CONTENTS

CONTENTS

FIGURES

TABLES

PLUTONIUM CANISTER COUNTER OPERATIONS AND PROCEDURES MANUAL

by

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ABSTRACT

A neutron coincidence counter has been designed for the measurement of plutonium powder contained in storage canisters. Each canister contains from one to four cans of mixed oxide. The neutron counter measures the spontaneous fission rate from the plutonium, and when this is combined with the plutonium isotopic ratios, the plutonium mass is determined. The system can accommodate plutonium loadings up to 8 kg, with 4 kg being a typical loading. This manual describes the system and its operation and gives performance and calibration parameters for typical applications.

We have designed a neutron coincidence counter for the verification of the amount of plutonium in storage canisters. This assay system is called the Canister Counter. The system consists of a detector head with stand, a shift-register electronics unit, and a Hewlett-Packard HP-85 minicomputer.

The Canister Counter can be used for the measurement of plutonium loadings up to 8 kg (24% ^{240}Pu-effective). The maximum sample diameter is 12 cm, and the uniform counting (flat response) region in the detector head is 95 cm.

This system resembles the high-level neutron coincidence counter[1] (HLNC) in that it uses similar digital electronics[2] and detects the coincidence neutrons from the spontaneous fission of the even isotopes of plutonium. However, it is designed to operate for much taller samples ($\sim$95 cm) than the HLNC and at much higher counting rates. The electronics in the Canister Counter are similar to those in the upgraded HLNC, that is, the HLNC-II.[3,4]

This manual describes the components, performance characteristics, and operating and calibration procedures for the Canister Counter.

DETECTOR BODY

To accommodate the shape and height of the sample container (canister), it was necessary to design the Canister Counter body in two sections where the top has a larger diameter than the bottom. Figure 1 is a diagram of the detector body, and Fig. 2 shows a side view cross section. Figure 3 is a photograph looking into the top of the detector. The detector tubes and amplifier

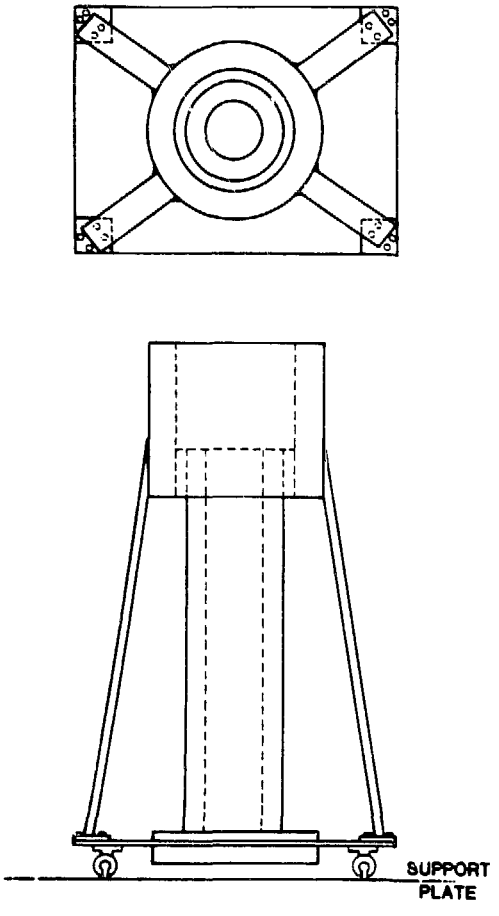

Fig. 1. Diagram of the cylindrical Canister Counter.

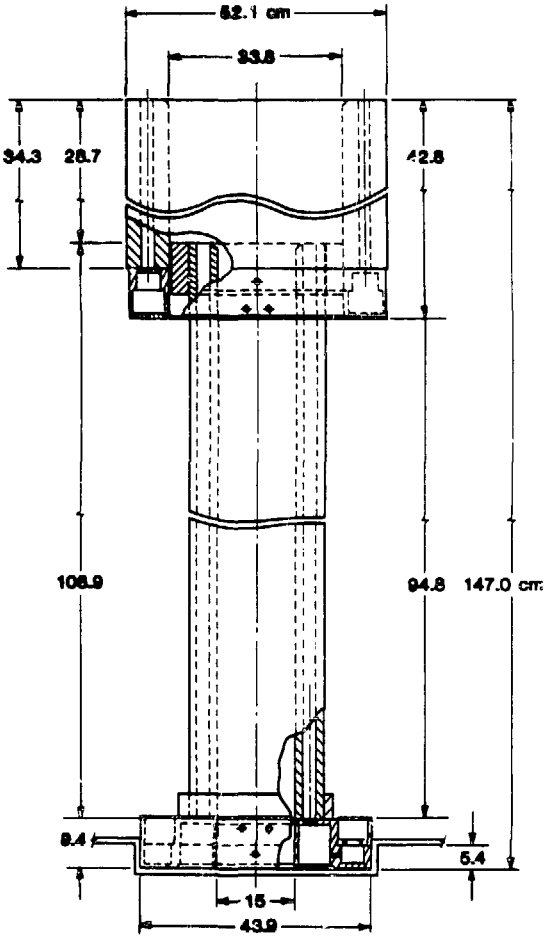

Fig. 2. Cross-sectional side view of Canister Counter.

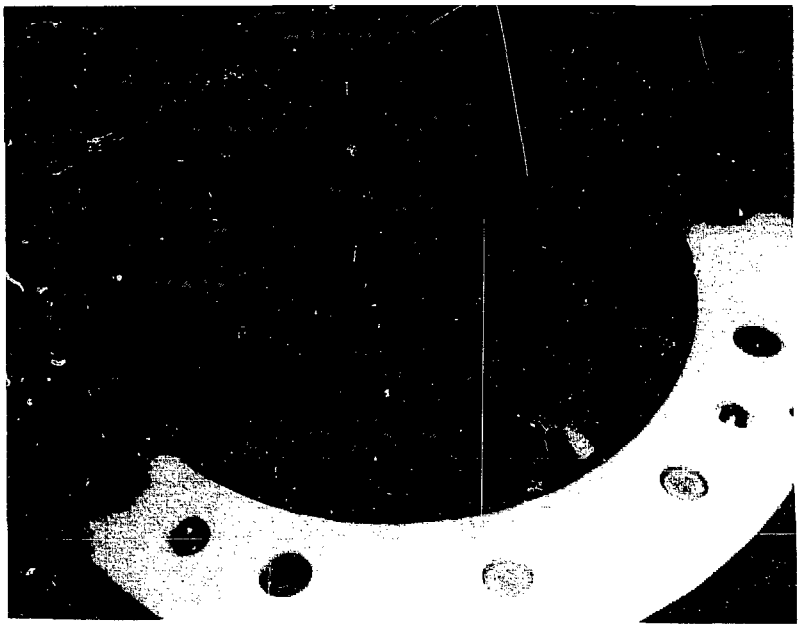

Fig. 3. Top view looking into Canister Counter.

