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PUREX PLANT CHEMICAL FLOWSHEET FOR THE
1970 THORIUM CAMPAIGN

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MASTER

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PUREX PLANT CHEMICAL FLOWSHEET FOR THE
1970 THORIUM CAMPAIGNINTRODUCTION

The first Hanford thorium production campaign was conducted in the Purex Plant in 1966 and successfully met all of its requirements. The second Hanford thorium production campaign is scheduled to start up in August, 1970, at Purex, and will require the processing of approximately 400 tons of thorium (elemental) to recover 570 kilograms of U-233. The primary purpose of the 1970 Campaign is to recover at least 360 kilograms of U-233 satisfactory for use at Bettis Laboratories in the demonstration core for the Light Water Breeder Reactor (LWBR).

The maximum allowable level of U-238 contamination in the U-233 product for Bettis Laboratories is significantly lower than the U-238 specification for the 1966 Campaign (0.5 percent vs. 3.9 percent of U-233). In addition, plant capacity is to be increased, and some alterations to the Purex facility have taken place since 1966. These changes have necessitated a careful review of the processing scheme to insure that all of the objectives for the 1970 Campaign are satisfied.

This document supersedes ARH-1287 (Secret) and ARH-727 in presenting the chemical flowsheet recommended for the 1970 Thorium Campaign.

SUMMARY

The chemical flowsheets recommended for the 1970 Thorium Campaign are presented in Figures I, II-A, B, C, D, E and F in the Appendix, and are basically the same as those used for the 1966 Campaign.

The 1970 Thorium Campaign will produce two grades of U-233, differentiated by the level of U-238 contamination. The high-grade product, which should represent approximately 275 tons of the thorium* processed and 400 kilograms of the U-233 recovered, will contain a maximum of 0.5 percent U-238 (U-233 basis). The balance of the U-233 is expected to exceed this specification due to both high plant U-238 bleed-in rate and higher U-238 in the associated thorium. This low-grade thorium is being processed in order to purge the Purex system of U-238 in preparation for producing the high-grade product. As was done in 1966, an extensive chemical flush of the entire Purex processing system will precede the campaign.

In addition to the two grades of U-233 to be produced, two different types of thorium elements will be processed during the campaign. Approximately 58 tons of the high-grade thorium to be processed will be in sintered-oxide "wafer" form. The balance of the thorium will be the same as that processed in 1966 which was made from vibratory compacted thoria powder.

*As elemental thorium unless specified as "thoria" (ThO_2).

Some changes in the processing mode were necessary for the 1970 Campaign in order to increase the maximum instantaneous plant capacity to 1.0 capacity factor (CF), to meet more stringent product specifications with respect to U-238 contamination, and to adjust for alterations in the Purex facilities since 1966. Briefly, the principle process and equipment changes from the 1966 Campaign are as follows:

1. The use of three, rather than two, annular dissolvers for the Aluminum Can Removal and Thorium Dissolution Operations.
2. The use of two, rather than one, dissolver receiver tank to allow blending in Headend for maintaining final U-233 product quality and uniformity.
3. The use of a new sectionalized concentrator (E-F11), rather than the old C3 Pot Dissolver, for the Feed Concentration and Acid Boil-off Operation in Headend.
4. The installation of an airlift in the lBX column-lBS column process route (lBXT) to increase the maximum flow rate above that required for a thorium processing rate of 1.0 CF.
5. The use of a modified version of the new sectionalized concentrator design for feed preparation to the Second Uranium Cycle in order to increase the fissile material mass limits of the vessel to a level satisfactory for safe operation during U-233 processing.
6. The installation of a new U-233 product sampling tank (TK-L9) to obtain more representative sampling, and reduce the work load of the Purex Analytical Laboratory.

7. The use of Tank F18 for reverse-strike neutralization of the final effluent stream from the Waste Concentration and Acid Recovery System to minimize solids deposition in the waste routes to underground storage.

All of the wastes generated during the campaign will have low enough fission product content to be sent directly to non-boiling storage for later processing through an in-tank solidification unit (ITS). This includes pre- and post-campaign flushes as well as all processing wastes.

DISCUSSION

The chemical flowsheets recommended for the 1970 Thorium Campaign are presented in Figures I, II-A, B, C, D, E and F in the Appendix.

During the 1966 Thorium Campaign, numerous problems were encountered and resolved to some degree as processing proceeded. In general, the chemical flowsheet proved satisfactory; and most of the equipment functioned about as expected. As a result, the flowsheet recommended for the 1970 Campaign is basically the same as the one used in 1966 and consists of the following major areas:

1. Headend Operations
2. Solvent Extraction
3. U-233 Product Finishing and Loadout
4. Solvent Treatment
5. Waste Concentration and Acid Recovery

However, some changes in the processing mode were necessary in order to increase the maximum instantaneous plant capacity to 1.0 capacity factor, to meet more stringent product specifications with respect to U-238 contamination, and to adjust to alterations in the Purex Plant facilities since 1966.

The following will review the principle operations of each of the above major areas of the chemical flowsheet, with particular emphasis on the process changes that have been incorporated. This is preceded by sections describing 1) the past and present efforts made by the Hanford Contractors to meet the U-238 specification, 2) thorium fuel elements, and 3) thorium handling and identification. A summary of the expected fission product content and total volume of the wastes to be generated during the campaign is presented following the flowsheet review.

U-238 Specification

The bulk of the U-233 produced during the 1966 Campaign averaged about 1.2 percent in U-238 content (U-233 basis). This contamination originated from two sources, the input thorium and the residual U-238 in the Purex Plant.

For the 1970 Campaign, a product specification of 0.5 percent U-238 has been established for the 360 kilograms of U-233 required by Bettis Laboratories. To meet this requirement, the following steps have been taken at Hanford to reduce the U-238 contributed from each of the above sources:

- a) DUN originally established a program with National Lead for selecting and purifying the virgin thorium in order to minimize the U-238 content of the high-grade fuel. The DUN specifications limited the running average of the U-238 content in the thorium to 3.5 ppm with a maximum allowable level in any one lot of 5.0 ppm.
- b) As was done in 1966, an extensive chemical flush of the entire Purex processing system will precede the campaign.
- c) Approximately 125 tons of low-grade thorium (equivalent to 1966 thorium in U-238 content) will be processed in advance of the 275 tons of high-grade material for the purpose of purging the residual U-238 from the Purex system.
- d) New or spare equipment will be installed in the Purex system in order to eliminate potential sources of significant U-238 contamination which would be difficult to flush adequately (i.e., E-H4 Concentrator and the A3 Dissolver Tower).

In addition, the grams of U-233 per ton of thorium* in the high-grade fuel elements were increased for the 1970 Campaign within the limits of the U-232 specification. This increase in the g/T, in combination with item (a) above, reduced the U-238 content with respect to U-233 in the high-grade thorium from an average of 0.7 percent in 1966 to 0.13 percent for 1970.

*All of the material to be processed during the 1970 Campaign will be in the oxide (ThO_2) form, and is properly termed "thorium." However, for the purpose of the flowsheet, all weights, weight ratios and processing rates will be in terms of elemental thorium (Th) unless otherwise specified.

Description of Thorium Fuel Elements [REDACTED]

Two types of thorium fuel elements will be processed during the campaign: thorium powder elements and thorium "wafer" elements. Both will be clad with C-64 and 6061-T6 aluminum with no intentional difference in the geometry of the clad elements.

