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RUSSIAN - US COLLABORATION ON IMPLEMENTATION OF THE ACTIVE WELL COINCIDENCE COUNTER (AWCC)*

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ABSTRACT

A standard active wall coincidence counter (AWCC) was modified and installed for nuclear material measurements at the Institute of Physics and Power Engineering (IPPE) in Obninsk. The AWCC is a very versatile instrument: it can be used either in active mode, to assay ^{235}U mass in highly enriched uranium (HEU) items, or in passive mode, to determine ^{240}Pu effective mass in plutonium-bearing items.

For initial work at the Obninsk IPPE, two active and one passive measurement configurations were established. For the first active configuration, the standard AWCC active (with AmLi sources) end plugs were lengthened and modified for optimum thermal-neutron-interrogation measurements of single HEU metal and oxide disks.

For the second active configuration, an aluminum carousel was fabricated to have the multiple HEU disk capacity of a single, full 50-cm storage tube. This carousel is designed to be used in the standard AWCC configuration, without the nickel ring, in fast-neutron-interrogation mode. From the standpoints of throughput, measurement precision, and accuracy, this configuration (or a similar one) for the standard 50-cm storage tube is preferable to measurement of single HEU disks. Results of measurements using this configuration are not reported in this paper.

Finally, for the third measurement configuration, special graphite end plugs were fabricated for passive (no AmLi sources), fast-neutron-interrogation mode measurements of plutonium disks. The measurement cavity will hold single or multiple disks stacked in one or more 25-cm storage tubes. This configuration can also be used for passive measurements of depleted uranium and UO_2, as well as NpO_2.

In summary, for the inventory of disks stored at Obninsk for the Bolshoi Physics Stand critical assemblies, the AWCC can be used for verification measurements of a large proportion of the uranium and plutonium materials and configurations present. This paper describes results obtained to date and future plans.

INTRODUCTION

The IPPE contains two zero-power reactors or critical assemblies (Bolshoi Physics Stands, BFS-1 and BFS-2) that are used to simulate reactors being developed by the institute. These critical assemblies have been used to investigate fast reactors, light-water reactors, uranium-graphite systems, sodium- and lead-cooled reactors, and space reactors. BFS-2 is currently being used to evaluate the critical parameters of the BN-800 fast reactor.

Various reactor materials are available at the BFS facilities, including about 8 MT of HEU and plutonium, about 280 MT of fertile materials, about 9 MT of coolant materials, and about 120 MT of structural materials. In addition, there are significant amounts of neptunium oxide and thorium metal, unavailable at other fast critical facilities in the world; these allow experimental investigations of advanced reactor cores intended for transmutation of minor actinides or for production of ^{233}U.

Nuclear materials are primarily in the form of disks, which range in mass from a few grams to 300 g each. These materials must be protected, controlled, and accounted for. The use of an active well coincidence counter (AWCC)[1-3] will facilitate these processes for the very large number of disks at BFS-1 and BFS-2 (see Fig. 1).

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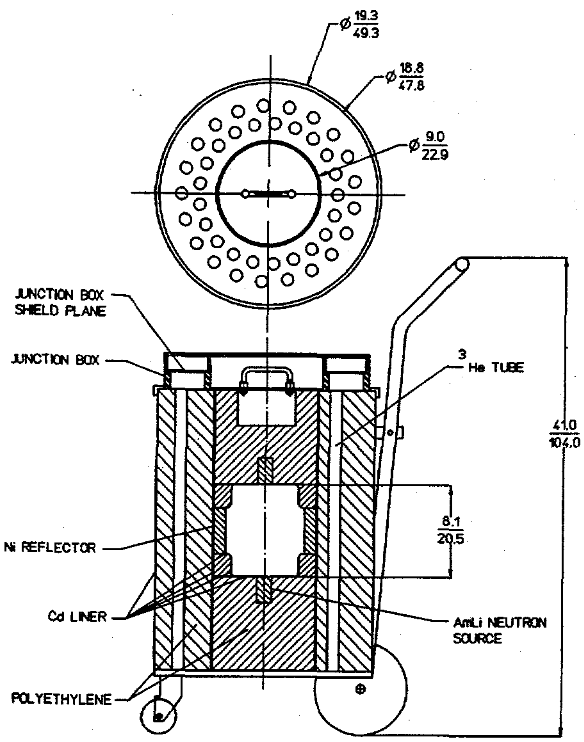

Fig. 1. Schematic diagrams of the AWCC.

