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PLANNED NORMALIZATION OF PLUTONIUM YIELD PREDICTIONS TO THE TWELVE TWO-TON TEST BATCH MEASUREMENTS

INTRODUCTION

This report is a comparison of the findings from the twelve two-ton test batches irradiated in the KE and H reactors[1-4] with respect to reactor plutonium yield predictions. Included are plans for the application of these findings to improve the accuracy of plutonium yield equations used for Hanford product accountability.

SUMMARY

A systematic review of the applicable physical constants and reactor parameters shows that plutonium yield predictions can be easily made consistent with both special batch and bulk separation results. Normalizations (downward) of 3.0% and 2.0% in the conversion of integrated fissions to observed MWD is applicable for total plutonium production from natural uranium at the older reactors and K reactors respectively. Similar normalizations of 2.5% and 1.5% respectively should be made for plutonium production from E metal (uranium enriched in U-235 to 0.946%).

The net effect of this normalization is to reduce the weighted average of previous IPD yield predictions by 1.6% from natural uranium and 1.1% from E metal. IPD predictions would still be expected to exceed CPD recovery by approximately 0.5% on the average.

Predicted Pu-240 isotope percentages as a function of exposure in the normalized calculations have shown close agreement with both batch test and bulk separation results.

K reactor normalization changes from previous tables will be greater than those at the older reactors. The revised SSA codes themselves should therefore be used in future planning studies instead of a blanket application of the above factors to previous SSA predictions. The revised SSA code will be put into service on June 30, 1961.

DISCUSSION

A. Background

A 2-3% IPD-CPD plutonium difference has been reported for the last several years and is attributed to plutonium yield prediction and dissolver solution measurement errors. Three projects were undertaken, and are now completed, for the resolution of this difference.

[redacted]

1. Development of a series of generalized Electronic Data Processing programs for predicting plutonium yields.

   Completion of the project was on January 1, 1960 with the adoption of the SSA programs based on rigorous analytical methods[5] which are capable of predicting plutonium yields for any given reactor loading. Test batch data indicate that excellent agreement (±2%) is obtained from the program calculation. At the time the programs were initiated they were normalized to the previous calculational system[6] because of limited empirical data. Wide fluctuations (±10%) and reported analytical errors precluded the use of routine CPD recovery data other than as a guide. It was for these reasons that the twelve test batches had been irradiated and were measured for plutonium content and isotopic ratios.

2. Development of accurate and reliable dissolver solution measurements. This project consisted of three programs:

   a. Development of the coulometric titration method as a specific analysis of uranium in dissolver solutions.

   b. Development of a reliable plutonium nitrate standard.

   c. Application of the Pu/U ratio calculation technique for CPD receipt measurements.

3. Irradiation and measurement of twelve test batches for plutonium concentration and isotopic ratios.

   These test batches were irradiated to provide a correlation of theoretical predictions to empirical data. From this correlation, parameters could be evaluated at measured values and the results used, along with bulk observations, to normalize prediction equations to recovery measurements.

B. <u>Findings</u>

1. Plutonium yield equations should be normalized to the test batches and the long term production data by the use of a normalization factor. Application of the normalization factor should be made directly to the final Pu/MWD conversion in the following manner:

   Natural Uranium Fuels

   K Reactors

   $$\text{Adjusted MWD} = \text{EQ}\overline{\text{N}} \times 1.01478$$

   Old Reactors

   $$\text{Adjusted MWD} = \text{EQ}\overline{\text{N}} \times 1.02956$$

Enriched Fuels

K Reactors

Adjusted MWD = $EQ\bar{N} \times 1.00985$

Old Reactors

Adjusted MWD = $EQ\bar{N} \times 1.01970$

where E = exposure

Q = heat of fission of 203 mev per fission

$\bar{N}$ = average concentration of fissions which have occurred during the irradiation period.

TABLE I

Recommended Normalization Factors

Reactor	Natural Uranium Factor	E Metal Factor
B, C, D, DR, F, H	1.02956	1.00985
KE, KW	1.01478	1.01970

IPD-CPD plutonium differences for irradiated normal and enriched uranium will be reduced to 0.5% ± 0.2%, with IPD high. The normalization factors will reduce predicted plutonium yields as follows:

TABLE II

Adjustments for Discharges

Reactor	Irradiated Normal Uranium	Irradiated 0.946 Enriched Uranium
B, C, D, DR, F, H	0.9%	0.7%
KE, KW	2.6	1.6
Weighted Average	1.6	1.1

It is to be noted that the greater reduction for the K reactors is the result of a partial normalization that was made on January 1, 1960, which primarily affected the old reactors.

