Comparison of Two Techniques for Determining Linear Absorption Coefficients

DONALD E. TIANO, Indiana Central College and JOHN F. HOULIHAN, DePauw University

The work to be considered in this discussion was undertaken to explain unexpected results which were obtained when two different techniques were used to determine the linear absorption coefficient of gamma rays of some sandstone blocks (3). The experimental design of the

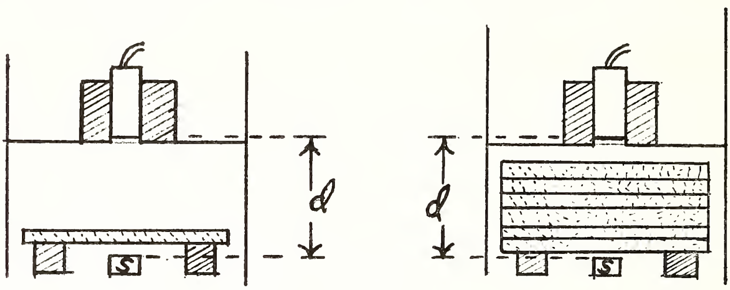


Figure 1.

first method is shown in Figure 1. In this "fixed distance" method the distance, *d*, remains constant. For the second method, the "variable distance," is shown in Figure 2, the detector was placed on top of the attenuating material. As the thickness of the material varies, the distance between the source and the detector also varies.

A rather large discrepancy remains when both methods are employed and the inverse-square correction for the difference of the distance is applied. This discrepency is shown in Figure 3 which shows the intensity of the gamma radiation for a Co^{60} source plotted as a function of the thickness of the attenuating sandstone block.

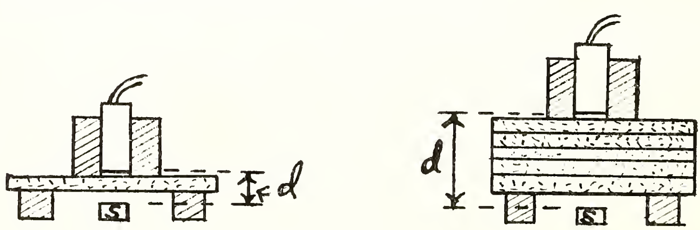


Figure 2.

The inverse-square correction is applicable only for a point source, thus it was necessary to determine the proper correction factor for the variation of distance in order to obtain a correlation between the two methods. This paper discusses the planning of an experimental procedure whereby such a correction factor can be determined. The need for a "solid angle of scattering" correction factor is also discussed.

