CALORIMETRY FOR ABSORBED DOSE MEASUREMENT AT 1–4 MeV ELECTRON ACCELERATORS

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Abstract

Calorimeters are used for dose measurement, calibration and intercomparisons at industrial electron accelerators, and their use at 10 MeV electron accelerators is well documented. The work under this research agreement concerns development of calorimeters for use at electron accelerators with energies in the range of 2–4 MeV. The dose range of the calorimeters is 3–40 kGy, and their temperature stability after irradiation was found to be sufficient for practical use in an industrial environment. Measurement uncertainties were determined to be 5% at k = 2.

1. INTRODUCTION

A polystyrene calorimeter for use at 10 MeV electron accelerators consists of a polystyrene disk situated within thermally insulating polystyrene foam [1]. The disk is 18-mm thick, with a diameter of 138 mm and the foam thickness is about 50 mm. The temperature is measured with a calibrated thermistor that is inserted into the side of the polystyrene disk. At this thickness the dose distribution through the disk is almost a straight line.

The temperature is measured before and after irradiation, and the temperature increase ΔT is in principle related to absorbed dose D by the relationship:

$$D = \Delta T * C_p \qquad (1)$$

where, C_p is the specific heat of polystyrene. This value is, however, not well known and instead a calibration is established by comparison of the temperature rise (ΔT) with the absorbed dose as measured with reference dosimeters. The reference dosimeters (usually alanine) are irradiated in the centre of an absorber with identical geometry to that of the calorimeter. Thus the dose to the reference dosimeter equals the average dose to the calorimeter. The relationship between dose and temperature becomes of the form:

$$D = \Delta T * (K_1 + T_{ave} * K_2) \qquad (2)$$

where, T_{ave} is the average temperature of the polystyrene disk, because the specific heat is a function of temperature.

2. DEVELOPMENT OF THIN CALORIMETERS

Calorimeters with 18 mm thickness are not useful at energies of 2 MeV. At this thickness the calorimeter becomes totally absorbing, and although a temperature increase can be measured after irradiation, it is not easy to relate this to absorbed dose through calibration as described above. Thinner absorbing disks have to be employed, and for use at 2 MeV a disk thickness of 2 mm was tested with a very small thermistor for measuring temperature. However, the radiation induced temperature of this disk dropped too rapidly after irradiation, and instead a sandwich of three 2-mm disks was tested, with the temperature being measured only in the middle disk. The disks were not thermally insulated form each other, but we observed that there was only a very slow rate of heat exchange between them.

Initial testing of the 2 MeV calorimeter was done at the Risø 10 MeV electron accelerator, where the disks were placed in the normal foam insulation with a total thickness of 100 mm, but height restrictions at the 2 MeV electron accelerator, where real life testing was to be carried out, made it necessary to design a new foam insulation with a total thickness of only 28 mm. This thin insulation made the cooling faster than with the 100 mm insulation, approximately 2.5% per minute after irradiation. However, under reproducible irradiation conditions this cooling could be corrected for, and it did not add significantly to the overall measurement uncertainty.

Calibration of this calorimeter could be carried out by using an absorber that would place alanine dosimeters at the same position as the middle of the three disks giving the same type of calibration relationship as in Eq. 2. In the same way the calorimeter could be used for calibration of thin film dosimeters when these were placed between two 3-mm plates located in the thermal insulation. That would ensure that the dose to the film dosimeters was the same as that to the calorimeter.

The lowest dose that could be measured by the calorimeter was determined by the smallest temperature increase that could be measured reproducibly. This was approximately 2°C corresponding to 3 kGy. The largest dose was determined by the maximum temperature at which the thermistors were calibrated, 55°C, leading to a maximum dose of 40 kGy for 25°C environmental temperature.

The components of the measurement uncertainty are:

Calibration by alanine reference dosimeters (type B):	1.5 %	
Measurement of temperature (type A):	1.0 %	
Establishment of calibration function (type A):	1.0 %	
Difference in irradiation geometries (type B):	1.5 %	
Total overall uncertainty:		2.5 %
At k = 2:		5.0 %

3. CONCLUSION

The 2 MeV calorimeters are now in use for documentation of radiation sterilization at one industrial electron accelerator and are being tested at two others.

REFERENCE

[1] AMERICAN SOCIETY FOR TESTING AND MATERIALS, Practice for use of calorimetric dosimetry systems for electron beam dose measurements and dosimeter calibrations, ASTM E1631, Annual Book of ASTM Standards, 12.02, ASTM, 1998