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Evaluation of Interim Salt Disposition Project (ISDP) Macrobatch Dilution Bases Experienced at Actinide Removal Process and Modular Caustic Side Solvent Extraction Unit (ARP/MCU)

Originators:

Carrie K. Chiu
C. K. Chiu, Waste Acceptance Engineering
Date: 4-25-2012

S. P. McLeskey, Waste Solidification Engineering
Date: 4/25/2012

Reviewer:

K. L. Lang, Tank Farm Process Engineering
Design Verification Method: Document Review (Attachments 2+3 of SH-ENG.51)
Date: 4/25/2012

Eric Harrison
E. W. Harrison, Engineering Technology Integration
Design Verification Method: Document Review
Date: 4/25/2012

Approvals:

J. E. Occhipinti, Waste Solidification Engineering Manager
Date: 4-26-12

for EJ Freed
E. J. Freed, Tank Farm Engineering Manager
Date: 4/26/12

Acronyms

ARP	Actinide Removal Process
CDT	Contactor Drain Tank
DSSHT	Decontaminated Salt Solution Hold Tank
ERD	Emergency Response Data
gpm	gallons per minute
HLLCP	High Liquid Level Conductivity Probe
ISDP	Interim Salt Disposition Project
LWHT	Late Wash Hold Tank
LWPT	Late Wash Precipitate Tank
MCU	Modular Caustic Side Solvent Extraction Unit
MST	Monosodium Titanate
NO_{eff}	$NO_{effective}$
SE	Strip Effluent
SSFT	Salt Solution Feed Tank
WAC	Waste Acceptance Criteria
WS	Waste Solidification

Executive Summary

The purpose of this report is to document and establish the dilution bases in the Actinide Removal Process (ARP) and Modular Caustic Side Solvent Extraction Unit (MCU) for the Interim Salt Disposition Project (ISDP) Macrobatch process. The variation of process flow rate and the scrub solution ratio at MCU can impact the dilution bases. This evaluation documents all potential operating scenarios at MCU and determines the maximum amount of non-process water allowed in both ARP and MCU to ensure the Tank 50 minimum NO_{eff} requirement, as defined by the Tank Farm Waste Acceptance Criteria (WAC), is met.

The dilution experienced at ARP with the Monosodium Titanate (MST) and water addition at 241-96H is 5.81 %. The greatest dilution of 28.38 % is experienced when MCU is operating at 4 gpm of salt solution flow with a scrub solution ratio of X/15. The least dilution of 20.17 % is experienced when MCU is operating at 8.5 gpm with a scrub ratio of X/15. Non-process water can be added to both 512-S and MCU. The amount allowed for sending into Tank 50 varies depending on MCU processing set points. In this evaluation, the worst case is evaluated. Using data from previous salt batches and sample analysis, an estimated Salt Batch 5 $NO_{effective}$ (NO_{eff}), is used to project an NO_{eff} of 2.95 M for future salt batches. Combined with the assumed NO_{eff}, the scrub solution ratio of X/15 and 4 gpm salt flow rate, the worst case will allow approximately 114 gallons of non-process water to be added to Tank 50. While 1.7 M is the minimum NO_{eff} for the bulk supernate in Tank 50 in Reference 1, the re-baseline performed by Engineering Technology Integration nominally evaluates Tank 50 material balance at a conservative NO_{eff} of 2.0 M for the influent streams. Any non-process water sent to Tank 50 will be tracked on a case by case basis by both facilities to ensure all non-process water is accounted for.

Introduction

As part of the ISDP Macrobatch qualification, Waste Solidification (WS) Engineering will evaluate the dilution effect experienced at MCU and 512-S. This evaluation will provide the dilution bases following hydroxide adjustment in Salt Batch preparation tanks due to process dilution experienced at the ARP and MCU and provide the maximum non-process water threshold to ensure non-process water is accounted for to protect Tank 50 minimum NO_{eff} requirement.

Inputs and Assumptions

The following inputs and assumptions are used to evaluate the dilution experienced following hydroxide adjustment in Tank 49.

