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COMPARISONS OF MONTE CARLO CALCULATIONS TO MEASUREMENTS OF NEUTRON LEAKAGE FROM THE TSF-SNAP REACTOR*

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ABSTRACT

The TSF-SNAP reactor is being used at ORNL as a realistic source for investigations of the light-weight shields required for space power systems. As part of this program, experimental and analytical determinations have been made of the energy and angular distribution of neutrons leaving an area roughly equal to 10% of the reactor lower surface. The agreement between experiment and Monte Carlo calculations was found to be quite good when the reactor was described in sufficient detail in the calculations.

*Submitted for journal publication.

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The TSF-SNAP reactor installed at the Tower Shielding Facility (TSF) at ORNL is to be used as a realistic source for experimental investigations of the light-weight shields required for space power systems. As one of the initial steps in the program using this reactor, experimental and analytical determinations have been made of the neutron radiation leaving the lower surface of the reactor. These determinations were made in some detail, obtaining the energy and angular distribution of neutrons leaving an area roughly equal to 10% of the reactor lower surface.

The reactor[1,2] is a modified SNAP-2 reactor designed by Atomics International, Inc. It is fueled with fully enriched ^{235}U mixed with ZrH moderator, reflected with Be, and cooled with NaK. Thirty-seven* fuel-moderator elements, each 1-1/4-in.-diam. by 12-1/4-in.-long, are densely packed in a hexagonal array within a 9-in.-diam by 16-in.-long pressure vessel. The beryllium neutron reflector surrounding the core vessel contains the four control drums. The relative power distribution[3] was determined by scanning individual fuel elements for fission product gammas, and the absolute fission rate was determined from uranium-foil activation.

Figure 1 shows the reactor in the experimental configuration, along with the detector collimator, but without the cylindrical stainless steel heat-and-weather shield which normally surrounds the sides and

*The actual final loading uses 36 SNAPTRAN-V elements and one stainless steel rod with a small quantity of boron carbide in the center position.

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Fig. 1. TSF-SNAP Reactor with NE-213 Detector Collimator.

top of the reactor. The reactor was suspended vertically from a boom so that it could be rotated about its own axis and be lowered or raised through a distance of 36 in.

The detector collimator was a lead-water shield 48 in. in diameter and 59 in. long containing a 2- by 2-in. NE-213 organic scintillator. The collimator was mounted on a support mechanism that permitted the shield to be rotated in a vertical plane about the horizontal axis of the detector and move in a line passing through and perpendicular to the vertical axis of the reactor. The collimator in the shield was designed using Monte Carlo calculations[4] to limit the background contribution (from scattered and transmitted neutrons) to less than 5% of the foreground contribution. The opening of the collimator was square in cross section and of the shape and size shown in Fig. 2. (The NE-213 detector was cylindrical but was used with the beam incident on its curved surface; therefore, the detector exhibits a square profile.)

Neutron spectra were obtained with the axis of the detector collimator making angles of 0°, 18° 12', 25° 50', and 36° 52' (cosines of 1, .95, .9, and .8) with respect to the vertical axis of the reactor, with the axis of the collimator looking at the center of the bottom of the pressure vessel. The detector collimator was also moved horizontally so that the axis of the collimator looked at points 7 and 14 cm along the radius of the reactor, and measurements were repeated for three of the above angles. For all the measurements the detector, looking along the axis of the collimator, was 56 in. from a horizontal plane passing through the bottom of the reactor pressure vessel.

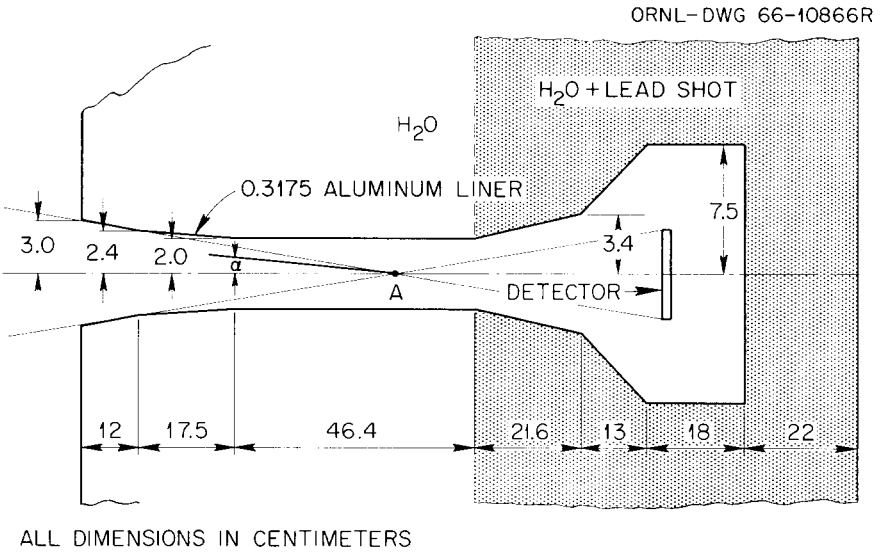

Fig. 2. Design of TSF-SNAP Core Mapping Collimator.

