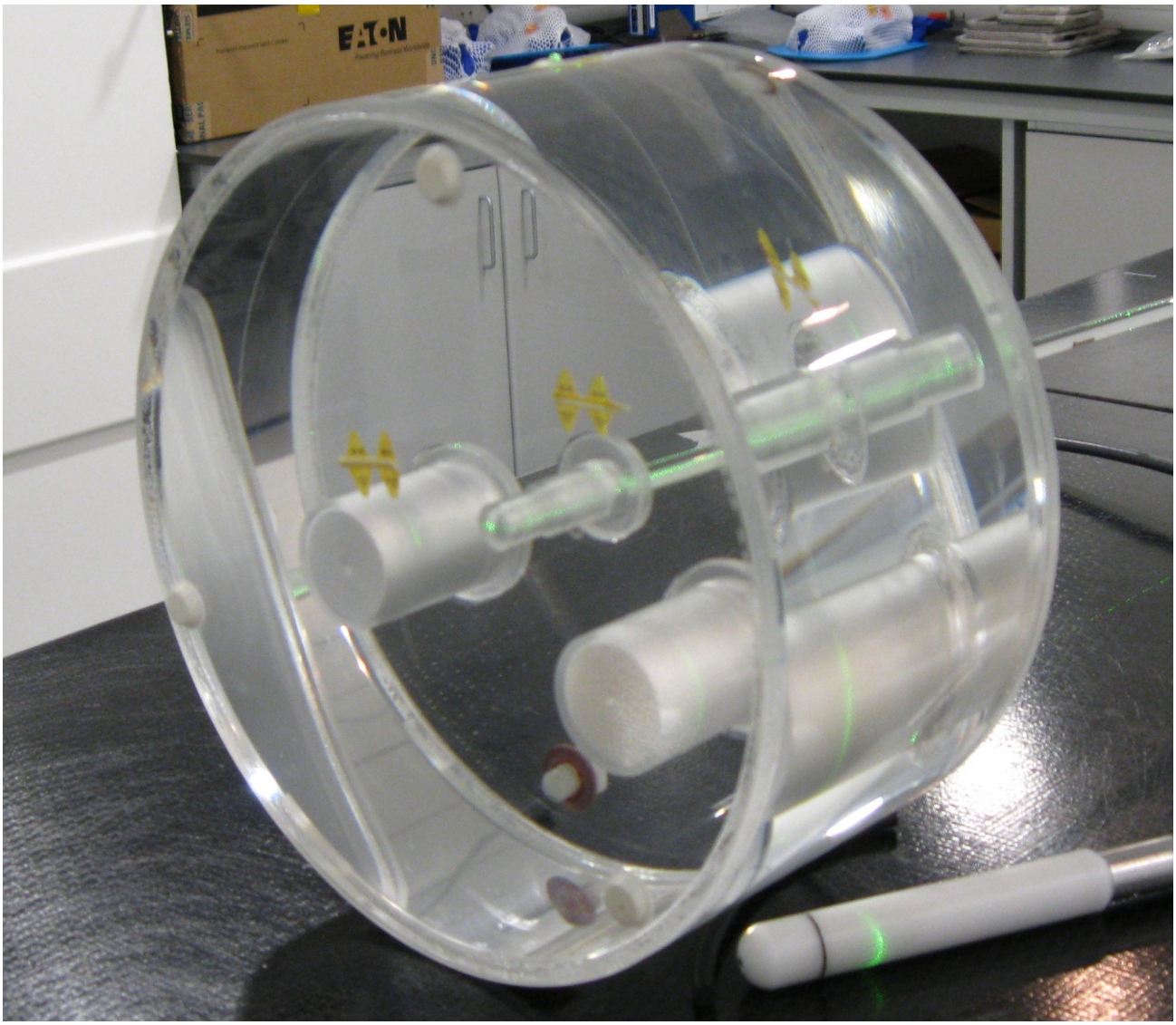
Micro-Phan

for Rapid Audit of
MV Photon dose delivery.

