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HW73615, SUP3

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December 18, 1962

FINAL REPORT ON E-N CONVERSION RATIO DATA
PRODUCTION TEST IP-350-C

Introduction

This document summarizes the results of all special separations made in conjunction with the two E-N core loadings and the single fringe blanket loading irradiated in the H Reactor during 1961 and 1962.

Tritium yields obtained at Savannah River from the N target elements have been reported previously.^{/1/} Bulk plutonium yield observations obtained from separation of the E-metal fuel elements in the first core and data from a limited number of small-scale separations were included in a comprehensive interim report.^{/2/} In addition to the above data

^{/1/} HW-73615, SUP2, Supplementary E-N Load Conversion Ratio Data, WS Nechodom, 8-13-62

^{/2/} HW-73615, Technical Evaluation of E-N Demonstration Loading, RD Carter, et al
5-11-62

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a detailed sampling program was carried out as a part of the production test, and 18 representative 6-8 tube batches from the E-N core and from the surrounding blanket have recently been separated and analyzed. This document includes this recent information in its treatment of all E-N conversion ratio data from loadings under PT IP-350-C.

Summary

Plutonium yield measurements are reported from 18 6-8 tube batches (selected to be representative of the E-N load and recently separated by Chemical Processing Department). The full-exposure core data, verified in selected cases by Hanford Laboratory mass spectrometer measurements, is consistently higher than calculated from current E-metal conversion tables. Figure 1, using data corrected to absolute yield values and a more nearly optimum loading, and showing the yield as a function of loading radius, agrees with previous calculational predictions of lower plutonium formation in the reactor fringe. The weighted average effect, when combined with the earlier full-pile data, is consistent with the yields reported in references 1 and 2; accumulated E-N conversion ratio data from this production test are shown in Table I. Under the actual exposure and loading conditions of this full-pile production test, the single blanket and two core cycles in H Reactor, a net gain of 13.5% in conversion efficiency is indicated relative to a natural uranium load with 610 MWD/T goal exposure.

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Table I

FULL PILE E-N LOAD CONVERSION TEST RESULTS
(Conversion Ratios at 800 MWD/T)

	E-N Load		Normal Load**	
	Core	Fringe	Natural U	Enriched U
Rel. Power Generation	0.67	0.33	0.85	0.15
Pu Yield (gms/MWD)				
1st Core (Bulk Separation Data)	0.722	-	-	-
2nd Core (Representative Samples)	0.741	0.728	-	-
Average	0.732	0.728	0.810	0.702
Pile Average		.730		
T Yield* (gms Pu Equiv./MWD)				
1st Core	0.209	-		
2nd Core	0.188	0.193		
Average	0.199	0.193		
Pile Average		.197		
Total Yield (gms Pu Equiv/MWD)				
1st Core	0.931	-		
2nd Core	0.929	0.921		
Average	0.930	0.921	0.810	0.702
Full Pile Average		.927		.794
Ratio, E-N to Normal Load at 800 MWD/T			1.168	
Ratio, E-N at 800 MWD/T, Normal Load at 610 MWD/T			1.135	

*Including 2% decay

**Pu yield from enriched and natural uranium reduced 1% from accountability prediction table value to agree with CPD load-out data during the period of time in which the plutonium bulk recoveries from this test were made.

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Figure 1

Plutonium Yield Data
E-N Conversion Ratios as a Function
of the Distance from the Edge of the Reactor

- Corrected Data -

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Discussion

The specific analytical determinations using the small groups specified by PT IP-350-C have only recently been completed and are combined in this document with previous data from the full-reactor loadings of this production test to provide a technical basis for estimating E-N yields. The different collections of data on E-N conversion ratio observations are referenced below:

1. Block test, 1957, at B Reactor, striped E-N columns, results summarized in HW-73615.
2. Block test, 1959, at H Reactor, striped E-N and blanket columns, results summarized in HW-73615.
3. Full Pile Tests, 1961-62, at H Reactor, first core load, all enrichment and Li-Al analyzed; second core load, all Li-Al analyzed, results summarized in HW-73615.
4. Analytical Tests, 1961-62, at H Reactor, natural and enriched uranium and lithium-aluminum from the regular load and/or the E-N load, in 6 and 8-tube groups, fringe and core (see HW-66300, Part 2, for specific details as to the number of tubes, groups and locations).

