CONF-9007106--72

Paper presented at the Institute of Nuclear Material Management 31st Annual Meeting, Los Angeles, CA, July 15-18, 1990.

CONF-9007106--72
DE90 017686

REPROCESSING INPUT DATA VALIDATION

by

P.J. Persiani, R.G. Bucher, R.B. Pond, and R.J. Cornella

Argonne National Laboratory
9700 S. Cass Avenue
Argonne, Illinois 60439

* Work supported by the U.S. Department of Energy.

REPROCESSING INPUT DATA VALIDATION

P.J. Persiani, R.G. Bucher, R.B. Pond, and R.J. Cornella

Argonne National Laboratory
Argonne, Illinois 60439

ABSTRACT

The Isotope Correlation Technique (ICT), in conjunction with the gravimetric (Pu/U ratio) method for mass determination, provides an independent verification of the input accountancy at the dissolver or accountancy stage of the reprocessing plant. The Isotope Correlation Technique has been applied to many classes of domestic and international reactor systems (light-water, heavy-water, graphite, and liquid-metal) operating in a variety of modes (power, research, production, and breeder), and for a variety of reprocessing fuel cycle management strategies. Analysis of reprocessing operations data based on isotopic correlations derived for assemblies in a PWR environment and fuel management scheme, yielded differences between the measurement-derived and ICT-derived plutonium mass determinations of (- 0.02 ± 0.23)% for the measured U-235 and (+ 0.50 ± 0.31)% for the measured Pu-239, for a core campaign. The ICT analyses has been implemented for the plutonium isotopics in a depleted uranium assembly in a heavy-water, enriched uranium system and for the uranium isotopes in the fuel assemblies in light-water, highly-enriched systems.

INTRODUCTION

The isotope correlation technique (ICT) is based on the fundamental physics principle that the isotopic composition of nuclear material in the fuel cycle contains information on the design and history of the fuel, from fabrication through irradiation to the input of reprocessing [1-3]. Isotope correlations are functional relationships, between the various isotopic weight percentages and/or the elemental Pu/U ratio, that trace the dynamics of isotopic production and depletion during the irradiation phase of the fuel cycle. These relationships can be established within a reactor class for a given composition and geometry independent of many details of the fuel management scheme. For example, all assemblies of a given enrichment in a PWR would obey the same correlation relating the U-235 weight percent and the Pu/U ratio. Isotope correlations provide a method to evaluate the measured isotopic and elemental concentrations at the reprocessing input, one, for the detection of anomalies in the fabrication, irradiation, or head-end reprocessing operations, and, two, for the determination of the input plutonium and uranium mass content.

One of the strengths of ICT is the ability to examine the measured reprocessing data for internal consistency. Detection of systematic deviations from the isotopic correlations indicate anomalous operations at an earlier point in the fuel cycle - in the specifications of the assembly composition, in the loading configuration or irradiation history of the reactor, or in the dissolution phase of the reprocessing. Diagnostic analysis of the measured data against the complete set of correlations identify and quantify the isotopic and Pu/U anomalies.

The isotope correlation technique, in conjunction with the gravimetric (Pu/U ratio) method for mass determination, provides an independent verification of the reprocessing input accountancy at the dissolver and/or the accountancy stage of the reprocessing plant. The plutonium and uranium mass content is determined by a three-factor formulation shown in Eq. 1 relating the Pu/U ratio, a correlation between the Pu/U ratio and the quantity (U+Pu)/Uo , and the fabricators specification of the initial uranium mass, Uo.

$$Pu = \left(\frac{Pu/U}{1+Pu/U}\right)\left(\frac{U+Pu}{Uo}\right) Uo \qquad (1)$$

If the Pu/U ratio is obtained from the measured isotopics, the methodology computes the masses that should be at the reprocessing input; if the Pu/U ratio is the measured value, the formulation yields the masses that actually are at the input.

The ICT technique, as developed at Argonne National Laboratory (ANL), is based on three-dimensional, multi-group diffusion theory calculations linked with a burnup module in order to compute the dynamics of the production and depletion of the significant isotopes in the nuclear materials. Burnup-dependent multi-group cross-sections are generated with a one-dimensional transport theory code that incorporates Monte Carlo corrections to account for cell-model inadequacies.

Fuel cycle analyses are performed either in an infinite-time equilibrium mode or explicit cycle-by-cycle non-equilibrium mode depending on the nature of the fuel management program. The reactor dynamics are also modeled to follow the operating conditions of the reactor as a function of time.

Isotope correlations have been applied by ANL to many classes of reactor systems (light-water, heavy-water, graphite, and liquid metal) operating in a variety of modes (power, research, production, and breeder). Calculated correlations and measured reprocessing data have been investigated over an extended range of initial enrichments and fuel burnups for a number of assembly compositions and geometries, fuel cycle management strategies, and reprocessor batch mixing options.