User Guide



1. Contents.

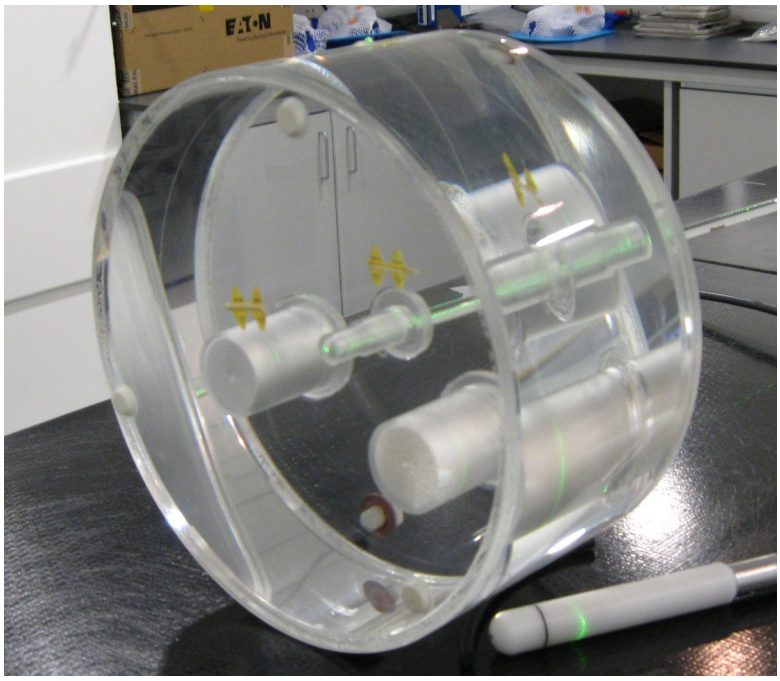
Section

2. Overview.

All the Stages of the Treatment process; CT imaging, Target and Critical Organ delineation, Dose prediction, Treatment parameter transfer and Machine performance contribute to the Treatment Dose. Audit is recognised as an exemplary method to evaluate treatment delivery systems and methods and provide confidence [1-3]. Audit can be performed with a simple phantom to verify and provide assurance that the dose delivered is within acceptable limits from that prescribed. Audit is of great value for clinical trials although it can require considerable manpower and equipment costs to implement. Nevertheless the routine use of audit, often on an individual patient basis to verify the accurate delivery of complex treatments is actively undertaken in well resourced facilities. For rapid Audit a low cost audit method is possible with a Micro-Phantom which enables the process from CT imaging through to dose delivery to be audited very quickly, with a minimum of time and equipment to provide confidence in the Treatment process.

The Micro-Phantom consists of three features.

1. A compact cylindrical drum which can be water filled to provide a body of uniform material density within which heterogeneous inserts can be inserted and a cavity located on the axis of rotation of the phantom at which dose measurements are made. A scribed line around the phantom identifies the Central Slice upon which the treatment should be planned.
2. Two cylindrical cavities into which calibrated heterogeneous drums can be inserted. The location of these cavities are positioned to ensure separation between applied fields which intersect on the location of the dose measurement cavity located on the axis of rotation of the phantom.
3. A cavity on the axis of rotation of the phantom with the cavity profiled to receive a Farmer 2571 type chamber and enable absolute dose measurements to be made directly. The scribed line around the phantom is coincident with the measurement point of the ionisation chamber.



3. Audit using the Micro-Phantom.

All the Stages or a sample of the Stages which constitute the Treatment process; CT imaging, Target and Critical Organ delineation, Dose prediction, Treatment parameter transfer and Machine performance can be audited with the Micro-Phantom. The essence in using the phantom is that it is treated by the appropriate staff groups in the same manner as would be done for a patient.

3.1. Phantom Presentation.

The phantom should be labelled as required: Left, Right, Superior and Inferior prior to being presented to the first staff group for treatment. This enables the treating staff to prepare, orient the phantom and specify the treatment beams as would be undertaken for a patient in the treatment process.

