AIM

Association for Information and Image Management

1100 Wayne Avenue, Suite 1100
Silver Spring, Maryland 20910
301/587-8202

Centimeter

Inches

MANUFACTURED TO AIM STANDARDS
BY APPLIED IMAGE, INC.

1 of 1

(CLASSIFICATION)

DECLASSIFIED

GENERAL ELECTRIC

HANFORD ATOMIC PRODUCTS OPERATION - RICHLAND, WASHINGTON

HW-79055 RD

SERIES AND COPY NO.

DATE

September 26, 1963

☒ X

THIS DOCUMENT CONTAINS RESTRICTED DATA AS DEFINED BY THE AEC ENERGY ACT OF 1954. ITS TRANSMITTAL IN ANY MANNER TO AN UNAUTHORIZED PERSON IS PROHIBITED.

TITLE

HIGH Pu-240-CONTENT PLUTONIUM
CHEMICAL PROCESSING COST ESTIMATES

☐

OTHER OFFICIAL CLASSIFIED INFORMATION

THIS MATERIAL CONTAINS INFORMATION AFFECTING THE NATIONAL DEFENSE OF THE UNITED STATES WITHIN THE MEANING OF THE ESPIONAGE LAWS, TITLE 18, U. S. C., SECS. 793 AND 794, THE TRANSMISSION OR REVELATION OF WHICH IN ANY MANNER TO AN UNAUTHORIZED PERSON IS PROHIBITED BY LAW.

AUTHOR

J. E. McDonald
R. E. Olson
H. C. Rathvon

ISSUING FILE

THIS DOCUMENT IS NOT BE LOANED OR WHERE AN UNAUTHORIZED PERSON HAS ACCESS TO IT. WHEN IN YOUR POSSESSION IT MUST BE STORED IN AN APPROVED LOCKED REPOSITORY WITHIN AN APPROVED GUARDED AREA. WHILE IT IS YOUR RESPONSIBILITY TO KEEP IT IN A SAFE PLACE, IT IS NOT TO BE LOANED, COPIED, REPRODUCED, OR TRANSMITTED IN ANY MANNER TO ANY OTHER PERSON. ITS TRANSMITTAL AND STORAGE AT YOUR PLACE OF RESIDENCE IS PROHIBITED. IT IS NOT TO BE DESTROYED. IF ADDITIONAL COPIES ARE REQUIRED, REQUEST THEM IN THE SPACE PROVIDED BELOW. PERSONS RECEIVING THIS DOCUMENT ARE REQUESTED TO SIGN IN THE SPACE PROVIDED BELOW.

ROUTE TO:

PAYROLL NO.

LOCATION

FILES ROUTE
DATE

SIGNATURE AND DATE

(CLASSIFICATION)

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DECLASSIFIED

DECLASSIFIED

HW-79055 RD

This document consists of
10 pages.

HIGH Pu-240-CONTENT PLUTONIUM
CHEMICAL PROCESSING COST ESTIMATES

J. E. McDonald
Financial Operation

R. E. Olson
Weapons Manufacturing Operation

H. C. Rathvon
Research and Engineering Operation

CHEMICAL PROCESSING DEPARTMENT

Classification Cancelled and Changed To

DECLASSIFIED

By Authority of *RM Ido*

CG-PR-2 3-30-94

By *DK Hanson, 4-16-94*

Verified By *J. M. M. 4-18-94*

September 26, 1963

Distribution:

1. J. W. Fillmore	11. J. W. McCurry
2. W. S. Frank	12. J. E. McDonald
3. W. J. Gartin	13. R. E. Olson
4. K. G. Grimm	14. H. C. Rathvon
5. M. K. Harmon	15. R. J. Sloat
6. H. H. Hopkins, Jr.	16. H. P. Shaw
7. R. E. Isaacson	17. R. E. Tomlinson
8. B. F. Judson	18. J. H. Warren
9. L. E. Kusler	19. 300 Files
10. L. W. Lang	20. Record File

HANFORD ATOMIC PRODUCTS OPERATION
RICHLAND, WASHINGTON

Work performed under Contract #AT(45-1)-1350
between the Atomic Energy Commission and the General Electric Company.

