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R.P. NOTE 137

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(September 2001)

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Introduction

Chipmunks are real-time radiation measuring instruments, which use tissue equivalent ion chambers as their detector. Chipmunks are capable of measuring dose rates in mixed radiation fields [Krueger01]. At Fermilab, TLD based radiation badges (Landauer Type F TLD/CR-39 Combination Dosimeter) are used as the personal radiation monitoring devices. These badges are composed of several passive radiation detection materials, capable of detecting photons, charged and neutral particles. Sometimes, both the Chipmunks and radiation badges are used for simultaneous measurements. Since the badges are intended to be worn on the body, the measurements reported in this note were conducted in three configurations: stand-alone badges; badges on a phantom; and badges on a chipmunk.

Setup

The measurements were conducted at the RPCF mezzanine. The floor of the mezzanine is a concrete slab. The walls and the ceiling are thin metal, with minimal effects on the radiation field.

The badges and the Chipmunk were placed 183 cm from the floor, on aluminum stepladders. Most of the small amount of plastic on the top of the ladders were removed and replaced with a wider thin aluminum plate. The neutron source was installed on a pole with wheels for positioning. Figure 1 shows a plan view of the experimental setup. The phantom was a polyethylene block, one foot square by six inches thick.

The stand-alone badges were mounted on a thin aluminum frame with three horizontal strips for hanging the badges. The phantom and the aluminum rack held nine badges each. The badges were arranged in three rows of three. The badges on the Chipmunk were arranged similarly, except the middle badge was removed to avoid the badge shadowing the ion chamber. The Chipmunk, the badges on the phantom, and the badges on the aluminum rack were arranged in a semi-circle, 127cm from the source at the center. The badges placed on the front face of the Chipmunk were10cm closer to source than the other badges.

Previous measurements of radiation fields behind thick shields have shown that the leakage neutron spectra resemble that of an AmBe source (Elwyn91). The AmBe neutron source 241Be-7 2-1 (2.13E7 neutrons/sec on 1/21/1988) was used for this measurement. A 1.6mm thick lead cup was placed on the source, to attenuate the 59.5 keV americium x-rays.

Measurements

Previous studies, using neutron sources at the RPCF mezzanine have shown that the radiation field from a neutron source, at similar geometries is fairly isotropic (Kemp96). Based on these previous measurements, it was assumed that the radiation field is isotropic and no additional measurements were conducted.

Neutron detection energy threshold for Chipmunks has been measured down to 400 keV. A PuLi source (formerly used at Fermilab) generated neutrons with this average energy. Comparison of the neutron dose measured with a Chipmunk to that measured with a SNOOPY [SNO] has indicated that the range of the sensitivity of the Chipmunk extends to sub-eV neutrons. SNOOPY is a neutron detector, which has a known and quantified neutron response from 0.02 eV to 10 MeV. Further experiments are planned to quantify the lower energy region. Table I shows the detection thresholds for the Chipmunk and the Badges.

Table I.

Detector t	Photon Detection Threshold (keV)	Neutron Detection Threshold (keV)	Photon Dose Equivalent Threshold (mrem)	Neutron Dose Equivalent Threshold (mrem)
Chipmunk	60	<eV (see text)	0.05	0.05
Badge	10	40	10	20

Five of the badges were randomly selected from the set used for this measurement and kept away from the irradiation area, in one of the RPCF caves. The readouts from these badges were used as the background and subtracted from all of the irradiated badge readings.

To cover a large dose range, three sets of irradiations were conducted. Table II shows the length of each run and the calculated dose for each run, using the source parameters.

Table II.

		Dose at 127cm		Dose at 117cm	
Run	Elapsed Time (hr)	Calculated N - DE (mrem)	Calculated Gamma Dose Equivalent (mrem)	Calculated N - DE (mrem)	Calculated Gamma Dose Equivalent (mrem)
1	16.78	264.067	6.924	313.706	8.289
2	3.18	50.086	1.313	59.501	1.572
3	66.15	1040.798	27.290	1236.444	32.669

Results and Analysis

The dose was calculated for the two source-to-badge distances of 127cm and 117cm. The calculated dose includes the contribution from room return. Room return was determined by measuring the dose rates from a neutron and a gamma source (independently) at different distances from the source at 183 cm from the floor (experiment height). Plotting the ratio of the measured dose to calculated dose versus distance, provides a representation of room return as measured by the instrument. (Figs. 2 and 3). The detail results of the Chipmunk and badges measurements are given in Table III.

