HW-12580

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Richland, Washington
3-4-49

Memorandum: To File

From: Chas. A. Rohrmann
Separations Process Survey Committee

Metal Recovery Process Comparisons

Introduction

In Documents HW-12348 and HW-12496 cost data and construction details of several possible metal recovery processes were presented in order to provide information on which to base decisions relating to the future course of action in process revision and expansion at Hanford.

In this present document items on which conclusions as to process preference may be drawn have been listed for Proposals 5, 7, 9, and 11 of HW-12496. On the basis of data and knowledge of the process proposals the order of preference has been assigned by letters on the attached table. Proposal 1 would have substantially the same order of preference on all items as has been assigned to Proposal 11. Relative and qualitative evaluation is thus presented. The items which form the basis for comparisons have been arranged in what is considered decending order of importance. These listings and orders of preference were arrived at by discussions among all committee members. Any numerical rating of proposals has been specifically avoided. The advantage of some proposals over others in some cases is extremely small. However, any such advantage has been considered in arriving at the order of preference.

It is probable that others outside the committee will have different points of view and will have reasons for a different order of preference. Because of differing points of view and the responsibility involved, the committee has

been requested to avoid making recommendations, since it has been the essential assignment of the committee to obtain data and facts for use by others in the formulation of recommendations and in the reaching of decisions.

Because of uncertainty in the matter of whether or not fluorination would be carried out at this site for the UAP processes in Proposals 5 and 11, we have shown the order of preference for situations involving no fluorination at this site and with fluorination for UAP in Proposals 5 and 11 and unit costs included in the other proposals.

As in Document HW-12496 we have further reduced the proposals to Number 5, 7, 9, and 11. The reasoning for this was as follows:

The UAP process Proposals 1 and 3 were dropped in favor of 11. Proposal 11 is our modification of Carbide and Carbon's UAP process proposal of their latest report, K-337. Proposal 3 was previously eliminated because of lack of experimental evidence to support it.

Proposal 2 and 4 were eliminated in favor of No. 9 which does essentially the same job cheaper. Proposal 2 was previously eliminated because its solvent extraction process was a sufficiently potent decontaminating procedure and did not need the aging period as originally proposed. With the elimination of the aging step No. 2 was identical with No. 4.

Proposal 6 was eliminated in favor of Proposal 7 because the latter could do the same job cheaper.

Proposal 8 was eliminated in favor of Proposal 9 because the latter could do the same job cheaper.

Proposal 11, which comprised half of No. 7 and half of No. 9, was eliminated because it has no features making it distinctly different from other proposals. Its costs were halfway between those of No. 7 and of No. 9.

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Letter designations indicate order of preference only.
See discussion for explanation of indicated preferences.

QUANTITATIVE SIGNIFICANCE IS NOT ATTACHED TO LETTER DESIGNATIONS

PROPOSAL FINAL PRODUCT EVALUATED	5 UNH UAP	7 UNH	9 UNH	11 UAP	5 UF_6*	7 UF_6*	9 UF_6*	11 UF_6
POINT OF COMPARISON								
ASSURANCE OF Pu PRODUCTION								
Facilities	B	B	A	C	C	C	A	B
Process	C	C	B	A	C	C	B	A
ASSURANCE OF U PRODUCTION								
Facilities	A	B	B	B	A	B	B	B
Process	B	A	A	C	B	A	A	C
SAFETY CONSIDERATIONS								
Process	B	B	B	A	C	A	A	B
Waste Disposal	B	B	B	A	C	A	A	B
TIMING CONSIDERATIONS								
Date Estimated Constr. Completion	A	A	A	A	B	A	A	B
U Storage Depleted**	C	B	B	A**	C	B	B	A**
Magnitude Essential Development Work								
Engineering	D	C	B	A	D	B	A	C
Process	D	C	A	B	D	B	A	C
ECONOMIC CONSIDERATIONS								
Potential U Yield	A	A	A	A	A	A	A	A
Manpower Requirements								
Peak (During Metal Recovery)	B	A	C	D	C	A	B	D
Stable (After Metal Recovery)	A	B	C	D	A	B	C	D
Initial Plant Cost	C	C	B	A	D	B	A	C
Ten Year Total Cost	B	C	D	A	D	B	C	A
Uranium Cost for Ten Year Period	A	B	C	D	C	A	B	D
Continued Annual Cost	A	A	B	B	A	A	B	B
Uranium Cost Annual Thereafter	A	A	B	C	A	A	C	B
Potential Decrease of Oper. Cost	B	B	A	C	B	B	A	C
PROCESS CONSIDERATIONS								
Potential Pu Yield	A	A	B	C	A	A	B	C
Simplicity of Operations	B	B	B	A	B	A	A	B
On-Stream Efficiency	A	A	A	A	A	A	A	A
Disruption by Shutdown	C	D	B	A	C	D	B	A
Number of Processes*	A	A	B	A	B	A	B	B
ADAPTABILITY TO CHANGED REQUIREMENTS								
Pu Batch Size	A	A	B	B	A	A	B	B
Pu Production								
Increase	A	A	B	B	A	A	B	B
Decrease	B	B	A	A	B	B	A	A
U Production								
Increase	A	A	A	B	A	A	A	B
Decrease	B	C	C	A	B	C	C	A
Better Decontamination								
Pu	B	B	A	A	B	B	A	A
U	B	A	A	C	B	A	A	C

