Y-AES-S-00002
Revision 0

# Defense Waste Processing Facility

# Mercury Removal Study

Savannah River Remediation
A URS COMPANY TEAMED WITH BECHTEL | CH2M HILL | B&W | AREVA

Savannah River Site
Aiken, SC 29808

Prepared for the U.S. Department of Energy Under
Contract Number DE-AC09-09SR22505

## DISCLAIMER

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# List of Acronyms and Abbreviations

| | |
|---|---|
| DOE | Department of Energy |
| DSA | Documented Safety Analysis |
| DWPF | Defense Waste Processing Facility |
| DWPF | Defense Waste Processing Facility |
| HLW | High Level Waste |
| IX | Ion Exchange |
| LPPP | Low Point Pump Pit |
| MAWT | Mercury Acid Wash Tank |
| MCU | Modular Caustic Side Solvent Extraction Unit |
| MWWT | Mercury Water Wash Tank |
| PVV | Process Vessel Vent |
| RAMI | Reliability, Availability, Maintainability and Inspectability |
| RCT | Recycle Collection Tank |
| SEE | Systems Engineering Evaluation |
| SME | Slurry Mix Evaporator |
| SMECT | Slurry Mix Evaporator Condensate Tank |
| SRAT | Sludge Receipt and Adjustment Tank |
| SRR | Savannah River Remediation (LLC) |
| SRS | Savannah River Site |
| TK | Tank |

# Summary of Revision

| Revision Number | Date | Description of Change |
|---|---|---|
| 0 | 9/29/15 | Initial Issue |
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**Executive Summary**

The mercury levels within the Liquid Waste System are higher than previously predicted. As part of an overall strategy to reduce the HLW System mercury level, a team was chartered to conduct a Systems Engineering Evaluation (SEE) to investigate a method to re-establish the capability to remove mercury from within the Defense Waste Processing Facility (DWPF) process stream.

The SEE process used for this evaluation was a structured alternative analysis with weighted evaluation criteria. 33 potential options were initially identified to remove mercury from the DWPF process stream. The 33 options were subsequently reduced to 14 options through a screening process. The evaluation of the 14 final options resulted in the following: a recommendation to deploy the two highest ranking options concurrently, monitor the DWPF recycle stream, and develop add on enhancements to be selected and ready for deployment if the desired mercury removal capability is not being observed. The two highest ranking options from the SEE were:

- Raise pH in SMECT to minimize mercury solubility, and collect Mercury primarily in the SMECT sump then pump out (repair or replace SMECT mercury Pump)
- Re-establish existing system for mercury removal and purification

This report documents in detail the activities and recommendations of the team.

# 1.0 Background

The mercury levels within the Liquid Waste System that are being encountered are higher than previously predicted. This may be attributed in part to ineffective removal of mercury from the waste streams being processed.

DWPF was initially designed with a mercury purge point which is no longer functional, and as part of an overall strategy to reduce the HLW System mercury level, a method of removing mercury from the DWPF process stream must be re-established.

Although flowsheet evaluations have indicated several areas related to mercury behavior requiring further study, it is clear that both the Liquid Waste Flowsheet and the DWPF process will benefit from a method that removes mercury from the process.

Mercury continues to be a difficult constituent in the DWPF flowsheet. Ineffective removal of mercury as defined by the current technical baseline has led to facility issues (e.g. PVV system performance) as well as downstream issues (e.g., increased saltstone Hg inventory).

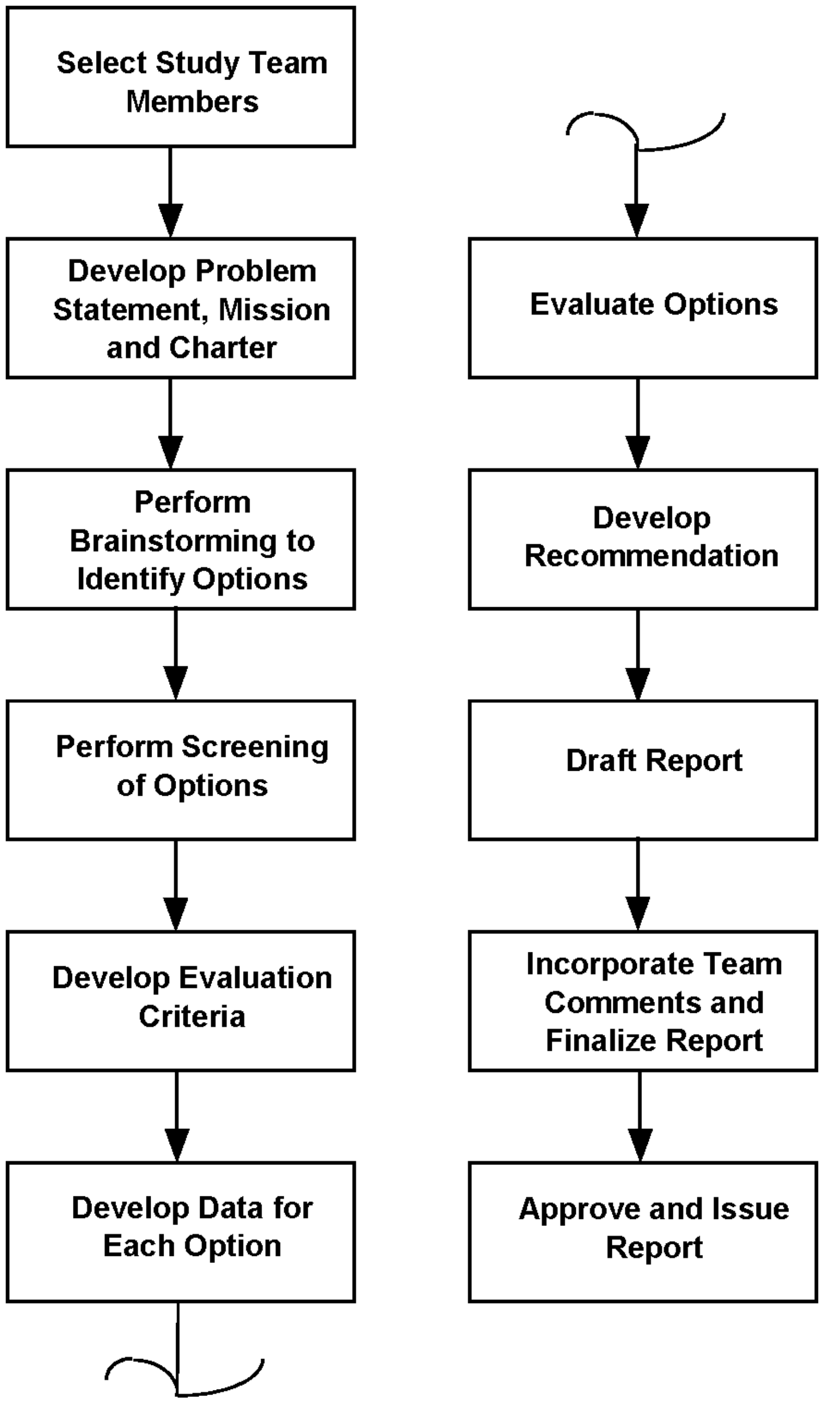
A team was subsequently chartered to perform a SEE to identify and examine options for the removal of mercury from the DWPF process and provide a recommendation for implementation of a preferred option(s). This report documents the activities and recommendations of the team.

# 2.0 Process

The process used for this evaluation was a structured alternative analysis with weighted evaluation criteria. The team used alternative study methods defined in E7 Manual procedure 2.15 (Reference 5.2) and Alternative Studies and System Engineering Methodology Guidance Manual, WSRC-IM-98-000033, Appendix A (Reference 5.3). This methodology is commonly used to select an alternative from two or more options which would be available to meet specific functions, selection criteria, and requirements.

The SEE process is shown in Figure 2-1 and is described in detail within the following sections.

**Figure 2-1: Study Process**



## 2.1 Selection of Study Team Members

The initial activity of the study was to identify SEE team members and resources. SEE Team members were selected for their experience, expertise, and history in the operation of DWPF and the Liquid Waste Program at SRS.

The following functional areas will be represented within the Team:

- Operations
- Maintenance
- Engineering
- SRNL
- Waste Characterization
- Nuclear Safety
- Flowsheet Development

The list of SEE team members is shown in Table 2.1-1:

**Table 2.1-1: Team Members**

| Name | Organization |
|---|---|
| Patrick Toohey | DWPF Operations/Maintenance |
| Jeremiah Ledbetter | DWPF Engineering |
| Steve Strohmeier | DWPF Engineering |
| Azadeh Samadi-Deffouli | DWPF Engineering |
| Jonathan Bricker | DWPF Engineering |
| Dan Lambert | SRNL |
| Andy Sudduth | DWPF Engineering |
| Andy Tisler | Project Engineering |
| Bob Petras | Env. & Waste Characterization |
| Aaron Staub | Facility Engineering |
| Aston Thompson | Engineering |
| Caitlin Wood | SRNL |
| David McGuire | SRNL |
| George Weeks | SRNL |
| Jeffrey Coughlin | SRNL |
| John Gregory | Ops & Facility Management |
| John McCrary | DWPF Engineering |
| John Neuville | DWPF Engineering |
| John Occhipinti | Closure Engineering |
| Jonathan Townsend | Nuclear Safety |

| | |
|---|---|
| Pedro Flores | DWPF Engineering |
| Gavin Winship | Risk Management |
| Richard Player | Engineering |
| Samuel Youmans | DWPF Operations/Maintenance |
| Terri Fellinger | Flowsheet Development |

### 2.2 Problem and Mission Statement

The initial step of this SEE was to identify and succinctly state the problem and define a mission and goal for the study. To ensure these perquisites were accepted by the facilities, management and engineering, a Charter was developed and approval obtained (Reference 1). Within this Charter the problem statement was defined as:

> **"A greater than planned level of mercury exists in the HLW System processing streams due to currently ineffective removal techniques."**

From this the team developed the following mission statement:

> **"As part of reducing the level of mercury in the HLW processing streams, re-establish the capability to remove mercury within the DWPF process stream."**

### 2.3 Brainstorming

Using the Problem and Mission/Charter statements, the team performed brainstorming to identify potential options. 33 potential options were identified (see Table 2.4-1) to remove mercury from DWPF. A brief description of these initial options is presented in Appendix A.

### 2.4 Screening

Screening criteria were developed by the team based on the desired function to remove mercury from DWPF and the constraints within which the mercury removal must be performed. As with the Problem and Mission statements these screening criteria were included in the Charter (Reference 1) and approved by management, facilities and engineering. The following screening criteria were developed:

- All removed mercury shall be either disposed of through existing waste disposal paths or captured and held for further treatment prior to final disposal.

- Option shall not constrain planned canister production.

- Option shall not result in any significant changes to current or planned Alternate Reductant flowsheets.

- Option shall not result in negatively impacting purge requirements.

