LA-UR- 98-2125

Approved for public release;
distribution is unlimited.

Title:

Preliminary Studies for a High
Energy Neutron Area Monitor

CONF-980707--

Author(s):

Robert T. Devine

and

Hsiao-Hua Hsu

Submitted to:

Radiation Protection Measurements

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

Los Alamos
NATIONAL LABORATORY

Los Alamos National Laboratory, an affirmative action/equal opportunity employer, is operated by the University of California for the U.S. Department of Energy under contract W-7405-ENG-36. By acceptance of this article, the publisher recognizes that the U.S. Government retains a nonexclusive, royalty-free license to publish or reproduce the published form of this contribution, or to allow others to do so, for U.S. Government purposes. Los Alamos National Laboratory requests that the publisher identify this article as work performed under the auspices of the U.S. Department of Energy. The Los Alamos National Laboratory strongly supports academic freedom and a researcher's right to publish; as an institution, however, the Laboratory does not endorse the viewpoint of a publication or guarantee its technical correctness.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

PRELIMINARY STUDIES FOR A HIGH ENERGY NEUTRON AREA MONITOR

Robert T. Devine and Hsaio-Hua Hsu

ESH-4, Health Physics Measurements, Los Alamos National Laboratory, Los Alamos, NM 87545

Abstract

Track etch detectors were exposed to neutrons produced by a spallation target struck by a beam of 800 MeV protons. The fields were filtered by 0, 10, and 40 centimeters of polyethylene. The track etch dosimeters were exposed on a polyethylene phantom. The dosimeters were exposed bare and behind lead filters of 0.25, 0.50, 0.75, 1.00, 1.25 and 1.50 cm of lead with the face of the dosimeter perpendicular to the beam and bare and behind lead filters of 0.50, 1.0, and 1.5 cm of lead with angle of incidence 45° and 75°. Monte Carlo calculations of these experimental configurations were done using MCNP and LAHET with input from the calculated spectra. These results are compared with the experimental results to understand the basic processes involved in the production of tracks with high energy neutrons and develop a high energy neutron area monitor.

PRELIMINARY STUDIES FOR A HIGH ENERGY NEUTRON AREA MONITOR

Robert T. Devine and Hsaio-Hua Hsu

ESH-4, Health Physics Measurements, Los Alamos National Laboratory, Los Alamos, NM 87545

Abstract

Track etch detectors were exposed to neutrons produced by a spallation target struck by a beam of 800 MeV protons. The fields were filtered by 0, 10, and 40 centimeters of polyethylene. The track etch dosimeters were exposed on a polyethylene phantom. The dosimeters were exposed bare and behind lead filters of 0.25, 0.50, 0.75, 1.00, 1.25 and 1.50 cm of lead with the face of the dosimeter perpendicular to the beam and bare and behind lead filters of 0.50, 1.0, and 1.5 cm of lead with angle of incidence 45° and 75°. Monte Carlo calculations of these experimental configurations were done using MCNP and LAHET with input from the calculated spectra. These results are compared with the experimental results to understand the basic processes involved in the production of tracks with high energy neutrons and develop a high energy neutron area monitor.

Introduction

Previous studies have indicated the utility of CR-39 for high energy neutron dosimetry.^{1 2 3} Monitoring fields outside of the shielding of accelerators presents a problem which the use of CR-39 might present a solution. Two difficulties in the use of the solid state track etch dosimetry as a monitor are apparent: angular dependence and energy dependence of response⁴. The effect of the use of lead radiators is investigated to determine their capacity to flatten energy response using the (n,xn) reaction. This reaction becomes significant above 20 MeV. The angular dependence is studied with varying radiator thickness.

Experimental Method

Materials

The CR-39 used was produced by the H. H. Wills Physics Laboratory of Bristol University under the trade name of TASTRAK. This is a polycarbonate of allyl diglycol with a chemical structure of $C_{12}H_{18}O_7$ and a density of 1.32 gm cm^{-3} . The plastic was precut into 2.0 cm by 2.5 cm by 0.15 cm foils. Lead sheets or radiators of thickness 0.25, 0.50, 0.75, 1.00, 1.25 and 1.50 cm formed in 10 cm x 10 cm squares were rolled by the Materials Science and Technology Division shops at Los Alamos National Laboratory.