DETECTOR BODY (cont)

electronics in the top and bottom sections are independent of each other. Both sections are lined on the inside and outside with 0.4-mm-thick cadmium. This cadmium is covered with a 0.8-mm layer of aluminum to protect the cadmium. The top section of the unit weighs ∿56 kg and the bottom weighs ∿58 kg. The top and bottom can be disconnected for assembly.

The sample canisters are loaded into the counter through the top, using an overhead crane.

Orientation

The counter was designed to be used in a chamber (Fig. 4) in the normal path of the canister transfer. The available room space restricted the length and design of the counter and made it

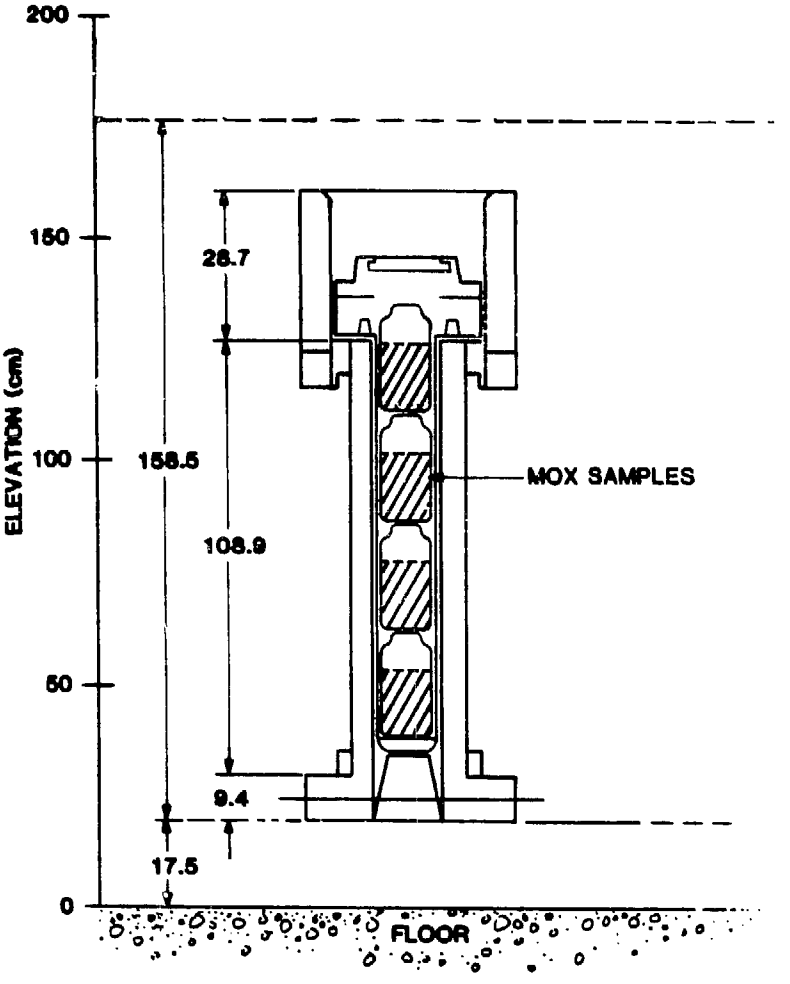

Fig. 4. Orientation of Canister Counter in measurement area.

Orientation (cont)

difficult to obtain a uniform counting efficiency over the fill height of the sample canister.

Response Profiles

Details concerning the response profiles are given in the section on Operating Characteristics on p. 15.

CALIBRATION SOURCE

Normalization

A ^{252}Cf source should be assigned to the system, and this source should be counted at the time of calibration and at each subsequent use of the detector for normalization purposes. A source with an initial emission rate of 5×10^4 n/s is adequate for at least 5 years of use in the Canister Counter. The initial reference source used with the unit was LANL CR-5. Sources owned by the IAEA have been cross-calibrated with the CR-5 source.

This source checks the system operation and can be used to normalize the calibration curve in the same manner as with the HLNC.

Insertion

A neutron source holder (Fig. 5) consisting of an aluminum plate having a 12-mm-diam by 94-mm-long

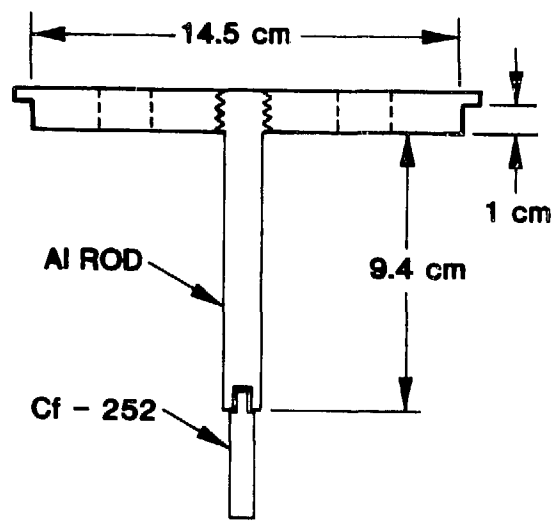

Fig. 5. Source holder for placing ^{252}Cf normalization source into top of Canister Counter.

Insertion (cont)

aluminum rod attached is supplied with the system. The source is set at the step between the top section and the bottom section so that it gives almost equal counting rates to all six amplifier channels in the two sections of the Canister Counter.

DETECTOR TUBES

The top of the detector head contains twelve ^{3}He tubes and the bottom section has ten tubes with characteristics as listed in Table I. The tubes have been matched to operate at the same electronic settings for both sections.

