*Calibration and Performance Testing of the
IAEA Aquila Active Well Coincidence Counter
(Unit 1)*

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CALIBRATION AND PERFORMANCE TESTING OF THE IAEA AQUILA ACTIVE WELL COINCIDENCE COUNTER (UNIT 1)

by

H. O. Menlove, R. Siebelist, and T. R. Wenz

ABSTRACT

An Active Well Coincidence Counter (AWCC) and a portable shift register (PSR-B) produced by Aquila Technologies Group, Inc., have been tested and cross-calibrated with existing AWCCs used by the International Atomic Energy Agency (IAEA). This report summarizes the results of these tests and the cross-calibration of the detector. In addition, updated tables summarizing the cross-calibration of existing AWCCs and AmLi sources are also included. Using the Aquila PSR-B with existing IAEA software requires secondary software also supplied by Aquila to set up the PSR-B with the appropriate measurement parameters.

I. INTRODUCTION

This Active Well Coincidence Counter (AWCC) produced by Aquila Technologies Group, Inc., was tested at Los Alamos National Laboratory in August 1995. The testing was done to determine the operating characteristics, to find mechanical or electrical problems, and to cross-calibrate the instrument with existing AWCCs.¹

We also calibrated the specially fabricated fuel rod insert supplied with this instrument² for uranium fuel rod bundles.

II. EQUIPMENT DESCRIPTION

This AWCC has serial number 1001. Forty two ³He detectors (RS-P4-0820-107) are connected in groups of seven tubes. Each group has one Amptek preamp/amplifier/discriminator board. All six of the Amptek units are ORed together to a common signal-output connector.

A LANL-supplied JSR-12 shift register coincidence counter was used during the initial testing while Aquila Technologies was modifying the PSR-B.

III. QUALITY CHECKS AND PERFORMANCE TESTS

A physical examination of the instrument revealed the following:

1. The ³He tubes were loose and could be turned by hand. They were tightened.
2. One ³He tube in bank #3 has a small dent. Aquila was aware of it and has spoken to the vendor. There is no indication of any malfunction in this tube and it was left in the system.

3. The ^3He tubes used in the detector contain a fill gas with a carbon dioxide additive formerly specified by LANL for the original AWCCs. An argon-methane fill gas mix is currently used, and Aquila will use ^3He tubes of this type in future detectors.
4. The humidity indicators in the original junction box lid were missing the desiccant tubes. Aquila delivered a replacement lid with the proper desiccant fixtures installed. The unit now has adequate desiccant.
5. The LED indicator lights were loose in their holes. They were subsequently fixed in place with silicone sealant.
6. The handle on the AWCC was made of a thin-walled tubing causing a bowing sensation whenever the detector was tipped on its side for the fuel assembly measurements. Newer versions of the detector handle are made with a thicker-walled tubing.

A. High-Voltage-Plateau Curve

We plotted the totals counting rate vs the high-voltage setting to determine the operating high-voltage to be used (see Fig. 1). A setting of 1760 V was chosen. This is somewhat higher than the 1680 V used for the High-Level Neutron Coincidence Counter (HLNC-II) because of the carbon dioxide gas mix in the ^3He tubes.

B. Amptek Amplifier Check

The individual detector banks were tested by comparing the totals rate from a neutron source centered in the AWCC. The goal was to determine if one or more ^3He tubes are malfunctioning in any of the banks. A ^{252}Cf source (CR-6) was used for the comparison, and the results are listed in Table I.

The ^3He detector tubes are wired in an alternating three inner ring plus four outer ring pattern for each preamplifier. This should result in the measured count rate alternating higher to slightly lower as each tube bank is measured. A 1-in-7 difference is not observed in the data listed in Table I, indicating that all the ^3He tubes are functioning. The gain and discriminator threshold settings were checked and found to be correct for all six amplifier channels.

C. Efficiency

Californium-252 source CR-6 was used to measure the totals efficiency in the Mode 1 configuration (see Fig. 2, Ref. 1). This was determined to be 23%, which is consistent with other AWCCs in use.

