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***Coincidence Measurements of
FFTF Breeder Fuel Subassemblies***

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Los Alamos Los Alamos National Laboratory
Los Alamos, New Mexico 87545

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Prepared by Jo Ann Barnes, Group Q-1

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Coincidence Measurements of FFTF Breeder Fuel Subassemblies

G. W. Eccleston
J. E. Foley
M. Krick
H. O. Menlove
P. Goris*
A. Ramalho**

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*Westinghouse Hanford Company, Richland, Washington.

**International Atomic Energy Agency, Vienna, AUSTRIA.

Los Alamos Los Alamos National Laboratory
Los Alamos, New Mexico 87545

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COINCIDENCE MEASUREMENTS OF FFTF BREEDER FUEL SUBASSEMBLIES

by

G. W. Eccleston, J. E. Foley, M. Krick,
H. O. Menlove, P. Goris, and A. Ramalho

ABSTRACT

A prototype coincidence counter developed to assay fast breeder reactor fuel was used to measure four fast-flux test facility subassemblies at the Hanford Engineering Development Laboratory in Richland, Washington. Plutonium contents in the four subassemblies ranged between 7.4 and 9.7 kg with corresponding ^{240}Pu -effective contents between 0.9 and 1.2 kg. Large count rates were observed from the measurements, and plots of the data showed significant multiplication in the fuel. The measured data were corrected for deadtime and multiplication effects using established formulas. These corrections require accurate knowledge of the plutonium isotopes and ^{241}Am content in the fuel. Multiplication-corrected coincidence count rates agreed with the expected count rates based on spontaneous fission-neutron emission rates. These measurements indicate that breeder fuel subassemblies with ^{240}Pu -effective contents up to 1.2 kg can be nondestructively assayed using the shift-register electronics with the prototype counters. Measurements using the standard Los Alamos National Laboratory shift-register coincidence electronics unit can produce an assay value accurate to $\pm 1\%$ in 1000 s. The uncertainty results from counting statistics and deadtime-correction errors.

I. INTRODUCTION

A prototype coincidence counter has been designed and constructed for non-destructive measurements of the ^{240}Pu -effective content in fast breeder fuel. The length of the fuel required that we develop a special detection head to be able to view the entire mixed-oxide region of a subassembly in one measurement. In addition, the large plutonium quantities contained in breeder fuel have high spontaneous fission rates, producing significant multiplication, which results in high measured count rates and deadtimes. Thus, in developing a fast breeder reactor (FBR) coincidence counter, we must show that the counter can measure a complete subassembly and must demonstrate that high count rates and multiplication effects will not adversely affect the assay capability of the instrument.

The prototype head developed to measure plutonium content in the total mixed-oxide region of breeder fuel subassemblies is described in Sec. II. Initial test data on the measurement profile, efficiency, and coincidence response of the FBR-I counter, which were collected at Los Alamos National Laboratory before the prototype was field tested, are presented in Sec. III. In the field testing, we measured four fast-flux test facility (FFTF) fuel subassemblies at the Hanford Engineering Development Laboratory (HEDL) in Richland, Washington, using the FBR-II counter. Section IV describes the measured FFTF subassemblies. Assay data collected from the subassembly measurements are listed in Appendix A; measurement results are shown and discussed in Secs. V and VI. The Summary section (Sec. VII) contains conclusions and overall results based on the field testing of the FBR-II coincidence counter.

II. COINCIDENCE COUNTER DESCRIPTION

The coincidence counter was designed to assay the entire mixed-oxide region of a fast reactor fuel subassembly in one measurement. The prototype FBR subassembly coincidence counter (Fig. 1) contains 12 neutron detectors equally spaced in a polyethylene ring. The ring geometry was selected to provide good coupling between the counter and a fuel subassembly during an assay. The detectors are 121.9 cm long, 2.54 cm in diameter, and contain 4 atm of ^3He . The tubes are attached to a sealed junction box at the counter top and are wired in parallel in groups of two, providing six outputs. Detector signals

Fig. 1. FBR subassembly coincidence counter and components.

are fed from the junction box to the preamplifier unit that is connected to the high-level neutron coincidence counter (HEC-100) electronics. The HEC-100 is a standard electronic module used to process neutron events output by a counter.

