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TRACK-ETCH DOSEMETER RESPONSE TO NEUTRONS UP TO 300 MEV

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Abstract

Electro-chemical and chemical track-etch dosemeters were obtained from commercial suppliers (American Acrylics and NE Technology) and exposed to neutrons produced at the LAMPF WNR white neutron source at 15° with no shielding and filtered by polyethylene blocks of 2.5, 5.1, 10.2, 20.3 and 40.6 cm thickness. The neutron spectrum was determined using calculations. Mean energies from 28 to 300 MeV were produced. Dose was calculated from the NCRP-38 flux-to-dose conversion. The results are compared with NTA film which was exposed in the same configuration. The response of track etch dosimeters was found to reach a miniumum and then rise as the the average neutron energy increased. The response of the NTA film increased as the neutron energy increased.

Introduction

NTA film produced by Eastman Kodak is the common method for measurement of dose from high energy neutrons. An alternative is the use of proton sensitive etched track detectors. Two systems were chosen for testing: an electro-chemical etch system described by Hankins[1] and a chemical etch system used by Harvey[2]. The exposures were made at the 15 degree, 90 meter flight path of the LAMPF Weapons Nuclear Research (WNR) white neutron source. Development was according to standard methods.

Experimental Method

Materials

NTA film was obtained from Eastman Kodak. The films were placed in plastic holder with a 0.066 cm cadmium pocket. The plastic holder is sealed and holds desiccant. The plastic holder is sealed in a dry nitrogen atmosphere and holds a desiccant. Dosimetry grade American Acrylics and Plastics CR-39 which was 0.063 cm thick covered on both sides with polyethylene of thickness 0.01 cm was laser cut into 3.5 cm. by 1.6 cm foils. The foils were mounted on a cardboard backing for exposure. PN3 foils (NE Technology) were precut into 2.0 cm by 2.5 cm by 0.15 cm foils. The PN3 foils were placed in a five element pyramidal holder. The holder has two dosemeters at the base of a triangular pyramid with the sides inclined at 40° to the base. Three dosemeters are placed on the faces of the pyramid. The configuration is held by a holder consisting of a base and a domed cap. The overall diameter is 5.8 cm and the height is 2 cm. The dosemeters were all placed on an ISO water phantom with the base against the face of the phantom.

Neutron Irradiation

The neutrons were produced by an 800 MeV proton beam striking a tungsten target. Exposures were made to the unfiltered beam and with polyethylene filters of 2.5, 5.1, 10.2 , 20.3 and 40.6 cm thickness. Electronic dosimeters (ALOKA CO., LTD., PDM-303) were used to scan the field uniformity. The beam was flat to within 5% over a square field of 10 cm width.. The dosemeters were exposed on an ISO water phantom.

The dose for each irradiation was determined using a neutron beam monitor, a small plastic scintillator, normalized by the proton current on the target. The dose per proton was calculated using the LAHET code, the calculation provided the neutron spectra per proton/cm^2 /MeV at the tungsten spallation target. The neutron spectra were then corrected for attenuation by the polyethylene filter and for air in the 90 meter flight path. The NCRP-38 fluence-to-dose conversion was then used to convert the neutron spectrum to a dose equivalent. A 5 kG magnet at the front of the detector shed was used to remove charged particles from the beam. The spectra are shown in Figure 1.

Development

The NTA film were developed in 68 °F baths. The first bath is a Kodak Rapid X-Ray Developer for five minutes with constant agitation. Development is stopped by a two minute running water bath. The film is transferred to a Kodak fixer bath for thirty minutes and then to a final wash bath with running water for thirty minutes. The electrochemical method used CR-39 (American Acrylics) with a three cycle etch. The dosemeters are placed in a 60°C oven overnight before the read cycle begins. The first cycle is a pre-etch for 1.75 hours in 6.5 N KOH solution which is added at the beginning of the cycle. Next a three hour cycle with 3000 volts at 60 Hz is used followed by 3000 volts at 2 KHZ for fifteen minutes. The temperature for all three cycles is 60°C. The dosemeters were taken from one sheet. Each batch of twenty-four foils contained four background foils and four control foils which were used for normalization between runs. The chemical etch procedure used PN3 plastic from NE Technology taken from one sheet. The dosemeters are given a pre-etch in a mixture of 60% by volume methanol and 6.25 N NaOH for one hour at 70°C. This is followed by six hours in a 6.25N NaOH solution at 70°C and ending with a through washing.