A previous report[5] described the basic calculational techniques being used and some preliminary results which were obtained assuming that the reactor control drums were fully inserted, that the fuel region of the core was homogenous, and that perfect detector collimation was used. The data reported here were obtained with the above assumptions modified and include absolute comparisons with experimental data.

At the time these calculations were started, the best available guess as to the actual final reactor configuration was that the central fuel element would be replaced with a solid Be cylinder and that this configuration would be critical with two control drums fully inserted and two control drums withdrawn 30°. Accordingly, these assumptions were made for the calculations. The axial geometry of the calculational model is shown in Fig. 3, and an x-y cross section is shown in Fig. 4. Also, collimator response functions which were obtained by independent calculations[4] were included in these calculations. Details of the above modifications, including listings of the computer codes and inputs, are given in a separate report.[6] In addition, it was found that some detectors were being perturbed by a vessel support ring which was not included originally. This ring was added,[7] mocked up as shown in Fig. 5, using the same material as the reactor vessel.

Ten different detector configurations were selected to provide the basic data for comparisons of experiment and calculation. These positions are described in Table I and shown in Fig. 6.

The x, y, and z coordinates give the spatial location (in cm.) of the detector with respect to a coordinate system with origin on the centerline of the lower reactor face. The u, v, and w coordinates give

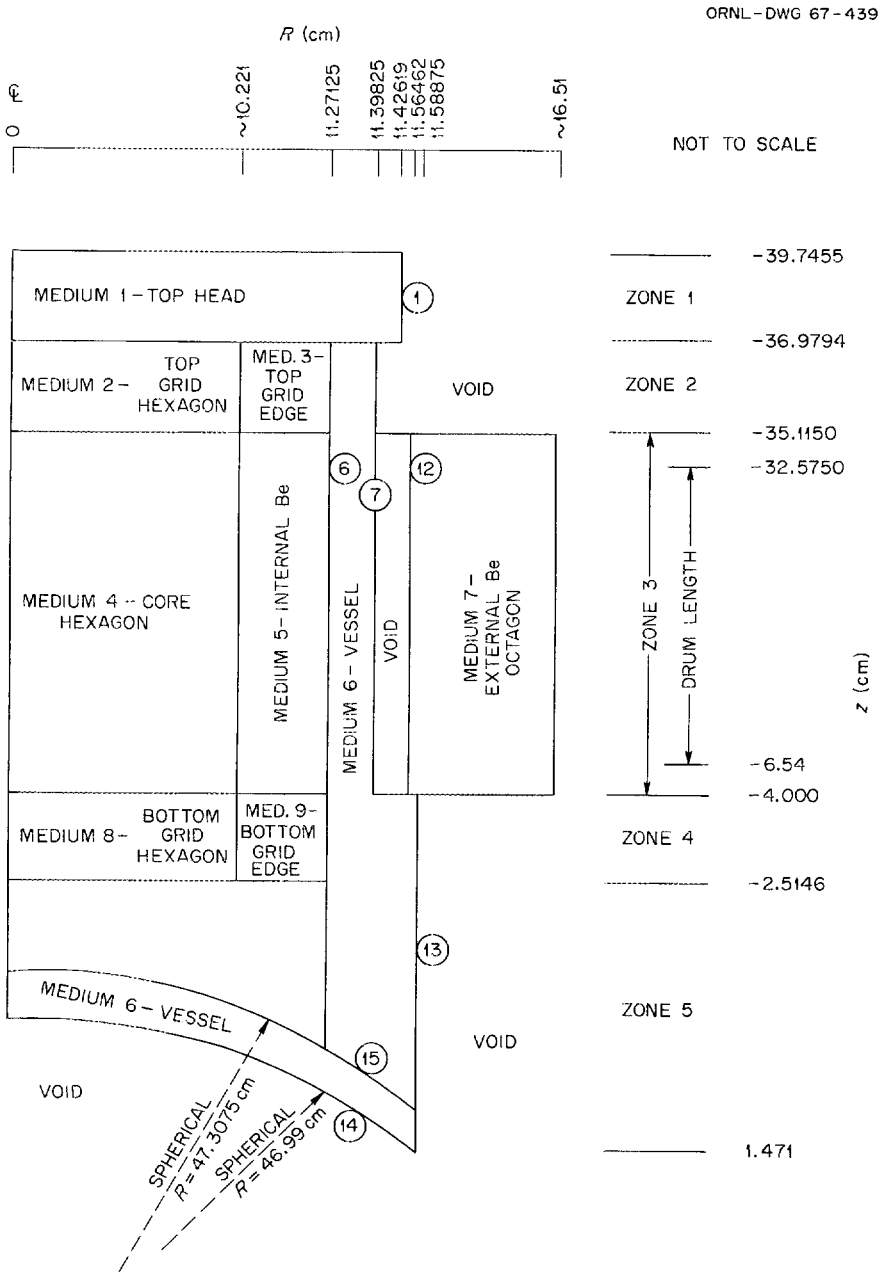

Fig. 3. Axial Geometry of TSF-SNAP Model.