Figure 2 is a schematic diagram of the FBR counter geometry. We constructed two prototype counters, FBR-I and FBR-II. Counter FBR-I, which has an inside dimension of 12.0 cm, was used for initial measurement testing at Los Alamos. Counter FBR-II is identical to FBR-I but has a larger inside diameter (14.35 cm) to accommodate the hexagonal-shaped FFTF fuel subassemblies. The FBR counters, 136 cm high, are designed to have a flat response over the plutonium region, <92 cm, of a breeder fuel subassembly. Cadmium lines the cavity except for 5 cm at the top and bottom. It is used to prevent return of low-energy neutrons to the fuel thus reducing multiplication effects on measurements. Removing this lining from the top and bottom of the counter increases

Fig. 2. FBR subassembly counter schematic diagram.

the detection efficiency near the edge of the fuel to compensate for effects of increased leakage and to provide a flat response over the plutonium fuel region of a subassembly.

Polyethylene surrounding the detectors in the FBR counter was decreased, compared with that in a standard system, to reduce the detection efficiency and weight of the counter. We needed reduced efficiency to limit deadtime and pileup effects in the standard HEC-100 electronics that would result from the high spontaneous fission rates produced by breeder fuels. Because half the detectors can be disconnected, measurements can be collected with 12 or with 6 detectors, which allows deadtime effects to be studied. In addition, for large plutonium load-

ings where the efficiency with 12 detectors produces excessive deadtime effects, measurements can still be obtained by switching to the 6-detector connection.

Breeder fuel subassemblies contain a central region of plutonium oxide with depleted or natural uranium on either end. Measurements of the active fuel or mixed-oxide region of a subassembly require centering the fuel in the FBR coincidence counter. We constructed an adjustable table (Fig. 2) to support the counter so that a fuel subassembly hanging from a crane can be lowered and centered in the counter for measurements.

III. COUNTER CHARACTERISTICS

Measurement characteristics of the FBR-I counter were determined experimentally using a ^{252}Cf (3.74×10^5 n/s) source and several americium-lithium

(AmLi) neutron sources. Initial tests with the counter consisted of measuring (1) efficiency with 6 tubes and with 12 tubes, (2) vertical response profile, (3) horizontal response profile, (4) die-away time, and (5) deadtime.

The neutron detection efficiency with the ^{252}Cf source at the center of the counter midplane was 8.37% with all 12 tubes connected. Monte Carlo calculations used to model the FBR-I counter geometry produced an efficiency of 8.4% for a fission spectrum source at the center of the counter. We repeated the efficiency measurement with all tubes in position but with only six tubes connected; the six-tube efficiency was 4.2%.

A vertical response profile was measured by collecting data with the californium source at various locations along the vertical axis of the counter's center. The source was centered by inserting it into a Zircaloy tube that extended down the vertical axis of the counter. Figure 3 shows the profile for total neutron counts. The response to a point source is constant over an ~80-cm region and then decreases as the source is moved close to the counter ends. The vertical response profile at the base of the counter was remeasured with 25 boiling-water reactor (BWR) fuel rods inserted in the counter end; that profile is labeled FUEL RODS in Fig. 3. The rods scatter and reflect neutrons, similar to the effect produced by the blanket regions at the ends of an FBR subassembly, effectively reducing the leakage and extending the flat-response length for the counter.

Fig. 3. Vertical response profile measured for the FBR-I fuel subassembly counter.

We measured a die-away time of 31.2 μ s for the FBR-I counter with the californium source at the center of the counter midplane. Deadtime data were collected from overnight measurements with AmLi sources of various strengths added to the californium source whose position in the counter was fixed. The instrument deadtime was 3.3 μ s.

