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TITLE: A COMPARISON OF CALCULATIONS AND MEASUREMENTS OF NEUTRON LEAKAGE FROM THE LITTLE BOY REPLICA

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A COMPARISON OF CALCULATIONS AND MEASUREMENTS OF NEUTRON LEAKAGE FROM THE LITTLE BOY REPLICA

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ABSTRACT

Measurements of the neutron leakage spectra from 0.6 to 10 MeV are compared with several calculations and earlier measurements of coarse models of Little Boy. Results indicate excellent agreement except at the nose of the device where the neutron exit path is longer, and neutron streaming through geometric discontinuities may present problems. As a result of the agreement, the longstanding difference between calculations and measurements of the Ichiban critical assembly can be resolved: the results reported in 1965 were not correct.

INTRODUCTION

In 1965, as part of the Ichiban program (Auxier 1977), Thorngate measured the neutron spectrum from the Ichiban critical assembly (Thorngate, Johnson, and Perdue 1966) . The assembly was constructed as a spherical mock-up of the Hiroshima bomb to allow comparison with the results of the one-dimensional calculations that could be performed at the time. In 1975, we calculated the neutron output of the Hiroshima bomb explosion (Bond and Thiessen 1982), and calculated the neutron spectrum from the Ichiban critical assembly. A comparison of the Ichiban neutron spectrum with the Thorngate measurements (Figure 1) shows poor agreement above 2 MeV.

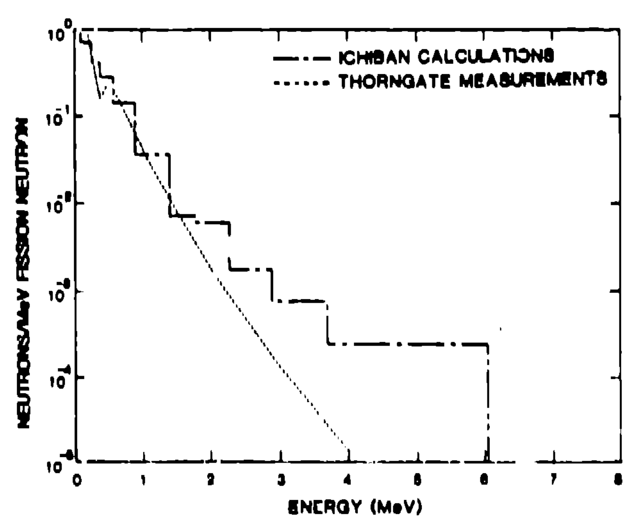

Figure 1. Comparison of measured and calculated neutron spectra from the Ichiban assembly.

W. A. Biggers of Los Alamos performed another set of Ichiban neutron spectrum measurements in 1965. As recounted at the US-Japan Workshop for Reassessment of Atomic Bomb Radiation Dosimetry in Hiroshima and Nagasaki (sponsored by the Radiation Effects Research Foundation in Hiroshima, Japan, in February 1983), this measured Ichiban spectrum was in much better agreement with the earlier calculations and gave us some confidence in the Hiroshima bomb calculations. These calculations were declassified and distributed to interested members of the neutron transport community.

In May 1981, Los Alamos scientists discovered the non-nuclear components of three replicas of the Hiroshima bomb and decided to repeat the Ichiban-type neutron measurements by operating a bomb replica as a critical assembly. Dr. Robitaille of the Defense Research Establishment in Ottawa, Canada, made the first measurements in September 1982 and presented a preliminary plot of the measurement results in Japan at the Reassessment Workshop. The plot compared the measured total (4π) replica neutron spectrum with the total neutron spectrum from the Los Alamos two-dimensional calculation of the Hiroshima explosion. The agreement between the measurements of the replica and the calculation of the explosion was encouraging.

