NEUTRON COINCIDENCE COUNTING

M.G. Hines, J.W. Boldeman, K.J. Thorpe, I. Delaney, J.P. Fallon
Applied Physics Division

Australian Atomic Energy Commission, Lucas Heights Research Establishment
Private Mail Bag, Sutherland, 2232

ABSTRACT

Neutron coincidence counting (NCC) is an established technique for the assay of plutonium waste from nuclear reactors and reprocessing plants. There are, however, basic limitations on existing instrumentation. This paper presents an outline of an original method of Pu assay based on a high efficiency liquid scintillation counter. Progress made using a recently constructed liquid scintillator is also included.

1. INTRODUCTION

The accurate assay of the plutonium content in reactor waste products is an important requirement in the application of effective safeguards. Current assaying techniques use neutron coincidence counting (NCC) to detect the neutrons associated with the spontaneous fission of ^{240}Pu. The technique is based on the time correlation of the spontaneous fission neutrons and existing instrumentation, notably the High Level Neutron Coincidence Counter (HLNCC), is capable of obtaining accuracies of up to 1%[1]. However the accuracy of this instrument, and of similar instruments, is determined principally by the availability of appropriate standards. Furthermore, standard NCC techniques suffer from neutron multiplication within the sample. Correction procedures for these effects require a large number of standards and are only suitable for samples of well defined composition.

2. LIQUID SCINTILLATION NEUTRON COINCIDENCE COUNTING (LSNCC)

Initial research in the principles of NCC has been performed using a large, high efficiency (up to 85% for neutrons), liquid scintillation tank. In comparison, the neutron detection efficiency of conventional He3, polyethylene moderated systems (e.g. HLNCC), is typically 12-17%. The higher efficiency of the LSNCC has made it possible to develop a NCC technique that involves the detection of a distribution of neutrons arising from a fission event[2]. Because of this, the amount of information from the measurement is increased, making it feasible to more accurately correct for neutron multiplication[3,4].

Because of difficulties encountered in obtaining appropriate samples, our investigations have so far been limited to several small ^{252}Cf and ^{240}Pu sources. These results are accurate to within a few percent and have illustrated the viability of the technique. The next step in instrumentation development has been the development of a small, portable LSNCC, to be used specifically for safeguards purposes.

3. PROTOTYPE SLNCC

A cross section of the new liquid scintillation detector is shown in Fig. 1. Preliminary investigations into the performance of the detector have begun.

Neutron detection within the prototype LSNCC is viewed by 2 sets of 3 photomultiplier tubes, and a coincidence condition is imposed to eliminate double pulsing of the tubes. The detector contains 70 L of NE323, a tri-methyl benzene based liquid scintillant containing .5% loading of Gd by weight. Computer calculations estimated the efficiency of the detector to be 65% for ^{252}Cf spontaneous fission neutrons. The lifetime of neutrons in the detector was measured as 9μs, this compares with the 11μs neutron lifetime of the large liquid scintillator tank.

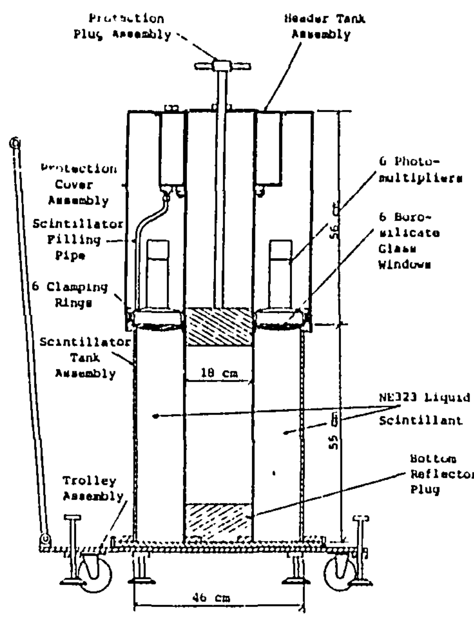

Fig. 1 - Cross section of portable LSNCC

3.1 NEUTRON EFFICIENCY MEASUREMENTS

The absolute neutron efficiency of the liquid scintillator may be measured by use of a ^{252}Cf fission chamber. Two 30μs counting gates are used for the measurement. The first gate is initiated by a spontaneous fission event, and counts the spontaneous fission neutrons, as well as random background events. The second gate opens 100μs later (100μs>> neutron lifetime) and contains background only. The efficiency is simply given by the ratio of the difference between the two gates, and the known number of neutrons emitted in the fission event $[\bar{\nu}(^{252}Cf)=3.757]$. Since the scintillant is also sensitive to the gamma rays emitted in a spontaneous fission event, the efficiency for the detection of this prompt gamma emission is an important characteristic of the detector. Fig. 2 illustrates the prompt gamma efficiency as a function of the neutron efficiency, for both ^{252}Cf and ^{240}Pu spontaneous fission.

