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MULTIPLE FUEL PROCESSING AT THE PUREX PLANT

By

J. B. Kendall, R. W. Lambert and S. M. Nielson

Purex Process Engineering
Research and Engineering
Chemical Processing Department

November 26, 1963

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RICHLAND, WASHINGTON

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PRELIMINARY STUDY OF
MULTIPLE FUEL PROCESSING AT THE PUREX PLANT

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I. INTRODUCTION

Processing of multiple types of irradiated fuel elements in Purex has been proposed to the Atomic Energy Commission as a means of realizing significant savings in overall CFD operating costs for weapons programs and permitting release of the Redox plant for non-weapons programs⁽¹⁾⁽²⁾⁽³⁾. The process and equipment requirements for implementing a multipurpose operations program have been under study in both plant and laboratory programs for processing slightly enriched Zircalloy-clad uranium metal fuels and plutonium-aluminum metal alloy fuels.

The purpose of this document is (a) to present the results of a preliminary engineering study on the processing of irradiated NPR, E-Metal, D-Metal, and normal uranium fuels and FRER and Pu-240 plutonium-aluminum alloy fuels and (b) to provide process flowsheets as the basis for scope design of a project for increasing processing flexibility at Purex.

II. SUMMARY

Campaign processing of NPR, E-Metal and D-Metal uranium fuels and FRER and Pu-Al alloys in addition to normal metal at the Purex plant is feasible. Flowsheet and equipment modifications, however, are required to (a) meet nuclear safety standards, (b) provide processing capabilities for the Zirflex process, and (c) segregate the various product streams between processing campaigns.

The flow diagrams, flowsheets and equipment requirements presented in this preliminary study are based on the following assumptions:

1. The U²³⁵ enrichment does not exceed 2.0 weight per cent and the plutonium concentration in irradiated uranium does not exceed 1500 grams per ton.
2. The metals processed do not contain a plutonium oxide mixture. Fuels exceeding 1.3 weight per cent plutonium will be handled on a batch basis for critical mass control.
3. Adequate storage facilities are available for storing FRER fuels for 1-1/2 years.
4. The conversion of the prototype IWW Sugar Denitration System to a production facility is completed in a separate program, and the facility will not limit the plant processing capacity for normal, E-Metal, D-Metal and NPR metals.
5. The batch TIA process for recovery of plutonium and neptunium from Purex IWW has been demonstrated and incorporated in the Purex plant.

6. The E-Cell Package modifications providing plutonium product and rework storage facilities are completed in a separate program.
7. The Redox silica gel and uranium storage facilities are available for back-up decontamination and segregation of Purex uranium products.
8. The U₃ and Z-Plant processing and storage capacities do not seriously limit the Purex plant processing rate or the length of a Purex processing campaign.
9. The U₃ plant has adequate storage facilities for segregating recovered nitric acid and rework solutions from the various uranium products without limiting the Purex plant processing rate or the length of a Purex processing campaign.

In these bases, the Purex plant requires the following modifications to permit campaign processing of NPR, E-metal, Z-metal, FRER, Pu-Al alloys and normal metal:

1. Purex basin modifications that permit storage of NPR and FRER fuel element canisters.
2. Annular-type dissolvers that may be adapted to various levels of U²³⁵ enrichment and MWDE exposure and capable of handling long elements such as FRER fuels.
3. Dissolver off-gas facilities suitable for the dissolution of aluminum, zirconium, uranium and Pu-Al alloys.
4. Make-up and storage facilities for handling aluminum nitrate, ammonium fluoride-ammonium nitrate, and uranium tetrafluoride metathesis solutions.
5. E-Cell modifications to (a) permit recovery of uranium from Zirflex decladding and metathesis solutions, (b) control the ammonia gas evolved during neutralization of Zirflex decladding solutions, and (c) handle the solids associated with neutralized Zirflex decladding, metathesis waste, and Zirflex decladding solutions.
6. A storage vessel for segregating 3WE materials between processing campaigns.
7. Geometrically favorable sumps for critical mass control. In addition, modifications to the N-Cell Hood Sump are required to meet nuclear safety requirements at high processing rates or high MWDE exposures.
8. A geometrically favorable 2AF Tank and associated routings that permit processing plutonium rework, plutonium recycle, and E-Cell Backcycle material via the 2AF Tank, and a routing to recycle the IBSF stream to the 1BKF Tank.

