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FLOWSHEET EVALUATION FOR THE PROCESSING OF U-MO MATERIALS IN H-CANYON

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SUMMARY

H-Canyon Engineering (HCE) is evaluating the feasibility of processing material containing 90% uranium (20% ^{235}U enrichment) alloyed with 10% molybdenum (Mo). The objective is to dissolve the material in nitric acid (HNO_3) in the H-Canyon dissolvers to a U concentration of 17-22 g/L (3-4 g/L ^{235}U) without the formation of precipitates. Following dissolution, the dissolved material will be processed through 1st and 2nd Cycle solvent extraction and the U sent to the U blend down program. The flowsheet must also consider any aqueous waste processing and solvent recycle issues.

HCE requested that the Savannah River National Lab (SRNL) define a flowsheet for safely and efficiently processing the U-10Mo material. The flowsheet definition will occur in two phases. The first phase involves the evaluation of all available data related to the dissolution and solvent extraction of U-Mo materials to determine if a viable flowsheet can be developed, and to assess if there are additional data that must be obtained.

Adequate data are available to conclude with confidence that a flowsheet is viable with sufficient operating margins. Data on the flowsheet development and processing of U-Mo fuels at Savannah River during the 1970's and 1980's provide the best information. Based on the data, the U-10Mo material can be dissolved in boiling 4.5-5.0 M HNO_3 to a U concentration of 17-22 g/L and a corresponding Mo concentration of 1.7-2.2 g/L. Any nickel (Ni) cladding associated with the material will dissolve readily. After dissolution is complete, traditional solvent extraction flowsheets can be used to recover and purify the U. Evaporation of the resulting 1AW waste stream may be limited by Mo solubility. Although the flowsheet is fairly well-characterized, it should be noted that the material to be processed during this campaign is different than those previously processed in that it does not have aluminum cladding. As a result, some additional work is recommended to verify important flowsheet parameters for the specific material to be processed.

INTRODUCTION

H-Canyon Engineering (HCE) is evaluating the feasibility of processing material containing 90% uranium (20% ^{235}U enrichment) alloyed with 10% molybdenum (Mo). The objective is to dissolve the material in nitric acid (HNO_3) in the H-Canyon dissolvers to a U concentration of 17-22 g/L (3-4 g/L ^{235}U) without the formation of precipitates. For the operating conditions to be employed, molybdic acid (MoO_3) is the only precipitate expected. Following dissolution, the dissolved material will be processed through 1st and 2nd Cycle solvent extraction and the U sent to the HEU blend down program. The flowsheet must also consider any aqueous waste processing and solvent recycle issues.

HCE requested that the Savannah River National Lab (SRNL) define a flowsheet for safely and efficiently processing the U-10Mo material. The flowsheet definition will occur in two phases. The first phase involves the evaluation of all available data related to the dissolution and solvent extraction of U-Mo materials to identify if a viable flowsheet for H-Canyon can be developed. The first phase will also include recommendations regarding experimental work required to validate critical data that have an unacceptable level of uncertainty. This report represents the first phase. The second phase of the flowsheet definition will provide a final recommended flowsheet based on new SRNL analyses and the various literature data.

Consultations between SRNL and HCE identified the principal process issues and requirements associated with U-10Mo material dissolution, solvent extraction, and waste processing. The issues are listed below according to process operation and elaborated in depth in the Discussion Section of this report.

Material Dissolution

1) What are the dissolution rates for U-10Mo material at 100 ^oC?
2) What is the acid consumption during dissolution?
3) What is the solubility of U-10Mo material as a function of acid concentration at 100 ^oC during dissolution to 1.7-2.3 g/L Mo, 15-20 g/L U and 1 g/L iron (Fe)?
4) Can a final dissolver solution nitrate (NO_3^-) concentration of 4-5 M be attained to avoid feed adjustment in an evaporator?
5) What level of hydrogen gas generation occurs during U-Mo material dissolution?