This paper discusses the application of isotope correlations for a spectrum of uranium fueled systems - from high enrichments characteristic of research reactors, to medium enrichment driver assemblies with interspersed depleted elements, to low enrichments characteristic of power reactors.

HIGH ENRICHED URANIUM SYSTEMS

The isotope correlations developed for high enriched uranium systems were derived from burnup calculations of a light-water cooled and moderated research reactor that is fueled with ninety-three percent enriched uranium. Figure 1 presents the U-235 (w/o) vs. U-236 (w/o) correlation (solid line) and the measured data for discharged fuel from several light-water research reactors.

The data for reprocessed fuel from foreign research reactors (Δ and +) are in good agreement with the calculated correlation. The calculations correctly predict the slope of the correlation over the range represented by these relatively low burnup fuels. Minor systematic deviations of the measured data from the correlation may be attributed to small inconsistencies in the initial concentrations of U-235 and U-236 assumed in the model used to generate the correlation. Heel cleanout was performed prior to the reprocessing campaign for each of these fuels and no mixing ofreactor fuel types ocurred during the dissolution or accountancy stages of the reprocessing operation.

Also presented in Figure 1 are reprocessing data for discharge fuel from a domestic reactor (o). These data are in good agreement with the correlation and indicate, together with the foreign data, that the calculations correctly predict the isotopic dynamics over a wide range of burnup. Deviations between measured and calculated data may be attributed to small inconsistencies in the initial concentrations assumed in the model.

DEPLETED URANIUM ELEMENTS IN MEDIUM ENRICHED URANIUM SYSTEMS

The isotope correlations for depleted uranium elements were based upon burnup calculations of a heavy-water cooled and moderated reactor fueled with medium enriched uranium. Two sets of depleted uranium reprocessing data have been analyzed using the calculated correlations for these elements. One set consists of three campaigns representing 174 assemblies each and the second set consists of nine batches representing 44 assemblies each.

Figures 2 and 3 show the adjusted (solid curve) Pu-240 vs. (100 - Pu-239) correlation for these two sets of data. The adjusted curves have been analyzed to minimize the least-squares difference between the measured isotopic data and the calculated correlation. The inconsistent data point in Fig. 3 has been identified using the ICT diagnostic analysis scheme, discussed below, as an anomalous Pu-239 measured value.

The Pu-239 isotopic correlation used to predict the Pu/U ratio in the three-factor formula of Eq. 1 is shown in Figure 4 for the set of three depleted-uranium reprocessing campaigns. Isotopic correlations for Pu-240 and Pu-241 have also been used to predict the Pu/U ratio. A summary of the analyses performed on these data are shown in Table I. The table lists the percent difference between the measured Pu/U ratio and the ICT-predicted Pu/U ratio together with similar data for the Pu mass. In all cases the predicted ratio or mass is the weighted-average value obtained using the three measured isotopics Pu-239, Pu-240, and Pu-241. The percent difference values show the degree of agreement between measured and ICT-predicted reprocessing data. Generally the agreement is satisfactory.

TABLE I. Pu/U RATIO AND PLUTONIUM MASS DETERMINATION BY ANL/ICT METHOD FOR DEPLETED-URANIUM ASSEMBLIES REPROCESSING INPUT MASS VERIFICATION

Campaign Label	Pu/U Ratio (gm/kg) Meas Pu/U	ICT Pu/U	DIFF (%)	Pu Mass (gm) Meas Pu/U	ICT Pu/U	DIFF (%)
CY1	-	-	-1.69	-	-	-1.68
CY2	-	-	0.87	-	-	0.87
CY3	-	-	0.86	-	-	0.86

LOW-ENRICHMENT URANIUM SYSTEMS

Isotope correlations for low-enrichment uranium systems have been extensively studied for both domestic and foreign reactor designs. The domestic system under study is the ZION II PWR which has been modelled over the first four start-up cycles. The foreign system, for which the ICT analysis algorithms have been fully implemented, is the Obrigheim PWR discussed below.

The methodology was used for the detailed analysis of the ESARDA Reprocessing Input Verification (RIV) Working Group's benchmark exercise

[4-7]. These data consisted for mixed batches of Obrigheim assemblies, whole and partial assemblies with various initial enrichments and degrees of burnup, reprocessed at the COGEMA facility. The data were divided into two groups: Set A, containing 24 batches, served as the reference data; Set B, containing 29 batches, included intentional anomalies in a fraction of the batches. Set B was to test the ability of the methodology to ascertain anomalies in the reprocessing data.