TABLE I

CHARACTERISTICS OF ^{3}He TUBES

	Top	Bottom
Tube model	RS-P4-0812-203	RS-P4-0840-203
Active length	30.5 cm	101.6 cm
Diameter	2.5 cm	2.5 cm
Fill pressure	4 atm	4 atm
Gas quench	Ar + CH_4	AR + CH_4
Cladding	Stainless steel	Stainless steel
Operating high voltage	1700 V	1700 V

ANALOG ELECTRONICS

The Canister Counter uses the new fast-counting circuitry[3] based on the miniature AMPTEK hybrid chip. These chips are located near the tops of the ^{3}He tubes (see Fig. 6) and contain the preamplifier, amplifier, and discriminator circuits. Five of these amplifier units are located in the bottom part of the detector head and one in the top part. The outputs of these six amplifiers are added and sent to the input of the shift-register board. The connection is made through the "external SR input" on the back panel of the shift-register electronics as shown in

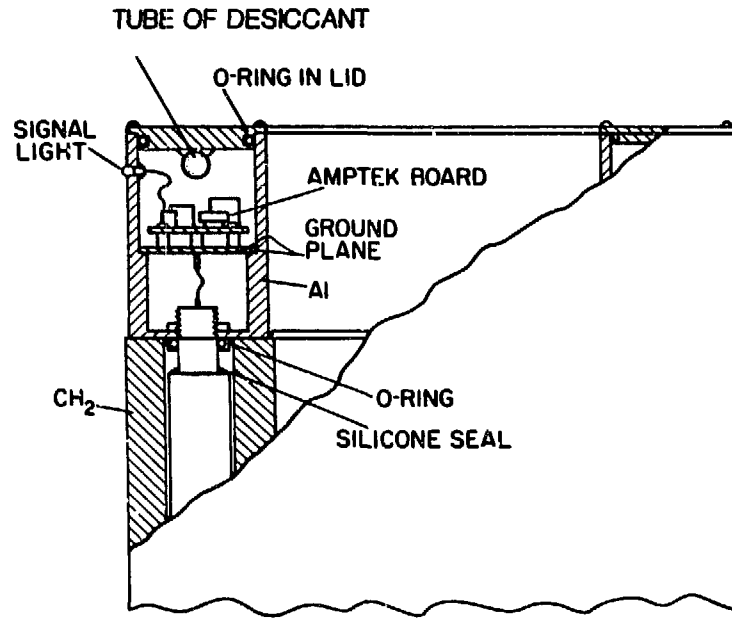

Fig. 6. Diagram of ^3He tube and AMPTEK amplifier board.

ANALOG ELECTRONICS (cont)

Fig. 7. Figure 8 is a photograph of the base of the Canister Counter.

The status of the six amplifier channels is indicated by six signal lights connected to the outputs of the six discriminators. These lights flash whenever the corresponding channel processes a discriminator output pulse. The ^3He tube high-voltage section of the detector is isolated from the AMPTEK amplifier board by the ground plate shown in Fig. 6.

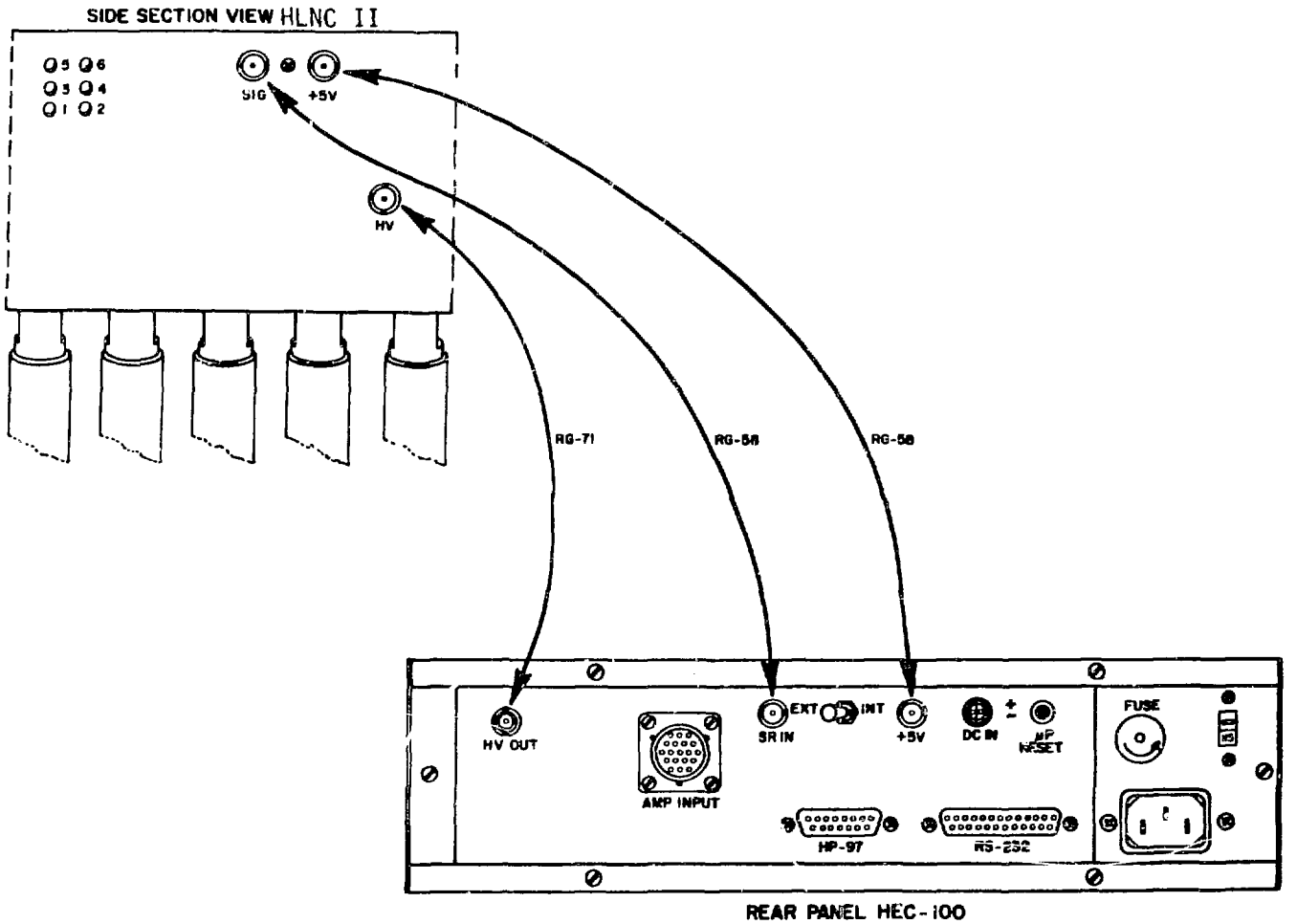

Fig. 7. Connections for the high-voltage, 5-V, and signal cables between the detector and the HEC-100.