DISCUSSION

As of this writing, the status of the Little Boy replica program stands with Robitaille's publication of his measurement results and the start of Los Alamos replica calculations. A total of 13 neutron spectra measurements were made, 7 measurements of an arc at 75 cm from the center of the fissionable material, which makes the replica critical, and 6 measurements of an arc at 200 cm. The neutron spectrum from 0.6 MeV to 10 MeV was measured with a NE-213 fast-neutron spectrometer. At the 200-cm locations, the neutron background was approximately 14%. Because of the higher fluence at 75 cm, we estimate the background at the 75-cm locations to be less than 2% and do not correct for it in the results.

A comparison of the calculated and measured spectra on the 75-cm arc at the waist (90° position) of the replica (Figure 2) shows close agreement.

A comparison of the Ichiban and replica waist calculations and measurements (Figure 3) shows that calculationally the Ichiban critical assembly was a good mock-up of the waist configuration of the unexploded Hiroshima bomb. The 1965 Thorngate fast-neutron measurements using Ichiban appear to be biased. The ratio of the calculated-to-measured spectra in each

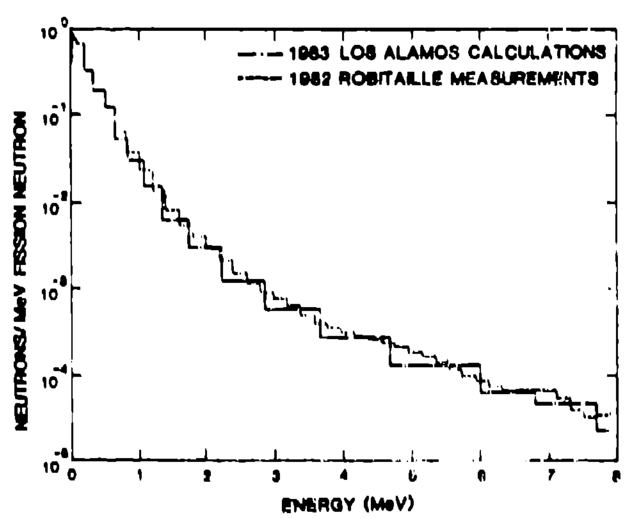

Figure 2. Comparison of the neutron spectra from the Little Boy replica at the waist (90°, 75 cm).

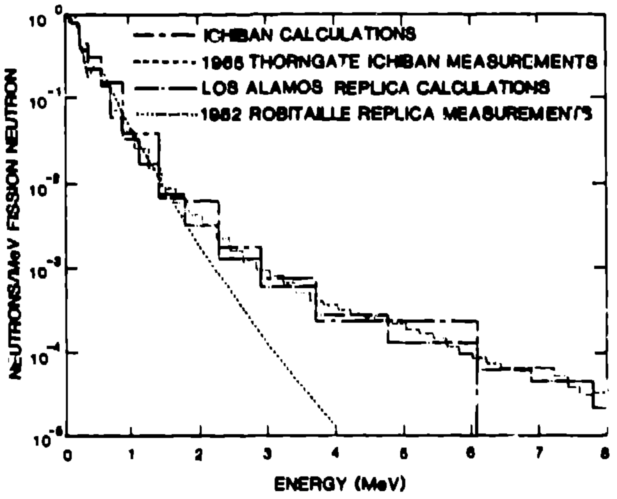

Figure 3. Comparison of neutron spectra from Ichiban and the Little Boy replica waist.