Conclusion

Table IV summarizes the results. Under controlled conditions the Chipmunk and the badge measurements agree very well within the measurements uncertainties of 5%. The badges and the Chipmunk consistently measure about 30% below the calculated dose from the AmBe source. This is expected, since the spectrum of the neutrons from the AmBe source, extends below the threshold of both instruments. The agreement between the badge readings and the Chipmunk showed that the region of the AmBe source spectrum that lies between the thresholds of the two instruments, is not a significant component of the dose. Only during the long run was there a measurable photon component. As columns 5 and 8 of Table III shows for run three, the measured and predicted photon doses agreed very well.

Considering the uncertainties associated with the measurements, no significant differences were found between the readings of the badges on the Chipmunks, badges on the phantom, or the badges on the aluminum rack.

When the Chipmunk and the badges are used in the field for the concurrent radiation measurements, the following points must be considered:

a) In a changing radiation field, where the components of field which lies between the thresholds of these two instrument changes, Chipmunk and the badge reading may not agree,
b) Chipmunk has a very sensitive electrometer (fempto-amp bias level) and digitizing circuitry (0.5pCoul/count), which is carefully designed to be stable under the outdoors environmental conditions that may exists at Fermilab [Krueger01]. However, very rapid changes in the environmental conditions, or other abnormal conditions, will affect the response of the Chipmunk
c) When the radiation levels in an area are monitored for the protection of the personnel in the area, the badges are the official dosimeter of the record. The dose recorded with the badges may be used as the record of the radiation levels in an area. However, badges are not real-time monitors and if one is defective, it may only be revealed during the reading of the badge. (One of the Chipmunk badges for Run 1 returned a minimal reading. The other badges of this set correctly read a neutron dose of about 200 mrem.)
d) Chipmunks' real-time response provide for the immediate mitigation of off normal beam loss conditions.

We gratefully acknowledge Matt Ferguson, John Larson and Sue McGimpsey's help with this study.

		AVERAGE Badge (N)	ST. DEV Badge (N).	AVERAGE Badge (P)	ST. DEV Badge (P).	Calculated (N)	Calculated (P)	Chipmunk Neutron Dose
Run 1								
	Phantom	214.44	20.68	0.00	0.00	264.07	6.92	220.63
	Chipmunk 308	228.57	24.10	0.00	0.00	313.71	8.29	220.63
	Alum. Holder	215.56	27.44	0.00	0.00	264.07	6.92	220.63
	Average=	219.52	13.99	0.00	0.00	280.61	7.38	220.63
Run 2								
	Phantom	40.00	10.00	0.00	0.00	50.09	1.31	42.15
	Chipmunk 308	36.25	16.85	0.00	0.00	59.50	1.57	42.15
	Alum. Holder	38.89	15.37	0.00	0.00	50.09	1.31	42.15
	Average=	38.38	8.30	0.00	0.00	53.22	1.40	42.15
Run 3								
	Phantom	817.78	63.99	24.44	5.27	1040.80	27.29	863.31
	Chipmunk 308	881.43	112.02	30.00	0.00	1236.44	32.67	863.31
	Alum. Holder	775.56	48.25	20.00	0.00	1040.80	27.29	863.31
	Average=	824.92	45.91	24.81	1.76	1106.01	29.08	863.31

Table III. Columns 3 and 5 are the measured average neutron and photon dose equivalent respectively, with standard deviation of the measurement given in columns 4 and 6. Columns 7 and 8 give the dose calculated from the AmBe source information. The last column shows the neutron dose as measured by the Chipmunk.

		% (N-calc)/(N-badge)	% (N-calc)/(N-chip)	% (N-badge)/(N-chip)
Run 1				
	Phantom	123.1	119.7	97.2
	Chipmunk 308	137.2	119.7	103.6
	Alum. Holder	122.5	119.7	97.7
Run 2				
	Phantom	125.2	118.8	94.9
	Chipmunk 308	164.1	118.8	86.0
	Alum. Holder	128.8	118.8	92.3
Run 3				
	Phantom	127.3	120.6	94.7
	Chipmunk 308	140.3	120.6	102.1
	Alum. Holder	134.2	120.6	89.8
	Ave(%)=	133.6	119.7	95.4
	+/-	13.0	0.7	5.1

Table IV. Columns 3 and 4 show a comparison of the calculated dose from the source to that measured with the badges and Chipmunks, respectively. Column 5 shows the ratio of the neutron dose measured with the badges to that measured with the Chipmunk.

