Equivalent spherical-shield-neutron-dose calculations

G. J. Russell and H. Robinson
Los Alamos Neutron Scattering Center
Los Alamos, New Mexico 87545 U.S.A.

ABSTRACT: Neutron doses through 162-cm-thick spherical shields were calculated to be 1090 and 448 mrem/h for ***regular*** and ***magnetite concrete***, respectively. These results bracket the measured data, for ***reinforced regular concrete***, of ~600 mrem/h. The calculated fraction of the high-energy (> 20 MeV) dose component also bracketed the experimental data. The measured and calculated doses were for a graphite beam stop bombarded with 100 nA of 800-MeV protons.

Introduction

Shielding issues were the highest priority concerns at the Los Alamos Neutron Scattering Center (LANSCE)[1] in FY-88. LANSCE uses 800-MeV protons from the Clinton P. Anderson Meson Physics Facility (LAMPF)[2] to produce neutrons for basic materials science and nuclear physics research. As can be seen in Fig. 1, the LANSCE target area has vertical proton insertion. LANSCE shielding concerns include: a) proton beam line shielding, b) target shielding, and c) neutron beam line, chopper, and beam-stop shielding. We launched both a computational endeavor[3] and an experimental effort[4] to better ***understand*** the complexities associated with adequately shielding a spallation neutron source.

Neutron-dose measurements were made[5] in the LANSCE experimental area below the proton beam line at a location downstream from where protons are extracted to the White Source experimental area (see Fig. 1). The 800-MeV proton beam impinged on a 50-cm-diam by 200-cm-long graphite beam stop. The proton current was 100 nA.

The shield under study was the reinforced regular concrete floor (152-cm-thick) of the proton beam line. Our previous experience had shown that the maximum dose (for this type of geometry) should be expected at about 60 degrees from the proton beam direction. Measurements were made at roughly 70 degrees (see Fig. 2).

The actual shield geometry was simplified for the calculations by assuming an equivalent spherical shield with a thickness of the 70-degree slant distance (162 cm) through the beam-channel floor. The high-energy (> 20 MeV) neutron-source term was chosen to be an isotropic point source located at the center of the spherical-shield cavity. The graphite beam stop per se was not mocked up in the Monte Carlo shielding calculations. The strength of the point source was taken to be 4π times the neutrons per steradian in the angle bin 50-105 degrees leaking from the graphite beam stop (see Fig. 2).

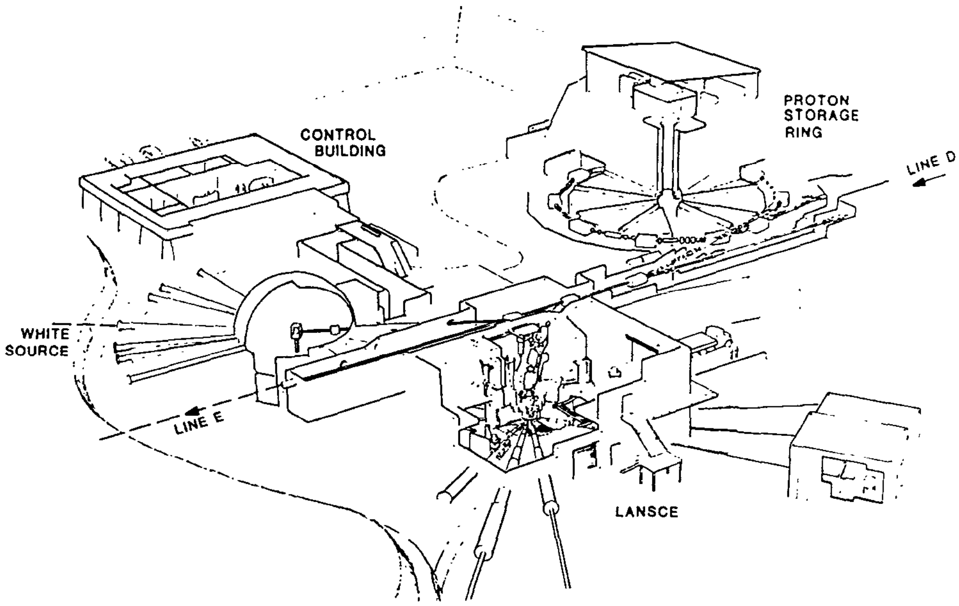

Fig. 1 General layout of the LANSCE/WNR complex. The Neutron Scattering Experimental Hall, completed in 1988, surrounds the present LANSCE experimental hall (shown in the foreground) and greatly enhances the overall LANSCE experimental area.

Primary low-energy (< 20 MeV) neutrons produced in the graphite beam stop were ignored in the calculations. The high-energy neutrons and secondary low-energy neutrons produced by high-energy reactions in the shield were tracked to the detector location and converted to dose. The floor of the LANSCE experimental area was ignored in the computations. Air-filled regions were assumed to be both inside and outside the shield zone.

The computations were done with the Los Alamos Monte Carlo code package.[6]

Results

The LANSCE beam-channel floor in the vicinity of the shield measurement is ***reinforced regular concrete***. Since we did not know the iron content of this shield, we performed computations for both ***regular*** and ***magnetite concrete***, hoping to bracket the effectiveness of the actual shield material. The results of the calculations, compared to experimental data, are shown in Table 1. Indeed, the experimental results are bracketed by our calculations. The magnetite concrete data is closer to the measured values, indicating the significance of the iron reinforcing bars used in the actual construction of the beam-channel floor. The effect of including the LANSCE experimental area floor in the computations would produce some low-energy albedo neutrons to add to the low-energy dose component at the detector location.