The efficiency of the FBR-II counter is lower than that of the FBR-I counter because of its larger diameter and smaller quantity of polyethylene. The FBR-II efficiency determined from source measurements was 7.85%. The counter deadtime is due principally to neutron count rates in the preamplifier and amplifier circuit and is essentially the same for both prototypes. The die-away time is less in the FBR-II counter than in the FBR-I counter but still within the range of a 32- μ s time gate.

IV. FFTF FUEL SUBASSEMBLY DESCRIPTION

HEDL provided the FFTF subassemblies that we measured. Figure 4 shows a subassembly being removed from its storage pit for measurement in the FBR-II counter. Each of the four subassemblies is 360 cm long with a 91.4-cm-long mixed-oxide region near its center. An FFTF subassembly consists of the components shown in Fig. 5 and identified below.

<u>Component</u>	<u>Length (cm)</u>
Handling socket	30.5 (subassembly top)
Fission gas plenum	106.7
Upper reflector	14.5
Upper insulator	2.0
Mixed-oxide core	91.4 (plutonium fuel)
Lower insulator	2.0
Lower reflector	14.5
Fuel-pin attachment	10.4
Shield-orifice block	54.6
Nozzle subassembly	34.0 (subassembly base)

The hexagonal-shaped assemblies have a cross section across the flats of 12 cm and contain 217 fuel pins. Each pin has a diameter of 0.584 cm. The

Fig. 4. FFTF fuel subassembly being removed from its storage pit for measurement in the FBR-II counter.

FFTF DRIVER FUEL ASSEMBLY

Fig. 5. FFTF fuel subassembly components.

distance from the bottom of a subassembly to the start of the plutonium region is 115.5 cm (45.5 in.); thus the counter must be placed on a table so that the plutonium region can be centered vertically in the counter.

Table I gives the plutonium contents and isotopics of the four subassemblies selected for measurements. The ^{241}Am contents, supplied by HEDL, were based on analysis of archival fuel samples.

V. MEASUREMENTS OF FFTF FUEL SUBASSEMBLIES

The FBR-II counter was located away from the fuel storage area to reduce background rates. Before the subassemblies were measured, four 100-s background measurements were completed. The total background rate was 675 ± 4 counts/s and the coincidence rate was zero.

Each fuel subassembly was lowered into the counter with a crane, as shown in Fig. 6, until the mixed-oxide fuel region was centered in the counter and accurately positioned vertically for a measurement. The vertical position was

TABLE I
FFTF FUEL SUBASSEMBLY MATERIAL LOADINGS

Material	Subassembly			
	16483	16471	8195	8181
Mixed Oxide (g)	37 428	37 436	37 669	37 589
Plutonium (g)	7 395.86	8 385.74	9 108.35	9 746.86
Isotope (wt%)				
^{238}Pu	0.06	0.05	0.06	0.07
^{239}Pu	86.35	86.85	86.47	86.47
^{240}Pu	11.82	11.62	11.67	11.89
^{241}Pu	1.56	1.27	1.62	1.43
^{242}Pu	0.21	0.21	0.19	0.22
^{241}Am (g)	35 ± 3	41	41.5 ± 3	28.4
(date 6/1/81)				

determined by collecting data (Table II) with a subassembly at various distances off the floor. The bottom of the coincidence counter was 108.5 cm above the floor for all measurements. The location producing the highest total count rate occurs when the mixed-oxide fuel region is centered in the counter. We then placed a 8.25-cm-high positioning block on the floor under the counter to provide an accurate vertical position reference. Figure 6 shows an FFTF fuel subassembly positioned in the counter for measurement.