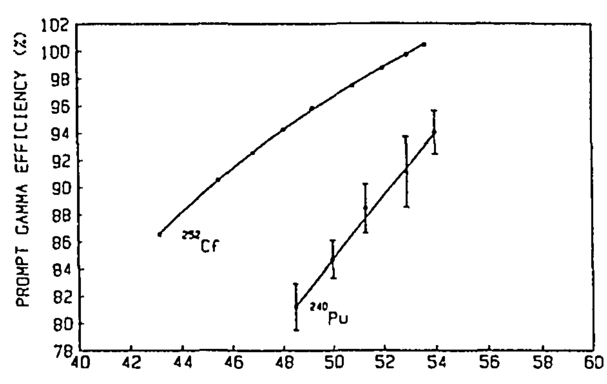

Fig. 2 - Prompt γ and Neutron detection efficiencies of prototype LSNCC for ^{252}Cf and ^{240}Pu spontaneous fission.

3.2 FISSION RATE CALCULATIONS

A fission rate calculation for a Pu sample involves the following general procedure:

1. The neutron efficiency for ^{252}Cf spontaneous fission neutrons is measured by the method previously outlined. This value is then used to determine the neutron and prompt gamma detection efficiencies for ^{240}Pu spontaneous fission.

2. By reference to standard nuclear data, the distribution of events that is seen by the scintillator is generated.

3. A plutonium sample is counted in a similar manner to the measurement of the neutron efficiency. However, instead of triggering off a fission event, a random scintillator event is used to initiate the foreground gate. This 'random triggered' distribution is then used to provide a number of fission rate estimates.

Fission rate measurements using the prototype detector have so far been limited to a number of ^{252}Cf sources. These results are presented in Table 1. The 4 fission rate estimates that are given in the table correspond to the evaluation of the fission rate from the probabilities of obtaining 0,1,2,3 counts in the foreground/background gates. These fission rate calculations have not yet been dead-time corrected. Since the values 'F_0' have been calculated from the probabilities of obtaining zero counts per foreground and background gates, this value is independant of dead-time and represents the most accurate result.

TABLE 1

^{252}Cf Fission Rate Measurements

Independant Evaluation	Fission Rate Estimates F_0	F_1	F_2	F_3	Average
99.6±.4	99.5	98.2	101.9	100.4	100.0
128.2±.6	128.2	127.3	132.0	125.6	128.3
224 ± 1	223.8	222.6	230.2	216.8	223.8
1388 ± 6	1402	1414	1441	1412	1417
1275 ± 6	1283	1257	1327	1294	1290
1403 ± 6	1413	1384	1467	1418	1421
1501 ± 6	1513	1490	1550	1541	1528
(10,000±40)*	10469	12518	10972	10569	11132

*Dead Time correction is not accurate

As can be seen, the results obtained using the LSNCC are in excellent agreement with the quoted independant values. Dead-time corrections for the fission rate estimates are presently being investigated, and work is in progress to determine the suitability of the detector for Pu assay.

5. REFERENCES

1. A. Ramalho, E. Dahn, E. Selleck, V. Kupryashkin, A. Dubreuil, "The High-Level Neutron Coincidence Counter (HLNCC) Family of Detectors", in Proc. Nucl. Safeguards Technology, Vienna, Nov. 1982, pp 81-104. IAEA-SM-260/53.

2. J.W. Boldeman, M.G. Hines, J.P. Fallon, I. Delaney, "Neutron Coincidence Counting", in Proc. 6th ESARDA Symp. Safeguards and Nuclear Materials Management, Venice, 14-18 May 1984, pp 285-288.

3. M.G. Hines, J.W. Boldeman, G.S. Robinson, "The Effect of Multiplication on the Neutron Probability Distribution in Neutron Coincidence Counting", in Proc. IAEA Annual General Meeting on the Evaluation of the Quality of Non-destructive Measurements, Vienna, Nov. 1984.

4. J.W. Boldeman, M.G. Hines, K.J. Thorpe, I. Delaney, P. Baxter, J.P. Fallon, "Development of a Liquid Scintillator Neutron Coincidence Counter", in Proc. 7th ESARDA Symp. Safeguards and Nuclear Materials Management, Liège, Belgium, 21-23 May 1985, pp 305-309.