

POTENTIAL APPLICATIONS OF THE TRUEX PROCESS

AT THE HANFORD SITE

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ABSTRACT

The TRUEX process is a newly-developed liquid-liquid solvent extraction process for removal of all +3, +4, and +6 actinide ions from HNO<sub>3</sub> waste solutions. Bench-scale batch and countercurrent tests with synthetic wastes coupled with results of engineering studies and evaluations demonstrate that the TRUEX process is well-suited for conversion of certain Hanford Site aqueous TRU (>3.7 x 10<sup>6</sup> Bq kg<sup>-1</sup>) to non-TRU wastes for possible inexpensive grouting and near-surface disposal. Reference TRUEX process chemical flowsheets and chemistry as well as current plans and schedules for plant-scale deployment are presented.

INTRODUCTION

The TRUEX (Transuranium Extraction) process is a new liquid-liquid extraction scheme for removal and, where economically warranted, recovery of all actinide elements from aqueous HNO<sub>3</sub> nuclear waste solutions. In the sense that it is capable of extracting any suite of +6, +4, and especially, +3 actinides (e.g., Am and Cm) from any HNO<sub>3</sub> solution, the TRUEX process is a generic one. Recent results obtained by Horwitz, et al., at the Argonne National Laboratory (ANL) indicate the TRUEX process is also applicable to removal of TRU elements from HCl solutions.

Development of the TRUEX process at ANL is the culmination of a 20-year long R&D effort in the U.S. to find a continuous solvent extraction process suitable for plant-scale removal of Am (and Cm if present) as well as U, Np, and Pu from HNO<sub>3</sub> waste solutions. Important contributions during the evolution of the TRUEX process were made by Siddall, Schulz, and McIsaac, et al.

The U.S. Department of Energy (DOE) is currently considering Rockwell Hanford Operations proposals and recommendations to proceed with implementation of TRUEX process technology and equipment (i.e., centrifugal contactors) to remove soluble plutonium and <sup>241</sup>Am values from acidic Plutonium Finishing Plant aqueous waste (Table I). Various economic benefits in terms of increased plutonium recovery and avoidance of future waste management costs will accrue by converting the PFP waste from a TRU to a non-TRU waste.

Recently-completed engineering analyses and preliminary laboratory studies indicate that the TRUEX process may also be applicable to removal of plutonium and <sup>241</sup>Am from acidified Complexed Concentrate (CC) waste. Approximately 9 100 m<sup>3</sup> of CC waste are currently stored in double-shell tanks at the Hanford Site; as shown in Table I, CC is an alkaline TRU waste containing high concentrations of various organic complexing agents such as EDTA (ethylenediaminetetraacetate), HEDTA (N-hydroxyethylenediaminetriacetate), citric acid, etc. (CC waste was generated during previous solvent extraction recovery of <sup>90</sup>Sr from neutralized pre-1973 PUREX process high-