Solvent Extraction

1) Are the distribution coefficients for U and Mo during extraction, strip and solvent washing acceptable?
2) Can precipitates form during the proposed solvent extraction operating conditions?
3) What is the effect of HNO_3 replacement for $Al(NO_3)_3$ as the salting agent in solvent extraction?
4) Does the feed have an acceptable U^{235} concentration to allow the use of operating parameters for 1st Cycle that were used for HEU material processing?
5) Can 1st Cycle provide a feed to 2nd Cycle that is similar enough to the current feed to 2nd Cycle to allow use of the current 2nd Cycle operating parameters? Can adequate U recovery and purification for higher LEU [U] feed be attained when compared with typical HEU feed for 1st & 2nd Cycles?
6) Can Mo in the 1EU stream be reduced to less than 800 μg Mo/gU (the basis for the specification is included in the Discussion Section)? Will U product from 2nd Cycle meet the Mo product specification for U blend down?
7) Does Mo extract into the solvent? If extracted, does Mo interfere with U recovery and purification? If extracted, is Mo effectively removed from the solvent during solvent washing?

Waste Processing

1) What is the solubility of 1AW during evaporation?
2) If precipitation does occur, what are solid concentrations and overall rheology characteristics?
3) What is the corrosion effect of Mo in the high activity waste (HAW) evaporator?

DISCUSSION

Material Dissolution

Dissolution of the U-10Mo will be performed in 4-6 M HNO_3 using reusable stainless steel charging bundles. The material will be charged in carbon steel cans and the charging bundles will have carbon steel end caps; the carbon steel will contribute approximately 1.0-2.3 g/L iron to the solution. Enough material will be charged to H-Canyon dissolvers to yield final U concentrations of 15-20 g/L (3-4 g/L ^{235}U) and Mo concentrations of 1.7-2.2 g/L. Small amounts of nickel (Ni) will also dissolve into solution from the 0.005-inch plating on the surface of the material. It is assumed that no aluminum is added as part of the feed stream, which eliminates the need to add either mercury or potassium fluoride. The final dissolver solution will undergo a gelatin strike prior to being fed to 1st Cycle solvent extraction. Adjustments to acidity may be made, as appropriate, with the goal of avoiding the need to use the process evaporator to increase the U concentration prior to solvent extraction. There are five principal questions associated with dissolution which are addressed by available data.

1) What are the dissolution rates for U-10Mo material at 100 ^oC?

The dissolution rates for U, Mo and U-Mo have been measured in 4 M HNO_3 at 100-105 ^oC and found to be adequate for H-Canyon operations. The measured rates show that the dissolution of U is the limiting factor. Uranium metal dissolves at 105 ^oC in 4 M HNO_3 at 0.309 mg/min-cm^2 and in 7 M HNO_3 at 1.285 mg/min-cm^2; in 2 M HNO_3 at 100 ^oC, the dissolution rate is 0.051 mg/min-cm^2 *(1)*. Molybdenum metal dissolves at a higher rate than U. In 4 M HNO_3 at 90 ^oC, the dissolution rate of Mo is 16 mg/min-cm^2 *(2)*.

The literature report dissolution rates for U-Mo materials in HNO_3. For U-3Mo alloy, dissolution rates in boiling HNO_3 are 30 mg/min-cm^2 for 4 M HNO_3 and 43 mg/min-cm^2 for 5 M HNO_3 *(3)*. Being alloyed with Mo appears to have a significant effect on dissolution rate, probably through the control of oxide layer formation at the material surface. In the same study, work dissolution studies using HNO_3-$Fe(NO_3)_3$ show that U-10Mo materials dissolve marginally faster (5-10%) than U-3Mo materials for both 0.5 M and 1.0 M $Fe(NO_3)_3$ in HNO_3. As a result, dissolution rates for U-10Mo in boiling HNO_3 can be estimated at 35 mg/min-cm^2 for 4 M HNO_3 and 50 mg/min-cm^2 for 5 M HNO_3. Tests at Savannah River with samples of Hallam fuel did not directly measure the dissolution rates for U-10Mo because the overall processing rates were limited by the dissolution of the Al cladding associated with the Hallam fuel *(4)*.

2) What is the acid consumption during dissolution?