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9. Uranium concentrator controls to eliminate the over-concentration or partial dehydration of enriched uranium solutions.
10. Instrumentation and piping changes to monitor for over-concentration of plutonium by reflux or precipitation in geometrically unfavorable equipment.
11. Routings that permit bypassing unnecessary and geometrically unfavorable equipment when processing FRER, Pu-Al alloys and E-metal.

III. DISCUSSION

A. E-Metal Processing

Processing of E-metal clad in aluminum at the Purex plant requires no changes to the existing process systems except those modifications and additions required for critical mass control. NPR metal requires more stringent critical mass controls than E-metal because of the higher MWD/E exposure and probably higher 235 concentrations. Since the processing of E-metal introduces no requirements exceeding those associated with NPR and normal metal, further discussions of E-metal needs are incorporated in NPR program needs.

B. Purex Storage Basin

The NPR and FRER fuel elements will be shipped in aluminum canisters according to present plans. The NPR canister has a total height of about 6 feet, and the overall height of the FRER canister is about 9-1/2 feet. In the future, it is anticipated that the aluminum canisters may be discontinued and returnable stainless steel canisters used in their place. However, it is unlikely that the dimensions of the aluminum and stainless steel canisters will differ due to the loading techniques at N Reactor and the length of the FRER elements.

The new fuel element shipping canisters cannot be stored in the Purex storage basin. To assure continuity of operation during a processing campaign, the Purex storage basin must be modified to allow storage of NPR and FRER canisters as well as the standard slug bucket.

C. Dissolver Charging

The length of the NPR and FRER elements requires modifications to the existing Purex charging techniques. The NPR and FRER elements are about 2 feet and 8 feet long, respectively. Dumping the FRER elements is of course impossible, but it may be feasible to dump NPR elements into an annular dissolver up to 235 enrichment of about 1.5 per cent. Tests are to be conducted in the near future to determine the feasibility of dumping NPR elements. Until these data are available, it must be assumed that the NPR elements will be charged in an aluminum canister. Provisions should be made, however, to allow dumping of NPR canisters in the future. The dissolver annulus will be large enough to permit dumping of the standard 8-inch normal uranium and 6-inch E-metal elements, but charging via a charging chute is impractical because of

the problems associated with (a) storing the dissolver chutes during NPR and FRER campaigns, (b) assuring uniform element distribution around the dissolver annulus, and (c) assuring the elements are always covered during processing. Dumping normal and E-metal directly into the annulus without a dissolver chute will also present problems associated with distribution unless several dumping stations are used.

D. Dissolver Annulus

The Purex plant may be required to process fuels with widely different critical masses. For this reason, the dissolver should be designed to allow varying the dissolver annulus to provide a geometrically favorable vessel over the maximum range possible and still provide a satisfactory dissolver capacity for normal uranium and E-metal. In Table I are shown the dissolver annuli required for the proposed Purex annular dissolver with an annulus outside diameter of 84 inches. No allowance was made in Table I for the use of gadolinium stainless steel crib since corrosion and critical mass tests are not completed.

TABLE I(17)

<u>Wt. % U235</u>	<u>Annulus Width Inches</u>
0.95	12.0
1.30	7.6
1.50	6.4
1.75	5.5
2.00	5.0

E. Aluminum Dissolution

The dissolution of aluminum by sodium hydroxide in a sodium nitrate medium is used in the Purex plant for removing the cladding from normal uranium fuel elements. The same technique will be used to remove the cladding from E-metal and dissolution of the NPR and FRER aluminum canisters. A flow diagram and flowsheet for the dissolution of NPR aluminum canisters are shown in Figures 1 and 7. The same flow diagram will be used for FRER canisters and aluminum clad elements, but the flowsheet compositions and flows will differ.