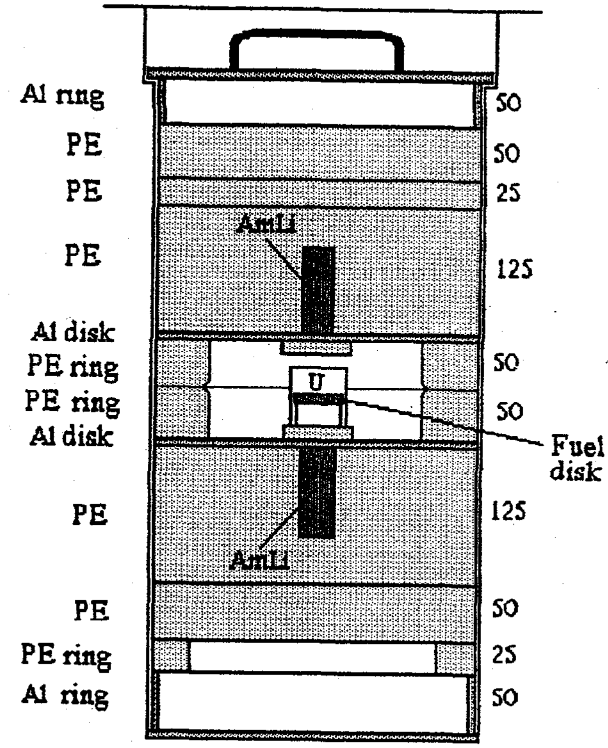

Fig. 2. AWCC measurement cavity for thermal-mode verification of single uranium disks.

INITIAL CALIBRATION

For active, thermal (no cadmium) measurements of individual HEU metal and oxide disks, the measurement cavity of a standard AWCC was modified by moving the active polyethylene (PE) end plugs (containing the AmLi sources) closer to the fuel disk, to increase the induced-fission rate per source neutron, and by attaching additional, small PE disks to the end plugs to boost the flux of thermal neutrons (see Fig. 2). This configuration yields a measurement precision of <3% for a sample containing 20 g of ^{235}U in 1000 s of counting. Using a variety of HEU metal disks and foils available at Los Alamos, an initial calibration curve was generated (see Fig. 3). This calibration curve can be used for initial verification measurements of single disks at Obninsk, but individual calibration curves for each material category will also be generated, using facility working standards. One such active calibration curve is given in the following section.

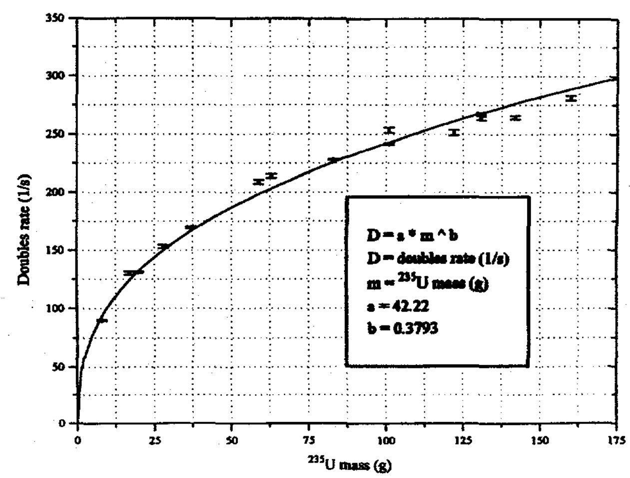

Fig. 3. AWCC calibration: thermal mode, 4 in. cavity height with doughnuts and 0.5 in. thick poly disks on AmLi sources, centered samples.

ACTIVE HEU MEASUREMENTS

The configuration of Fig. 2 was used to measure the ^{235}U masses of 29 single uranium oxide disks, selected from an inventory of several hundred. Five of the disks were used as calibration standards (see Table I).