The thorium powder elements, which constitute approximately 340 tons of the 400 tons of thorium to be processed, consist of an aluminum can filled with vibratory compacted, sand-like thoria particles ranging in size from smaller than 325 mesh up to 6 mesh. The thoria particle densities are 90 to 95 percent of theoretical (10.03 g/cc), and the bulk densities are specified in the range of 7.2 to 7.8 grams per cubic centimeter for the vibratory compaction technique. The thorium powder elements are not intended to retain their geometry once the aluminum can is removed. The resulting loose, heavy thoria sand settles rapidly in an aqueous phase, thus requiring vigorous agitation to maintain a satisfactory exposed surface area for dissolution. As a result, the maximum allowable charge size with the powder elements is limited to 5,700 pounds of thorium (6,500 pounds of thoria) to avoid overloading the airlift circulators in the dissolvers and reducing the dissolution rate excessively. [REDACTED]

The balance of the thorium to be processed, or approximately 58 tons of the high-grade material, will be in "wafer" form. The "wafers" are fabricated from the same thoria powder as described above through a process consisting of cold-pressing and sintering. The result is a right-cylindrical geometry approximately 1.5 inches in diameter and

2.8 inches long with bulk densities in the range of 7.3 to 7.9 grams per cubic centimeter. Three of the "wafers" are placed in the aluminum can to make up a single element. With the exception of fractures which develop from thermal stresses created during irradiation, the "wafers" retain their original geometry under dissolution conditions. Recent laboratory studies have indicated that only approximately 5 percent of the material in "wafer" form will settle through the grate in the dissolvers. As a result, the maximum allowable charge size with the "wafer" elements may only be limited by the physical capacity of the dissolver.

Table I in the Appendix presents the physical characteristics of the thorium elements to be processed during the 1970 Campaign. The low-grade material (high in U-238) was irradiated in the B, C, and both K Reactors, and consists of all powder elements. The high-grade thorium was irradiated in the K Reactors only, and consists of both powder elements and "wafer" elements (core only). Full buckets from the K Reactor core will contain 250-260 elements. Full buckets from B Reactor, C Reactor, and K Reactor fringe will contain 290-300 elements.

The low-grade thorium was discharged from the reactors from mid-1966 through 1968, and has a weighted average cooling time in excess of 3 years. Similarly, the high-grade thorium was discharged from mid-1968 through 1969, and has a weighted average cooling time in excess of 1 year. As a result of these extended cooling times, and with proper charge scheduling, the protactinium content of the feed to the Purex processing system can be maintained below 1.0 gram per ton of thorium throughout the 1970 Campaign.

Thorium Handling and Identification

The irradiated thorium elements will be shipped from the Hanford reactors to the Purex Plant in the same equipment used for shipping irradiated uranium. The cask cars used for thorium will be identified by a red "T" placard located at both ends of the car, and on the top and bottom of the well lid. The transfer papers will also be marked with a red "T".

The thorium elements will be placed on end, and will be stacked in two layers in the shipping bucket (see Figures III-A&B in the Appendix). The vertical loading pattern was chosen to differentiate thorium from other fuel types handled at the Hanford reactors, and to facilitate the identification of an (I and E) uranium element which may have been placed in a thorium bucket by mistake (the [I and E] uranium element has an end-to-end hole through its center while the thorium element is solid). Photographs were taken at the reactors of each of the layers when the bucket was originally loaded, and will be taken of the top layer only just prior to shipment to ARHCO. These photographs are used to confirm piece count and to insure that the bucket does not contain an (I and E) uranium element. As an additional check, the Purex crane operator will be requested to be on the alert for uranium elements in the thorium buckets as he charges the dissolvers.

Buckets containing thorium wafer elements will have two ½-inch aluminum tubes, which have been anodized bright green, placed diagonally across the top layer of elements (see Figure III-B in

the Appendix). [REDACTED] This visual method of identification is to be used by the Purex crane operator as a secondary check to insure that the thorium wafer and powder elements are charged as scheduled. Charging powder elements when wafer elements are intended could result in temporarily disabling (plugging up) a dissolver.

Headend Operations

The flow sketch and chemical flowsheets for the Headend Operations are presented in Figures I, II-A and II-B in the Appendix.

The Headend System for thorium processing consists of the following principle operations:

1. Aluminum Can Removal with the associated thorium recycle and waste handling
2. Thorium Dissolution
3. Feed Concentration and Acid Boil-off
4. Accountability Sampling and Solvent Extraction Feed Adjustment.

The chemical flowsheets for the Headend Operations are intended for processing thorium powder elements only. However, they are also satisfactory for thorium "wafer" elements as long as the charge size is not significantly greater than the 5,660 pounds of thorium specified. For significantly larger charges of "wafer" elements, additional Headend flowsheets would be required for the Aluminum Can Removal, Thorium Dissolution, and Feed Concentration and Acid Boil-off Operations.

The following will review each of the above principle Headend Operations for the processing of thorium powder elements, and conclude with a discussion of the significant process and equipment changes from the 1966 Campaign.

1. Aluminum Can Removal

The flow sketch and chemical flowsheet for the Aluminum Can Removal Operation are presented in Figures I and II-A in the Appendix.

The aluminum cans are dissolved by the conventional sodium hydroxide-sodium nitrate process. A charge of thorium elements, typically consisting of 5,660 pounds of thorium and 400 pounds of aluminum, is dumped into a 15-weight percent sodium nitrate solution in the dissolver. Caustic soda is then added at a controlled rate to maintain hydrogen and ammonia evolution within tolerable limits as the aluminum is dissolved. The resulting solution is allowed to digest in the dissolver for two hours after completion of the caustic addition. The solids are then allowed to settle and the decladding waste is transferred through tanks D2 and E3 to the centrifuge for recovery of the entrained thorium. The centrifuge cake, which contains approximately 10 percent of the thorium originally charged to the dissolver is washed with caustic soda and water. The centrifuged waste solution and cake wastes are combined in Tank E5 and are transferred to non-boiling waste storage. The thorium cake is slurried from the centrifuge to Tank E1, and dissolved there in a $12.2M$ HNO_3 - $0.025M$ KF - $0.075M$ $Al(NO_3)_3$ solution before being recycled to Tank D4 to be combined with dissolver thorium solution.

The total solution volume in the dissolver following the addition of the thorium elements is based on obtaining a level approximately 6 inches above the solid partition between the inner and outer annuli.

Total caustic addition is specified at 2.25 moles per mole of aluminum dissolved. This is significantly higher than that used during normal U-Pu processing (1.25 moles NaOH per mole aluminum) and is considered necessary to minimize precipitation of sodium aluminate during the subsequent prolonged processing of the decladding waste in E Cell.

During the Aluminum Can Removal Operation, the circulators in the dissolvers are operated at minimum steam flow to minimize dispersion of particulate thorium while preventing the plugging of the circulators. In addition, the dip leg on the jet used for jetting the decladding waste solution from the dissolvers terminates 6 inches from the dissolver floor to prevent plugging during the transfer. From the results of 1966, this short dip leg will result in a heel of approximately 150 gallons of solution being carried over to the subsequent Thorium Dissolution Operation.

2. Thorium Dissolution

The flow sketch and chemical flowsheet for Thorium Dissolution are presented in Figures I and II-B in the Appendix.

The bulk of the sand-like thorium remains in the dissolver following the Aluminum Can Removal Operation and is dissolved with a solution which is originally about 11.5M HNO_3 - 0.025M KF - 0.13M $\text{Al}(\text{NO}_3)_3$. Approximately 85 percent of the initial aluminum in the solution is a result of the heel and precipitate carried over from the Aluminum Can Removal Operation. The balance is from the recovered

acid. The aluminum is used as a complexant for fluoride to keep corrosion in the stainless dissolver within tolerable limits. However, the presence of the aluminum retards the thorium dissolution rate significantly as does the presence of thorium. Thus, after boiling the dissolver for two hours, the KF concentration is increased to 0.05M to accelerate the dissolution rate. This is allowable with respect to dissolver corrosion, since thorium is also an effective complexing agent for the fluoride ion.

