Dose Equivalent LiF TLD Area Monitor
Corrects Personnel Dosimeter Neutron Energy Response

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1. Purpose

What is an area monitor? It is a LiF TLD inside a moderator/shield that makes its response proportional to the dose equivalent over a wide range of neutron energies.

What is its purpose?

Where personnel are not monitored: To record maximum potential doses.
Where personnel wear dosimeters: To correct the response of the dosimeter.

Is there another way to correct the energy response? Yes, there are methods using energy dependent counters (Riel 95). However, they require a special survey when work conditions change. A monitor capable of correcting the response can alert the dosimetry group when the neutron spectrum changes.

2. Background

2.1 Energy Response: The cross section of Li falls with neutron energy, while the dose equivalent rises with energy, compare Figures 1 and 2., Glickstein 1981. Albedo neutrons from a person, or a phantom, improve the response, but a rem meter is far better. Compare the response relative to the dose equivalent of the albedo dosimeter with the SNOOPY in figure 3. The albedo response changes by three orders of magnitude from thermal to 14 MeV, where the rem meter changes by less than one order of magnitude.

2.2: What is a rem meter? One model of the dose equivalent is the energy deposited at the center of a 30 cm. diameter sphere. This sphere weights about 14 kg (31 lbs.). One wants to reduce the weight, but smaller spheres have a relatively lower response at higher neutron energies. A rem meter adds a leaky thermal neutron absorber at the proper radius to flatten the energy response.

3. Hardware

3.1 Remmeter and Area Monitor: The rem meter in figure 4. is made from an outer 21.6 cm. (8.5”) diameter by 23.6 cm. (9.3”) long polyethylene cylinder and an inner 6.3 cm. (2.5”) diameter polyethylene cylinder with an annular borated rubber cylinder between them. Holes in the rubber pass a fraction of the thermal neutrons from the outer to the inner cylinder. Fast neutrons that pass through the outer cylinder may become thermal in the inner cylinder. Thermal neutrons are measured by a detector at the center. In the rem meter, below the 20 inch ruler, the detector is a BF3 proportional counter. In the area monitor, above the ruler, the detector is a pair of Harshaw 8802LiFTLDs.

3.2 Special Area Monitor: The Special Area Monitor (SAM) adds four dosimeters around the center of the polyethylene cylinder. The polyethylene holders that support them may be seen in the corners of the aluminum box, figure 5. The area monitor is a good phantom, so a dosimeter on its surface will respond like one on a person while dosimeters in the center measure the dose equivalent. So the SAM response ratio “Outside to Inside” measures the TLD Response per rem.

4. Measurements

4.1 Reading dosimeters: The measurements span a decade, during which changes were made in the dosimetry system (Devine 1990). We are in the process of repeating them, so the results should be considered illustrative rather than definitive.

4.2 Reading SNOOPY: We counted pulses from the audio output of the Navy’s SNOOPY (AN/PDR-70) on a pulse integrator. We connected a multichannel analyzer to the proportional counter tube to measure rates too high for the acoustic pulse. Some rates were still too high, so we used an external pulser to correct for coincidental losses.

4.3 Fields, Table 1: The Naval Research Laboratory (NRL) constructed neutron environments to test the energy response of neutron dosimeters (Nash 1985). The LiF TLD response per rem observed, from 0.09 to 2.8, covers a factor of 30. The bare and moderated californium are the standard fields at the National Institute of Standards and Technology (NIST). We determined the dose equivalent in the submarine by Bonner multi-sphere and N2-213 liquid scintillation spectrometry. We measured the 14 MeV response at several distances and separated the direct from the scattered radiation by a dose versus distance regression. The thermal results are tentative. The thermal beam at the NIST reactor is being upgraded, and then we will repeat the measurements.

5. Results and Conclusions

5.1 Response per rem: Table 1. shows how neutron energy changes the response of five devices. The fields cover the energy range from thermal to 14 MeV, producing an albedo dosimeter response range from 0.04 to 28, a factor of 700. The SNOOPY compresses this range to a factor of 2.4, from 0.5 to 1.2. The response of the area monitor, except for its low response to thermal neutrons, is flatter than the SNOOPY.