F. Zirflex Process and NPR Processing

The Zirflex process will be used to dissolve the NPR and FRER Zircalloy claddings. The flow diagram and flowsheets proposed for adapting the Zirflex process to NPR processing at Purex plant are shown in Figures 2 through 11, inclusive. This process uses a NH_4NO_3 - NH_3 mixture to dissolve zirconium (4)(5)(6)(7)(8)(9). A large quantity of ammonia (5 moles/mole of Zy) and a small amount of hydrogen (0.1 moles/mole of Zy) are produced by the dissolution, along with a small amount of insoluble uranium tetrafluoride. The rate of zirconium dissolution is dependent on several factors of which the ammonia concentration (or pH) in the dissolvent is of major importance. In order to maximize the zirconium dissolution, the ammonia must be removed. The most efficient and practical method of removing ammonia is by steam stripping. This can

be accomplished by boiling the dissolver and adding make-up water or by steam sparging a gently boiling dissolver. The latter technique is recommended for the Purex plant dissolvers.

G. Zirconium Dissolution Rate

The dissolution rate of zirconium is increased by increasing the NH_4F concentration and temperature. Above about 5.5 M NH_4F , however, the dissolution path passes very near the $(\text{NH}_4)_2\text{ZrF}_6$ solubility limit and there exists the danger of forming a precipitate which would coat the zirconium surface⁽⁷⁾. Therefore, at the Purex plant, a 5.5 M NH_4F -0.5 NH_4NO_3 solution will be used for dissolving the tube-in-tube type NPR elements. For Purex conditions, the maximum penetration rate is expected to be about 16 mils per hour and the average integrated rate should be 4 mils per hour⁽⁴⁾⁽⁵⁾⁽⁶⁾⁽⁸⁾⁽⁹⁾. However, for other Zircalloy-clad fuels, a more dilute solution would be used if the volume of 5.5 M NH_4F -0.5 M NH_4NO_3 required to dissolve the zirconium ($\frac{\text{NH}_4\text{F}}{\text{Zr}}$ mole ratio = 7) did not cover the elements.

H. Zirconium Solubility

The solubility of the zirconium complex depends on the free fluoride concentration, ammonium ion concentration and temperature⁽⁴⁾. In the case of dissolving NPR Zircalloy cladding at the Purex plant, the zirconium complex will precipitate upon cooling unless the solution is adequately diluted.

I. Ammonia Scrubbers

The ammonia gas in the dissolver off-gas from the Zirflex and the dissolution of aluminum processes must be removed to prevent the formation of NH_4NO_3 crystals and to control ammonia explosive hazards in the Purex off-gas system. Ammonia scrubbers are presently installed in the Purex plant, but the hydraulics of the ammonia scrubber system are not adequate for the Zirflex process. At present, the dissolver off-gas is routed through a down-draft condenser and the condenser condensate is routed to the dissolver. With the Zirflex process, either the down-draft condenser must be operated above 100° C to prevent returning ammonia to the dissolver or the down-draft condensate must be rerouted. For the Purex plant, it is recommended that the condensate be rerouted during zirconium dissolution and combined with the ammonia scrub waste water in a catch tank before discharge to a crib. This technique has the additional advantage of reducing the heat and vapor load on the ammonia scrubber.

J. Dissolver Off-Gas Hazards

Hydrogen and ammonia can form explosive mixtures. The hydrogen produced by the dissolution of zirconium is quite small as long as NH_4NO_3 concentration is ≥ 0.5 M and can be diluted below the lower explosive limit with air. The ammonia gas generated, however, is too large to dilute with air at the Purex plant. Since the ammonia is removed from the dissolver off-gas by the ammonia scrubber, an explosive mixture can only occur between the dissolver and the ammonia scrubber. Generally, an explosive mixture 12 to 27 per cent NH_3 when in an air stream saturated

with water vapor, (10) will only occur in the down-draft condenser because the ammonia concentration is increased to an explosive mixture by the condensation of the water vapor. However, during high zirconium dissolution rates, an explosive mixture could also occur in the dissolver and the dissolver off-gas system because sufficient steam dilution cannot be obtained to compensate for the high reaction rate. An ammonia-air-water vapor mixture is not explosive, however, as long as the gas mixture is above 45° C (113° F). Thus in order to prevent an ammonia explosion, the vapor in the dissolver and down-draft condenser will be maintained above 45° C during the dissolution of zirconium.