* In these proposals, UNH is considered to be the final HN product of solvent extraction processes, with fluorination being done at some other site. Fluorination is also, of course, required at Hanford in Proposal 5 for aged waste which is processed entirely via the UAP process. Unit costs for conversion of UNH to UF_6 are included in the economic comparisons.

** In Proposal 11, a two year inventory of in-process uranium is maintained.

Reasons for Preferences

1. Assurance of Plutonium Production

a. Facilities

It is recognized that certain proposals have advantages toward assuring that plutonium production will be uninterrupted by accident, forced shutdown or depreciation to the point of disuse.

In this evaluation the heading is divided into two categories in order to expand and specify the comparisons. Where one proposal may have advantage by having spare plants and facilities another proposal may be preferred because of the nature of the process.

Proposal No. 9 retains one 221 Building as a usable plant for the $BiPO_4$ process. This process will continue in the other 221 Building and therefore the proposal maintains the present "know how". Proposals 5 and 7 do not maintain this "know how" because of the operation of entirely different processes, but do retain usable facilities. In Proposal 11 the present process is undisturbed but in this case no spare facilities will exist as in the case of No. 9. With or without fluorination the preference is therefore in the indicated order in the facilities category.

b. Process

In the process category 11 is rated higher than 9 because the present proved process is retained. It may be argued that 9 also retains the proved aspects of the present process when it is considered that it could with little change operate as the original No. 4 proposal and would then leave the present plutonium process undisturbed. No. 9 and 11 should then be equal. We are, however, retaining in this present evaluation No. 9 as the more economical original S. E.-$BiPO_4$ process of No. 4. With this view we prefer No. 11 over 9 followed by 5 and 7 as the proposals of equal and least preference because an unproved plutonium process is involved in the latter. From the plutonium standpoint fluorination could not change the order of preference.

2. Assurance of Uranium Production

a. Facilities

Proposal 5 is preferred here because it has two methods of recovering uranium. The others with only one method are considered equal. Fluorination does not influence this order of preference in this category.

b. Process

In Proposals 7 and 9 the solvent extraction process for uranium is preferred because a similar process is commercially established. Such can not be said for the UAP process. We, therefore, consider the UAP proposals, No. 11, the least preferable with No. 5 intermediate. With fluorination, we indicate the same order of preference and consider the fluorination of UAP as undemonstrated, while recognizing that fluorinatio[n]

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via UO_2 from UNH, the product of the solvent extraction Proposals 7, 9, and part of 5, as a commercially demonstrated operation.

3. Safety Considerations

a. Process

Proposal 11 is preferred because it avoids the use of the inflammable solvent common to the solvent extraction processes. With fluorination Proposal 5 is least preferred because it has added to it the hazardous fluorination operation. Because of the addition of the fluorination operation Proposal 11 has less preference than the solvent extraction processes of 7 and 9 which have equal and highest preference.

b. Waste Disposal

Proposal 11 is preferred because it has no organic waste disposal problem. Its wastes are held in black iron lined tanks the same as at present. Solvent extraction processes have been designed to use stainless steel disposal tanks. The "foolproof" fabrication (welding) of stainless steel for this service has not been demonstrated. It should be understood that in the Redox processes (solvent extraction) the uncertainty of the materials to be processed determined the decision to use stainless steel for waste storage. This decision has been retained in this evaluation although for highly alkaline aluminum nitrate wastes black iron has been demonstrated in laboratory tests to be satisfactory. Black iron is known to be satisfactory for sodium nitrate solutions (the essential waste of the UAP and $BiPO_4$ processes) but this use should be demonstrated for the UAP wastes in the proposed concentrations which will be saturated alkaline solutions. Fluorination shifts the preference so that Proposals 7 and 9 are preferred over 11 which is considered less safe because of the fluorination operation required for decontamination which involves the added hazard of the disposal of radioactive dusts. Proposal No. 5 is least preferred because it has hazards of both fluorination and solvent processing.