Inputs:

1. A batch transfer from Tank 49 to 241-96-H MST Strike Tank is 3,615 gallons. This allows for transfers from Tank 49 to MST Strike Tanks 1 and 2 until the tank level reaches 72 inches (Refs. 2 and 3).

2. 10 gallons of MST and 200 gallons of process water are added to the Strike Tanks 1 and 2 at 241-96H (Refs. 4 and 5).

3. Section 11.2.2 of the Tank Farm Waste Acceptance Criteria (WAC) and Section 5.4.14 of the DWPF Waste Compliance Plan (WCP) require a hydrogen generation limit for transfer into Tank 50 of 2.9E-08 ft^3/hr/gal, (with an NO_{eff} of 1.7 M minimum at 43°C), where $NO_{eff} = [NO_3] + 0.5 *[NO_2]$ (Refs. 1 and 6).

4. The nitrite and nitrate concentrations for the Tank 21 qualification sample are 25,750 mg/L and 175,000 mg/L respectively (Ref. 7).

Assumptions:

1. The Caustic Wash feed-and-bleed flow rate is assumed to be at a constant flow rate of 0.55 gpm.

   Basis: The caustic contribution due to the feed-and-bleed addition has changed based on the procedures for the Manual Startup (Ref. 8). As a result of increasing the salt flow rate, the Caustic Wash feed-and-bleed flow rate will be constant at 0.55 gpm (Ref. 9). This is to ensure the pH will be maintained in the Caustic Wash Tank. Should this flow be reduced, the assumption of 0.55 gpm flow will remain bounding.

2. Additional caustic addition at 512-S will be eliminated for process improvement.

   Basis: Caustic was added at 512-S as a process improvement during ISDP Macrobatch 2. For ISDP Macrobatches 3 and 4, the caustic addition at 512-S was eliminated. ISDP Macrobatch 5 and future Macrobatches will eliminate the caustic addition.

3. Scrub solution ratio of X/15 is the current flow rate for MCU processing.

   Basis: MCU typically adds scrub solution either at X/7.5 or X/15 of the salt solution flow where X is the volume of salt solution sent to MCU. During ISDP Macrobatch 4 operations, CMT-HTF-2011-00082 was generated to return the scrub solution ratio from X/7.5 to X/15 (Ref. 10). The ratio was originally increased in an attempt to prevent solids precipitation in the Strip Effluent Stream. However, subsequent operation has determined that the effect of this increase was negligible and the risk of precipitation is insignificant. MCU will continue to operate with a scrub solution ratio of X/15 unless another CMT and associated changes are made. This assumption is valid unless the scrub solution ratio is reverting back to X/7.5.

4. Non-process water at the MCU sump is assumed to be disposed through the Salt Solution Feed Tank (SSFT).

   Basis: Several flow paths can allow for disposition of the sump materials at MCU. Once the contents from the Process Enclosure Sumps are transferred to the Contactor Drain

Tank (CDT), the contents can either be transferred to the Decontaminated Salt Solution Hold Tank (DSSHT) (directly or by way of the DSS Decanter) or the Salt Solution Feed Tank (SSFT) (Refs. 11, 12, 13, 14, and 15). The CDT to SSFT transfer path is the most conservative due to the fact that the addition of water at the beginning of the MCU process results in the maximum possible dilution due to the contribution of additional scrub solution and caustic feed-and-bleed.

5. Up to 600 gallons of non-process water can be added at 512-S per transfer.

   Basis: Occasionally, non-process water can be added at 512-S. There are three cell sumps located at 512-S. The working volumes for the Late Wash Precipitate Cell Sump, the Late Wash Filtrate Cell Sump, and the Late Wash Filter Cell Sumps are identically 179.9 gallons (Refs. 16, 17, and 18). Assuming the entire content from the three cell sumps at their maximum volume are added into the salt solution, the maximum volume that can be added will be 539.7 gallons. Therefore, this evaluation assumes 600 gallons for conservatism for each transfer.

