Title

Response to 'A comment on "Signatures of fissile materials: High-energy gamma rays following fission," by Zeev B. Alfassi'

Authors

Norman, Eric B.
Prussin, Stanley G.
Larimer, Ruth-Mary
et al.

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Response to "A Comment on "Signatures of fissile materials: high-energy γ rays following fission" by Zeev B. Alfassi, Department of Nuclear Engineering, Ben Gurion University of the Negev, Beer Sheva 84105, Israel

Eric B. Norman[1], Stanley G. Prussin[2], Ruth-Mary Larimer[1], Howard Shugart[3], Edgardo Browne[1], Alan R. Smith[1], Richard J. McDonald[1], Heino Nitsche[1,4], Puja Gupta[2], Michael I. Frank[5], and Thomas B. Gosnell[5]

[1]Nuclear Science Division, Lawrence Berkeley National Laboratory, Berkeley, CA 94720, USA

Departments of Nuclear Engineering[2], Physics[3] and Chemistry[4], University of California, Berkeley, CA 94720, USA

[5]National Security, International Cooperation and Arms Control Directorate, Lawrence Livermore National Laboratory, Livermore, CA 94550, USA

Prof. Alfassi has pointed out that radionuclides that are not fission products, but which emit γ rays with energies $E_\gamma > 3$ MeV, can be produced by neutron irradiation. He suggested that the decays of such activation products would interfere with the identification of fissionable materials. However, the combination of the energy spectrum and the temporal variation of the fission product gamma rays can be used to distinguish fissionable material from other nuclides.

The activation of nuclides that could produce interferences will depend upon the specifics of the cargo and, possibly, the local surroundings. As discussed in our original publication, in addition to the steel that Prof. Alfassi referred to in his *Comment*, we studied the activation of wood, polyethylene, aluminum, and sandstone. Activation by thermal neutrons will always occur, and Prof. Alfassi correctly points out that nuclides such as ^{49}Ca and ^{37}S can be formed in this way. These nuclides are representative of most potential interferences. Both ^{48}Ca and ^{36}S have very low isotopic abundances (0.187% and 0.02%, respectively) and small thermal neutron capture cross sections (0.20 barns and 0.98 barns, respectively). In addition, their half lives are more than an order of magnitude longer than the gross average observed from the fission products, and more than two orders of magnitude longer than the lifetimes of the shorter-lived fission products that contribute significantly to the total intensity in the energy range of interest. These differences make it possible to distinguish between fission products and thermal neutron activation products.

Prof. Alfassi also pointed out that interferences, of which ^{16}N is likely to be the most important, can be produced by fast neutron reactions. (As described in our original publication, we did not use a 14 MeV generator in our work.) Fortunately, a judicious choice of the source neutron energy can limit the extent of these interferences quite significantly. For example, the laboratory threshold for the reaction $^{16}O(n,p)^{16}N$ is 10.2 MeV, while that for the reaction $^{19}F(n,\alpha)^{16}N$ is 1.6 MeV. Thus a source neutron energy around 5 MeV would completely eliminate the $^{16}O(n,p)^{16}N$ reaction and limit the $^{19}F(n,\alpha)^{16}N$ reaction to that portion of the cargo in which neutrons with energies greater than 1.6 MeV were present. However, even in the presence of ^{16}N, the energy spectrum and temporal variation of the fission product gamma rays should be decisive in distinguishing fissionable material from these interferences.