Plant operating experience is that 4.0-4.5 moles of HNO_3 are consumed per mole of U metal dissolved *(5)*. Since U comprises almost 90% of the overall charge, assuming 4.0-4.5 moles of HNO_3 consumption per mole of material is a good estimate. Specific data are not available, but balanced chemical reactions (Reactions 1 and 2) for Mo and Fe metal dissolution yield similar HNO_3 consumptions. After factoring in the total moles of Mo and Fe expected, assuming 4.5 moles of HNO_3 consumption per mole of metal dissolved will provide a reasonable estimate.

$$Mo + 6\ HNO_3 + H_2O \rightarrow H_2MoO_4 + 3\ H_2O + 6\ NO_2 \qquad (1)$$

$$Fe + 4\ HNO_3 \rightarrow Fe(NO_3)_3 + 2\ H_2O + NO \qquad (2)$$

Even though the Piqua fuels contained an Al cladding, similar acid consumption values were measured in the plant. For example, processing of Piqua fuels started at 5.6 M HNO_3/0.004 M Hg and finished at 2.6 M HNO_3, 0.40 M Al, 0.004 M Hg, 66.7 g/L U, 2.78 g/L Mo and 0.42 g/L Ni *(6)*. The process dissolved enough material to yield a metal concentration of 0.72 M metal with the consumption of 3.0 M of HNO_3 for a consumption of 4.2 moles of HNO_3 per mole of metal. Studies at Oak Ridge with U-10Mo materials measured typical acid consumption of 3.5-5.5 moles of HNO_3 per mole of material regardless of whether the alloy contained 3%, 8.4%, or 10% Mo *(7)*.

3) What is the solubility of U-10Mo material as a function of acid concentration at 100 ^{o}C during dissolution to 1.7-2.3 g/L Mo, 15-20 g/L U and 1 g/L Fe?

Extensive HNO_3-U-Mo data exist in the literature, principally from Faugeras, et al. *(8)*. The report shows that the effect of 1 g/L Fe on Mo solubility is negligible. The effect of of adding 15-20 g/L U to the HNO_3-Mo system is to shift the HNO_3 concentration that supports complete Mo solubility to lower acid concentrations. Based on the interpolation of data for U concentrations of 0 and 50 g/L, it is possible to estimate the following limiting acid conditions for Mo solubility at 100 ^{o}C: 2.5 g/L Mo and 20 g/L U is soluble in 2.4-4.5 M HNO_3 and 1.7 g/L Mo and 15 g/L U is soluble in 1.7-5.5 M HNO_3 (see Figure 1). Studies at SRNL have validated the solubility data reported *(4)*.

It should be noted that Mo solubility data in 2 M HNO_3 have been reported as a function of temperature: 2 g/L at 100 ^{o}C, 3 g/L at 70 ^{o}C, 6 g/L at 50 ^{o}C, and 20 g/L at 25 ^{o}C; more limited data for 4 M HNO_3 show a similar trend *(8)*. As a result, solutions that do not precipitate MoO_3 during dissolution will not precipitate upon cooling. Furthermore, the inverse solubility of Mo as a function of temperature limits the usefulness of evaporation for the dissolver product. For the U-10Mo material, it is preferable to dissolve to a ^{235}U concentration sufficiently high to avoid evaporation of the dissolver product.

If MoO_3 solids happen to form, they can be removed with the centrifuge and washed *(8)*. Molybdic oxide does not readily dissolve upon cooling. X-ray analyses demonstrated that any U with the solids is sorbed liquid and can be removed by washing with acid *(3)*.

It is worth noting that the Piqua fuel contained 0.5 wt% Ni as a bonding agent. The Ni readily dissolved into the HNO_3 and did not yield a precipitate *(10)*.

4) Can a final dissolver solution nitrate (NO_3^-) concentration of 4-5 M be attained to avoid feed adjustment in an evaporator?

The solubility data and acid consumption data were used to calculate whether a final dissolver NO_3^- concentration of 4-5 M could be obtained starting with 4-6 M HNO_3. The calculations estimate a total acid depletion of ~0.6 M. A plot of the interpolations in Figure 1 shows that the desired end point should be attainable.