When the specific gravity of the dissolver solution reaches about 1.60, the thorium charge is essentially dissolved. The solution is then adjusted with $\text{Al}(\text{NO}_3)_3$ to a final aluminum-to-fluoride ratio of 3:1, cooled, settled and transferred to the respective dissolver receiver tank. A water rinse follows and is also jetted to the dissolver receiver tank which is Tank D3 for the A3 and B3 Dissolvers, and Tank D1 for C3 Dissolver. The solutions from Tanks D1, D3 and E1 are then blended in Tank D4 as makeup for the Feed Concentration and Acid Boil-off Operation which follows.

During the Thorium Dissolution Operation, the airlift circulators in the inner and outer annuli of the dissolvers are alternated between high and low air flow for suspending the thoria particles in the liquid and to maintain uniform distribution throughout the dissolver. In addition, a maximum air velocity of 50 feet per second through the circulators is used in order to insure that the dissolver floor is not eroded by the abrasive thoria particles.

The thorium "wafer" elements will be processed through C3 Dissolver only in the latter part of the campaign. This will afford an opportunity to evaluate the dissolution capabilities of the "wafer" elements under full-scale operating conditions and will require additional Headend flowsheets and procedures if it is decided to make a full evaluation.

3. Feed Concentration and Acid Boil-off Operation

The flow sketch and chemical flowsheet for the Feed Concentration and Acid Boil-off Operation are presented in Figures I and II-B in the Appendix.

The blended dissolver solution is accumulated in Tank D4 and transferred on a batch basis to the E-F11 Sectionalized Concentrator for the Feed Concentration and Acid Boil-off Operation. As the name implies, this operation has two distinct phases, one followed by the other:

- a. The feed concentration phase in which the dissolver solution is transferred continuously from Tank D4 to the E-F11 Concentrator at the rate required to maintain a constant volume of 2,100 gallons in the concentrator. This transfer continues until the solution reaches a thorium concentration of 3.0M. This phase has a primary control of total thorium addition to the concentrator and secondary controls by boiling temperature and specific gravity.
- b. The acid boil-off phase in which water is added continuously to the E-F11 Concentrator at the rate required to maintain a constant volume of 2,100 gallons in the concentrator. This water addition continues until the solution reaches a nitric

acid concentration of $-0.20M$ (acid deficient). This phase has a primary control of total water addition to the concentrator and secondary controls by boiling temperature and specific gravity.

When the acid boil-off phase is completed, the solution is simultaneously diluted and transferred with a submerged water jet to Tank F12. The "hot" transfer is necessary to avoid crystallization of the 3 molar thorium solution which has a freezing point of about $55^{\circ} C$. The dilution from the water jet reduces the freezing point of the solution below subsequent operating temperatures.

A significant quantity of hydrogen fluoride will be volatilized in the E-F11 Concentrator during the Feed Concentration and Acid Boil-off Operation. As a result, aluminum nitrate is added to the tower spray water to minimize the fluoride corrosion of the "Tophet M" de-entrainment pad.

After passing through the de-entrainment pad in the tower of the concentrator, the off-gas is routed to a surface condenser where essentially all of the water and nitric acid vapors are recovered. The resulting condensate will be routed directly to the Acid Recovery System (via Tank F3) for further processing (see the discussion on Process Changes in Headend for further details).

4. Accountability Sampling and Solvent Extraction Feed Adjustment

The flow sketch and chemical flowsheet for the Accountability Sampling and Solvent Extraction Feed Adjustment Operations are presented in Figures I and II-B in the Appendix.

The solution in Tank F12 is transferred on a batch basis to Tank D5 where an initial sample is taken for feed adjustment analysis. Based on the results of this analysis, the solution is then treated as follows to produce solvent extraction feed which is 1.5M in thorium and 0.10M acid deficient:*

- a. If the solution is high in thorium concentration, which should normally be the case, the appropriate amount of water is added at Tank D5.
- b. If the solution is high in nitric acid content, the appropriate amount of 50 percent sodium hydroxide is added at Tank D5.
- c. If the solution is low in nitric acid content, the appropriate amount of 57 percent nitric acid is added at Tank E6 (following transfer).

Following the necessary additions, samples are taken at Tank D5 and/or Tank E6 to verify that the solution meets solvent extraction specifications. Further additions are made if necessary. The

*In 1966, the actual solvent extraction feed specifications were:

Th: 2.3 lbs/gal to 3.3 lbs/gal
HNO₃: -0.026 lbs/gal to 0.079 lbs/gal

These same specifications should be satisfactory for the 1970 Campaign.

final solution is then transferred to the solvent extraction feed tank, TK-H1.

The accountability sample is obtained from Tank D5 after steps (a) and (b), above, have been completed. This sample is analyzed separately and used for determining the quantity of U-233 and thorium input to the plant during the campaign.

Thorium solution from Tank K6 (or K1) in the Second Thorium Cycle and/or uranium solution from Tank L11 in the U-233 Product Finishing and Loadout Area can be recycled to Tank E6 for rework. When these transfers are scheduled, the dilution and/or chemical addition at Tank D5 should be adjusted accordingly.

5. Process Equipment Changes in the Headend Operations

The operation of the Headend in 1970 will be essentially identical to the final flowsheet used in 1966, with the following exceptions:

a. Three Dissolvers

During the 1966 Campaign, only two annular dissolvers with airlift circulators were available for use in the Aluminum Can Removal and Thorium Dissolution Operations. The third dissolver, the C3 Pot Dissolver, was used for the Feed Concentration and Acid Boil-off Operation. The use of only two dissolvers limited the maximum Headend capacity to 0.70 CF.

For the 1970 Campaign, three annular dissolvers, equipped with airlift circulators will be used for Aluminum Can Removal and Thorium Dissolution Operations in order to meet the required maximum processing rate of 1.0 CF.

b. Aluminum-to-Fluoride Ratio

For the 1970 Campaign, the minimum allowable aluminum-to-fluoride ratio for solutions in Headend and throughout the process, has been reduced from the 4:1 used in 1966 to 3:1 (mole ratio). This conforms to current allowable minimums in the processing of PRTR and NPR fuels at Purex, and will reduce the aluminum content (and total volume) of the waste solutions resulting from the 1970 Campaign.

c. Aluminum Can Removal Waste Routing

In the 1966 Campaign, the aluminum can removal waste solutions were jetted directly from the dissolver to Tank E3 via the D Cell manifold. The D Cell manifold has subsequently been modified and this transfer route does not exist. As a result, the aluminum can removal solutions will be transferred to Tank E3 via Tank D2 during the 1970 Campaign.

d. Dissolver Solution Blending

For the 1970 Campaign, two, rather than one, dissolver receiver tanks will be used in Headend. Tank D3 will receive solution from the A3 and B3 Dissolvers while Tank D1 will serve as the receiver for the C3 Dissolver. The solution from Tanks D1 and D3 (and E1) will be combined (blended) in Tank D4 prior to being transferred to the Feed Concentration and Acid Boil-off Operation.

This equipment arrangement was chosen to allow continuous blending of dissolver solution from thorium powder and "wafer" material. With the blending capability at Tank D4, a dissolver charging schedule can be setup to combine the thorium "wafer" and powder material so that the high-grade U-233 product quality and uniformity can be maintained along with a consistent and flexible mode of operation.

e. New Feed Concentration and Acid Boil-off Equipment

In the 1966 Campaign, the C3 Pot Dissolver was used for the Feed Concentration and Acid Boil-off Operation in Headend. This equipment did not perform satisfactorily with respect to processing capacity and solution de-entrainment.