Position repeatability measurements were obtained by removing the subassembly from the counter and then reinserting it, each time measuring the total rate. Initial repeatability measurements were poor showing variations in the total rate of 3% to 4%. Vertical alignment of the counter was found to be important to the repeatability of measurement data. After the counter was leveled, three subassembly repositioning total rate measurements T_d

Fig. 6. FFTF fuel subassembly centered in the FBR-II counter for measurement.

TABLE II
VERTICAL ALIGNMENT DATA FOR SUBASSEMBLY 8281

<u>Distance from Floor (cm)</u>	<u>T_m (Counts/s)</u>
0.64	92 820
5.72	93 312
10.8	93 267
15.9	92 542

were collected, and the deadtime-corrected total rate T_c (Table III) was then repeatable to within the statistical precision of the measurement.

How angular position of fuel subassemblies in the counter affects count rates was determined from rotation measurements of deadtime-corrected total and coincidence (R_c) rates. Subassembly 8281 was centered in the counter and aligned using the vertical

position block. Three measurements were collected with the subassembly rotated 30° between measurements. A rotation of 60° for the hexagonal subassembly corresponds to the same angular alignment in the counter. Table IV contains the angular rotation data and indicates that subassembly angular position has no observable effect within the statistical precision of the data.

How off-axis positioning affects count rate measurements was determined by collecting data with subassembly 8281 located on the counter sidewall. Table V lists the three repeat measurements. A comparison between data with the fuel centered (Table II) and data with the fuel sidewalled shows a slight decrease (0.2%) in the total count rate with the subassembly on the sidewall.

Following alignment, repeatability, and positioning-effect studies, we collected two sets of measurements from four fuel subassemblies. One set of data corresponds to 6 detectors operational in the coincidence counter; the other, to all 12 detectors operational. Appendix B gives the total and coincidence counts collected in these measurements. Section VI contains a discussion of data reduction and plots of the collected data.

TABLE III

REPOSITIONING DATA FOR SUBASSEMBLY 8281

<u>Measurement</u>	<u>T_d (Counts/s)</u>
1	93 086 $\pm$ 45
2	93 050 $\pm$ 45
3	<u>92 965 $\pm$ 45</u>
Av	93 033 $\pm$ 62

TABLE IV

ANGULAR ROTATION DATA FOR SUBASSEMBLY 8281

<u>Angle (deg)</u>	<u>T_d (Counts/s)</u>	<u>R_d (Counts/s)</u>
0	92 872 $\pm$ 45	2 488 $\pm$ 98
30	92 820 $\pm$ 45	2 640 $\pm$ 98
60	<u>92 806 $\pm$ 45</u>	<u>2 495 $\pm$ 98</u>
Av	92 833 $\pm$ 35	2 541 $\pm$ 86

TABLE V
OFF-AXIS DATA FOR SUBASSEMBLY 8281

<u>Measurement</u>	<u>T_d</u> <u>(Counts/s)</u>	<u>R_d</u> <u>(Counts/s)</u>
1	93 202 ± 45	2 467 ± 98
2	93 198 ± 45	2 568 ± 98
3	93 204 ± 45	2 351 ± 98
Av	93 201 ± 4	2 462 ± 108

VI. DATA REDUCTION AND MEASUREMENT RESULTS

A. Deadtime Correction

Deadtime and background corrections to the total and coincidence count rates are listed in Table VI for the four fuel subassemblies that were measured. Deadtime formulas used to get the corrected total ($\dot{T}_m$) and coincidence ($\dot{R}_m$) count rates are

$$\dot{T}_m = \dot{T}_d e^{\dot{T}_d \delta / 4}$$

and

$$\dot{R}_m = \dot{R}_d e^{\dot{R}_d \delta}.$$

where $\dot{T}_d$ and $\dot{R}_d$ are the measured uncorrected total and coincidence count rates.