6. Tank 49 final volume is assumed to be at 350 inches. This is equivalent to a volume of 1,228,500 gallons.

   Basis: Revision 594 of the Tank Farm Emergency Response Data (Ref. 19) indicates the High Liquid Level Conductivity Problem (HLLCP) is at 367 inches and the tank level should not exceed 350 inches (Ref. 19). Using the conversion factor of 3510 gallons/inch, this will be equivalent to a volume of 1,228,500 gallons. For previous salt batches, the final volume in Tank 49 had been close to 350 inches.

7. The amount of salt solution transferred to Tank 49 from Tank 21 is assumed to be 695,000 gallons and Tank 49 will have a heel of 533,169 gallons.

   Basis: The H-Tank Farm Morning Report (Ref. 20) indicated the Tank 49 level is at 151.9 inches. Using the conversion factor of 3510 gallons per inch, the current volume of Tank 49 is 533,169 gallons. Therefore, approximately 695,000 gallons of Tank 21 material can be transferred to Tank 49 to reach a total volume of 1,288,500 gallons (i.e., 350 inches). For every salt batch qualification, the volume used for the qualification will be baselined at the current tank volume. The qualification uses the "good plus good" strategy to allow flexible commencement date of the next salt batch.

8. The maximum allowable non-process water added to MCU will be evaluated at a higher NO_{eff} value greater than the minimum NO_{eff} of 1.70 M for conservatism.

   Basis: The Tank Farm WAC has a Tank 50 minimum NO_{eff} requirement of 1.70 M (Ref. 1). The quarterly Tank 50 WAC Slurry Sample will be used to re-baseline material balance to ensure Tank 50 NO_{eff} is met. LWO Technology Integration Engineering re-baselines the Tank 50 material balance to provide allowable non-compliant material at an

NO_{eff} of approximately 2.0 M, which is conservative to protect the minimum NO_{eff} of 1.70 M.

9. The salt solution feed rate at MCU can operate between 4 and 8.5 gpm.

   Basis: Existing procedures and process controls are in place to ensure that flow rate varies between 4 and 8.5 gpm. Therefore, this evaluation assumes the operational feed rate to be between 4 and 8.5 gpm.

Results and Discussion

The example below shows the dilution bases using the case of scrub solution ratio of X/15 (Assumption 3) and salt feed flow rate of 4 gpm (Assumption 9).

Determine the dilution percentage without water addition at MCU/512-S.

Volume transferred to 512-S:

(Equation 1)

$$V_{at\ 512-s} = V_{Tank\ 49} + V_{Water} + V_{MST}$$

Where:

$V_{at\ 512\text{-}S}$ is the volume transferred to 512-S LWPT from 241-96-H, in gallons
$V_{Tank\ 49}$ is the volume transferred from Tank 49, 3,615 gallons (Input 1)
V_{Water} is the volume of process water addition at 241-96H, 200 gallons (Input 2)
V_{MST} is the volume of MST addition, 10 gallons (Input 2)

$$V_{at\ 512-s} = 3615\ gal + 200\ gal + 10\ gal = 3825\ gal$$

Percentage of dilution at 512-S after 241-96H:

(Equation 2)

$$D_{512-S} = \frac{(V_{at\ 512-S} - V_{Tank\ 49})}{V_{Tank\ 49}} \times 100\%$$

Where:

$D_{512\text{-}S}$ is the dilution percentage at 512-S after 241-96H (%)
$V_{at\ 512\text{-}S}$ is the volume transferred to 512-S LWPT from 241-96H (gallons)
$V_{Tank\ 49}$ is the volume transferred from Tank 49, 3,615 gallons (Input 1)

$$D_{512-S} = \frac{(3825\ gal - 3615\ gal)}{3615\ gal} \times 100\% = 5.81\%$$

Volume transferred to MCU without dilute sodium hydroxide added at 512-S will be the same as volume at 512-S.

$$V_{MCU} = V_{at\ 512-s}$$

Where:

