LETTERS TO THE EDITOR

COMMENT ON SHIELDING METHODS FOR THE DESIGN OF PLUTONIUM PROCESSING FACILITIES

Gillett et al. present a modified point kernel technique for radiation analysis of plutonium processing components in their recent paper.[1] The application of a radiation transport code to generate point kernel data for use in a three-dimensional point kernel code (QAD-Pu in their case) is a useful technique that we ourselves have used.[2]

However, as the authors themselves state, care must be taken where more than one important shielding medium exist. We believe a key factor has been overlooked in their approach that is likely to be important for their tank vault configuration. The missing item is to account for secondary gamma rays (from capture and inelastic scattering) generated in the concrete wall.

To do this properly, their ANISN calculation should have used a coupled neutron-gamma-ray cross-section set, such as DLC-23 (Ref. 3). While two of their neutron source spectra are fairly hard, it must be realized that the neutron source in the tank vault configuration is present in a 2-ft-diam tank containing water, and this water will significantly slow down the energetic source neutrons. Thus, the neutron spectrum impinging on the concrete wall will be primarily in the lower energy groups (<0.1 MeV). Calculations by Schmidt have shown[4] that for a neutron flux of 0.1 MeV (upper energy of the four lowest neutron groups) incident on a 30-cm concrete wall, the emerging dose rates due to neutrons and secondary gamma rays are equal. For any larger thickness of concrete, the dose rate component due to secondary gamma rays dominates.

The application of the QAD-Pu code may still be appropriate, but only if the point kernel data utilized were based on a response such as total dose rate, which included both neutron and secondary gamma-ray contributions (similar to that used in Ref. 2). To confirm our observations, measurements for the tank vault configuration, with both neutron and gamma-ray detectors, would be very helpful. Finally, it should be realized that the same general observations apply to the glovebox configuration as well, although the effect of secondary gamma rays would probably be smaller because there is less hydrogenous material between the source and shield.

A final word is in order regarding the low-energy buildup factors. Buildup factor tabulations based on the "straight ahead" approximation have been developed[5] for the standard materials covering most of the Z range for low-energy photons (<200 keV). These buildup factors are in rough agreement with values obtained through Monte Carlo calculations.[6] More recently,[7] buildup factors for water and concrete covering the range 0.03 to 10 MeV have been calculated using the moments method and then fit to the Berger formula. Since the buildup factor peaks in the approximate range of 0.1 to 0.2 MeV, which includes the major part of the plutonium gamma sources, it would be prudent to check how use of such data affects the calculated dose rates, since the authors' extrapolated buildup factors[1] may not have exhibited this peak.

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REPLY TO "COMMENT ON SHIELDING METHODS FOR THE DESIGN OF PLUTONIUM PROCESSING FACILITIES"

We are writing in response to Normand's comments[1] on our paper, "Shielding Calculation Techniques for the Design of Plutonium Processing Facilities."[2]

We hope the brevity of our statement that secondary gamma rays were included in our calculations did not

imply to the reader that their contribution is unimportant. We did not choose to include secondary gamma rays in our neutron kernels in the QAD code, as suggested by Normand, because many of the tanks and source regions in the facility are enclosed with significent gamma-ray shielding. The effect of this shielding would be difficult to remove from the calculated dose.

The approach we took was not very elegant. However, it was consistent with the uncertainty in other aspects of the calculations. Correction factors for the contribution of secondary gamma rays were determined as a function of shield composition and thickness from data reported in the *Californium Shielding Guide*.[3] The concrete in the Rocky Flats facility is similar to Type 03 concrete. Secondary gamma-ray contributions for walls 1 and 2 ft thick were determined to be 10 and 25% of the total neutron dose, respectively. In addition, an ANISN calculation was performed for a tank configuration surrounded by a 2-ft-thick concrete wall using a coupled neutron-gamma-ray set. The secondary gamma-ray contribution for this case was found to be 40% of the total neutron dose.

Incidentally, we must disagree with Normand's assumption about the spectrum of neutrons incident on concrete walls. Rather, the spectrum of neutrons from fission hardens with increased penetration in water. The thermal flux is further reduced by the presence of borated Raschig rings. Thus, although there is a thermalized component of the spectrum incident on the walls, the principal contribution to neutron dose on the far side of the wall originates from energetic neutrons. The actual fraction of the dose from secondary gamma rays is therefore not as high as Normand implies.

Normand is correct in his statement that use of 0.5-MeV buildup factor coefficients for lower energy groups could lead to nonconservative results. The authors were aware of this when the code was written. However, dose rates from shielded plutonium sources such as those in the Rocky Flats facility are in general dominated by sources in energy groups 4, 5, and 6 of Table V in our paper—that is, the 0.3-, 0.4-, and 0.5-MeV groups. The degree of error in those groups is quite small.

As an example, a glove-box configuration calculation—2 or 3 relaxation lengths in the groups described above—showed that using 0.5-MeV buildup factor coefficients for the lower energy groups gave a dose rate that was low by ~5%. This was in comparison to the same calculation performed with buildup factor coefficients from one of Normand's references.[4]

A far greater degree of uncertainty than this exists in the proper choice of a buildup factor reference material for a laminated (water-iron-lead) shield. As is seen in Fig. 4 of our paper, our choice of iron as the appropriate buildup factor reference material inherently leads to an ~20% conservatism in this situation. A similar condition exists in the tank vault configuration, where comparison calculations found an error of no more than 8% in 7 to 9 relaxation lengths. Once again, this was well within the "conservatism band" of ~25% of this configuration.

While care must certainly be taken in the calculation of buildup factors for very "soft" spectra, 0.2 MeV and less, we have shown that for the spectra encountered at the Rocky Flats facility, use of the higher energy buildup factor coefficients did not lead to an induced error of any significance. In fact, the calculations performed by this method remain both conservative and reasonably accurate.

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