Using the Deming curve-fitting routine of the software package NCC/WIN, the calibration curve $R = (aM)/(1 + bM)$ was fit, where R is the measured coincidence count rate and M is the ^{235}U mass in grams. Values obtained for the fitting coefficients a and b were $a = 17.867 \pm 0.038$ and $b = 0.07701 \pm 0.00032$.

The measurement time for each fuel disk was 1000 s. Measurement results for the 29 disks are given in Table II and Fig. 4.

Considering the small mass of these disks, averaging only 4.76 g each, the results of these active AWCC measurements are considered to be good. There is a small negative bias in the mean difference between the AWCC assay mass and the passport value: 1.8%; the standard deviation in the difference is 3.9%, which is actually lower than that predicted from counting statistics: 4.2%.

PASSIVE PLUTONIUM MEASUREMENTS

The second (passive) measurement configuration was used for calibration and assay measurements of 30 single plutonium metal disks, each containing ~52 g of plutonium. This configuration of the AWCC uses special graphite end plugs for optimum neutron reflection. The measurement chamber can be used for single or multiple disk geometries. To reduce neutron multiplication in the fuel disk, the measurement chamber is lined with cadmium. Five of the plutonium metal disks were used as calibration standards (see Table III).

Again using the Deming curve-fitting routine of the general-purpose software package NCC/WIN, the calibration curve $R = (aM)/(1 + bM)$ was fit, where R is the measured coincidence count rate and M is the ^{240}Pu (effective) mass in grams. Values obtained for the fitting coefficients a and b were $a = 69.4 \pm 0.9$ and $b = -0.0505 \pm 0.0028$.

The measurement time for each plutonium fuel disk was 300 s. Measurement results for the 30 disks are given in Fig. 5 and Table IV.

The results of Table IV and Fig. 5 are considered to be quite good—with the exceptions of disks 14 and 30, for which the plutonium assay values are ~13% higher than the passport values. Even including these points, the mean difference for the assays of the 30 disks is less than 1%, and the standard deviation is less than 2%, approximately that predicted from counting statistics. The average plutonium mass for the 30 plutonium disks is ~52 g. The AWCC results of Table IV and Fig. 5 include differences in not only the $^{240}Pu_{eff}$ mass values from the AWCC measurement, but in plutonium isotopic abundance values.

SUMMARY AND CONCLUSIONS

The feasibility of using a standard AWCC at the Obninsk IPPE has been demonstrated through active measurements of single, UO_2 (36% enriched) disks and through passive measurements of plutonium metal disks used for simulating reactor cores. The role of the measurements is to verify passport values assigned to the disks by the facility, and thereby facilitate the mass accountability procedures developed for the very large inventory of fuel disks at the facility.

The AWCC is a very flexible instrument for verification measurements of the large variety of nuclear material items at the Obninsk IPPE and other Russian facilities (Table V summarizes possible measurement configurations for a large majority of these materials). Future work at the IPPE will include calibration and verification measurements for other materials, both in individual disks and in multi-disk storage tubes; it will also include training in the use of the AWCC.

TABLE I. Description of IPPE UO_2 Disks Used as Calibration Standards

Disk Number	UO_2 Mass (g)	Enrichment (%)	Uranium Content (%)	^{235}U Mass (g)
1	15	35.9	87.85	4.731
2	15	36.3	88.00	4.792
3	15	35.9	87.85	4.731
4	15	36.0	87.70	4.736
5	15	36.0	87.70	4.736

