A COAXIAL DOUBLE CYLINDRICAL TEPC FOR MICRODOSIMETRY OF NEUTRONS <850 keV IN MIXED FIELDS OF FASTER NEUTRONS

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SUMMARY: A new low pressure tissue-equivalent proportional counter (TEPC) in coaxial double cylindrical form has been developed to measure separately the microdosimetric spectrum from any desired energy band of neutrons in the presence of mixed field of faster neutrons. Details are given of the construction, measured gas gain and resolution characteristics and some applications for measurement of radiation quality of neutrons <850 keV of radioactive neutron sources.

Key Word: Microdosimetry.

INTRODUCTION

The introduction of microdosimetric concepts for the specification of radiation quality based on the stochastic quantities of linear energy, y, and the specific energy, z, and their frequency distributions has contributed greatly to our understanding of energy distributions in a simulated tissue volume. This has been achieved with the use of tissue-equivalent proportional counters (TEPCs) which comprise of tissue-equivalent (TE) wall and TE gas of low density (1). These gas cavity devices enable absorbed dose, D, and quality factor, Q, to be determined in terms of y from a single measurement, and hence to obtain dose equivalent, H, for radiation protection purposes.

A notable feature of TEPCs relevant to radiation protection in mixed fields is that pulses produced by fast neutrons are in general larger than those produced by photons. This enables the separation of quality of neutron and γ-ray components in mixed radiation field by a pulse height discriminator (3). However, in the present form, these conventional Rossi type TEPC devices are incapable of selectively separating the partial microdosimetric distribution due to neutrons in any desired energy band in mixed field of faster neutrons (4). For example, the ability to discriminate the dose equivalent due to inter mediate energy neutrons which may be present in a mixed field of higher energy neutrons (5), would be of value for interpretive purposes in radiation protection in the vicinity of nuclear reactors and accelerator installations.

This paper describes the design and development of a new microdosimeter which can be operated to discriminate in favor of neutrons of lower energy in mixed fields of faster neutrons. The energy deposition spectra of neutrons in the energy region of interest can be determined by a appropriate choice of thickness of the common TE dividing wall, separating the inner and outer counters, to be equivalent to the corresponding maximum proton ranges, which ensures charged particle equilibrium for the relevant neutron energy. The inner counter serves as a microdosimeter with the optimal response to the selected energy bands of neutrons, while the events due to faster neutron-generated recoils which interact with both the counters are removed by an anti-coincidence technique (6).

MATERIALS AND METHODS

The counter consists of an outer annular eight-anode TEPC and an inner single-anode TEPC separated by a self-supporting TE dividing wall of 16 μm in thickness which permits selective detection of proton recoils from neutrons with energy <850 keV. The dividing wall was specially prepared from A-150 plastic powder by molding at temperature approximately 200°C. The uniformity of the TE film thickness was measured by the energy loss of α-particles which gave the surface density variation of less than.

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RESULTS AND DISCUSSION

The energy losses of 5.48 MeV α-particles traversing perpendicularly to both the inner and outer TEPCs at various mean chord lengths are shown in Figure 1. Typical values for the inner and outer counters at 1.0 μm mean chord length are 105.2 and 138.2 keV respectively. At higher mean chord lengths the spectrum of the inner counter is non-gaussian, as is typical for energy loss spectrum of α-particles in a thick absorber. However, the spectrum becomes gausian in shape when the mean chord lengths are less than 0.3 μm. The measured resolution of the inner counter are in good agreement with the theoretical calculation as shown in Figure 2. No measurement was made for the resolution of the outer counter since it is only used for anti-coincidence arrangement and not for spectra measurements.

Figure 1: Mean energy loss in the coaxial double cylindrical proportional counter as a function of mean chord length for propane based TE gas.