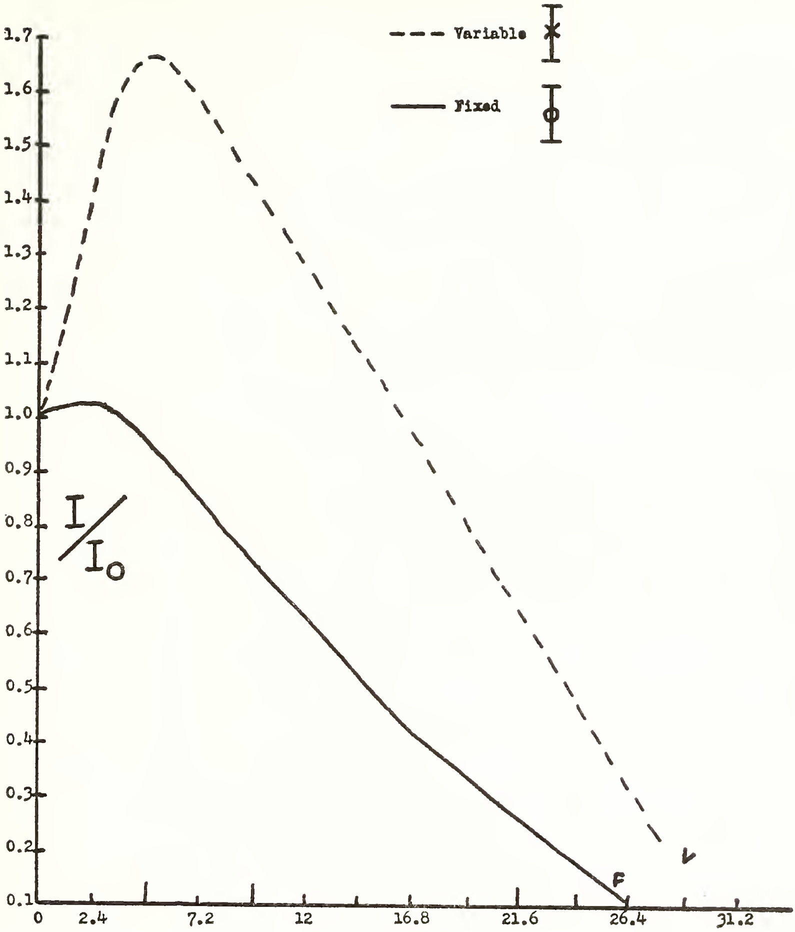


Figure 3.

In the experimental work, aluminum was used instead of the sandstone blocks. This substitution of attenuating material was made because the original blocks were very large and handling them caused other problems.

It has been shown empirically that in any given material, a homogeneous beam of gamma rays is absorbed exponentially. If a beam of gamma rays has an intensity I at a distance x in an attenuating material and there is a decrease of intensity due to the attenuation of the gamma ray beam in a thickness dx, one obtains,

$$dI = -\mathrm{I}u\,dx \qquad 1.$$

where u is is a constant of the attenuating material and is termed the linear absorption coefficient. Separating the variables and integrating equation 1 between the limits O and t we obtain,

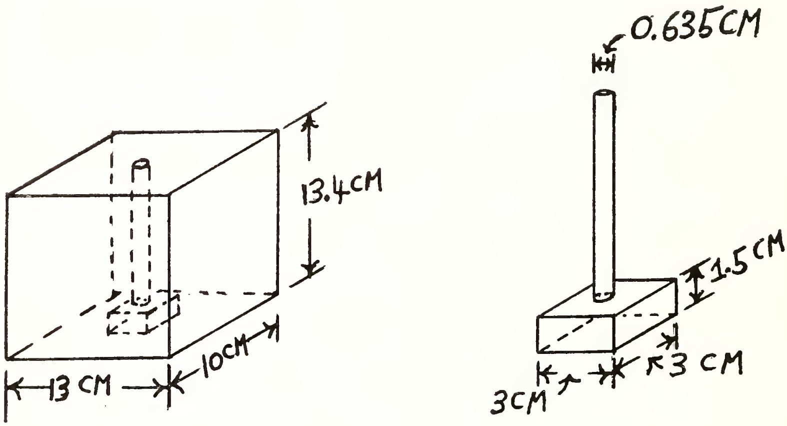
$$\int_{\mathrm{I_o}}^{\mathrm{I_t}} \mathrm{dI/I} = -\int_{\mathrm{O}}^{\mathrm{t}} u\,dx \quad \text{or} \quad \mathrm{1n(I_t/I_o)} = -\mathrm{ut} \qquad 2.$$

where t is the total thickness of the attenuating material and I_o and I_t are the initial and final intensities of the beam respectively. From equation 2 it can been seen that if $\ln(I_t/I_o)$ is plotted as a function of the thickness of the absorber in centimeters, the linear absorption coefficient is given by the slope of the curve (1).

To determine the correction factor for the variation of distance, the following procedure was used: a source shield and collimator were constructed to obtain a nearly parallel beam of gamma rays. The 1/100 value thickness of lead was determined for the Co-60 source using the following expression:

$$\ln(I_t/I_o) = -ud \qquad \text{where } I_t = 0.01, \quad I_o = 1.0, \quad u = 0.537 \tag{3}$$

The 1/100 value thickness of lead was found to be approximately nine centimeters. The source shield and collimator were constructed with the dimensions shown in Fig. 4.