After applying the above screening criteria to the 33 options identified during brainstorming, 14 options were screened out. The results of initial brainstorming and screening are shown below in Table 2.4-1:

**Table 2.4-1: Brainstorming and Screening Results**

| # | Option | Screening Results | Remarks |
|---|---|---|---|
| 1 | Pump out SMECT and accumulate in MWWT and remove to MAWT (Re-establish existing system without purification) | N/A | Combine with Option 2. |
| 2 | Reestablish existing system | Pass | |
| 3 | Pump from SMECT to MAWT | Pass | |
| 4 | Pump from MWWT to SMECT then SMECT to MAWT | Pass | |
| 5 | Pump from MWWT to SRAT (Clean MWWT and use existing system) | N/A | Combine with Option 2. |
| 6 | Routing SRAT Condensate to SMECT then pump SMECT mercury to MWWT | Pass | |
| 7 | Develop a new dip/scoop to pull out of SMECT | Pass | |
| 8 | Use Centrifugal Separator | Pass | |
| 9 | Use Electrostatic means (Anode) | Fail | Cannot be deployed without evaluation of significant flowsheet changes. |
| 10 | Dissolve mercury in SMECT using pH change (with acid) and remove dissolved mercury using mercury resin | Pass | |
| 11 | Collect elemental mercury in SMECT using pH change (increase) and pump (to purification, storage or amalgamation) | Pass | |
| 12 | IX column at SMECT sample loop | Pass | |

| # | Option | Screening Results | Remarks |
|---|---|---|---|
| 13 | Change pH in MWWT by adding sodium hydroxide prior to each SRAT batch | Fail | Cannot be deployed without evaluation of significant flowsheet changes. |
| 14 | Install organic strip system prior to MWWT | Fail | Cannot be deployed without evaluation of significant flowsheet changes. |
| 15 | Redesign MWWT to a strip system | Fail | Cannot be deployed without evaluation of significant flowsheet changes. |
| 16 | Add coalescer to MWWT | Pass | |
| 17 | Reflux at beginning of boiling in SRAT | Pass | |
| 18a | Sparge the MWWT to remove sludge | N/A | Note 1; Already included in Options 2 and 3. |
| 18b | Replace the jumper between the SRAT condenser and the MWWT. | N/A | Note 1; Not a solution. |
| 18c | Use a continuous gravity Hg decanter instead of the MWWT Hg transfer pump | Pass | Note 1 |
| 18d | Use a continuous gravity Hg decanter as a direct feed to a small columns for Hg purification based on disposal requirement | N/A | Note 1; Moved to disposal options. |
| 18e | Replace SRAT Condensation Bell | N/A | Note 1; All indications to date show this is not required. |
| 19 | Add more acid in SRAT | Pass | This is a flowsheet change for current flowsheet, however should be noted in the report that this could be considered for the Alternate reduction flowsheet. |
| 20 | Add a reductant to the SMECT | Fail | Cannot be deployed without evaluation of significant flowsheet changes. |
| 21 | Use mercury removal resin in RCT | Pass | |
| 22 | Use amalgam | N/A | Moved to disposal options. |
| 23 | Convert organic to elemental for easier collection | Fail | No practical conversion method unless major flowsheet changes occur. |
| 24 | Passive decanter as part of SME overheads | Pass | |
| 25 | Install settling tank (after pumping out of SMECT) | Pass | |
| 26 | Filtration and IX after RCT | Pass | |
| 27 | Change operating mode of RCT to allow decanting | Pass | |
| 28 | Utilize Jet Eductor and Temporary Bucket | Pass | |

| # | Option | Screening Results | Remarks |
|---|---|---|---|
| 29 | Install Filtration/IX at LPPP | Fail | Cannot be deployed without evaluation of significant flowsheet changes. However during discussion the concept of utilizing Building 512-S was identified as a potential for consideration for deployment after SWPF became operational. The evaluation of such an option is beyond the Charter of this team but the concept will be identified in the final report. |

## 2.4 Develop Evaluation Criteria

Evaluation criteria were developed based on those specific attributes that the team considered critical to mission success and of specific interest to stakeholders. The evaluation criteria were also considered to be discriminating between options in that each option would vary in how well they perform against each criterion. The evaluation criteria developed by the team and topics associated with the criterion were as follows:

**Mercury Removal Capability**
Options with greater mercury removal were considered more favorable than options with lesser mercury removal capability.

**Ease of Disposal**
The more easily the form of mercury captured is to dispose of, the more favorable the option. (e.g. clean elemental mercury is preferable).

**Operability**
Options with the least operator dependability (e.g. fewer operations or fewer actions) were more preferable than options that were operator intensive.

**Maintainability**
Systems that are easier to maintain (e.g. no moving parts, long component design life) are preferred options from a maintainability perspective.

**Deployment Schedule**
The shorter the duration from receiving notice to proceed to complete deployment, the more preferable.

**Outage Window Duration**
The shorter the outage window needed to deploy the option, the more preferable.

**Technical Maturity**

The more technically mature options were the more preferred the option.

## 2.5 Data Development

After the development of evaluation criteria, the final options that passed screening were investigated further and matured to provide an understanding of how they would perform for each of the evaluation criteria. The final options and developed data are presented in Appendix B.

## 2.6 Evaluation

A software package specifically designed for alternative analyses was used to perform the evaluation. The software, Expert Choice Pro© provides an analytical platform capable of recording data in the form of weighted criteria and scoring and performing a synthesis of these data to arrive at rankings. Secondary features are the ability to modify criteria weights and show in real time, ranking changes. Using the data developed for each option and weighted criterion, the options were scored, ranked, and a sensitivity analysis performed. After interpreting the results, options were determined not to be mutually exclusive, so a grid was prepared to optimize the solution. Risks were assessed for top option(s) as discussed below.

### 2.6.1 Criteria Weighting

The analysis hierarchy was developed using Expert Choice Pro© and a pair-wise comparison of criteria performed to establish weights based on preference judgements. The resulting hierarchy and criteria weights are shown in Figure 2.6.1-1:

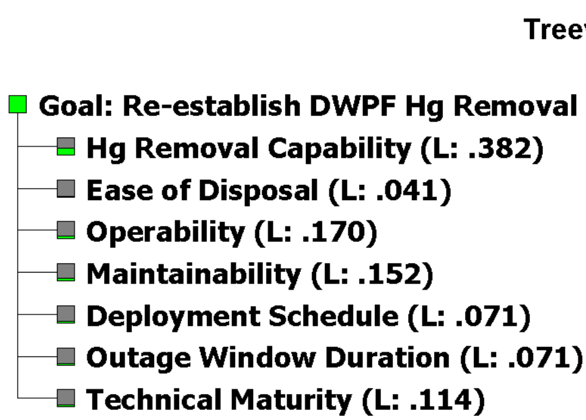



**Figure 2.6.1-1: Analytical Hierarchy and Criteria Weights**

As expected the capability to remove mercury was weighted highest as it is essentially the mission of the preferred option. Operability, then maintainability (both less than half the weight of capability to remove mercury) were the next heavily weighted criteria, as the team considered once the capability was deployed, it would be a long term burden on the facility if the option were difficult to maintain. Technical maturity was next which was considered more important than outage window or deployment schedule as once the option was deployed, it would be in place for the life of DWPF; whereas a technically immature option could prove difficult to mature and may not be as successful at meeting the mission goal as was envisioned during the analysis.

### 2.6.2 Scoring

To facilitate assigning a numerical value to the team assessment of how an option would perform relative to a specific criterion, a guide scale was developed as shown in Table 2.6.2-1:

**Table 2.6.2-1: Scoring Guide Scale**

| | |
|---|---|
| Excellent | 1 |
| | |
| Very Good | |
| | 0.75 |
| Good | |
| | |
| Acceptable | 0.5 |
| | |
| Marginal | |
| | 0.25 |
| Poor | |
| | |
| Very poor | 0 |

The team then proceeded to apply a score to each criterion for each option. The results of the scoring are shown in Appendix C.

### 2.6.3 Ranking

After the scoring had been completed the software program synthesized the results by multiplying the score by the weighting factor for each criterion and totaling the score for each option to arrive at a ranking. Figure 2.6.3-1 shows the ranking score results for all options.

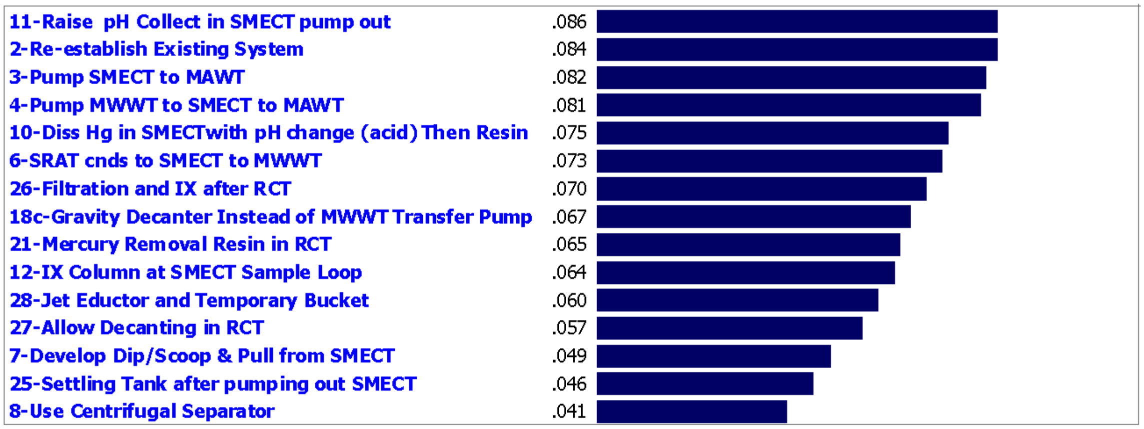



**Figure 2.6.3-1: Results**

As can be seen from Figure 2.6.3-1, Option 11 (Raise pH in SMECT, collect in SMECT then pump out), and Option 2 (Re-establish existing system) were the highest ranking options.

### 2.6.4 Sensitivity Analysis

A model's results are considered robust if evaluation criteria weights can be altered by ± 10% and the top ranking option is not displaced. A sensitivity analysis was performed by increasing and decreasing the weight of a particular criterion, resulting in the increase or decrease being proportionally distributed to the other criteria. This changed the scores of the options. It was observed that in no case did this degree of change displace the top two options. The criteria generally had to be changed upwards of 30% to change position and in many cases drastic decreases or increases in selected criteria did not displace the top two options. This model and result were therefore considered robust and valid.

### 2.6.5 Solution Optimization

Unlike most evaluations of this type, the majority of options were not mutually exclusive, i.e. if one were deployed the others could not. This gave the team the opportunity to select the top two ranking options for deployment, with the possibility of having additional "add-on" options deployed to further optimize the solution. To enable this optimization, a grid of compatibility was developed focusing on the "add-on" options that could be used with the top two options and is presented within Appendix D.

### 2.6.6 Risk Assessment

A premortem process was used to identify risks and opportunities associated with the top two options from the SEE. The risks/opportunities identified and their associated handling strategies are presented in Appendix E. The two highest risks identified were:

1. Achieving desired mercury removal capacity
    - Handling strategies include sampling RCT stream to Tank Farm to confirm satisfactory mercury removal; phased deployment of add-ons to enhance mercury removal system capacity to meet target

2. Equipment reliability, functionality, failures, maintenance, replacement, obsolescence
    - Handling strategies included mockup and testing, identification and redesign of obsolete components, optimization of process steps, development of cleaning options

## 3.0 Discussion of Results

The evaluation results show that Option 11 (Raise pH in SMECT, collect in SMECT then pump out), and Option 2 (Re-establish existing system) were the highest ranking options that could be deployed in concert. The sensitivity analysis demonstrated this to be a robust model and ranking. The risk assessment further showed that although risks did exist, they were considered manageable. The deployment of the top two options had a high confidence of success and as they did not exclude many of the other lower-ranked options, these too could be candidates for future deployment.