For the 1970 Campaign, a new sectionalized concentrator (E-F11) will be used for this operation. The capacity of this equipment will exceed the required maximum processing rate of 1.0 CF, and solution entrainment should be reduced by a factor of 10 to 100. This improvement in solution de-entrainment, along with the longer average cooling time of the thorium being processed in 1970, should allow the overheads from the concentrator to be routed directly to the Acid Recovery System (via TK-F3) throughout the campaign, rather than to the Waste Concentration System as was necessary in the latter half of the 1966 Campaign. This will be discussed in more detail in the section on improvements in the Waste Concentration and Acid Recovery Operations.

f. Feed Adjustment Samples at Tank D5

In 1966, the required sampling, chemical addition and/or dilution for the final solvent extraction feed adjustment was accomplished in Tank E6. The before and after samples were taken at the TK-E6 sampler pit and analyzed in the Purex laboratory.

At the request of Purex Analytical Laboratory personnel, a portion of this operation has been switched to Tank D5 so that most of the bulk samples required can be taken in the D5 Analytical Cave. This change eliminates the problems associated with taking bulk samples at the TK-E6 sampler pit and takes advantage of the analytical capabilities and better sampling equipment at the D5 Cave. In general, the result should be improved laboratory service for this particular sample requirement.

Solvent Extraction

The flow sketch and chemical flowsheets for the Solvent Extraction Operations are presented in Figures I, II-C and II-D in the Appendix.

The Solvent Extraction System consists of the following principle operations:

1. Codecontamination and Partition Cycle
2. Second Thorium Cycle
3. Second and Third Uranium Cycles

All of the solvent extraction cycles use 30 volume percent tributyl

phosphate in a normal paraffin hydrocarbon diluent (NPH) as the solvent. The following will review each of the above principal operations and conclude with a discussion of the significant process changes in the Solvent Extraction System.

1. Codecontamination and Partition Cycle

The flow sketch and chemical flowsheet for the Codecontamination and Partition Cycle are presented in Figures I and II-C in the Appendix.

In the codecontamination or HA Column (T-H2), the thorium and uranium in the feed stream (HAF) from Tank H1 are co-extracted into the organic phase to obtain primary separation from other radioisotopes. Uranium and thorium also enter the column in the organic recycle stream (1BSU) from Tank J2 in the Partition Cycle. Since the self-salting of the thorium decreases as its concentration decreases, a 13M nitric acid stream (HAX-HNO₃) is added near the bottom of the HA Column to reduce the loss of thorium to the aqueous waste stream (HAW).

The solvent phase is scrubbed in the top portion of the HA Column to improve decontamination. The scrub stream (HAS) is prepared in the Aqueous Make-up Facilities (AMU) and contains phosphoric acid and ferrous sulfamate. The phosphoric acid is used to enhance decontamination with respect to protactinium and zirconium-niobium through the formation of inextractable complexes, while the ferrous ion serves to reduce plutonium and

chromium to a less extractable valence state. [REDACTED] The chromium in the system is a corrosion product most likely oxidized during the Thorium Dissolution, and Feed Concentration and Acid Boil-off Operations in Headend.

The organic product stream (HAP), which contains the thorium and U-233, overflows the HA Column and is combined with the organic waste streams from the stripping columns in the Second and Third Uranium Cycles in Tank J3. The resulting solution in Tank J3 then becomes the feed stream (LBXF) to the LBX Partition Column (T-J6). The aqueous waste stream (HAW) from the HA Column, containing the majority of the fission products, is routed to Tank F7 in the Waste Concentration and Acid Recovery System for further processing and disposal.

In the LBX Partition Column (T-J6) the thorium is preferentially back-extracted (or stripped) from the organic phase by controlling the acidity, temperature, and aqueous to organic flow rates. The aqueous feed stream (LBX) to the column consists of dilute nitric acid and is line blended. The aqueous product stream leaving the column (LBXT) contains all but a trace of the thorium and approximately 10 percent of the U-233. This stream is airlifted to the LBS Column (T-J7) and is scrubbed with organic to extract the U-233. The resulting organic stream (LBSU) overflows the LBS Column to Tank J2 where it is recycled to the codecontamination or HA Column (T-H2) as the HAO stream. The aqueous thorium product stream (LBT)

from the 1BS Column is transferred to the E-J8 Concentrator where it is steam stripped and concentrated. The resulting stream (1TC) overflows the concentrator to the Second Thorium Cycle feed tank, TK-K1, for further decontamination. The overhead condensate from the E-J8 Concentrator is routed to the 216-A-10 Crib for disposal.

The organic uranium product stream (1BU) from the 1BX Partition Column (T-J6) overflows to the 1C Column (T-H3) where the U-233 is back-extracted (or stripped) into the aqueous phase. The aqueous feed stream (1CX) to the 1C Column consists of dilute nitric acid and is line blended. The organic waste stream (1CW) overflows from the 1C Column and is returned to the No. 1 Solvent Treatment System.

The aqueous uranium product stream (1CU) from the 1C Column is routed to the E-H4 Concentrator where it is steam stripped and concentrated. The resulting product stream (1UC) overflows the concentrator to Tank J1, where it is combined with the overhead condensate from the E-N6 Concentrator, and is then transferred to the Second Uranium Cycle feed tank, TK-J21, for further decontamination. The overhead condensate from the E-H4 Concentrator is routed to the 216-A-10 Crib for disposal.

2. Second Thorium Cycle

The flowsketch and chemical flowsheet for the Second Thorium Cycle are presented in Figures I and II-C in the Appendix. Additional decontamination of the thorium product solution from the Partition Cycle is achieved as follows:

- a. The thorium is extracted in the 2D Column (T-K2) into an organic phase in the presence of ferrous sulfamate and phosphoric acid.
- b. The resulting organic phase is scrubbed in the top portion of the 2D Column with a dilute nitric acid and water stream (combination of the 2DIS and 2DS streams).
- c. The thorium is then back-extracted (or stripped) into an aqueous phase in the 2E Column (T-K3).

The aqueous thorium product stream (2ET) from the 2E Column is then routed to the E-K4 Concentrator where it is steam stripped and concentrated. The resulting solution overflows the concentrator to Tank K5 and is jetted to Tank K6 just prior to being transported by tank trailer to the WR Vault or 204S tanks in 200 West Area for final storage. The overhead condensate from the E-K4 Concentrator is routed to the 216-A-10 Crib for disposal.

Ferrous sulfamate and phosphoric acid are used in the 2D Column to obtain additional decontamination with respect to plutonium, protactinium and zirconium-niobium. A water scrub (2DS) of the organic phase in the top section of the 2D Column is used to reduce the nitric acid concentration in the organic product stream (2DT) and, hence, minimize the volume of the final thorium nitrate solution. The 2DIS Stream to the 2D Column will be prepared in AMU for this campaign to improve the control of the phosphoric acid addition. The Second Thorium Cycle flowsheet does not provide any significant decontamination with respect to U-233.

The aqueous waste stream (2DW) from the 2D Column is routed to Tank F10 in the Waste Concentration and Acid Recovery System for

further processing and disposal. The organic waste stream (2EW) from the 2E Column is routed to Tank R1 in the No. 2 Solvent Treatment System. A rework route is available from Tank K6 (or Tank K1) to Tank E6 in Headend.

3. Second and Third Uranium Cycles

The flow sketch and chemical flowsheet for the Second and Third Uranium Cycles are presented in Figures I and II-D in the Appendix.

Additional decontamination of the uranium product solution from the Partition Cycle is achieved as follows:

- a. The uranium is extracted in the 2A Column (T-J22) into an organic phase in the presence of ferrous sulfamate.
- b. The resulting organic phase is scrubbed in the top part of the 2A Column with a dilute nitric acid stream (2AS).
- c. The uranium is back-extracted (or stripped) into an aqueous phase in the 2B Column (T-J23).
- d. These same basic steps are repeated again in the Third Uranium Cycle with the exception that no ferrous sulfamate is used.