TABLE I

Composition of Candidate TRUEX Process Feed at the Hanford Site

| PFP <sup>(a)</sup> Waste     |                                      | CC <sup>(b)</sup> Liquid Waste   |   |
|------------------------------|--------------------------------------|----------------------------------|---|
| Constituent <sup>(c)</sup>   | Concentration, M                     | Constituent <sup>(d)</sup>       | Concentration                           |
| NO <sub>3</sub> <sup>-</sup> | 3.0                                  | Na <sup>+</sup>                  | 9.9M                                    |
| HNO <sub>3</sub>             | 1.5                                  | NO <sub>3</sub> <sup>-</sup>     | 3.6                                     |
| Al <sup>3+</sup>             | 0.43                                 | NO <sub>2</sub> <sup>-</sup>     | 1.1                                     |
| F <sup>-</sup>               | 0.09                                 | CO <sub>3</sub> <sup>2-</sup>    | 1.1                                     |
| Mg <sup>2+</sup>             | 0.06                                 | Al(OH) <sub>4</sub> <sup>-</sup> | 0.37                                    |
| Ca <sup>2+</sup>             | 0.06                                 | OH <sup>-</sup>                  | 0.18                                    |
| Na <sup>+</sup>              | 0.04                                 | SO <sub>4</sub> <sup>2-</sup>    | 0.074                                   |
| Fe <sup>2+</sup>             | 0.03                                 | Cl <sup>-</sup>                  | 0.068                                   |
| K <sup>+</sup>               | 0.003                                | K <sup>+</sup>                   | 0.049                                   |
| Mn <sup>2+</sup>             | 0.003                                | PO <sub>4</sub> <sup>3-</sup>    | 0.035                                   |
| U                            | 0 to 0.2                             | Fe <sup>2+</sup>                 | 0.019                                   |
| Pu                           | 10 <sup>-5</sup> to 10 <sup>-4</sup> | Ca <sup>2+</sup>                 | 0.019                                   |
| <sup>241</sup> Am            | 10 <sup>-6</sup> to 10 <sup>-5</sup> | Mn <sup>2+</sup>                 | 0.013                                   |
|                              |                                      | Si <sup>4+</sup>                 | 0.011                                   |
|                              |                                      | TOC <sup>(e)</sup>               | 0.039 kg L <sup>-1</sup>                |
|                              |                                      | <sup>137</sup> Cs                | 1.4x10 <sup>6</sup> Bq mL <sup>-1</sup> |
|                              |                                      | <sup>89,90</sup> Sr              | 6.4x10 <sup>5</sup>                     |
|                              |                                      | <sup>155</sup> Eu                | 1.2x10 <sup>4</sup>                     |
|                              |                                      | <sup>154</sup> Eu                | 6.2x10 <sup>3</sup>                     |
|                              |                                      | <sup>60</sup> Co                 | 2.5x10 <sup>2</sup>                     |
|                              |                                      | <sup>241</sup> Am                | 1.9x10 <sup>2</sup>                     |
|                              |                                      | <sup>241</sup> Pu                | 1.3x10 <sup>2</sup>                     |
|                              |                                      | <sup>239,240</sup> Pu            | 2.1x10 <sup>2</sup>                     |

(a) Plutonium Finishing Plant

(b) Complexed Concentrate

(c) Concentrations of Be, Cr, Ni, Cu, Zn, and Pb all ≤ 6x10<sup>-4</sup>M

(d) Small (<10<sup>-4</sup>M) concentrations of Mg, Mo, Cr, Zn, Cd, Ca, Cu, Pb, Zr, Ba, La, Ni, and Nd also present.

(e) TOC = Total Organic Carbon

level waste.) Removal of TRU elements from the CC waste may permit its possible safe and inexpensive disposal in near-surface facilities after conversion to a grout-form.

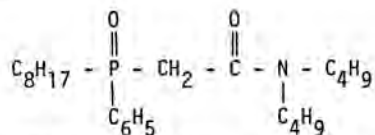
This paper summarizes the present status of development, testing, and evaluation of reference TRUEX processes for use with PFP and, possibly, acidified CC waste. ANL investigators have conducted extensive batch TRUEX process tests with simulated PFP waste; they have also completed one very successful countercurrent process test using centrifugal contactors. Results of very limited batch tests with actual PFP waste, performed in Rockwell Hanford laboratories, support and are in agreement with ANL results. Plans and schedules for deployment and

operation of plant-scale prototype TRUEX process equipment in the PFP are discussed.

#### GENERAL TRUEX PROCESS CHEMISTRY

The essential elements of the chemistry of the TRUEX process for operation with aqueous  $\text{HNO}_3$  media include:

- The TRUEX process solvent is a carefully selected blend of octyl, phenyl-N, N-diisobutylcarbamoyl-phosphine oxide [ $\text{o}\phi\text{D}(\text{IB})\text{CMPO}$ ], tri-n-butyl phosphate, and normal hydrocarbon or chlorinated hydrocarbon (e.g.,  $\text{CCl}_4$ ) diluent. The primary function of TBP is to allow relatively high organic phase loadings of actinide elements without formation of a second organic phase.
- The structural formula of the bifunctional organophosphorus reagent  $\text{o}\phi\text{D}(\text{IB})\text{CMPO}$  (hereafter CMPO) is



Although fairly expensive, CMPO is commercially available (M&T Chemicals, Rahway, NJ) in a satisfactorily pure form. Its favorable properties -- low aqueous phase solubility, high resistance to chemical degradation, compatibility with various organic diluents, high affinity and capacity for all +3, +4, and +6 actinides from  $\text{HNO}_3$  solutions, ease of stripping, etc. -- make CMPO the reagent of choice for the TRUEX process.