The deadtime value $\delta = 3.32 \mu s$ used for the FBR-II counter was determined from measurements on the FBR-I counter. Table VI lists data for both the 6- and the 12-detector setups. Figure 7 is a plot of the coincidence data in

TABLE VI

BACKGROUND- AND DEADTIME-CORRECTED TOTAL ($\dot{T}_m$) AND COINCIDENCE
COUNT RATES ($\dot{R}_m$) FROM FFTF FUEL SUBASSEMBLY MEASUREMENTS
COLLECTED WITH THE FBR-II COUNTER

Subassembly	$^{240}\text{Pu-eff}$ Mass (g)	6 Detectors		12 Detectors	
		$\dot{T}_m$ (Counts/s)	$\dot{R}_m$ (Counts/s)	$\dot{T}_m$ (Counts/s)	$\dot{R}_m$ (Counts/s)
16483	909.7	69 898 $\pm$ 17	1 696 $\pm$ 14	140 760 $\pm$ 35	7 102 $\pm$ 55
16471	1 012	77 940 $\pm$ 137	2 006 $\pm$ 15	-	-
8195	1 104	86 705 $\pm$ 26	2 193 $\pm$ 17	175 008 $\pm$ 9	9 336 $\pm$ 73
8281	1 210	92 340 $\pm$ 19	2 544 $\pm$ 18	186 050 $\pm$ 10	10 245 $\pm$ 73

Fig. 7. Coincidence count rate from FFTF fuel subassemblies. The 12-detector data are represented with squares; the 6-detector data, with diamonds.

Table VI and clearly shows the effect of multiplication in producing an increasing nonlinear response curve as a function of ^{240}Pu mass. The lines drawn through the data points were obtained from a power function fit of the form

$$R = A \cdot \text{Mass}^B$$

The coefficients A and B were obtained from a least squares fit to the data using Deming's¹ method and yielded the values:

<u>No. of Detectors</u>	<u>A</u>	<u>B</u>
6	0.131	1.390
12	0.846	1.327

B. Multiplication Corrections

Corrections to the coincidence response measured from the FFTF fuel sub-assemblies were based on theoretical models developed by Ensslin² that describe the effect of neutron multiplication on thermal neutron coincidence counting. The correction formula expresses the multiplication-corrected coincidence rate $\dot{R}_C$ for the assay sample as

$$\dot{R}_m = \dot{R}_C / rM ,$$

where $\dot{R}_m$ is the deadtime-corrected coincidence rate, M is the sample multiplication, and r is a ratio between the rates for the measured multiplying sample and a small nonmultiplying reference sample. The sample multiplication M is expressed in terms of the ratio of the coincidence count rate $\dot{R}_m$ to the total count rate $\dot{I}_m$ in the coincidence counter. Information needed to perform this correction is listed below (a detailed procedure has been outlined by Krick³).

$\rho_0 = R_0/T_0$ = ratio of the coincident rate to total rate in a small nonmultiplying reference sample. The value of $\rho_0 = 0.0548$ was measured by placing a small plutonium sample in the high-level neutron coincidence counter (HLNCC).

α_0 = ratio of (α, n) neutrons to spontaneous fission neutrons in the nonmultiplying reference sample. The value of α_0 is 0

for a plutonium metal sample and is not 0 for nonmetal samples, such as PuO_2 .

$\rho_m = R_m/T_m$ = ratio of the measured coincident rate to the total rate corrected for background and deadtime.

α_m = ratio of (α, n) neutrons to spontaneous fission neutrons in the multiplying sample. The value of α_m for PuO_2 samples is given by

$$\alpha_m = \frac{140f_{238} + 0.406f_{239} + 1.52f_{240} + 0.01f_{241} + 0.02f_{242} + 27.9f_{241\text{Am}}}{10.22(2.43f_{238} + f_{240} + 1.69f_{242})},$$

where f_A is the mass of the plutonium isotope with mass number A and $f_{241\text{Am}}$ is the mass of ^{241}Am . Therefore, we get