Analysis of the Set A data was based on isotopic correlations derived from calculations of the isotopic dynamics for the Obrigheim assemblies in a typical PWR environment and fuel management scheme adjusted with the measured reprocessing data of this reference set. A summary of the mass determination analysis for each batch in the campaign, derived with the U-235 isotopic correlation, is presented in Table II. The differences between the measurement-derived (from measured Pu/U) and ICT-derived (from measured isotopic) plutonium mass determinations for the entire campaign are (-0.02 ± 0.23)% for the measured U-235 and (+0.50 ± 0.31)% for the measured Pu-239. The plutonium mass uncertainties for a single batch are 1.14% and 1.54%, respectively.

DIAGNOSTIC ANALYSIS OF OPERATIONAL ANOMALIES

Intermittent Irradiations: This analysis identified anomalies in the irradiation histories of many assemblies; that is, an assembly may have been irradiated for one or two cycles, withdrawn from the configuration for as many as three cycles, and subsequently reinserted for additional burn cycles -- a behavior referred to as intermittent irradiation. The build-up and decay of transuranic isotopes during the unloaded portion of the assembly's irradiation history significantly alters the isotopics in subsequent burnup cycles and in the discharged assembly. First-order correction factors, independent of specific fuel cycle parameters, have been computed to correct the isotopics and Pu/U ratio for this effect. The correction factors are dependent only upon the number of cycles preceding and the number of cycles during which the assembly was removed and not upon the specific fuel cycle parameters. This correction improves the agreement between the measurement-derived and ICT-derived mass determinations for the entire campaign and reduces the spread in the ICT-derived Pu/U ratios and, hence, the overall uncertainty. By its nature, this correction is more significant for the U-235 vs. Pu/U correlation; for Set A, the percent difference in the plutonium mass determination is (-0.02 ± 0.23)% with the correction versus (+0.84 ± 0.32)% without the correction. The effect of the corrections is shown in Figure 5 for the 3.10% enrichment batches of Set A, where open circles represent the data without correction and the asterisks, the data with correction. The intermittent irradiation corrections have been applied in the analysis for the Set A results referenced above and in all Set B analysis discussed below.

U-236 Initial Concentration: For both Set A and Set B of the reprocessing data, the correlation between U-235 and U-236 reveals a definite systematic underprediction of the U-236 weight percent. For the 3.10% enrichment batches in Set A, the magnitude of this bias is (0.017 ± 0.001) w/o; for the 3.10% enrichment batches in Set B, the bias is (0.019 ± 0.001) w/o. The isotopic correlation analysis identified that the source of this bias is an initial concentration of U-236 in the uranium fuels. Analysis of the compositions of the uranium fuels used in the ZPR critical facilities at ANL corroborates this concentration level. The U-235 and U-236 weight percents for six uranium oxide or metallic fuels, spanning nearly the complete range of enrichments, represent a dependence of U-236 concentration on uranium enrichment. Interpolation of this fitted curve yields a U-236 concentration of 0.027 w/o at 3.10% enrichment. The value is in reasonable agreement with the U-236 bias in the reprocessing data.

Partial MOX Fuel Loading: Initial analysis of Set B data with both the U-235 and Pu-239 correlations revealed a 2.25% bias in the Pu/U ratio between Sets A and B. Calculations to generate the isotopic correlations identified the source of this bias as the introduction of mixed-oxide fuel assemblies in the Obrigheim loading configurations. Set A assemblies, those with the greater Pu/U ratio, were for the most part irradiated in the later cycles in which significant numbers of MOX assemblies were loaded; Set B assemblies, however, were irradiated in the earlier cycles in which few, if any, MOX assemblies were present. Scoping calculations verified that the presence of MOX fuel assemblies would produce a bias qualitatively consistent with the observed discrepancy.

DIAGNOSTIC ANALYSIS OF ISOTOPIC CONSISTENCY

Diagnostic analysis procedures were employed to identify the anomalies intentionally introduced into Set B. Because of the observed Pu/U bias, the diagnostic correlations were derived from the calculated relationships adjusted with the unmodified Set B data. The diagnostics examined the Reprocessing data for three categories of intentional anomalies:

1. misstated assembly burnup (batches: 14, 26),
2. misstated assembly content of batch (batches: 3, 8, 21, 29), and
3. misstated isotopics and/or Pu/U ratio (batches: 6, 12, 14, 17, 18, 27).

The misstatement of the assemblies constituting the batch manifested itself through erroneous values in other quantities, such as, initial enrichment, effective burnup, decay correction factors, and intermittent irradiation factors; the present scheme identifies these anomalies as biases in initial enrichment. The analysis algorithm examined seven measured quantities: U-235, U-236, Pu-239, Pu-240, Pu-241, Pu-242, and Pu/U for internal consistency by evaluating these data in a unified manner relative to the complete set of diagnostic correlations.