- Greater than 99.9% of +3, +4, and +6 actinides and, if present, +3 lanthanides report to the CMPO phase when extraction is performed with aqueous phases containing at least 0.5M  $\text{NO}_3^-$ . If present, small but varying amounts of Tc, Zr, Fe, Ru and Pd co-extract with actinides and lanthanides; other metal ions are essentially inextractable. Co-extraction of Zr and Fe can be largely prevented by addition of oxalic acid to the acid aqueous feed.
- Additional amounts of certain co-extracted inert (e.g., Fe) and/or radioactive (e.g.,  $^{95}\text{Zr}$ ) impurities can be removed by scrubbing the CMPO extract with dilute  $\text{HNO}_3$  or oxalic acid solutions.
- Dilute (<0.1M)  $\text{HNO}_3$  solutions preferentially strip trivalent actinides (Am, Cm) and, if present, trivalent lanthanides from the scrubbed CMPO solution.
- Dilute  $\text{HNO}_3$ -HF or oxalic acid solutions effectively strip tetravalent plutonium from the CMPO phase. These solutions also remove any residual trivalent metal species but do not strip U(VI).
- Dilute  $\text{Na}_2\text{CO}_3$  solutions effectively strip U(VI) and any residual metallic contaminants (e.g., actinides, fission products, Fe, etc.) from the CMPO solvent. (The spent carbonate wash is a non-TRU waste.) The carbonate solution also serves as an effective solvent wash step to remove degradation products of both TBP and CMPO.
- Additional cleanup and purification of the recycled CMPO-TBP extractant can be obtained, if

necessary or desirable, by tailend passage through a bed of  $\text{OH}^-$ -form macroreticular anion exchange resin to remove traces of acidic degradation impurities.

- The CMPO-TBP-diluent extractant is remarkably resistant to both hydrolytic and radiolytic (either alpha or gamma radiation) attack. Even for gross amounts of solvent damage, scrubbing with aqueous  $\text{Na}_2\text{CO}_3$  solution restores the original americium extraction and stripping capability of the solvent.

#### TRUEX PROCESS APPLICATION TO PFP WASTE

##### PFP Waste Source and Composition

PFP acidic waste (Table I) is a composite of several aqueous solutions generated by various plutonium processing operations in the PFP. The chief contributor of soluble  $^{241}\text{Am}$  and plutonium values and also TRU-bearing solids is the aqueous raffinate generated in the Plutonium Reclamation Facility (PRF); a tributyl phosphate (TBP) solvent extraction process is operated in the PRF to recover plutonium from  $\text{HNO}_3$ -HF solutions of unirradiated metallurgical scrap (e.g., incinerator ash,  $\text{PuO}_2$ , etc.). Other aqueous waste solutions which go to make up the PFP waste include the spent  $\text{Na}_2\text{CO}_3$  wash of the PRF TBP solvent, HF- $\text{Al}(\text{NO}_3)_3$  solutions generated by scrubbing HF from certain offgasses, and miscellaneous wastes produced during production of plutonium metal.

The uranium concentration of PFP waste ranges from zero up to a maximum of about 0.02M depending on whether or not the PRF is processing scrap containing uranium. The PFP waste normally does not contain either inert or radioactive lanthanides; other species (e.g., Zr, Tc, Pd) which are extracted by CMPO are also not present. Thus, in many respects, the PFP acidic waste is an "ideal" feed to the TRUEX process.

##### Solvent Extraction Flowsheet

Figure 1 presents a reference TRUEX process chemical flowsheet for removal of plutonium and americium from acidic PFP wastes of the typical composition listed in Table I. This flowsheet has been drawn up by ANL investigators on the basis of their recent extensive bench-scale tests with simulated PFP waste. As is evident from Fig. 1, this flowsheet is designed for operation in ANL-designed centrifugal contactors, the currently preferred equipment.

Significant features of the reference flowsheet include:

- Countercurrent contact of the aqueous acidic PFP waste with TRUEX process solvent (0.15M CMPO-0.75M TBP- $\text{CCl}_4$ )<sup>a</sup> to extract soluble  $^{241}\text{Am}$  and plutonium values. Conditions (5 stages, organic/aqueous flow ratio = 0.375) are chosen to reduce the total concentration of TRU elements in the aqueous raffinate to  $3.7 \times 10^5 \text{ Bq kg}^{-1}$ , a factor of 10 below the limit for non-TRU waste.
- Any uranium in the PFP co-extracts with the plutonium and americium; small amounts of iron also co-extract. The distribution ratio for Fe(III) under countercurrent extraction column conditions is about 0.29. Other components (Table I) of the PFP waste are not extracted by the TRUEX process solvent.

