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MASTER

EFFECTS OF SOURCE-FISSILE MATERIAL DISTRIBUTIONS ON THE ACCURACY OF TIME CORRELATED COUNTING

BY

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Time correlated counting[1,2,3] has been proposed as a possible criticality monitor at the Transuranic Waste Treatment Facility (TWTF)[4,5]. This paper investigates possible errors which might arise in estimates of k_{eff} due to the assumption implicit in time correlated counting, that neutron multiplication is constant from generation to generation. Although the calculations are performed for the TWTF, they are applicable to any situation where time correlated counting is used for assay or criticality monitoring, such as the Nuclear Emergency Search Team (NEST) effort.

The TWTF

The TWTF is designed to reduce the volume of low level transuranic waste and convert it to a chemically inert and physically stable basalt-like substance through use of a slagging pyrolysis incinerator. Because the waste contains plutonium and other fissile materials and the precise content of the waste is not known, steps must be taken to ensure against an inadvertant criticality. One of the proposed steps is the use of time correlated counting for criticality monitoring, making use of spontaneous fission and (α, n) reactions in the incinerator as a source of neutrons. The region of the incinerator used for this study, the drying region, is a cylinder of 73.66 cm radius and 256.54 cm height.

Time Correlated Counting

Time correlated counting makes use of the fact that neutrons emitted from a chain of fissions are related in time, whereas, neutrons produced by spontaneous fission or (α, n) reactions occur randomly. The higher the multiplication of neutrons, the more non-random the counting. Thus, by monitoring the randomness of the count rate, an estimate of the multiplication (and therefore k_{eff}) can be obtained.

However, one assumption made in relating k_{eff} to the observed randomness is that the multiplication will be uniform between generations (i.e., k_{eff} neutrons will be produced in the first generation, k_{eff}^2 neutrons in the second generation, etc.). In other words, k_{eff} is assumed to be related to multiplication by the equation:

$$M = \frac{1}{1 - k_{eff}}$$

In actuality

$$M = 1 + k_1 + k_1k_2 + k_1k_2k_3 + \ldots$$

and the first equation will be true only when all k_i are equal to k_{eff}. Thus, the k_{eff} of a system can be underestimated if the multiplication of the first generations of neutrons is lower than the assymptotic multiplication. This assumption is critical to any time correlated measurement where there is a possibility that the source and fissile material distribution are not identical.

Investigation of Source-Fissile Material Distribution Effects at TWTF

At TWTF, the presence of free lumps of both source and fissile material and the buildup of source and fissile material on the walls are postulated. To investigate this effect, five radial source-fissile material distributions were postulated and investigated using the S_n transport code SCAMP. A representative model of the drying region of the incinerator from the initial criticality analysis was used for the calculations. Plutonium concentration was adjusted to achieve a k_{eff} of approximately 0.8 to 0.9 to determine whether a high value of k_{eff} could occur without being detected by time correlated counting. The multiplication from each generation of neutrons was calculated by inputting the postulated source distribution as the fission source guess for a homogeneous eigenvalue problem. With no accelerated convergence, the eigenvalue obtained for each iteration is equal to the multiplication of the corresponding generation of neutrons. The error incurred using time correlated counting can then be calculated using the above equations relating multiplication and k_{eff} of a system.

The results are shown in Table I. Cases 1 and 2, where the fissile material and the source have the same distribution, yield estimates of k_{eff} very close to the actual value. However, in Cases 3, 4, and 5, where the source and fissile material distributions are different, the lower multiplication of the first few generations of neutrons cause k_{eff} to be underestimated. In the one extreme case (5), a 1 cm buildup of plutonium on the wall with a point source in the center, the error is large enough that use of time-correlated counting might fail to prevent criticality limits from being exceeded (even in the case where the administrative limit is quite low).

Conclusions

It appears that the assumption of uniform multiplication of neutrons between generations will not generally produce large errors in time correlated counting. However, in situations such as Case 5, and other cases which could not be considered with the one-dimensional model (such as a point source at the edge of a system) large errors occur which invalidate time correlated counting.

References

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4. K. B. McKinley, et al., TWTF Criticality Task Force Final Review and Assessment, EG&G 2055, Final Draft, September 1980.

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Table I. ERRORS IN TIME CORRELATED COUNTING DUE TO VARIOUS RADIAL SOURCE-FISSILE MATERIAL DISTRIBUTIONS

	Case	K_{eff}	k_{eff} estimated by time correlated counting	% Error
1.	Uniform Pu-239 Uniform Source	.898	.879	- 2.1
2.	1 cm Pu-239 on Wall Source in Pu-239	.836	.820	- 1.9
3.	1 cm Pu-239 on Wall Uniform Source	.836	.704	-15.8
4.	Uniform Pu-239 1 cm Source on Wall	.898	.754	-16.0
5.	1 cm Pu-239 on Wall Point Source on Axis	.836	.283	-66.2