## 4.0 Recommendation

It is the recommendation of the team that Option 11 (Raise pH in SMECT, collect in SMECT then pump out), and Option 2 (Re-establish existing system) be deployed. With the additional recommendations that:

1. Begin monitoring RCT transfer mercury level to confirm satisfactory mercury removal is taking place

2. Develop the remaining options/add-ons for use in combination to increase the mercury removal capability should monitoring indicate the need for an enhanced capability:

    - Reflux at beginning of boiling in SRAT
    - Passive decanter as part of SME overheads
    - Pump from SMECT to MAWT
    - Pump from MWWT to SMECT then SMECT to MAWT
    - Routing SRAT condensate to SMECT then pump SMECT mercury to MWWT
    - Filtration and IX after RCT
    - Use mercury removal resin in RCT
    - IX column at SMECT Sample Loop

- Utilize jet eductor and temporary bucket
- Add coalescer to MWWT
- Use centrifugal separator and return to SMECT sump

3. Provide screened out options to other teams for consideration:

    - Use electrostatic means to separate mercury (e.g. anode)
    - Change pH in MWWT by adding sodium hydroxide prior to each SRAT batch
    - Install organic strip system prior to MWWT
    - Redesign MWWT to a strip system
    - Add reductant to SRAT
    - Install filtration /IX at LPPP
    - Install filtration/IX at 241-96H if no MST strike is used for MCU processing or deploy after MCU shutdown
    - Install filtration/IX at 512-S after MCU shutdown

## 5.0 References

5.1 SRR-WSE-2015-00035, Removal of Mercury from DWPF Vessels/Process, Evaluation Team Charter, July 21, 2015.

5.2 Manual E7, Procedure 2.15, Alternative Studies.

5.3 Systems Engineering Methodology Guidance Manual, WSRC-IM-98-00033, Appendix A.

## 6.0 Appendices

Appendix A – Initial Option Descriptions
Appendix B – Final Option Description and Data
Appendix C – Option Scoring
Appendix D – Compatibility Grid
Appendix E – Premortem Results

# Appendix A – Initial Options

DWPF Mercury Removal SEE 7/7/15

P.J. Toohey - DWPF Operations

**Option 1** – Pump the Accumulated Mercury from the SMECT Hg Sump to the MWWT using the Canyon Mercury Pump (existing transfer system). Then transfer the MWWT Hg to the MAWT in the Mercury Purification Cell. The Hg Purification System would not be used to process the Hg. The MAWT would simply hold the Mercury temporarily.

Positives: The design exists and we have proven that we can make the transfer from the MWWT to the MAWT.

Negatives/Limitations: The impact on Hg inventory would be small. It would be a one-time transfer of only 26 gallons. The MAWT can only hold 26 gallons and there is at least 70 gallons of Mercury in the SMECT. Once this transfer was completed, it would complicate the restoration of the purification system (if we decided to pursue that option). It would require significant equipment repairs. Additionally, we have not yet demonstrated the ability to transfer Hg from any canyon process vessel to the MWWT. Finally, this option does not (alone) address the issue of sending Hg back to the Tank Farms.

Equipment Requirements: This method would require (at a minimum) the repair/replacement of the following equipment:

- High Press Water Pump
- Mercury Cart (including hoses and instrumentation)
- Canyon Mercury Pump

DWPF Mercury Removal SEE 7/7/15

P.J. Toohey - DWPF Operations

**<u>Option 2</u>** – Restore the existing System. This is the same as Option 1 with the addition of restoring and using the Hg Purification System. The Hg would be transferred from the SMECT to the MWWT and then from the MWWT to the MAWT for processing/purification.

Positives: The design already exists and we have proven we can make the transfer from MWWT. Additionally, restoration of the purification system would allow us to continue to remove Hg that accumulates in the DWPF Process vessels. Most of the physical repair/restoration work could be completed without impacting processing. We would have the ability to remove accumulated Hg from any process vessel. The only impact to processing would be the time it takes to install the canyon mercury pump and complete the transfer.

Negatives/Limitations: It would be expensive, take a lot of time and effort to restore the purification system. We have already proven that the existing purification system cannot process the Hg presently in the MWWT(*). This option alone does not address the issue of sending Hg back to the Tank Farm.

Equipment Requirements: This method would require (at a minimum) the repair/replacement of the following equipment:

- High Press Water Pump
- Mercury Cart (including hoses and instrumentation)
- Canyon Mercury Pump
- Removal and replacement of the purification system
- (*) Clean and flush of the MWWT (plus a strategy of continued clean and flush)

DWPF Mercury Removal SEE 7/7/15

P.J. Toohey - DWPF Operations

**Option 3** – Restore the existing System (same as Option 2) but transfer Hg directly from the SMECT to the MAWT for processing/purification. (Bypass the MWWT).

Positives: The purification system design already exists. Additionally, restoration of the purification system would allow us to continue to remove Hg that accumulates in the DWPF Process vessels. Most of the physical repair/restoration work could be completed without impacting processing. We would have the ability to remove accumulated Hg from any process vessel. The only impact to processing would be the time it takes to install new jumper(s) (for the new transfer path from SMECT to MAWT), the canyon mercury pump and complete the transfer.

Negatives/Limitations: It would be expensive, take a lot of time and effort to restore the purification system. We would have to identify a new transfer path and fabricate new jumper(s). We do not know if the existing purification system design can process the Hg presently in the SMECT (although this risk is probably very small considering the relative cleanliness of the SMECT Hg). This option alone does not address the issue of sending Hg back to the Tank Farm.

Equipment Requirements: This method would require (at a minimum) the repair/replacement of the following equipment:

- High Press Water Pump
- Mercury Cart (including hoses and instrumentation)
- Canyon Mercury Pump
- Removal and replacement of the purification system
- Fabrication of new jumper(s)

**Option 4 – Pump from MWWT to SMECT then SMECT to MAWT**

This process would take the 'dirty' contents of the MWWT and pump it to the SMECT. The idea is that the acidic pH in the SMECT would clean/separate out the elemental mercury from the dirty sludge components. The sludge could then be sent back via the recycle path. The "clean" Hg in the SMECT would then be pumped to the MAWT in the Mercury Purification Cell for storage/transfer to bottles.
This would require the following that is not in place:
1) proceedure for pumping MWWT to SMECT via a direct path or the mercury transfer header. Assumes MWWT Hg pump is operational.
2) Repair of the SMECT Hg pump (or an alternate pump) capable of pumping from the SMECT to the MPC (~30 ft elevation). The current pump was not designed for this path and is borderline (was designed to go to the MWWT).
3) clean out of the MPC at least to the MAWT
4) clean out of the Mercury transfer header

Option 5 – Pump from MWWT to SRAT (Clean MWWT and use existing system)

This process would basically reestablish as new system conditions in the MWWT. Drain the MWWT using the installed drain line from the Hg sump to the SRAT. Flush/clean the MWWT draining to the SRAT. Then pump remainder of MWWT sump Hg to MAWT. Then operate the system as designed and as successfully operated prior to 2008.
Requires the following:
1) SRAT batch review for compatability
2) clean out of the MAWT
3) MWWT Hg pump operational

6. Route SRAT condensate to SMECT and pump SMECT mercury to MWWT.

- Description:
    - Make the SRAT more like the SME in the fact that the condensate goes directly to the SMECT. This will allow the MWWT to be properly cleaned so that any residual contaminants can be removed. The condensate would direct mercury to the sump of the SMECT instead of the MWWT. Could transfer mercury from the SMECT to the MWWT more frequently and use the MWWT as a holding vessel for mercury until enough accumulated so that it could then form a full batch for the mercury purification cell. Since the mercury from the SMECT is relatively clean / pure and the MWWT is now clean and subjected to no other sources other than the SMECT sump pump, the MWWT would hold relatively clean mercury. Relatively clean mercury would mean that the mercury purification cell could be rebuilt as is and process the way that it used to be. Also required to do this is to fix the SMECT mobile mercury pump and to reassemble the mercury purification cell.
- Benefits:
    - Would mean that DWPF could use existing equipment and have very little design changes to fix current problems of 'Dirty Mercury'
    - Relatively cheap when measured against some other options.
    - Would seem like a quick change and easier to implement
- Problems / setbacks:
    - Still have never had a successful working SMECT mercury pump and existing design may not work.
        - Existing design does work for the MWWT, so do not expect this issue.
    - Rebuilding the existing mercury purification cell is still very expensive and time intensive process.
    - Carryovers from SRAT could affect clean/pure mercury in SMECT and make that mercury 'Dirty'.
        - Maybe the MWWT is keeping majority of contaminants from the SMECT (after all, it is a decanter)
    - SMECT chemistry still allows Hg to be dissolved up with lower pH.
        - May need to be used in conjunction with Action #11.

Option 7 – Centrifugal Separation

This "option" was suggested as a technology to effect mercury separation and then concentration; not in conjunction with a specific plan i.e. process tank, jumper, etc. It could be used in many scenarios ranging from mercury removal in supernate to heel. A suggested plan is offered below, but DWPF Engineering may have much better implementation based on facility knowledge.

This option would exploit mercury's density so it can be separated from the lighter water and diverted into the heavy effluent flow stream of the centrifugal separator. The separator could be used stand-alone or in conjunction with other components such as an electrostatic coalescer. In this case, the separator could be placed upstream and/or downstream of the electrostatic coalescer.

Concerns:

One concern is that the separator breaks larger droplets into smaller such that the effectiveness of the device is negated.

One assumption is that mercury can be separated using this method, dissolved mercury would be unaffected. Similarly, the effectiveness for any mercury forms considered should be tested to verify it is practical.

Potential Installation Plans:

1. Install on the SMECT or other process tank in a manner allowing recirculation of the supernate; through something like the sample loop. This would likely involve collection of the mercury outside of the process tank with the balance returned via the loop. The heavy stream containing the concentrated mercury would return through an arrangement to retain settled mercury.
2. A variation on Plan 1 above would be to position the entire loop inside of the process vessel. The concentrated mercury would be drained into the revitalized mercury pump (or similar). The loop and recirculation pump might be attached to the fixture that holds the existing mercury pump. (Again this plan might also involve an electrostatic coalesce etc. in addition to the centrifugal separator.) The mercury pump would be used to transfer the mercury to a location outside of the process vessel. It may be difficult to determine when the mercury pump needs to be energized, conductivity change could be used except that the sludge tends to insulate the probe tips. Some challenges in that area and others would need attention in order to optimize.
3. This is aimed at legacy mercury. Consider a vessel like the SMECT where the supernate has been removed such that the heel remains concentrated but in a state where it can be pumped. In this situation a loop is set up to recirculate the heel and segregate the mercury. It is likely that the Plan 2 scenario would be used in this case given the higher likelihood of elemental mercury in significant quantity.

Option 8 – Dip/Scoop to remove Mercury from SMECT

This option involves custom remote mechanical means to dip or scoop mercury along with any associated heel from the tank. SMECT tank nozzle E is the likely entry location for such equipment if the lowest tank elevation is to be accessed. The equipment would operate in a manner necessary to fill its container with mercury etc. Similar equipment has been developed and used to sample in the same location for mercury in the past. This equipment would be designed to handle a larger payload but otherwise be very similar in design. A crane is used to remove the material and transport to another receptacle as needed. A number of schemes may have to be devised to treat the mercury removed. Depending on the “purity” of the removed mercury; it may be necessary to concentrate which will involve additional equipment.

Concerns

One concern is associated with getting the mercury present in the sump such that it can be dipped and then removed from the SMECT. It is likely the bottom surface of the SMECT is covered with sludge. Settled mercury may not migrate 10-12’ across the sludge-filled tank bottom into the 12” ID mercury sump. While the bottom of the vessel is sloped toward the sump (0.25/ft), it is possible with enough sludge that zero (or reduced) slope exists at the top of the sludge. Even with slope it is possible the mercury will not “drain” to the mercury sump. This may require additional equipment to overcome the issue.

The material removed may need further processing in order to concentrate the mercury sufficiently for practical removal.

Option 9 - Electrostatic Separation

Electrostatic coalescers are commonly used in the chemical and oil industries for liquid - liquid phase separation. Oil - water emulsion breaking is a common application of this technology. A force normal to the flow is exerted on Polar liquids moving through an electric field. This force is not exerted on non-polar liquids moving though the same field. This differential force causes droplets to coalesce affecting significant efficiency improvements over other separation methods. Electrostatic coalescers are available from a number of manufacturers. Designs vary widely. Some coalescers use alternately charged insulated plates while others use a loosely woven mesh of conducting and oppositely charged non-conducting fibers.

Since elemental Mercury is non-polar, this technology could be applied to help separate Mercury from aqueous solutions. However, it could also have the undesirable side effect of separating some solids and other non-polar liquids as well. Fluid/suspension composition would need to be evaluated for each application to verify the efficacy of this method.

Electrostatic Separation will be similar in application as Option14 - solvent separation. Installation as part of the MWWT system or receiving solution from the SMECT.