This document contains restricted data as
defined by the Atomic Energy Act of 1954.
It is transmitted for the disclosure of its
content in any manner to an unauthorized
person is prohibited.

MASTER

DECLASSIFIED

Excluded from Automatic Downgrading
and Declassification

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

HIGH Pu-240-CONTENT PLUTONIUM
CHEMICAL PROCESSING COST ESTIMATES

INTRODUCTION

In response to an inquiry by Euratom, estimates of the costs for the production of 85 kg of 15% Pu-240 metal and for the production of 15 kg of 25% Pu-240 oxide at HAPCO were recently requested by the Atomic Energy Commission.^(1, 2) In connection with this inquiry, comments were requested regarding the possibility of establishing and measuring product plutonium oxide "sinterability" parameters.⁽²⁾ This report presents estimates of the costs for separations processing by the Chemical Processing Department for the cases of interest. Process ground rules and any necessary assumptions are explained. In addition, the problems of measuring oxide "sinterability" are briefly discussed. Highlights of this study were previously transmitted to the Irradiation Processing Department for incorporation in a formal reply to the original Commission request.⁽³⁾ Subsequently, some adjustments in ground rules have caused cost changes which are included in this report.

SUMMARY

A study was made of the Chemical Processing Department processing requirements and costs associated with the proposed production of 85 kg of plutonium metal containing 15% Pu-240, and 15 kg of plutonium oxide containing 25% Pu-240. Three production cases were specified by the Irradiation Processing Department, and chemical processing for all cases was assumed to be accomplished at the Redox Plant and at the 234-5 Building.

- (a) Case 1 is the production of 15% Pu-240 product by irradiation and chemical processing of depleted uranium.
- (b) Case 2 is the production of 15% Pu-240 product and 25% Pu-240 product by irradiation and chemical processing of depleted uranium.
- (c) Case 3 is the production of 25% Pu-240 product by irradiation and chemical processing of Pu - Al alloy.

Campaign-type operation of the Redox Plant to effect the basic separations from irradiated depleted uranium and/or irradiated Pu - Al alloy would be feasible. Production of either an oxide or metal product at the 234-5 Building would be possible utilizing the existing facilities of Room 179.

Estimated CPD costs for the three cases are itemized in Table 1. For Cases 1 and 2, these costs include penalties which account for a reduction in the conversion ratio associated with required supporting E-metal in comparison to normal natural uranium loads. The penalty is expressed in terms of the full processing costs for an amount of E-metal specified by IPD. For Case 3, the costs include a charge for processing 6 tons of irradiated depleted uranium which is required by the Pu - Al alloy irradiation. On a full-cost basis, including overheads and depreciation, CPD costs vary from \$6.39 to \$6.92 per gram for 85 kg of 15% Pu-240 product, and from \$18.70 to \$19.40 per gram for 15 kg of 25% Pu-240 product.

DECLASSIFIED

Plutonium oxide product produced by the normal 234-5 Building processing method has been found by experience to be highly sinterable, a physical condition which is desirable for fuel element fabrication. However, no suitable and simple laboratory methods are available for measuring and evaluating this sinterability characteristic. At the present time, it would appear that a reliable evaluation of sinterability would most practicably be accomplished by a customer, using his own facilities and specific techniques.

DISCUSSION

For the proposed production of 85 kg of 15% Pu-240 metal and 15 kg of 25% Pu-240 oxide, three study cases were selected by the Irradiation Processing Department. These three cases have been evaluated with respect to chemical processing requirements, and Chemical Processing Department costs have been estimated.

Chemical Processing Requirements

Case No. 1

IPD would irradiate 57 tons of depleted uranium, using 370 tons of 0.94% enriched uranium driver, to produce 89.5 kg of Pu of 15% Pu-240 content. Allowing about 5% loss to rework at the 234-5 Building, 85 kg of product metal would be produced. The out-of-reactor Pu-240 content would be about 16% to allow for some dilution in the separations plant by weapons-grade product. The irradiated uranium would be available for delivery to CPD in from 19 to 24 months from program authorization.