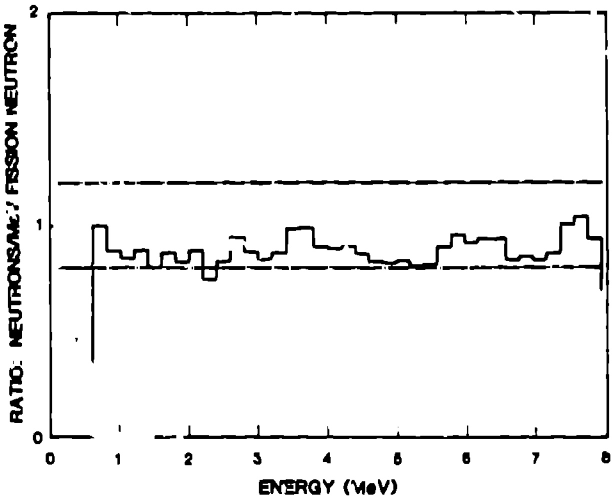

Figure 4. Ratio of Los Alamos calculations to Robitaille measurements of the Little Boy replica.

energy interval (Figure 4) displays the spectacularly good agreement between calculation and measurement at the replica waist.

Based on the excellent agreement of these calculations and measurements at the waist of the replica, we have high confidence in the Los Alamos two-dimensional output calculations of the Hiroshima bomb explosion. We used the same Monte Carlo code with the same set of cross sections in performing the calculations of the neutron output from the replica and from the Hiroshima bomb. (This argument presupposes that the results of other experiments will agree with this experiment and, of course, applies only to those neutrons with energies above 0.6 MeV.)

If we stopped with the waist measurements, everyone would be satisfied. However, measurements we made at 12 other locations and the agreement between calculation and measurement is not so good for those locations where the exiting neutrons must traverse increasing thicknesses of material. Figures 5 and 6 show all the measured neutron fluence integrals at the measurement points on the 75-cm and 200-cm arc, respectively. Figures 7 and 8 show the current status of the calculations of the measured quantity. It is rather apparent that the good agreement between calculation and measurement at the waist (90° position) and the near waist (67.5° and 112.5° positions) breaks down as the measurements approach the pole and near-pole (0° and 22.5°) positions. It is also apparent that the statistics for the calculation at the pole and near-pole positions are poor.

The statistics will improve dramatically after we make some simple modifications to the code. At the moment, the code follows neutrons of all energies to perform a simultaneous criticality calculation (which depends on fissions) and a calculation

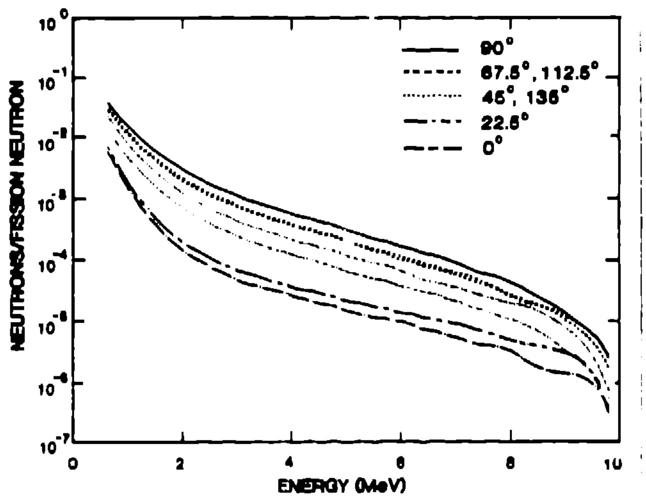

Figure 5. Robitaille's 1982 measured neutron fluence integrals at 75 cm as a function of elevation angle.

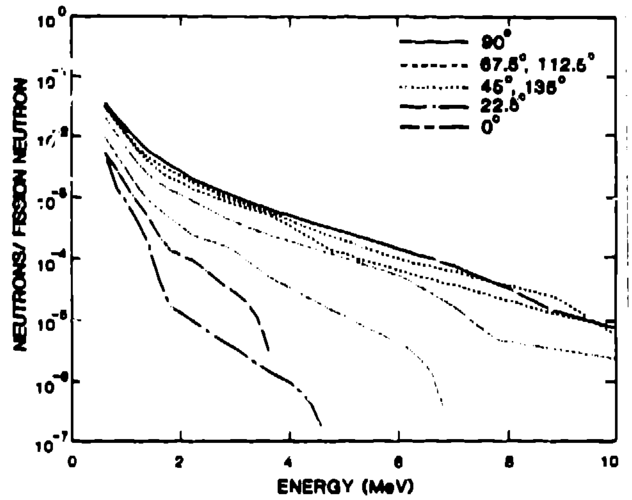

Figure 7. Los Alamos calculated neutron fluence integrals at 75 cm as a function of elevation angle.