Track Counting

The NTA films were read using a microscope with a field size of one mm^2. The CR-39 foils were read using a standard microscope with a video camera. The image of the camera is input to a Biotran III Digimatic Indicator. Three fields totaling 0.6 cm^2 are read to determine the track count. The PN3 foils were read using the NE Technology AUTOSCAN 60. The reader used light incident on the edge of the PN3 plastic which undergoes total internal reflection from the faces where a defect or pit exists. The foil is viewed through a vidcon tube and camera lens and processed using an image grabber by a personal computer. The area read is 1.6 cm^2.

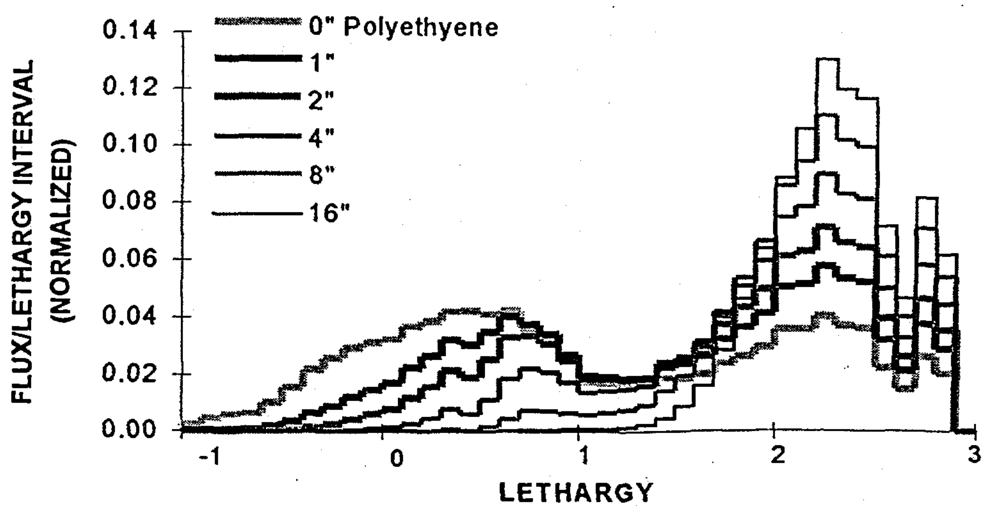

Figure 1. Fluence per Unit Log Energy (Lethargy) Normalized to Total Flux

Results

The results are presented below in Table 1. An interesting observation is the common effect in both plastic dosemeters of a minimum of response ration followed by a rise in response. This would be consistent with the rise in kerma as the energy increases above 70 MeV to 1000 MeV.. A corresponding increase is also observed in the NTA film. The results for the spectra corresponding to lower average energies are consistent with previous work[3]. Further studies which could be useful would be around 35 MeV and 66 MeV to fill in the middle energy portion. These studies when combined with the known energy response function from 0.2 MeV to 20 Mev and both a Monte Carlo estimate and comparison with kerma should allow a reasonable estimate of the energy response.

Table 1 Dose Equivalent Response of NTA Film, CR-39 and PN3 to High Energy Neutron Spectra

Material	Bare Cf Response ± SD ($cm^{-2}mSv^{-1}$)	Background ± SD	Filter Thickness (cm)	Response Relative to Bare Cf N	Ratio ± SEM
NTA	1090 ± 120	one mm^{-2} (Poisson Distributed)	0.0	2	1.88 ± 0.29
			2.5	2	2.40 ± 0.35
			5.1	2	2.48 ± 0.34
			10.2	2	4.33 ± 0.56
			20.3	2	5.40 ± 0.69
			40.6	2	6.11 ± 0.81
CR-39	351 ± 30	41 ± 14 cm^{-2}	0.0	3	0.27 ± 0.02
			2.5	3	0.33 ± 0.04
			5.1	3	0.16 ± 0.03
			10.2	3	0.11 ± 0.01
			20.3	3	0.11 ± 0.01
			40.6	3	0.15 ± 0.02
PN3 Planar	280 ± 15	71 ± 9 cm^{-2}	0.0	4	0.36 ± 0.03
			2.5	4	0.51 ± 0.05
			5.1	4	0.45 ± 0.04
			10.2	4	0.35 ± 0.05
			20.3	4	0.39 ± 0.03
			40.6	4	0.50 ± 0.05
PN3 Pyramid	230 ± 15	71 ± 9 cm^{-2}	0.0	6	0.49 ± 0.03
			2.5	6	0.55 ± 0.05
			5.1	6	0.50 ± 0.07
			10.2	6	0.38 ± 0.06
			20.3	6	0.37 ± 0.07
			40.6	6	0.52 ± 0.04

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