3.2. Treatment Planning.

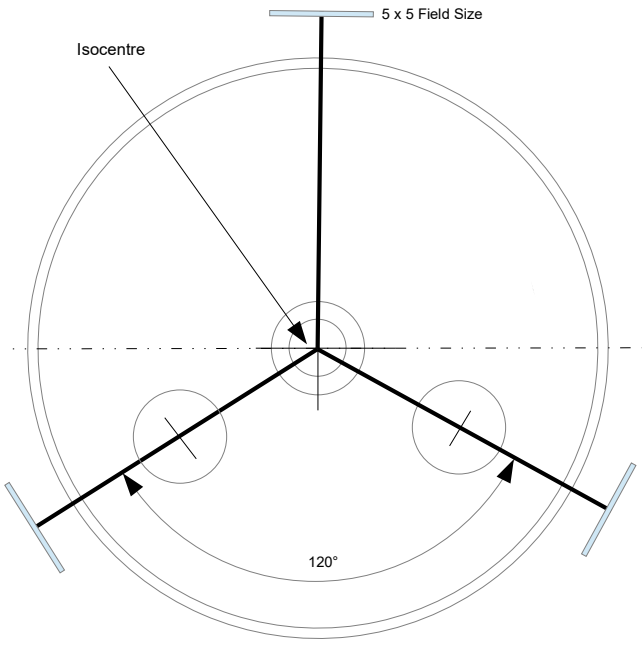
The phantom should be oriented in the CT scanner so that the axis of the cylinder is coincident with the axis of the cylindrical bore of the CT scanner to provide circular slices of the phantom. Once the phantom is rotated to the desired orientation, it can be stabilised by pushing the rubber rods tight between the phantom and the couch-top.

A scribed line around the phantom identifies the Central Slice upon which the treatment should be planned. The transverse laser should align with that scribed line. The Central Slice is coincident with the measurement point of the chamber. Since the phantom is transparent the isocentre position indicated by the lasers should be aligned with the centre of the cavity for the chamber.

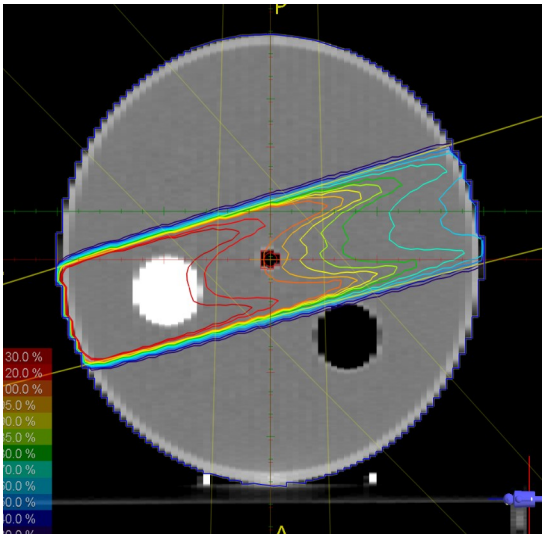
Treatment markers such as Beekley's can then be placed on the surface of the phantom as in normal practice for scanning, treatment planning and treatment set-up.

Along with the insert for the ionisation chamber there are two inhomogeneity inserts, centred at a distance of 50mm from the centre of the phantom along radii separated by an angle of 120°. These inserts are commercially available with certified electron densities which lie at the extremes of the clinical range encountered. One is representative of Inhaled Lung with electron density of 0.25 relative to water and the other is representative of Cortical Bone with an electron density of 1.69 relative to water.

Irradiation of the phantom is predicted in the Treatment Planning System using the image set acquired from the CT scan of the phantom. The isocentre is placed at the centre of the phantom which is the location of the ionisation chamber and 5cm x 5cm beams are applied to deliver a specified dose to the isocentre. A typical dose from each beam would be 200cGy. The beam arrangement is chosen to evaluate the traversal through the inserts, see Figure below.



The Treatment Planning System dose prediction will visually indicate that the effect of the inhomogeneity insert is being accommodated by the TPS, as shown on the right.