K. Uranium Tetrafluoride Metathesis

During the dissolution of zirconium, some uranium will react with the zirconium dissolvent to form insoluble uranium tetrafluoride (4). At present, data regarding the characteristics, and the quantity of uranium tetrafluoride formed are not clearly defined, but it appears that about two per cent of the uranium metal for the NPR tube-in-tube element will form uranium tetrafluoride and essentially all of this material will remain as a coating on the dissolver and fuel element surfaces (6). The fluoride that remains in the dissolver is of concern to the Porex plant because aluminum must be added to complex the fluoride and reduce the corrosion rates of stainless steel processing equipment. The addition of aluminum to the process in turn will affect the performance of the HA Column, increase the LWW flow, and complicate the Waste Management Program. For these reasons, it is essential that the fluoride in the HAF be reduced to a minimum. Techniques for removing the fluoride from the dissolver are being studied in the laboratory and pilot plant tests will be made to confirm laboratory data and check scale-up factors. For purposes of this presentation, it was assumed that 80 per cent of the uranium tetrafluoride could be metathesized in the dissolver by contacting with 2.0 M NaOH (11). However, removal of the uranium tetrafluoride with a rinse solution and subsequent precipitation of the uranium for recovery may prove to be better processing technique. Regardless of the technique selected, it does not appear that the equipment and routing requirements will differ from those required by the metathesis or the rinse methods. The flow diagram and flowsheet for the metathesis operation at the Porex plant are shown in Figures 2 and 9.

L. Metathesis and Deccladding Wastes

The zirconium deccladding waste and the metathesis waste solutions will contain recoverable quantities of insoluble uranium tetrafluoride and uranium diuranate. These can be recovered by centrifuging the waste solutions. The uranium tetrafluoride collected in the centrifuge from the zirconium cladding solution can be metathesized in the centrifuge to remove the fluoride. The two waste solutions, however, should not be mixed before centrifugation as the zirconium would precipitate and ammonia gas would be generated.

Neutralization of the zirconium deccladding waste solution will generate a substantial quantity of ammonia gas and produce a large volume of precipitate. The ammonia gas from the neutralization operation must

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be removed to prevent accumulation of ammonia gas and ammonia nitrate crystals in the Purex plant vent system.

The flow diagram and flowsheet for the handling of the zirconium de-cladding and metathesis waste solution are shown in Figures 2 and 10. It should be noted that the E-Cell facility has been provided with a separate vent header. While this is preferred, a separate vent system for the neutralization tank (EK-E5) probably will suffice. In the flowsheet, the uranium tetrafluoride recovered from the zirconium de-cladding waste is metathesized with the metathesis waste solution in order to remove the fluoride. In addition, the metathesis waste is used to flush the line from EK-E5 to UGS (underground storage) and to complete the neutralization of the zirconium de-cladding waste solution (pH increased from about 9 to 10). A slurry pump is shown for transferring the zirconium de-cladding waste to UGS, however, a steam jet that will produce Reynolds numbers in excess of 2500 in the jet suction and UGS line should suffice⁽⁴⁾. Since solids will be present in Tanks D1, D2, E3 and E5 and small volume flushes are desired between the de-cladding and metathesis processes, the installation of the standard Purex agitator is not recommended for these vessels. The special type agitator presently installed in EK-E3 should be adequate for service in Tanks D1, D2, E3 and E5.