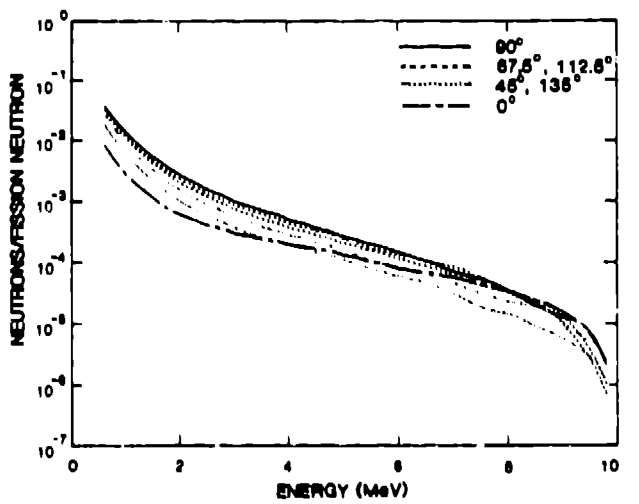

Figure 6. Robitaille's 1982 measured neutron fluence integrals at 200 cm as a function of elevation angle.

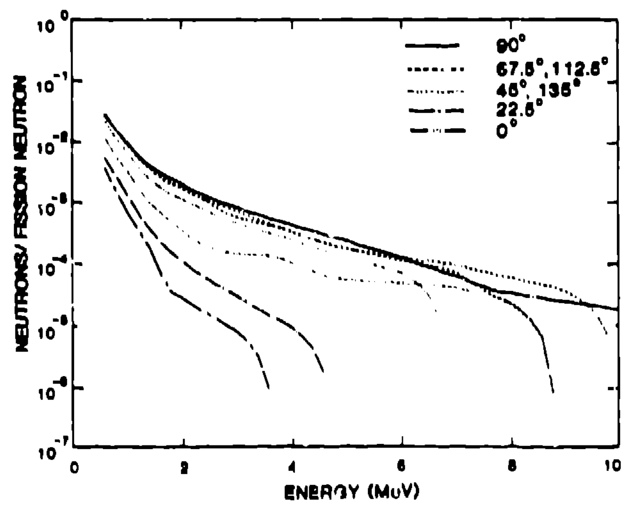

Figure 8. Los Alamos calculated neutron fluence integrals at 200 cm as a function of elevation angle.

of the high-energy output. The improvement in statistics will improve the agreement with the measurement. That is, forcing even one Monte Carlo particle out of the pole position with an energy greater than 4 MeV will bring the calculation closer to the measurement.

Even with the poor agreement between calculated and measured spectra at the pole and near-pole position, there is good spectral agreement between calculation and measurement of the total neutron spectrum. This is because first, there aren't many high-energy neutrons coming from the pole locations (which are about 20% of the waist intensity) and second, these positions contribute less than 10% of the total solid angle. That is, these positions contribute only 2% to the total fast-neutron spectrum.

CONCLUSION

On the basis of comparison of calculations with Robitaille's experimental measurements, the only ones that have been reported, we conclude that the code and cross sections used in the replica calculations give a fairly reasonable match to the measurement for neutrons with energies above 0.6 MeV. Because the same code and cross sections were used in the two-dimensional calculation of the neutron output of the Hiroshima explosion, we conclude that the calculated numbers presented at the Reassessment Workshop are fairly reasonable, assuming that the yield of the calculation was fairly reasonable.

ACKNOWLEDGMENTS

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