$$r = [\rho_m(1 + \alpha_m)]/[\rho_o(1 + \alpha_o)],$$

where the m subscript refers to the multiplying assay sample, and the zero subscript refers to a nonmultiplying sample;

and

$$M = \frac{-B + \sqrt{B^2 - 4AC}}{2A},$$

where

$$A = 3(1 + \alpha_m),$$

$$B = -(3.022 + 4.192 \alpha_m + 0.8689r), \text{ and}$$

$$C = 1.192 \alpha_m + 0.8909.$$

The values of $\dot{R}_m$ and $\dot{I}_m$ are listed in Table VI. Based on measurements in the HLNCC, the value of $\rho_0 = 0.0548$ for a small nonmultiplying plutonium metal sample. The value of ρ_0 must be adjusted, as shown below, to account for the difference in efficiency of the HLNCC and the FBR counter in the 6- and 12-detector configurations:

$$\rho_0 (6 \text{ detectors}) = \frac{\epsilon_{6\text{det}} (0.0548)}{\epsilon_{\text{HLNCC}}} = \frac{3.89(0.0548)}{12.1} = 0.0176$$

and

$$\rho_0 (12 \text{ detectors}) = \frac{\epsilon_{12\text{det}} (0.0548)}{\epsilon_{\text{HLNCC}}} = \frac{7.85(0.0548)}{12.1} = 0.0356$$

The isotopic information listed in Table I for the measured FFTF fuel subassemblies provides the information for determination of α_m . Table VII contains the calculated values for multiplication correction of the coincidence rates for the 6- and 12-detector configurations. The multiplication correction factor CF varied between 4.7 and 5.9. The multiplication-corrected data points for the 6- and 12-detector configurations are plotted in Fig. 8. The straight lines drawn through the data points are the expected coincidence rates with no multiplication effects. These lines are determined based on the knowledge of the counter efficiency and the spontaneous fission rate as a function of mass for each fuel subassembly. The 6-detector configuration produces 0.651 coincidence counts per second per gram of effective ^{240}Pu . When the measurement

TABLE VII
MULTIPLICATION-CORRECTED COINCIDENCE RATES

Assembly	$^{240}\text{Pu-eff}$ Mass (g)	6 Detectors					12 Detectors				
		$\dot{R}_m$	α_m	M	CF ^a	$\dot{R}_{CF}$	$\dot{R}_m$	α_m	M	CF ^a	$\dot{R}_{CF}$
16483	909.7	1 697	0.560	1.513	4.770	356	7 102	0.593	1.545	5.170	1 374
16471	1 012	2 006	0.596	1.559	5.337	376	-	-	-	-	-
8195	1 104	2 193	0.595	1.547	5.198	422	9 336	0.596	1.586	5.625	1 660
8281	1 210	2 544	0.593	1.609	5.883	432	10 245	0.560	1.604	5.738	1 785

^aCF = 1/rM.

configuration is changed from 6 to 12 detectors, the efficiency for neutron detection is doubled.

Comparing data between these two configurations provides a consistency check on measurements of the FFTF fuel subassemblies. Measurements using a calibrated californium source provided efficiency measurements of 3.89% and 7.85% for the 6- and 12-detector configurations, respectively. The efficiency ratio of corrected total data should then be

$$\frac{\epsilon_{T12}}{\epsilon_{T6}} = \frac{7.85}{3.89} = 2.02 \quad .$$

The efficiency ratio of corrected coincidence counts between the 12- and 6-detector configurations should be

$$\frac{\epsilon_{R12}}{\epsilon_{R6}} = \frac{7.85^2}{3.89^2} = 4.07 \quad .$$

Table VIII contains the corrected total and coincidence ratio comparisons between the 6- and 12-detector configuration measurements on the FFTF fuel subassemblies.

VII. SUMMARY

Four FFTF subassemblies at HEDL were measured using the prototype FBR fuel subassembly coincidence counter. Plutonium contents in the four subassemblies ranged between 7.4 and 9.7 kg with corresponding ^{240}Pu -effective contents

Fig. 8. Multiplication-corrected coincidence count rate from FFTF fuel subassemblies. The 12-detector data are represented with squares; the 6-detector data, with diamonds.