<sup>a</sup>Tetrachloroethylene (TCE) may be substituted, without additional flowsheet change, for the more volatile  $\text{CCl}_4$ .

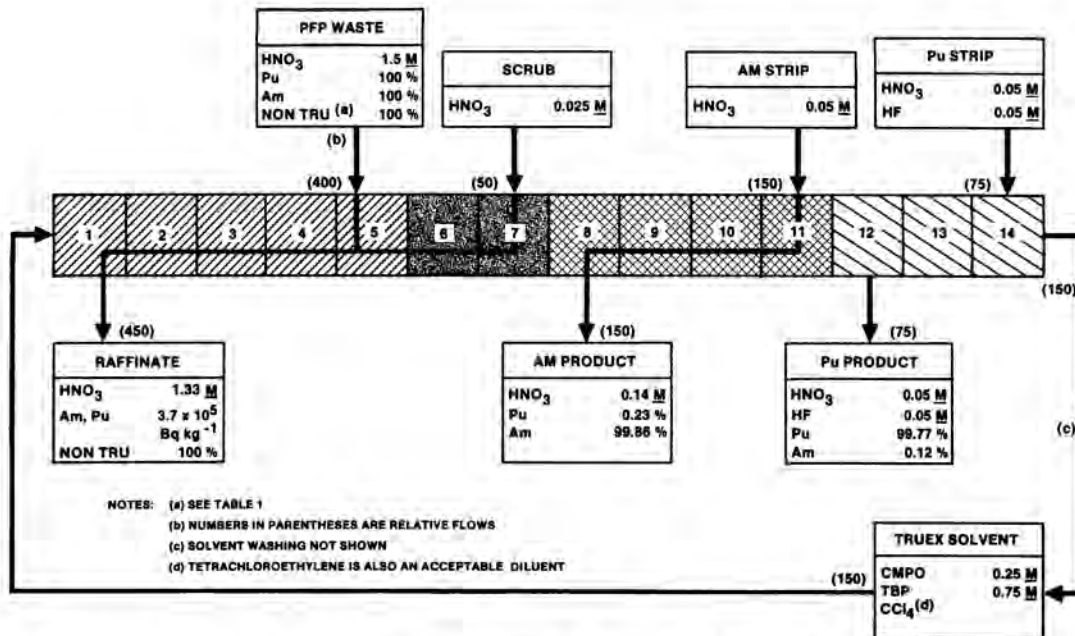


Fig. 1. Reference TRUEX Process Flowsheet for Removal of Am and Pu from PFP Acid Waste

- Co-extracted iron can be removed from the CMPO extract by contacting it with a small volume of 0.25M HNO<sub>3</sub>. The reference flowsheet (Fig. 1) calls for only two scrub stages; if required, additional scrub stages would provide for additional removal of iron.
- Essentially all the <sup>241</sup>Am, accompanied by less than 1% of the plutonium, can be effectively stripped from the scrubbed CMPO phase by counter-current contact (4 stages) with an equal volume of 0.05M HNO<sub>3</sub>. Most of the iron not previously scrubbed from the organic phase reports to the <sup>241</sup>Am strip solution.
- Following removal of <sup>241</sup>Am, the organic phase is contacted with one-half its volume of 0.05M HNO<sub>3</sub>-0.05M HF solution to strip the plutonium, along with residual <sup>241</sup>Am and iron. The plutonium product solution is suitable for recycle to the TBP extraction circuit in the PRF.
- Any uranium co-extracted with the <sup>241</sup>Am and plutonium does not strip with either TRU element. But, dilute Na<sub>2</sub>CO<sub>3</sub> solution, through formation of anionic uranium carbonate species, effectively removes uranium from the CMPO-TBP-diluent phase. Aqueous carbonate solutions, as noted previously, also serve to wash the TRUEX process extractant free of degradation products of both TBP and CMPO. Because the preceding HNO<sub>3</sub>-HF strip step so effectively removes both plutonium and <sup>241</sup>Am from the CMPO reagent, spent carbonate solvent washes are non-TRU wastes.