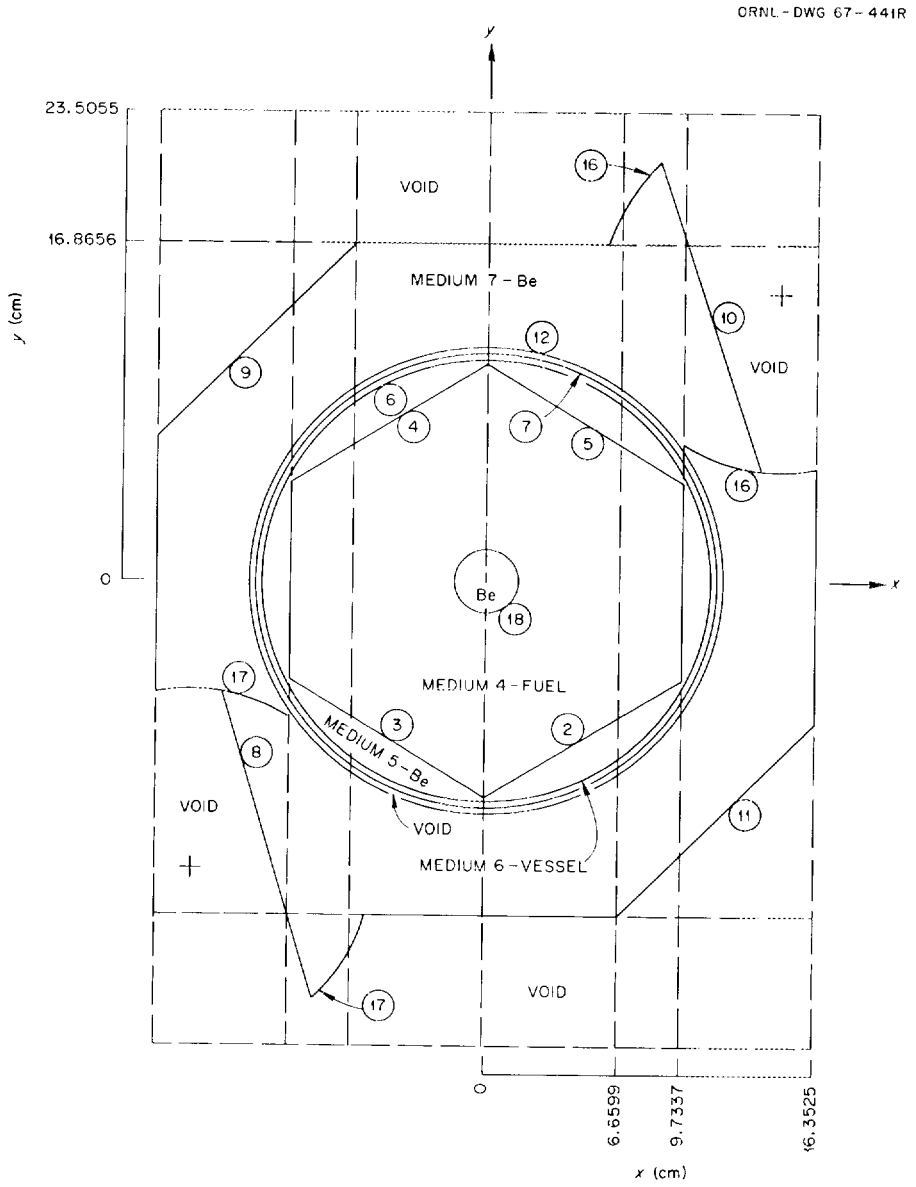

Fig. 4. X,Y Cross Section of Core Zone of TSF-SNAP Reactor Model, Control Drums Rotated Out 30°.

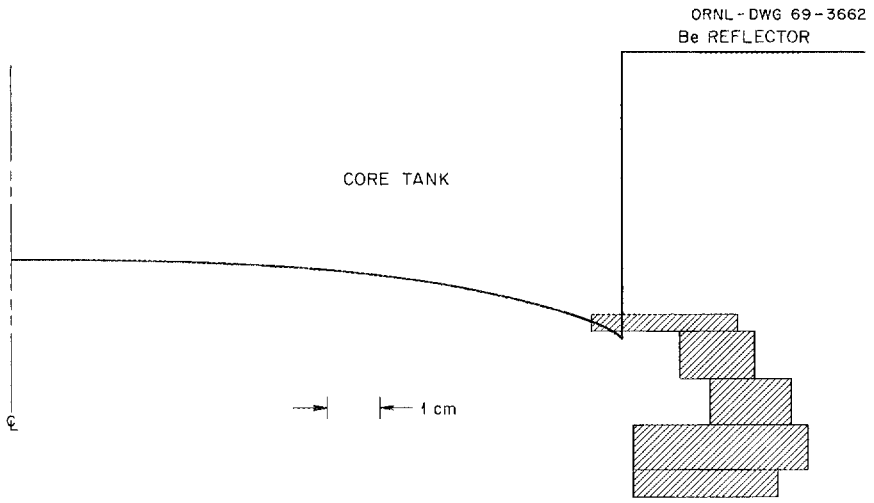

Fig. 5. Albedo Regions Used to Mock Up Reactor Vessel Support Ring.