D. Deadtime

The totals and reals deadtime correction parameters were measured by using two ^{252}Cf sources of different strengths. The reals ratio of sources CR-10 to CR-5 is 84.4. The resulting deadtime coefficients are

$$a = 0.808 \mu\text{s} \text{ and}$$

$$b = 0.261 \mu\text{s}^2 .$$

Fig. 1. Detector bias plateau curve for the AWCC. The recommended operating voltage is 1760 V.

TABLE I. Results of Individual Detector Bank Measurements		
Detector Bank	Totals Rate (counts/s)	Sigma (counts/s)
1	410.02	2.12
2	422.57	2.57
3	408.23	2.02
4	409.67	2.02
5	400.70	2.00
6	431.32	2.08

Fig. 2. Cross section of AWCC end plug configuration and sample position, Fast Mode 1, used for the cross-calibration exercise.

E. Noise Test

The AWCC was set up in the fast mode configuration to measure room background without the end plugs and AmLi sources for 27 hours in 4 000-s counting intervals. The results of these measurements are shown in Table II where the totals and reals rates are listed with their corresponding statistical errors for each of the measurements. Two runs with cosmic-ray spallation events were eliminated from the data set by the outlier test resulting in the lower coincident background rate listed at the bottom of Table II. The unit is free of any electronic noise problems.

F. AmLi Sources

The AmLi neutron sources supplied with this AWCC are labeled NO61 and NO73. These sources were counted relative to AmLi source MRC-95. The deadtime-corrected totals rates relative to MRC-95 are 1.197 for NO61 and 1.128 for NO73. These values will be added to Table XX of Ref. 1 (see Appendix A).

IV. CROSS-CALIBRATION

We cross-calibrated for high-enriched uranium (HEU) metal under the following conditions:

1. AWCC in Mode I (Ref. 1) geometry with the nickel reflector ring in place (see Fig. 2).
2. AmLi source NO73 in the top end plug and AmLi source NO61 in the bottom end plug. Both AmLi source containers have their screw caps directed away from the sample cavity.

TABLE II. Results of Background Measurements				
Run	Totals (counts/s)	sig-T (counts/s)	Reals (counts/s)	sig-R (counts/s)
1	4.096	0.032	0.022	0.002
2	4.123	0.032	0.016	0.002
3	4.047	0.032	0.016	0.002
4	4.024	0.032	0.019	0.002
5	3.975	0.032	0.017	0.002
6	3.966	0.031	0.014	0.002
7	4.095	0.032	0.018	0.002
8	4.053	0.032	0.015	0.002
9	4.056	0.032	0.018	0.002
10	4.043	0.032	0.019	0.002
11	4.035	0.032	0.013	0.002
12	4.048	0.032	0.021	0.002
13	4.134	0.032	0.014	0.002
14	4.072	0.032	0.017	0.002
15	4.085	0.032	0.023	0.002
16	4.062	0.032	0.016	0.002
17	4.036	0.032	0.017	0.002
18	4.002	0.032	0.019	0.002
19	4.019	0.032	0.018	0.002
20	4.069	0.032	0.021	0.002
21	4.037	0.032	0.018	0.002
22	4.013	0.032	0.016	0.002
23	4.055	0.032	0.022	0.002
24	4.043	0.032	0.013	0.002
Ave	4.049	0.008	0.017	0.001

3. AWCC in Fast Mode configuration, all cadmium in place.
4. The HEU disk C20-8 positioned 2 in. (5 cm) above the bottom on an aluminum stand.

Metal disk C20-8 has a ^{235}U mass of 246.28 g. The measured real response was 37.810 ± 0.439 counts/s. The response for this metal disk relative to the reference AWCC will be added to Table V of Ref. 1 (see Appendix B).

V. FUEL ASSEMBLY CALIBRATION

The fuel rod insert, as supplied by Aquila, includes a source holder that separates the sources in the insert by about 127 mm (see Fig. 3a). The fuel assembly measurements made by Krick² had the sources together at the center of the insert (see Fig. 3b). The calibration measurements were performed with the sources in both geometries. The results of these measurements are grouped by geometry in Table III.

The response is 9.6% higher with the sources together in the center than for the sources separated by 127 mm. With the sources separated, an increase in end leakage of neutrons occurs accounting for the reduction in response.