4. Timing Considerations

a. Date Estimated for Completion of Construction

The preference here is also for the process which completes metal recovery at the earliest date.

Without Fluorination Proposal	5	7	9	11
Date Metal Recovery Completed	Feb.'58	Sept.'57	Sept.'57	Sept.'54
Preference	C	B	B	A*

With Fluorination Proposal	5	7	9	11
Date Metal Recovery Completed	Feb. '59	Sept.'57	Sept.'57	Mar.'57
Preference	C	B	B	A*

*In Proposal 11 the early completion date reflects the time gained by the lower volume of uranium recovered in view of the maintenance of a two year inventory of active metal for aging to reduce activity. If at any time the $BiPO_4$ process is stopped, it will require an additional 1.2 years for the UAP process operating at 5 tons per day (uranium basis) to consume the stored, aged material.

c. Magnitude and Status of Essential Development Work

It is recognized that all proposals require essential development work in the engineering and processing before any of the proposals reach the production stage. Those proposals having the least magnitude of development work are preferred.

1) Engineering Development Required on Equipment Selection and Design

Proposal 11

(a) Solids - liquid separation equipment
(b) pH control equipment
(c) Slurry transfer

Proposal 7

(a) Hot, controlled, metering transfer of fluids
(b) Contactor
(c) Disposal methods for organic wastes
(d) Coating development for concrete
(e) Stainless steel welding development
(f) Feed solution clarification equipment
(g) Other items same as in 11 for feed preparation via the UAP-Metathesis.

Proposal 5

Same as for 7 and 11

Proposal 9

(a) Closed cycle extractor
(b) Hot metering of fluids is less of a problem than in 7
(c) Other problems same as 7 for uranium recovery.

Our preference is for Proposal 11. No. 9 is preferred over 7 because the solvent extraction problems in 7 also apply to plutonium processing which is not the case with 9. No. 5 is least preferred because it has all problems of both 7 and 11. Fluorination adds problems such as dust disposal, remote operation and disposal of dry hot waste to 11 and 5 to lower their preference.

2) Process

Proposal 11

(a) Demonstrate that recycle does not interfere with decontamination
(b) Demonstrate yield
(c) Demonstrate that one UAP precipitation on current acid waste plus two years of aging plus a second UAP precipitation gives the required decontamination obtainable by two years aging of alkaline waste followed by two UAP precipitations.

Proposal 7

(a) Demonstrate material balances
(b) Demonstrate concurrently U and Pu yield, recovery and decontamination
(c) Develop a feed preparation process from aged waste
(d) Investigate mass throughput effects on decontamination and yield
(e) Develop an economical source or process for aluminum nitrate

Proposal 5

Same as 11 and 7 (except feed preparation from aged waste not required in 5).

Proposal 9

(a) Demonstrate closed cycle extractor
(b) Other items of 7 that relate to uranium processing only.

3) Status of Development Work

Experimental facilities are operating on solvent extraction and Redox processes at Argonne and Oak Ridge.

The Oak Ridge pilot plant for UAP investigation will be ready by April 1, 1949. Fluorination investigations have already been made and are being continued.

Process development work on No. 9 is considered to be nearer to completion than any of the others since it is so much like the uranium end of the Redox process which has received considerable attention. UAP still requires study, therefore, 11 is second in preference. Nos. 7 and 5 are of least preference because of the development work which is yet to be done in the plutonium end of these Redox processes.

5. Economic Considerations

On the basis of accumulated costs an economic comparison is shown on the attached graph for the proposals with and without fluorination. The first part of the family of curves indicates the costs accumulated in operating the present $BiPO_4$ plants at the 1.5 metric ton rate. The rapid change in slope in the years immediately following 1950 indicates the expenditure for new construction required by each proposal. The slope from then on to the end of the period for recovering stored wastes remains constant and indicates the costs accumulating during the metal recovery period. At the end of the metal recovery period there is a decrease in the slopes which then remain essentially constant into the future indicating the annual rate of expenditure after the metal recovery job has been completed with production continuing on the 1.5 ton basis. Because annual rates of expenditures are somewhat different for each proposal, at some year the lines will cross at which point the same expenditure will have accumulated for the proposals whose cost curves are intersecting. In cases without fluorination intersecting points are in the future and outside the range of the graph. In the cases with fluorination Proposals 5 and 9 have equal accumulated costs in 1960-1961. Proposals 7 and 11 are equal in about 1963. Specific items of economies for comparison of proposals are discussed below.

a) Potential Uranium Yield

No proposal is considered to have any substantial uranium yield advantage, therefore, there is no preference; they are equally rated.

b) Manpower Requirements

The preferences were based on the manpower requirements. Those proposals with the least requirement were favored.