Shield and collimator Hollow center of collimator

Figure 4.

After consideration of the geometry of the shield and collimator and the scintillation detector crystal, the maximum distance the detector could be located from the shield while still detecting all of the incident beam was determined so that the solid angle considerations could be ignored.

A plateau was taken to determine the best operating voltage. Observations were made using a Picker Compact Scaler and gamma crystal. The intensity of the beam as a function of distance above the top of the lead shield and collimator is recorded in Fig. 5. The "best fitting curve" was found by applying the statistical analysis method of least squares. This data and most of the subsequent data was analyzed with an IBM 1620 computer. The flags on the graphs represent the probable error due to fluctuations in background (4).

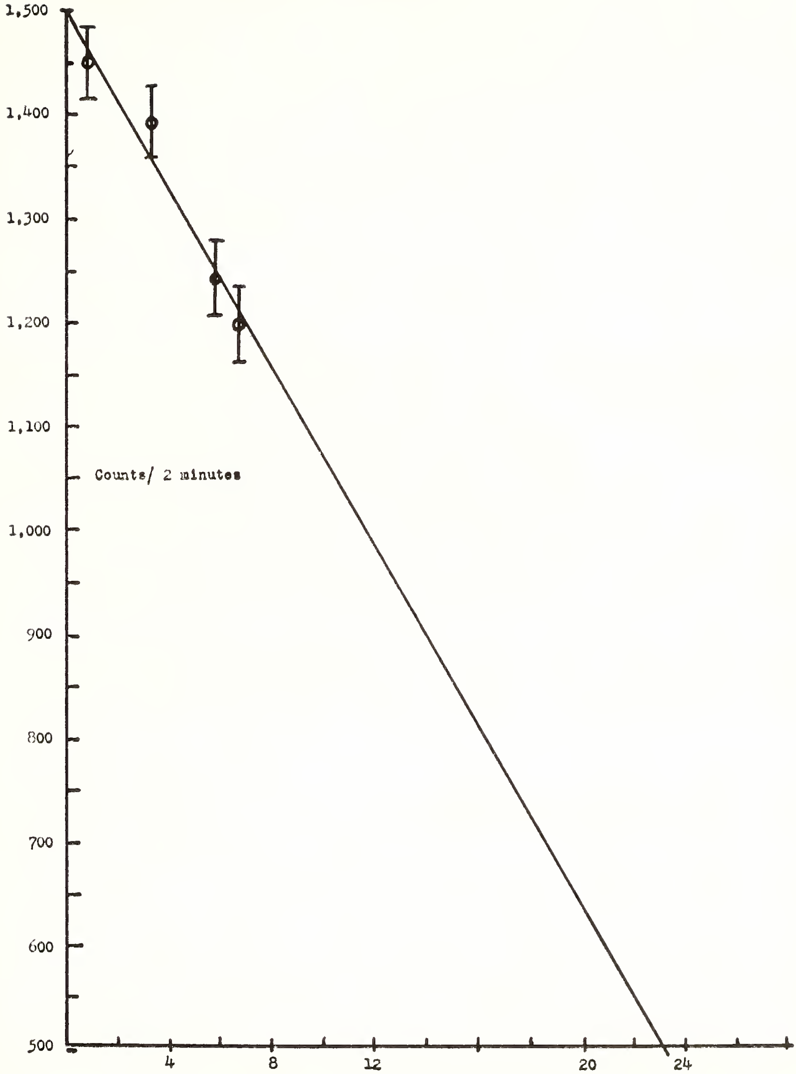


Figure 5.