Issues:

1) Significant research to identify proper flows and nitrate solvents and sludge removal partitions. U and Pu extraction could be realized.

2) Significant changes to the facility. The Separator will require additional space and facility reconfiguration.

Advantages

1) Mercury cleaning can be done in the Canyon and will not require additional work in the Mercury processing cell.

2) Elimination or removal of dirty mercury from the system.

3) Removal of mercury prior to accumulation into the SMCECT or downstream vessels.

Option 10 - Dissolve mercury in SMECT using pH change (with acid) and remove dissolved mercury using mercury resin

Intentionally oxidize/dissolve elemental mercury by adding additional nitric acid to the SRAT. At present, most of the SMECT elemental mercury is dissolved by the nitric acid produced from nitrite destruction combined with nitric acid added to the SMECT for pH control. It is likely that a relatively small increase in the amount of nitric acid added. Since the mercury would be dissolved in the SMECT, all SMECT condensate would need to processed through an ion exchange resin to remove the mercury. Both IDMS (DWPF pilot plant) and ETP have use GT-73 resin to remove mercury successfully. The Ion exchange process will be a non-elutable process which will be installed as a unit operation on the SMECT condensate line, requiring a redesigned jumper, ion exchange column and spent resin/eluate capture using a temporary storage tank which will be emptied periodically by eductor to a storage tank (repurposed salt cell tank) for further processing.

Option 11 - Collect elemental mercury in SMECT using pH change (increase) and pump (to purification, storage or amalgamation)

Description

Minimize the oxidation/dissolution of elemental mercury by raising the pH limit of the SMECT to ~6 (the pH must be low enough to scrub and retain ammonia) through the addition of sodium hydroxide to the SMECT. At present, most of the SMECT elemental mercury is dissolved by the nitric acid produced from nitrite destruction combined with nitric acid added to the SMECT for pH control. Raising the pH of the SMECT should allow collection of elemental Hg from both the SRAT and SME. Since elemental mercury is expected to accumulate in the SMECT, the mercury should be frequently pumped to the mercury cell to minimize loss of Hg during transfer of the SMECT to RCT.

Option 12 - Ion Exchange Column on SMECT Sample Loop

Ion exchange can be used to extract mercury ions when in solution. Mercury is present in DWPF and in large known quantities in the SMECT. Due to the chemical conditions in the SMECT, it is possible that the mercury is dissolved in solution in this tank. Mercury removal by ion exchange is a technology already implemented in Liquid Waste at ETP. The mercury extraction in the SMECT can be similar to ETP and use a non-elutable GT-73 resin. However, testing will need to be done to determine how effective GT-73 is under the conditions in the SMECT. Modifications will include but not be limited to at least 1 redesigned jumper, installation of the ion exchange column and a designed system for storage/retrieval/replacement of spent resins. Additionally a prefilter may be required for the ion exchange to filter out solids present in the SMECT.

Advantages

1) The sample loop is outside of the CPC and therefore more accessible

2) The SMECT sample loop can be run in a constant recirculation to gradually extract the mercury

3) Already existing technology on site and waste disposal path for GT-73 already exists

Disadvantages

1) Major design change and modification to the plant

2) Unknown solubility of mercury in the SMECT

3) Design could be constrained by the amount of resin needed to extract the desired quantity of mercury

Option 13 - Change pH in MWWT by adding sodium hydroxide prior to each SRAT batch

Description

Minimize the oxidation/dissolution of elemental mercury by adding sodium hydroxide to the MWWT. At present, most of the MWWT elemental mercury is dissolved by the nitric acid produced from nitrite destruction. Raising the pH of the SMECT should allow collection of elemental Hg during SRAT. Since elemental mercury is expected to accumulate in the MWWT, the mercury should be frequently pumped to the mercury cell to minimize loss of Hg during subsequent batches.

**Option 14 - Solvent extraction system prior to MWWT**

Organic solvent extraction is the transport of solutes, e.g. heavy metal ions, from an Inorganic (or aqueous) phase to an organic phase. Solvents used comprise of an extractant + diluent combination. The roles of each are as follows: 1) the extractant, as a specific metal ion extractant; 2) the diluent, as a solvent condition controller, i.e. hydrophobicity, which affect the molecules extractability. Using this concept, an extraction bank cycle could be implemented before the mercury wash vessel. The bank will be target to extract the mercury from the SRATs overheads. Two stage solvent wash will be required. First stage will remove the Hg into the organic phase and transport to the second solvent wash, the aqueous will be returned to the SMECT. Second stage will release the Hg from the solvent into an aqueous phase transfer into the MWWT. At that point the MWWT can be a holding stage for mercury or use to transfer the mercury to the Mercury Processing Cell.
Issues:

1) Organics introduction to the facility. Controls will need to be implemented to solvent explosion, accumulation of ignition.
2) Significant research to identify proper flows and nitrate solvents and sludge removal partitions. U and Pu extraction could be realized.
3) Significant changes to the facility. The banks will require additional space and a vessel that will provide the aqueous low acid solvent strip flow.

Advantages

1) Mercury cleaning can be done in the Canyon and will not require additional work in the Mercury processing cell.
2) Elimination or removal of dirty mercury from the system.
3) Removal of mercury prior to accumulation into the SMCECT or downstream vessels.

**Option 15: Use solvent extraction bank and MWWT as solvent wash vessel.**

Organic solvent extraction is the transport of solutes, e.g. heavy metal ions, from an Inorganic (or aqueous) phase to an organic phase. Solvents used comprise of an extractant + diluent combination. The roles of each are as follows: 1) the extractant, as a specific metal ion extractant; 2) the diluent, as a solvent condition controller, i.e. hydrophobicity, which affect the molecules extractability. Using this concept, an extraction bank cycle could be implemented before the mercury wash vessel. The bank will target the extraction of mercury from the SRATs overheads. Two solvent washes will be required. First wash using the extraction bank will extract the Hg into the organic phase and transport the organic phase to the second solvent wash in the MWWT, the aqueous will be returned to the SMECT. Within the MWWT the organic phase will be washed with a high nitric solution and transfer the Hg from the solvent to the aqueous phase. The mercury will collect in the MWWT sump and the solvent can be recycled back to the extraction bank. At that point the MWWT can be a holding stage for mercury and eventually the mercury could be transferred to the Mercury Processing Cell by transfer of the MWWT sump to the MAWT at the Mercury Processing Cell.

Issues:

1) Organics introduction to the facility. Controls will need to be implemented to solvent explosion, accumulation of ignition.
2) Significant research to identify proper flows and nitrate solvents and sludge removal partitions. U and Pu extraction could be realized.
3) Significant changes to the facility. The banks will require additional space and a vessel that will provide the aqueous low acid solvent strip flow.
4) Significant modifications to MWWT.

Advantages

1) Mercury cleaning can be done in the Canyon and will not require additional work in the Mercury processing cell.
2) Elimination or removal of dirty mercury from the system.
3) Removal of mercury prior to accumulation into the SMCECT or downstream vessels.
4) Elimination of construction of a second stage bank by retooling and modifying the MWWT.

16. Add coalescer to MWWT

- Description:
    - Coalescers are designed to coalesce a liquid into larger droplet from smaller droplets or separate liquids by coalescing a liquid. The intent behind a coalescer is to get tiny 'floating' mercury droplets to coalesce into larger droplets so that it will sink into the sumps of the vessel. This would ensure that the mercury is directed to the sump where it is wanted instead of allowing these tiny particles of mercury to pass through to the SMECT. There are a couple of types of coalescers. There are mechanical or electrical coalescers. The mechanical coalescers are generally no moving parts, but sometimes require cartridge change outs. Electrical versions can require work when they short out.
- Benefits:
    - Benefits of a coalescer is that it would theoretically help trap more mercury in the sump of the MWWT and keep it there instead of allowing it to go to the SMECT.
- Problems / setbacks:
    - If a cartridge style, frequent change outs could create added down time, more expense to order cartridges and possible worker exposure to radiological contamination. Also would have to find what to do with used cartridges.
    - Electrical coalescers require electricity and would present an electrical hazard within the facility.

**Option 17 - Reflux at the beginning of boiling in SRAT**

The solubility of Hg, as some $Hg^{2+}$ species, increases with nitric acid concentration. It is possible that the nitric acid refluxed could dissolve a significant amount of Hg collected in the MWWT. Concentrating the SRAT under acidic condition would most likely result in soluble mercury going from MWWT to SMECT. Hence, it is suggested to Reflux at the beginning of boiling in SRAT when SRAT stream is acidic. Once the SRAT stream has become more neutral, concentrating the SRAT should be started. This would drive the elemental mercury to accumulate in the bottom of MWWT.

Option - 19. Add more acid to SRAT

Typically, excess acid is added to the SRAT by way of multiplying the total moles of acid required by a stoichiometric factor, which is required to accommodate variations in the chemical and rheological properties of sludge macrobatches. During sludge batch simulant flowsheet testing, a stoichiometric acid window is determined based upon protection of assumptions in the safety basis, namely, nitrite destruction (which determines the minimum acid requirement), and hydrogen and ammonia generation (which determine the maximum acid requirement). Processing issues (i.e. transport issues, mercury recovery, etc.) are a secondary concern when adjusting the acid stoichiometry and only affect the stoichiometric acid window within the bounds of the safety basis. During a macrobatch, minor adjustments can be made to the acid stoichiometry within the stoichiometric window to help control chemical processing.

The recommended stoichiometry per SRNL for SB8 is 110-126%. Early batches in SB8 did not show issues with hydrogen generation and nitrite was sufficiently destroyed so the stoichiometry remained at the lower end of 110-115%. This has resulted in 250-350 gallons of formic and 85-150 gallons of nitric added to each SRAT batch. Since SB6, we have used 115% for the stoichiometry parameter but have used higher stoichiometry in the past based on the chemistry of those particular sludge batches: SB4-5 (130%), SB3 (155%), SB2 (125%-180%), S1b (137.5%), SB1a (125%).

Historically in experiments, higher quantities of acid result in higher recovery yield of mercury. The method is thought to be that more acid would destroy nitrite faster leading to a more neutral state in the DWTT. Spending a longer amount of time in a more neutral state during concentration will cause more mercury to precipitate in the MWWT and carry less over to the SMECT.

18. RJR Engineering Report Review

A RJR Engineering report, 13012-REP-0024 rev. 0, DWPF Mercury Balance Preliminary Assessment and Recommendations, was issued on June 30, 2013. The report contained many recommendations with no conclusive conclusion and indicated additional analysis, facility testing, and lab testing would be required.

The report centered on Hg chemistry and processing control that could improve mercury removal. Several equipment items were discussed.

**Option 18 a - Sparge the MWWT to remove sludge**. Large amount of sludge may be trapped in the MWWT. The likely effect of un-agitated sludge in the MWWT would be to prevent liquid Hg from flowing to the bottom of the MWWT which would create a shortcut for Hg to pass directly into the SMECT.

**Option 18 b - Replace the jumper between the SRAT condenser and the MWWT**. The jumper between the SRAT condenser and the MWWT is a 2" jumper connected to a 3" Hanford nozzle. This forms a trap collecting Hg as a liquid phase. The change in jumper size would eliminate this trap.

**Option 18 c - Use a continuous gravity Hg decanter instead of the MWWT Hg transfer pump**. This would remove elemental Hg as soon as it is collected in the MWWT without operator intervention. If the disposal requirements allow direct disposal of Hg as drained from the MWWT without further decontamination, this would also avoid pumping and processing the mercury in the mercury purification cell. This option involves canyon design and processing details that would need to be resolved.

**Option 18 d - Use a continuous gravity Hg decanter as a direct feed to a small columns for Hg purification based on disposal requirement**. See 18c

**Option 18 e – Replace SRAT Condensation Bell** - A fatigue induced cracked weld in the condensate collection "bell" in the SRAT condenser could be draining almost 100% of the condensed elemental Hg back to the SRAT rather than passing it on to the MWWT. Plan for inspection. Plan for replacement.

