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Development of NIM in water calorimeter for absolute determination of absorbed dose to water

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INTRODUCTION

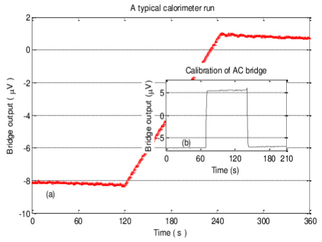
Water calorimeter has been widely used as an important tool for absolute determination of absorbed dose to water in the National Metrology Institutes (NMIs). The NIM primary standard water calorimeter follows the design of the NRC water calorimeter, which is operated at a water temperature of 4 ℃, and is designed for use in high-energy photon beams. In order to further meet the requirement of absorbed dose to water in clinical electron beams, NIM began to continuously improve and upgrade the current water calorimeter.

AIM

Development of a new plane-parallel glass vessel and thermistor probes to upgrade the water calorimeter currently suitable for high-energy photon beams, and then used to carry out absorbed dose to water in accelerator electron beams.

METHOD

Replace the original calorimeter core with new plane-parallel glass vessel and thermistor probes to form upgraded water calorimeter. This upgraded water calorimeter was used to measure the absorbed dose to water in accelerator photon beams, and compared with the water calorimeter previously involved in the K6 comparison organized by the Bureau International des Poids et Mesures (BIPM).



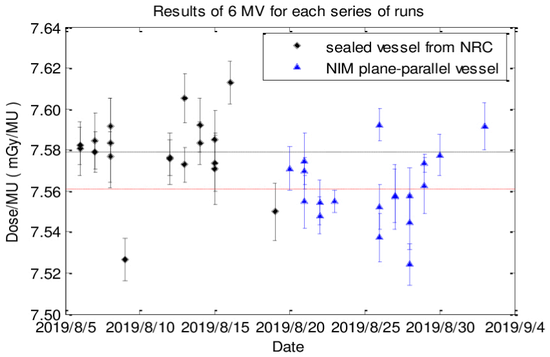
Typical irradiation run obtained using the NIM 6MV photon beams in (a), the uncorrected voltage signal was 9.377 μV and the water temperature was 3.983 ℃measured by three Pt-100 probes. The response to a 1 Ω increase in the decade box resistance is shown in (b), the uncorrected voltage signal was 12.801 μV, and the water temperature was 4.059 ℃.

RESULTS

The new thermistor probes have been developed in NIM, which is 10% more sensitive than current thermistor probes. A new plane-parallel vessel is made in NIM, increasing the measurement depth range of the current water calorimeter.

Calorimetry measurements made at 6 MV, 10 MV and 25 MV with two different calorimeter core are consistent within an uncertainty of 0.32%.

The ratios of the cylindrical sealed vessel with probes 1,2 and the new plane-parallel vessel with new probes are 1.002 at 6 MV, 1.002 at 10 MV and 1.000 at 25MV after correction for the vessel perturbation and other related corrections.



Results obtained using the NIM Elekta synergy 6MV. Each datum point is the average of 10 individual runs. The uncertainty bars show the type A standard uncertainty on the average value. The results represented by black diamond were obtained using NRC cylindrical vessel with probes 1 and 2, while those represented by blue upper triangle were obtained using NIM plane-parallel vessel with NIM thermistor probes. The horizontal double dotted and dashed line are the mean values for cylindrical vessel and NIM plane-parallel vessel, respectively. The results are presented as the absorbed dose rate to water, normalized to the mean value of PTW TM30012

Uncertainty budget (in %) of the absorbed dose to water determination in accelerator photon beams using water calorimeter.

Source and type of uncertainty	Sealed cylindrical vessel	New plane-parallel vessel
Type A		
Reproducibility ΔT/MU	0.08	0.08
Reproducibility linac monitors	0.10	0.10
Type B (Calorimeter related quantities)		
Specific heat capacity	0.01	0.01
Thermistor sensitivity	0.08	0.06
Heat conductive	0.10	0.13
Vessel perturbation	0.10	0.10
Profile non-uniformity	0.06	0.06
Density of water	0.02	0.02
Heat defect	0.15	0.20
Positioning calorimeter, probes and vessel	0.12	0.12
Combined uncertainty	0.29	0.32

CONCLUSIONS

At NIM, the water calorimeter was developed with plane-parallel vessels and thermistor probes. To obtain a low standard uncertainty, the different quantities influencing measurements results are considered. The results were verified by extensive comparisons between cylindrical vessel and NIM plane-parallel vessel.

The results show that the new plane-parallel vessel with the new thermistor probes can be used to measure the absorbed dose to water in accelerator photon beams. Reduce the minimum measuring depth of the current calorimeter to 1.8 cm. Furthermore, this upgraded water calorimeter will be applied to the measurement of absorbed dose to water in clinical electron beams.

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