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The Epithermal Neutron Multiplicity Counter at Hanford

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ABSTRACT

The Epithermal Neutron Multiplicity Counter (ENMC) and the associated Advanced Multiplicity Shift register (AMSR) electronics package, developed at Los Alamos under the US Department of Energy (DOE) Office of Safeguards and Security Technology Development Program, was evaluated at the Hanford Plutonium Finishing Plant earlier this year. Initial demonstration measurements involved Hanford facility personnel and two International Atomic Energy Agency (IAEA) inspectors who measured selected IAEA standards and items the IAEA had experienced problems with previously. Items were measured in the ENMC and also in the Plutonium Scrap Multiplicity Counter (PSMC), which belongs to the IAEA but is also used by the facility. Each item was measured for 15 minutes. The Pu mass ranged from 250 to 1700 g. Alpha (the ratio of alpha, n to spontaneous fission neutrons) ranged from 0.5 to ~15. In all cases, the precision of the ENMC measurements was far superior to that of the PSMC and provided 8.3 to 42.5 faster measurements, with the larger factors coming from the high-alpha items. The seven IAEA standards had alpha values ranging from 0.5 to 13, and the average bias was 0.75% with a standard deviation of 3.18% for the ENMC. The mean bias for the PSMC measurements is 4.02% with a standard deviation of 8.27%. In addition, the ENMC was used to assay 17 process residues with alpha values ranging from 2 to 20. The facility and the IAEA were impressed with the performance of the ENMC, and the facility is attempting to procure a unit for its use. The IAEA would also like to use the ENMC for its inspections once the facility has acquired the device.

INTRODUCTION

Thermal neutron multiplicity counters (TNMCs) are used in several US Department of Energy (DOE) facilities for domestic material control and accountability (MC&A) and for International Atomic Energy Agency (IAEA) inspections. The same is true in Japan. TNMCs are also being implemented in Russian facilities for MC&A. A comprehensive review of the US experience can be found in Ref. 1.

Occasionally, an item will be encountered where the ratio of (α,n) to spontaneous fission neutrons (the quantity "α") will be so high that TNMC multiplicity assay precision is degraded to the point

that long count times are required for acceptable results. For a 1-kg item, precision worsens by a factor of ~20 for an α of 10 compared to an α of 1. Currently, the IAEA uses the Plutonium Scrap Multiplicity Counter (PSMC)[2] for inventory verifications at the Hanford Plutonium Finishing Plant (PFP). Although the majority of PFP items are verified satisfactorily with the PSMC, the occasional item presents difficulties. For example, one item with 1,311 g of plutonium and an α of 4.5 requires 2 h to reach a precision of 3%, or 18 h to reach a precision of 1% using the PSMC. Another 1,350-g plutonium item with an α of 0.74 requires only 30 m to reach 1% precision in the PSMC. Another item with 879 g plutonium and an α of ~30 would require 30 h to reach 3% using the PSMC. This item would best be assayed by the Epithermal Neutron Multiplicity Counter (ENMC)[3] (~1.5 h measurement time) or calorimetry (~8 h measurement).

For active measurements of uranium, precision is limited by accidental coincidences produced by the AmLi interrogation sources. Therefore, the ENMC plays an important role for improving the precision of active as well as passive measurements.

As more US plutonium is placed under IAEA safeguards, more examples of precision limitations of TNMCs will occur. Also, more examples will occur in Japan, Russia, and other nations.

RESULTS

The ENMC and PSMC were evaluated side-by-side at the Hanford Plutonium Finishing Plant (PFP). The PSMC has an efficiency of 53% and a die-away time of 47 μs. The ENMC has an efficiency of 65% and a die-away time of 22 μs. The higher efficiency and lower die-away time account for the improved precision of the ENMC compared to the PSMC. The measurements were performed by facility personnel, IAEA inspectors, and Los Alamos National Laboratory (LANL) personnel. The first items to be measured were 7 IAEA standards. All measurements were made for 15 m. Results of the measurements are shown in Table I.

Table I. Results of ENMC and PSMC Measurements of 7 IAEA Standards.