Table III summarizes the intentional anomalies for the eleven modified batches and also identifies and quantifies the anomalies detected by the diagnostic analysis scheme. Anomalies in U-234 and Pu-238 were not deduced since these isotopics were not included in the diagnostic routine. Since the ANL method does not utilize assembly burnup in any phase of its isotopic correlation analysis, the diagnostics scheme does not recognize a misstatement of burnup as an anomaly; that is, the method diagnoses anomalies in the measured quantities without requiring an accurate estimate of the calculated burnup, as shown in batch 14.

The rightmost column in the Table III signifies the difference in the deduced anomaly from the intended value in units of standard deviation of the uncertainty in the deduced anomaly. The magnitude of the deduced anomaly considers the deviation of the modified data from the correlation; the statistical error in the data before the anomaly was introduced is a component of this difference. Errors associated with the diagnostic scheme yield another component. Since statistical uncertainties for the reprocessing data were not specified, the contributions to the difference from these sources cannot be estimated.

The diagnostic technique also produced a unified estimate of the ICT-derived Pu/U ratio based on all measured isotopics not diagnosed to be a probable anomaly. Referring to the diagnostic analysis campaign summary, Table V, large percent differences, on the order of 3.5%, exist between the measurement-derived and ICT-derived Pu/U ratios, and hence mass determinations, for batches 14 and 27. Table III shows that these batches contained anomalies in the Pu/U ratio which were "correctly" deduced by the diagnostic algorithm. Hence, the percent differences in Table IV are computed relative to incorrect measurement-derived values of the ratio of mass content, yielding misleading comparisons. If the -3.23% difference for the Pu/U ratio of batch 14 is corrected for the 3.58% intentional anomaly, the true difference, that is, the difference between the diagnosed and non-anomalous Pu/U ratio, is 0.24%. Similarly, if the -3.83% difference of batch 27 is corrected for the 3.12% intentional anomaly, the true difference is -0.83%. The additional section at the bottom of Table V presents these unbiased comparisons for batches 14 and 27 and the campaign/batch averages if these values replaced the corresponding lines of the Table. The overall campaign and batch results for the diagnostic analysis of the Set B data with intentional anomalies is in close agreement with those from the analysis of the same data without the anomalies. The percent difference between the measurement-derived (with unmodified Pu/U ratios) and the ICT-derived (with these unified Pu/U estimates) plutonium mass determinations for the campaign is (0.01 ± 0.15%).

SUMMARY

The application of isotope correlations derived from calculational methods has illustrated the ability of the technique to verify the dynamics of isotope production in a variety of reactor systems. The implementation of the ANL ICT has demonstrated the power of the methodology as an instrument for diagnosing anomalies in the fuel cycle from fabrication, reactor, and reprocessing operations and in the measured reprocessing batch data and as an independent verification of the mass input to the reprocessing plant.

REFERENCES

1. P. J. PERSIANI, KALIMULLAH, R. G. BUCHER, and R. B. POND, "Isotope Correlations for Safeguards and Accountability Methods for Light Water Reactor Fuel Cycles," Proc. INMM Conference of Safeguard Technology: The Process-Safeguards Interface, Hilton Head Island, SC, CONF-831106, p. 204-216 (August 1984).

2. J. BOUCHARD and P. PATIGNY, "Techniques for Material Control at the Input of a Reprocessing Plant," Proc. INMM Conference on Safeguards Technology: The Process - Safeguards Interface, Hilton Head Island, SC, CONF-831106, p. 348-355 (August 1984).

3. J. SATKOWSKI, "Isotope Correlation Verification of Analytical Measurements for Dissolver Solutions," Savannah River Plant, Proc. 29th INMM Annual Meeting, Las Vegas, NV. p. 710-713 (June 1988).

4. P. J. PERSIANI and R. G. BUCHER, "Implementation of Isotope Correlation Technique for Safeguards," 11th ESARDA Conference on Safeguards and Nuclear Material Management, Luxembourg, p. 45 (May 30-June 1, 1989).

5. A. GIACOMETTI, "ESARDA Exercise to Test Performance of ICT Procedure," Proc. ESARDA, 6th Ann. Symp. on Safeguards and Nuclear Material Management, Venice, Italy, p. 213-222 (May 1984).

6. A. GIACOMETTI, R. GIRIEUD, and M. ARIES, "Calculated ICT Improvements: Consequences of Five Years of Industrial Implementation," Proc. ESARDA, 6th Ann. Symp. on Safeguards and Nuclear Material Management, Venice, Italy, (May 1984).