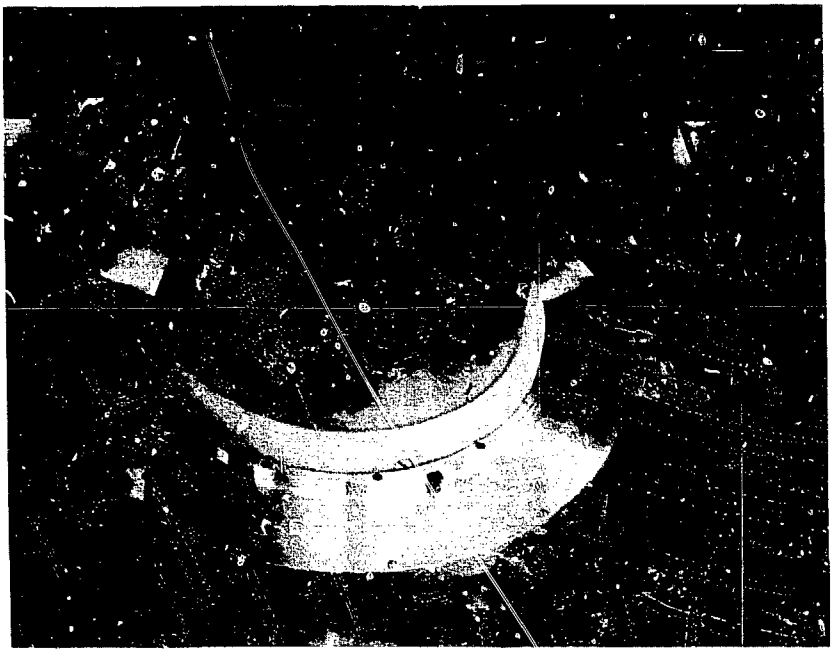

Fig. 8. Base support and lower junction box for Canister Counter.

DIGITAL ELECTRONICS

The shift-register electronics* for the Canister Counter is the same as that used for the HLNC or the upgraded HLNC-II;[4] however, the HEC-100 unit has been modified to provide +5 V to the AMPTEK amplifier, and a derandomizing buffer has been added to the HEC-100 shift-register circuit.[3] The electronics from JOMAR Systems (Model JSR-11) can be used with no modifications.

MOISTURE SEAL

To avoid moisture buildup in the high-voltage junction box of the detector, this space contains

*HEC-100 SR electronics package, IRT Corporation, San Diego, California, or Model JSR-11, JOMAR Systems, Los Alamos, New Mexico.

MOISTURE SEAL
(cont)

desiccant, and the openings are sealed with O-rings and silicone rubber (see Fig. 6) and rubber gaskets. A bead of silicone sealant was applied around the perimeter of the ^{3}He tubes where the high-voltage connector screws into the tube.

EFFICIENCY

The efficiency for a ^{252}Cf neutron source in an empty counter is 9.5%. The detector was designed to be undermoderated, that is, to have less polyethylene wall thickness than would be the case for maximum counting efficiency. This design accommodates the high plutonium loading in the canisters and keeps the counterweight low.

DETECTOR NEUTRON DIE-AWAY TIME

The proper gate setting in a neutron coincidence counter depends on the neutron die-away time (τ) in the system. For minimum error, the coincidence gate length should be set equal to $\sim 1.2\ \tau$. A ^{252}Cf source was used to measure the die-away time, and the result was 50 μs in the top section and 40 μs in the bottom section. We are using a gate setting of 64 μs.

DETECTOR DEADTIME

The Canister Counter uses the same basic electronics and amplifiers (six channels-AMPTEK) as does the new HLNC-II.[4] Therefore, we used the same deadtime coefficient during calibration* as for the HLNC-II,

$$\delta(T) = (0.62 + 0.20 \times 10^{-6}\ T)\ \mu s\ ,$$

*Subsequent deadtime measurements for the Canister Counter on October 30, 1985, showed that the actual deadtime coefficient is

$$\delta(T) = (0.677 + 0.218 \times 10^{-6}\ T)\ \mu s\ ;$$

however, this new value should not be used unless the calibration parameters are changed also.

DETECTOR DEADTIME (cont)

where T is the measured totals rate in counts/s. The corrected counting rates are

$$T(\text{corr.}) = T\, e^{\delta T/4}$$

and

$$R(\text{corr.}) = R\, e^{\delta T} \quad .$$

It is important to use the same deadtime coefficient for both calibration and assay so that any errors in the correction will cancel to a first approximation.

AXIAL RESPONSE PROFILES

To determine sample geometry effects, a ^{252}Cf neutron point source was positioned at various axial locations in the sample cavity. Both totals and coincidence rates were measured at each location, and the results of the measurements using a 64-μs gate are shown in Fig. 9. The uniform axial-efficiency zone of ∿95 cm was obtained in the detector design by adding the top detector ring to increase the rate near the top. The large head on the sample canister and the restricted overhead space prevented the further extension of the flat counting zone.

Because the canisters are filled with four or less separate cans, the PuO_2 distribution is guaranteed to be nonuniform along the axis. This makes it important to have a uniform counting efficiency.