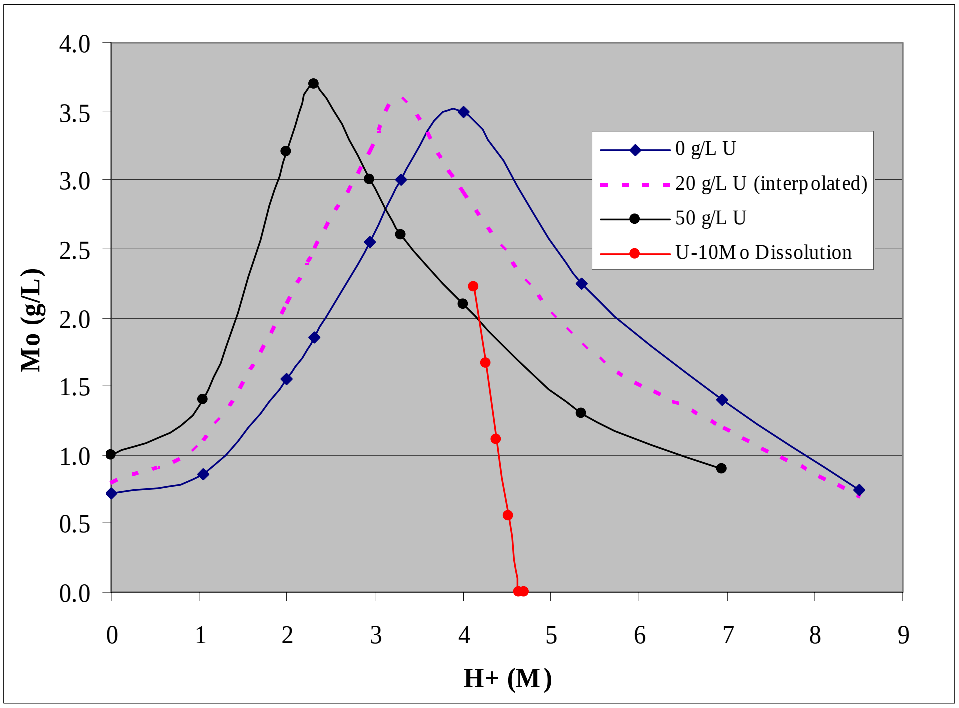

Figure 1. U-10Mo-HNO_3 Dissolution Profile

5) What level of hydrogen (H_2) gas generation occurs during U-Mo material dissolution?

Sufficient data exist to state that the H_2 generation rates for U-10Mo material will be less than 2 vol%, and most likely less than 0.1 vol %. Hydrogen generation for Hallam fuel dissolution yielded less than 2 vol%, and most of the H_2 can be attributed to the dissolution of Al using a Hg catalyst (9). Hydrogen generation rates for dissolution of U, Mo, U-Mo, and carbon steel in the absence of Al dissolution all show much less than 1.0 vol% H_2. Less than 0.1 vol% H_2 was evolved for U metal dissolution at 100 ^{o}C in both 4 M HNO_3 and 7 M HNO_3 *(1)*. Molybdeum metal dissolution in 4 M HNO_3 at 90 ^{o}C found less than 0.1% H_2 in the evolved gases *(2)*. Hydrogen gas measured from the dissolution of U-3Mo in HNO_3-$Fe(NO_3)_3$ ranged from 0.05-0.20 vol% while U-10Mo showed no detectable H_2 under similar conditions *(3)*. Measurements of off gas during the dissolution of the Piqua (U-3Mo) fuels in H-Canyon yielded a maximum of 0.2 vol% H_2 *(10)*. The dissolution of carbon steel in 2 M HNO_3 with 0.025 M KF and 2 g/L boron at 95 ^{o}C produced less than 0.1% H_2 *(11)*.

Solvent Extraction

The adjusted dissolver solution is fed to 1st Cycle A-Bank along with 7.5% tributyl-phosphate (TBP) in kerosene (1AX stream) and 4 M HNO_3 (1AS stream). Uranium and small amounts of Mo are extracted into the 1AU stream. The rest of the A-Bank aqueous feed exits the bank as the 1AW waste stream. The 1AU stream proceeds to the B-Bank where it is further purified. The U and Mo remain in the TBP and the aqueous effluent stream from the B-Bank, 1BP, is discarded as a waste stream. The U is stripped into the 1CU stream from the TBP in the C-Bank with 0.01 M HNO_3. It is expected that the Mo will remain in the solvent, 1CW and be removed from the solvent during solvent washing with sodium carbonate (Na_2CO_3).

The 1CU product solution is transferred to 2nd Cycle extracted again into 7.5% TBP in the D-Bank and stripped into 0.01 M HNO_3 in the E-Bank. The D- and E-Banks provide additional decontamination of impurities from the U product. The 1EU product stream exiting the E-Bank is sent for blending with natural uranium (NU) to produce LEU for off-site shipment. It is calculated that the 1EU stream must contain less than 800 μg Mo/gU to meet the product specification for its intended use.

1) Are the distribution coefficients for U and Mo during extraction, strip and solvent washing acceptable?