M. Feed Preparation and Fluoride Corrosion

The dissolution of NFR metal will be handled in the same manner as the dissolution of normal and E-metal except that a uranium heel will not be left in the dissolver. The uranium heel is removed as this would complicate charging the NFR canisters and would substantially increase the quantity of uranium tetrafluoride formed during zirconium dissolution. The flow diagram and flowsheet for the dissolution of NFR uranium is shown in Figures 3 and 11. It should be noted that all the dissolvers are routed to the same UMF feed tank, and the aluminum nitrate is added to the HAF Butt Tank. Both of these techniques are used to produce a uniform feed composition. If the aluminum nitrate must be added to the dissolver to reduce fluoride corrosion, it will be difficult to maintain a reasonable constant salting concentration in the HAF stream and this in turn would complicate control of the HA Column. Tests are presently in progress to determine the feasibility of eliminating the aluminum from both the dissolver and the HAF solutions⁽⁴⁾. At present, it is planned to add the aluminum to the HAF stream, but depending on the HA Column performance, it may be more desirable to add all or a large portion of the aluminum to the IWF (EK-F12). For this study, it was assumed that three moles of aluminum per mole of fluoride will be adequate to prevent excessive corrosion in the IWF Concentrator, however, no data are as yet available for the fluoride concentrations anticipated⁽¹¹⁾.

N. IWF From Zirflex Process

The IWF flow will increase as the aluminum concentration in the IWF increases. The maximum IWF aluminum concentration permissible in the IWF is about 1.0 M. For practical purposes, the IWF flow can be approximated by the following equation:

$$\text{IWF Relative Flow} = 6.0 + (\text{IWF Relative Flow})(\text{M Al in IWF})$$

where 100 flows = 720 gallons/ton

No laboratory difficulties were experienced in sugar denitration tests of Purex IWW spiked to 1.1 M Al. Above this concentration, precipitation was noted in the spiked IWW and the volume of precipitate increased during sugar denitration(12).

O. Turnaround Between Campaigns

For the Purex plant to segregate adequately various kinds of plutonium and uranium products and still maintain a satisfactory overall processing rate, an additional storage tank for rework and/or 3WB solution is required. Using this new tank and the E-F11 Concentrator in addition to periodic use of Tanks E3, E5, E6 and F8, the Purex plant could satisfactorily segregate normal, NPR and E-Metal rework solutions (See Figure 6). Occasionally, however, even with all these vessels, process problems could still occur which would require either downgrading products or loss of production time. Without an additional storage tank, routine downgrading is required unless (a) uranium product is recycled until essentially all the plutonium and uranium are removed from the plant streams, primarily the 3WB, and (b) the neptunium is not recovered from the 3WB stream. Eliminating the uranium from the 3WB would cause a loss of neptunium to the uranium product. If the neptunium is made to follow the HAW stream and is recovered by TLA extraction of the IWW, then the feasibility of removing the plutonium and uranium from plant streams is more attractive. However, this method would only be attractive if the Purex plant production load would permit an increase in turnaround time between processing campaigns.

With existing information, it is not possible to fix a definite downgrading cost if the new tank is not provided. Assuming that NPR fuel is 0.947 percent enriched and the exposure is 2000 MWL/T, then the annual downgrading cost for two NPR campaigns a year would be a minimum of about \$80,000 per year when blended with normal Purex uranium product. The calculations assumed a normal 3WB uranium inventory of about 4000 pounds. The annual downgrading cost when blended with E-Metal would be greater for the 2000 MWD/T case.

The potential downgrading costs certainly warrants the consideration of additional storage. Although the problem of installing an additional tank has not been thoroughly studied, it appears a tank can be provided by (a) splitting the F10 Tank or stacking two tanks in the F10 position, (b) freeing-up the F12 Tank by using the HAC Tank (TK-32) for the IWF Pump Tank, (c) freeing-up the F12 Tank by routing the HAW stream either directly or via TK-F14 to the IWW Concentrator (E-F6), or (d) splitting the F7 Tank for IWF and IWW service. With existing process knowledge and future Purex plant plans, the technique of adding HAW to the IWW Concentrator via TK-F14 using TK-F14 either as a decanter or IWF Pump Tank is attractive from a process viewpoint.