5.2 Efficiency: Does the moderator/shield of the area monitor reduce the response of the dosimeter inside it? The answer depends on the energy. The albedo dosimeter is calibrated in a moderated californium spectrum, where it has a response per rem of 1.0 and its Cs equivalent light output is 11.2 per neutron rem. The area monitor is calibrated in a bare californium spectrum, where its Cs equivalent light output is 1.79 per rem. The monitor appears to have reduced the sensitivity six fold, but the dose of record is the product of the calibration factor and the response per rem. In a bare californium spectrum, the albedo response per rem is 0.10 so its Cs equivalent is 1.12, and the area monitor is more sensitive by a factor of 1.6. So, the area monitor increases the sensitivity of the TLD in spectra where its sensitivity is low, and reduces it in spectra where its sensitivity is high.

5.3 Albedo TLD energy response correction: We hoped that dosimeters on the outside of the area monitor's polyethylene cylinder would respond like dosimeters on a person, or on a phantom. They do; the "LiF TLD" and "Outside SAM" columns are about equal. So, to the degree that "Inside SAM" equals the dose equivalent, the ratio "Out/In SAM" will approximate the TLD response per rem. We plot the TLD response per rem versus the ratio Outside/Inside SAM in figure 6. We find:

TLD Response per rem = (SAM Out/In)/1.27 with a standard deviation of 35%

So, we have reduced the response range from a factor of 70 (thermal is excluded) to a factor of less than two. The albedo dosimeter, corrected by the Special Area Monitor, is equivalent to a remmeter.