The aqueous uranium product stream (3BU) from the 3B Column (T-L2) is then routed to Tank N1 for final U-233 product processing in N Cell and loadout in the PR Room.

Additional thorium decontamination is obtained in the Second and Third Uranium Cycles, and the decontamination factor is estimated to be in the range of 400 - 1000.

Decontamination from residual traces of plutonium is achieved by adding ferrous sulfamate to the 2AS stream. To maximize the purity of the final U-233 product solution, ferrous sulfamate is not added to the Third Cycle, and distilled water is used in the preparation of the 3BX stream. In addition to decontaminating the final product solution, the Second and Third Uranium Cycles increase the U-233 concentration by a factor of 15.

The aqueous waste streams from the 2A Column (2AW) and the 3A Column (3AW) are routed to Tank F10 in the Waste Concentration and Acid Recovery System for further processing and disposal. The organic waste streams from the 2B Column (2BW) and 3B Column (3BW) are recycled to the 1BX Partition Column feed tank, TK-J3.

4. Process and Equipment Changes in the Solvent Extraction System

The operation of the Solvent Extraction System in 1970 will be essentially identical to the final flowsheet used in 1966, with the following exceptions:

a. Thorium Dibutyl Phosphate Formation

During the 1966 Campaign, solvent extraction capacity and efficiency were markedly reduced by the accumulation of a white precipitate (identified as thorium dibutyl phosphate) on the plates of various columns in the system.

This was particularly noticeable in the 1C Uranium Stripping Column (T-H3) and required a periodic shutdown and flush of the column. Although lower protactinium content in the

thorium feed to the plant is expected to reduce solvent degradation, it is doubtful if the problem can be completely eliminated. However, from our experience in 1966, the following changes have been incorporated and will hopefully permit a sustained thorium processing rate of 1.0 CF for periods of at least two to three weeks during the 1970 Campaign.

- 1) Installing a mixed, plastic (Kel-F)-stainless steel plate cartridge in the 1C Uranium Stripping Column which should improve operating stability.
- 2) Maintaining processing temperatures in the Codecontamination and Partition Cycle, and the Second Thorium Cycle at 30°C.
- 3) Extending the cooling time of the irradiated thorium elements to an average in excess of one year and scheduling the processing of the thorium such that the maximum protactinium content in the solvent extraction feed is less than 1.0 gram per ton of thorium.

b. 1BX Column - 1BS Column Process Route (1BXT System)

During the 1966 Campaign, the flow through the 1BXT system was limited to a thorium processing rate of 0.75 CF. A steam jet was installed during the campaign to eliminate this restriction. However, the steam jet was removed after a two-week operating period because the increased 1BXT temperature was a potential contributor to the solvent degradation problem.

For the 1970 Campaign, an airlift is being provided in the 1BXT route. This will increase the maximum flow through this route above that required for a thorium processing rate of 1.0 CF without affecting the rate of solvent degradation.

c. 2DIS Stream

In the 1966 Campaign, the 2DIS stream consisted of two separate controlled additions of concentrated nitric and phosphoric acid which were line blended just prior to entering the 2D Column (T-K2). The flow control of the very small concentrated phosphoric acid addition was poor throughout the campaign, and generated some concern relative to the potential of thorium phosphate precipitation contributing to the instability encountered with the 2D Column.

For the 1970 Campaign, the 2DIS stream will be prepared in AMU from the two concentrated acids. The resulting solution will be analyzed for nitric and phosphoric acid content prior to the controlled addition to the column. This is expected to increase the control of phosphoric acid to the 2D Column without significantly increasing the workload of the Purex Analytical Laboratory.

d. E-H4 Concentrator

In order to minimize U-238 contamination from process equipment during the 1970 Campaign, a new E-H4 Concentrator is being installed for feed preparation to the Second Uranium Cycle. However, calculations showed that the new sectionalized

concentrator design had fissile material mass limits much more restrictive than those applicable to the previous design. [REDACTED] As a result, a modified version of the new sectionalized concentrator design will be installed for the 1970 Campaign. The modification consists of a downward extension of the tube bundle compartments so that the bottoms of all concentrator components are on a common plane. With this modification, the new E-H4 Concentrator will also be satisfactory for U-Pu processing.

e. Water Addition to the 3AF Tank (TK-J5)

The 3A Column (T-L1) will be operating near its minimum volume velocity at a thorium processing rate of 1.0 CF. In addition, during the 1966 Thorium Campaign, the 2B Column (T-J23) operation indicated marginal stability which was attributed to deposition of thorium dibutyl phosphate on the 2B Column cartridge. [REDACTED] At a processing rate of 1.0 CF, the flowsheet for the 1970 Campaign has a higher 2B Column velocity than was used during the 1966 Campaign. If instability should again develop in the 2B Column, the 2BX flow can be reduced from 40 to 30 flows without an excessive increase in 2BW losses. However, if the 2BX flow is reduced, then it will be necessary to add a comparable flow of water to the 3AF Tank (TK-J5) to insure stable operation of the 3A Column. The existing nitrite control system to Tank J5 (FM-J5-3) will be used for this addition.

U-233 Product Finishing and Loadout

The flow sketch and chemical flowsheet for the U-233 Product Finishing and Loadout System is presented in Figures I and II-D in the Appendix.

This system consists of the following principle operations:

1. Final Thorium Decontamination
2. Final Product Concentration
3. Finished Product Sampling
4. Product Loadout

The aqueous product stream from the Third Uranium Cycle overflows continuously into Tank N1. The solution is then pumped through the cation exchange column (T-N50) where it receives final thorium decontamination. The solution overflows T-N50 continuously and is routed to the E-N6 Concentrator where the U-233 concentration is increased by a factor of 50 to 60 to meet a final product specification of 300 to 375 grams per liter. The condensate from the E-N6 Concentrator is recycled to Tank J1 in the Second Uranium Cycle. The concentrated U-233 product solution overflows continuously from the E-N6 Concentrator to the receiver tank, TK-N7. When sufficient product has been accumulated (approximately 30 to 36 liters), the solution is vacuum transferred from TK-N7 to the new product sampling tank, TK-L9. Here the solution is circulated and then sampled for analysis. At the completion of sampling, the solution is vacuum transferred in 3-liter increments to the new loadout tank, TK-L13, for filling the 3-liter polyethylene product bottles.

Rework routes for unsatisfactory product solution are available from Tanks N1 and L9 via vacuum transfer to Tank L11. Overflow product solution from Tank L13 is also vacuum transferred to Tank L11. Solution will be accumulated in Tank L11 and scheduled for transfer to Tank E6 in Headend as required. During the 1966 Campaign, no rework of product solution was required. [REDACTED]

The cation exchange column (T-N50) which will contain Dowex 50W-X8 resin, is used to preferentially remove thorium from the U-233 solution in order to meet a final product specification for thorium content of 1000 ppm. [REDACTED] The resin will be pretreated with 4M nitric acid to remove the associated sodium, washed with 0.05M nitric acid, and then slurried into the column prior to startup. If necessary, the resin can be changed out during the campaign without affecting the column. The old resin is simply backflushed and slurried out through the R8 Jet to Tank R8 in the No. 2 Solvent Treatment System. The new, pretreated resin is added to the column in the same way as for startup.

During the campaign, the resin may become saturated with thorium, accompanied by a decrease in the decontamination performance of the column. If this occurs, the resin should be regenerated, rather than discarded, by first performing a U-233 elution with a 0.5M nitric acid solution. This is then followed by an elution of the thorium from the resin with a solution containing 2M nitric acid and 0.5M oxalic acid. The resulting thorium solution will be discarded to Tank F10 while the solution containing U-233 will be recycled to Tank J1 in the Second Uranium Cycle (both transfers via the XAW Jet).