TABLE I. COLLIMATED DETECTOR POSITIONS AND DIRECTIONS

Detector No.	x	y	z	u	v	w
1	0	0	142.2	0	0	-1.0
2	0	44.402	135.09	0	-.31225	-0.95
3	0	61.983	127.98	0	-.43589	-0.9
4	0	7.0	142.2	0	0	-1.0
5	0	14.0	142.2	0	0	-1.0
6	0	85.32	113.76	0	-.6	-0.8
7	0	68.983	127.98	0	-.43589	-0.9
8	0	92.32	113.76	0	-.6	-0.8
9	0	75.983	127.98	0	-.43589	-0.9
10	0	99.32	113.76	0	-.6	-0.8

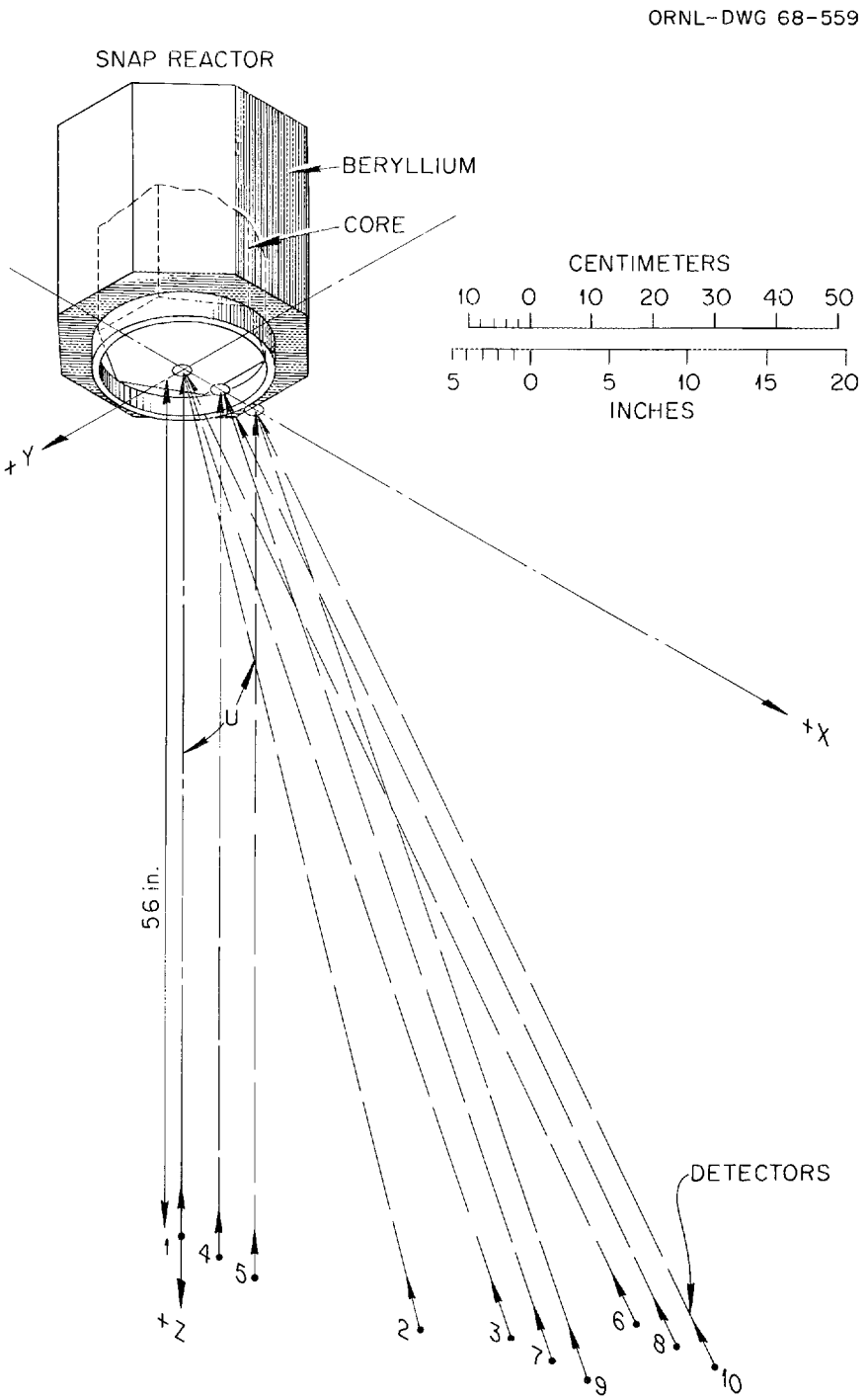

Fig. 6. Detector Positions - TSF-SNAP Experiments.

the x, y, and z direction cosines, respectively, of the direction the collimator was pointing.