TABLE II. Results of Active AWCC Measurements of IPPE UO_2 Fuel Disks		
Disk Number	^{235}U Mass in Disk (g) (passport data)	^{235}U Mass Difference Between Passport and Measured Data (%)
1	4.731	+0.00 ± 4.08
2	4.731	-11.77 ± 2.30
3	4.792	-0.48 ± 2.23
4	4.736	+5.49 ± 0.68
5	4.736	-3.97 ± 6.08
6	4.747	-1.33 ± 3.54
7	4.792	-2.07 ± 5.20
8	4.747	+1.43 ± 3.20
9	4.792	-2.09 ± 4.61
10	4.747	-2.97 ± 4.85
11	4.747	-3.03 ± 6.13
12	4.823	+2.26 ± 1.64
13	4.736	-5.93 ± 4.03
14	4.731	-0.93 ± 5.41
15	4.736	3.42 ± 5.95
16	4.731	-8.03 ± 5.07
17	4.736	+3.34 ± 6.52
18	4.736	-6.19 ± 3.42
19	4.792	-0.81 ± 4.44
20	4.747	-3.03 ± 3.52
21	4.792	-3.32 ± 5.88
22	4.823	-6.12 ± 1.22
23	4.747	+1.77 ± 5.16
24	4.736	+2.17 ± 6.52
25	4.823	-1.22 ± 5.45
26	4.736	-3.19 ± 3.89
27	4.826	-2.88 ± 3.15
28	4.747	+3.22 ± 4.04
29	4.731	-6.98 ± 5.50
Mean		-1.84
Standard Deviation		3.92

TABLE III. Description of IPPE Plutonium Metal Disks Used as Calibration Standards					
Disk Number	Plutonium Mass (g)	^{239}Pu (%)	^{240}Pu (%)	^{241}Pu %	Separation Date
1	52.27	95.06	4.65	0.29	1973.05
2	51.34	96.23	3.60	0.17	1969.12
3	52.91	95.21	4.51	0.28	1973.10
4	51.84	95.22	4.53	0.25	1973.12
5	52.72	95.06	4.73	0.21	1974.08

TABLE IV. Results of Passive AWCC Measurements of IPPE Plutonium Metal Fuel Disks

Disk Number	Plutonium Mass in Disk (g) (Passport Data)	Plutonium Mass Difference Between Passport and Measured Data (%)
1	52.54	1.83
2	51.68	-0.43
3	52.53	1.81
4	52.32	0.67
5	52.05	-4.46
6	52.44	1.54
7	52.32	0.34
8	52.08	1.06
9	51.99	0.81
10	51.86	-0.17
11	52.76	-0.70
12	52.98	0.98
13	51.78	1.54
14	51.12	13.4
15	51.95	0.96
16	53.39	3.17
17	51.85	2.60
18	51.94	0.60
19	52.33	1.68
20	52.29	3.19
21	52.78	-2.65
22	52.02	0.87
23	52.26	0.00
24	52.69	0.27
25	51.89	2.79
26	53.28	0.58
27	52.19	0.00
28	51.97	0.94
29	52.09	-1.34
30	51.78	13.0
Mean		+0.77
Standard Deviation		1.83

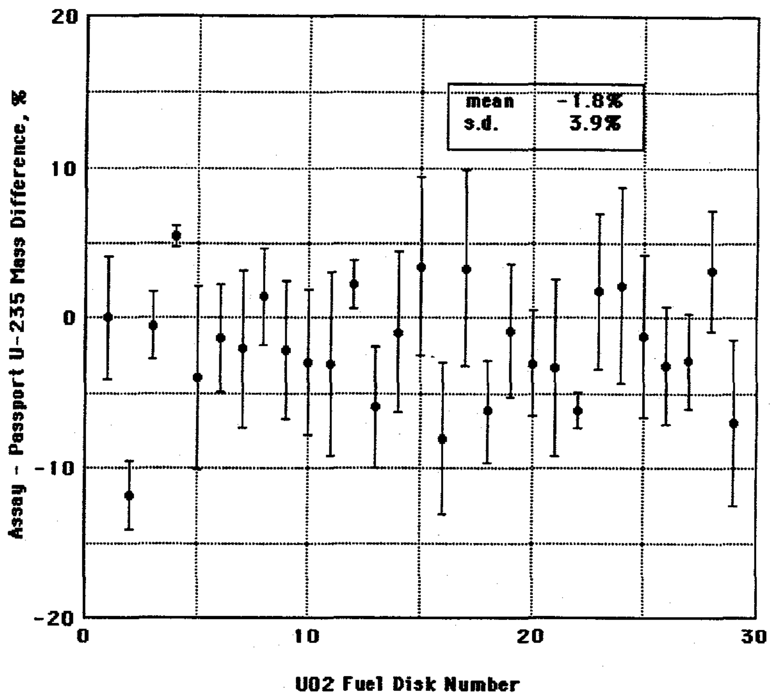

Fig. 4. Results of AWCC measurements of IPPE UO_2 fuel disks: percent difference in assayed ^{235}U mass compared with passport values.