Item	Decl. Pu (g)	Detector	Multiplication	α	(D-A)/D, %
1	264.2	ENMC	1.043 ± 0.001	0.497 ± 0.003	-0.694 ± 0.277
		PSMC	1.041 ± 0.002	0.478 ± 0.002	-0.927 ± 0.800
2	268.5	ENMC	1.039 ± 0.001	7.518 ± 0.186	-6.735 ± 2.391
		PSMC	1.046 ± 0.001	9.54 ± 32.31	14.87 ± 9.214
3	384.7	ENMC	1.046 ± 0.001	2.499 ± 0.025	-2.108 ± 0.822
		PSMC	1.040 ± 0.003	2.41 ± 0.097	-4.342 ± 3.142
4	467.4	ENMC	1.056 ± 0.002	12.711 ± 0.737	2.351 ± 5.08
		PSMC	1.050 ± 0.010	11.419 ± 28.76	-7.132 ± 28.03
5	878.4	ENMC	1.103 ± 0.001	8.709 ± 0.290	2.651 ± 2.805
		PSMC	1.102 ± 0.006	9.854 ± 10.576	13.897 ± 13.07
6	1369.1	ENMC	1.103 ± 0.001	0.757 ± 0.007	0.546 ± 0.478
		PSMC	1.099 ± 0.003	0.769 ± 0.032	1.142 ± 2.115
7	1659.7	ENMC	1.223 ± 0.001	0.852 ± 0.006	-1.272 ± 0.370
		PSMC	1.208 ± 0.002	0.796 ± 0.017	-4.726 ± 1.147

The mean bias for the ENMC measurements is -0.75% with a standard deviation of 3.18%. The mean bias for the PSMC measurements is 4.02% with a standard deviation of 8.27%. The accuracy and precision are better for the ENMC than the PSMC when measuring the 7 IAEA standards. The ENMC is faster than the PSMC and reaches the same precision by factors of 8 to 30. The data of Table I are shown in Fig. 1.