In 1966, a Vycor glass bed was used for final protactinium decontamination of the U-233 product. However, the bed was bypassed early in the campaign because no decontamination could be observed, and small quantities of boron contamination were found in the U-233 product. Based on this experience, the Vycor glass bed was not included in the flowsheet for the 1970 Campaign.

The addition of the new L9 sampling tank should result in more representative product sampling as well as reducing the workload of the Purex Laboratory. In 1966, samples were required from each product bottle as it was loaded out because there was no other sample point available. For 1970, a sample will be required for each L9 composite of 30 to 36 liters, or 10 to 12 product bottles.

The transfer of the U-233 Product Loadout Operation to the new hood in the PR Room is a significant improvement in the working conditions for operating personnel. In 1966, this operation was conducted in the old N Cell loadout hood and required the operator to work in a bent-over position in cramped quarters.

Solvent Treatment

The flow sketch and chemical flowsheet for the Solvent Treatment Systems are presented in Figures I and II-E in the Appendix.

The Purex Solvent Treatment System for thorium processing consists of two principle recycle operations:

1. The No. 1 Solvent Treatment System which supports the operation of the Codecontamination and Partition Cycle, and the Second and Third Uranium Cycles.

2. The No. 2 Solvent Treatment System which supports the operation of the Second Thorium Cycle.

The No. 1 Solvent Treatment System receives the organic waste stream (1CW) from the 1C Uranium Stripping Column (T-H3) in Tank G1. The system then successively provides a carbonate-permanganate wash in Tank G1, a dilute nitric acid wash in the 10 Column (T-G2), a dilute carbonate wash in Tank G7, and acidification in Tank G5 before recycling the solvent to the respective extraction batteries listed above. The system is continuous with respect to the organic stream. The aqueous waste stream from the No. 1 System, which consists of the batch wash solutions from Tanks G1 and G2, and the continuous wash solution from the decanter Tank G6, is collected in Tank G8 and transferred to non-boiling waste storage.

The operation of the No. 1 System is essentially identical to the final flowsheet used in 1966, with the exception that the level of permanganate in TK-G1 has been reduced to the concentration currently used for normal uranium-plutonium operation. This change should help reduce the solids problem experienced in 1966 in Tank G1, the 10 Column (T-G2) and the 10S recycle sampler. In addition, as was done at the end of the 1966 Campaign, sodium carbonate will be used in place of sodium hydroxide in Tank G7 to reduce the possibility of U-233 precipitating, and thus accumulating in the G Cell vessels. [REDACTED]

The No. 2 Solvent Treatment system receives the organic waste stream (2EW) from the 2E Thorium Stripping Column (T-K3) in Tank R1. This

system then successively provides a carbonate-permanganate wash in Tank R1, and a nitric acid wash in the 20 column (T-R2) before recycling the solvent to the Second Thorium Cycle. The system is continuous with respect to the organic stream. The aqueous waste stream from the No. 2 System, which consists of the batch wash solutions from Tanks R1 and R2, is collected in Tank R8 and routed to non-boiling waste storage.

The operation of the No. 2 System is essentially identical to the final flowsheet used in 1966, with the following exceptions:

1. The level of permanganate in Tank R1 has been reduced as described above for the No. 1 System. This change may be more effective in the No. 2 System since the solids problems experienced in 1966 were much more severe in R Cell.
2. The centrifuge, G-R4, which was used in 1966 to remove entrained aqueous solution and solids in the organic product stream (200) from the 20 Column (T-R2), is out of service and therefore is not included in the flowsheet for 1970. This should have no effect on the performance of the No. 2 System during the 1970 Campaign except for a possible increased buildup of solids and an aqueous phase in Tank R7.
3. An aqueous selective jet has been installed in Tank R1 for transferring batch waste solution to Tank R8 for disposal. This change is expected to reduce the solvent losses in R Cell significantly below the 370 gallons per day experienced in 1966.

Waste Concentration and Acid Recovery

The flow sketch and chemical flowsheet for the Waste Concentration and Acid Recovery System are presented in Figures I and II-F in the Appendix.

This system consists of the following principle operations:

1. Waste Concentration and Acid Boil-Off
2. Acid Recovery
3. Final Waste Treatment and Disposal

Each of these operations will be discussed below followed by a section reviewing the significant changes since 1966.

1. Waste Concentration and Acid Boil-Off

The 2AW, 3AW and 2DW aqueous waste streams are routed from the respective solvent extraction columns to Tank F10 and are combined with condensate from the plant vent system (this tank is also the alternate route for the overhead condensate from the E-F11 concentrator). The resulting waste solution is transferred continuously to Tank F7 where it is combined with the aqueous waste stream (HAW) from the codecontamination or HA Column (T-H2). A small flow of sugar solution is added to Tank F7 for suppression of ruthenium volatilization from the subsequent Waste Concentration and Acid Boil-off Operation in the E-F6 Concentrator. In addition, depending on the concentration of acid in the combined waste solution, dilution water may also be added to Tank F7 to improve subsequent acid recovery.

The solution in Tank F7 is continuously blended with the bottoms in the E-F6 Waste Concentrator. The specific gravity of the bottoms and the overflow rate from the concentrator are used as the primary controlling parameters. The concentrated waste (1WW) overflows continuously to Tank F26 as the feed stream to the Final Waste Treatment Operation. The water and nitric acid vapors boiled off the bottoms pass through two "Tophet M" de-entrainment pads and are combined in the concentrator tower with the sugar denitration off-gas from the Final Waste Treatment System. The resulting gas-vapor stream (1WD) serves as the feed to the Acid Recovery Operation.

2. Acid Recovery

The water vapor, nitric acid vapor and sugar denitration off-gas (1WD) enter the Acid Absorber Column (T-F5) and are scrubbed with a countercurrent dilute acid reflux stream (AAD-Reflux).

For the purpose of the flowsheet, it was assumed that approximately 80 percent of the effective nitric acid content in the 1WD stream (includes NO_x as nitric acid) is absorbed in the T-F5 Column. The resulting solution exits the bottom of the column as approximately 25 percent nitric acid and is routed to Tank F3 for further processing.

The off-gas from the column passes through a surface condenser where a dilute nitric acid solution is recovered. A portion of

this solution (AAD) is refluxed to the column and the balance is discarded to the 216-A-10 Crib.

The balance of the off-gas from the column is not recovered in the associated condenser, and is routed to the vessel vent system. Assuming no additional recovery in the vessel vent system, and a normal stack gas rate of 120,000 SCFM, this stream would contribute about 210 ppm of NO_x to the plant stack discharge.

The 25 percent acid solution from the T-F5 Column is combined in Tank F3 with the overhead condensate from the E-F11 Concentrator in Headend operations. Both of these streams contain significant quantities of fluoride ion. In order to minimize fluoride corrosion in the subsequent processing equipment, aluminum nitrate solution is added at the T-F5 Column to obtain a 3:1 aluminum to fluoride ratio in Tank F3. Batch additions of aluminum nitrate solution can also be made directly to Tank F3 in the event the addition to T-F5 is not adequate.

The combined acid solution (AAA) in Tank F3 is transferred to Tank U5 where fresh 57 percent nitric acid is added for makeup as required. The resulting acid solution is then fed continuously to the tower on the U6 Vacuum Fractionator for final concentration. Demineralized water ($\text{AFS-H}_2\text{O}$) is added to the top of the tower for reflux. The acid vapors from the reboiler section are absorbed by the descending feed solution and water. The nitric

acid in the reboiler is essentially a constant 60 percent solution and overflows to Tanks U1 and U2 for storage and recycle to the process. The specific gravity of the reboiler solution and the overflow rate are the primary control parameters for the U6 Vacuum Fractionator.

The off-gas from the fractionator is routed to a surface condenser where essentially all of the water and nitric acid vapors are recovered. The resulting condensate is neutralized and discarded to the 216-B-3 Pond.