7. P.J. PERSIANI, R.G. BUCHER, R.B. POND, AND R.J. CORNELLA, "Fuel Reprocessing Data Validation Using the Isotope Correlation Technique," Proc. Int. Conf. on the Physics of Reactors (PHYSOR 90), Marseille, France, Vol. 2, p. XI:109-117 (April 23-27, 1990).

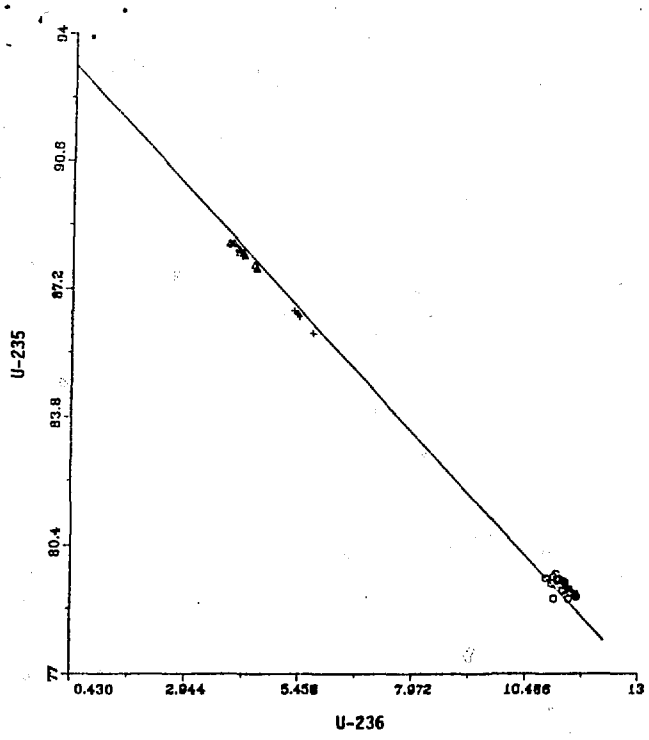

FIG 1. CALCULATED CORRELATION (solid curve) FOR HIGHLY-ENRICHED URANIUM, LIGHT-WATER RESEARCH SYSTEMS AND REPROCESSING DATA FOR TWO FOREIGN (Δ, +) AND ONE DOMESTIC (o) REACTOR.

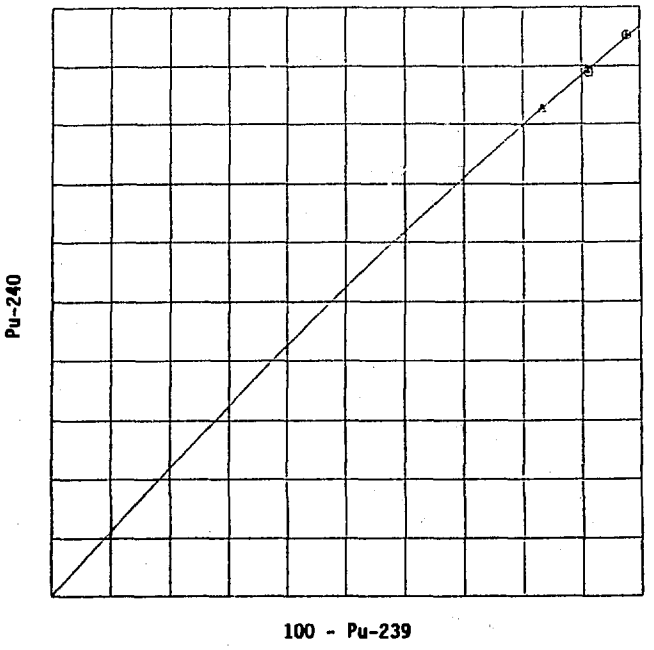

FIG 2. ADJUSTED CALCULATED CORRELATION (solid line) FOR CAMPAIGNS OF DEPLETED-URANIUM ASSEMBLIES IN A MEDIUM-ENRICHED-URANIUM, HEAVY-WATER SYSTEM: Pu-240 vs. (100 - Pu-239)