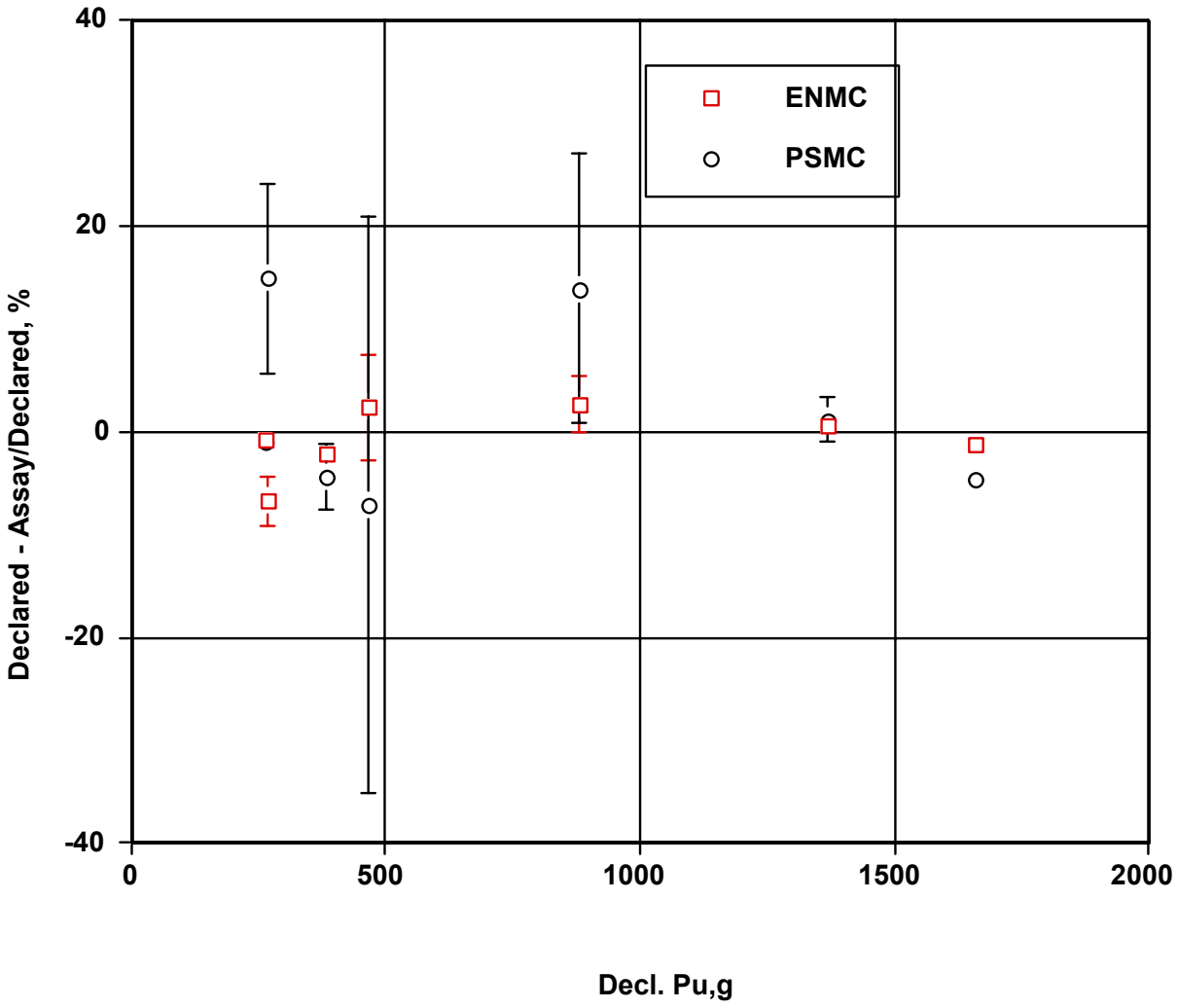

Fig. 1. ENMC and PSMC Measurements of 7 IAEA Standards.

Results of ENMC and PSMC measurements of 17 residue items are shown in Table II.

Table II. Results of ENMC and PSMC Measurements of 17 Residue Items.

Item	Decl. Pu (g)	Detector	Multiplication	α	(D-A)/D, %
1	952.4	ENMC	1.090 ± 0.001	2.929 ± 0.037	13.469 ± 0.828
		PSMC	1.088 ± 0.003	2.965 ± 0.152	15.128 ± 3.055
2	873.1	ENMC	1.095 ± 0.061	4.279 ± 0.072	-2.096 ± 1.473
		PSMC	1.089 ± 0.003	4.172 ± 0.314	-4.667 ± 5.018
3	969.4	ENMC	1.114 ± 0.001	5.471 ± 0.105	-19.392 ± 1.86
		PSMC	1.108 ± 0.004	5.691 ± 5.42	-16.26 ± 9.04
4	1050.5	ENMC	1.132 ± 0.001	1.811 ± 0.016	-1.521 ± 0.639
		PSMC	1.128 ± 0.003	1.769 ± 0.55	-1.762 ± 2.1
5	916.5	ENMC	1.092 ± 0.001	2.679 ± 0.039	1.477 ± 1.159
		PSMC	1.089 ± 0.002	2.65 ± 0.09	1.699 ± 2.682
6	1401.2	ENMC	1.091 ± 0.002	14.211 ±2.189	-22.322 ± 8.97
		PSMC	1.048 ± 0.015	30.606 ± 6.2	41.857 ± 35.1
7	943.3	ENMC	1.126 ± 0.001	3.886 ± 0.039	-25.429 ± 1.06
		PSMC	1.123 ± 0.004	4.209 ± 0.53	-12.237 ± 6.89
8	972.9	ENMC	1.089 ± 0.001	2.664 ± 0.036	12.806 ± 0.898
		PSMC	1.089 ± 0.003	2.669 ± 0.106	9.08 ± 2.802
9	951.5	ENMC	1.093 ± 0.001	2.254 ± 0.022	-0.899 ± 0.745
		PSMC	1.095 ± 0.003	2.345 ± 0.085	3.931 ± 2.62
10	885.3	ENMC	1.083 ± 0.001	3.825 ± 0.058	4.331 ± 1.207
		PSMC	1.081 ± 0.004	3.832 ± 0.318	5.905 ± 5.409
11	937.2	ENMC	1.100 ± 0.001	2.994 ± 0.037	7.883 ± 0.928
		PSMC	1.095 ± 0.004	2.787 ± 0.139	4.251 ± 3.841
12	272.8	ENMC	1.028 ± 0.001	7.471 ± 0.292	-4.524 ± 3.324
		PSMC	1.026 ± 0.005	7.74 ± 244.4	-5.006 ± 10.41
13	826.9	ENMC	1.085 ± 0.001	2.221 ± 0.022	-11.474 ± 0.83
		PSMC	1.081 ± 0.003	2.172 ± 0.078	-13.13 ± 3.109
14	875.4	ENMC	1.083 ± 0.001	3.739 ± 0.063	2.341 ± 1.230
		PSMC	1.076 ± 0.005	3.808 ± 0.465	0.332 ± 7.142
15	1053.1	ENMC	1.135 ± 0.001	1.48 ± 0.001	5.653 ± 0.358
		PSMC	1.138 ± 0.003	1.517 ± 0.004	7.627 ± 1.976
16	860.6	ENMC	1.085 ± 0.001	3.396 ± 0.036	2.807 ± 0.869
		PSMC	1.089 ± 0.003	3.614 ± 0.169	9.073 ± 3.479
17	763.3	ENMC	1.079 ± 0.001	2.753 ± 0.026	1.255 ± 0.741
		PSMC	1.073 ± 0.003	2.709 ± 0.108	0.181 ± 3.086

The mean bias for the ENMC measurements is -2.1% with a standard deviation of 11.4%. The mean bias for the PSMC measurements is 2.7% with a standard deviation of 13.2%. The accuracy and precision are better for the ENMC than the PSMC when measuring the 17 PFP residues. The ENMC is faster than the PSMC and reaches the same precision by factors of 8 to 40. The data of Table II are shown in Fig. 2.