3. Final Waste Treatment

The concentrated waste solution (1WW) from the E-F6 Concentrator is accumulated in Tank F26 for cooling and subsequent batch transfer to Tank F15. After taking the accountability sample, the waste solution in Tank F15 is heated to 95°C and sugar solution is added at a controlled rate to destroy nitric acid (the efficiency of this reaction is assumed to be 16 moles of nitric acid per mole of sugar addition). This reaction proceeds very rapidly in concentrated nitric acid (above 1.0 molar) and is nearly completed in the time required to add the sugar solution to Tank F15. When sugar addition has been completed, the waste solution is transferred to Tank F16 for an additional eight hours of digest to terminate the denitration reaction.

The gaseous products of the denitration reaction in Tank F15, consisting of oxides of carbon and nitrogen, are routed to the tower of the E-F6 Concentrator for further processing in the Acid

Recovery System. The small amount of off-gas from the final phases of the denitration in Tank F16 are routed to the vessel vent system and ultimately to the plant stack.

Following the eight-hour digest in Tank F16, the waste solution will be transferred to Tank F18 for reverse strike neutralization with 50 percent sodium hydroxide to a final minimum pH of 8.0. After sampling, the solution is then transferred to non-boiling waste storage. However, Tank F18 will also be used during the campaign for the neutralization and disposal of accumulated wastes from the canyon cell sumps. As a result, there may be times during the campaign when Tank F18 will not be available for processing the waste solution from Tank F16. When this occurs, the sugar treated waste solution will be neutralized by direct strike, sampled, and transferred from Tank F16 to non-boiling waste storage.

4. Process Changes in the Waste Concentration and Acid Recovery System

The operation of the Waste Concentration and Acid Recovery System in 1970 will be essentially identical to the final flowsheet used in 1966, with the following exceptions:

a. AAD Reflux

A portion of the aqueous waste stream (AAD) from the surface condenser on the T-F5 Acid Absorption Column will be refluxed to the column, eliminating the AAS-H₂O demineralized water stream. This is currently the practice in normal uranium-plutonium processing and has the primary advantage of reducing the volume of waste discharged to the environs.

b. Tank F18

The sugar-treated waste solution from the process will be reverse-strike neutralized in Tank F18 for the 1970 Campaign in order to minimize the solids deposition in the waste routes to underground storage. The primary precipitant of concern in this case is alumina.

c. Overhead Condensate from the Feed Concentration and Acid Boil-Off in Headend

During the latter part of the 1966 Campaign, the overhead condensate from the Feed Concentration and Acid Boil-off Operation in Headend (which was performed in the C3 Pot Dissolver) was diverted to the Waste Concentration System (via Tank F10), rather than routed directly to the Acid Recovery System (via Tank F3). This was necessary due to a buildup of activity, principally protactinium and ruthenium, in the recovered acid which posed a radiation hazard to personnel in the Sample Gallery.

Processing this significant volume of concentrated nitric acid solution through the Waste Concentration System permitted sugar addition for suppression of ruthenium volatilization, and provided a distillation step without permitting significant solution entrainment. As a result, the activity in the recovered acid returned to normal levels.

For the 1970 Campaign, a new sectionalized concentrator (E-F11) will be used for the Feed Concentration and Acid

Boil-off Operation in Headend. The off-gas de-entrainment system in the E-F11 Tower should be a factor of 10 to 100-fold better than the C3 Dissolver System. This will significantly improve the protactinium decontamination, and may also have a beneficial effect on ruthenium containment.

In addition, the irradiated thorium to be processed during the 1970 Campaign will be cooled a minimum of 180 days, with the average exceeding one year. This compares to an average of 180 days in 1966. Thus, the protactinium and ruthenium content of the thorium to be processed in 1970 will be significantly below that experienced in 1966.

Based on the above, the overhead condensate from the E-F11 Concentrator will be routed directly to the Acid Recovery System (via Tank F3) at the start of the 1970 Campaign. This will minimize the load on the Waste Concentration and Final Treatment Systems. If the activity in the recovered acid should increase above tolerable levels during the campaign, the overhead condensate from the Feed Concentration and Acid Boil-off Operation can again be diverted to the Waste Concentration System (via Tank F10); or as an alternate, sodium nitrite can be added to the E-F11 Concentrator to suppress ruthenium volatilization (sugar will not be used in this case due to the potential of thorium oxalate precipitation).

Waste Management Information

The following waste management information is estimated for the principal Purex plant waste streams for the 1970 Thorium Campaign. [REDACTED]

Basis: October 1, 1970

Total Heat Generation Rate: <20,000 BTU/Hr.

Total Isotopic Content:

Ce/Pr-144	484 KCi
Ru/Rh-106	36 KCi
Ru-103	2 KCi
Zr/Nb-95	96 KCi
Cs-134	1 KCi
Sr-89	<u>10 KCi</u>
SUBTOTAL.....629 KCi	
Sr-90	33 KCi
Cs-137	33 KCi
Other FPs	<u>142 KCi</u>
TOTAL.....837 KCi	

Estimated Waste Solution Volumes:

Pre-Campaign Flush	350,000 gals.
Post-Campaign Flush	150,000 gals.
Headend Coating Waste	270,000 gals.
Organic Wash Waste	450,000 gals.
Neutralized, Sugar-Treated Waste	220,000 gals.
Contingency*	<u>260,000 gals.</u>
TOTAL.....1,700,000 gals.	

*Allowance for process upsets.

The neutralized, sugar-treated waste will contain essentially all of the fission products, protactinium, and associated heat. In addition, it is important to note that the waste solutions from the pre-campaign and post-campaign flushes will be generated in relatively short time periods (four to six weeks), while the other three waste categories will be spread over the three months of processing.

Based on the waste management specifications for thorium processing, all of the waste solutions generated during the 1970 Campaign can be routed directly to nonboiling storage for final processing through an ITS unit. [REDACTED]

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TABLE IDESCRIPTION OF THORIUM FUEL ELEMENTS

	<u>Element Length (In.)</u>	<u>Element Diameter (In.)</u>	<u>Aluminum Per Element (Lbs.)</u>	<u>Thorium Per Element (Lbs.)</u>
B Reactor:				
010T Powder Element	8.885	1.445	0.22	2.90
C Reactor:				
C4T Powder Element	8.885	1.472	0.22	3.00
K Reactor Core:				
K3T Powder Element	8.885	1.600	0.26	3.60
K9T "Wafer" Element	8.885	1.600	0.26	3.60
K Reactor Fringe:				
K4T Powder Element	8.885	1.480	0.22	3.04

REVISIONS	MINOR REVISION	4
	UP-DATED	3
	GENERAL UP-DATE	2
U.S. ATOMIC ENERGY COMMISSION		
RESERVE OPERATIONS OFFICE		
Atlantic Richfield Hanford Company		
Richland, Washington 99352		
THORIUM PROCESS		
FLOW SKETCH		
FIGURE I		
DATE	202-A	7000
REVISED	NONE	
SK-52421

2nd S. D.	REV NO.	SA Wang	SAH INCH 10.	REV SHD 5
RE OPEN F DRAWINGS		CONNEN	RT BEVE	CHECK PR ISSUE NO
		DRAWING E A 115.		