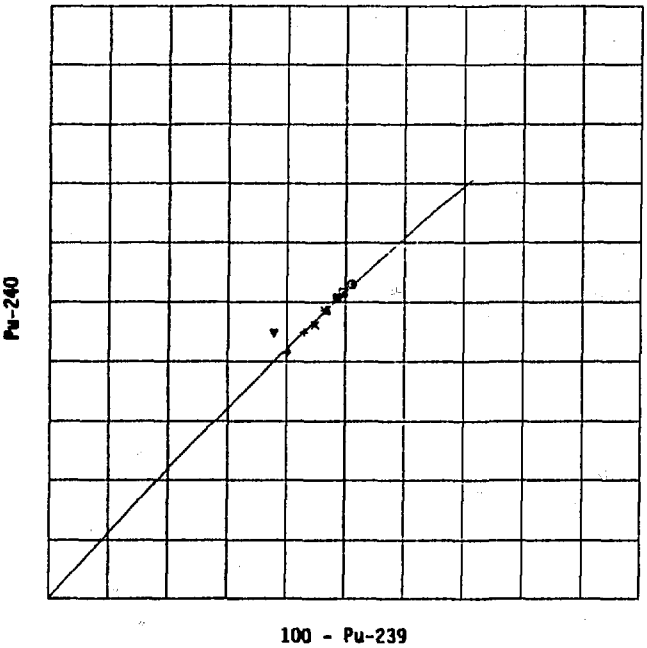

FIG 3. ADJUSTED CALCULATED CORRELATION (solid line) FOR BATCHES OF DEPLETED-URANIUM ASSEMBLIES IN A MEDIUM-ENRICHED-URANIUM, HEAVY-WATER SYSTEM: Pu-240 vs. (100 - Pu-239)

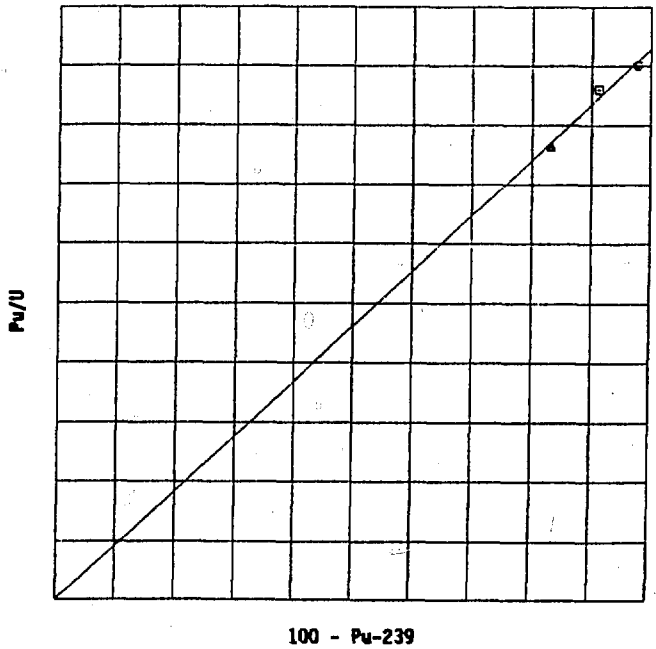

FIG 4. ADJUSTED CALCULATED CORRELATION (solid line) FOR CAMPAIGNS OF DEPLETED-URANIUM ASSEMBLIES IN A MEDIUM-ENRICHED-URANIUM, HEAVY-WATER SYSTEM: Pu/U RATIO VS. (100 - Pu-239)