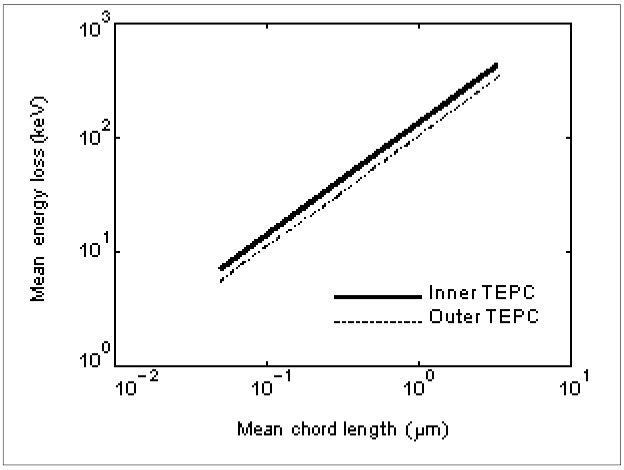


Figure 2: Resalution characterics of the inner TEPC, FWHM vs. mean chord length.

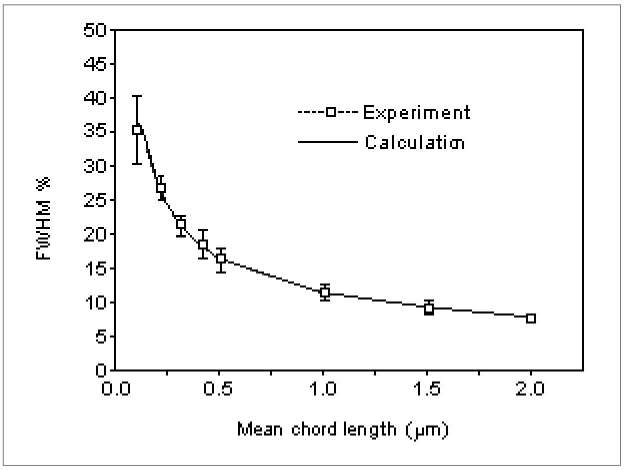
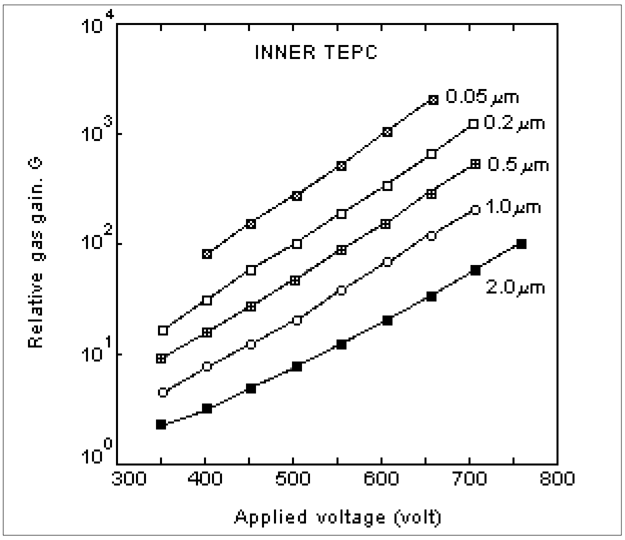


Figure 3: Gas gain characteristics of the inner TEPC at various anote voltages.



The gas gain characteristics of the inner and outer counter are shown in Figures 3 and 4 respectively. The gas gain of the inner TEPC is twice as high than that of the outer TEPC for a given mean chord length and applied voltage as expected because the reduced field strength in the inner TEPC is higher than that of the outer TEPC. However there is no significant difference in the operational characteristics between the two counters for

Figure 4: Gas gain characteristics of the outer TEPC at various anode voltages.