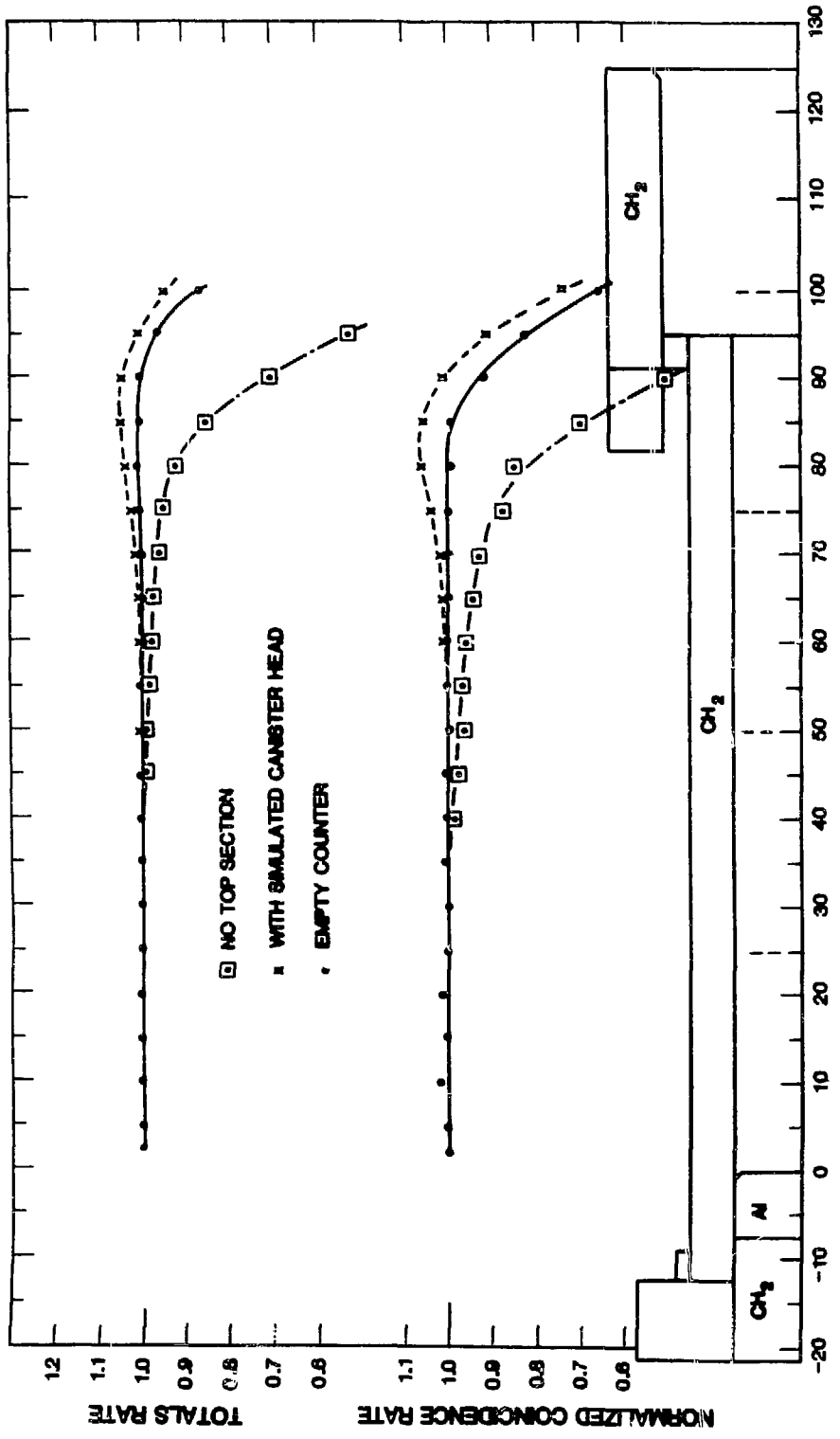

Fig. 9. Totals and coincidence efficiency profiles along axis of Canister Counter.

SAMPLE CONTAINER

A diagram of the sample canister is shown in Fig. 10. This canister contains up to four cans of mixed oxide (MOX) stacked on top of each other. Each can typically contains ∿2 kg of MOX of which ∿1 kg is PuO_2.

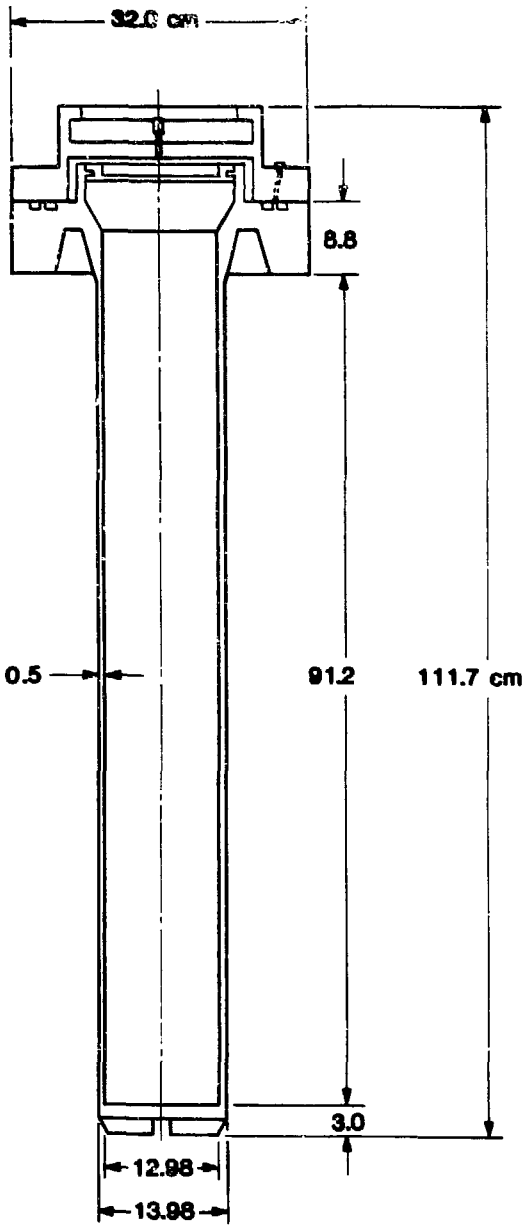

Fig. 10. Cross-sectional view of stainless steel sample canister.

INITIAL CHECK-OUT

The initial check-out and operating procedures are the same as for the HLNC-II. Use the following procedure:

(1) Connect the HEC-100 or JSR-11 to the bottom detector using three labeled cables (HV, +5 V, and signal) as illustrated in Fig. 7. Connect the top section to the bottom section by three similar cables. These cables are provided with the system, and all connections are labeled.

(2) Check the HEC-100 or JSR-11 for proper line voltage (110 or 240 V) and set controls as listed below.

Discriminator level	N/A
High voltage	= 1700 V
Gate	= 64 μs
Time	= Desired run time

(3) Turn on power and verify that the six output lights that show detected events are blinking.

(4) Measure room background and observe that there are no net coincidence counts above normal statistical fluctuations and that the totals rate is consistent with the amount of plutonium stored near the measurement position.

INITIAL CHECK-OUT (cont)

(5) Place the ^{252}Cf calibration source attached to the source holder (shown in Fig. 5) in the top of the detector head and count to achieve a precision of a few tenths of a per cent.

If the counting rate (after decay corrections) is within a few per cent of the expected value from the calibration measurement, then proceed with assay and normalize the calibration to the source rate (the precision should be good to a few tenths of a per cent).

If the ^{252}Cf counting rate is outside the expected range, then do a thorough check on electronics as described in the Experimental Setup section of the HLNC manual.[1]

CANISTER ASSAY

The canisters can be positioned into the detector through the top, using the overhead crane.

PROCEDURE

To calibrate the Canister Counter, MOX samples are required that cover a large range of plutonium mass. Because the samples have considerable neutron multiplication, the material geometry, density, and isotopic content are important.