The decrease in intensity of the beam as a function of distance above the shield can be determined for any point desired. The decrease due to distance considerations as found in Figure 5 is thus added onto the observed count as a correction factor. The reason for this variation of beam intensity as a function of distance of the counter from the source is primarily due to the inability of the collimator to produce a truly parallel beam of gamma rays.

The source of gamma rays used in the experimental work under discussion was cobalt-60. When cobalt-60 decays by emission of a 0.314

MeV beta particle it results in the formation of nickel-60 in an excited state, or a nickel-60 isomer. The Ni-60 isomer decays by emission of a 1.17 MeV gamma ray to form another lower energy Ni-60 isomer. This Ni-60 isomer then decays by the emission of a 1.33 MeV gamma ray to form the stable nickel-60 isotope. During the experimental procedure the Co-60 is emitting 0.314 MeV beta particles and 1.17 and 1.33 MeV gamma rays as well as trace amounts of other beta and gamma energies (1). There are two 1.17 MeV gamma rays and one 1.33 NeV gamma ray from each nucleus that disintegrates (2).

Observations were made using both the fixed distance and the variable distance techniques. Fig. 6 shows the resulting curves with no correction applied and Fig. 7 shows the resulting curves with the correction obtained from Fig. 5 applied. Figs. 8 and 9 show the

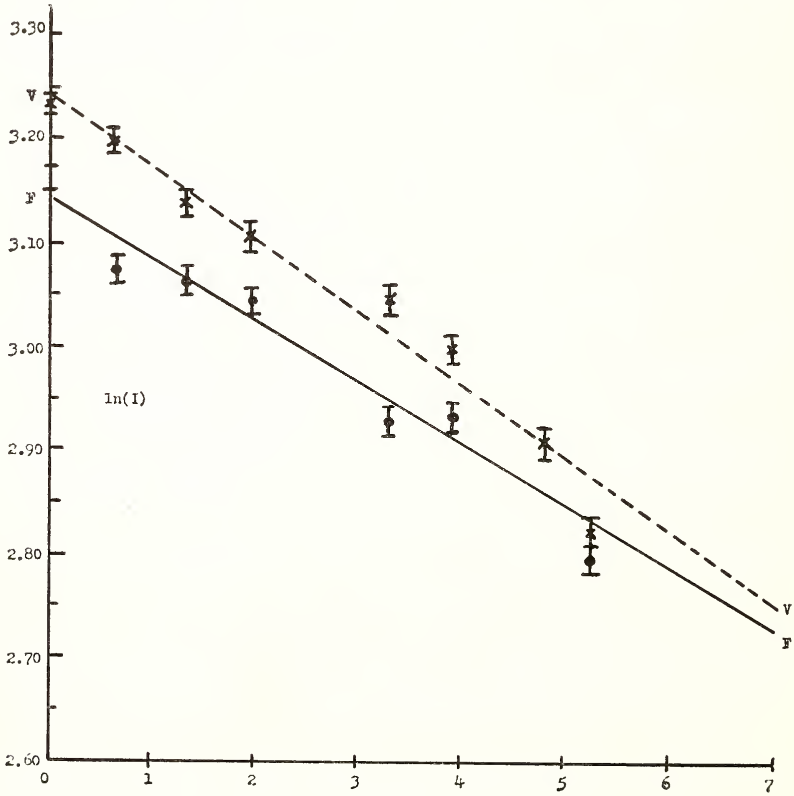


Figure 6.

uncorrected and corrected plots to determnie the linear absorption coefficients respectively. Both Fig. 7 and Fig. 9 suggest that there is some systematic error operating in the results since in both cases the corrected values for the variable distance curve are all higher than the corresponding value of the fixed distance curve. This systematic error is probably due to a difference in the "solid angle of scattering,"