P. Purex Plutonium Capacity

With present information, it is difficult to determine whether or not the Purex plant will be dissolver limited or plutonium limited when processing NPR fuels. With NPR fuels exposed to 2000 MWD/T, the Purex plant will probably be plutonium limited by the XCP Concentrator (E-N6). The E-N6 Concentrator is presently limited to about 25 Kgs of plutonium per day.

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If the processing rate becomes limited by the XCP Concentrator, additional concentrator capacity will be provided by routing part of XCP stream to the L-Cell Package Concentrator (E-14).

Q. Zirflex AMU and Chemical Storage Facilities

The Zirflex process will require additional chemical storage and make-up facilities for the NH_4F - NH_4NO_3 , ANN, and metathesis solutions. Adequate tanks and headers are available (see Figure 4), but some make-up, scheduling and shipping problems are involved.

The Purex plant has two outside storage tanks, TK-342 and TK-10, that are not in service. TK-342 and TK-10 are both jacketed for temperature control and have storage capacities of 8000 and 4000 gallons, respectively. TK-105, TK-205, TK-206 and TK-219 have capacities of 3000, 750, 750 and 80 gallons, respectively. These tanks and associated headers will be available when the Purex plant is not needed for fission product recovery.

These tanks and headers may be utilized in several ways to handle the additional chemical storage and make-up facilities required for the Zirflex process. The scheme shown in Figure 4, however, is the only method that does not require the installation of additional tanks. The disadvantages of this scheme are (a) the ANN storage tank (TK-10) is smaller than required for an NPR Campaign, and for this reason, ANN shipping schedule problems may be encountered, (b) the ANN butt tank (TK-219) capacity is smaller than required for a HAF make-up. The addition of several batches of ANN from TK-219 to a batch of HAF could lead to make-up errors, (c) the storage of rather large quantities of solid ammonium fluoride and ammonium nitrate are required, (d) an average of 2.5 NH_4F - NH_4NO_3 make-ups are required per day at a capacity factor of 3.0 for NPR fuels; these make-ups will require handling about 7 tons of solid chemicals per day and (e) TK-10 may be needed for TIA storage in the near future.

Redox has purchased a concentrated NH_4F - NH_4NO_3 solution offsite. For the proposed Purex Zirflex process, this solution would be diluted by a factor of two. Based on a 300-ton NPR campaign, a storage tank with a capacity of 40,000 gallons would be required unless shipments could be rigidly scheduled or the railroad tank cars were used for storage during a 15-day campaign.

A larger ANN feed tank or additional tanks for chemical storage make-up could be acquired by continuous make-up of the 2AS stream (0.75 M HNO_3). By this technique, either TK-211 and/or TK-212 (700 gallons each) could be made available for other service.

R. Critical Mass Considerations

Purex can safely process enriched uranium containing up to 2.0 per cent U^{235} exposed to 2000 MWD/ton without changing the basic Purex flowsheet (TBP concentration in the solvent or feed uranium concentration). At enrichments greater than 2.0 per cent, the "always safe" solution concentration limit of U^{235} is reached in the dissolvers and uranium concentrators. Although this "always safe" concentration is conservative because it does not allow for the poisoning effects of U^{238} and nitrate, it is felt that this is a reasonable basis for establishing the concentration control limit.

To implement processing of uranium with up to 2.0 per cent U^{235} will require some changes in Purex equipment, instrumentation and operating practices. These changes are summarized as follows:

- (1) Install Multipurpose Annular Dissolvers with Capability of Dissolving up to 2.0 per cent U^{235}

To accommodate greater than 0.94 per cent U^{235} and still maintain adequate throughput rates for natural and normal E-Metal will require a dissolver design which provides for varying the size of the charging annulus.

- (2) Revise Critical Mass Control Specifications using "Concentration Control" as the Basis

When processing uranium of 0.94 per cent U^{235} or greater, it is no longer possible to operate the Purex plant such that for the case of precipitation, an "always safe" ratio of U^{238} to fissionable material is present. A new basis for assuring criticality control is therefore required.

- (3) Adopt Administrative Controls and the use of "Nuclear Blanks" to Insure that Precipitating Agents are not added to Uranium or Plutonium Solutions

Because "concentration control" does not provide safety should precipitation occur, the possibility of precipitation must be eliminated as far as practically possible.