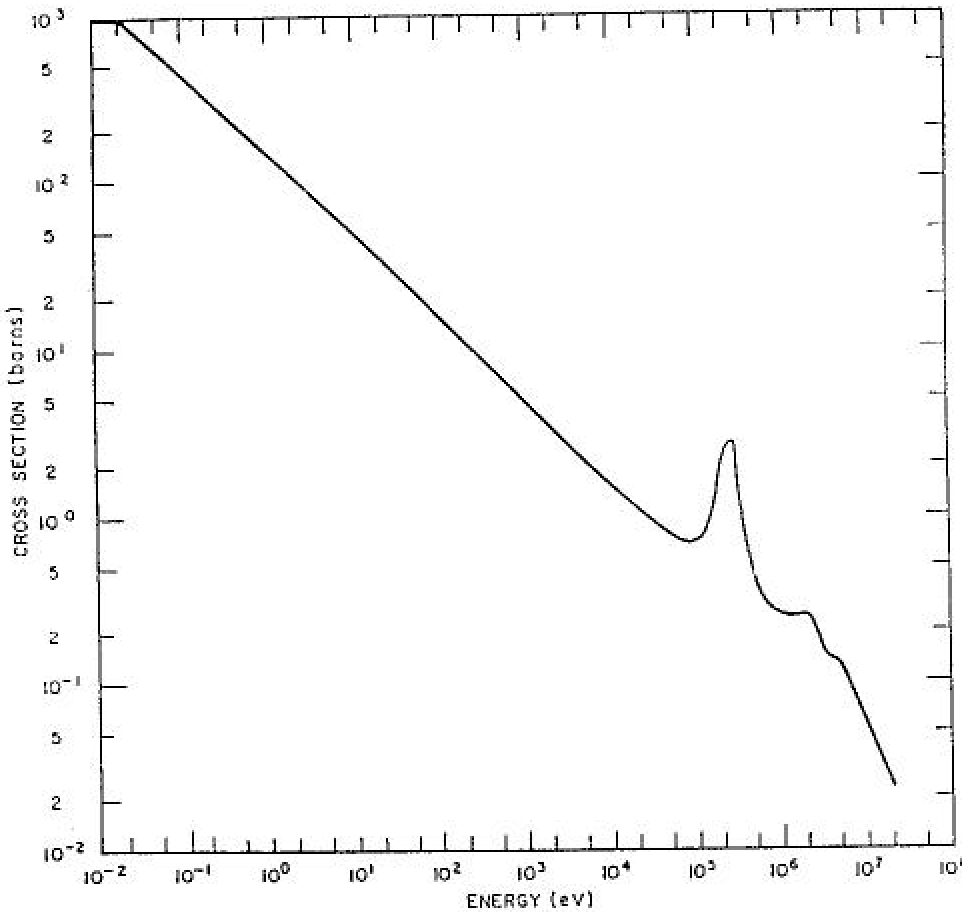
References

Devine 1990: R. T. Devine, M. Moscovitch, and P. K. Blake, *The US Naval Dosimetry Center Thermoluminescence Dosimetry System*, Radiation Protection Dosimetry **30** (4) 231-236

Glickstein 1981: Glickstein, S.S., *Analytical Modeling of Thermoluminescent Albedo Detectors for Neutron Dosimetry*, DOE Research and Development Report WAPD-T-2767, Bettis Atomic Power Laboratory, West Miffin, PA 15122

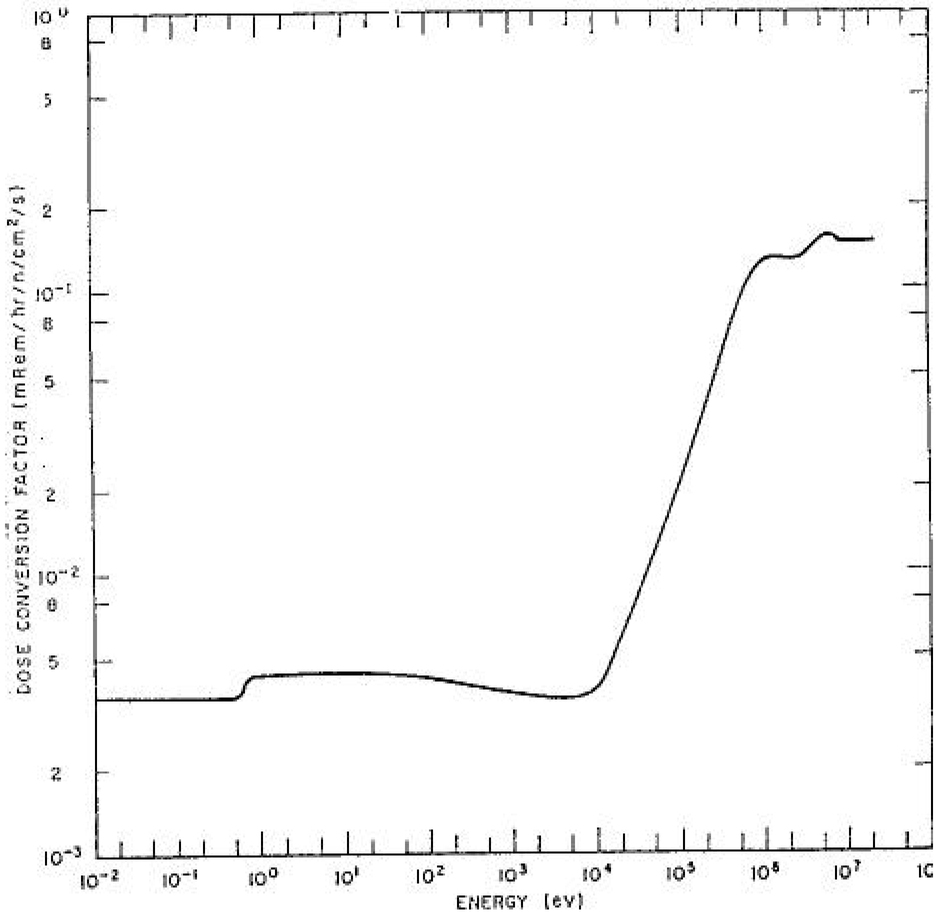
Nash 1985: Nash, A.E. & Johnson, T.L. USNRL; Riel, G., Woo, K., Wang, J. C. Y., and Scofield, N. NSWC, *The Response of an Albedo Neutron Dosimeter to Moderated AmBe and Cf-252 Neutron Sources*, Report 8909, Naval Research Laboratory, Washington, DC