Specific measurements of distribution coefficients in the literature and overall decontamination factors for Savannah River miniature mixer-settler tests are available. These indicate that the U and Mo distribution coefficients are acceptable for extraction, strip and solvent washing. In the literature, the extraction of Mo from 0.25-1.0 M HNO_3 with 20% TBP/dodecane was measured at 0.05-0.96 g/L *(12)*. Another reference discusses that Mo extraction into 30% TBP/n-dodecane is fairly low and that most Mo is rejected to aqueous waste; the report cites Mo extraction with or without the presence of 60 g/L U at 0.16 g/L Mo *(13)*.

Miniature mixer-settler tests were previously conducted at SRNL with actual Piqua fuel (14). Piqua fuel testing was performed at 25 g/L U with 1 g/L Mo and 4 M HNO_3. The tests demonstrated that most of the Mo is rejected to the aqueous waste. Furthermore, the extracted Mo was not stripped by acid in any bank, but remained in the solvent until removed in the caustic solvent washing step. Tests showed that under all expected conditions the Mo does not strip with the U in the 1C bank but goes to the solvent washers. Earlier tests also confirm that U can be recovered from solutions containing Fe and Ni without interfering with recovery or contaminating the products.

Of particular interest is that the SRNL mixer-settler tests were run with the objective of maximizing Mo extraction. Nonetheless, the data reveal that U can be recovered and a reasonably high Mo DF attained. Depending on the process conditions, the following was observed: 1AW contained 82-94% of Mo; 1BU Mo DF = 3000-4000; 1CU Mo DF > 300; and 1EU Mo DF > 50. During the tests, it was shown that increasing the Al concentration (increased salting agent) increases HNO_3 extraction by the solvent which, in turn, decreases Mo extraction. The tests verified that Mo was removed from 1CW solvent using a 2.5% sodium carbonate wash.

2) Can precipitates form during the proposed solvent extraction operating conditions?

Under normal expected operating conditions, precipitation of Mo is not likely. The principal reason is related to the strong negative solubility Mo has as a function of temperature. Molybdenum solubility data for 2 M HNO_3 have been reported: 2 g/L at 100 ^oC, 3 g/L at 70 ^oC, 6 g/L at 50 ^oC, and 20 g/L at 25 ^oC; more limited data for 4 M HNO_3 show a similar trend *(8)*. Because dissolver solutions will be cooled to ~40 ^oC prior to feeding to 1st Cycle, the solubility should be three time higher than for dissolution. The absence of solids was demonstrated to some extent during the processing of Hallam fuels. Although concentrations of Fe and Mo were high in the 1AF feed to 1st Cycle feeds from Hallam fuel, no precipitates were observed *(9)*.

3) What is the effect of HNO_3 replacement for $Al(NO_3)_3$ as the salting agent in solvent extraction?

Aluminum nitrate has been replaced as a salting agent by both HNO_3 and $Fe(NO_3)_3$ *(15)*. For example, six different tests were run at 4 M HNO_3, 25 g/L U, 2 g/L B, 0.001 M Al, 0.15 M Fe, 0.016 M Ni, 0.041 M Cr and 0.004 Mn and exhibited excellent recovery and purity of U. The presence of minimal amounts of Al along with both Fe and Ni provides good correlation for a proposed flowsheet that will have lesser quantities of both Fe and Ni and no Al. In a separate study, both HNO_3 and $Fe(NO_3)_3$ were used to replace $Al(NO_3)_3$ as the salting agent for solvent extraction *(4)*.

4) Is it acceptable to use the feed [U^{235}] and operating parameters for 1st Cycle that were used for HEU material processing?

A detailed SRNL report provides operating conditions for >99.99% U recovery without U reflux *(15)*. The processing of Piqua fuel using miniature mixer-settlers demonstrated 1st and 2nd cycle performance in the presence of Mo using the standard HM flowsheet *(14)*. PST-79-464 (p. 2): Mixer-settler tests with the U-10Mo Hallam alloy demonstrated that the fuel can be processed by solvent extraction under HM technical standards using the HM solvent extraction flowsheet with no modifications *(4)*. For Hallam fuel tests, U and Pu partitioning was good and Mo decontamination was high enough to give an acceptable uranium product.

5) Can 1st Cycle provide a feed to 2nd Cycle that is similar enough to the current feed to 2nd Cycle to allow use of the current 2nd Cycle operating parameters? Can adequate U recovery and purification for higher LEU [U] feed be attained when compared with typical HEU feed for 1st & 2nd Cycles?