However although this indicates that inhomogeneity correction is implemented in the TPS it requires dose measurements to ensure that the calibration table in the TPS was accurate as can be seen from the following example.

The measured dose in the table below indicates a 17.5% difference from the dose expected. In this example, that difference was due to the incorrect calibration of the TPS for CT images. Correction of this fault eliminated the difference.

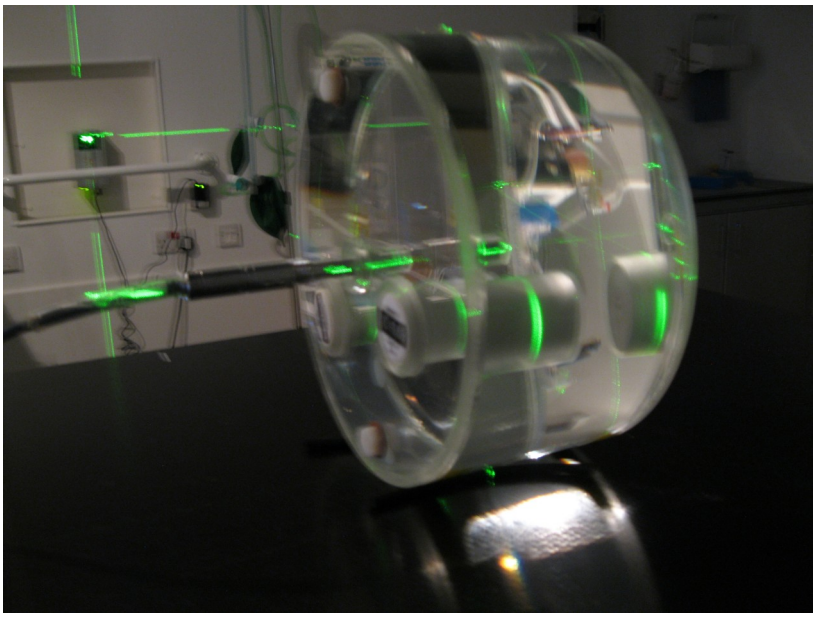
Beam	Inhomogeneity	MU	Measured Dose cGy	Difference due to Inhomogeneity	Difference to 200cGy
1	None	276	193.4	-	-1.7%
2	Inhaled Lung	259	192.6	-0.6%	-2.1%
3	Cortical Bone	349	227.2	17.5%	15.5%
Overall			613.2	-	3.9%

3.3. Treatment Data Transfer.

The Monitor Units calculated by the Treatment Planning System along with the machine parameters such as gantry and diaphragm orientation, field size etc. can then be transferred through the Patient Management System to the Treatment Machine.

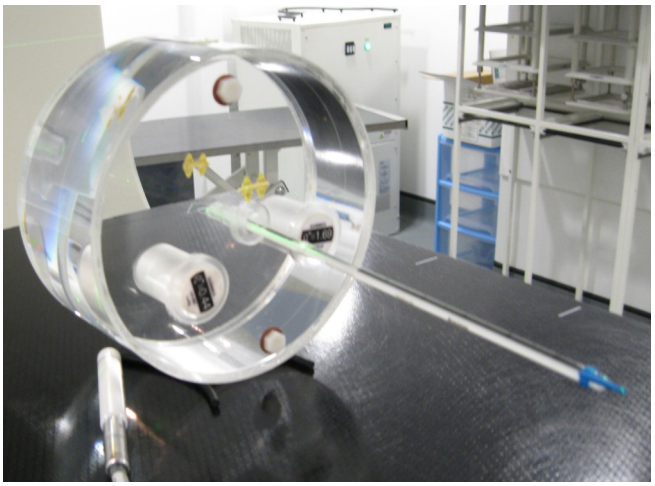
3.4. Treatment Delivery.