TABLE VIII

MEASURED CORRECTED TOTAL AND COINCIDENCE COUNT RATE RATIOS
 BETWEEN THE 6- AND 12-DETECTOR CONFIGURATIONS FOR
 VARIOUS ^{240}Pu -EFFECTIVE LOADINGS IN THE FBR-11 COUNTER

Subassembly	Mass ^{240}Pu -eff (g)	$\frac{\epsilon_{T12}}{\epsilon_{T6}}$	$\frac{\epsilon_{R12}}{\epsilon_{R6}}$
16483	909.7	2.014	3.862
16471	1012	-	-
8195	1104	2.018	3.934
8281	1210	2.015	4.129

between 0.9 and 1.2 kg. We observed large count rates from the measurements, and plots of the data showed significant multiplication in the fuel. Deadtime and multiplication corrections were performed on the measured data using established formulas. These corrections require accurate knowledge of the plutonium isotopics and ^{241}Am content in the fuel. Multiplication-corrected coincidence count rates agreed with the expected count rates based on spontaneous fission-neutron emission rates. These measurements indicate that breeder fuel subassemblies with ^{240}Pu -effective contents up to 1.2 kg can be nondestructively assayed. Measurements using the standard Los Alamos shift-register coincidence electronics unit (HEC-100) can produce an assay value accurate to $\pm 1\%$ in 1000 s. The uncertainty results from counting statistics and dead-time-correction errors.

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APPENDIX A

FFTF FUEL SUBASSEMBLY PLUTONIUM ISOTOPIC SPECIFICATIONS

FFTF fuel subassemblies consist of 217 fuel pins and are assembled with fuel pellets fabricated from various lots of mixed-oxide materials. Plutonium isotopic data for the lots used to fabricate the subassemblies that were measured with the FBR-II counter are listed in Table A-I. The americium content of fuel subassemblies 16483 and 8195 is specified in Table A-II. The americium loadings in subassemblies 16471 and 8281, listed in Table A-III, were determined based on chemical analysis of archival fuel pellets from the various lots composing the subassemblies.

TABLE A-I

FFTF FUEL SUBASSEMBLY PLUTONIUM ISOTOPIC SPECIFICATIONS

Subassembly	Fuel Lot No.	Pins per Lot	Chemistry Data				
			238Pu (wt%)	239Pu (wt%)	240Pu (wt%)	241Pu (wt%)	242Pu (wt%)
16483	43	46	0.06	86.17	11.90	1.66	0.22
	48	5	0.07	86.18	11.76	1.80	0.20
	49	30	0.06	85.94	12.03	1.75	0.21
	50	14	0.06	86.00	12.01	1.73	0.21
	52	13	0.06	86.59	11.70	1.43	0.21
	54	4	0.06	86.58	11.72	1.43	0.21
	55	60	0.06	86.59	11.71	1.43	0.21
	N56	9	0.06	86.14	11.81	1.80	0.19
	KM56	36	0.06	86.62	11.70	1.41	0.21
16471	432	14	0.05	86.81	11.66	1.30	0.19
	433	82	0.06	86.87	11.62	1.26	0.21
	434	121	0.05	86.85	11.61	1.28	0.21
8195	21	15	0.06	86.33	11.69	1.73	0.19
	24	177	0.06	86.49	11.66	1.60	0.19
	25	1	0.06	86.25	11.77	1.72	0.19
	26	19	0.06	86.34	11.71	1.70	0.20
	30	1	0.06	86.45	11.68	1.61	0.21
	38	4	0.05	86.63	11.67	1.43	0.21
8281	503	45	0.08	86.32	11.93	1.44	0.23
	504	71	0.06	86.70	11.87	1.43	0.22
	505	47	0.08	86.34	11.92	1.44	0.23
	505A	54	0.07	86.41	11.87	1.43	0.22