Neutron Irradiation

The exposures were made at the Los Alamos Neutron Science Center. 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 10.2, 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 three dosimeters were placed unshielded or between two sheets of lead of the same thickness and supported by a polystyrene foam jig centered in front of an ISO water phantom. The dose for each irradiation was determined using a neutron beam monitor and a small plastic scintillator, normalized by the proton current on the target. A calculation provided the neutron per proton/cm²/MeV at the tungsten spallation target. The neutron spectra were then corrected for attenuation by the polyethylene filter and air in the 90 meter flight path using the LAHET code. 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 chemical etch procedure used CR-39 plastic taken from one sheet. The dosimeters 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 washing.

Track Counting

The PN3 foils were read using the NE Technology AUTOSCAN 60⁵. 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 cm².

Calculation

The Monte Carlo programs MCNP⁶ and LAHET⁷ were used to compute the absorbed dose using as input the spectra supplied by LANSCE. The experiment was modeled using the experimental configuration described above. The program was run until a statistical confidence of 10% was obtained. The contributions to dose from the production of protons, alpha, deuterons, tritons and helium-3 particles was included.

Results

The results of the angular dependence and radiator study are shown in Fig. 2. The response does not vary with increasing angle of incidence to the phantom at the two higher energies for any radiator thickness. However for the lowest energy spectrum the response with angle at every radiator thickness varies roughly as that reported by Harvey⁴ for energies between 0.565 and 5.3 MeV. The effect of the radiators is marked in the highest energy experiment. It would seem that adding 2.5 or 5.0 mm of lead brings the response of this spectrum up to that of the lowest energy at zero angle of incidence to the phantom. The middle spectrum shows some increase with increasing radiator thickness but not as large as in the highest spectrum. The decision on a preliminary design for further testing is to use the 35° wedge used by Harvey with a 2.5 mm lead radiator.

The results of the Monte Carlo study are shown in Fig. 3. The dose at zero angle of incidence is compared with the dose calculated from the Monte Carlo method. Both responses are normalized to the configuration with no radiator. The agreement is good for the case studies but a divergence appears at the highest energy.

¹ Devine, R. T., Walker, S., Staples, P., Mundis R., Miller, J. and Duran, M., *Etched Track Dosimeter Response to High Energy Neutrons*, Radiat. Prot. Dosim. 66 (1-4) 349-352 (1996)

² Devine, R. T., Walker, S., Staples, P., Mundis R., Miller, J. and Duran, M., *Track-etch Dosimeter Response to Neutrons up to 300 MeV*, Proceedings, IRPA9, Ninth International Conference of the International Radiation Protection Association, 4 398-400 (1996)

³ Devine, R. T. and Hsu, H-H, *Neutron-Charged Particle Reactions in CR-39 Calculated using MCNP and LAHET*, Proceedings of the 30th Midyear Topical Meeting of the Health Physics Society, 181-183 (1997)

⁴ Harvey, J. R., *A Three Element Etched Track Neutron Dosimeter with Good Angular and Energy Response Characteristics*, Radiat. Prot. Dosim. 44 (1-4) 325-328 (1992)

⁵ NE Technology Limited, *AUTOSCAN 60 Automatic Reader*, Bath Road, Beenham, Reading, Berkshire RG7 5PR England (1993)

⁶ Briesmeister, J. F., *MCNP—A General Monte Carlo n-Particle Transport Code, Version 4A*, Los Alamos National Laboratory, Report LA-12625, Los Alamos NM (1988)

⁷ Prael, R. E. and Lichtenstein, H., *Users Guide to LCS: The LAHET Code System*, Los Alamos National Laboratory, Report LA-UR-89-3014, Los Alamos NM (1989)

FIG 1 SPECTRA AT LANSCE 15 L PORT

FIG 2. Response ($\text{cm}^{-2}\text{mSv}^{-1}$)

FIG 3 Calculated and Experimental Responses Normalized at 0 mm Lead