The Monte Carlo estimation was actually done by forcing the neutron's last flight to pass through a virtual point on the collimator centerline 51.1 cm. closer to the reactor. The solid angle calculation used the distance to the detector given in the table and the relative response of the collimator was given as a function of the angle between the neutron flight and the collimator axis.

Figures 7 through 16 show neutron energy spectra at detector positions 1 through 10, respectively, as measured experimentally and as calculated. The calculations for detectors 8, 9, and 10 included the support ring as shown in Fig. 5; all other calculations were done without this ring. As can be seen, the absolute agreement is quite good, the total areas under the calculated and experimental spectra differing by less than 10% for all ten cases.

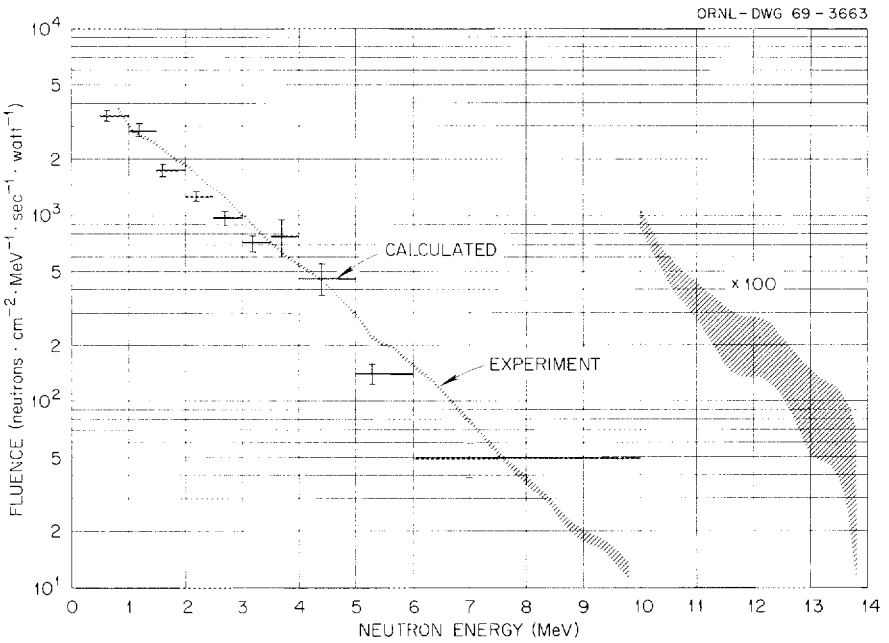

Fig. 7. SNAP Core Leakage Spectrum: Detector No. 1.

Center Core: Cos U = 1.

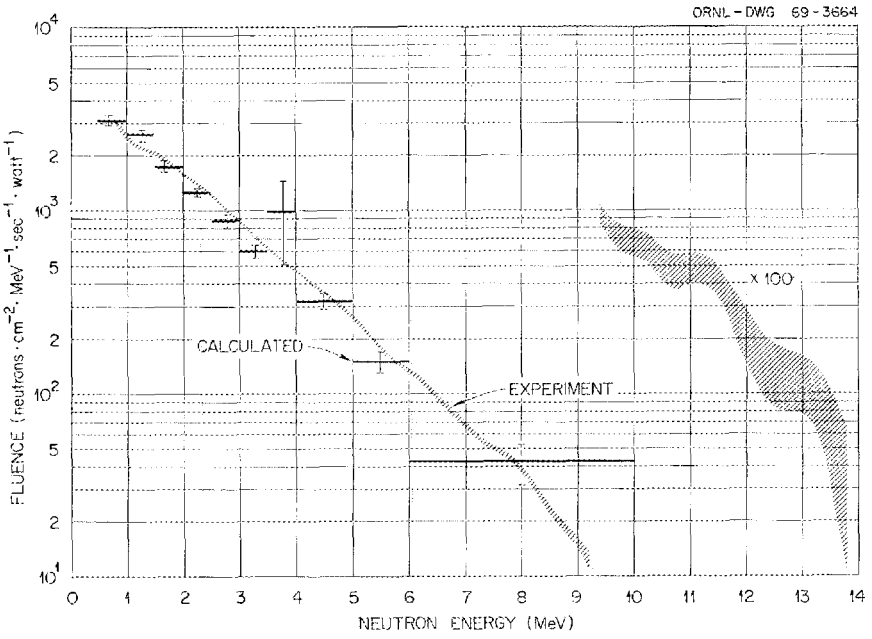

Fig. 8. SNAP Core Leakage Spectrum: Detector No. 2. Center Core: Cos U = .95.