References

Elwyn91 Elwyn, A. J. *Characteristics of Neutron Radiation Fields Outside of Shielding* RP Note 93 (October 1991)

Kemp96 Kemp, A., Boehnlein, D., Elwyn, A.J., Vaziri, K. *A Study of Neutron Room-Scattering at RPCF* RP Note 125 (1996)

Krueger92 Krueger, F. *Determining the Fast Neutron Energy Response Characteristics of Fermilab Instrumentation* RP Note 86 *(1992)*

Krueger98 Krueger, F. *Determining the Fast Neutron Energy Response Characteristics of Fermilab Instrumentation* RP Note 86 (June 1990)

Krueger01 Krueger F. and Larson J. *Chipmunk IV Development and Experience with A New Generation of Radiation Area Monitors for Accelerator Applications* Submitted to Nuclear Instruments and Methods.

SNO SNOOPY: a BF_3 counter, Nuclear Research Corporation Radiac probe model DT-371/PDR-70 coupled to an Eberline ESP-2 digital survey meter

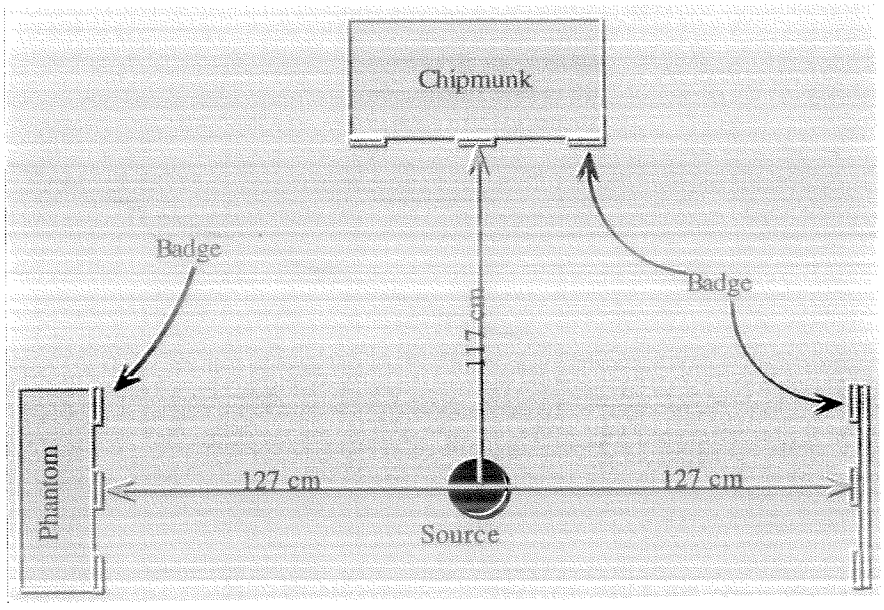

Figure 1. Plan view of the irradiation setup.

