

Neutron spectrum measurement, LANSCE/ER-1

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ABSTRACT: Neutron spectral measurements were made in LANSCE Experimental Room 1 during an intentional spill of 100 nA on a carbon block in the beam channel. The relative response of two neutron dosimetry badges and a neutron survey meter were investigated. The resultant neutron spectrum had a strong high-energy component containing 25% of the flux density and 70% of the neutron dose equivalent. The dosimetry badges and the survey meter underresponded by 80, 20 and 50%, respectively. Due to their individual energy responses, a simple sum of the two dosimeter results gives a total dose equivalent, which is close enough to the unfolded spectrum value to be used for personnel dosimetry records.

Introduction

On July 22, 1987 an experiment was run to measure the neutron energy spectrum in the LANSCE Experiment Room 1 (ER-1) with the proton beam being stopped in the carbon beam block in Line D directly downstream of the IR bender. The purpose of this measurement was to determine the neutron-energy spectrum and dose rate found in ER-1 under the conditions of beam spill, and determine the relative sensitivities of the Albatross-IV neutron survey instrument, the LANL TLD dosimeter badge that is worn by TA-53 personnel, and the NTA-type nuclear-track-emulsion dosimetry badge that formerly was used at the Lab for personnel neutron dosimetry.

Detectors

The detectors used to determine the energy spectrum included a set of six polyethylene moderator spheres (5.08-to 30.48-cm diameter) with TLD 600 and TLD 700 LiF detectors in the center, an unmoderated set of TLD detectors, a cadmium covered set of unmoderated TLD detectors, a plastic scintillator C(n,2n) threshold activation detector, and a large bismuth fission counter. Each of these ten detectors has a unique sensitivity for neutron detection as a function of neutron energy. Computer codes are used to unfold the neutron-energy spectrum that matches input data from the ten detectors. The unfolding codes yield a spectrum that covers the energy range from 0.01 eV to 400 MeV. The upper limit is determined by the limits on the known response functions of the detectors. The C(n,2n) reaction has an energy threshold of 20 MeV, and the bismuth fission counter has a 50-MeV threshold energy. In addition, an Albatross-IV and two personnel dosimeter badges on a polyethylene phantom were placed next to the detector array. Two other sets of dosimeter badges were placed on phantoms in other locations in ER-1.

Measurements

The array of detectors was set up in ER-1 at the location (#2) indicated in Fig. 1 at an elevation of ~1 m above the floor. The location of the carbon beam block in Line D (above) is also indicated on Fig. 1. The detectors were at an angle of ~70 degrees relative to the incident proton beam. The floor of the Line-D beam tunnel is 1.5 m of ordinary concrete at this location. The locations of other sets of dosimeters is also shown on Fig. 1 (#1 and #3). The proton beam was directed onto the carbon block from 2140 to 2245 hours with a down time of eight minutes at about the half-way point of the run. The proton beam current was determined to be steady at ~100 nA, based on several methods of estimation.

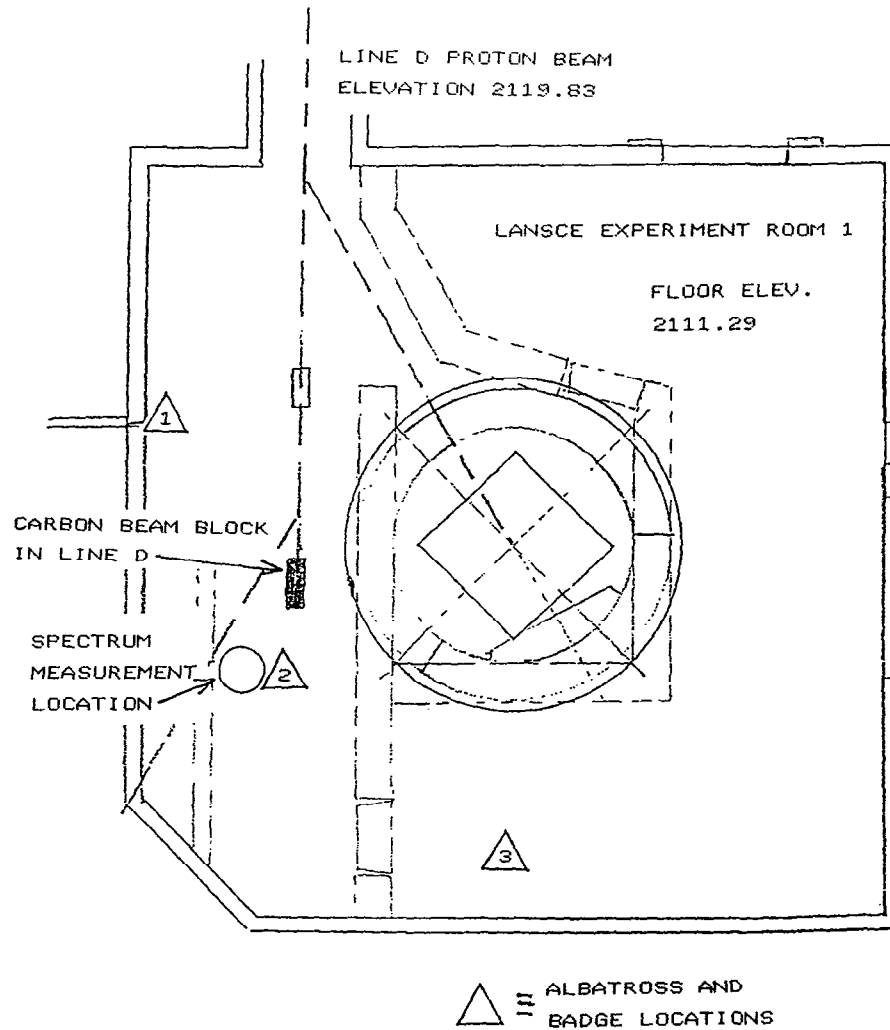


Fig. 1 Locations of neutron measurements in LANSCE/ER-1 relative to location of carbon block in Line D (above).