V_{MCU} is the volume transferred to MCU (gallons)

$$V_{MCU} = V_{at\ 512-s} = 3825\ gal$$

Amount of scrub solution added:

(Equation 3)

$$V_{scrub} = V_{MCU} \times \frac{X}{15}$$

Where:

V_{scrub} is the volume of scrub solution added (gallons)

$$V_{scrub} = 3825\ gal \times \frac{X}{15} = 255\ gal$$

Therefore, the total volume that will be used to calculate the dilution due to caustic wash at MCU:

(Equation 4)

$$V_{MCU+Scrub\ Solutions} = V_{MCU} + V_{scrub}$$

Where:

V_{MCU} is the volume transferred to MCU (gallons)
V_{scrub} is the volume of scrub solution added (gallons)

$$V_{MCU+Scrub\ Solutions} = 3825\ gal + 255\ gal = 4080\ gal$$

Amount of caustic wash added:

(Equation 5)

$$V_{caustic} = \frac{V_{MCU+Scrub\ Solutions} \times F_{feed\ and\ bleed}}{F_{salt\ feed}}$$

Where:

$V_{caustic}$ is the volume of caustic wash (gallons)
V_{MCU} is the volume transferred to MCU (gallons)
$F_{feed\ and\ bleed}$ is the flow rate of feed and bleed, 0.55 gpm (Assumption 1)
$F_{salt\ feed}$ is the flow rate of caustic wash, 4 gpm (Assumption 9)

$$V_{caustic} = \frac{4080\ gal \times 0.55\ gpm}{4\ gpm} = 561\ gal$$

Volume transferred to Tank 50:

(Equation 6)

$$V_{Tank\ 50} = V_{MCU} + V_{scrub} + V_{caustic}$$

Where:

$V_{Tank\ 50}$ is the volume transferred to Tank 50 (gallons)
V_{MCU} is the volume transferred to MCU (gallons)
V_{scrub} is the volume of scrub solution added (gallons)
$V_{caustic}$ is the volume of caustic wash (gallons)

$$V_{Tank\ 50} = 3825\ gal + 255\ gal + 561\ gal = 4641\ gal$$

Percentage of dilution at Tank 50:

(Equation 7)

$$D_{Tank\ 50} = \frac{V_{Tank\ 50} - V_{Tank\ 49}}{V_{Tank\ 49}} \times 100\%$$

Where:

$D_{Tank\ 50}$ is the dilution percentage at Tank 50 (%)
$V_{Tank\ 50}$ is the volume transferred to Tank 50 (gallons)
$V_{Tank\ 49}$ is the volume transferred from Tank 49, 3,615 gallons (Input 1)

$$D_{Tank\ 50} = \frac{4641\ gal - 3615\ gal}{3615\ gal} \times 100\% = 28.38\%$$

The same method is used for all scenarios with different salt feed flow rates and scrub solution ratios. Table 1 below summarizes the dilution percent seen without 512-S water addition at scrub solution ratio of X/15. As seen below, the maximum dilution percentage can be seen at salt flow rate of 4 gpm.

Table 1, Dilution Percentage at Tank 50 without water addition at 512-S.

Salt Flow Rate (gpm)	Scrub Solution Ratio: X/15
4	28.38%
5	25.28%
6	23.21%
7	21.73%
8	20.62%
8.5	20.17%

Determine the maximum allowable non-process water addition at MCU to protect Minimum $NO_{effective}$ of 1.70 M

Non-process water addition can be added to both 512-S and MCU. The NO_{eff} is affected for previous salt batches are listed below. For Salt Batch 5, the NO_{eff} will not be readily available for qualification. Therefore, the NO_{eff} for Tank 49 is calculated based on Assumptions 4, 5, and 6 and the Tank 21 sample results for nitrate and nitrite (Input 4).