Chemical processing of the 57 tons of depleted uranium was assumed to be accomplished at the Redox Plant, with a campaign-type operation to insure both uranium and plutonium segregation from products of normal isotopic contents. This assumption was based on the presumed greater versatility of the Redox Plant for campaign operations of this size. It has been suggested, however, that studies be made of the Purex Plant capability for this type operation in order to insure minimum costs for future studies of this type.

The 57 tons of depleted uranium with the associated 370 tons of E-metal would displace about 585 tons of natural uranium in the reactors. The production pattern at CPD would thus be changed, in that a part of the usual Purex Plant load would be displaced by enriched and depleted uranium which would be scheduled for the Redox Plant.

The irradiated depleted uranium fuel elements would be of normal geometry with normal aluminum cladding, and 120 days "cooled". At the proposed 9- to 10-months reactor exposure, the expected neptunium content would be of the order of 50% greater than for normally irradiated natural uranium. Thus, neptunium recovery would be included in the reprocessing scheme.

DECLASSIFIED

Primary separations processing of the depleted uranium would be accomplished at the Redox Plant using normal flowsheets, including neptunium recovery. The separated depleted uranium would be discarded as cheaply as possible. Disposal to non-boiling underground waste storage was assumed. An estimated 16 days of total processing time would be required, including 6 days for one period of plant flushing to insure both Pu and U segregation. It was assumed that a second required period of plant flushing would be timed with normal plant shutdown and would not be chargeable to the depleted uranium processing campaign. An instantaneous Redox processing rate of 10 T/day was assumed.

At the 234-5 Building, Pu metal would be produced by the normal flow-sheet, but precautions would be taken to control the problem of radiation exposure associated with high Pu-240 content and to insure good segregation of the Pu product. Processing to the oxide would be accomplished in equipment located in Room 179 (presently a Research and Engineering facility) which is sufficiently shielded to eliminate concern regarding radiation exposure. Reduction to the metal would be accomplished in either the laboratory furnace or in the "A" button-line furnaces. Portable shielding might be required to reduce exposure levels during this step. A total of about 30 operating days would be required for 234-5 Building processing.

Case No. 2

IPD would irradiate 20 tons of depleted uranium to produce plutonium of slightly over 20% Pu-240 content. About 6 tons of this material would contain 15.8 kg of a nominal 25% Pu-240 product, which would be segregated at the reactor. An actual Pu-240 content of about 27% would allow for some downgrading during chemical processing. The remaining tonnage would contain 21 kg of a nominal 15% Pu-240 product. An additional 65 kg of 15% Pu-240 product would be produced by the separate irradiation of about 43 tons of depleted uranium (similar to Case No. 1). A total of approximately 471 tons of E-metal driver would be required, and about 745 tons of natural uranium would be displaced by these two irradiations. The 20-ton irradiation would be available for delivery to CPD 23 to 28 months after program authorization, assuming 120 days of "cooling". The 37-ton balance would be available for delivery to CPD in 19 to 24 months, assuming 120 days of "cooling".

As with Case No. 1, chemical processing for Case No. 2 would be accomplished at the Redox Plant using normal flowsheets, including neptunium recovery. Two campaigns would be included, to separately produce a 15% Pu-240 product (nominal 85 kg) and a 25% Pu-240 product (nominal 15 kg). Again, the depleted uranium would be discarded as economically as possible. For the 6 tons of 25% Pu-240 material, about 9 days of Redox processing time would be required, including one plant flush. For the remaining 57 tons of 15% Pu-240 material, about 16 days processing time would be required.

DECLASSIFIED

At the 234-5 Building, 85 kg of 15% Pu-240 product metal would be produced as described for Case No. 1, above, utilizing facilities of Room 179. As a separate campaign, 15 kg of 25% Pu-240 product oxide would be produced in 6 operating days, utilizing the same facility. For this latter case, assuming the higher Pu-240 content would result in excessive personnel exposure in spite of some existing shielding, the use of additional portable shielding presently located in the old Recuplex area would be planned.

Case No. 3

IPD would irradiate 21 kg of plutonium as 3% Pu - Al alloy to produce 15.7 kg of a nominal 25% Pu-240 product. The actual Pu-240 content should be about 27% to allow for some dilution during chemical processing. For absorption of excess neutrons, about 6 tons of depleted uranium would be charged and irradiated with the Pu - Al. In the depleted uranium charge, about 5 kg of 15% Pu-240 product would be formed. About 12 tons of natural uranium would be displaced by this loading. Both the Pu - Al alloy and the depleted uranium would be available for delivery to CPD in about 13 to 14 months from the time of program authorization, assuming 120 days of "cooling".