Riel 1995: G. K. Riel *Neutron Energy Correction of Albedo Dosimeters*, Harshaw/Bicron User Symposiumits



Li-6 ABSORPTION CROSS SECTION

Figure 1



NEUTRON FLUX-TO-DOSE CONVERSION FACTOR

Figure 2

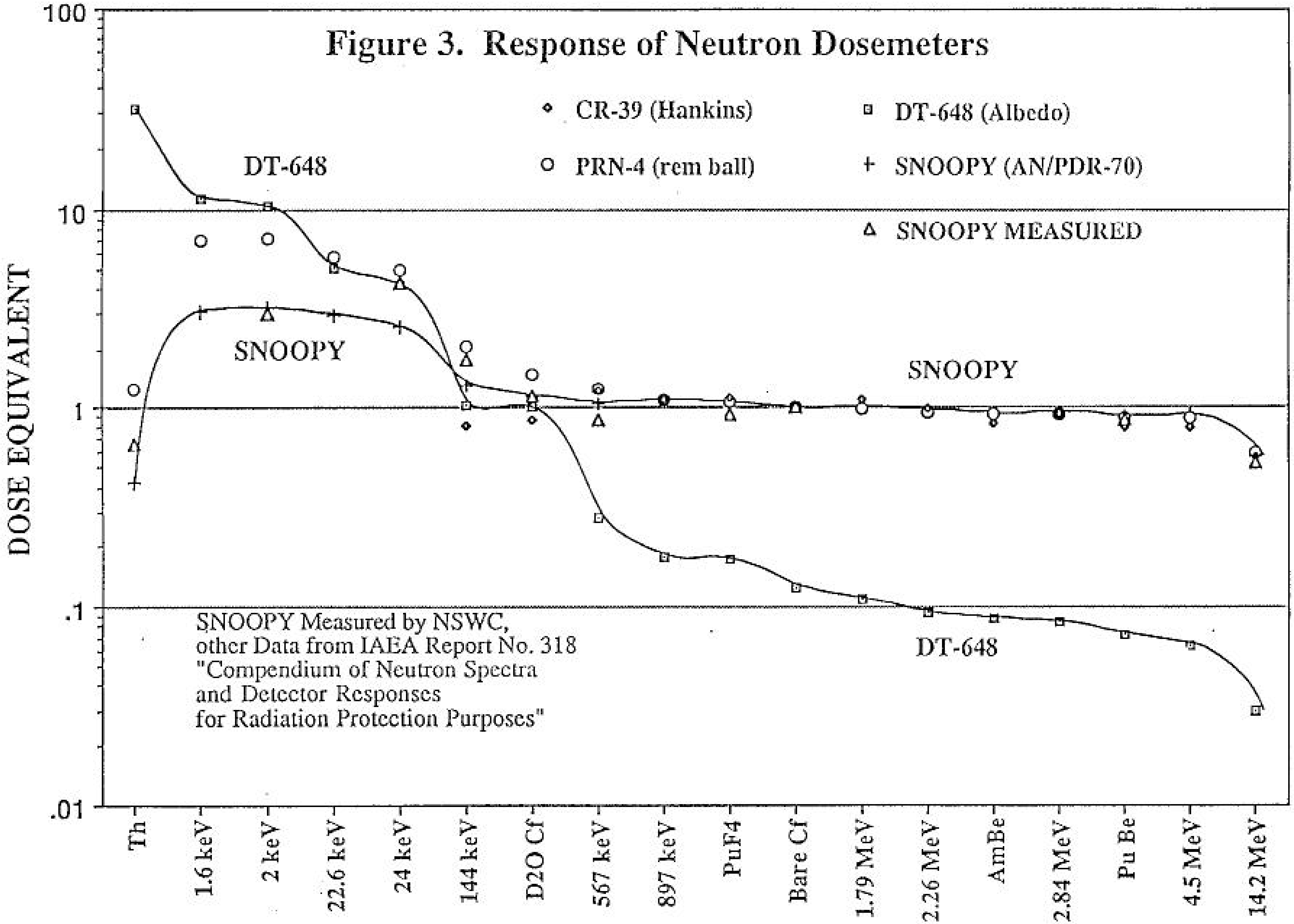


Figure 3. Response of Neutron Dosemeters
CR-39 (Hankins)
PRN-4 (rem ball)
DT-648 (Albedo)
SNOOPY (AN/PDR-70)
SNOOPY MEASURED
DT-648
SNOOPY
SNOOPY
DT-648
SNOOPY Measured by NSWC,
other Data from IAEA Report No. 318
"Compendium of Neutron Spectra
and Detector Responses
for Radiation Protection Purposes"
DOSE EQUIVALENT
100
10
1
.1
.01
Th
