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WELL COINCIDENCE COUNTING AND ANALYSIS*

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WELL COINCIDENCE COUNTING AND ANALYSIS*

1. INTRODUCTION

In several recent papers (Refs. [1] and [2]) a physical/mathematical model was developed to describe the nuclear multiplicative processes in samples containing fissile material from a general statistical viewpoint, starting with the basic underlying physical phenomena. The results of this model agreed with the established picture used in "standard" HLNCC (High Level Neutron Coincidence Counter) measurements (Refs.[3] and [4]), but considerably extended them, and allowed a more detailed interpretation of the underlying physical mechanisms and of the higher moments of the neutron counts.

The present paper examines some recent measurements made at Y-12 (Oak Ridge) using the AWCC, in the light of this model. The results show internal consistency under a variety of conditions, and give good agreement between experiment and theory.

2. EXPERIMENTAL DATA

In the AWCC an active neutron source (AmLi) is introduced into the end plugs of a detector well to induce fission reactions in U^{235} samples. The coincidence neutrons from these induced fission reactions are then a measure of the U^{235} mass in the sample.

The data examined and analyzed below were as follows:

Samples containing crushed, highly enriched (>90%) U^{235} metal pieces, in various irregular configurations, were inserted into the AWCC (with an Am-Li source),

and the "totals", T , (total single count rate) and "reals" (real coincidence count rate) were measured. This process was repeated a number of times with changed amounts of the sample masses. Corresponding to each measurement¹, T_0 and R_0 , the background count rates were measured (without a sample present). R is determined as the difference of the measured coincidences, $R + A$, and the accidental coincidences, A .

3. THEORETICAL BACKGROUND

The following discussion does not consider other instrumental effects relating to the measurements considered. Thus, questions of dead-time and die-away-time are not dealt with here; these factors are important and have been discussed elsewhere, but they are not germane to the present approach, and are presumed to have been corrected for. This paper is largely concerned with the physical processes which underlie the measurements, and their explication.

Using the ratio T/T_0 as an estimate of the leakage multiplication factor M , and using the models developed in References [1] and [2], one finds that

$$\frac{R}{\left(\frac{T}{T_0}\right)^2} = \left(\frac{\epsilon_0^2 v_2 S}{2(v_1 - 1)} \right) (M - 1). \quad (1)$$

where ϵ_0 is the detector efficiency, $v_1 = \langle v \rangle$ is the average number of neutrons emitted per induced fission, $v_2 = \langle v(v - 1) \rangle$ is the second factorial moment of the induced neutron distribution, etc., and S is the known source rate.

Since one expects a close correlation between the values of $M - 1$ and m , the U^{235} mass, it is convenient to put so that

$$f(m) = C \frac{R}{\left(\frac{T}{T_0}\right)^2} \quad (3)$$

¹ Actually this was done for each group of three or four measurements.

Figure 1 shows the relation

$$C \frac{R}{\left(\frac{T}{T_0}\right)^2}$$

versus the declared mass of U-235 for the consolidated data in the three sets of experiments². The determination of the appropriate calibration constant(s) C is shown in Fig. 2, in which

$$\frac{R}{\left(\frac{T}{T_0}\right)^2}$$

is plotted against m for the three cases (cases 2 and 3 were combined because of their similarity) Note that a single calibration constant is used (in each case), and that no other arbitrary constants are needed.

Thus, in these sets of experiments there is an excellent linear correlation between the leakage multiplication factor M and the declared fissile (U²³⁵) mass, and thus for the measured U²³⁵ mass and the declared U²³⁵ mass. For similar experimental configurations and samples a similar linear relationship may be expected, though the constant C may vary, depending, as it does, on the source strength, and the parameters relevant to the induced fission probability. In the present case, the difference in the values of C can be attributed to a change in the geometric configuration of the experiment; in the first set of measurements the effective source strength was increased due to the different placement of the sample in the well.

The final figure, Fig. 3, based on the first set of experiments, shows relations between the calculated and the declared mass based on different measurement models.

It should be noted that the linearity observed here, while heuristically plausible, is by no means the consequence of general physical requirements. In the case of the

² The combined data for the three sets is shown in the table labelled Consolidated AWCC Data. The column labelled "Calculation" is the quantity $R/(T/T_0)^2$.

HLNC a more complicated relationship applies, though the calculated mass is proportional to the declared mass when the latter is small. It will be of interest to determine the correlation for differently constituted samples and for larger U²³⁵ masses.

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REFERENCES

- [1] LU, M-S., TEICHMANN, T., "A generalized model for neutron coincidence counting", Nuclear Instruments and Methods in Physics Research, A313, (1992) 471-476.
- [2] LU, M-S., TEICHMANN, T., "Statistical modelling of coincidence counting", Nuclear Instruments and Methods in Physics Research, A327, (1993) 544-550.
- [3] MENLOVE, H. O., "Calibration and Error Reduction in Neutron Coincidence Counting", Journal of Nuclear Materials Management, 21, (1987) 20-28.
- [4] HOOTON, B. W., "A Review of Plutonium Measurement By Passive Neutron Coincidence Counting", AEA-FS-0073H, Nuclear Consultancy Services Ltd., OXON, UK, July 1991.

Fig. 1: Consolidated AWCC Data

Fig.2: Calibration Constant Determination

Fig. 3: Comparison of Different Models

List of Captions

Fig. 1 Consolidated AWCC Data

Fig. 2 Calibration Constant Determination

Fig. 3 Comparison of Different Models

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