It is not immediately known whether 1st Cycle can provide a feed to 2nd Cycle that is similar enough to 2nd Cycle to allow use of the current 2nd Cycle operating parameters. Computer modeling may be needed to validate the parameters for this specific material. It is known, however, that LEU containing Mo can be processed through 1st and 2nd Cycles and attain adequate U recovery and purification. Operating experience with both the Hallam fuel (3.6% 235U) and the Piqua fuel (~2% 235U) have shown satisfactory performance in solvent extraction *(2, 10, 14)*. The Piqua fuel performance is somewhat misleading because it was blended with other materials prior to solvent extraction. Second cycle demonstration tests show DF>50 and U product with <10 ppm Mo even though conditions were adjusted for maximum Mo extraction. The experiments show that the recovery and purity of uranium are not affected by the expected concentrations of Mo in the feed *(14)*.

6) Can Mo in the 1EU stream be reduced to less than 800 μg Mo/gU? Will U product from 2nd Cycle meet the Mo product specification for HEU blend down?

The basis for this requirement is as follows. Following the current flowsheet for HEU blend down, the 1EU product will be evaporated to 7 g ^{235}U/L. This evaporation step will yield a total U concentration of 35 g/L. The blend ratio with natural uranium (NU) to get the evaporated 1EU stream to the low enriched uranium (LEU) shipping specification will be about 3.5 NU:1 EU on a gram U basis. The product specification for Mo is <200 μg/gU and the Mo specification for the NU being blended is <10 μg/gU. Therefore, the 1EU must be <865 μgMo/gU. Allowing for uncertainties, the target Mo concentration in the unevaporated 1EU stream is 800 μgMo/L.

Solvent extraction with TBP and methyl isobutyl ketone have shown that U products with very low Mo concentrations can be produced. SRNL tests demonstrated that Mo can be extracted into TBP with uranium and maintained in the organic through both the B and C banks *(14)*. In the same study, successful solvent extraction testing was conducted at 100 g/L U and 10 g/L Mo. It was observed that Mo extracts into solvent but does not strip with U. Based on available data, an overall decontamination factor for Mo of $>1.5 \times 10^4$ was calculated for 1EU. Second Cycle provided a decontamination factor of at least 50 for Mo.

Although not directly related to Mo impurities, past production experience with the Piqua and Hallam fuels indicate that a product low in contaminants can be attained. Works Technical Reports for solvent extraction of Hallam fuel reported no negative effects from the presence of Mo. Decontamination factors for Pu/Np ranged from 49,000 – 68,000 and U losses to the 1AW were 0.001-0.002%. For the Hallam fuels, 1EU product typically showed Pu/Np alpha values below 1.0 d/m/mgU. Similarly, solvent extraction tests with Hanford REDOX solvent (methyl isobutyl ketone) produced a product with less than 5 ppmU Mo from feeds containing 5.7 g/L Mo *(3)*. The notation of "ppmU" is an older notation that uses a mole basis comparison instead of the current weight basis comparison used when reporting impurities as "μg impurity/gU." Assuming that the H-Canyon feed is 2.2 g/L Mo and the DF measured by Hanford would be the same for the HM flowsheet, the product would be about 2 ppmU Mo, or <1 μg Mo/gU.

7) Does Mo extract into the solvent? If extracted, does Mo interfere with U recovery and purification? If extracted, is Mo effectively removed from the solvent during solvent washing?

To reiterate what was written above, the extraction of Mo from 0.25-1.0 M HNO_3 with 20% TBP/dodecane was measured at 0.05-0.96 g/L *(12)*. Also, Mo extraction into 30% TBP/n-dodecane is fairly low and most Mo is rejected to aqueous waste. With or without the presence of 60 g/L U, Mo extraction was reported at 0.16 g/L *(13)*.

Laboratory miniature mixer-settler tests have demonstrated under all acid stripping test conditions that the Mo does not strip with the uranium in the 1C bank but goes to the solvent washers. The same tests show that that Mo is removed from 1CW using 2.5% sodium carbonate but not with either concentrated or dilute acid. This result indicates that Mo is present as H_2MoO_4 *(14)*.