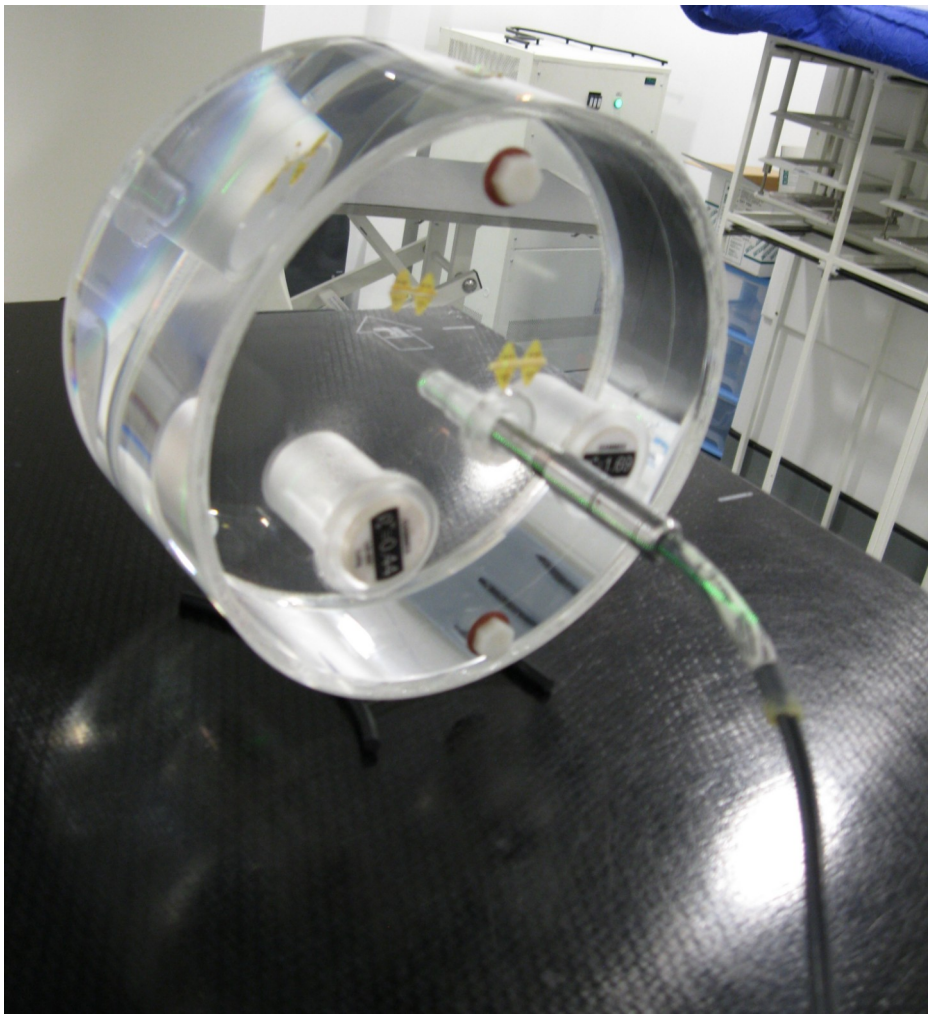
The phantom is set up on the Treatment Machine as described by the Patient Data Management System and the absolute dose which is delivered can then be independently measured during a simulated treatment delivery.



3.5. Dose Measurement.

A Farmer type 2571, 0.6cc chamber is inserted into the cavity on the axis of rotation of the phantom. This chamber and the electrometer used should ideally be independent of the dose measurement equipment used routinely on the treatment unit or at the Centre. .