A very successful countercurrent demonstration of the TRUEX process flowsheet shown in Fig. 1 was recently completed by ANL investigators. The ANL test employed synthetic PFP waste spiked to full feed levels of <sup>241</sup>Am and plutonium. Under the conditions noted in Fig. 1, the aqueous raffinate, at steady state, contained only about 10<sup>5</sup> Bq kg<sup>-1</sup> for non-TRU waste. ANL investigators attributed the greater than expected extraction of TRU elements to unanticipated evaporation of the CCl<sub>4</sub> diluent which resulted in an

increased organic phase CMPO concentration (0.30M versus the nominal flowsheet 0.25M value). As a result of the increased CMPO concentration and HNO<sub>3</sub> extraction, only 88% of the <sup>241</sup>Am reported to the <sup>241</sup>Am strip product; however, the HNO<sub>3</sub>-HF strip section removed all the plutonium plus the residual <sup>241</sup>Am. Thus, for operation of the TRUEX process in centrifugal contactors, TCE is preferred to CCl<sub>4</sub> as a diluent for the CMPO reagent.

The ANL workers concluded from their hydrolytic and radiolytic experiments with the CMPO-TBP-CCl<sub>4</sub> extractant that solvent degradation would be minimal for a year of processing the PFP waste. Furthermore, even for gross amounts of solvent damage (typical of 100 years of processing PFP waste), scrubbing with aqueous Na<sub>2</sub>CO<sub>3</sub> solution will restore the original americium extraction and stripping capability of the CMPO-TBP extractant.

#### Removal of TRU-Bearing Solids

Although not shown in Fig. 1, the acidic PFP waste contains variable but small amounts of finely-divided solids. These solids represent principally residual scrap materials (e.g., PuO<sub>2</sub>, incinerator ash, etc.) not solubilized by the HNO<sub>3</sub>-HF dissolvent and not removed prior to PRF solvent extraction operations. Because of their typically high concentration of TRU elements, these solids must be removed prior to (or, less desirably, after) TRUEX process operation to ensure that the aqueous raffinate from the TRUEX process is a non-TRU waste.

Initial experimental work to determine the kinds, compositions and relevant physical properties (e.g., particle size distribution, particle density etc.) of solids in actual PFP waste is just underway at the Hanford Site. Parallel engineering analyses to select suitable equipment to achieve the required solid-liquid separation is also in progress. One potentially attractive separation technique to be examined is High Gradient Magnetic Filtration which would make use of the paramagnetic properties of PuO<sub>2</sub>.

## Solidification of $^{241}\text{Am}$ Concentrate

One product of TRUEX process operation with PFP waste is a dilute  $\text{HNO}_3$  aqueous solution containing  $^{241}\text{Am}$  and small amounts of plutonium and iron. Currently, it is anticipated that this americium concentrate would be converted to a high density solid form suitable for interim storage at the Hanford Site and eventual shipment and disposal at the Waste Isolation Pilot Plant repository in New Mexico. (Of course, if desired for some reason, the  $^{241}\text{Am}$  could be purified from plutonium and iron to produce a product, e.g.,  $\text{AmO}_2$ , suitable for beneficial use.) Methodology for conversion of the  $^{241}\text{Am}(\text{NO}_3)_3$  solution to a solid oxide form has not been chosen. Possible procedures include precipitation of americium(III) oxalate and calcination of the oxalate to  $\text{AmO}_2$  and, perhaps, direct calcination of the nitrate to the oxide.

### Process Deployment Plans and Schedule

If approved and funded by the DOE, prototype production-scale equipment, including 8- to 10-cm diameter centrifugal contactors, to operate the TRUEX process will be installed in the PFP. The TRUEX process prototype system could begin operation as early as FY 1989. Completion of ANL flowsheet development with simulated PFP waste is scheduled in FY 1986. Bench-scale batch and countercurrent (4-cm dia centrifugal contactors) tests in Hanford laboratories of various parts of the TRUEX process with actual PFP waste are planned for the years 1986 through 1988. This latter work will include studies and tests to define technology and equipment for removing TRU-containing solids from PFP waste.