VI. SOFTWARE COMPATIBILITY

The IAEA uses the Active Neutron Counting System (ANCS) software with the AWCC. This software was originally designed to operate with an AWCC and a JSR-11 shift register. Parameters such as count time, gate width, high voltage, and predelay would be set by the operator using the external manual controls on the JSR-11. The ANCS software is then used to start the measurement, collect the data from the shift register at the end of the measurement, and perform the required data analysis to obtain grams of ^{235}U . The software does not set any of the shift register parameters mentioned above.

With the Aquila PSR-B, there are no external manual controls for setting the high voltage, count time, gate width, predelay, or baud rate; software is required to set these parameters. Consequently, when the Aquila PSR-B is used with the ANCS software, these setup parameters must be preset using default values or an auxiliary software code supplied by Aquila. To this end, Aquila has supplied two programs for setting and resetting the parameters on the PSR-B. This software is executed before starting the ANCS software. The first program, INIT.EXE, sets the shift register parameters to those in Table V and displays the current settings and status of the PSR-B. The second program, PARAM.EXE, provides an interface so the operator can change any of the shift register parameters listed in Table V except the baud rate.

VII. SOFTWARE SETUP

Before starting the ANCS software for taking measurements, the measurement parameters on the PSR-B need to be set or verified with software or both. There are two programs to do this: INIT.EXE and PARAM.EXE. The software can either be loaded onto the hard drive of the controlling computer or used from the diskette. If desired, a call to these programs could be included in the batch file that starts the ANCS program.

Running the INIT program results in the PSR-B measurement parameters being set to those listed in Table V. No user input is required. On the computer screen, the current status of the PSR-B is displayed along with the current shift register parameters. Once the parameters are set,

(a) Separated Source Position

(b) Centered Source Position

Fig. 3. Cross section of fuel assembly insert for measuring fuel assemblies showing separated (a) and centered (b) source positions used to measure data in Table III.

TABLE III. Calibration Results for Uranium Fuel Rod Bundles					
Source Position	gU/cm	No. of Pins	$g^{235}\text{U}$ per cm	Reals Rate (counts/s)	Sigma (counts/s)
separated	0.0	0	0.00	0.01	0.002
separated	315.7	53	10.07	58.66	1.44
centered	315.7	53	10.07	63.89	0.69

TABLE V. Shift Register Parameters Supplied to the PSR-B from the INIT Program.	
Parameter	Value
Baud Rate	300
Count Time	100 s
Gate Width	64 μ s
High Voltage	1760 V
Predelay	4.5 μ s

they are stored in a Programmable Read Only Memory (PROM) chip so that the next time the PSR-B power is turned on, the same values will be used. The stored values are updated whenever INIT or PARAM are run. Once the parameters are loaded, the ANCS software can be started to begin the measurements.

To set the shift register parameters to values other than those listed in Table V requires the PARAM program. When running PARAM, the current status and shift register parameters for the PSR-B are displayed on the screen and the user is asked whether to change any of the values. If the response is yes, the user is prompted for values of each of the parameters in Table V except the baud rate. If no is selected, no changes are made and the program exits.

Occasionally when starting a measurement with the ANCS software, the user will see an error message saying the instrument is not ready. Simply press F3 to start the measurement again and communication will be established with the PSR-B.

REFERENCES

1. H. O. Menlove and J. E. Stewart, "A New Method of Calibration and Normalization for Neutron Detector Families," Los Alamos National Laboratory report LA-11229-MS (ISPO-287) (April 1988).
2. M. S. Krick, L. R. Cowder, et al., "Active Well Coincidence Counter Measurements of Enriched Uranium Fuel Assemblies in Scanning and Stationary Modes," Los Alamos National Laboratory report LA-12224-MS (ISPO-334) (December 1991).

APPENDIX A

(Updated Version of Table XX from LA-11229-MS)