SETUP

For the initial calibration work, the Canister Counter was set up at Los Alamos, and measurements were made with PuO_2 and MOX standards. An aluminum pipe was fabricated with a similar diameter and length as the sample canister. The cans containing plutonium were then stacked into the pipe to simulate a loaded canister.

Normalization

A small ^{252}Cf neutron source (CR-5) was measured periodically during the experiment to provide future calibration normalization. The ^{252}Cf source was attached to the source holder for insertion in the top of the Canister Counter (see Fig. 5).

The stability of the instrument was checked by two overnight runs (10 x 6000 s each) with the normalization source (CR-5). The coincidence results at the date of the measurement (June 5, 1984) are

579.27 ± 0.31 counts/s

579.30 ± 0.31 counts/s .

POSITION SENSITIVITY TESTS

To determine the sensitivity of the totals and coincidence rates to the location of the canister

POSITION SENSITIVITY TESTS (cont)

in the counter, a series of measurements were made with varying axial and radial positions.

Axial Position

One of the plutonium cans was measured at several axial positions to determine the sensitivity of the detector to the sample's vertical position. The results of these measurements were essentially the same as those for the point source before multiplication corrections. However, the multiplication-corrected results drop off less at the top of the counter than do the uncorrected results. This is caused by the decrease in ρ_0 (reference reals-to-totals ratio) at the end of the counter, which causes a decrease in the multiplication.

The results show that the detector response is uniform in the bottom and middle parts. Because of the slightly increased response in the upper part, we expect that the detection efficiency for the top can in a canister is about 3% above the average for multiplication-corrected coincidences but about 3% below the average for uncorrected coincidences (assuming a fill height of 16 cm).

Radial Position

A PuO_2 can was measured in several different radial positions to determine the sensitivity of the counter to positioning error.

For the extended geometry of the can (diam = 10.9 cm), the response at the wall was <1% higher than at the center. Therefore, radial positioning variability for the canister is not a significant problem.

STANDARDS SPECIFICATIONS

The standards used in the calibration were both pure PuO_2 powder and MOX. The specifications for the PuO_2 standards are listed in Table II and for the MOX samples, in Table III.

The value of ^{240}Pu-eff. is defined as

$$^{240}Pu\text{-eff.} = 2.49\ M_{238} + M_{240} + 1.57\ M_{242} \quad ,$$

where M is the mass of the different plutonium isotopes. The α value listed in the last column of Table II is the ratio of (α,n) neutrons to spontaneous fission neutrons calculated from the isotopic fractions, the (α,n) yields in oxide, and the spontaneous fission rates. This value is used in the self-multiplication correction.[5]

TABLE II

PLUTONIUM STANDARDS DATA
(June 1, 1984)

		Isotopic Weight Per Cent							
Sample No.	g Pu	^{238}Pu	^{239}Pu	^{240}Pu	^{241}Pu	^{242}Pu	^{241}Am	^{240}Pu-eff	α
1	59.97	0.058	82.18	16.19	1.24	0.334	0.145	10.11	0.381
2	171.92	0.065	81.96	16.36	1.28	0.344	0.158	29.33	0.384
3	321.89	0.057	82.13	16.22	1.25	0.344	0.150	54.42	0.380
4	384.84	0.060	82.10	16.26	1.24	0.339	0.132	65.19	0.379
5	543.84	0.070	82.07	16.26	1.25	0.340	0.149	92.31	0.388
6	616.69	0.057	81.97	16.38	1.24	0.356	0.176	104.64	0.381
7	848.60	0.060	81.98	16.35	1.28	0.340	0.126	144.53	0.376
8	876.58	0.060	81.98	16.35	1.28	0.340	0.126	149.29	0.376
Average	---	0.060	82.01	16.33	1.26	0.34	0.14	---	--

TABLE III

MOX CAN DATA
(Corrected to June 1984)

ID	Ref. Date	Net Wt (g)	U/Pu	%238	%239	%240	%241	%242	% Am 241 Pu	Pu (g)	$^{239+241}$Pu (g)	^{240}Pu-eff. (g)	α
HUA-5069 (1%)	8/3/83	1206.8	5.99	0.062	87.07	11.64	1.043	0.185	0.878	146.6	129.2	17.7	0.658
HUA-5256 (depl.)	10/14/83	1029.6	2.81	0.053	87.09	11.67	0.994	0.185	0.362	228.1	200.9	27.6	0.536
HUA-5301 (depl.)	10/14/83	1400.1	2.20	0.052	87.18	11.61	0.968	0.184	0.329	377.3	332.6	45.4	0.531
HUA-5062 (nat.)	7/20/83	757.1	1.635	0.069	86.90	11.77	1.084	0.176	1.056	244.3	214.9	29.8	0.698
HUA-5065 (nat.)	8/3/83	890.6	1.44	0.069	86.88	11.79	1.086	0.176	1.070	308.0	270.9	37.7	0.700
HUA-5175 (depl.)	7/19/83	1058.3	3.49	0.053	87.12	11.65	0.997	0.181	0.318	204.3	180.0	24.7	0.528
HUA-8971 (1%)	7/20/83	1131.4	2.65	0.062	86.88	11.76	1.084	0.208	0.400	264.3	232.5	32.4	0.548

STANDARDS SPECIFICATIONS (cont)

The MOX powders contained significant moisture and this reduced their usefulness as calibration standards.

CALIBRATION RESULTS

Response Function for PuO_2 Powders

A calibration curve of the Canister Counter has been determined for PuO_2 powders by using a series of eight cans filled with that material. The plutonium weight of the single can varied between 60 and 877 g and for ^{240}Pu-eff. between 10 and 149 g. The cans with an outer diameter of 109 mm and a height of 130 mm were stacked in an aluminum tube in the center of the counter. The influence of the canister walls has been simulated by placing a steel disk, about 20 mm thick, on the bottom plug and some circular steel pieces of an adequate shape in the upper part of the counter. The results of the PuO_2 measurements are given in Table IV. The first points of the calibration

TABLE IV

CALIBRATION DATA FOR PuO_2 STANDARDS
(June 5, 1984)

Standard[a]	No. of Cans	^{240}Pu-eff. (g)	T[b] (s^{-1})	R[b] (s^{-1})	σ_R (s^{-1})	R / g 240	R_c[c] (s^{-1})	R_c / g 240	R_c[d] (s^{-1})
1	1	29.33	3 842	179.7	2	6.13	140.3	4.78	141.7
2	1	65.20	8 738	452.0	4	6.93	310.0	4.75	314.9
3	1	104.65	14 133	745.1	7	7.12	497.1	4.75	505.6
4	1	149.31	20 378	1 152	10	7.72	702.3	4.70	717.3
5	2	214.49	28 843	1 544	14	7.20	1 012	4.72	1 031
6	2	253.95	34 323	1 914	16	7.54	1 186	4.67	1 211
7	3	319.13	42 583	2 305	20	7.22	1 487	4.66	1 517
8	3	346.26	46 383	2 525	22	7.29	1 613	4.66	1 645
9	4	411.40	54 697	2 947	26	7.16	1 910	4.64	1 946
10	5	555.94	73 620	3 930	35	7.07	2 582	4.64	2 628
11	7	595.37	79 150	4 176	38	7.01	2 787	4.68	2 837
CR-5	0	^{252}Cf	5 995	579.3	0.3	--	Av = 4.70 ± 0.05		

[a]Standards are made of PuO_2 cans (LAO series in Table II) stacked end on end in an aluminum pipe.