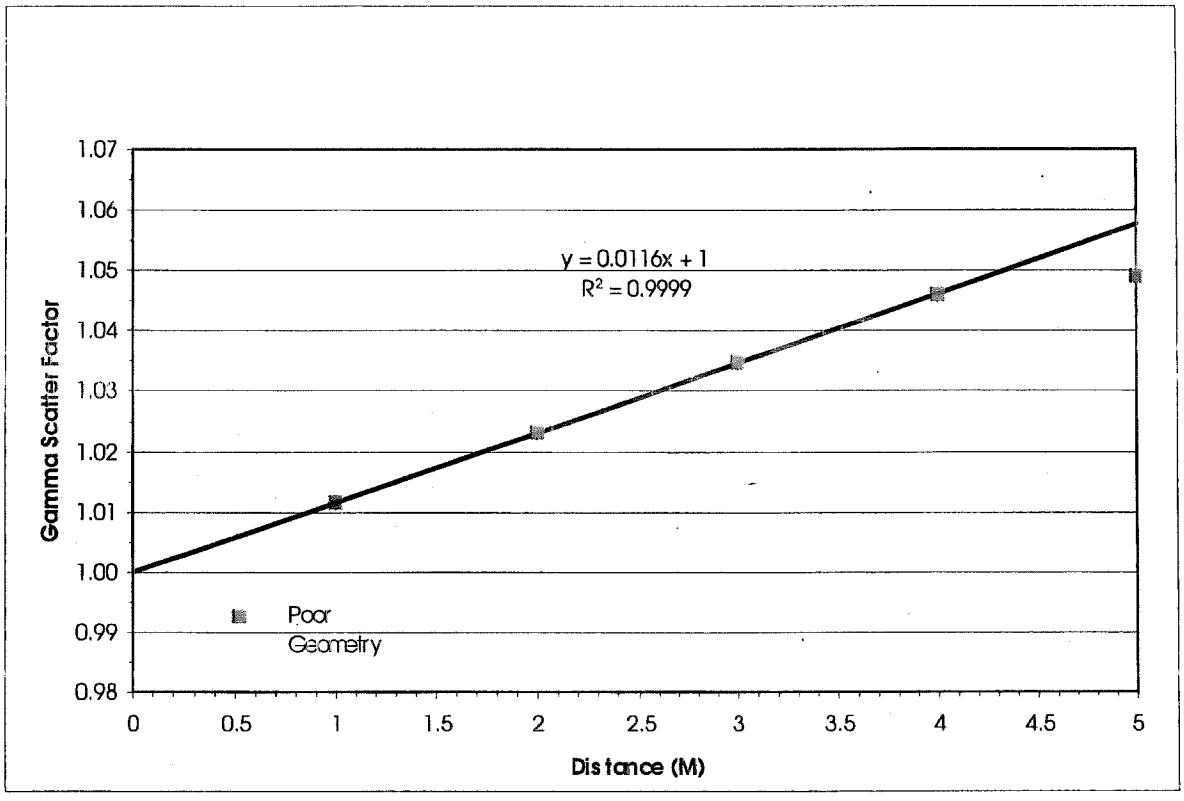

Fig. 2: Gamma (Co-60) room-return measurements at RPCF mezzanine, for a Chipmunk.

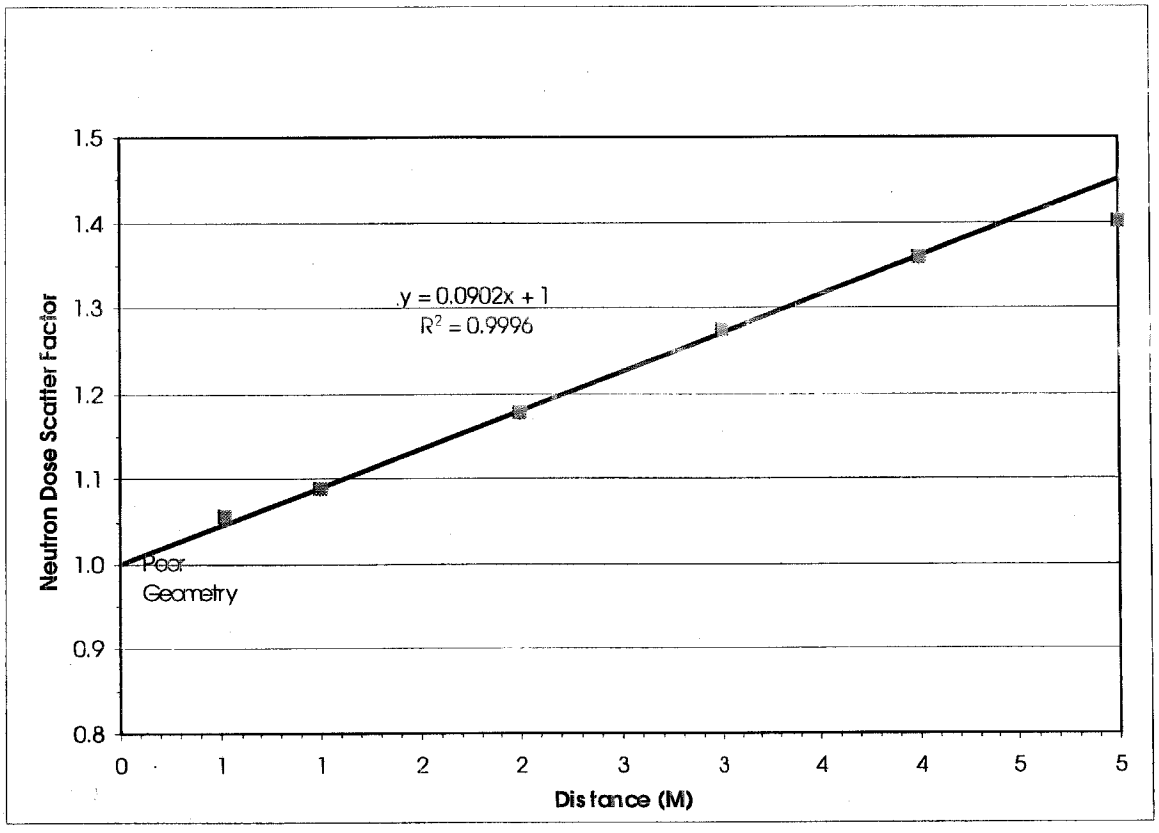

Fig. 3: Neutron room-return scatter factor measurements at the RPCF mezzanine, for a Chipmunk.