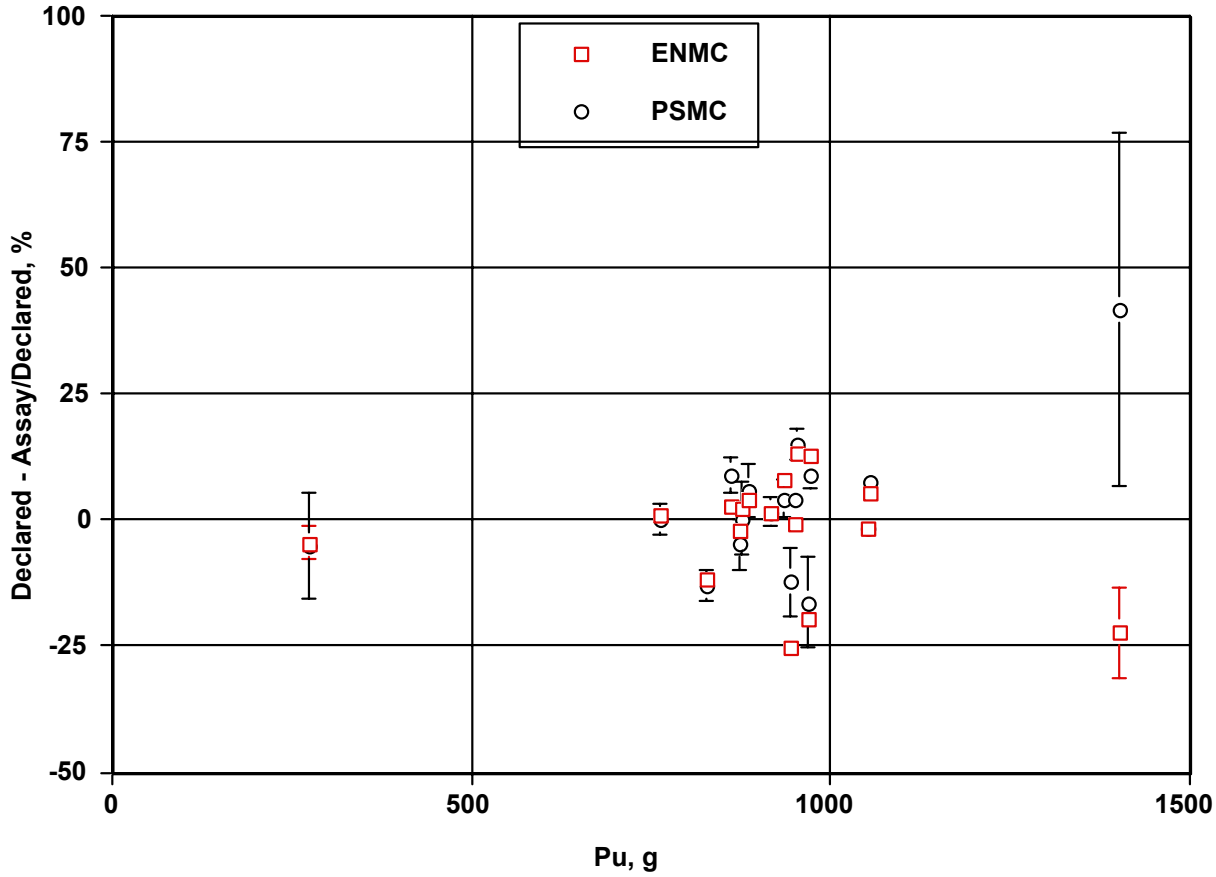

Fig. 2. ENMC and PSMC Measurements of 17 PFP Residues.

CONCLUSIONS

The ENMC has been used at the PFP to demonstrate its performance capabilities compared with the PSMC, currently used by the IAEA for routine inspections. Its superior performance has been shown for measurements of 7 IAEA standards and 17 PFP residues. The superior performance is most clearly shown for the measurements of the 7 IAEA standards. For these items, the declared values are considered to be of higher quality than for the residues. For the standards, the bias and precision of the ENMC are much better than those of the PSMC. For the residues, a similar bias between the two counters was determined. For all the items measured, the ENMC count times for a given precision were factors of 8 to 40 faster than for the PSMC. The ENMC represents the state-of-the-art in TNMCs.

ACKNOWLEDGEMENT

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