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2. Plutonium yield equations should be normalized on June 30, 1961, effective for all inventory accounts. Adjustment quantities will thus be reflected in fiscal 1961 and provide a uniform fiscal 1961 production base. Basin accounts will be adjusted downward by the percentages shown in Table II, in-reactor inventories downward by the percentages shown in Table III, below.

TABLE III

Adjustments for In-Reactor

Reactor	Irradiated Normal Uranium	Irradiated 0.946 Enriched Uranium
B, C, D, DR, F, H	0.7%	1.1%
KE, KW	2.8	2.0

3. The SSA programs now in use should be continued as the primary method for accountability calculations until new procedures are developed as reactor technology improves. These programs render a high degree of accuracy; however, they should be updated when necessary to include current calculation methods and constants. Current improvements incorporated in the normalized program are:

   a. All temperatures are being adjusted to the weighted average temperatures consistent with present power levels.

   b. The heat of fission is being readjusted to 203 mev per fission, the current accepted value.

   c. The resonance integral in the probability function has been corrected by the "best" accepted method.

4. Weighting factors should be applied to inventory accounts where special irradiation and segregation programs have significantly influenced predicted plutonium yields or isotopic distributions. Total predicted plutonium production will not be affected; this measure will simply provide a more accurate assignment on a shorter term basis.

5. Normalizing the predicted values to test batch data may still result in small IPD-CPD differences. The test batches are small samples of one fuel element type irradiated in two out of eight reactors and do not adequately describe results for every type element or reactor. It may be necessary to make minor adjustments to the normalization factor during the first few months following its original application.

6. Tables IV and V provide a comparison between test data and the yield from these batches as predicted by the revised equations.

[redacted]

TABLE IV

Prediction and Measurement Comparisons Based on Test Batches, H Reactor*

	442 MWD/T				805 MWD/T			
	Pu/MWD	%Pu-239	%Pu-240	%Pu-241	Pu/MWD	%Pu-239	%Pu-240	%Pu-241
Measured	0.886	95.61	4.13	0.25	0.828	92.55	6.79	0.66
Adjusted Predicted	0.872**	95.74	4.04	0.22	0.819	92.56	6.79	0.65

TABLE V

Prediction and Measurement Comparisons Based on Test Batches, KW Reactor*

	458 MWD/T				832 MWD/T			
	Pu/MWD	%Pu-239	%Pu-240	%Pu-241	Pu/MWD	%Pu-239	%Pu-240	%Pu-241
Measured	0.946	95.49	4.19	0.32	0.876	92.24	7.04	0.72
Adjusted Predicted	0.929**	95.61	4.11	0.28	0.870	92.39	6.83	0.78

* These test batch comparisons illustrate IPD-CPD differences for one single fuel element and are not necessarily applicable to all fuel elements. The adjusted values were influenced by IPD-CPD actual monthly average differences (i.e. 1.7% to 2.0% for natural uranium fuel and 1.35% to 1.50% for enriched fuel).

**The measured vs. Adjusted Predicted Values are different for the following reasons:

1. Test batch data at the K Reactor varied over a 2% range.

2. Comparison with data from other Hanford programs indicates the values may be influenced by the predominantly central location of the test batch charges. Due to fringe leakage effects, the average reactor conversion ratio may be up to 1% less than that in the central flattened zone; the 1% difference shown between measured and predicted thus indicates good agreement for gross reactor predictions.

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REFERENCE

/1/ Richey, C. R., "Production Test IP-177A Irradiation of Uranium to Improve Conversion Ratio Information," HW-56368, May 25, 1959.

/2/ Zimmer, W. H., "Analysis of the Twelve Two-Ton Test Batches for the Review of Plutonium Formation Rates as a Function of MWD," HW-68438.

/3/ Hoba, D. W., "IPD Predicted vs CPD Measurement Differences, Twelve Two-Ton Test Batches," HW-68674, March 29, 1961.

/4/ Hoba, D. W., "Status of the Twelve Two-Ton Test Batches for the Review of Plutonium Formation Rates as a Function of MWD," HW-64886 RD, April 29, 1960.

/5/ Richey, C. R., "Technical Description of the New SS Accountability Program on the IBM-709," HW-63159, January 7, 1960.