[b]Reals and totals rates have been corrected for deadtime, $\delta = (0.62 + 0.20 \times 10^{-6} T)$ μs, and room background (320 s^{-1}).

[c]Multiplication-corrected reals rate using old multiplication parameters and $\rho_0 = 0.0537$.

[d]Multiplication-corrected reals rate using new multiplication parameters and $\rho_0 = 0.0537$.

Response Function for PuO_2 Powders (cont)

curve (low plutonium mass) were measured with single cans at the bottom end of the sample tube. For higher masses, other cans were added subsequently (up to seven cans total). The effect of can sequence in composite samples has been determined separately (see results below).

The isotopic composition of the eight PuO_2 samples (updated to June 1, 1984) is given in Table II.

Response Function for PuO_2 Powders (cont)

The average isotopic composition was calculated for each measurement point. The measured data were used to derive the response functions as follows:

Before multiplication correction

$$R = (-53.1 \pm 3.1) + (7.94 \pm 0.06)M - (0.00143 \pm 0.00015)M^2$$

R = reals count rate (counts/s)

M = ^{240}Pu-eff. mass (g)

After multiplication correction

$$R_c = (4.693 \pm 0.013)M \quad ,$$

where the reference multiplication constant was taken as $\rho_0 = 0.0537$.

In an additional experiment, the effect of the sequence of cans in the counter has been checked. Two measurements with the same composite sample (seven cans, 595.4 g ^{240}Pu-eff.), but first with the big cans in the center and then with the big cans at both ends, gave a difference of only 0.3% (well within the statistics) for uncorrected coincidences. This finding means that there is very little multiplication interaction between adjacent cans. Considering the fact that the cans were not completely filled and the void in the upper parts

Response Function for PuO_2 Powders (cont)

of the cans separated the fissile material, this result could be expected.

Response Function for MOX Samples

For determination of the response function of the instrument for MOX samples, seven cans with that type of material (HUA series, see Table III) were available, ranging in the total plutonium weight from 147 to 264 g and in the ^{240}Pu-eff. from 17.7 to 32.4 g. The uranium/plutonium ratio covered the range from 1.44 to 5.99; also the uranium enrichment varied from depleted over natural to 1% enriched. The size and type of cans were exactly the same as for the PuO_2 samples. The average isotopic composition of the MOX on June 5, 1984, was the following:

Plutonium-238 = 0.06%
Plutonium-239 = 87.02%
Plutonium-240 = 11.70%
Plutonium-241 = 1.03%
Plutonium-242 = 0.19%
Americium-241 = 0.62%

The variation in composition of individual samples was considerably larger than for the PuO_2 samples.

The response function of the instrument was determined using combinations of several cans (up to all seven) ranging in ^{240}Pu-eff. from 45.4 to 215.2 g; the actual composition had been carefully calculated for each sample. The data are given in

Response Function for MOX Samples (cont)

Table V. The resulting response functions are as follows:

Before multiplication correction

$$R = (37.74 \pm 12.46) + (5.87 \pm 0.28)M + (0.00184 \pm 0.00127)M^2 \quad .$$

After multiplication correction

$$R_c = (5.012 \pm 0.027)M \quad ,$$

with $\rho_0 = 0.0537$.

TABLE V

CALIBRATION DATA FOR MOX SAMPLES
(June 5, 1984)

Sample[a]	^{240}Pu-eff. (g)	T[b] (s^{-1})	R[c] (s^{-1})	σ_R (s^{-1})	R[d] (s^{-1})	R[d]/g 240	R[e] (s^{-1})
1	45.38	6 951	308.5	3	227.4	5.01	230.2
2	90.69	13 860	583.0	5	450.8	4.97	455.3
3	158.22	25 458	1 026	12	800.3	5.06	806.6
4	215.25	34 047	1 377	16	1 086.0	5.05	1 094.8
CR-5	^{252}Cf	5 995	579.3	0.3			
						Av = 5.02	

[a]Standards are made of MOX cans (HUA series in Table III) stacked end on end in an aluminum pipe.

[b]Totals rate has been corrected for deadtime, $\delta = (0.62 + 0.20 \times 10^{-6}\ T)\ \mu s$, and room background (320 s^{-1}).

[c]Reals rate has been corrected for deadtime.

[d]Multiplication corrected with old procedure and $\rho_0 = 0.0537$.

[e]Multiplication corrected with new procedure and $\rho_0 = 0.0537$.

Response Function for MOX Samples (cont)

In a set of measurements, composite samples of PuO_2 were measured; after that some cans were replaced by MOX cans with approximately the same ^{240}Pu-eff. A comparison of the results gives mainly the effect of the added uranium (0.5 - 1 kg per can). The results are given in Table VI. For determination of ^{240}Pu-eff. of the samples, the response function for PuO_2 (after multiplication correction) has been used. The results show that there is a noticeable influence from uranium only for the last sample. The reason for the small difference in behavior of the two sets is not clear. Normally, the uranium in the MOX increases the response by a few per cent.

TABLE VI

MIXTURES OF PuO_2 AND MOX

Declared ^{240}Pu-eff. (g)	Uranium (total g)	R_c (s^{-1})	Determined ^{240}Pu-eff.	Δ (%)
333.24	-	1560.40	332.50	0.22
336.15	1914.2	1568.70	334.26	0.56
387.68	-	1825.30	388.94	-0.33
388.92	1896.9	1872.80	399.06	-2.61

CALIFORNIUM SOURCE NORMALIZATION

High-Voltage Problem

During the calibration of the Canister Counter at Los Alamos in June 1984, the IAEA's electronics (HEC-100, IAEA 5166/12) contained an erroneous high-voltage calibration. Subsequent tests have

High-Voltage Problem (cont)

shown that this particular electronics unit has a 54-V bias in the high-voltage dial setting. That is, a dial setting of 8.50 (1700 V) supplies only 1646 V to the detectors (AMPTEK). This low high-voltage value resulted in a low counting rate in the detector.

