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UNITED STATES ATOMIC ENERGY COMMISSION

EXPERIMENTAL VERIFICATION OF GAMMA
SCATTERING CALCULATIONS

By
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June 14, 1951

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KAPL

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SUBJECT: Experimental Verification of Gamma Scattering Calculations

The experimental results obtained by Clifford at ORNL on the scattering of gamma rays in water indicate that the group calculations of KAPL-504 are correct within an order of magnitude.

To compensate for the difference in geometry between the ORNL test and the group calculation model, the following scheme was used (see attached figure):

1. The distance from the Co source to the steel "hull" in the test was 12.5 centimeters. The relaxation length of the "average" cobalt gammas (1.25 Mev) in water is 15.9 centimeters. If the Co source is assumed to be at the center of an imaginary cubic box having a side of 25 centimeters, 1/6 of the Co gammas escaping from that cube emerge through one of the six equivalent faces. It is assumed that the average attenuation of gamma intensity between the Co source and the face of the cube is a factor "e" since the relaxation length of the Co gammas in water (15.9 cm) is "somewhere" between the shortest distance from the source to the cube face (12.5 cm) and the half-diagonals of that cube (17.7 and 21.6 cm).

2. The source strength is calculated from the experimental dosage value of 4.4 r/hr at 100 centimeters in air. This corresponds to:

$$2.9 \times 10^{11} \text{ Mev/sec}$$

emerging from the source.

3. The average gamma intensity through the top face of the cube described in paragraph 1 is then:

$$\frac{2.9 \times 10^{11}}{6 \times 25^2 \times e} = 2.85 \times 10^7 \text{ Mev/cm}^2 \text{ sec}$$

4. The gammas reaching the "hull" after escaping from the cube through faces other than the top one are neglected since they get into the iron at a large angle from the normal. This amounts to assuming that the point source produces a partially collimated gamma intensity of $2.85 \times 10^7 \text{ Mev/cm}^2 \text{ sec}$ over an area of 625 square centimeters of the steel hull. The above intensity corresponds to a dosage of:

$$5.4 \times 10^4 \text{ mr/hr}$$

inside the steel hull and inside the secondary shield.

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-2-

5. If instead of having a dosage of 5.4×10^4 mr/hr over an area of 625 square centimeters, we had the same dosage over a semi-infinite plane inside the hull and inside the secondary shield, by what factor should we multiply the experimental value of 0.033 mr/hr at the "crew position" (see attached figure), at 90 centimeters from inside the lead shield? This factor is assumed to be:

$$\frac{1150}{625} = 1.8$$

where 1150 square centimeters is the important area of the semi-infinite source. Consequently, the dosage at the crew position would be, for such a plane source:

$$.033 \times 1.8 = .06 \text{ mr/hr}$$

6. The "experimental" attenuation in the case of a plane source is defined as the ratio of dosage inside the hull and inside the secondary shield to the dosage at the "crew position" and is equal to:

$$\frac{5.4 \times 10^4}{.06} = 9 \times 10^5$$

A group calculation has been run, as in KAPL-504, assuming a semi-infinite plane source of 1.25 Mev gamma radiation, a black shield 90 centimeters thick and a steel hull 7/8" thick (same as in test).

Such a group calculation gives an attenuation of:

$$40 \times 10^5$$

or roughly 4 times the experimental value.

Such an agreement is probably as good as can be expected in view of the coarseness of the calculations. Furthermore, there are some fundamental differences between experiment and analysis which have been disregarded. First, the artificial collimation introduced in the adjustment of experimental data (by use of the imaginary cube) is different from the cosine distribution of the source in the group calculation. The build-up factor and geometrical divergence between the two scattering regions in water has tacitly been assumed to be the same for the two geometries when they must certainly differ. Finally, no correction has been made in the experimental data for the direct contribution through the lead shield, for the streaming along the slots between the lead shield and the "hull", and for the scattered radiation coming back from the "sea" between the lead shield and the "crew position."

Sodium Source

Considerations identical to what precedes could be repeated to interpret more recent ORNL data obtained with a sodium point source and a steel "hull" of 1 3/4 inch.

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-3-

The "experimental" attenuation in this case, after geometrical correction, is equal to:

$$3.1 \times 10^6$$

The attenuation calculated in KAPL-504 was corrected for the slight difference in hull thickness and turned out to be:

$$8 \times 10^6$$

The agreement is even better than in the case of a Co source. It should be said that the data obtained with the sodium source are not as yet as accurate as those obtained with the cobalt source. More precision and certainty will be attained after the tests now underway at ORNL with a sodium source have been completed. In fact, those tests will eliminate some of the assumptions that were necessary to compensate for the geometrical difference from the model studied in KAPL-504. Varying the position of the point source and the detector will make it possible to convert the data to a plane geometry more directly.

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WATER

The γ rays escaping from the cube of water through this top face are assumed to be the only ones penetrating the $\frac{1}{8}"$ "hull" in the ORNL test

Top face of cube
(625 cm²)
above point source

Effective area of semi infinite plane source
(1150 cm²)

12 cm = λ of ^{60}Co γ in water after 45° scattering

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5

y-207-4