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Memorandum

21 July 2010

To: Mike Gerardi

From: Bill Higgins

Subject: Polyethylene shielding effectiveness

This note supersedes my message to Mike Gerardi of 3 Mar 2003, "Using polyethylene to attenuate low-energy neutrons" (because a larger packing fraction for polyethylene beads is justified).

Polyethylene can be used to shield against the effects of neutrons. The question arises of how thick a polyethylene shield must be in order to achieve a given attenuation.

According to graphs published as figures in NCRP-38 [Reference 1], attenuation of dose from neutrons by a 12-inch thickness of polyethylene depends upon energy:

Figure	Energy (MeV)	Relative Dose
61	5	2.50E-02
62	3	6.00E-03
63	2	1.00E-03
64	1	2.00E-05
65	0.5	<1.00E-05

For energies below 1 MeV, polyethylene is extremely effective at attenuating neutron doses, thanks to its hydrogen content. For example, at 1 MeV, a dose of 1000 millirem would be reduced to a few hundredths of a millirem by passing through one foot of solid polyethylene.

At Fermilab, penetrations are often blocked by bags of polyethylene beads. These are less effective than solid polyethylene, due to voids between the beads. The upper limit of packing fraction for uniform close-packed spheres is 0.74, but beads used in shielding are not uniform in size.

Wayne Schmitt has recently measured 1 liter of polyethylene beads, and found its mass to be 660 grams. Since the density of polyethylene is typically between 0.91 and 0.95 grams per cubic centimeter, this measurement represents a packing fraction between 0.68 and 0.72.

Assuming, to be conservative, their packing fraction exceeds 0.5, two feet of polyethylene beads should attenuate better than one foot of solid polyethylene.

This reasoning applies only to low-energy neutrons, not to situations where high-energy particles directly from a loss point can enter a penetration.

Reference 1: National Council on Radiation Protection and Measurements, Report 38, "Protection against Neutron Radiation," 1971, Appendix E, figures 61 through 65, p. 116-119.

CC:

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Roger Zimmermann