In January 1985, we made measurements with a ^{252}Cf (CR-5 absolute yield of 5.92×10^4 n/s on January 10, 1985) source at both the low high voltage (1646 V) and the correct high voltage (1700 V) to obtain correction factors for the calibration data. These correction factors are

$$\frac{T(1700\ V)}{T(1646\ V)} = \frac{5604}{5458} = 1.029 \quad \text{and}$$

$$\frac{R(1700\ V)}{R(1646\ V)} = \frac{524.0}{491.6} = 1.065 \quad .$$

In future work with the Canister Counter operating with the correct high-voltage value, the measured totals and reals rates will be increased by the above factors.

The totals and coincidence rates given in Tables IV, V, and VI are low because of the incorrect high-voltage value. However, the ^{252}Cf (CR-5) reference rate is also low by the same factor. Thus, the ^{252}Cf source normalization procedure during future field work will automatically correct for the high-voltage problem

High-Voltage Problem (cont)

for low to medium counting rates. However, for high rates ($T \geq 100\,000$ counts/s), there will be some deadtime error because the deadtime has a slight increase at the lower high-voltage value.

Field Normalization

The calibration of the Canister Counter can be carried forward in time by using the ^{252}Cf neutron source normalization method. To do this, the net totals rate T_0 and the coincidence rate R_0 are measured at the time of calibration with standards. At any future time, the ^{252}Cf source is remeasured and the values of R and T are compared (after decay correction) with the original rates. The normalizations are made as follows:

$$R_c = R_m k_1 \quad ,$$

where

R_c = corrected coincidence rate,

R_m = measured coincidence rate, and

$$k_1 = \left(\frac{R_0}{R}\right)_{Cf} \quad .$$

Similarly,

$$T_c = T_m k_2 \quad ,$$

Field Normalization

(cont)

where

$$k_2 = \left(\frac{T_0 \text{ net}}{T \text{ net}}\right)_{Cf} .$$

Note that k_1 and k_2 are not equal and that, in general,

$$k_1 \simeq (k_2)^2 .$$

It is not necessary to use the same ^{252}Cf source for normalization as was used for calibration, as long as the second source is cross-calibrated with the original source. To avoid an error buildup in this procedure, the statistical precisions for the ^{252}Cf measurements should be good ($\sim$0.2%).

For the specific case of the Canister Counter calibration at Los Alamos, we measured CR-5 with

$R_0 = 579.3 \pm 0.3$ counts/s and

$T_0 = 5995$ counts/s

on June 5, 1984. The calibration data listed in Tables IV, V, and VI correspond to the above reference rates.

This calibration information can be related to the IAEA sources listed in Tables VII and VIII by using the ratios to CR-5.

TABLE VII

CALIFORNIUM-252 SOURCE STANDARDS INTERCOMPARISON SUMMARY
(November 17, 1983)

Source Number	Absolute Yield[a] (n/s)	Relative Yield	σ_R (%)	Californium (µg)
IPL F274	5.77×10^4	0.7278	0.2	0.0247
IPL F275	5.33×10^4	0.6716	0.2	0.0228
IPL F276	5.30×10^4	0.6676	0.2	0.0227
IPL F277	5.74×10^4	0.7231	0.2	0.0245
IPL F278	5.63×10^4	0.7097	0.2	0.0241
IPL F279	5.20×10^4	0.6553	0.2	0.0222
CR-5	7.93×10^4	1.000	0.2	0.0339

[a]The absolute yields were determined by intercomparison with CR-6 that was calibrated by National Bureau of Standards with an accuracy of ±1.2% on October 16, 1979.

TABLE VIII

LOS ALAMOS RESULTS
FOR THE ^{252}Cf SOURCE STANDARDS INTERCOMPARISON
(June 18, 1984)

Source	Coincidence Rate[a] (counts/s)	σ_R[b] (%)	Relative Yield	Absolute Yield[c] (n/s)
CR-5	5 423.5	0.03	1.000	6.81×10^4
CR-6	14 101.1	0.06	2.600	1.77×10^5
CC-15	984.4	0.11	0.1815	1.24×10^4
F-698	3 601.2	0.16	0.6640	4.53×10^4
F-699	3 184.7	0.16	0.5872	4.00×10^4
F-700	3 324.6	0.14	0.6130	4.17×10^4
F-701	3 656.9	0.13	0.6743	4.59×10^4
F-702	3 292.2	0.11	0.6070	4.13×10^4
F-703	3 652.4	0.08	0.6734	4.59×10^4

[a]The totals and coincidence rates have been corrected for deadtime using $\delta = 2.30 + 1.62 \times 10^{-6}$ T corresponding to the calibration pile.

[b]The error on the coincidence rate was calculated from the R and R+A values.

[c]The yield of CR-5 was taken as 7.93×10^4 n/s on November 17, 1983, and the decay constant is 0.2623 Y^{-1}.

GENERAL

The Canister Counter has no moving parts and requires little periodic mechanical maintenance. Maintenance and repair of the shift register electronics package are the same as for the HLNC.

DETECTOR BODY

The desiccant in the junction boxes of the detector body should be changed approximately once a year if the instrument is in a humid environment. To change desiccant, use the following procedure:

(1) Shut off the high voltage. Remove high-voltage cable from the tube junction box and ground the high-voltage input.

(2) Remove the screws holding the lid in place. Remove the lid from the junction box. Take care not to damage the rubber O-ring.

(3) Remove the desiccant holder from the undersurface of the lid (see Fig. 6) and discard the old desiccant.

(4) Replace the desiccant and reassemble the holder. (Note that the old desiccant can be rejuvenated by placing it in an oven overnight at ∿150°C or until it regains its blue indicating color.)

(5) Date the junction box for future reference.

AMPTEK AMPLIFIER TEST PROCEDURES

If the measurements described in the Initial Check-Out section indicate that one or more of the

AMPTEK AMPLIFIER TEST PROCEDURES (cont)

amplifier channels is out of specification, then additional tests are necessary (see Ref. 3).

The six amplifier signal lights on the detector allow the user to observe the discriminator signal from each of the six channels at the output of the discriminator circuits.

Field repairs of the AMPTEK amplifier boards can be made by plugging in a spare board in place of the bad board.

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