- (4) Install a Geometrically Favorable EK-35

The present Purex flowsheet routes all plutonium-bearing wastes along with the majority of the plutonium rework back through the first decontamination cycle. This manner of operation creates extreme fluctuations (up to a factor of 2) in the plutonium content of the most sensitive control area, the EBX Column, and would seriously limit the credibility of maintaining adequate concentration control. Routing the two largest and unpredictable plutonium streams, the XAW-XSW and Pu rework, to a critically safe EK-35 downstream of the EBX Column would eliminate this problem.

- (5) Install Neutron Monitors and an Additional Liquid Level Detector on E-38 and E-34

At enrichments of greater than 0.94 per cent U^{235} , over-concentration in the uranium concentrators could result in reaching the "always safe" solution concentration limit of U^{235} . To provide adequate protection against over-concentration, the present instrumentation should be supplemented with an additional liquid level dip tube to measure the liquid level near the overflow and a neutron monitor adjacent to the concentrator to monitor the U^{235} concentration within the concentrator.

- (6) Install Duplicate Flow Measuring Instrumentation and/or Flow Alarm Systems on Critical Process Streams

To protect against excessive reflux of plutonium in the EBX and EBS

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Column, it is essential that the flow of the streams which affect the amount of reflux be accurately known and not subject to instrument failure. Such flows, IBX, IBXP and IBP, should be equipped with a back-up flow measuring system. Other process streams which have a bearing on maintaining adequate criticality control should be equipped with simple alarm systems to indicate loss of flow. These include the ICX, 2EX, IBXP-HNO₃ and 2AF-NO₂ streams.

(7) Modify J-Cell and K-Cell Shallow Sumps such that they are Always Safe

Plutonium rework and waste solutions are to be added to a geometrically safe TK-35 and therefore any leaks in the J-Cell nozzle connections or in the trench lines running past K-Cell would allow highly concentrated plutonium to reach the sumps. Other canyon sumps, although of concern, do not absolutely require modification based on the fact that the contents of vessels in the cells may not exceed the concentration control limit at which the sumps are safe. At this concentration, the shallow sumps would be safe even for the case of precipitation.

(8) Modify N-Cell Hood Sump to allow for up to 20 Grams per Liter Plutonium Concentration in TK-N1

The plutonium concentration of TK-N1 is now limited by the sump based on the assumption that TK-N1 may fail and its contents be dropped to the floor. Current plant operation occasionally approaches the present concentration limit and with the expected doubling of plutonium concentration from NPR processing, the plant capacity would be limited.

(9) Install Administrative Controls over Caustic Addition to Dissolvers and F-Cell Vessels

Certain tanks, such as dissolvers and TK-F18, are used such that caustic additions are routinely made. The systems must be controlled such that caustic additions are not made when unsafe amounts of dissolved uranium and plutonium are present in the tanks. A possible solution, not solely dependent upon administrative controls, would be to install small secondary addition tanks such that the volume of caustic which might be accidentally added would not precipitate uranium in excess of the safe amount.

S. PRTR Processing

The processing flow diagram for PRTR and Pu-Al alloy materials is shown in Figure 12. The flowsheet is not presented in this report since basically the same technique is used for preparing the feed from PRTR fuels as is used for NPR fuels. The Purex plant flowsheet is modified slightly to separate and decontaminate the uranium and plutonium. Since the production load is small and segregation problems are more difficult, unneeded equipment or equipment difficult to flush are bypassed. For the same reason, the 2AW, 3AW and IBU plutonium losses are not backcycled directly, but with the flowsheet used, these losses will be extremely small. However, even these small neptunium and plutonium losses are recovered and recycled via TLA extraction. The depleted uranium is processed through the Second Uranium Cycle in order to permit burial of the depleted UNH in the desert. Disposal of the depleted UNH by this method is not as costly as disposal to Coating Waste Storage.