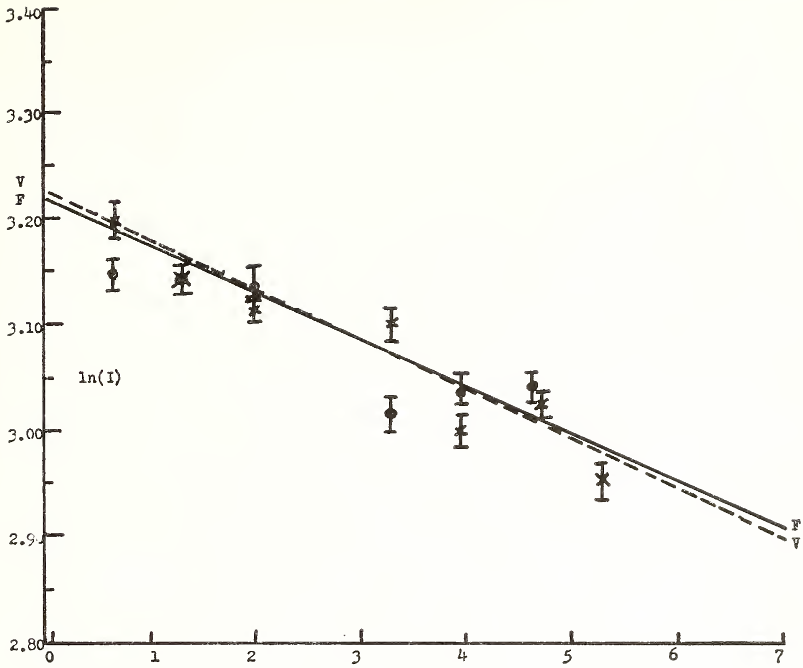


Figure 7.

i.e., the solid angle subtended by the detector crystal with respect to the random direction of the scattered particles and photons. This systematic error could be almost completely eliminated by the use of a discriminating type of circuit.

It might be well to point out that a comparison of the values of the linear absorption coefficient of Al as obtained in Figure 9 with the commonly accepted value of 0.15 cm^{-1} (5) reveals an error of 50%. This error is due to two factors. First, to approach the accepted values, the geometry of the equipment should consist of a very narrow beam of gamma rays incident on a detector that has a surface area no greater than the diameter of the beam. Finally, and most importantly, the detector should be adjusted to discriminate against all secondary emission, that is, adjusted to record only those pulses at or very near 1.17 or 1.33 MeV.

An effort is being made to obtain the necessary equipment to allow this latter correction to be made. This correction will improve the correlation of the relative values of u for the fixed and variable distance methods through the elimination of the difference of the "solid angle of scattering," while at the same time bringing the absolute value of u_f and u_v much closer to the accepted value for the linear absorption coefficient of aluminum.