**Option 20 - Add a reductant to the SMECT**

The goal would be to convert mercury from its soluble form (i.e. mercuric nitrate) to elemental mercury, which would precipitate from solution and accumulate in the bottom of SMECT.

Option 21 - Use mercury removal resin in RCT

There are currently no locations within the facility in which mercury accumulates in appreciable amounts, thus precluding the ability to consistently remove mercury from the process. There are two primary mechanisms which currently limit accumulation: incompatible chemistry and/or mechanical interferences. The chemistry of the RCT is favorable for mercury accumulation since normal processing of condensate requires adjustment of the heel to ensure the contents remain at an elevated pH. The primary limitation of accumulation in the RCT is due to residence time of the condensate and consistent vessel agitation, which maintain suspension (and subsequent transfer to the Tank Farm) of mercury.

This option is similar to Option #12 (Ion Exchange Column on SMECT Sample Loop), but would locate the unit operation inside the RCT vessel. Additionally, the RCT chemistry is different (RCT high pH versus SMECT low pH). The option would require modification of the vessel to incorporate a removable basket/strainer such that Duolite GT-73 resin would contact the condensate. Efficiency will depend upon contact time and resin. Will require resin change-out and either disposal, or a storage vessel (Catalyst Make-up Tank?) and subsequent unit operation for resin-recovery.

Option 22 - Amalgam

There is no established disposal path for the elemental mercury. One possibility (as discussed by environmental) is to convert the liquid mercury into a solid waste form by adding other metals and forming an amalgam (similar to tooth filling). This is not a solution by itself but may be useful in handling "dirty" mercury.

**Option 23 - Convert organic to elemental mercury for easier collection**

Mercury can exist naturally as elemental, oxidized inorganic (mercuric or mercurous) mercury, or oxidized organic (methyl/ethyl mercury) forms. RCT samples were sent to the Eurofins lab for Hg speciation.
These were the first samples where ethyl mercury was measured rather than calculated from the methyl mercury calibration, but no detectable ethyl mercury above the reporting limits of the analytical method was observed. Similarly, no dimethyl Hg above the reporting limit was determined. Methyl Hg was much lower in these DWPF samples, both in absolute terms and as a percentage of total Hg in the sample, than was observed in Tank 21, 22, 49, or 50. Hence, based on these sample results, converting organic to elemental mercury in DWPF might not be necessary.

24. Passive decanter as part of SME overheads

- Description:
  - Since there is some mercury stripping in the SME cycle similar to the SRAT cycle, a decanter similar to the MWWT would be beneficial for the SME as well. This would help keep the mercury from the acidic chemistry in the SMECT and in turn help keep the mercury from returning to the tank farm. This would need to be properly sized to make sure the mercury has adequate time to settle to the sump as it has been suggested that the MWWT could be sized better to be more efficient.
- Benefits:
  - Having an additional decanter for the SME would keep the mercury from the SMECT which is one transfer from going back to tank farm. Assuming the condensate from the SME is fairly neutral; keeping the mercury in this decanter assuming it is properly sized would seem like a fairly easy task.
- Problems / setbacks:
  - An additional tank that would take up resources from design, engineering, and procurement.
  - Very little space inside of the CPC
  - Procurement times on a tank could be lengthy
  - Could potentially cost lots of money.
  - If the MWWT doesn't work effectively, what makes us think this vessel will?
  - Have to tie this vessel into the MTH and be able to pump to the MWWT. If it is not sized exactly like the MWWT, might need a new pump design which could incorporate additional large costs.
  - ve a pump that could pump from these CPC vessels

25. Install settling tank (after pumping out of SMECT)

- Description:
    - Installing a settling tank after the SMECT, but before the RCT might give the advantage of allowing any dissolved up mercury to settle back down and separate from rest of the waste. This would then make additional removal area for mercury.
- Benefits:
    - Using this could potentially allow for the settling tank to remove more mercury from the system that otherwise would have went to the RCT and then to the tank farm. Could do similar chemistry that the RCT receives and caustically adjust so that the mercury could potentially drop out or precipitate out.
- Problems / setbacks:
    - The reason the RCT is continuously mixed is to avoid solids building in the tank and to help purge. If you did not agitate your settling tank, could potentially have large amounts of solids buildup in this tank and create 'Dirty mercury'.
    - Room for another vessel, especially one as large as the SMECT would be near impossible.
    - Believe that they have been trying to procure another vessel similar to the CPC vessels for a few years now and have yet to be successful. Long implementation time.
    - Big vessel = big money
    - Not sure with this amount of money that the return investment would be there for what little you could potentially gain.
    - Would once again have to have a pump that could pump from these CPC vessels

Option 26 - Filtration and IX downstream of RCT

There are currently no locations within the facility in which mercury accumulates in appreciable amounts, thus precluding the ability to consistently remove mercury from the process. There are two primary mechanisms which currently limit accumulation: incompatible chemistry and/or mechanical interferences. The chemistry of the RCT is favorable for mercury accumulation since normal processing of condensate requires adjustment of the heel to ensure the contents remain at an elevated pH. The primary limitation of accumulation in the RCT is due to residence time of the condensate and consistent vessel agitation, which maintain suspension (and subsequent transfer to the Tank Farm) of mercury.

This option is similar to Option #12 (Ion Exchange Column on SMECT Sample Loop) with different chemistry (RCT high pH versus SMECT low pH). Eliminates need to accumulate mercury in the RCT, which could prove difficult. This option would require design and fabrication of a recycle loop containing in-line filtration elements and an ion exchange column with Duolite GT-73. Efficiency will depend upon contact time and resin. Will require resin change-out and either disposal, or a storage vessel (Catalyst Make-up Tank?) and subsequent unit operation for resin-recovery.

Option 27 - Change operating mode of RCT to allow decanting

There are currently no locations within the facility in which mercury accumulates in appreciable amounts, thus precluding the ability to consistently remove mercury from the process. There are two primary mechanisms which currently limit accumulation: incompatible chemistry and/or mechanical interferences. The chemistry of the RCT is favorable for mercury accumulation since normal processing of condensate requires adjustment of the heel to ensure the contents remain at an elevated pH. The primary limitation of accumulation in the RCT is due to residence time of the condensate and consistent vessel agitation, which maintain suspension (and subsequent transfer to the Tank Farm) of mercury.

Since the chemistry of the RCT (high pH) is likely favorable for mercury accumulation in the RCT sump, the idea is to adapt how the RCT is processed to optimize the potential for accumulation of mercury in the RCT sump. Examples include securing agitation with the exception of chemical additions (beginning of RCT) and prior to transfer (end of RCT). Concern would be whether or not agitation re-suspends sludge solids (without re-suspending mercury) to prevent accumulation. Change in processing strategy may need to be mode dependent. Likely inefficient, and would need to be supported by testing to determine the optimal operating conditions for mercury accumulation.

**Removal of Mercury from DWPF Vessels Pro-Forma**

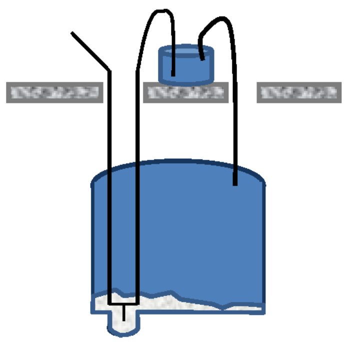
**Option 28**

**Title:** Utilize jet eductor pump and temporary bucket

**Originator:** Andy Tisler

**Description:**

Utilize a jet eductor pump in the SMECT mercury sump to pump any mercury that is in the tank into a temporary storage vessel. This will clean the SMECT of any accumulated mercury. The temporary storage vessel would drain back into the SMECT and the mercury would be retained in the vessel. Once the vessel is either full or no more mercury exists to pump, the vessel can be relocated to an area to be dispositioned.



**Scope:**

**Schedule:**

**Approval:**

**Cost:**

**Compatibility:**

**Risks:**

## Appendix B – Final Option and Data

DWPF Mercury Removal SEE 7/22/15

P.J. Toohey - DWPF Operations

### Option 2

Restore the existing (original) Mercury Transfer System and Mercury Purification System. In this option, the Hg is transferred from the SMECT to the MWWT and then from the MWWT to the MAWT for processing/purification in the Hg Purification System. Eventually, purified mercury is packaged to shipment.

**Flowpath**


**Positives:**

- The design already exists and we have proven we can make the transfer from MWWT
- Restoration of the purification system would allow us to continue to remove Hg that accumulates in the DWPF Process vessels
- Most of the physical repair/restoration work could be completed without impacting processing
- We would have the ability to remove accumulated Hg from any process vessel
- The only impact to processing would be the time it takes to install the canyon mercury pump and complete the transfer

**Negatives/Limitations:**

- It could be expensive and might take a lot of time and effort to restore the purification system
- We are not sure the existing purification system design will process the Hg presently in the MWWT
- This option alone may not address the issue of sending Hg back to the Tank Farm

Equipment Requirements: This method would require (at a minimum) the repair/replacement of the following equipment:

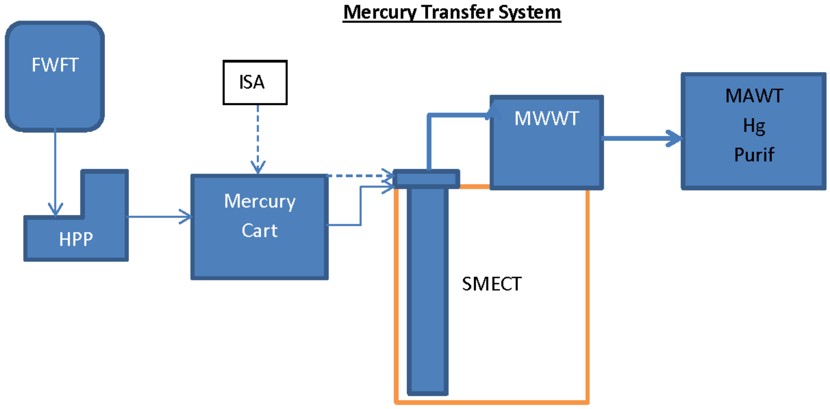
- High Press Water Pump
- Mercury Cart (including hoses and instrumentation)
- Canyon Mercury Pump
- Removal and replacement (restoration) of the purification system

NOTE: The fact that this option includes a purification step (and generally others may not) should be considered as an advantage during scoring.

DWPF Mercury Removal SEE 7/22/15

P.J. Toohey - DWPF Operations

**Mercury Transfer System**




Evaluation Data:

1. Mercury Removal Capability

*This option has a proven ability to remove accumulated mercury from the DWPF process vessels. The impact this will have on Hg returned to the Tank Farms is a question. The ability to process/purify Hg from the MWWT is a question.*

2. Ease of Disposal

*If the process works as designed, the product mercury will be clean elemental mercury.*

3. Operability

*The procedures and design already exist. This process is man-power intensive. The installation of the canyon transfer pump into the SMECT (or any canyon vessel) will require a non-processing window and a canyon Tagout (CTO). The hook up of the Hg Cart requires both Operations & maintenance support. The operation of the transfer system requires a non-processing window & is performed by the CRO.*
*The purification portion of the process is performed by a field operator and alone does not impact processing.*

4. Maintainability

*Maintainability is not well defined. The purification system has the potential of being difficult to maintain based on the mercury transferred to it. Routine operations/transfers from process vessels require maintenance & RCO support every time the Hg Cart is installed or removed. The Hg Cart hoses/instruments require routine maintenance.*

5. Deployment Schedule

*Estimate six months to restore mercury transfer system. Estimate 1 year to restore the mercury purification system. All work could be performed without a process break prior to deployment.*

DWPF Mercury Removal SEE 7/22/15

P.J. Toohey - DWPF Operations

6. Outage Window Duration
*Short deployment window duration (days).*

7. Technical Maturity
*Proven technology. Questions associated with impurities/chemistry in the process. Questions involving impact on Mercury sent back to the Tank Farms*

Combinations
*Stand alone*

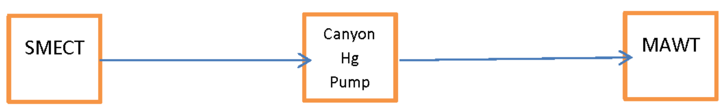
DWPF Mercury Removal SEE 7/22/15

P.J. Toohey - DWPF Operations

## Option 3

Restore the existing System (same as Option 2) but transfer Hg directly from the SMECT to the MAWT for processing/purification (Bypass the MWWT) in the Hg Purification System. Eventually, purified mercury is packaged to shipment. Use the MWWT as a filter only.