The operational aspects of the E-N loading, including reactivity observations, fuel performance, and special handling and irradiation process limitations, were covered in the comprehensive earlier report;^{/2/} this document is directed only to conversion efficiency observations.

A. Chemical Analysis

The analytical test information obtained under PT IP-350-C was planned to include data from 12 batches of natural uranium of 6 tubes each, 27 batches of enriched uranium of 8 tubes each, and one 4-tube batch of fringe Li-Al. (For a more detailed description see HW-66330, Part 2.) The enriched uranium included 21 batches from the E-N core or fringe blanket. One batch from the first E-N core was inadvertently mixed with the rest of the core during discharge, and a bulk separation of the entire first core enriched uranium was substituted; the yield was reported in HW-73615. The Li-Al charges, expanded to two batches of 7 and 12 tubes, were analyzed by Savannah River Operation and reported in HW-73615, SUP2. The remaining 18 special batches from the E-N load were analyzed by Redox Operation. Three batches of enriched uranium from the E-ring and three batches of natural uranium which were discharged as planned after the second E-N core was discharged have not been analyzed; the latter batches, intended to supplement base point information, are not directly associated with the E-N load itself.

The specific isotopic analysis results have been documented by the Chemical Processing Department in HW-73219, HW-73220, HW-73699, HW-74032, HW-74033, HW-74034, HW-75693, HW-75694, HW-75704, HW-75705, HW-75799 and HW-75800.

1. Normal Load Batches

The normal load batches discharged prior to charging of the E-N load consisted only of fringe natural uranium and enrichment divided into three-batch groups. All three batches within a group were intended to be of the same exposure. Due to the difficulty of obtaining a sufficient number of charges at

the same exposure, some batches were selected at half-goal exposure. Most of the resulting data showed a sufficiently wide scatter that an adequate basis for determining absolute conversion ratios could not be assumed. Although this frustrated the determination of yield as a function of location, mass separations data are available for the entire plant from natural uranium loadings and supporting enrichment; base case plutonium yield values were thus evaluated from normal bulk yield information.

2. E-N Load Batches

The E-N load batches were initially analyzed by Redox Operation. The resulting raw data are shown in Figure 2, along with the determination of yield for the entire first E-N core load. Sample batches from the second E-N core load were analyzed in two groups, one at half-goal and one at full-goal exposure. From the raw data it is seen that the half-goal yield per MWD appears to be less than at full-goal exposure. Since this cannot be the case (compare with the accountability yield curve) all three full goal groups and one still-available half-goal group were reanalyzed by Hanford Laboratories Operation; these points are also shown on the graph.^{/3/} HLO analysis supported the full goal yield determination but indicated a higher half-goal yield. Since the full-goal yield data are more reliable, both by HLO verification and by the greater weighting of the accumulated plutonium buildup at higher exposure, the half-goal central column samples were not included in the over-all analysis.

The raw chemical analyses data, normalized to an exposure of 800 MWD/T, were as follows:

<u>Location and Type of Charge</u>	<u>Conversion Ratio (Normalized to 800 MWD/T)</u>
2nd Lattice Unit 43-piece OIIE	
0.5 Goal Exposure	.6783
1.0 Goal Exposure	.6877
Average	.6830
3rd Lattice Unit, 43-piece OIIE	.6962
5th Lattice Unit, 34-piece OIIIE	.7354
6th Lattice Unit, 34-piece OIIIE	.7127
Core, E-N, OIIIE	
0.5 Goal	See text above
1.0 Goal	.7260

B. Corrections to the Original Data

1. Modernization of Fuel Designs

Calculated conversion ratios for OIIIE metal pieces are 1.4% greater than for OIIE pieces at the same exposure. Since, in the E-N load, the first and second lattice unit samples were of the now-obsolete OIIE, the conversion

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ratio in these regions should be corrected to that for OIIIE. Since the expected difference between OIIN and OIIIN is only 0.16%, no correction is considered necessary.

2. CPD-IPD Book-Physical Inventory Differences

The analysis of the analytic test samples was a head-end measurement of plutonium yield at the Redox plant; samples were analyzed in essentially the same manner as the normal large scale extractions. Redox and Purex records^{/4/} show consistent differences between head-end, load-out and accountability table^{/5/} (predicted) values. Averaged over several months, observed differences were as follows (where a plus sign indicates overprediction):

	<u>Enriched U</u>	<u>Natural U</u>
Predicted vs. Head-end, %	+3.0	> 3.0
Predicted vs. Load-out, %	+1.0	> 0 (~1% in early 1962)

The above data indicate that the true yield is 2% higher than the head-end determination and 1% less than the yield predicted from accountability table values. Since the yield of the special batches in the analytic tests is from head-end analyses, the resulting E-N yields should be increased by 2%. Additionally, in comparisons of conversion ratios between the E-N load and the normal load, accountability table value for enriched and natural uranium in the normal load should be decreased by 1%.