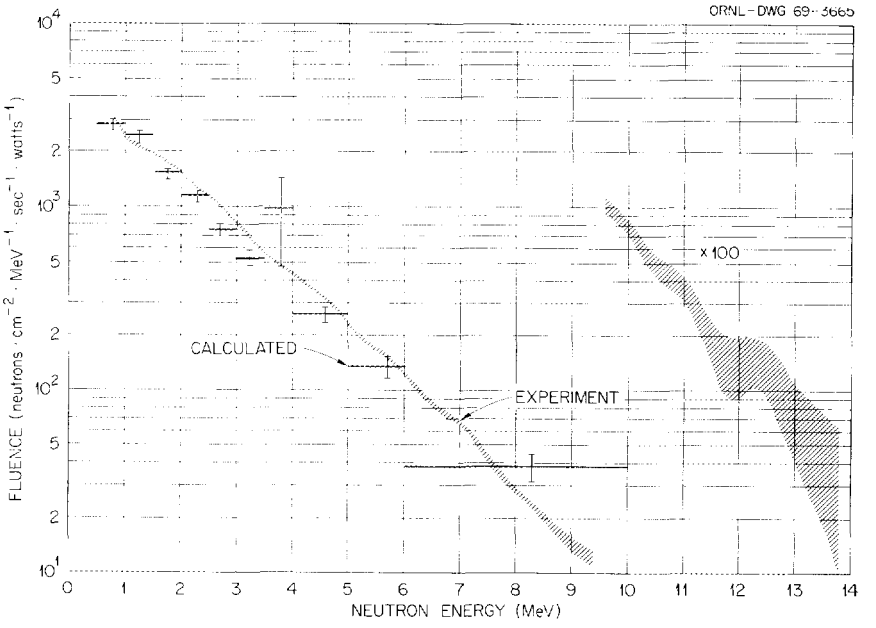

Fig. 9. SNAP Core Leakage Spectrum: Detector No. 3. Center Core: Cos U = .90.

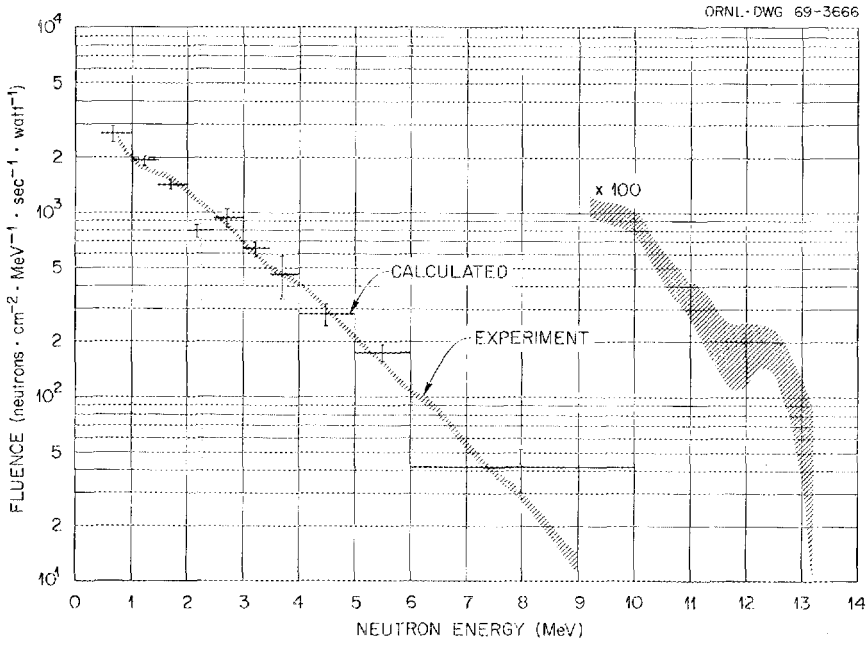

Fig. 10. SNAP Core Leakage Spectrum: Detector No. 4.

Mid-Core: Cos U = 1.

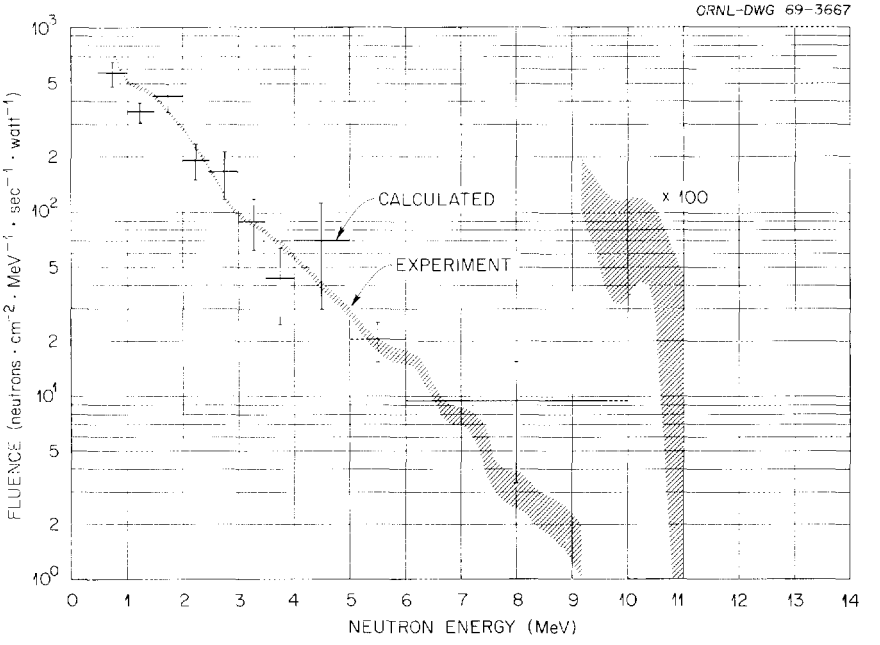

Fig. 11. SNAP Core Leakage Spectrum: Detector No. 5.