Waste Processing

It is preferred that the volume of the 1st Cycle aqueous waste stream (1AW) be reduced prior to neutralization with sodium hydroxide (NaOH) and disposal. The 1AW stream will contain most of the Mo, the Fe, small amounts of Ni and trace U in ~4 M HNO_3. There will be no ferrous sulfamate (often added to 1st Cycle scrub solution to ensure proper valence adjustments for decontaminating Pu from U) or aluminum (often present from fuel cladding) in the 1AW. The 1AW will be evaporated to a total NO_3^- concentration of 7-8 M. After evaporation, manganese nitrate is added as a neutron poison in proportion to fissile content of the evaporated 1AW stream. Because the fissile content should be at trace levels, negligible amount of manganese nitrate will be added. After manganese nitrate addition, the 1AW stream is neutralized and discarded.

1) What is the solubility of 1AW during evaporation?

The expected solvent extraction flowsheet for 1st Cycle adds only 4 M HNO_3 to the dissolved material. Therefore, the 1AW stream will contain the unextracted components of the dissolved material plus some additional HNO_3. Consequently, the solubility limits for evaporation of the 1AW stream are the same as those for dissolution. This conclusion is consistent with the flowsheet employed at the Savannah River Site during laboratory tests and processing of the Piqua fuels *(10)*.

2) If precipitation does occur, what are solid concentrations and overall rheology characteristics?

The literature describes MoO_3 precipitates as bulky solids which do not settle well *(16)*. Centrifuged volumes of unwashed solids range from 6-17 volume percent. The principal consideration regarding solids in the literature is that, once formed, the solids do not readily dissolve upon cooling of the solution *(2)*. Once formed, MoO_3 solids must be removed by solid-liquid separation or be transferred with the bulk solution to waste.

3) What is the corrosion effect of Mo in the high activity waste (HAW) evaporator?

No specific corrosion data were found discussing the effect of Mo might have in HNO_3 during dissolution. The only reference is an indirect one from the processing of Piqua fuels at Savannah River. The Test Authorization document for the processing of the Piqua fuels allowed the 1AW stream to be handled through the evaporator provided that it was not blended with other wastes containing Cr(VI), which is corrosive *(6)*. The implication is that the Mo is not sufficiently corrosive to cause a problem.

CONCLUSIONS

Adequate data are available to conclude with confidence that a flowsheet is viable with sufficient operating margins to process U-10Mo materials with small amounts of Ni. Data on the flowsheet development and processing of U-Mo materials at Savannah River during the 1970's and 1980's provide the best information. The principal issue for dissolution is the precipitation of MoO_3. The operating window for dissolution without MoO_3 formation is fairly well-characterized. The consequences of MoO_3 precipitation, if it does occur, do not pose a safety or criticality issue. The solvent extraction flowsheet for processing U-Mo materials can use the traditional HM flowsheet. The HM flowsheet has been successfully employed to recover U from materials with both lower and higher U enrichments than the ones being considered for this campaign. The available data indicate that small amounts of Mo extracted into TBP will not affect product purity or cause additional U losses to waste. Evaporation of the 1AW stream will be limited by the same parameters as dissolution. The effect of Mo on corrosion during 1AW evaporation has not been characterized.

Although the flowsheet is fairly well-characterized, some further experimental work is recommended in the following areas to define moderate-risk items better:

1) Acid consumption studies with actual U-10Mo material to ensure that the dissolution conditions will preclude the precipitation of MoO_3.
2) HNO_3-Mo solubility curve for 20 g/L U and 1 g/L Fe at 100-105 ^{o}C.
3) Batch distribution coefficient measurements for extract, strip and wash with particular emphasis on the distribution of Mo.

4) Sephis modeling to confirm adequate U recovery and purification for higher LEU [U] feed concentration versus that for HEU feed for 1st & 2nd U cycles.

The following additional data could prove beneficial to mitigating low-risk issues**:**

1) If Mylar TID seals are used and removed prior to dissolution,
   a) Determine if the Mylar tape residues dissolve.
   b) Determine what effect the Mylar tape residue has on the solubility of the Mo.
   c) Determine what effect the Mylar tape residue has on downstream processing.
   d) Determine if undissolved Mylar tape residue will be removed with the gelatin strike.
2) Measure H_2 generation rates during the dissolution of U-10Mo material at proposed flowsheet conditions.
3) Corrosion studies for 1AW waste evaporation to evaluate the effect of Mo.
4) Centrifuge studies of MoO_3 precipitated during dissolution.
5) Waste evaporation studies to confirm evaporation operating envelope and to qualitatively characterize the rheological properties of solids in the event that precipitation does occur.

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