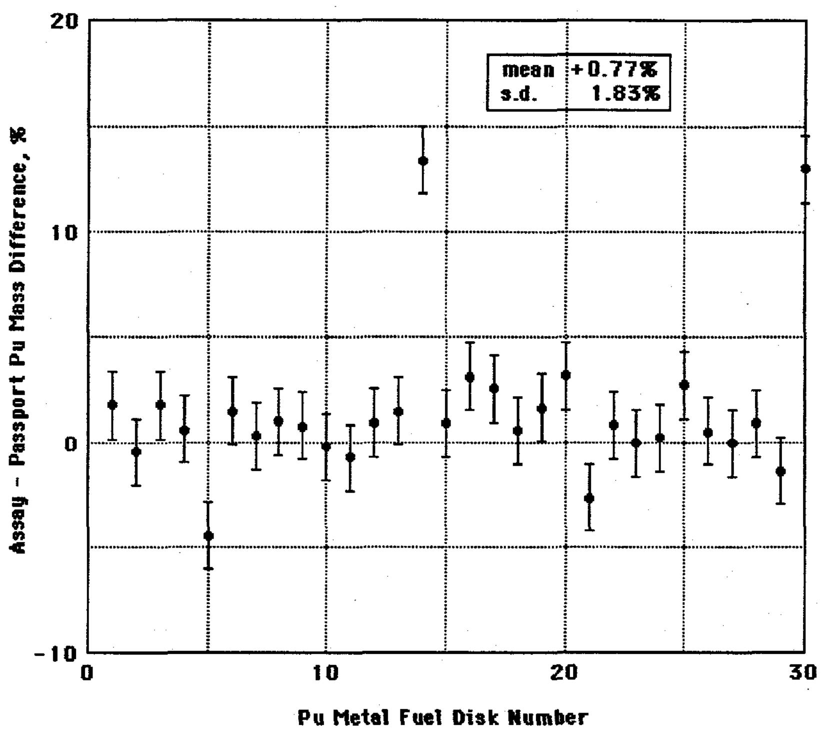

Fig. 5. Results of passive AWCC measurements of IPPE plutonium metal fuel disks: percent difference in assayed plutonium mass compared to passport values.

TABLE V. Possible AWCC Configurations for Measurement of Obninsk IPPE BFS-1 and BFS-2 Critical Assembly Disks				
Material	Measurement Mode	Number of Disks per Measurement: Single (S) or Multiple (M)	Cavity Configuration	Cavity Height (cm/in.)
Plutonium (89-96% ^{239}Pu)	Passive, (no AmLi), Fast (cadmium)	S or M (cavity holds 1 or more 25-cm storage tubes)	Graphite end plugs	35.6/14
Uranium (90% ^{235}U)	Active, (2 AmLi), Fast	M (contents of 1 50-cm storage tube)	Aluminum carousel disk holder, standard PE end plugs	20.3/8 (with PE rings)
	Active, Thermal (no cadmium)	S	Long PE end plugs with small PE disks covering AmLi sources	10.2/4 (with PE rings)
Uranium (36% ^{235}U)	Active, Fast	M (contents of 1 50-cm storage tube)	Aluminum carousel disk holder, standard PE end plugs	20.3/8 (with PE rings)
	Active, Thermal	S	Long PE end plugs with small PE disks covering AmLi sources	10.2/4 (with PE rings)
UO_2 (36% ^{235}U)	Active, Fast	M (contents of 1 50-cm storage tube)	Aluminum carousel disk holder, standard PE end plugs	20.3/8 (with PE rings)
	Active, Thermal	S	Long PE end plugs with small PE disks covering AmLi sources	10.2/4 (with PE rings)
UO_2 (depleted)	Passive, Fast	M	Graphite end plugs	35.6/14
NpO_2	Passive, Fast	M	Graphite end plugs	35.6/14
U (depleted)	Passive, Fast	M	Graphite end plugs	35.6/14

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