Design of a water calorimeter for medium energy x-rays; A status report

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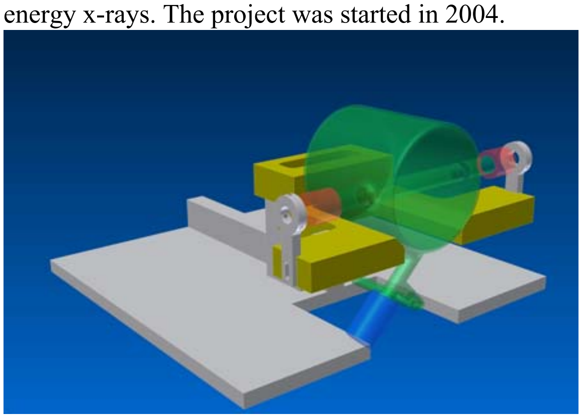
Introduction

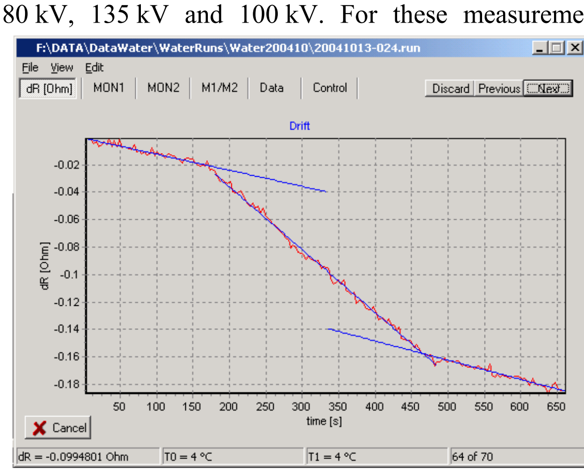
As a follow-up of the portable NMi watercalorimeter for high-energy gamma rays and ^{60}Co-radiation (CCRI(I)/03-35), it was decided to design a water calorimeter as a new primary standard for medium energy x-rays. The project was started in 2004.



The absorbed dose to water can be measured directly by measuring the temperature changes of the water due to the irradiation. To do so, a detection cell of glass was designed. In the detection cell, two thermistor probes are inserted. With these thermistor probes, the temperature changes due to the incoming x-radiation are measured. The cell is filled with ultra pure water, saturated with argon. In the figure, a schematical overview of the detection cell and its holder is shown. The detection cell in its holder is placed in a water phantom of 30×30×30 cm^3 filled with demineralized water. The water phantom is surrounded by several layers of insulating material and a heat exchanger, to keep the water at 4 °C. At this temperature, the density of water is almost temperature independent, and there is no convection.
The IAEA protocol [1] requires that the absorbed dose to water due to medium energy x-rays is determined at a depth of 2 g·cm^{-2} of water. To do so, the glass detection vessel has a flat and very thin (0.7 mm) front window, which makes an exact positioning of the detection cell relative to the front window of the water phantom in a horizontal beam possible. Moreover, a flat front window is easier to model compared to a spherical front window.

Measurements

In 2004, measurements have been performed for 4 CCRI qualities for medium energy x-rays: 250 kV, 180 kV, 135 kV and 100 kV. For these measurements the water phantom and cooling unit of the



watercalorimeter for high-energy gamma rays was used. As the design of a new type of 10 kΩ thermistor probes was not finished at the time of measurements, 20 kΩ thermistor probes were used. Each measurement consists of monitoring the temperature changes without radiation, and monitoring the temperature changes during irradiation. The temperature change without irradiation is measured both before and after the irradiation. Thus, each measurement consists of a pre-drift, an irradiation and an after-drift. An example of a measurement is shown in the figure. In the figure the red line presents the measured resistance changes of the thermistor probes, the blue lines are a fitting of the measured data. The x-axis shows the time and the y-axis the resistance change. As the temperature changes due to the irradiation are very small, it is necessary to keep the pre- and after-drift as small and linear as possible, for an accurate fitting. Experiments showed that an excellent thermal isolation of the front side of the water phantom is necessary. This will be implemented in the design of a special phantom and cooling unit for this purpose.

Preliminary results

Most of the measurements performed in 2004, were performed for the x-ray quality of 250 kV. The effects of irradiation time and monitoring time of pre- and after-drift were studied. It can be concluded that the statistical uncertainty in measurement results does not improve when times of measurement that are longer than 180-300-180 seconds are selected.
For 70 measurements, the absorbed dose to water has been calculated for this x-ray quality. After that, the absorbed dose to water has been compared with ionization chamber measurements in water. The table shows the absorbed dose to water at 2 $g\cdot cm^{-2}$ the 250 kV CCRI quality measured with the water calorimeter and measurements with an ionization chamber (NE2571). To determine the absorbed dose to water for the ionization chamber, the data from the NCS-protocol [2] have been used.

Method	D_w (Gy/s)
NMi (watercalorimeter)	3.194×10^{-3}
NCS (ionisation chamber) [2]	3.175×10^{-3}

The standard [type A] uncertainty in the measurements with the watercalorimeter is 0.83%.
These preliminary results show a difference of 0.6 % only between the measurements performed with the water calorimeter and with an ionization chamber. A detailed uncertainty analysis still has to be performed on these measurements.

Future plans

In 2005, a new water phantom with a new cooling unit will be designed. Secondly, experiments will be performed with the new 10 kΩ thermistor probes. It is also planned to study the effect of saturation gas for which, so far, argon has been used. Finally, it is planned to determine the correction factors of the new watercalorimeter.

References

[1] IAEA Technical Report Series No. 398, “Absorbed Dose Determination in External Beam Radiotherapy”, IAEA, Vienna, 2000.
[2] Nederlandse Commissie voor Stralingsdosimetrie, Rapport 10 “Dosimetry of low and medium energy x-rays”, NCS, July 1997.