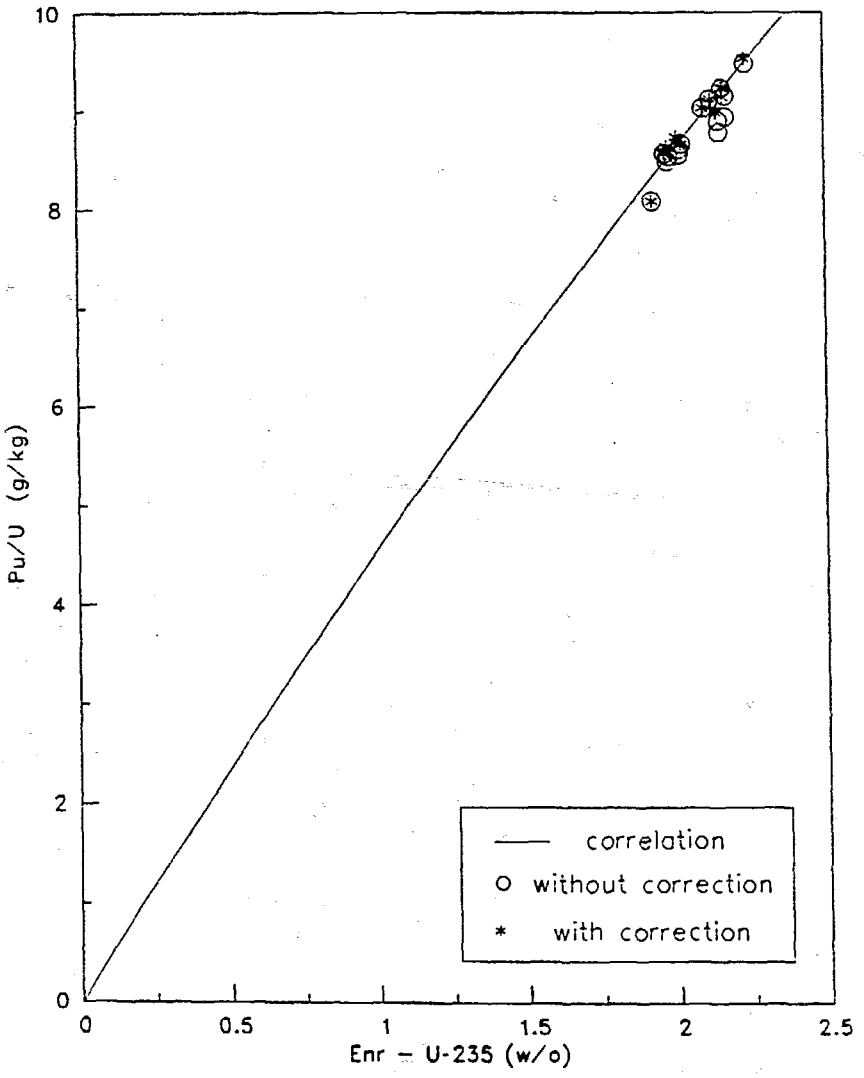

FIG 5. EFFECTS OF INTERMITTENT IRRADIATION ON CORRELATION Pu/U RATIO VS. (ENR - U-235)

TABLE II. MASS DETERMINATION AND Pu/U RATIO BY ANL/ICT METHOD
COGEMA REPROCESSING INPUT MASS VERIFICATION
OBRIGHEIM PWR SPENT FUEL ASSEMBLIES
SET A DATA, AT REPROCESSING
WITH INTERMITTENT IRRADIATION CORRECTIONS
FOR U-235 VS. Pu/U CORRELATION

Batch Label	Pu/U Ratio (gm/kg) Meas Pu/U	ICT Pu/U	DIFF (%)	Pu Mass (gm) Meas Pu/U	ICT Pu/U	DIFF (%)
A 01	7.933	8.175	3.05	4237.9	4361.1	2.91
A 02	8.517	8.509	-.10	4355.2	4351.1	-.09
A 03	8.273	8.297	.29	4408.7	4420.9	.28
A 04	8.483	8.534	.60	4506.6	4532.3	.57
A 05	8.475	8.367	-1.28	4470.7	4416.5	-1.21
A 06	8.125	7.953	-2.12	4148.1	4064.4	-2.02
A 07	8.802	8.794	-.09	4681.4	4677.3	-.09
A 08	9.220	9.189	-.34	4891.2	4875.6	-.32
A 09	9.329	9.281	-.51	4928.9	4905.1	-.48
A 10	9.003	8.998	-.06	4771.0	4768.5	-.05
A 11	9.075	9.057	-.19	4868.9	4860.0	-.18
A 12	8.647	8.796	1.73	4575.5	4650.1	1.63
A 13	8.489	8.669	2.13	4500.7	4590.9	2.00
A 14	8.798	8.871	.83	4651.7	4688.3	.79
A 15	8.754	8.890	1.56	4646.0	4714.2	1.47
A 16	8.411	8.290	-1.44	4463.1	4401.9	-1.37
A 17	8.363	8.270	-1.11	4453.9	4406.9	-1.05
A 18	8.422	8.362	-.71	4457.8	4427.9	-.67
A 19	8.476	8.510	.40	4514.4	4531.7	.38
A 20	8.547	8.432	-1.35	4570.4	4512.0	-1.28
A 21	8.883	8.823	-.68	4753.6	4723.2	-.64
A 22	8.973	8.915	-.65	4799.0	4769.5	-.61
A 23	8.817	8.857	.46	4642.6	4662.7	.43
A 24	8.415	8.341	-.87	4466.3	4429.2	-.83
Campaign Average =			-0.02 ± 0.24			-0.02 ± 0.23
Batch Uncertainty =			± 1.20			± 1.14