Table 3, NO_{eff} for ISDP Macrobatches

ISDP Macrobatch	Tank 49 NO_{eff} (M)	Reference
1	2.96	X-ESR-H-00120, Rev. 0
2	2.24^	X-ESR-H-00158, Rev. 0
3	2.99	X-ESR-H-00226, Rev. 1
4	2.96	X-ESR-H-00303, Rev. 0
5	3.04	*

^Note: Caustic addition at 512-S is not included in this NO_{eff} value.
*Note: Estimated value for Salt Batch 5.

To convert nitrate and nitrite concentration from mg/L to mol/L or M:

$$concentration = \frac{mg}{L} * \frac{1\ g}{1000\ mg} * MW_i$$

Where:

Concentration is the concentration in mol/L or M
MW_i is the molecular weight of nitrate or nitrite, 62 g/mol and 46 g/mol, respectively

For nitrate:

$$concentration = \frac{175000\ mg}{L} * \frac{1\ g}{1000\ mg} * \frac{mol}{62\ g} = 2.82\ M$$

For nitrite:

$$concentration = \frac{25750\ mg}{L} * \frac{1\ g}{1000\ mg} * \frac{mol}{46\ g} = 0.56\ M$$

To calculate the NO_{eff} for Tank 21 (Input 4):

(Equation 8)

$$NO_{eff\ Tank\ 21} = NO_3 + 0.5 * NO_2$$

Where:

$NO_{eff\ Tank\ 21}$ is the calculated NO_{eff} for Tank 21 (M)

$[NO_3]$ is the concentration for nitrate (M)
$[NO_3]$ is the concentration for nitrite (M)

$$NO_{eff\ Tank\ 21} = 2.82 + 0.5 * 0.56 = 3.10\ M$$

To calculate the predicted Tank 49 NO_{eff} for Salt Batch 5:

(Equation 9)

$$NO_{eff\ Salt\ Batch\ 5} = \frac{NO_{eff\ Salt\ Batch\ 4} * V_{Tank\ 49\ Heel} * \frac{3.785\ L}{gal} + NO_{eff\ Tank\ 21} * V_{Tank\ 21} * \frac{3.785\ L}{gal}}{V_{Tank\ 49} * \frac{3.785\ L}{gal}}$$

Where:

$NO_{eff\ Salt\ Batch\ 5}$ is the predicted NO_{eff} for Tank 49 once Salt Batch 5 material is transferred
$NO_{eff\ Salt\ Batch\ 3}$ is the current NO_{eff} for Tank 49, 2.96 M
$V_{Tank\ 49\ Heel}$ is the volume in the Tank 49 heel, 533,169 gallons (Assumption 5)
$NO_{eff\ Tank\ 21}$ is the calculated NO_{eff} for Tank 21 using Tank 21 sample result (Input 4)
$V_{Tank\ 49\ Heel}$ is the maximum volume in Tank 49, 1228,500 gallons (Assumption 4)

$$NO_{eff\ Salt\ Batch\ 5} = \frac{2.96 * 533196\ gal * \frac{3.785\ L}{gal} + 3.10 * 695000\ gal * \frac{3.785\ L}{gal}}{1228500 * \frac{3.785\ L}{gal}} = 3.04\ M$$

The most conservative value to calculate the maximum amount of non-process water addition to protect the minimum $NO_{effective}$ of 1.70 M will be 2.24 M, which was the NO_{eff} for Salt Batch 2. Because this value did not include the caustic addition at 512-S, the NO_{eff} experienced at Tank 50 is even lower. Based on process knowledge, ISDP Macrobatches 3 and 4 were qualified in a similar manner. From the above predicted NO_{eff} for Salt Batch 5, the NO_{eff} is predicted to be 3.04 M, which is higher than Salt Batches 3 and 4. Therefore, it is assumed that from the recent salt batches, the NO_{eff} will be approximately 2.95 M.

<u>To determine the amount of non-process water for nominal processing at MCU:</u>

The worst case for the dilution for the current MCU process strategy will be at a salt flow rate of 4 gpm.