/6/ Gumprecht, R. O., "Product Yield and Quality and U-235 Depletion in Irradiated Natural Uranium," HW-31285, November 10, 1955.

/7/ "Doppler Coefficient for U-238," Power Reactor Technology, March 1959.

/8/ Bowers, C. E., "IBM Production Calculations," HW-64336, March 15, 1960.

Acknowledgements: C. E. Bowers performed the preliminary studies on the test batch analysis. J. D. Massey performed all the reprogramming and setting up of input data.

[redacted]

APPENDIX I

The following input was changed from the original formula to the following:

$$\text{Resonance Integral} = A\left[1 + \alpha\,(T-20)\right] + B\sqrt{S/M}\left[1 + \beta\sqrt{S/M}\,(T-20)\right]$$

where $A = 2.81$ barns

$B = 24.7$ barns

$\alpha = 1.6 \times 10^{-4}/°C$

$\beta = 3.18 \times 10^{-4}/°C$

Ref. /7/

The following parameters were inserted in place of the original input data.

Reactor	Physical Graphite Temperature	Physical Metal Temperature
B, C, D, DR, F, H	517°C	232°C
KE, KW	597°C	232°C

APPENDIX II

STATUS DISCUSSION

The present system of SSA programs for predicting plutonium yields provides a high degree of accuracy and flexibility for the calculation of reactor factors. Essentially each fuel element is considered as an entity; plutonium buildup, Pu and U-235 fissioning, and U-238 transmutation are computed from weighted longitudinal and radial exposure distribution functions. Each unique fuel element and load pattern is computed from actual physical dimensions and distribution.

There are, however, prevalent limitations which affect the system's accuracy:

1. Reactor and tube coolant temperature and flow measurement inaccuracies, reported to be at least $\pm$ 2 - 3%.

2. Physical uncertainties of reactor and nuclear parameters, such as moderator temperatures affecting neutron temperature and isotopic cross sections.

3. Normalization; any volumetric element within a reactor is considered subjected to the same conditions as any other volumetric element. This has the consequence of normalizing every variable parameter to an average value.

By application of weighting factors and empirical fitting to test data, these differences are minimized. In addition, the production and accountability systems are based on total reactor performance which provides an additional normalization.

Since January 1, 1960, at initiation of the present SSA programs, moderator and fuel temperatures and resonance integral formula have become obsolete due to changes in operating power levels and improved reactor technology. Two other important considerations are:

1. At the time the SSA programs were adopted there was a limited amount of isotopic data, which is now augmented by the test data. The available data at that time did not adequately represent current operating conditions and was based on measurement methods which have since been improved.

2. As of January 1, 1960, the SSA programs were adjusted to a level consistent with the data available. In the execution thereof calculated parametric values were used for the moderator temperatures. It was also found necessary to use calculated heat of fission values in order to maintain the predicted plutonium yields consistent with the exponential approximations of the prior system. Neither of these procedures were considered ideal but represented the maximum application of the data as of that date.

The effect of the adjustment procedure resulted in an approximate 2% reduction in yields for old reactors with K's remaining unaffected. In addition, the review pointed out the desirability of independent verification of parameter and heat of fission values. The development of such data constituted portions of the test batch program since executed.

Once the test batch data became available, all parameter values in the SSA programs were checked for accuracy and changed where necessary so as to describe current reactor conditions and accepted reactor technology. Required adjustments consisted of fuel and moderator temperatures, as well as a replacement with a new resonance escape probability formula. Finally, the heat of fission was replaced with the presently accepted value.

The SSA programs are now considered as physically correct as possible; all temperatures, geometries, physical factors, and cross sections are either calculated from accepted theories or taken from actual reactor measurements. Results from the "clean" (unadjusted) programs would predict plutonium yields two percent greater than recoveries. Plutonium isotopic percentages, however, are predicted to within one percent whether the adjustment factors are used or not.

Agreement of predicted plutonium vs test data to within one percent was attempted by varying physical parameter values within known uncertainty ranges. Agreement was achieved only at the sacrifice of isotopic ratios. It was therefore concluded that the most accurate and meaningful method of forcing agreement was the use of a normalization factor applied to the final calculational results for conversion from number of fissions to Pu/MWD.

The twelve two-ton test batch data provide the bases for the normalization factor and were used as a verification of reactor parameter values affecting isotopic ratios.