**Flowpath**




**Positives:**

- The purification system design already exists
- Most of the physical repair/restoration work could be completed without impacting processing
- We would have the ability to remove accumulated Hg from any process vessel
- The only impact to processing would be the time it takes to install new jumper(s) (for the new transfer path from SMECT to MAWT), the canyon mercury pump and complete the transfer

**Negatives/Limitations:**

- It would be expensive, take a lot of time and effort to restore the purification system
- We would have to identify a new transfer path and fabricate new jumper(s)
- We do not know if the existing purification system design can process the Hg presently in the SMECT (although this risk is probably very small considering the relative cleanliness of the SMECT Hg)
- There is a question as to if the Hg pump can make the physical lift required to go from the SMECT Hg sump to the MAWT (in one step)
- This option alone does not address the issue of sending Hg back to the Tank Farm.

Equipment Requirements: This method would require (at a minimum) the repair/replacement of the following equipment:

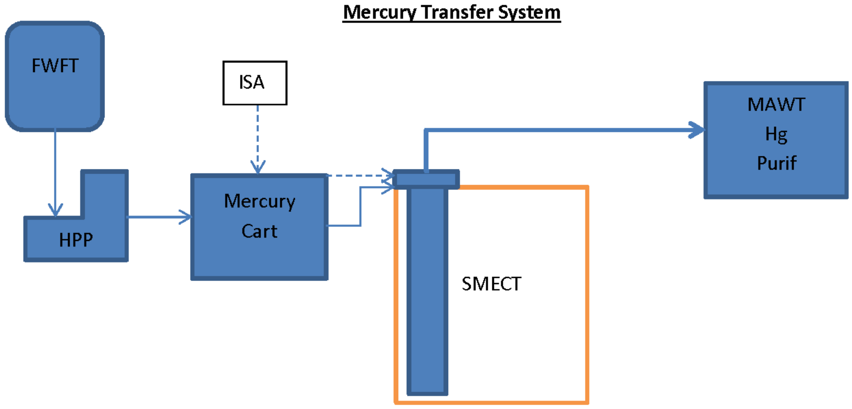
- High Press Water Pump
- Mercury Cart (including hoses and instrumentation)
- Canyon Mercury Pump
- Removal and replacement of the purification system
- Fabrication of new jumper(s)

DWPF Mercury Removal SEE 7/22/15

P.J. Toohey - DWPF Operations

NOTE: The fact that this option includes a purification step (and generally others may not) should be considered as an advantage during scoring.

**Mercury Transfer System**




1. Mercury Removal Capability

*This option has a proven ability to remove accumulated mercury from the DWPF process vessels. The impact this will have on Hg returned to the Tank Farms is a question. The ability to process/purify Hg from the SMECT is a question.*

2. Ease of Disposal

*If the process works as designed, the product mercury will be clean elemental mercury.*

3. Operability

*The procedures and design will need to be developed for transfers. This process is man-power intensive. The installation of the canyon transfer pump into the SMECT (or any canyon vessel) will require a non-processing window and a canyon Tagout (CTO). The hook up of the Hg Cart requires both Operations & maintenance support. The operation of the transfer system requires a non-processing window & is performed by the CRO.*

*The purification portion of the process is performed by a field operator and alone does not impact processing.*

DWPF Mercury Removal SEE 7/22/15

P.J. Toohey - DWPF Operations

4. Maintainability

*Maintainability is not well defined. The purification system has the potential of being difficult to maintain based on the mercury transferred to it. Routine operations/transfers from process vessels require maintenance & RCO support every time the Hg Cart is installed or removed. The Hg Cart hoses/instruments require routine maintenance.*

5. Deployment Schedule

*Estimate six months to restore mercury transfer system. Estimate 1 year to restore the mercury purification system. All work could be performed without a process break prior to deployment.*

6. Outage Window Duration

*Short deployment window duration (days).*

7. Technical Maturity

*Proven technology. Questions associated with impurities/chemistry in the process. Questions involving impact on Mercury sent back to the Tank Farms*

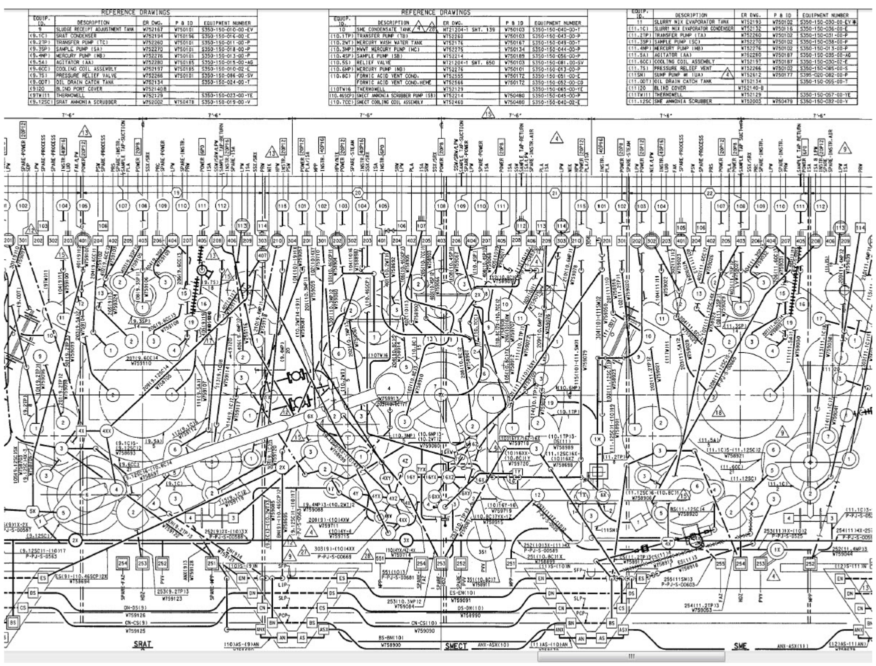
Combinations

*Stand alone*

Option 4 – Pump from MWWT to SMECT then SMECT to MAWT

This process would take the 'dirty' contents of the MWWT and pump it to the SMECT. The idea is that the acidic pH in the SMECT would clean/separate out the elemental mercury from the dirty sludge components. The sludge could then be sent back via the recycle path. The "clean" Hg in the SMECT would then be pumped to the MAWT in the Mercury Purification Cell for storage/transfer to bottles.
This would require the following that is not in place:
1) proceedure for pumping MWWT to SMECT via a direct path or the mercury transfer header. Assumes MWWT Hg pump is operational.
2) Repair of the SMECT Hg pump (or an alternate pump) capable of pumping from the SMECT to the MPC (~30 ft elevation). The current pump was not designed for this path and is borderline (was designed to go to the MWWT).
3) clean out of the MPC at least to the MAWT
4) clean out of the Mercury transfer header

This is essentially the same as option 3 with the change of pumping the MWWT to the SMECT instead of directly to the MAWT.



Evaluation Data:

1. Mercury Removal Capability

*This option results in all MWWT mercury going through the SMECT acidic conditions to 'clean' it up. The ability to pump from the MWWT to the SMECT would have the same issues as pumping 'dirty' mercury to the MAWT. The mercury removal efficiency should be equivalent to the current system (option 2) or the SMECT to MAWT (option 3) with a slight possible decrease in the likelihood of pluggage in the MAWT.*

2. Ease of Disposal

*The mercury should be in the cleanest elemental mercury form in the system. It should be acid washed in the SMECT already prior to be received in the MAWT. The mercury from the MWWT should also be in a cleaner form than if pumped directly to the MAWT.*

3. Operability

*This should have roughly the same operator load as the existing system process. In will require new procedures and jumpers to make the transfers. As the SMECT is the most congested of the tanks in the CPC as far as jumpers and components above and on it, the routing of the jumpers may be problematic.*

4. Maintainability

*The maintainability of this option would be essentially the same as Option 2 or 3. No new pumps are required. New jumpers are required but they would not require any valving.*

5. Deployment Schedule

*The deployment would require the design and building of at least two new jumpers, one from MWWT to SMECT, and one from SMECT Mercury pump to MAWT. There are no unused nozzles on the SMECT to pump the MWWT into. Other jumpers may have to be redesigned to accommodate.*

*The MWWT to SRAT jumper could be rearranged to drain the MWWT to the SMECT directly, not using the MWWT mercury pump. The lack of unused nozzles on the SMECT still impedes this option.*

*The DSA would be required to change as it describes in the mercury removal system.*

*It is assumed that it would take 6 months to 1 year to implement.*

6. Outage Window Duration
*The outage to implement would be 1 to 2 weeks.*

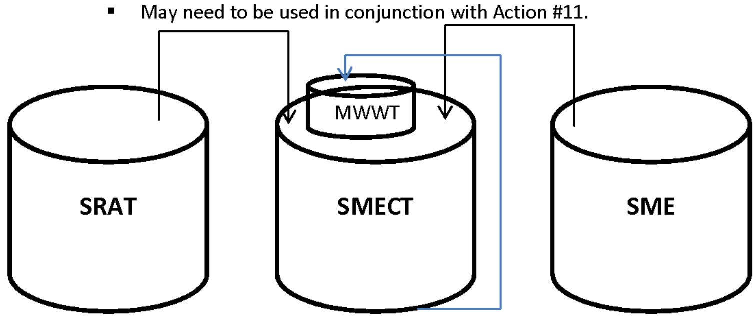
7. Technical Maturity
*This is technically mature, would require no R&D.*

Combinations

*This is really just a slight modification of option 3.*

6. Route SRAT condensate to SMECT and pump SMECT mercury to MWWT.

- Description:
  - Make the SRAT more like the SME in the fact that the condensate goes directly to the SMECT. This will allow the MWWT to be properly cleaned so that any residual contaminants can be removed. The condensate would direct mercury to the sump of the SMECT instead of the MWWT. Could transfer mercury from the SMECT to the MWWT more frequently and use the MWWT as a holding vessel for mercury until enough accumulated so that it could then form a full batch for the mercury purification cell. Since the mercury from the SMECT is relatively clean / pure and the MWWT is now clean and subjected to no other sources other than the SMECT sump pump, the MWWT would hold relatively clean mercury. Relatively clean mercury would mean that the mercury purification cell could be rebuilt as is and process the way that it used to be. Also required to do this is to fix the SMECT mobile mercury pump and to reassemble the mercury purification cell.
- Benefits:
  - Would mean that DWPF could use existing equipment and have very little design changes to fix current problems of 'Dirty Mercury'
  - Relatively cheap when measured against some other options.
  - Would seem like a quick change and easier to implement
- Problems / setbacks:
  - Still have never had a successful working SMECT mercury pump and existing design may not work.
    - Existing design does work for the MWWT, so do not expect this issue.
  - Rebuilding the existing mercury purification cell is still very expensive and time intensive process.
  - Carryovers from SRAT could affect clean/pure mercury in SMECT and make that mercury 'Dirty'.
    - Maybe the MWWT is keeping majority of contaminants from the SMECT (after all, it is a decanter)
  - SMECT chemistry still allows Hg to be dissolved up with lower pH.
    - May need to be used in conjunction with Action #11.