Volume transferred to Tank 50 with non-process water:

(Equation 10)

$$V_{Tank\ 50} = V_{MCU} + V_{scrub} + V_{caustic} + Y$$

Where:

$V_{Tank\ 50}$ is the volume transferred to Tank 50 (gallons)
V_{MCU} is the volume transferred to MCU (gallons)
V_{scrub} is the volume of scrub solution added (gallons)
$V_{caustic}$ is the volume of caustic wash (gallons)

Y is the maximum non-process water addition process through MCU to achieve a NO_{eff} of 2.0 M (gallons)

Volume transferred to MCU:

$$V_{MCU} = V_{at\ 512-s} = V_{Tank\ 49} + V_{water} + V_{MST} + Y$$

$$V_{MCU} = V_{at\ 512-s} = 3825 + Y\ gal$$

Therefore, a bounding dilution will be calculated for the purpose of this evaluation in order to achieve a NO_{eff} of 2.0 for Tank 50 Material Balance.

NO_{eff} = 2.0 M = (2.95E+00) * (1-x%)
X = 32.2%

Amount of scrub solution added:
This is equal to the salt solution flow rate multiplied by the X/15.

(Equation 3)

$$V_{scrub} = V_{MCU} \times \frac{X}{15}$$

$$V_{scrub} = 3825 + Y\ gal \times \frac{X}{15} = 255 + \frac{Y}{15}\ gal$$

Therefore, the total volume experienced at caustic wash at MCU:

(Equation 4)

$$V_{MCU+Scrub\ Solutions} = V_{MCU} + V_{scrub} = 3825 + Y\ gal + 255 + \frac{Y}{15}\ gal$$

Amount of caustic wash added:
The dilution effect is highest when the salt solution flow rate is at 4 gpm.

(Equation 5)

$$V_{caustic} = \frac{V_{MCU+Scrub\ Solutions} * F_{feed\ and\ bleed}}{F_{salt\ feed}}$$

$$V_{caustic} = \frac{3825 + Y + 255 + \frac{Y}{15}\ gal * 0.55\ gpm}{4\ gpm} = 561 + 0.1467\,Y\ gal$$

And to simplify:

$$V_{Tank\ 50} = 3825 + Y\ gal + 255 + \frac{Y}{15}\ gal + 561 + 0.1467\,Y\ gal$$
$$= 4641 + 1.213\,Y\ gal$$

Therefore, the maximum allowable amount of non-process water that can be added to MCU to protect the NO_{eff} requirement:

(Equation 7)

$$D_{Max} = \frac{V_{Tank50} - V_{Tank\,49}}{V_{Tank49}} * 100\%$$

Where:

D_{Max} is the maximum dilution for non-process water to the system, 32.2%
$V_{Tank\,50}$ is the volume transferred to Tank 50 (gallons)
$V_{Tank\,49}$ is the volume in Tank 49 (gallons)

$$32.2\% = \frac{4641 + 1.213\,Y\ \ gal - 3615\ gal}{3615\ gal} * 100\%$$

$$Y \approx 114 gal$$

The maximum amount of non-process water allowable from 512-S and MCU for nominal processing at MCU is approximately 114 gallons. Therefore, for any non-process water added beyond 114 gallons at MCU would be counted against the Tank 50 material balance for non-compliant material. Occasionally, non-process water can be added at 512-S. A separate analysis will be done on a case by case if needed.

Conclusion

ISDP Macrobatch material will experience dilution of 5.81% in the Strike Tanks at 241-96H prior to transfer to 512-S. The maximum dilution, due to normal processing, of 28.38 % is experienced with a salt flow rate of 4 gpm and a scrub solution ratio of X/15. The minimum dilution of 20.17 % is experienced with a salt flow rate of 8.5 gpm and a scrub ratio of X/15. Assuming an NO_{eff} of 2.95 M for future salt batches, this corresponds to a dilution percentage of 32.2% to dilute Tank 50 NO_{eff} to 2.0 M. It is determined that approximately 114 gallons of non-process water can be added to a batch before transferring to Tank 50. Therefore, these volumes will be tracked on a case by case basis to ensure all non-process water additions are accounted for at both facilities.

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