TABLE A-II
AMERICIUM AND PLUTONIUM CONTENTS
IN SUBASSEMBLIES 16483 AND 8195 ON JANUARY 1, 1980

<u>Subassembly</u>	<u>^{241}Pu Content (g)</u>	<u>^{241}Am Content (g)</u>
16483	91	29 ± 3
8195	113	34 ± 3

TABLE A-III
AMERICIUM CONTENTS FROM CHEMICAL ANALYSIS
OF ARCHIVAL FUEL PELLETS

<u>Subassembly</u>	<u>Fuel Lot</u>	<u>Fuel Pins</u>	<u>^{241}Am (ppm)</u>	<u>Date</u>
16471	432	14	1097	9/8/81
	433	82	1105	9/8/81
	434	121	1108	9/8/81
8281	503	45	766	9/10/81
	504	71	772	9/10/81
	505	47	758	9/10/81
	505A	54	752	9/10/81

APPENDIX B

FUEL SUBASSEMBLY MEASUREMENT DATA

Data collected from coincidence measurements on four FFTF fuel subassemblies are listed in Tables B-I and B-II. Table B-I consists of coincidence data using all 12 ^3He detectors. The detectors were wired in units of two, permitting all 12 detectors to be connected to the 6 inputs of the coincidence electronics unit or every other detector to be disconnected, leaving 6 operational detectors connected to the electronics. Data in Table B-II were collected with 6 of the 12 ^3He tubes connected to the shift-register coincidence electronics unit. The output of the coincidence counter consists of four values called time, total, reals plus accidentals ($R + A$), and accidentals (A). The coincidence data, often called the reals, is obtained by subtracting the accidental counts from the $R + A$ counts, that is $R = (R + A) - A$.

TABLE B-I

FBR-II FFTF SUBASSEMBLY COINCIDENCE MEASUREMENT DATA
USING 12 DETECTORS

Subassembly	$^{240}\text{Pu-eff}$ Mass (g)	Time (s)	Total Counts	R + A Counts	Accidental Counts, A
16483	909.7	200	25 560 435	105 463 610	104 514 064
		200	25 570 878	105 546 392	104 623 271
		200	25 558 342	105 429 149	104 512 924
		200	25 557 402	105 424 990	104 498 407
8195	1104	200	31 016 041	155 036 283	153 916 905
		200	31 016 979	155 060 366	153 947 513
		200	31 007 641	154 968 428	153 832 410
		200	31 008 802	154 945 609	153 851 773
8281	1210	200	32 723 457	172 546 736	171 332 389
		200	32 720 535	172 496 173	171 314 934
		200	32 728 736	172 568 689	171 411 633
		200	32 712 080	172 427 446	171 220 328

TABLE B-II

FBR-II FFTF SUBASSEMBLY COINCIDENCE MEASUREMENT DATA
USING 6 DETECTORS

<u>Subassembly</u>	²⁴⁰ Pu-eff <u>Mass (g)</u>	<u>Time (s)</u>	<u>Total Counts</u>	<u>R + A Counts</u>	<u>Accidental Counts, A</u>
16483	909.7	500	33 392 011	72 040 306	71 350 432
		500	33 384 526	72 009 768	71 330 739
		500	33 376 233	71 970 927	71 301 419
16471	1012	500	37 010 926	88 443 080	87 667 554
		500	36 998 825	88 399 619	87 595 496
		500	36 894 167	87 885 686	87 112 359
8195	1104	500	40 840 818	107 592 646	106 744 782
		500	40 823 929	107 522 914	106 690 186
		500	40 817 112	107 462 533	106 635 408
8281	1210	500	43 287 114	120 874 652	119 917 130
		500	43 289 689	120 868 835	119 930 642
		500	43 273 026	120 802 567	119 836 392