3. Data Corrections to Uranium

With the above corrections a relationship between lattice location and conversion ratio becomes apparent (Figure 1). From the curve the following conversion ratios are obtained:

2nd Lattice Unit	.7065
3rd Lattice Unit	.7200
4th Lattice Unit	.7293
5th Lattice Unit	.7364
6th Lattice Unit	.7397
Core	.7405

Each lattice generates a particular fraction of the fringe power. With weighting of the various conversion ratios for power generation through the fringe lattices, the average fringe plutonium yield rate becomes 0.7277 grams per MWD at 800 MWD/T.

4. Tritium Yields and Adjustments

a. Core Loading

HW-73615 calculates a relative gain of 4-5 percent in tritium formation based upon replacement of a calculated amount of excess reactivity held in control rods and other nonproductive poisons with additional target elements. However, somewhat different but more precise data now

/4/HW-75564, Irradiation Processing Nuclear Materials Control, October, 1962,
JH Handsnuk, 11-29-62

/5/HW-50300-B, IPD Plutonium Conversion Tables, DW Hoba

available indicate that at least one piece of lithium may be added to every fifth charge in the core; this is an increase of one piece out of 17 or 5.9%. Since the original pieces will be rearranged to maintain homogeneity, it can be assumed that the added piece will correspond to an average piece in an average flux and that the increase in tritium production in future E-N loads will be proportional to the increase in the number of Li-Al pieces. In other words, the rate of tritium formation should be 5.9% greater in a more nearly optimum E-N core than in the second E-N core at the same exposure.

HW-73615 calculates a fractional increase of 2% in tritium production with the use of E-metal mixers instead of natural uranium mixers. It should be noted that the change would occur only if an E-N type load became normal operation, however.

HW-73615, SUP 2, reports the uncorrected second core load Li-Al conversion ratio as 0.178 (atom-equivalent grams per MWD). Correction of this value by 1.059×1.02 (respective corrections for poison displacement and mixer effects) shows the conversion ratio for a more nearly optimum load to be 0.192 atom-equivalent gms per MWD. The corrected value for the first core load was reported as 0.213. It may be assumed that a good approximation for the core load conversion ratio is the average of these two values, or 0.203 equivalent grams per MWD.

The average conversion ratio for the fringe blanket Li-Al was reported in HW-73615, SUP 2, as 0.193 equivalent grams per MWD.

Allowance for tritium decay requires a reduction of 2% in the values reported above. The core and fringe tritium yield rates thus become 0.199 and 0.193 equivalent grams per MWD, respectively.

C. Effects of Further Loading Modifications

The extension of the 34-piece enriched uranium charges to a full length charge, either 43-piece enriched uranium or some combination of enriched uranium and Li-Al, should increase the pile conversion ratio by at least 0.5%. A more rigorous study is underway to determine the degree of operational compatibility of longer charges. This change is more attractive for an E-N type load because differences in power generation rates in the E-ring relative to the core are not as large as in the normal load. This increase was not assumed in corrections of present conversion ratios in this document, however, since a definitive study has not been completed.

D. Error Analysis

HW-73615 reported a probable error of $\pm 1.93\%$ (95% confidence level) over-all including $\pm 1.06\%$ in the E-N Pu yield measurement. Although chemical analysis of the samples involves a probable error of only about $\pm 1\%$, the exposure calculation has a greater error in the individual column exposures involved in the

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6-8 tube batches from the blanket columns and the second core. The probable error on individual tube exposures may be 5-10%; exposure deviation on a group of eight tubes would then be $\pm 1.8\%$ to $\pm 3.5\%$. The resulting "probable error" in the conversion ratio associated with exposure effects would be $\pm 2.1\%$ to $\pm 3.6\%$, and the over-all "probable error" may be ± 2.5 to $\pm 4\%$. Bulk recovery results from additional E-N loadings would of course reduce the range of possible uncertainty.

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Figure 2

Pu Conversion Ratio Data from PT IP-350-C
(Uncorrected Data)

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