Evaluation Data:

1. Mercury Removal Capability

*This option will not remove Hg at a greater quantity than the system today allows with the exception of what we do pull out of the system is considered 'clean' Hg and should be able to be purified in the MPP. One theory of DWPF not accumulating is that the process is lending itself to easily and readily dissolving Hg up in the SMECT, which may be negated if DWPF were able to regularly pump collected SMECT Hg from sump rather than let it sit in diluted Nitric Acid conditions.*

2. Ease of Disposal

*The Hg captured in this process should be very clean elemental Hg. This would lend itself to just continuing to run the MPP as it was intended. This would mean coupling with Option #2 and rebuild the MPP as it was originally designed. There have been no indications that clean elemental Hg will clog the system as it is currently configured. In fact, the opposite is true since the facility has processed clean elemental Hg in the past.*

3. Operability

*This should be a fairly easy process. The SRAT process would only need to be modified (whether by another tank or just piping) during reflux mode so that the material can drain back to the SRAT. You would still need operators for the MPP and a transfer from SMECT to MTH to MWWT would be required every few SRAT batches.*

4. Maintainability

*This option depends upon the mobile CPC Hg pump. If this pump is fixed and deemed reliable, there will be no issues with the system that is currently already there. In other words, there will still be a need from the high pressure water cart and the MPP can be a tricky process from prior operators' experience.*

5. Deployment Schedule

*Since I am not as familiar with time schedule since I am fairly new out here, I will not speculate. There will need to be a design change to change the routing of the SRAT to the SMECT. There might even need to be lab concurrence on this. Also, would need to fix pump and rebuild MPP. It should take less than a year for all of this, but the MPP could be fixed while the plant is pouring cans and does not affect production. Same can be said of the mobile Hg pump.*

6. Outage Window Duration
*Would not expect it to take long to clean MWWT and flush, remove jumpers from SRAT to MWWT and install new jumpers from SRAT to SMECT.*

7. Technical Maturity
*Would need to make sure that it is plausible to keep this option and still be able to reflux in the SRAT under this new configuration. All of the operability under this option relies heavily on being able to reflux in the SRAT.*

Combinations
*Could be used directly with options 1, 2, and indirectly with 18e, 19, 21, 27*

Option 7 – Dip/Scoop to remove Mercury from SMECT

This option involves remote mechanical means to dip or scoop mercury along with any associated heel from the tank. SMECT tank nozzle E is a likely entry location for such equipment if the lowest tank elevation is to be accessed. The equipment would operate in a manner necessary to fill its container with mercury etc. Similar equipment has been developed (Figure 1) and used to sample in the same location for mercury in the past. This equipment would be designed to handle a larger payload but otherwise could be very similar in design. A crane is used to remove the material and transport to another receptacle as needed. A number of schemes may have to be devised to treat the mercury removed. Depending on the "purity" of the removed mercury; it may be necessary to concentrate which will involve additional equipment (perhaps option 8 and/or 9). Note that while this option is written for the SMECT, it can also be considered for any process vessels with a mercury sump and drain bottom structure.

Concerns

One concern is associated with getting the mercury present in the sump such that it can be dipped and then removed from the SMECT. It is likely the bottom surface of the SMECT is covered with sludge. Settled mercury may not migrate 10-12' across the sludge-filled tank bottom into the 12" ID mercury sump. While the bottom of the vessel is sloped toward the sump (0.25/ft), it is possible with enough sludge that zero (or reduced) slope exists at the top of the sludge. Even with slope it is possible the mercury will not "drain" to the mercury sump. This may require additional equipment to overcome the issue.

The material removed may need further processing in order to concentrate the mercury sufficiently for practical removal.

Figure 1: Dip sampler used in several CPC process tanks mercury sumps

Evaluation Data:

1. Mercury Removal Capability

If a significant quantity of elemental mercury is present in the mercury sump and accessible with the dip tool, removal should be very effective. The design of the previous dip sampler will be used as a starting point with attention toward increasing payload.

If the majority of the mercury mass in a tank to be de-inventoried is not settled in the sump, i.e. floating, suspended in the supernate, or retained in the heel; the effectiveness of this method will suffer. In some cases it could be rendered completely ineffective. In all these cases other option(s) would have to be coupled in order to get the mercury present in the sump.

It is important to realize that this option (if viable) assumes a dense form of mercury is present in the sump and that it has largely displaced other liquids out of that space.

2. Ease of Disposal

The dipper will not alter the form of mercury. However, if the sump contains heavy mercury such that the dipper works effectively; it will have the effect of concentrating the mercury due to the fact the container will be designed to preferentially fill with heavy liquid. Still, the disposal path is not expected to be altered by this option.

3. Operability

In general, the operation involves dipping mercury from the sump and transporting into a container. The other container will likely serve as a long-term collection vessel until final disposal occurs. It is envisioned the crane will be used to move and operate the dipping tool as well as locate the vessel. Additional containers or tool related items may be included as part of the plan, however the basic operation listed above should remain as described.

The procedure will be driven using the crane and therefore will require a commitment from the crane operations group during the evolution. It is also possible that a part of the procedure could occur in front of the cell window and make use of the MSM.

4. Maintainability

It is likely the unit will require seals and some type of sliding or rotating motion. If the maintenance is problematic an option is to simply make the tool (or a portion of the tool) replaceable.

5. Deployment Schedule

The tools could be designed and built in 1-2 months assuming an engineer and a couple of fabricators are available. Testing with mercury would require discussion and commitment from test facility management to determine realistic schedule and cost impact from conduct of research and similar.

6. Outage Window Duration

An outage window will be required. Actual time will depend on the amount of mercury in sump, volume of the dipper, efficiency of mercury extraction (volume of mercury vs. other liquid in each dipper load), speed the crane is operated.

7. Technical Maturity

Technology Readiness Level should be at approximately 8 or 9. A smaller version has been used to extract dip samples from process vessels a short time ago.

Combinations:

This option will require removal of the mercury pump, access to E nozzle, require crane operation, require mercury to be settled, and possibly make use of the manipulators. Any options that support these requirements can be performed in parallel.

It is possible the dipper will deliver a number of “dilute” payloads to a skid that contains a separator of some type to further concentrate the mercury.

Option 8 – Centrifugal Separation

This "option" was suggested as a technology to effect mercury separation; not in conjunction with a specific plan i.e. process tank, jumper, etc. It could be used in many scenarios ranging from mercury removal in supernate to heel. A suggested plan is offered below, but DWPF Engineering may have much better implementation based on facility knowledge.

This option would exploit mercury's density in order to separate it from the lighter water. The mercury would be diverted into the heavy effluent flow stream of the centrifugal separator. The separator could be used stand-alone or in conjunction with other components such as an electrostatic coalescer. In this case, the separator could be placed upstream and/or downstream of the electrostatic coalescer.

Concerns:

One concern is that the separator breaks larger droplets into smaller such that the effectiveness of the device is negated. Another is that the efficiency of separation is too low to be practical.

One assumption is that mercury can be separated using this method, dissolved mercury would be unaffected. Similarly, the effectiveness for any mercury forms considered should be tested to verify it is practical.

Potential Installation Plans:

1. Install on the SMECT or other process tank in a manner allowing recirculation of the supernate; through something like the sample loop. This would likely involve collection of the mercury outside of the process tank with the balance returned via the loop. The heavy stream containing the concentrated mercury would return through an arrangement to retain settled mercury.
2. A variation on Plan 1 above would be to position the entire loop inside of the process vessel. The concentrated mercury would be drained into the revitalized mercury pump (or similar). The loop and recirculation pump might be attached to the fixture that holds the existing mercury pump. (Again this plan might also involve an electrostatic coalesce etc. in addition to the centrifugal separator.) The mercury pump would be used to transfer the mercury to a location outside of the process vessel. It may be difficult to determine when the mercury pump needs to be energized, conductivity change could be used except that the sludge tends to insulate the probe tips. Some challenges in that area and others would need attention in order to optimize.
3. This is aimed at legacy mercury. Consider a vessel like the SMECT where the supernate has been removed such that the heel remains concentrated but in a state where it can be pumped. In this situation a loop is set up to recirculate the heel and segregate the mercury. It is likely that the Plan 2 scenario would be used in this case given the higher likelihood of elemental mercury in significant quantity.

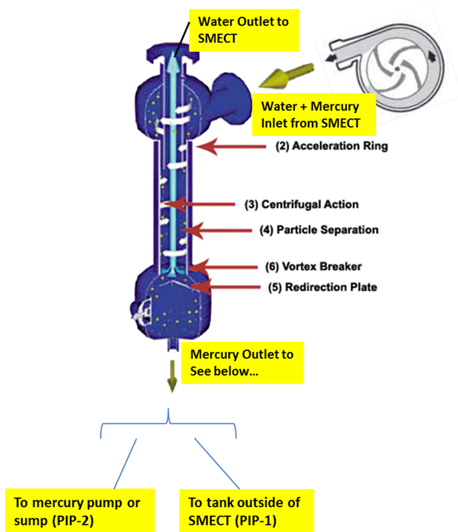



Figure 1: Flow Loop

Evaluation Data:

1. Mercury Removal Capability

Efficacy of mercury removal including limitations will require testing. In general, the technique should be somewhat effective on immiscible droplets and insoluble compounds. Used alone, the technique is not expected to have effect on ionic dissolved mercury or colloids.

2. Ease of Disposal

Should not have any effect other than to separate and concentrate the mercury in the material collected for disposal.

3. Operability

In PIP-1, a skid containing a pump, tank and separator with necessary plumbing is located on the SMECT (or other process vessel). The flow loop is established by tying to the sample loop or dropping a suction line into the process vessel. With the equipment located using the crane, flow is started by energizing the circulation pump which runs until separation is complete. This involves considerable operations attention, not only for the crane but also monitoring the loop and mercury collection.

In PIP-2, the equipment is installed as part of the mercury pump and remains resident in the process vessel. The design approach may be different as the components would need to survive prolonged periods of tank exposure and fit on the same mast as the existing mercury pump. The idea would be to make operating the loop possible without an outage window. Mercury transfer out of the tank would be via the Mercury Pump via any of the currently existing options.

4. Maintainability

In PIP-1 or PIP-2, the circulation pump and its drive are the items that have moving parts. It is expected both the pump and the separator will need replacement at some point. If necessary, remote individual component (or a group of components) can be considered.

5. Deployment Schedule

4-6 Months for skid deployment or up to 1 year for a permanent installation

6. Outage Window Duration

PIP-1 will require a typical outage duration.

PIP-2 once installed on the Mercury Pump should not require an outage for use.

7. Technical Maturity

Centrifugal separators have and are commonly used components to separate materials on a flow stream. Typically solid particulate are removed from a liquid flow stream. However, it is likely they will be quite effective on mercury in water given the density difference, the droplet size in the chamber may create problems if too small and will therefore require test. The component is fully mature, but the application will require demonstration to determine if practical. An estimate for the technical maturity relative to the application is TRL 5-6.

Combinations
This option could possibly be complimented by use of an electrostatic separator or settling chamber in conjunction with this option.

In PIP-2 the installation is equivalent to the current Mercury pump, so short of the circulation pump drive means, the option should not preclude other options that can occur with the Mercury pump installed.

In PIP-1 equipment will need to be positioned with the crane and suction and return lines positioned in the SMECT. Other options could be run in parallel so long as this physical arrangement can be supported during the same time-frame and the circulation pump energized.

Option 10 - Dissolve mercury in SMECT using pH change (with acid) and remove dissolved mercury using mercury resin

Intentionally oxidize/dissolve elemental mercury by adding additional nitric acid to the SMECT. At present, most of the SMECT elemental mercury is dissolved by the nitric acid produced from nitrite destruction combined with nitric acid added to the SMECT for pH control. It is likely that a relatively small increase in the amount of nitric acid added. Since the mercury would be dissolved in the SMECT, all SMECT condensate would need to processed through an ion exchange resin to remove the mercury. Both IDMS (DWPF pilot plant) and ETP have used **Duolite® GT-73** resin to remove mercury successfully. The Ion exchange process will be a non-elutable process which will be installed as a unit operation on the SMECT condensate line, requiring a redesigned jumper, ion exchange column and spent resin/eluate capture using a temporary storage tank which will be emptied periodically by eductor to a storage tank (repurposed salt cell tank) for further processing.