DATE	TIME	U S ATOMIC ENERGY COMMISSION RICHFIELD OPERATIONS OFFICE
DATE	TIME	Atlantic Richfield Hanford Company Richland, Washington 99352
DATE	TIME	PUREX THORIUM PROCESS THORIA DISSOLUTION & FEED ADJUSTMENT FIGURE II-B
DATE	TIME	SK-2-21905 2100

~~SECRET~~
DECLASSIFIED

BASIS

- 1 100 FLOWS = 691 GALLONS PER TON OF THORIUM
- 2 ALL SPECIFIC GRAVITIES VOLUMES & MOLARITIES @ 25°C

SECOND URANIUM CYCLE

SECRET
DECLASSIFIED

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BASIS

- 1 100 FLOWS = 681 GALLONS PER TON OF THORIUM
- 2 ALL SPECIFIC GRAVITIES VOLUMES & MOLARITIES @ 25°C

THIRD URANIUM CYCLE

U.S. ATOMIC ENERGY COMMISSION RICHLAND OPERATIONS OFFICE Atlantic Richfield Hanford Company Richland, Washington 99352	
PUREX THORIUM PROCESS SECOND URANIUM CYCLE THIRD URANIUM CYCLE	
FIGURE II-D	
DATE: 10-1-60	BY: EOE A
REVISION: 1	7000
DECLASSIFIED	5K-2-21905 14

NO 1 SOLVENT TREATMENT SYSTEM

SECRET
DECLASSIFIED

ARH-1748
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NO 2 SOLVENT TREATMENT SYSTEM

BASIS

- 100 FLOWS - 691 GALLONS PER TON OF THORIUM
- ALL SPECIFIC GRAVITIES VOLUMES & MOLARITIES @ 25°C

U.S. ATOMIC ENERGY COMMISSION
RICHMOND OPERATIONS OFFICE
Atlantic Richfield Hanford Company
Richland, Washington 99312

PUREX THORIUM PROCESS
NO 1 SOLVENT TREATMENT SYSTEM
NO 2 SOLVENT TREATMENT SYSTEM

FIGURE II-E

SK-2-21905 516

WASTE CONCENTRATION & ACID RECOVERY

SECRET
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NO 2 ACID WASTE
(2AW, 3AW, EDW)

FLOW 541
TEMP AMB
SpG 1.05
Th % 0.18
U % <0.00017
HNO₃ 1.65 M
H₃PO₄ 0.011
FeSA 0.0011

VENT CONDENSATE

FLOW 187
TEMP AMB
SpG 1.00

2WF

FLOW 698
TEMP AMB
SpG 1.04
Th % 0.116
U % <0.00013
HNO₃ 1.28 M
H₃PO₄ 0.0085
FeSA 0.00085
(TK-F10)

IWF SUGAR

FLOW 3.0
TEMP AMB
SpG 1.09
SUGAR 0.7 M
(TK-204)

HAW

FLOW 240
TEMP AMB
SpG 1.08
Th % 0.29
U % <0.0003
HNO₃ 1.58 M
KF 0.028
Al(NO₃)₃ 0.11
NaNO₃ 0.17
KNO₃ 0.703
H₃PO₄ 0.0054
FeSA 0.004

ALTERNATE
H₂O ADDITION

F

FLOW 441
TEMP AMB
SpG 1.05
Th % 0.16
U % <0.00017
H % 1.35
KF 0.0075
Al(NO₃)₃ 0.5
NaNO₃ 0.044
KNO₃ 0.0714
H₃PO₄ 0.0017
FeSA 0.0023
SAR 0.022
(TK-F1)

TO STACK VIA VESSEL
VENT SYSTEM, OXIDES OF
NITROGEN EQUIVALENT
TO 18.5 FLOWS OF 12 M
NITRIC ACID

AAD (TO CRIB)

FLOW 760
TEMP 60°C
SpG 1.00
HNO₃ 0.03 M

AAD REFLUX

FLOW 200
TEMP 60°C
SpG 1.00
HNO₃ 0.03 M

AAS-ANN

FLOW 20
TEMP AMB
SpG 1.27
Al(NO₃)₃ 1.68 M

AAA

FLOW 447
TEMP AMB
SpG 1.16
HNO₃ 5.01 M
HF 0.0024
Al(NO₃)₃ 0.0075
(TK-F3)

F II
ACID BOIL-OFF
OVER HEADS

FLOW 235
TEMP AMB
SpG 1.17
HNO₃ 5.37 M
HF 0.0034
(ALT TO TK-F10)

57% NITRIC ACID
ADDED AS REQ'D

AAA

FLOW 447
TEMP AMB
SpG 1.16
HNO₃ 5.01 M
HF 0.0024
Al(NO₃)₃ 0.0075
(TK-US)

AFS-H₂O

FLOW 120
TEMP AMB
SpG 1.00

AED (TO POND)

FLOW 425
TEMP 50°C
SpG 1.00
HNO₃ 0.10 M

PUREX RECOVERED
ACID

FLOW 169
TEMP 30°C
SpG 1.37
HNO₃ 13.0 M
HF 0.0065
Al(NO₃)₃ 0.020
(TKS U14 U2)

78 FLOWS
WATER TO
DEMISTER
PAD

E F6
CONC R

IWW

FLOW 480
TEMP 50°C
SpG 1.30
Th % 5.6
U % <0.0038
HNO₃ 4.00 M
KF 0.16
Al(NO₃)₃ 0.63
NaNO₃ 0.80
KNO₃ 0.025
H₃PO₄ 0.17
Fe 0.045
SO₄ 0.090
(TK-F26)

IWW SUGAR

FLOW 192
TEMP AMB
SpG 1.03
SUGAR 0.7 M
(TK-204)

DENITRATION
OFF G

2114 FLOW
MOLES OF NTRC
ACID AS OX DES C
NITROGEN

ALT ROUTE
TO UG5

ALT NaOH
ADDITION

STW NaOH

FLOW 97
TEMP AMB
SpG 1.52
NaOH 19.0 M

NW (TO UG5)

FLOW 77.5
TEMP AMB
SpG 1.13
Th % 1.93
U % <0.0021
KF 0.0088
NaA (OH) 0.54
NaNO₃ 2.57
KNO₃ 0.014
Na₃PO₄ 0.083
Fe 0.025
SO₄ 0.049
NaOH 0.047

STW

FLOW 540
TEMP 97°C
SpG 1.17
Th % 2.8
U % <0.0030
HNO₃ 1.00 M
KF 0.12
Al(NO₃)₃ 0.49
NaNO₃ 0.7
KNO₃ 0.020
H₃PO₄ 0.134
Fe 0.035
SO₄ 0.070
(TK-F15)

STW (TO CRIB)

FLOW 56
TEMP 93°C
SpG 1.16
Th % 2.6
U % <0.0027
HNO₃ 0.5 M
KF 0.12
Al(NO₃)₃ 0.49
NaNO₃ 0.72
KNO₃ 0.019
H₃PO₄ 0.126
Fe 0.035
SO₄ 0.067
(TK-F16)

STW NW (REV
S147C)

FLOW 73.8
TEMP 55°C
SpG 1.13
Th % 2.0
U % <0.0022
K 0.0033
NaA (OH) 0.56
NaNO₃ 2.70
KNO₃ 0.015
Na₃PO₄ 0.098
Fe 0.026
SO₄ 0.049
NaOH 0.050
(TK-F18)

BASIS

- 100 FLOWS = 691 GALLONS PER
TON OF THORIUM
- ALL SPECIFIC GRAVITIES
VOLUMES & MOLARITIES @ 25°C

RESTRICTED DATA

CLASSIFIED BY 11E Ransom
ON 11/1/88 BY 11E Banger
1-70

CLASSIFIED BY 11E Ransom
ON 11/1/88 BY 11E Banger
1-70

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ON 11/1/88 BY 11E Banger
1-70

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ON 11/1/88 BY 11E Banger
1-70

U S ATOMIC ENERGY COMMISSION
Richland Operations Office
Atlantic Richfield Hanford Company
Richland, Washington 99352

PUREX THORIUM PROCESS
WASTE CONCENTRATION
ACID RECOVERY

FIGURE II-F

SK-2-2190516

DECLASSIFIED

DECLASSIFIED

DECLASSIFIED

DECLASSIFIED

DECLASSIFIED