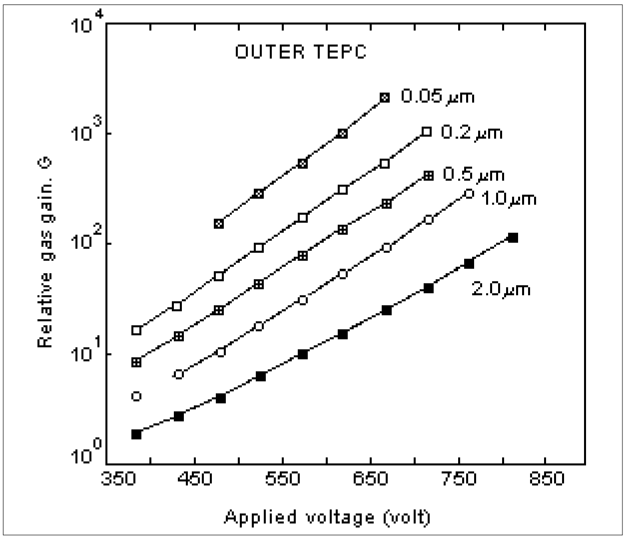


Table 1: The quality factor of neutrons and dose equivalent rates of the neutron and γ-ray components of the radioactive neutron sources.

	Quality Factor		Dose Equivalent Rate (μSv/hr)			
	Q_n		H_n		H_γ	
Neutron	Without	With	Without	With	Without	With
Sources	A/C	A/C	A/C	A/C	A/C	A/C
Cf-252	14.4	17.7	270	460	2.34	2.54
Am-Be	13.1	16.0	36	72	0.67	0.77

reduced field strength from 670 to 6700 V $torr^{-1}$. At the reduced field strengths greater than 200 V $torr^{-1}$, the gas gain characteristics could be fitted for Campion formula with the 5%. All other walls of the counter were constructed from a pre-cast block of A-150 TE plastic with the thickness of about 2.0 μm. The diameter and length of the dosimeter are 1.9 and 5.2 cm respectively. To improve the uniformity of the electrical field of the outer counter, a cathode wire was fixed centrally between two anodes on the same circumference. The microdosimeter was enclosed in an aluminum canister to provide electrostatic screening and to form a high vacuum enclosure.

The micro dosimeter was filled with propane-based TE gas (55.1% C_3H_8, 39.5% CO_2 and 5.4% N_2) and equipped with internal Am-241 calibration a source. A small bore-hole α-particle beam of diameter 0.3 μm was admitted to the sensitive volumes with the direction perpendicular to the counter axes. The resolution and gas gain measurements were performed using the same calibration source. The gas gain for both the inner and outer counters was measured at various simulated mean chord lengths from 0.05 to 2.0 μm and for different voltages.

A series of measurements were performed in mixed fields of neutrons from a nuclear reaction Am-Be and a spontaneous fission Cf-252 radioactive neutron sources at an operating gas pressure corresponding to a mean chord length of 1.0 μm. The microdosimeter position was 11 cm and 38 cm from the Cf-252 and Am-Be source respectively. The event spectra were recorded from the inner TEPC when operated with and without anti-coincidence modes with the outer TEPC. Constant values of A and B being 22.5 $torr^{-1}$ cm^{-1} and 396 V $torr^{-1}$ cm^{-1} respectively.

The measured event spectra were converted to microdosimetric spectra in the usual manner and that the dose distribution is dominated by proton events which produce a proton edge at about 150 keV/μm. The quality factor (7) and dose equivalent rate of the measured spectra are shown in Table 1. The dose equivalent rates of the γ-ray component are also shown.

The results show that the quality factor and dose equivalent rate of spectra with anti-coincidence are higher than the spectra without anti-coincidence indicating the significant importance of slow protons generated from the mixed fields of neutrons. Dose equivalent rates measured using a Sievert meter were less than 600 and 60 mSv/hr for the Cf-252 and Am-Be sources respectively. The γ-ray dose equivalent rate in the room was about 3 and 0.5 mSv/hr for the respective sources as measured by an ionization chamber type R02A.

CONCLUSION

A TEPC in coaxial double cylindrical form is not only capable of measuring Q and H, as does the conventional TEPC but it has an important feature that it can discriminate the component of neutrons in any desired energy band in the mixed field of faster neutrons by an appropriate choice for thickness of the TE dividing wall and by operating the inner TEPC in anti-coincidence mode with the outer TEPC. The present microdosimeter is selectively sensitive to neutrons <850 keV in mixed field of faster neutrons. There is an increase in the radiation quality and the corresponding dose equivalent of the anti-coincidence spectrum indicating the importance of neutrons at lower energies in the mixed field of faster neutrons.

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