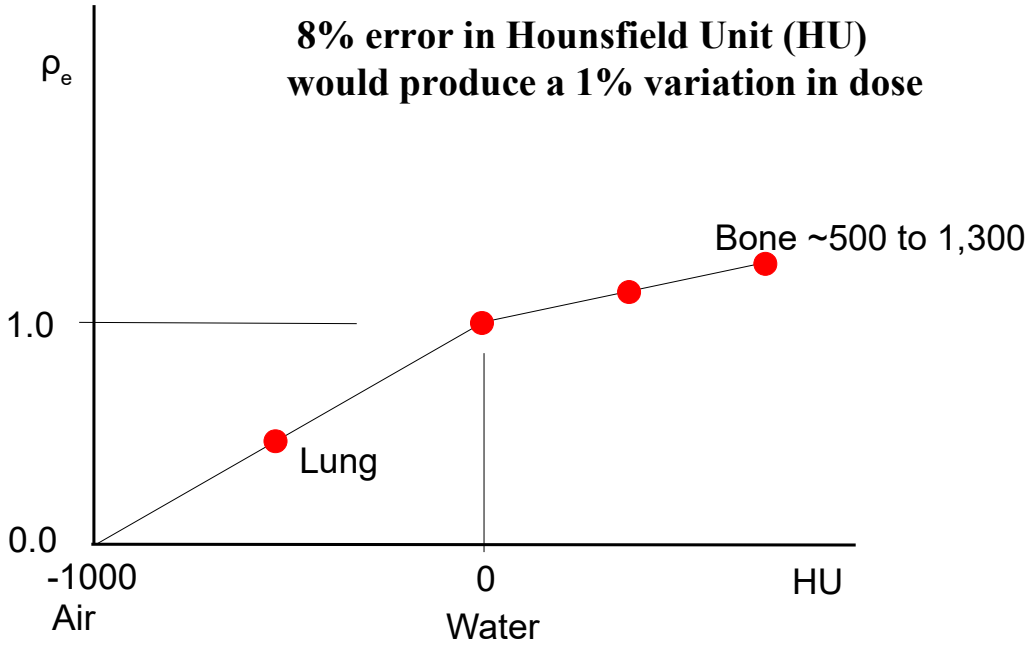
The dose measured is sensitive to several aspects critical to safe and accurate dose delivery such as the CT Scanner, the Treatment Planning System dose prediction, output factors, the calibration of the machine output, the setting up of the phantom on the machine and the parameter transfer via the Patient Management System.

4. CT Calibration using the Micro-Phantom.

It has been reported that an 8% error in Hounsfield Unit (HU) or CT number would produce a 1% variation in dose [4]. In a recent study on the effect of the CT imaging protocol it was reported that the variation in predicted dose does not exceed 1.5% for variations in HU of up to 20% [5]. In addition the bi-linear nature of the CT calibration curve for electron density is well established. These two aspects indicate that confidence in the dose prediction accuracy can be assured with a simple measurement at the extremities of the Calibration curve, coupled with confirmation that the data stored in the Treatment Planning System is bi-linear simply by inspection.

The phantom should be aligned in the CT scanner so that the axis of the cylinder is coincident with the axis of the cylindrical bore of the CT scanner to provide circular slices of the phantom.

The two inhomogeneity inserts, centred at a distance of 50mm from the axis of the phantom along radii separated by an angle of 120°. These inserts are commercially available with certified electron densities which lie at the extremes of the clinical range encountered. For example Inhaled Lung with electron density of 0.44 relative to water and Cortical Bone with an electron density of 1.69 relative to water. The range of the calibration of the CT scanner for electron density against Hounsfield Unit for dose prediction can be routinely checked using scans of these inserts in the micro-phantom.