Results

The neutron spectrum determined from the unfolding codes is shown in Fig. 2. The codes show good general agreement up to about 60 MeV. There is poorer agreement in the number of neutrons present above that energy. The neutron-radiation field parameters resulting from the spectrum unfolding codes are summarized on the figure. The important quantity is the computed dose equivalent rate of 610 mrem/h. The dose equivalent distribution in neutron energy indicates that 70% of the neutron dose is due to neutrons of energy greater than 10 MeV, although this region includes only about 25% of the total flux density.

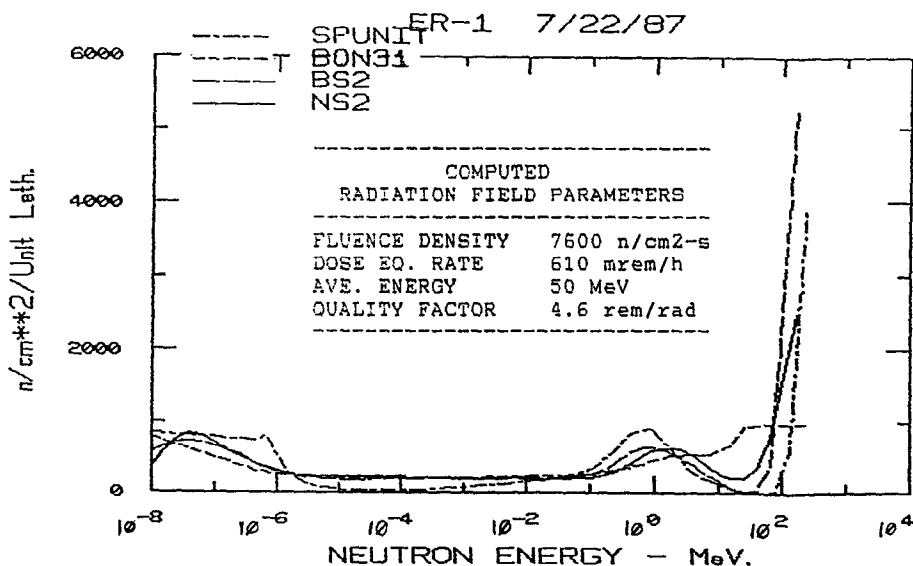


Fig. 2 Unfolded-neutron-energy spectrum (four unfolding codes) in LANSCE/ER-1.

Table 1 summarizes the results from each of the detectors used at the location of the spectrum measurement.

Table 1

Detector/Systems Used	DE Rate mrem/hr	Flux Density n/cm ² s
Spectrum Unfolding (Ave.)	610	7600
Albatross (Location #2)	300	n/a
Carbon Scintillator	340	1700
Bismuth Fission Counter	420	2100
TLD Personnel Badge	100	n/a
NTA Track Film	480	n/a

The TLD Personnel Badge and the NTA Track Film were interpreted as if they were ordinary badges being worn by personnel, with the calibrations based on Cf-252 and Pu/Be neutrons, respectively.

The TLD and NTA dosimeters on phantoms at the other two locations in ER-1 indicated the dose results compared to the Albatross readings as shown in Table 2.

Table 2

Location	Dose (mrem)		
	TLD	NTA	Albatross
1	23	16	44
4	11	64	56

The Albatross readings are "eyeball" type averages of the remote readouts during the course of the measurement. Again, the TLD and NTA data were interpreted with the normal dosimetry calibrations.

Conclusions

The following observations and conclusions can be made from these comparison data:

- The Albatross underestimates the true dose rate by ~50% for the measured neutron spectrum. This is not unexpected because the response of the Albatross falls off severely above 20-MeV neutron energy.
- The sum of the Albatross plus the plastic scintillator result gives good agreement with the total dose from the unfolded spectrum. This good agreement may be fortuitous, but it does look reassuring that everything is consistent.
- The TLD badge underresponds by a factor of six in the neutron spectrum at Location 2. This is because the sensitivity of the albedo-type dosimeter falls off very badly for neutrons of energy above 1 MeV.
- The NTA film at Location 2 also underresponds, but only by about 20%. (The NTA film has an effective threshold of ~1 MeV.) The sum of the TLD and NTA is 580 mrem, which is very close to the results from the spectrum-unfolding results. This, again, may be fortuitous, but it is consistent with the ranges of sensitivities of the two types of dosimeters.
- The TLD badges at the other two locations (1 and 4) also underestimated the dose compared to the Albatross to about the same degree as Location 2. What we don't know is how much the Albatross is underestimating at Locations 1 and 4.

Based on the above results and conclusions, personnel who had access and reason to work in ER-1 during the 1988 LAMPF running period were assigned both a TLD and an NTA badge. Interpretations for any positive results were based on the same calibrations as used in Table 1. The sum of these two numbers was used for an individual's total neutron-dose equivalent. For neutron spectra similar to those measured at location #2, this estimated value of dose equivalent should be within $\pm 30\%$ of the true value.