Fig 2-2

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OBLIQUITY FACTORS FOR SHIELDS

Harvey Brooke

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Obliquity Factors for Shields

If a spherical sample is placed inside a spherical shield having an absorption coefficient μ and a thickness t , then the number of neutrons captured in the sample is reduced by the factor:

$$e^{-\mu t} \quad (1)$$

On the other hand, if the shield is some other shape, the neutrons may traverse different total amounts of shielding material, depending upon the direction from which they arrived at the sample. This may be expressed by saying that the thickness t is a function of (θ, ϕ) , the direction of the incident neutron. In this case the attenuation factor is:

$$\frac{1}{4\pi} \int \mu e^{-\mu t(\theta, \phi)} d\Omega \quad (2)$$

where $d\Omega$ is the element of solid angle. The ratio of (2) to (1) is called the obliquity factor, and is a number usually between 10 - 100% for most practical cases.

For an infinitely long cylinder of constant wall thickness, equation (2) becomes:

$$\textcircled{1} = \int_0^{\pi/2} \cos \theta e^{-\frac{x}{\cos \theta}} d\theta \quad (3)$$

where θ is the angle between the incident neutron direction and the cylinder axis and $x = \mu t_0$ with t_0 the perpendicular thickness of the

cylinder wall.

For a cylindrical shield of length equal to its diameter the calculation is also simple, giving:

$$\textcircled{2} = \int_0^{\pi/4} (\cos \theta + \sin \theta) e^{-\frac{x}{\cos \theta}} d\theta \quad (4)$$

The numerical magnitudes* of the expressions (1), (3), and (4) are shown graphically in figure 1. The corresponding obliquity factors for the expressions (3) and (4) are graphed in figure 2.

It should be emphasized that these results are only applicable when the sample itself has equal probability of capturing a neutron from any direction. This condition, however, is automatically fulfilled for samples in the form of flat foils, thin enough to avoid self-absorption. Thus the results are applicable to most activation experiments. In order to see this conclusion, we note that the number of neutrons intercepted by the sample is proportional to the projected area of the foil, that is to $A/\cos(\hat{n}, \hat{r})$ where $\hat{n}$ is the normal to the foil and $\hat{r}$ is the incident direction. However, the distance traveled by the neutron through the foil is equal to $d/\cos(\hat{n}, \hat{r})$ where d is the thickness of the foil. For thin foils the absorption is proportional to the distance, hence the total number of neutrons captured is proportional to Ad , independently of the incident direction, Q.E.D.

* These were obtained by numerical integration using Simpson's Rule. The numerical work was carried out by Miss Hibbert.

The result may be easily generalized to any sample shape.

In the opposite case, where the foil is practically black, equation (2) is replaced by:

$$\frac{\int \Lambda(\theta, \phi) e^{-\mu(\theta, \phi)} d\Omega}{\int \Lambda(\theta, \phi) d\Omega} \quad (5)$$

where $\Lambda(\theta, \phi)$ is the projected area of the sample as a function of incident direction.

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(1) $\int_0^{\frac{\pi}{2}} \cos \theta e^{-\frac{x}{\cos \theta}} d\theta \rightarrow$ (2) $\int_0^{\frac{\pi}{2}} (\cos \theta + \sin \theta) e^{-\frac{x}{\cos \theta}} d\theta \rightarrow$ (3) $e^{-x} \rightarrow$

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