TABLE III. EVALUATION OF DIAGNOSTIC ANALYSIS RESULTS FOR OBRIGHEIM SET B DATA

BATCH LABEL	QUANTITY	COGEMA INTENTIONAL ANOMALY	ANL/ICT DIAGNOSED ANOMALY	COGEMA-ANL DIFFERENCE (Std. Dev)
B 03	Enrichment	-0.131	-0.149 ± 0.34	0.5
B 06	U-234	-0.002	(a)	(a)
	U-235	0.057	0.065 ± 0.010	0.8
	U-236	0.011	0.012 ± 0.001	1.0
	U-238	-0.066	0.077 ± 0.010	1.1
B 08	Enrichment	0.135	0.120 ± 0.028	0.5
B 12	Pu-239	0.400	(b)	(b)
	Pu-242	-0.400	-0.376 ± 0.039	0.6
B 14	Pu/U	-0.300	-0.280 ± 0.023	0.9
	Burnup	Burnup not used in ANL ICT		
B 17	U-235	0.050	0.068 ± 0.005	3.6
	U-238	-0.050	0.068 ± 0.005	3.6
B 18	Pu-238	-0.002	(a)	(a)
	Pu-239	0.840	0.972 ± 0.140	0.9
	Pu-240	-0.753	-0.750 ± 0.048	0.1
	Pu-241	0.237	0.153 ± 0.117	0.7
	Pu-242	-0.322	-0.414 ± 0.040	2.3
B 21	Enrichment	-0.042	-0.048 ± 0.028	0.2
B 26	Burnup	(Burnup not used in ANL ICT)		
B 27	Pu/U	-0.259	-0.328 ± 0.067	1.0
	Pu-238	-0.025	(a)	(a)
	Pu-240	-0.722	-0.875 ± 0.133	1.1
	Pu-241	0.747	0.811 ± 0.089	0.7
B 29	Enrichment	0.056	0.052 ± 0.026	0.2

(a) Anomalies in U-234 and Pu-238 not included in diagnostic algorithm.
(b) Anomaly undetected by diagnostics.

TABLE IV. MASS DETERMINATION AND Pu/U RATIO BY ANL/ICT METHOD
COGEMA REPROCESSING INPUT MASS VERIFICATION
OBRIGHEIM PWR SPENT FUEL ASSEMBLIES
SET B DATA, AT REPROCESSING
DIAGNOSTIC ANALYSIS

Batch Label	Pu/U Ratio (gm/kg) Meas Pu/U	ICT Pu/U	DIFF (%)	Pu Mass (gm) Meas Pu/U	ICT Pu/U	DIFF (%)
B 01	8.095	8.216	1.49	4531.6	4595.6	1.41
B 02	8.147	8.235	1.08	2281.3	2304.7	1.03
B 03	8.288	8.274	-.17	4511.1	4503.8	-.16
B 04	8.211	8.273	.76	4597.0	4630.0	.72
B 05	8.256	8.243	-.15	4515.9	4509.4	-.15
B 06	8.304	8.369	.78	4439.5	4472.2	.74
B 07	8.249	8.211	-.46	4372.1	4353.2	-.43
B 08	8.385	8.396	.13	4455.6	4461.1	.12
B 09	8.605	8.716	1.29	4533.6	4588.5	1.21
B 10	8.140	8.142	.02	4367.7	4368.5	.02
B 11	8.122	8.154	.40	4326.5	4342.9	.38
B 12	8.178	8.140	-.46	4341.0	4322.0	-.44
B 13	8.305	8.413	1.31	4427.3	4481.9	1.23
B 14*	8.672	8.392	-3.23	3465.4	3359.7	-3.05
B 15	8.180	8.168	-.15	5474.9	5467.1	-.14
B 16	8.211	8.336	1.52	4374.4	4437.5	1.44
B 17	8.223	8.229	.07	4404.0	4407.1	.07
B 18	8.237	8.152	-1.03	6544.5	6480.4	-.98
B 19	8.129	8.136	.09	6476.3	6481.7	.08
B 20	8.223	8.201	-.27	6562.5	6546.0	-.25
B 21	8.258	8.220	-.46	4429.8	4410.5	-.44
B 22	8.066	8.033	-.41	5394.5	5373.4	-.39
B 23	8.307	8.377	.84	5535.3	5579.2	.79
B 24	8.785	8.660	-1.42	5812.0	5734.1	-1.34
B 25	8.588	8.439	-1.74	5691.3	5597.8	-1.64
B 26	8.363	8.284	-.94	5569.2	5519.5	-.89
B 27*	8.569	8.241	-3.83	5698.3	5491.4	-3.63
B 28	8.403	8.342	-.72	5589.5	5551.2	-.69
B 29	8.554	8.504	-.59	3413.1	3394.3	-.55
Campaign Average =		-0.22 ± 0.23				-0.20 ± 0.22
Batch Uncertainty =		± 1.23				± 1.16
B 14	8.372	8.392	.24	3352.2	3359.7	.22
B 27	8.310	8.241	-.83	5534.7	5491.4	-.78
Campaign Average =		0.01 ± 0.16				0.01 ± 0.15
Batch Uncertainty =		± 0.85				± 0.80

*These large percent differences are caused by comparisons of the ICT-derived values with measured Pu/U values containing intentional anomalies of approximately 3.5%. Refer to text for more detailed discussions.