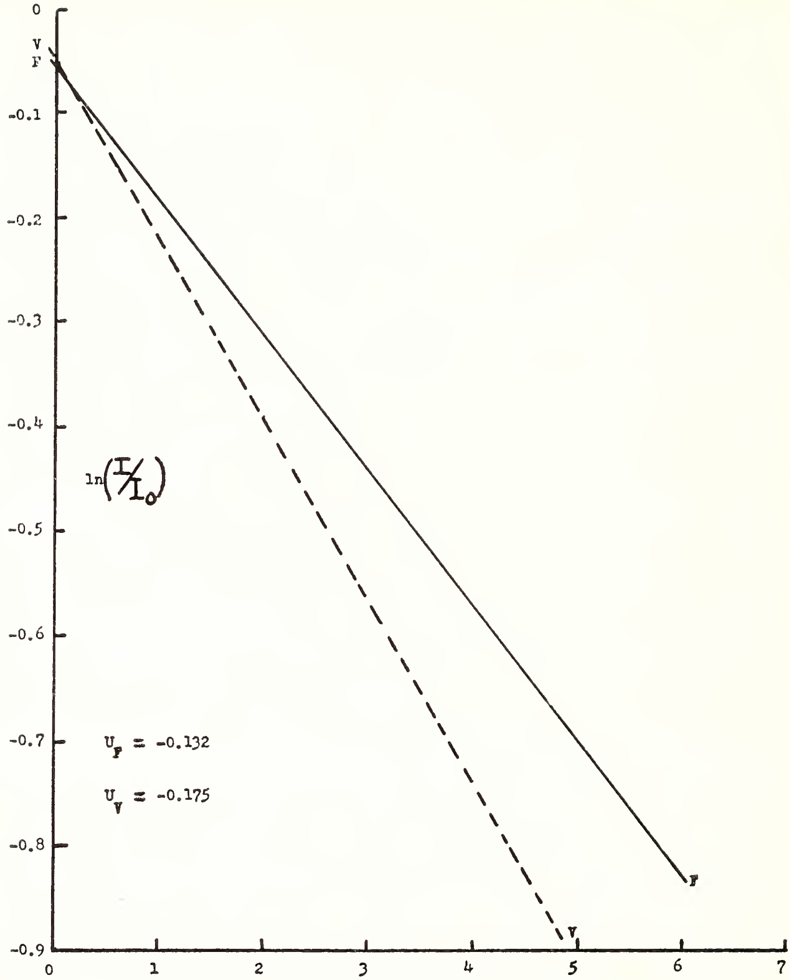


Figure 8.

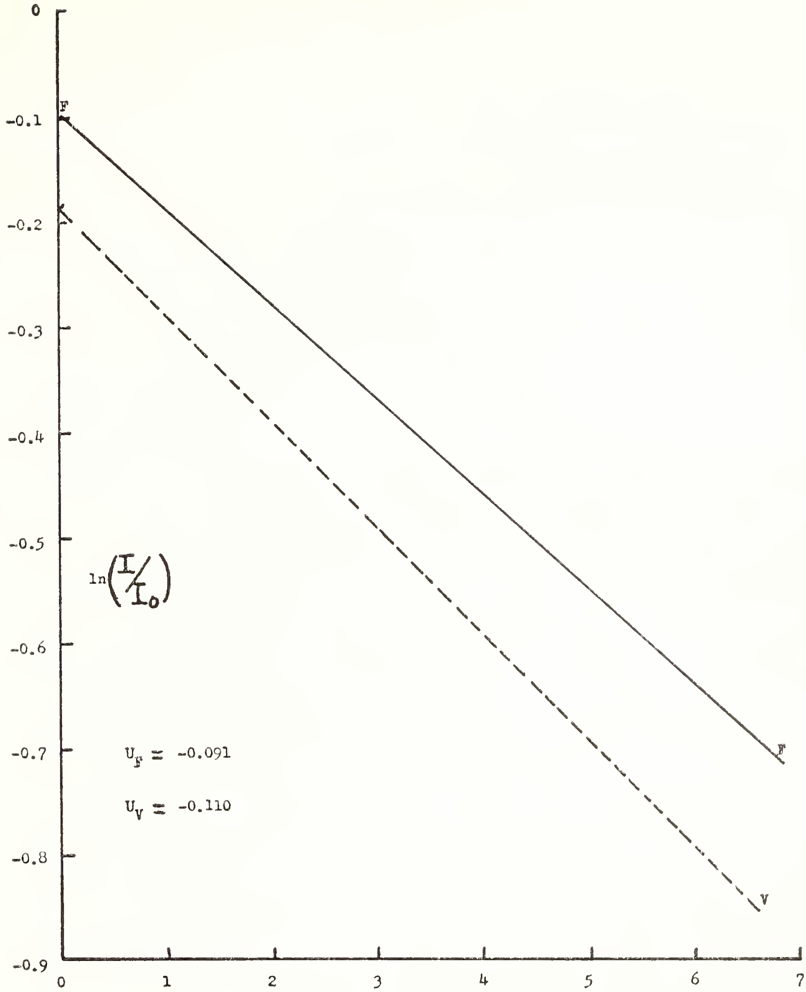


Figure 9.

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