5. Spatial Accuracy and Uniformity using the Micro-Phantom.

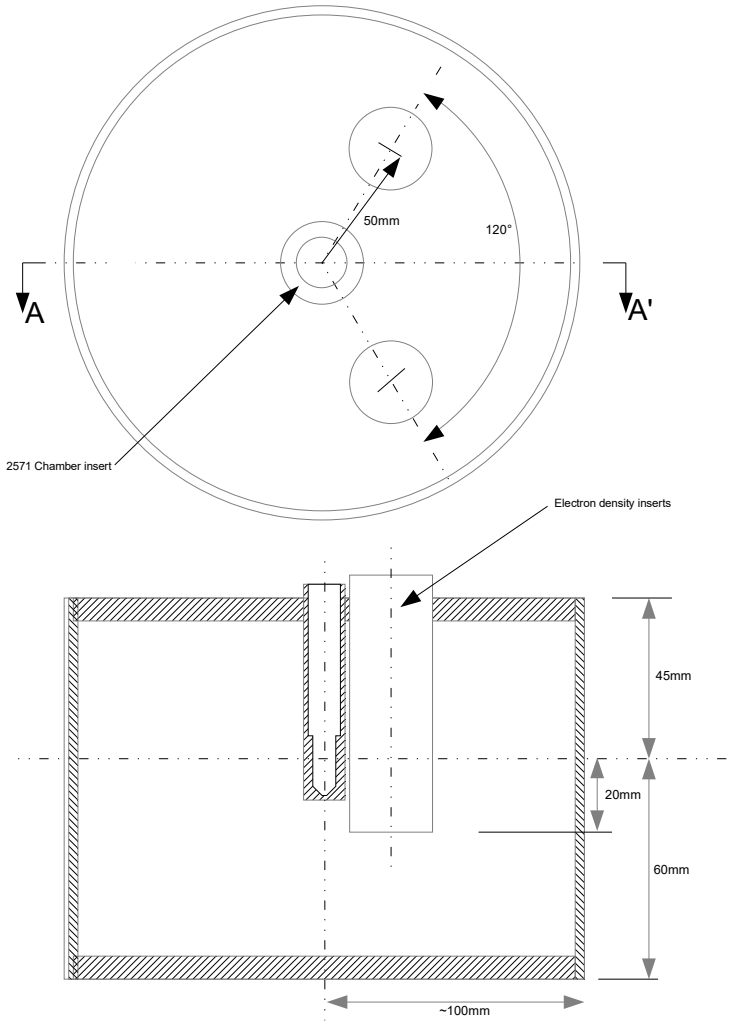
Longitudinally the phantom measures 105mm which is of sufficient length beyond the inhomogeneity inserts to provide a uniform CT slice image. The Uniformity of the CT scanner can be checked with any local protocol using the mean and standard deviation of regions of interest across the uniform slice. Likewise the dimensional accuracy of the images can be checked against the known size of the phantom with the measurement tool on the CT scanner and to ensure accurate data transfer also on the Treatment Planning System.

6. Glossary.

CT	Computed Tomography
HU	Hounsfield Units, which is the parameter displayed as the intensity in a CT image.
Electron density	A measure of the number of electrons per unit volume of space. Essential for dose prediction at Megavoltage energies.
Inhaled Lung	The lung when the diaphragm is moved, chest expanded and the lung expands and fills with air.
Cortical Bone	Dense bone with higher calcium content than trabecular bone.
Farmer 2571 Chamber	A widely used 0.6cc graphite walled thimble ionisation chamber
Uniformity	The variation in the Hounsfield Units across a region of an image, usually quantified as mean and standard deviation of the HU in the region.
Critical organ	Tissue and/or organs which it is desirable to avoid or minimise irradiating during treatment.
Dose prediction	Calculation of the Dose within the patient prior to treatment in order to predict the optimum treatment.
Central Slice	The CT image usually chosen to be close to the centre of the Target and in which the central axis of the radiation beams are positioned and in which the most accurate dose prediction is achieved.

7. Specification.

Diameter	mm	200
Length	mm	105
Material	-	PMMA
Main wall thickness	mm	4
Insert wall thickness	mm	3
Weight empty	kg	0.5
Weight filled	kg	3.3
Insert diameter	mm	29
Insert length	mm	70
Low electron density Insert		~ 0.25
High electron density Insert		~ 1.69



8. References.

1 Izewska J and Andreo P. The IAEA/WHO TLD postal programme for radiotherapy hospitals. Radiother Oncol 2000, 54: 65-72.

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3 Izewska J, Azangwe G and Bera P. 40 years of the IAEA/WHO TLD postal dose audit for radiotherapy. SSDL Newsletter. IAEA, Vienna, Austria. 2010; 58: 17-23.

4 Thomas S J. Relative electron density calibration of CT scanners for radiotherapy treatment planning. Br J Radiol 1999; 72:781-786.

5 Zurl B, Tiefling R, Winkler P, Kindl P and Kapp K S. Hounsfield units variations. Impact on CT-density based conversion tables and their effects on dose distribution. Strahlenther Onkol 2014; 190: 88-93.

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