties in the horizontal methodology is shown in table 1. PDD and profiles at depths of 50, 100 and 200 mm were acquired and compared via the full width half maximums (FWHM) and calculations of the flatness and symmetry following IEC methods [4].

For build-up region data in the horizontal beam, Gafchromic® EBT3 film (International Specialty Products, USA) was placed horizontally in solid water and irradiated using a horizontal beam. The film were scanned on a EPSON V700 scanner (Seiko Epson Corp, Japan) and calibrated via optical density in RIT (Radiological Imaging Technology Inc, USA) with no filtering or smoothing applied. A PDD was acquired from the film scan and appended to water tank data to show the build up region. The PDDs from the water tank and gafchromic film were normalised to each other at 5 cm depth. The maximum of the film was then used to normalise the combined PDD to  $d_{max}$ .



**Table 1.** Uncertainty budget in water tank alignment.

Uncertainty in Alignment of Water Tank	X-axis (mm)	Y-axis (mm)	Z-axis (mm)
<b>Alignment of water tank</b>			
Align water tank marks at front and back to lasers. Refraction of lasers through air/PMMA/air is negligible	-	-	-
Correct Distance ( $\pm 1.0$ mm)			1.0
Water tank level ( $\pm 0.1$ °)	0.87	0.87	0.87
Rail movement mechanism level ( $\pm 0.1$ °)	0.87	0.87	0.87
<b>Alignment of chamber</b>			
Alignment of chamber to laser ( $\pm 2$ mm) - Chamber can shift by approximately the thickness of the laser across the entire movement in the water tank $\sim 500$ mm	2	2	2
<b>Filling with water</b>			
Re-adjusting height – Check alignment of tank. Uncertainty already included.	-	-	-
Alignment of chamber to laser - Checked, but is included in prior uncertainty	-	-	-
<b>Scanning Accuracy</b>			
Accuracy of movement - assessed by moving tank to known positions over large travel distances and reading out position in software ( $< 0.5$ mm)	0.5	0.5	0.5
<b>Total Uncertainty</b>	<b>2.4</b>	<b>2.4</b>	<b>2.6</b>

### 3. Results

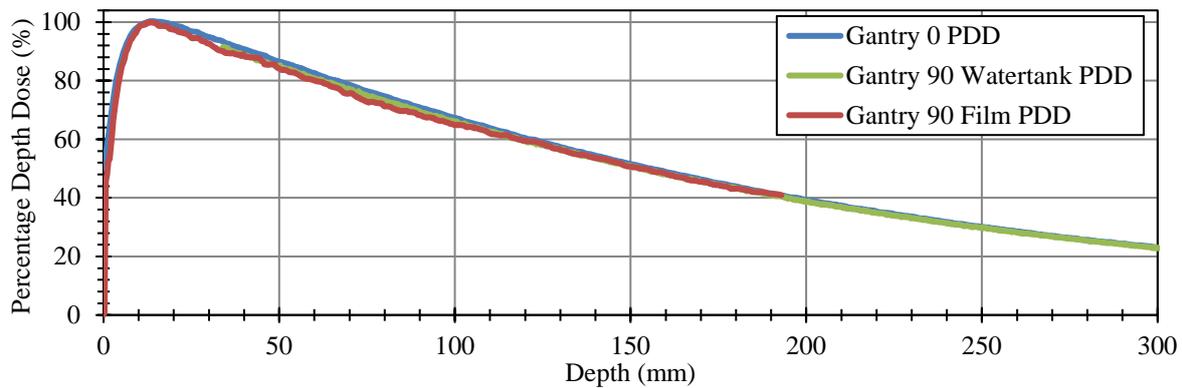
A comparison of PDD and profiles measured in Gantry 0 and 90° geometries is shown in figures 2 and 3, respectively. Comparison of the combined water tank and gafchromic PDD measured at gantry 90° relative to the reference gantry 0° PDD showed agreement to within 2.0%. Increased uncertainty is associated with merging of the gafchromic and water tank curves together to measure the full gantry 90° PDD. Profiles acquired at multiple depths showed good agreement with both inplane and crossplane FWHM, agreeing to within 1 mm for all depths. Flatness and symmetry were within 1.1 % of each other for both inplane and crossplane profiles at all depths.

Aligning the water tank to the correct distance is limited by the resolving ability of the laser distance measurement device. Additionally, the bulge of the water tank window when the tank is filled with water needs to be accounted for. Chamber alignment uncertainty is predominately caused by the thickness of the laser. Improved precision could be achieved with a thinner laser. A limitation in our methodology is the use of the relatively thick entrance window for our horizontal beam geometry. The calculated uncertainty in water tank alignment does not include any uncertainties due to detectors.

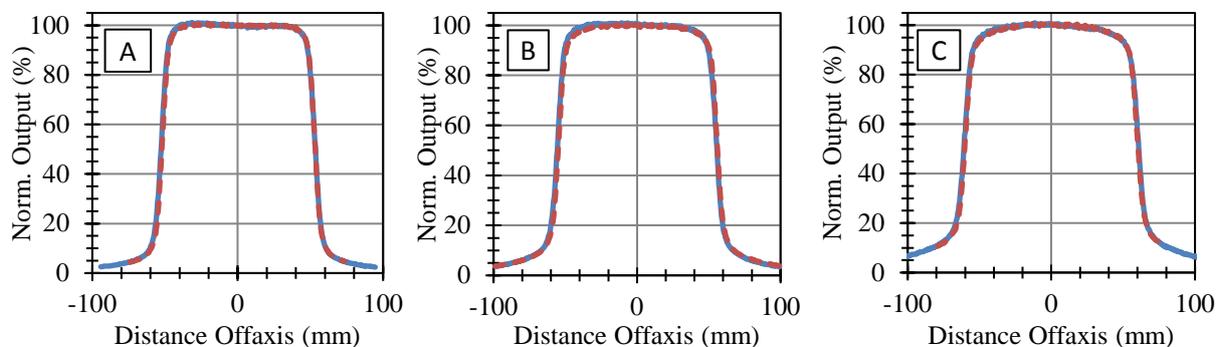
Positional uncertainty in film measurements was minimised by carefully placing the edge of the film parallel to the edge of the solid water block which was perpendicular to the direction of the beam. Due to scanner size limitations, the film long axis was placed parallel to the light source movement, which has previously been shown to cause variation in measured optical density [4]. Improved film dosimetric accuracy could be achieved by appropriate orientation of the film in the scanner, however this would restrict the depth to which the PDD can be measured.

### 4. Conclusion

The agreement observed between the PDD and profiles acquired in the two different geometries indicates the methodology described can be used to undertake dosimetry measurements with horizontal beams consistently as necessary for the Australian MRI-linac program.



**Figure 2.** Comparison of PDD measured at Gantry 0 and 90°



**Figure 3.** Inline profiles measured in a water tank with the Gantry at 0 ° (Blue Solid line) and 90 ° (Red Dashed line) for depths of A) 50, B) 100 and C) 200 mm depth.

## 5. Acknowledgements

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