Chemical processing of both the Pu - Al and the small depleted uranium tonnage was assumed to be accomplished at the Redox Plant. The Pu - Al would be processed as a separate campaign-type operation. The depleted tonnage would be processed with the Case No. 1 Redox campaign as a one-day additional operating time. The extra Pu product, however, would be added to CPD other scheduled non-representative plutonium production.

The 3% Pu - Al fuel elements would be 1.4-inch-diameter by about 10 inches long, with 20 mils of zirconium cladding and about 1/4-inch zirconium end caps. The fuel element aluminum would also contain roughly 1.5% nickel. Neptunium recovery would not be a consideration.

Redox Plant chemical processing would include Zirflex decladding of the Pu - Al fuel elements followed by dissolution in annular dissolvers at the rate of 500 grams of Pu per charge. The dissolver solution would be blended with Redox UNH product at the rate of 20 tons of U for the total 16 kg of Pu. Solvent-extraction processing would use a flowsheet similar to that used for PRTR fuel elements; advantage would be taken of the absence of neptunium, and the Pu product ion exchange equipment probably would not be operated. About 12 days of processing time would be required, including 6 days for plant flushing. This estimate assumes the availability for this job of a scheduled second dissolver at Redox.

At the 234-5 Building, 15 kg of 25% Pu-240 product oxide would be produced as described for Case No. 2. The 5 kg of 15% Pu-240 product would be added to other scheduled non-representative plutonium and would be processed in the normal manner.

DECLASSIFIED

Cost Estimates

Chemical Processing Department costs for each study case are shown in Table 1, along with definitions of required production changes. General assumptions in the development of these costs are as follows:

- (a) Full costs, including allocated plant overheads. Depreciation charges shown separately include waste storage charges.
- (b) The CPD production schedule at the time of these campaigns would require Redox operation on a seven-day-week.
- (c) Variable costs for each campaign include \$2500 for Redox Plant flushing.
- (d) A net variable cost reduction has been included which results from
 - (1) the difference in variable costs between the decreased natural uranium tonnages in Purex and the increased enriched tonnages in Redox; and
 - (2) the decreased total uranium load in the UO_3 Plant.
- (e) Full costs for processing penalty tons are allocated to Cases 1 and 2 of this program to remove unit and total cost influence on weapons'-grade plutonium production. Reactor perturbation to implement this program results in reduced plutonium production because of lower reactor conversion ratios and would therefore result in increased per unit allocation of fixed costs to regular production if the penalty were not recognized. Penalty quantities were furnished by IPD and were based on the change in conversion ratio for the supporting E-metal load, as compared to a normal natural uranium load.
- (f) In accordance with study ground rules, neptunium-237 recovery costs have been excluded.
- (g) For Case 3, the irradiation of Pu - Al alloy, a penalty such as described under (e), above, does not apply since no supporting E-metal tonnage is required. However, a cost penalty does result from the requirement of processing 6 tons of depleted uranium required in the reactor for neutron absorption. It was assumed that this depleted uranium would be irradiated to 15% Pu-240 and would be combined with the Case 1 depleted uranium for reprocessing. It was also assumed that the additional 15% Pu-240 product would be added to, and would become part of, other normally scheduled non-representative Pu. Thus, for the 6-ton penalty, variable costs and costs for reduction of the associated Pu are not included in the Case 3 total.

DECLASSIFIED

Sinterability of Plutonium Oxide Product

Sinterability of plutonium oxide is a function of the surface energy of the oxide particles. Thus, for the general case, it has been found that sinterability increases as particle size decreases. Also, sinterability is increased by "chemical milling", that is, by chemical reactions in the particles which alter the physical characteristics. For example, in the case of uranium oxide particles, changes in the oxidation state of the uranium will improve the uranium sinterability.

