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This paper reports preliminary results of the two-dimensional discrete-ordinate, calculations for the air-over-ground transport of radiation from the Hiroshima and Nagasaki weapon devices. It was found that the gamma-ray kerma dominated the total kerma for both environments.

Considerable effort in the area of radiation shielding during the last two decades has been directed toward developing adequate transport methods and cross section data to accurately describe the numerous neutron and gamma-ray interactions within various materials. Once these methods and cross sections have been benchmarked against integral data, they can be used with confidence in calculating solutions to problems which have little or no experimental data such as the Hiroshima and Nagasaki bursts. For problems of this type that can be described in two-space dimensions, are not time-dependent, and require the particle fluence throughout the entire system, the discrete ordinates method may be used effectively. The results described herein were produced mainly with the two-dimensional, discrete ordinates code DOT,[1] run in R-Z geometry with P_3 scattering.

The neutron and gamma-ray leakage spectra from the Hiroshima and Nagasaki devices were obtained from Preeg.[2] This data was placed into the energy group structure of the Defense Nuclear Agency (DNA) Library,[3] which contains the standard cross-section data and response factors used in this study. The atmospheric data for determining the air atomic number densities was obtained from Malik.[4] Since the original devices were exploded at such high altitudes (570-580m for Hiroshima and 503m for Nagasaki) and preliminary calculations indicated that the ground contributed only fifteen percent of the prompt and secondary gamma-ray kerma, a simplified four element ground[5] was used. An initial calculational effort in 1976 gave neutron kerma results for the Hiroshima device which were higher than those given later by Loewe.[6] An investigation of this disagreement revealed that the 1/E weighted DNA cross sections did not represent properly the scattering phenomenon associated with the Hiroshima neutron leakage spectrum. Therefore, new cross-section sets for both the Hiroshima and Nagasaki air environments were produced by collapsing the VITAMIN-C[8] 171 neutron/36 gamma-ray group cross sections into the DNA group structure using the ANISN[7] one-dimensional transport code.

An anomaly known as "ray effects" may occur in two-dimensional discrete-ordinates geometry if the source and detector are small, the scattering mean free path is large compared to the space mesh, and portions of the space mesh are not intersected by at least one of the discrete polar directions. If ray effects are dominant, then the particle fluences in the mesh intervals intersected by the discrete polar directions tend to be too large, and in mesh intervals not intersected, the fluences tend to be too small. This effect can be mitigated by 1) use of the first-collision source in each space mesh, or by 2) using a higher order angular quadrature (more polar angles). For most cases, 1) will insure accurate results. However, if the localized source which characterizes the device leakage in turn produces another localized source (e.g., secondary gamma-ray production), then a combination of 1) and 2) must be used to obtain the proper particle fluences. For the neutron calculations, technique 1) was sufficient. But since hydrogen was present in the air, a large secondary gamma-ray source was produced near the device and technique 2) was used to mitigate these ray effects.

The total collided particle fluence was calculated with the DOT code using the first collision source as input. Any calculations which required a high-order (e.g. S_{20}) quadrature set for ray smoothing, were run with a low-order (S_8) set until converged, then restarted with the high-order set until convergence was once again obtained (usually no more than two iterations). The final scalar fluence was then available to convolute with any desired response factors.

Calculational results indicate that because of differences in the moisture in the leakage spectra of the two devices and in the air, the neutron free-in-air tissue kerma relaxation lengths changed at different rates for the two bursts. The relaxation length for the Nagasaki device reached a constant value for a ground range much closer to ground zero than did the Hiroshima device. The relaxation lengths were ultimately determined by neutrons of energies greater than two MeV. This explained the basic difference between the high Hiroshima neutron T65D[9] kerma values and the lower calculational values. The T65D data assumed the neutron relaxation lengths to be equal for both the Hiroshima and Nagasaki bursts. The gamma-ray kerma for the T65D data and the recent calculations were in better agreement than were the neutron kerma. The gamma kerma tend to dominate the total kerma in the recent calculations for both Hiroshima and Nagasaki.

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