### APPLICATION OF TRUEX PROCESS TO CC WASTE

#### Composition

As indicated in Table I, CC waste contains  $0.039 \text{ kg L}^{-1}$  of total organic carbon. Organic complexing agents (e.g., EDTA, HEDTA, citric acid, hydroxyacetate, etc.) originally present in the CC waste when it was first placed in double-shell tanks still account for about 50% of the TOC. The other half of the TOC represents various chemical and radiolytic degradation products of the original complexants. Some of these degradation products have been identified; unidentified organic compounds are believed to be polar organic acids, which are difficult to separate from the aqueous phase, and high molecular weight polymers. A program to identify at least the major classes of organic compounds in CC waste is underway in the Pacific Northwest Laboratories organization.

In addition to the large liquid fraction ( $9 \text{ } 10^3 \text{ m}^3$ ), CC waste also comprises about  $360 \text{ m}^3$  of solids. These solids contain, typically, 2.5 to 7.2 weight percent TOC and from  $1.6 \times 10^6$  to  $1.3 \times 10^8 \text{ Bq kg}^{-1}$  of TRU elements. These solids also contain varying amounts of almost all the inert and radioactive constituents listed in Table I. The exact nature and origin of the solids in the CC waste is not known; presumably such solids are produced as the results of radiolytic and chemical degradation of organic complexing agents in the CC.

#### Conceptual TRUEX Process Pretreatment of CC Waste

Studies of the applicability of the TRUEX process to removal of TRU elements from acidified Hanford Site CC waste are much less advanced than those for PFP waste. Some preliminary batch-type extraction experi-

ments have been performed with both simulated (ANL) and actual (Rockwell Hanford) CC waste. Engineering studies which evaluated the technical and economic feasibility of various pretreatment (e.g., TRU elements removed and/or destruction of organic complexants) procedures for the CC waste prior to final disposal were recently completed. Of the various treatment-disposal alternatives evaluated, TRUEX process removal of the TRU elements followed by near-surface disposal of the grouted TRU-free solution is the simplest and least expensive.

Figure 2 depicts the currently-envisioned TRUEX process pretreatment scheme for CC waste. Key steps include:

#### • Retrieval and Acidification

Because the CC waste is stored in double-shell tanks, well-known hydraulic sluicing and pumping methods can be used to retrieve and transport it to the Hanford B Plant. The B Plant, presently in wet standby condition, contains equipment (e.g., centrifuges, tanks, solvent extraction pulse columns, etc.) which will be or can be used in pretreatment of various Hanford Site wastes prior to grouting or vitrification for final disposal.

Judging from initial results obtained at ANL, addition of  $\text{HNO}_3$  to alkaline CC solution proceeds smoothly without precipitation of solids or excessive evolution of gases. Because of the several acid-base equilibria involved, control of the acidification process to obtain the desired  $1\text{M } \text{HNO}_3$  solution is difficult.

Behavior of solids in the retrieved CC slurry toward  $\text{HNO}_3$  is unknown. It is anticipated that at least part of such solids will dissolve during the acidification step, particularly if the acidified solution is heated. The need to remove undissolved solids, if any, will be established on the basis of their TRU element content.

#### • TRUEX Process Operation

Both batch and countercurrent TRUEX process extraction circuits are being considered for removal of TRU elements from acidified CC waste. The batch process involves co-extraction of  $^{241}\text{Am}$  and plutonium and co-stripping of both elements with a small volume of aqueous  $\text{HNO}_3\text{-HF}$  or  $\text{Na}_2\text{CO}_3$  solution. The TRU product solution thus obtained is a suitable feed to the planned Hanford Waste Vitrification Plant. After suitable modification, equipment currently installed in the B Plant may be suitable for operation of a TRUEX process with CC waste; if not, new centrifugal contactors could be installed in one of the B Plant cells.

A chemical flowsheet for countercurrent extraction of TRU values from acidified CC waste would be similar to that shown in Fig. 1. Operation of a countercurrent TRUEX process with the CC waste would provide a small volume of partially-purified plutonium product suitable for final purification in the Hanford PUREX Plant or, possibly, the PFP. Existing pulse column solvent extraction equipment in the B Plant is likely suitable for TRUEX process operation; alternatively, if desirable or necessary, banks of centrifugal contactors could be provided.