The plutonium oxide product for the case studies described above (15 kg of 25% Pu-240) would be produced normally by calcination of the precipitated oxalate at a relatively low temperature (approximately 300 °C). Based on Hanford Laboratory experience, the PuO₂ powder obtained by such low-temperature calcination is highly sinterable.⁽⁴⁾ The surface area of this material is estimated to be about 28 square meters per gram. The favorable sinterability characteristics of this material are partly attributed to "chemical milling" during production, probably a change in the oxidation state occurring as the oxalate decomposes.

The low-temperature oxide product is also characterized by a moderate carbon and oxygen content (about 5%, or less). Since these materials would be evolved as gases during a subsequent sintering operation, allowance must be made for their presence. If the carbon and oxygen are objectionable in the oxide product, they could be effectively eliminated by calcination at around 800 °C (with no increase in cost) at the sacrifice of some sinterability.

The sinterability of both uranium and plutonium oxides has been very difficult to measure quantitatively by the laboratories. In practice, the characterization has not been reduced to anything approaching a system of simple testing. Thus, no controls or definitive tests of PuO₂ sinterability have been set up. Given a particular PuO₂ product, the evaluation of sinterability would best be accomplished by pilot-plant demonstration of fuel-element fabrication and the determination of fuel-element product quality. Thus, for a production effort such as that described above, sinterability of the oxide product would best be evaluated by the customer, presumably in facilities of his own which may be presently existing.

DECLASSIFIED

REFERENCES

1. Letter, F. P. Baranowski to J. E. Travis, "High Pu-240 for Euratom", August 12, 1963.
2. Letter, F. P. Baranowski to J. E. Travis, "Pu Production for Euratom", August 14, 1963.
3. Kusler, L. E., L. W. Lang, and J. W. McCurry. Higher Isotope Case Study. HW-78782. August 29, 1963. (SECRET)
4. J. B. Burnham, Jr., Personal Communication. August 26, 1963.

DECLASSIFIED

TABLE 1

HIGH Pu-240 STUDY CASES
PROCESSING DEPARTMENT COST ESTIMATES

CASE 2						CASE 3		
85 kg - 15% Pu-240 From 57 Tons Depleted U			15 kg - 25% Pu-240 From 6 Tons Depleted U			15 kg - 25% Pu-240 From Pu-Al Alloy		
471.2 63.3 (745.3)						- 6.0 (11.9)		
Full Costs						Full Costs		
57 Tons Depleted U	47-Ton E ⁽²⁾ Metal Penalty	Total	6 Tons Depleted U	32-Ton E ⁽²⁾ Metal Penalty	Total	Kg Pu As Pu - Al	6-Ton ⁽³⁾ Depleted U	Total
216	80	296	120	54	174	162	13	175
33	22	55	6	15	21	14	-	14
<u>137</u>	<u>45</u>	<u>182</u>	<u>75</u>	<u>30</u>	<u>105</u>	<u>81</u>	<u>7</u>	<u>88</u>
386	147	533	201	99	300	257	20	277
(23)	(9)	(32)	(12)	(6)	(18)	(0)	(1)	(1)
(21)	-	(21)	(13)	-	(13)	(3)	-	(3)
342	138	480	176	93	269	254	19	273
42	16	58	7	11	18	7	-	7
<u>1</u>	<u>4</u>	<u>5</u>	<u>1</u>	<u>3</u>	<u>4</u>	<u>1</u>	<u>-</u>	<u>1</u>
) 385	158	543 ⁽⁷⁾	184	107	291 ⁽⁷⁾	262	19	281 ⁽⁷⁾
6.39						18.70		
19.40								

Notes:

- (1) All overheads are included.
- (2) Penalty quantities assumed by IPD; see text.
- (3) Assumed to be processed with U of Case 1, with separated Pu added to HAPU non-representative Pu inventory.
- (4) Seven-day-week operation at Redox Plant is assumed. The necessity for 7-day-week operation is not charged to these study programs, however.
- (5) Includes plant flushing expenses.
- (6) Variable cost difference associated with decreased natural uranium tonnage in Purex and increased enriched uranium tonnages in Redox, plus UO_3 variables on each.
- (7) Totals have been adjusted (reduced in Cases 1 and 2; increased in Case 3) less than 5% from previous verbal transmittal. These adjustments were due primarily to ground rule changes to calculations.

END

10/19/94

FILMED

DATE