	Without Fluorination				With Fluorination			
Proposal	5	7	9	11	5	7	9	11
Peak (During Metal Recovery)	1410	1390	1483	1665	1563	1390	1483	1987
Preference	B	A	C	D	C	A	B	D
Stable (After Metal Recovery)	1158	1167	1376	1399	1158	1167	1376	1641
Preference	A	B	C	D	A	B	C	D

c) Initial Plant Cost

The preference in this category was, of course, for the proposal with the cheapest construction costs. The initial plant construction costs exclusive of waste storage were as follows:

	Without Fluorination				With Fluorination			
Proposal	5	7	9	11	5	7	9	11
Cost, in Mega$	62.9	63.0	53.3	36.9	80.5	63.0	53.3	72.2
Preference	C	C	B	A	D	B	A	C

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d) Ten Year Total Cost

The cheapest proposal was preferred according to the following figures:

	Without Fluorination				With Fluorination			
Proposal	5	7	9	11	5	7	9	11
Ten Year Cost in Mega $	238.6	246.6	250.0	213.2	292.0	287.1	290.5	278.6
Preference	B	C	D	A	D	B	C	A

e) Ten Year Cost of Uranium

In this category it should be noted that the cost per pound of uranium includes the plutonium cost. The lowest cost proposal was preferred.

	Without Fluorination				With Fluorination			
Proposal	5	7	9	11	5	7	9	11
Ten Year Cost in $ per lb.U	7.89	8.15	8.26	8.39	9.65	9.49	9.60	10.96
Preference	A	B	C	D	C	A	B	D

It should be also noted that in the ten year period proposal 11 has not recovered as much uranium as has been recovered by the other proposals, 11,560 metric tons versus 13,750. (See also Item b, under Timing Considerations).

f) Continued Annual Cost

The proposal with the lowest annual cost after the metal recovery assignment has been completed was the preferred proposal.

	Without Fluorination				With Fluorination			
Proposal	5	7	9	11	5	7	9	11
Annual Cost in Mega$	15.3	15.3	17.6	17.7	18.9	18.9	21.2	20.75
Preference	A	A	B	B	A	A	B	B

g) Annual Cost of Uranium After Aged Waste Recovery

Here again as in Item e above the cost per pound of uranium makes no allowance for the cost of plutonium. The lowest cost proposal was preferred.

	Without Fluorination				With Fluorination			
Proposal	5	7	9	11	5	7	9	11
Annual Cost in $ per lb. U	6.35	6.35	7.30	7.34	7.84	7.84	8.80	8.60
Preference	A	A	B	C	A	A	C	B

h) Potential Decrease in Operating Cost

Proposal 9 was considered to have the greater potential for decrease in operating cost. By this it is not meant that it will have the lowest cost. Proposal 7 and 5 also have potential for cost reduction but these are already lower cost processes. The opportunity for major cost reduction therefore favors 9 particularly from the standpoint of plutonium processing. The possibility of eliminating the third uranium cycle is also greater in the case of 9 because of the better condition for decontamination in the first cycle in comparison with the first cycle in the Redox systems.

[redacted]

6. Process Considerations

a. Potential Plutonium Yield

Solvent extraction processes were considered to have the greater potential for attaining the highest yield. The order of preference therefore favored 7 and 5 followed by 9 which retains some advantage in potential yield via the closed cycle extractor to achieve concentration of the plutonium into a smaller volume which should assist in yield improvement in the $BiPO_4$ process. Fluorination does not, of course, change the rating in this category.

b. Simplicity of Operation

Because of the batch operation and the "common know how", proposal 11 is favored. The other proposals are rated equal. Fluroination makes 5 and 11 less attractive with 7 and 9 favored equally.

c. On-Stream Efficiency

With the conception that "on-stream efficiency" is the ratio of batches processed to batches possible to process in a given time or the time "on-stream" to total time, it was considered that our batch processes were comparable with continuous processes. All proposals are rated equal with no preference including the situations with fluorination.

d. Disruption by Shutdown

Batch processes were considered to be less disrupted by shutdown than the continuous extraction processes of proposals 5, 7, and 9. Proposals 7 and 5 having solvent extraction processes on both uranium and plutonium streams were least favored but with 5 having the advantage with two separate means for uranium recovery. The order of preference is not altered by including fluorination.

e. Number of Processes

The preference favors the proposal with the least number of kinds of operations at this site.