TABLE XX. AmLi Source Yield Comparison^a

<u>Source No.</u>	<u>Yield Relative to</u> <u>MRC-95</u>	<u>IAEA</u>	<u>Location</u>
MRC-67	0.554		Los Alamos
MRC-68	2.872		Los Alamos
MRC-75	0.1760		IAEA
MRC-77	0.1633	(0.165)	IAEA
MRC-79	1.107		
MRC-80	1.062		
MRC-81	1.037		
MRC-82	0.956		
MRC-91	0.995		IAEA
MRC-92	0.996		IAEA
MRC-93	1.042		IAEA
MRC-94	1.013		Los Alamos
MRC-95	1.000		Los Alamos/EURATOM
MRC-96	1.009		Los Alamos
MRC-99	1.899		Los Alamos
MRC-100	1.845		Los Alamos
MRC-104	1.144		IAEA
MRC-105	1.106		IAEA
MRC-110	1.048		IAEA
MRC-111	1.132		IAEA
MRC-112	1.150		IAEA
MRC-113	1.211		Los Alamos/IAEA
MRC-114	1.164		Los Alamos/IAEA
MRC-115	1.287		Los Alamos
MRC-116	1.305	(1.289)	Los Alamos
MRC-117	1.220		Los Alamos
MRC-118	1.220		Los Alamos
MRC-121	1.628		EURATOM
C-119	1.142		EURATOM
C-171	1.217		
C-172	1.193	(1.180)	IAEA
C-173	1.176		
C-174	1.223		
C-176	1.255		EURATOM
C-180	1.270		EURATOM
C-181	1.211		EURATOM
C-182	1.193		EURATOM
C-183	1.176	(1.099)	EURATOM
C-186	1.009		
C-188	1.063		
C-200	1.105		
C-270	1.382		EURATOM
C-271	1.169		EURATOM
C-272	1.009		

TABLE XX (cont.)

<u>Source No.</u>	<u>Yield Relative to MRC-95</u>	<u>IAEA</u>	<u>Location</u>
C-282	1.474		EURATOM
C-283	1.439		EURATOM
C-297	1.102		EURATOM
C-298	1.108		EURATOM
C-299	1.138		EURATOM
C-300	1.109		EURATOM
C-470	1.132		
C-471	1.153		
C-472	1.136		
C-473	1.116		
C-474	2.554		
C-475	2.627		
C-476	2.580		
C-477	2.600		
C-539	2.499		
C-540	2.511		
C-541	2.610		
C-542	2.468		
N-009	0.965		IAEA
N-010	1.040		IAEA
N-058	1.575		
N-061	1.197		IAEA
N-071	1.469		
N-072	1.378		
N-073	1.128		IAEA
N-074	1.430		
N-075	1.495		
N-158	1.169		
N-159	1.166		
N-160	1.252		
N-161	1.195		

^aMRC-95 has yield of 4.00×10^4 n/s on 85-06-01.

APPENDIX B

Updated version of Table V from LA-11229-MS (Ref. 1)

TABLE V. AWCC Calibration Cross-Referenced Data for HEU Metal Disks (Mode-1)					
Detector ID	AmLi Top/Bottom	Net T_0 (AmLi) (s ⁻¹) (yr-mo-d)	Cf ID	R_0 (Cf) (s ⁻¹) (yr-mo-d)	$\frac{R_0(AWCC - ref)}{R_0(AWCC - XX)}$
AWCC (LANL/EUR) (SN300)	MRC-116/115	~7110 (84-09-05)	CR-5	3058 (87-06-03)	~1.04
AWCC (IAEA-4699/1) (AMPTEK)	MRC-114/113	~6350 (85-08-10)	CR-5	3012 (87-06-01)	1.00
AWCC (IAEA-4699/5) (NNC-AMPTEK)	MRC-114/113	—	CR-5	2807 (87-06-11)	—
AWCC (EUR-2) (main MTR)	C-180/176	—	CR-5	3160 (87-06-10)	—
AWCC (EUR-4) (8601801)	C-298/297	—	CR-5	2953 (87-06-02)	—
AWCC (EUR-5) (8601802)	C-300/299	—	CR-5	2934 (87-06-3)	—
AWCC (EUR-3) (JCC51)	C-181/182	~7065 (85-10-24)	CR-5	—	~0.913
AWCC (LANL-Black) (AMPTEK)	MRC-100/99	~8880 (87-05-05)	CR-5	2945 (87-06-03)	0.840
AWCC (LANL/IAEA) (Canada unit)	MRC-81/82	—	—	—	—
AWCC (Aquila SN 1001)	N-073/061	~4667 (95-8-23)	CR-5	3065 (87-06-03)	1.12
AWCC (Canberra SN 04956568)	N-074/075	~6068 (95-8-23)	CR-5	—	0.864

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