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CALORIMETRIC DOSIMETRY IN NEUTRON AND CHARGED PARTICLE BEAMS

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A portable tissue equivalent (TE) calorimeter, constructed of A-150 plastic, has been employed for the measurement of absorbed dose in several neutron radiotherapy fields and a high energy proton field. The therapy facilities visited so far include: The University of Washington, Seattle; Fermi National Accelerator Laboratory, Chicago; Texas A and M University, College Station; and the Harvard Cyclotron Laboratory, Cambridge. Comparisons of spherical, cylindrical and thimble shaped TE ionization chambers have been carried out using either air, or a flow of TE gas in the chambers. The dosimeters were mounted within a 25 cm cubic polystyrene phantom, and measurements were carried out at several depths within A-150 plastic.

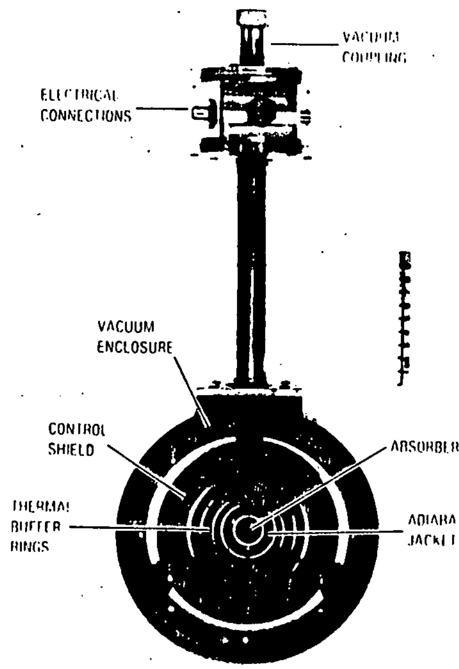

Fig. 1. Photograph of A-150 plastic calorimeter with cover plates removed.

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The design of the instrument is based on the original concept of the local absorbed dose calorimeter, first developed by Laughlin (1952). The calorimeter core is 2 cm in diameter and 2 mm in thickness. This element, in which absorbed dose is measured, is thermally isolated from the surrounding TE material by a 0.5 mm vacuum gap around all sides. Therefore, except for the negligible perturbation due to the presence of small vacuum gaps, this calorimetric dosimeter measures absorbed dose in A-150 plastic at a point within a homogeneous TE medium. Specific charge is measured using a cylindrical TE ionization chamber which has dimensions identical to the calorimeter core, or by using either 1 cm^3 or 0.1 cm^3 spherical ionization chambers.[1] In this way one can compare the response sensitivity ratios (ICRU, 1977) for ionization chambers of various types in ^{60}Co gamma ray and in neutron beams, referenced to the measurement of absorbed dose by the calorimeter. The response sensitivity ratio for the cylindrical TE ionization chamber filled with methane based TE gas in neutron fields produced at the Sloan-Kettering cyclotron with mean energies of about 6 and 8 MeV, relative to ^{60}Co has been determined to be 1.07 ± .02 (McDonald, Ma and Laughlin 1977). This quotient is a measure of the product of the mass stopping power ratio for secondary charged particles between the chamber wall and gas (ρ) and $\overline{W}_n$, the average energy expended in the gas per ion pair collected. A value of $\overline{W}_n$ for these neutron spectra can be computed by utilizing Bragg-Gray theory, assuming $\overline{W}_e$ for ^{60}Co to be 29.2 eV/ion pair, and taking ρ to be unity for both radiations. The value we have determined to be applicable for these two broad neutron spectra is 31.2 ± .6 eV/ion pair.

The field experiments carried out to date have been encouraging. The ionization chamber based dosimetry has been found to be in close agreement to the absorbed dose measured by the calorimeter. Measurements in the 160 MeV proton field at Harvard were carried out at several positions along the spread out Bragg peak. The dosimeters compared to the calorimeter included ionization chambers, a silicon diode probe and a Faraday cup based system. The largest differences in dosimetric methods have been generally less than 1-2%. Therefore, it appears that the values employed by the U.S. neutron radiotherapy trial centers for ρ and $\overline{W}_n$ are probably correct to within the limits of experimental uncertainty. In addition, the correction applied to dose obtained using the 1 cm^3 spherical chambers in order to account for the material displaced by the collecting volume has been verified to be 0.97 as initially computed by Shapiro (1976). This correction can also be made by placing the effective measuring point of the 1 cm^3 chamber at approximately 0.8 R (where R is the internal radius).

The absolute accuracy of the calorimetric measurement of absorbed dose in A-150 plastic is estimated to be ±2.5%. The largest contribution to this quantity is due to the convervative estimate of a ±2% uncertainty in the value of the thermal defect for A-150 plastic, which is taken to be 4% at present (ICRU 1977). Experiments are now underway (McDonald, Laughlin and Goodman 1976) to measure the thermal defect in a more complete manner, and this should help reduce the overall uncertainty to better than ±1.5%.

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[1]Obtained from E.G. and G., Goleta, California

REFERENCES

ICRU (1977). International Commission on Radiation Units and Measurements, Neutron Dosimetry for Biology and Medicine, ICRU Report 26.

Laughlin, J. S. (1952). Biological and Clinical Dosimetry. Annual Report on Research Project. AEC Contract AT(30-1)-1451.

McDonald, J. C., Laughlin, J. S. and Goodman, L. J. (1976). Calorimetric dose measurements in fast neutron and cobalt-60 gamma-ray fields. Proc. of Symp. Measurements for the Safe Use of Radiation, NBS SP-456, 327-333.

McDonald, J. C., Ma, I. C. and Laughlin, J. S. (1977). Calorimetric and ionometric dosimetry for cyclotron produced fast neutrons. Proc. Third Symposium on Neutron Dosimetry in Biology and Medicine. G. Burger and H. G. Ebert, (Eds.), Euratom, Brussels, pp. 619-633.

Shapiro, P., Attix, F. H., August, L. S., Theus, R. B. and Rogers, C. C. (1976) Displacement correction factor for fast neutron dosimetry in a tissue equivalent phantom. Med. Phys. 3, 87-90.