	Without Fluorination				With Fluorination			
Proposal	5	7	9	11	5	7	9	11
Number of Processes	2 { Sol.Ext. UAP	2 { Sol.Ext. UAP-Met.	3 { Sol.Ext. $BiPO_4$ UAP-Met.	2 { $BiPO_4$ UAP	3 { Sol.Ext. UAP Fluorn.	2 { Sol.Ext. UAP-Met.	3 { Sol.Ext. $BiPO_4$ UAP-Met.	2 { $BiPO_4$ UAP-Met. Fluorn.
Preference	A	A	B	A	B	A	B	B

7. Adoptability to Changed Requirements

It is recognized that some proposals may have advantages of adoptability or flexibility toward new conditions which might appear. For example, process preference is certain to exist in a case where production increase is required, where production decrease is required or where better decontamination of either product is required.

[redacted]

a. Plutonium Batch Size

Solvent extraction processes are not batch and can be varied by rate of throughput or time of hold-up in tanks between stages. Proposals 5 and 7 were preferred over the batch plutonium processing of proposals 9 and 11. Fluorination does not apply to this category.

b. Plutonium Production

1) Increase

Solvent Extraction, continuous processes were preferred because they are more adaptable than batch processes by reason of flexibility in throughput range particularly under conditions of increased throughputs. Fluorination does not apply to this category.

2) Decrease

Batch processes are favored under conditions of decreased production because production would be reduced simply by processing a smaller number of batches per day. In continuous extraction processes the performance of columns, for example, favors high throughputs. Reduced throughputs result in higher HETS values and thus tend toward lower recovery of product. To compensate, chemical consumption per unit of plutonium would have to be increased; thus introducing additional control requirements and possible yield losses. Fluorination does not apply to this category.

c. Uranium Production

1) Increase

As for plutonium above, solvent extraction, continuous processes were favored. Fluorination does not change the order of preference.

2) Decrease

As for plutonium above, batch processes were favored. Fluorination does not change the order of preference.

d. Better Decontamination

1) Plutonium

Because of present "know how" plutonium decontamination via the present batch processes considered more favorably. Fluorination does not apply to this category.

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2) Uranium

Solvent extraction processes were considered to have greater adaptability toward increased decontamination than the batch UAP process which already requires a final fluorination step to yield a satisfactorily decontaminated product. The order of preference is not altered by the situations including fluorination.

Revisions to Document HW-12496

Some of the economic factors used in this document do not agree with those presented in HW-12496. Corrections in the data of that document should be made as follows:

Under Proposal 11 (Fluorination at HW)

The Waste Storage figure	13,700,000	should be changed to	17,900,000
The Construction Cost Subtotal figure	85,900,000	then becomes	90,100,000
The Grand Total (UF_6) figure	274,400,000	then becomes	278,600,000
Total Cost, dollar per lb. U figure	10.79	then becomes	10.96

The Annual Cost; 1959 and thereafter

Waste Storage Cost figure	1,400,000	should be changed to	1,850,000
Grand Total Figure	20,400,000	then becomes	20,750,000

Under Proposal 11 (Fluorination Step Omitted)

The Waste Storage figure	13,700,000	should be changed to	17,900,000
The Construction Cost Subtotal figures	50,600,000	then becomes	54,800,000
The Labor, Repair Power figures	73,600,000	should be changed to	72,300,000
The Security, overhead figure	62,600,000	should be changed to	61,300,000
The Operating Cost Subtotal figure	158,000,000	then becomes	156,600,000
The Grand Total (UF_6) figure	211,400,000	then becomes	213,200,000
The total cost, dollar per lb. U figure	8.31	then becomes	8.39

The Annual Cost; 1959 and thereafter

Waste Storage Cost figure	1,400,000	should be changed to	1,850,000
Operating Cost figure	16,000,000	should be changed to	15,480,000
Grand total figure	17,900,000	then becomes	17,700,000

For all proposals the Annual Cost; 1959 - Total Cost, dollars per lb. U should be changed as follows:

	(Fluorination at HW--)					(Fluorination Step Omitted)				
Proposal	1	5	7	9	11	1	5	7	9	11
HW-12496 figure	5.46	4.70	4.70	5.28	5.08	4.70	3.81	3.81	4.39	4.47
Revised figures	9.09	7.84	7.84	8.80	8.60	7.84	6.35	6.35	7.30	7.34