Edge Core: Cos U = 1.

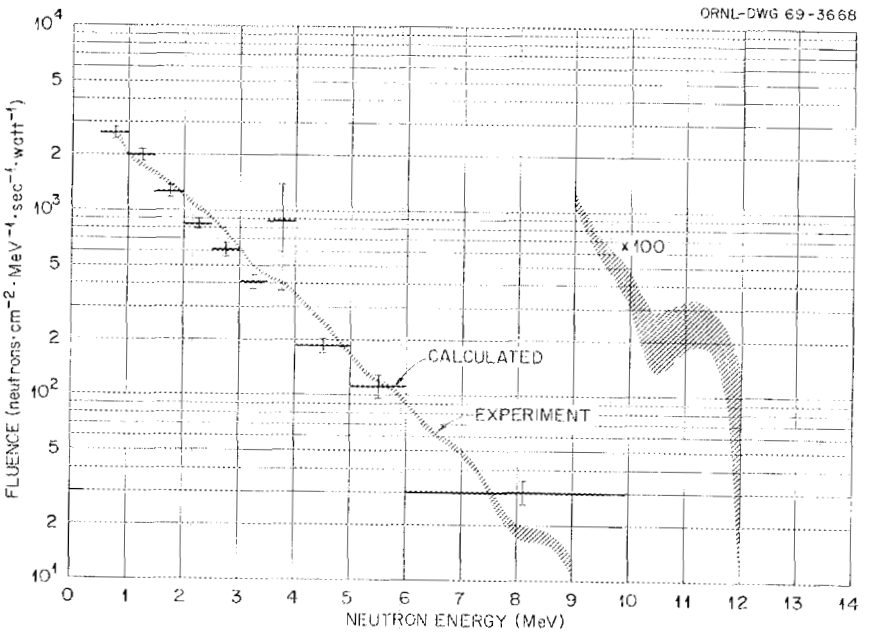

Fig. 12. SNAP Core Leakage Spectrum: Detector No. 6. Center Core: Cos U = .8.

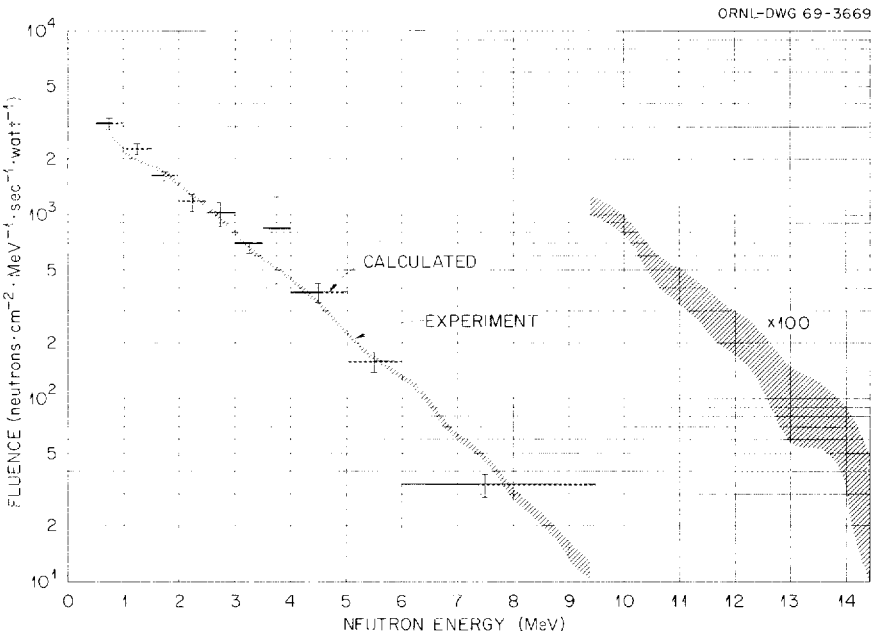

Fig. 13. SNAP Core Leakage Spectrum: Detector No. 7. Mid-Core: Cos U = .9.