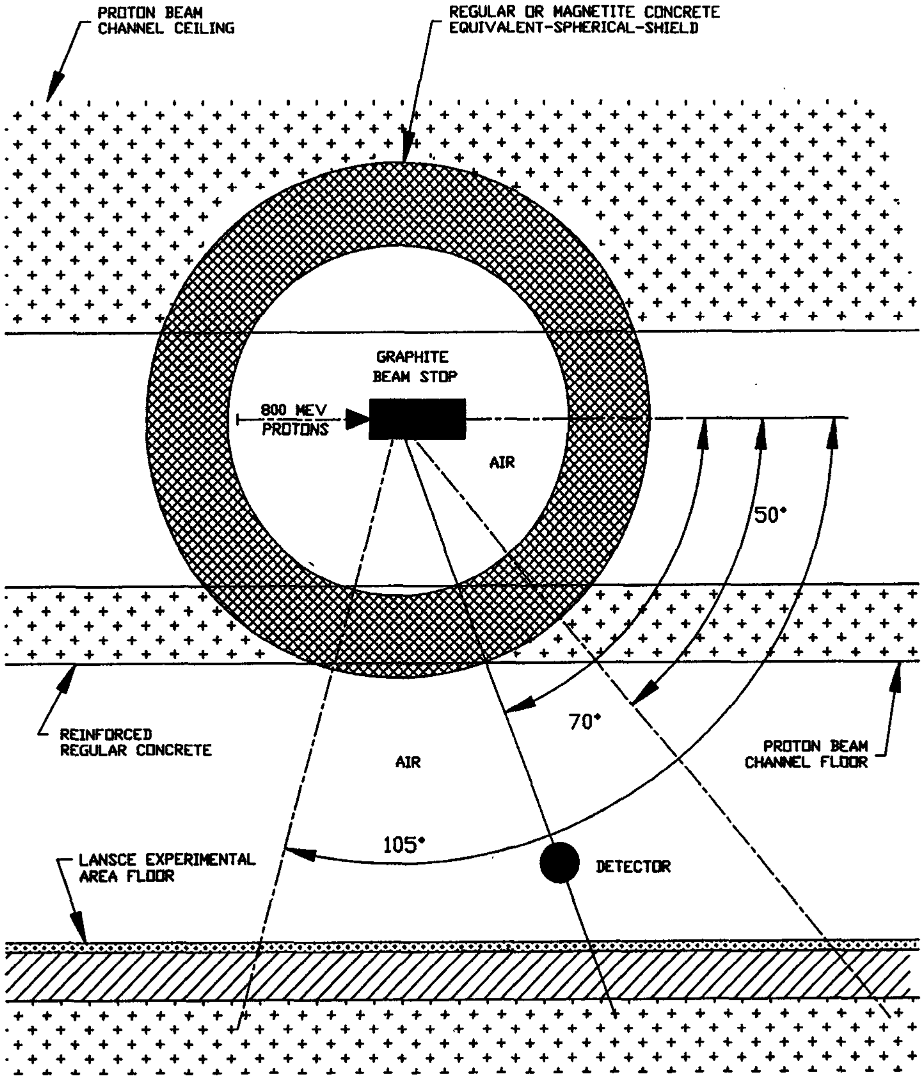

Fig. 2 A simplified schematic diagram of the LANSCE proton beam channel, showing the equivalent spherical shield for the beam channel floor. The location of the measurement, relative to the proton beam stop, is also illustrated. The graphite beam stop was replaced by a point isotropic source in the calculations.

	mrem/hr		
Shield	Hi-E E>20 MeV	Lo-E E<20 MeV	Total E<800 MeV
Magnetite Concrete (calc)	289	159	448
Reinforced Regular Concrete (exp)*			500-700
Regular Concrete (calc)	753	337	1090
	Dose E > 10 MeV		
Magnetite Concrete (calc)	69.4%		
Reinforced Regular Concrete (exp)*	70.0%		
Regular Concrete (calc)	74.0%		

*M. Howe and R. Mundis (Ref. 5)

Table 1 Neutron dose through various shields for 100 nA of 800 MeV protons on a graphite beam stop.

Conclusions

Equivalent-spherical-shield calculations of a relatively complex proton-beam-stop/proton-beam-line shielding scenario yield results that agree with measured values. This lends confidence to employing simplified shield approximations to geometrically complicated problems.

Acknowledgements

We appreciate useful discussions with Bill Wilson and Gail Legate and the continued support of Roger Pynn and Dick Woods for this work. We thank Teri Cordova for her typing help.

This work was performed under the auspices of the U. S. Department of Energy, Office of Basic Energy Sciences.

References

1. G. J. Russell, et al., "The LANSCE Target System", ICANS-IX Proceedings of the 9th Meeting of the International Collaboration on Advanced Neutron Sources, Villigen, Switzerland, September 22-26, 1986, ISBN 3-907998-01-4, pp. 177-244 (April 1987).

2. M. S. Livingston, "LAMPF, A Nuclear Research Facility", Los Alamos National Laboratory Report, LA-6878-MS (1977).

3. G. J. Russell, "Shielding Concerns at a Spallation Source", these proceedings.

4. G. L. Legate, R. L. Mundis, and M. L. Howe, these proceedings

5. M. L. Howe and R. L. Mundis, "Neutron Spectrum Measurement, LANSCE/ER-1", these proceedings.

6. R. E. Prael, "High-Energy Particle Monte Carlo at Los Alamos", Monte Carlo Methods and Applications in Neutronics, Photonics, and Statistical Physics, eds., R. Alcouffe, R. Dautray, A. Forster, G. Ledanois, and B. Mercier, Springer-Verlag Publisher, Berlin/Heidelberg, 1985, pp. 196-206.