For either batch or countercurrent extraction of TRU elements from CC waste, a mixture of normal paraffin hydrocarbons (NPH) will be used to dilute the CMPO-TBP reagents. For operation with CC waste, the

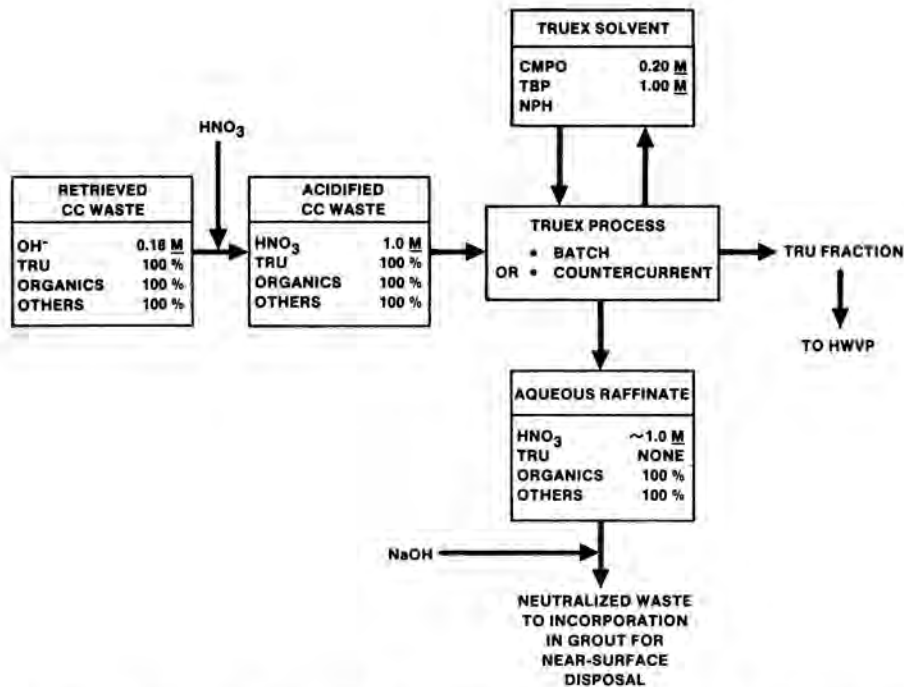


Fig. 2. Conceptual TRUEX Process for Removal of TRU Elements from Acidified CC Waste

NPH diluent is preferred to either  $\text{CCl}_4$  or TCE because the B Plant pulse columns are designed for use with organic extractants which are less dense than the aqueous phase. Use of the NPH diluent also eliminates any possibility that radiolytically-generated  $\text{Cl}^-$  will cause excessive corrosion of stainless steel equipment.

Although more definitive data are needed, batch contact data with both simulated and actual acidified CC solutions indicate that none of the various organic compounds extracts into the CMPO-TBP-NPH reagent. Radioactive (e.g.,  $^{155}\text{Eu}$ ) and inert lanthanides in the CC waste will, of course, co-extract with the americium and plutonium. Of the other inert metal ions, only small amounts of iron would be expected to report to the CMPO phase.

#### • Neutralization and Grouting

Following TRUEX process operation, NaOH will be added to the TRU-depleted CC waste to make it alkaline. The resulting solution will then be converted to a grout form suitable for near-surface disposal in lined trenches at the Hanford Site. Experimental work to define conditions and formulation for preparing a satisfactory disposal form grout from CC waste still needs to be completed.

#### SUMMARY AND CONCLUSIONS

The TRUEX process, a long sought after solvent extraction scheme, utilizes CMPO diluted with TBP and a normal or chlorinated hydrocarbon to extract +3 as well as +4 and +6 actinide ions from strongly acidic nuclear waste solutions. Extensive experimental work demonstrates that the TRUEX process is especially well suited to cost-effective removal of  $^{241}\text{Am}$  and plutonium from Hanford Site PFP waste. Deployment and operation of production scale TRUEX process prototype equipment in the PFP is planned for the period 1989-1991.

In its present state of development, the TRUEX process also appears to be applicable to removal of TRU elements from acidified Hanford Site CC waste. Preliminary batch contact tests with both simulated and actual CC waste indicate the technical feasibility of TRU element removal via the TRUEX process.<sup>24</sup> From an economic viewpoint, TRUEX process removal of  $^{241}\text{Am}$  and plutonium from acidified CC waste before grouting and near-surface disposal is substantially less expensive than disposal options which involve destruction of organic complexants. Experimental work to define reference batch and countercurrent TRUEX process flow-sheets for use with CC waste is in progress.

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