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The processing of PRTR fuels containing a plutonium oxide mixture was omitted from this study since the dissolution process and associated corrosion problems are not adequately defined for irradiated plutonium oxides. Based on preliminary dissolution and corrosion studies of unirradiated plutonium oxide mixtures in a concentrated nitric acid medium containing fluoride, the 304L multipurpose Purex dissolver would be satisfactory for processing the PRTR production load on a once per year campaign basis. However, since the dissolution of irradiated plutonium oxide mixtures may differ substantially from the unirradiated species, the feasibility of using the Purex dissolvers has not yet been established.

T. Pu-Al Alloy Processing⁽¹³⁾⁽¹⁵⁾

The aqueous feed solution from Pu-Al alloys will be processed in exactly the same manner as PRTR fuels except the ICU stream is also routed to TK-F10. Preparing the feed solution will require dissolution of the Zircalloy cladding followed by a mercury catalyzed nitric acid dissolution of the Pu-Al alloy. Since hydrogen will be generated during the Pu-Al dissolution, the Purex annular dissolver off-gas system should be provided with a means for measuring hydrogen concentrations⁽¹⁶⁾.

U. D-Metal Processing⁽¹³⁾⁽¹⁴⁾⁽¹⁵⁾

The aqueous feed solutions from D-Metal can be processed in exactly the same manner as PRTR fuels, but the processing rate is small and therefore practical only for extremely small loads (~ 3 tons). For larger loads, the D-Metal will be processed as shown in Figure 13. Except for minor modifications to minimize IBU, 2AW and 3AW plutonium losses, to compensate the HA Column flowsheet for omission of the 3WB streams, and to prevent the neptunium from following the uranium and plutonium streams, the Purex plant flowsheet will be used. The extraction of neptunium in the HA Column is prevented by omitting the HAX-NO₂ flow and adding sulfamic acid to the HAF stream. The processing rate for this processing scheme will be limited to about 18 tons per day by the IWW Concentrator. When processing D-Metal as with PRTR and Pu-Al alloy processing, the plutonium and neptunium losses will be recovered and recycled by TLA extraction.

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FIGURE 1
FLOW DIAGRAM FOR ALUMINUM DISSOLUTION

FIGURE 1
PRELIMINARY FLOW DIAGRAM FOR ZINCALLOY DISSOLUTION

Notes:

1. TK-D1, TK-D2, TK-E3, and TK-E5 require special agitator for handling solids.
2. TK-E5 requires a high capacity slurry pump.

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FIGURE 4
PRELIMINARY FLOW IN A FLOW FOR AMM AND CHEMICAL STORAGE

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FIGURE 5
PRELIMINARY DIAGRAM FOR PLUTONIUM REWORK AND RECYCLE

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FIGURE 6
PRELIMINARY FLOW DIAGRAM FOR 3WB TURNAROUND AND REWORK

Notes:

1. TK-E6 is available for storage while processing NPR metal.
2. TK-E3 and E5 are available for storage while processing E and normal metal.

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FIGURE 7
PRELIMINARY FLOWSHEET FOR THE DISSOLUTION OF ALUMINUM CANISTERS

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FIG. 8
PRELIMINARY FLOWSHEET FOR THE DISSOLUTION OF ZIRCONIUM CLADDING

Notes:

1. Based on a maximum Zy penetration rate of 16 mils per hour.
2. Based on an integrated average Zy penetration rate of 4 mils per hour.
3. Numbers in lines show processing sequence for batch operations.
4. Five percent jet dilution assumed for steam jet transfers.

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FIGURE 2
PRELIMINARY FLOW SHEET FOR THE METATHESIS OF URANIUM TETRAFLUORIDE

- Notes:
1. Based on 80% conversion of UF_4 during metathesis.
 2. Numbers in lines show processing sequence for batch operations.
 3. Five percent jet dilution assumed for steam jet transfers.

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Step 1. Zirconium Cladding Waste

Notes:

1. Numbers in lines show processing sequence for batch operations.
2. Five percent jet dilution assumed for steam jet transfers.

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FIGURE 13
FLOW DIAGRAM FOR PROCESSING DEPLETED METAL

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