1.6 keV
2 keV
22.6 keV
24 keV
144 keV
D2O Cf
567 keV
897 keV
PuF4
Bare Cf
1.79 MeV
2.26 MeV
AmBe
2.84 MeV
Pu Be
4.5 MeV
14.2 MeV

Figure 4. Area Monitor and SNOOPY Remmeter
The Monitor's white outer polyethylene cylinder is enclosed in aluminum box
The rem meter's black outer polyethylene cylinder has a handle.
LiF TLDs in the Area monitor replaces the BF3 proportional counter tube of the SNOOPY.

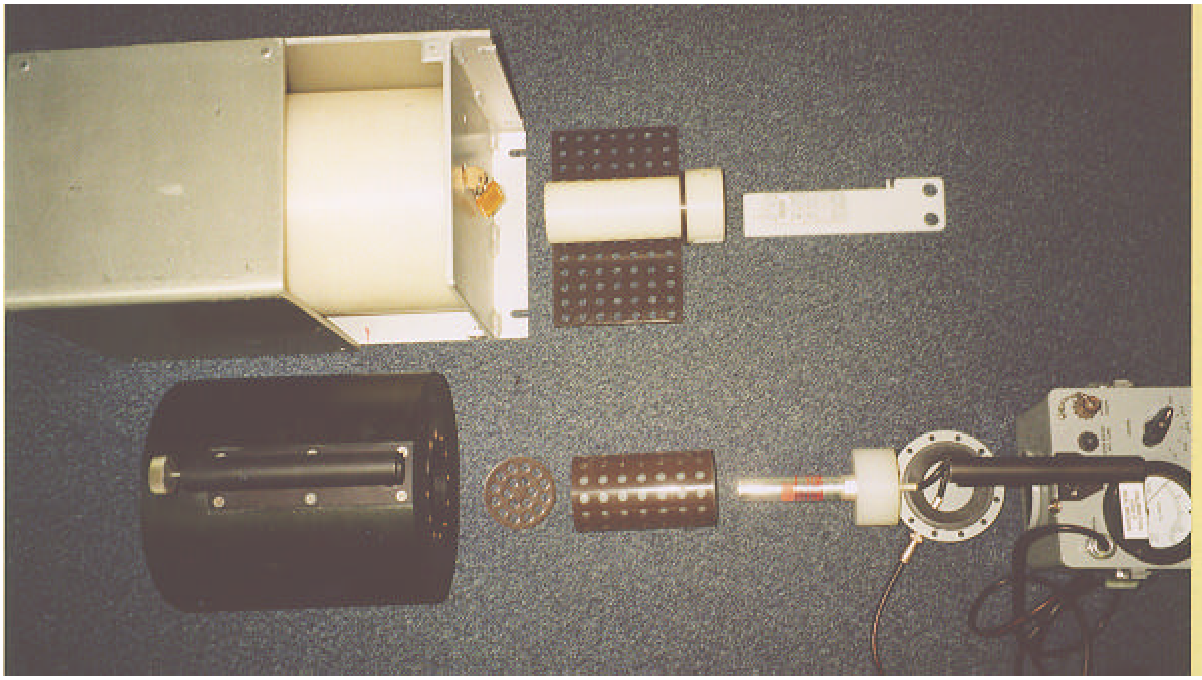


Figure 5. Special Area Monitor
Two LiF TLDs in the center measure the dose equivalent
Four LiF TLDs on the outside measure the albedo response