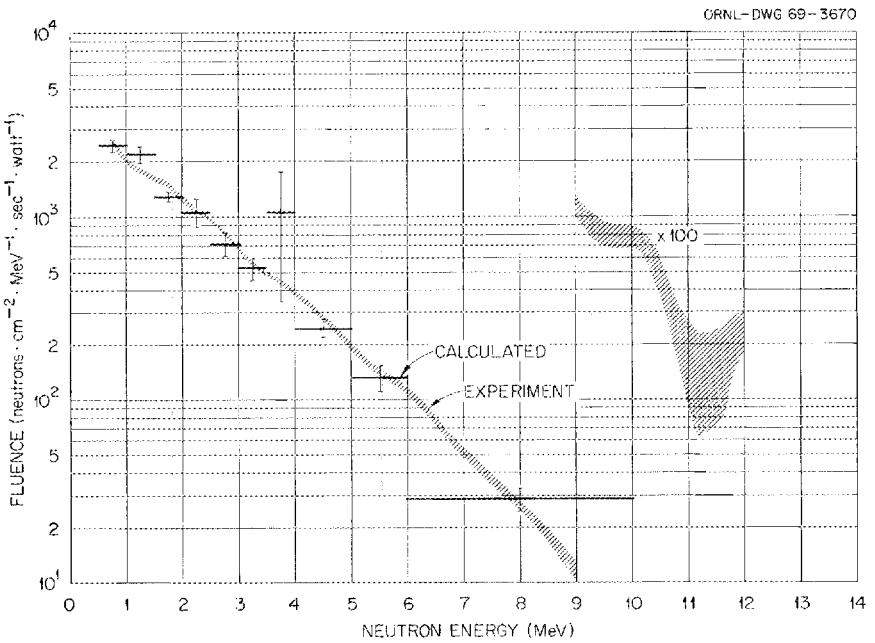

Fig. 14. SNAP Core Leakage Spectrum: Detector No. 8. Mid-Core: Cos U = .8.

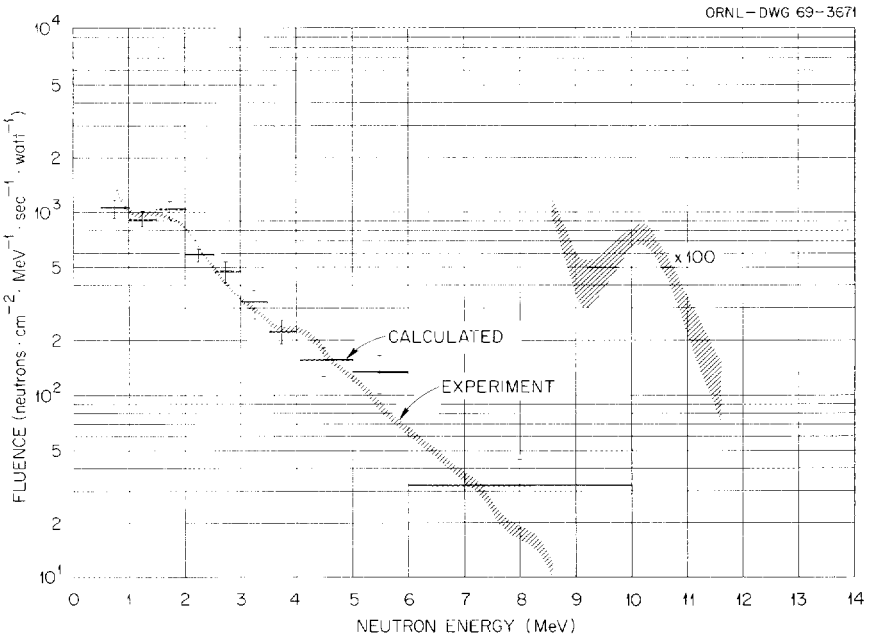

Fig. 15. SNAP Core Leakage Spectrum: Detector No. 9.

Edge Core: Cos U = .9.

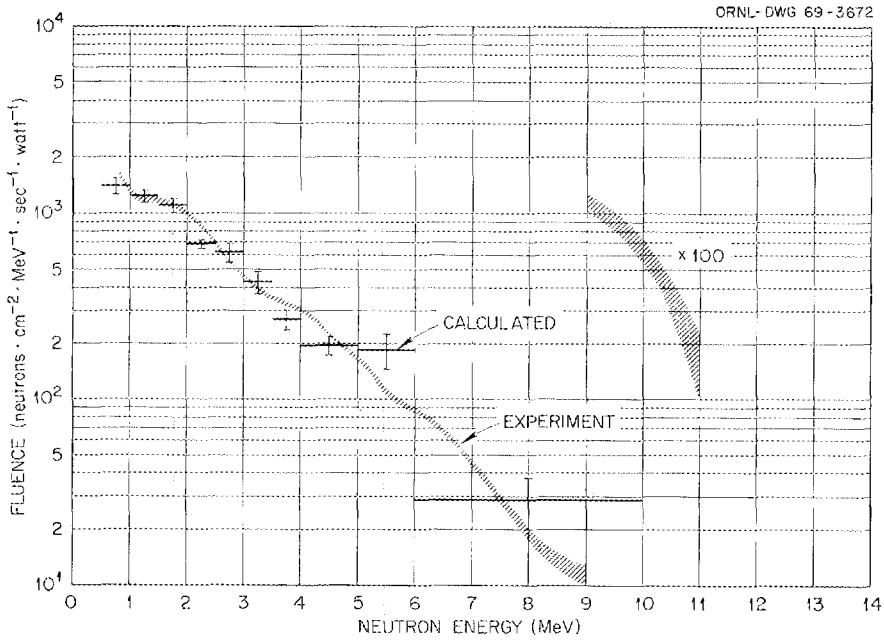

Fig. 16. SNAP Core Leakage Spectrum: Detector No. 10. Edge Core: Cos U = .8.

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