Evaluation Data:

1. Mercury Removal Capability
In long outages, SMECT elemental mercury is completely dissolved by nitric acid. The lower the pH the more the mercury will dissolve. However, a mercury removal resin to remove the residual mercury is also needed for this to be implemented and for it to work effectively. The resin would likely remove other radioactive insoluble solids.

2. Ease of Disposal
The resin with adsorbed mercury would be the final waste form. However, it would still need to be transferred to a suitable storage container and transported to an offsite location for storage.

3. Operability
Adding a mercury removal column and associated equipment would complicate the operations in an already tight area. The operation of adding more acid would just be changing procedures and therefore would be simple to implement.

4. Maintainability
There are no maintenance changes for increasing the acid addition to the SMECT. Additional maintenance needed would be for the ion exchange equipment and resin loading equipment.

5. Deployment Schedule
Significant testing would be needed before implementing this option, including choosing the best resin for mercury removal. The fabrication of equipment and jumpers were further complicate the deployment.

6. Outage Window Duration
The mercury resin equipment would need to be installed during an outage and could be installed in approximately one week.

7. Technical Maturity

The greatest amount of development needed would be on the ion exchange: how to implement it, cost, and time factors.

Combinations
Option 12 (the ion exchange) is necessary

Option 11 - Collect elemental mercury in SMECT using pH change (increase) and pump (to purification, storage or amalgamation)

Description

Minimize the oxidation/dissolution of elemental mercury by raising the pH of the SMECT through the addition of sodium hydroxide to the SMECT. At present, most of the SMECT elemental mercury is dissolved by the nitric acid produced from nitrite destruction combined with nitric acid added to the SMECT for pH control. Raising the pH of the SMECT to 3 should allow collection of elemental Hg from both the SRAT and SME. Since elemental mercury is expected to accumulate in the SMECT, the mercury should be frequently pumped to the mercury cell to minimize loss of Hg during transfer of the SMECT to RCT.

Evaluation Data:

1. Mercury Removal Capability
This option should allow the removal of the majority of the mercury in the SMECT. This includes both the elemental mercury collected in the MWWT along with the elemental mercury that is steam stripped in the SME and any elemental mercury not retained in the MWWT. The collection of elemental mercury is dependent on minimizing the oxidation/dissolving of mercury by nitric acid. The collection of mercury is dependent on the mercury coalescing and collecting in the bottom of the tank. Dissolved mercury will not be retained and will be transferred back to the tank farm.

2. Ease of Disposal
Assuming the SMECT to MWWT transfer pump is operable, the collected elemental mercury can be transferred to the MWWT and the MWWT pumped to the mercury cell. The ease of processing is related to the number and size of foamovers as the sludge and frit solids will likely collect with the mercury.

3. Operability
Assuming the SMECT to MWWT transfer pump is operable, the reduction in nitric acid is an easy implementation. Eliminating the addition of nitric acid to the SMECT and adding sodium hydroxide instead of nitric acid for pH control should be simple to operate. A higher pH limit for the SMECT would improve the operability and would likely retain more elemental mercury.

4. Maintainability
The equipment for mercury transfer and purification would need to be maintained unless the SMECT is used to serve as mercury collection point.

5. Deployment Schedule
Changes to procedures to remove addition of nitric acid and add the addition of sodium hydroxide would be needed. In addition, piping

6. Outage Window Duration

No outage would be necessary to implement. However, the mercury transfer and processing equipment would need to be returned to service to allow mercury to be processed. If the SMECT is allowed to serve as the mercury collection point for DWPF for the foreseeable future, even the operability of the mercury pumps aren't needed.

7. Technical Maturity

No testing of this pH range in the SMECT has been completed. A simple simulant test could compare the collection of mercury at pH 1 versus pH 3, but the best test might be a demonstration in DWPF.

Combinations

This could be combined with Option 7 to scoop out the mercury out of the SMECT.

This could be combined with Option 2/3

This could be combined with Option 17

This could be combined with Option 24 or 25

Option 12 - Ion Exchange Column on SMECT Sample Loop

Ion exchange can be used to extract mercury ions when in solution. Mercury is present in DWPF and in large known quantities in the SMECT. Due to the chemical conditions in the SMECT, it is possible that the mercury is dissolved in solution in this tank. Mercury removal by ion exchange is a technology already implemented in Liquid Waste at ETP. The mercury extraction in the SMECT can be similar to ETP and use a non-elutable GT-73 resin. However, testing will need to be done to determine how effective GT-73 is under the conditions in the SMECT. Modifications will include but not be limited to at least 1 redesigned jumper, installation of the ion exchange column and a designed system for storage/retrieval/replacement of spent resins. Additionally a prefilter may be required for the ion exchange to filter out solids present in the SMECT.

Advantages

1) The sample loop is outside of the CPC and therefore more accessible

2) The SMECT sample loop can be run in a constant recirculation to gradually extract the mercury

3) Already existing technology on site and waste disposal path for GT-73 already exists

Disadvantages

1) Major design change and modification to the plant

2) Unknown solubility of mercury in the SMECT

3) Design could be constrained by the amount of resin needed to extract the desired quantity of mercury

Evaluation Data:

Mercury Removal Capability

Ion Exchange is a proven method of effectively removing mercury. The limitation in mercury removal is that, depending on the mercury concentration in the feed, the number of resin columns may create a footprint too large for available space on the sample loop.

Ease of disposal

The Ion exchange would capture elemental and organic mercury out of solution. The spent resin will be relatively easy to dispose of. There already exists a waste disposal path for mercury loaded GT-73 resin because it already implemented at ETP. In order to ease this process, the ion exchange columns would be best installed in a cartridge form that would allow for easy and remote resin change out.

Operability

The operation of the SMECT sample loop would not change. The sample loop would be constantly recirculated until the ion exchange columns are loaded then the columns would be replaced. The removal process would be switching out ion exchange columns.

<u>Maintainability</u>

Maintenance of this implementation would involve replacing spent ion exchange columns when necessary.

<u>Deployment Schedule</u>

Preparations for deployment involve R&D, design, procurement, safety basis changes and jumper fabrication. ~ 9 months

<u>Outage Window</u>

The outage activities would include replacing jumpers and performing necessary PMTs. ~2 weeks

<u>Technical Maturity</u>

Ion exchange for mercury removal is a technically mature option and already implemented at ETP

<u>Combination</u>

Can be used with any of the other options

16. Add coalescer to MWWT

- Description:
    - Coalescers are designed to coalesce a liquid into larger droplet from smaller droplets or separate liquids by coalescing a liquid. The intent behind a coalescer is to get tiny 'floating' mercury droplets to coalesce into larger droplets so that it will sink into the sumps of the vessel. This would ensure that the mercury is directed to the sump where it is wanted instead of allowing these tiny particles of mercury to pass through to the SMECT. There are a couple of types of coalescers. There are mechanical or electrical coalescers. The mechanical coalescers are generally no moving parts, but sometimes require cartridge change outs. Electrical versions can require work when they short out.
- Benefits:
    - Benefits of a coalescer is that it would theoretically help trap more mercury in the sump of the MWWT and keep it there instead of allowing it to go to the SMECT.
- Problems / setbacks:
    - If a cartridge style, frequent change outs could create added down time, more expense to order cartridges and possible worker exposure to radiological contamination. Also would have to find what to do with used cartridges.
    - Electrical coalescers require electricity and would present an electrical hazard within the facility.

Evaluation Data:

1. Mercury Removal Capability

*If a large portion of Hg were not coalescing, this option could have significant impacts on the MMWT Hg collection. Some of this Hg could remain suspended when it enters the SMECT and dissolve into solution. If coalescing in the MWWT is possible, this option could potentially increase Hg collection a lot. This option may limit collection in the SMECT.*

2. Ease of Disposal

*It's not sure what form of Hg would be collected in the sump from this. It is possible that the Hg could still be 'Dirty mercury', but it could also help the mercury be cleaner by agglomerating larger Hg beads with most of the contamination moving on to the SMECT and to tank farm.*

3. Operability

*The option presented above could cause change out of cartridges, but may not require any change out and may not have to be dealt with at all. Might be able to install the system and run like nothing happened or changed. If this system fails, it does not matter as much in the short term since it is not required to pour cans. DWPF can fix at their discretion.*

4. Maintainability

*Once again, may need cartridges here, but may not. If you have cartridges, need to look at when to change, what to do with the old one, any contamination issues and such. If no cartridges, may not need* *to maintain the system at all. Could run to failure and as mentioned above, replace at DWPF's discretion.*

5. Deployment Schedule

*May need to make a design change to the MWWT. Could take up to 1 year to test, design, fabricate, develop DSA/procedure changes and deploy.*

6. Outage Window Duration

*Would expect this to be do during an outage. Might have to remove the MWWT and clean in the REDC to get the MWWT in the area to install the coalescer. May also just replace MWWT with coalescer installed so that it can be done in the quickest manner.*

7. Technical Maturity

*Don't know how technically mature this idea is, but if we believe that the mercury is 'floating' to the overflow pipe into the SMECT and leaving DWPF this way, then this would definitely help prevent this as an exit route. Some coalescers can be very effective and remove/separate high fraction of the substance from the process stream.*

Combinations

*This option could directly be used with 1, 2, 4, 5, 17, 18c, 19,*

### Option 17 - Reflux at the beginning of boiling in SRAT

Evaluation Data:

1. Mercury Removal Capability

*The greater the ability of the option to remove mercury, the more favorable the option. Describe how effectively the option can remove mercury and present its limitations.*

The solubility of Hg, as some $Hg^{2+}$ species, increases with nitric acid concentration. It is possible that the nitric acid refluxed could dissolve a significant amount of Hg collected in the MWWT. Concentrating the SRAT under acidic condition would most likely result in soluble mercury going from MWWT to SMECT. Hence, it is suggested to Reflux at the beginning of boiling in SRAT when SRAT stream is acidic. Once the SRAT stream has become more neutral, concentrating the SRAT should be started. This would drive the elemental mercury to accumulate in the bottom of MWWT.

The challenge is that refluxing when the SRAT level is high (i.e. refluxing prior to concentrating) poses a great carryover risk. This risk cannot be addressed without potentially adding extra antifoam and risk of failing melter offgas flammability.

2. Ease of Disposal

*The more easily the form of mercury captured is to dispose of, the more favorable the option. (e.g. clean elemental mercury is preferable). Describe what form the captured mercury will be, e.g. elemental, dirty, amalgam etc. and how easy it is to dispose of the material. Identify which add on options (i through v can be used)*

This would drive the elemental mercury to accumulate in the bottom of MWWT. Hence, allowing easier collection option for Hg as compared to the soluble mercury.

3. Operability

*The less operator load, (e.g., fewer operations, fewer actions), the more preferable. Describe briefly the operations needed to complete the removal process and estimate if this is a difficult (complex) or easy (simple) operation to perform*

Once elemental mercury is collected in MWWT, it is easier to collect than the soluble form of mercury. However, refluxing prior to concentrating poses some operational risks.

4. Maintainability

*The easier to maintain (e.g. no moving parts, long component design life), the more preferable. Describe what the maintenance of the deployed option will entail.*

Processing change. No maintenance involved.

5. Deployment Schedule

*The shorter the duration from receiving notice to proceed to complete deployment, the more preferable. Provide an estimate of how long from the authorization to proceed, the deployment could be complete and operational.*

It is a processing change that can be done by a few IPCs. However, refluxing prior to concentrating poses some operational risks.

6. Outage Window Duration

*The shorter the outage window needed to deploy the option, the more preferable. Provide an estimate of the outage window(s) if any needed to deploy the option.*

No outage required for this change.

7. Technical Maturity

*The more technically mature the more preferred the option. Provide an estimate of technical maturity e.g. TRL or identify the aspect of the option requiring the greatest amount of development.*

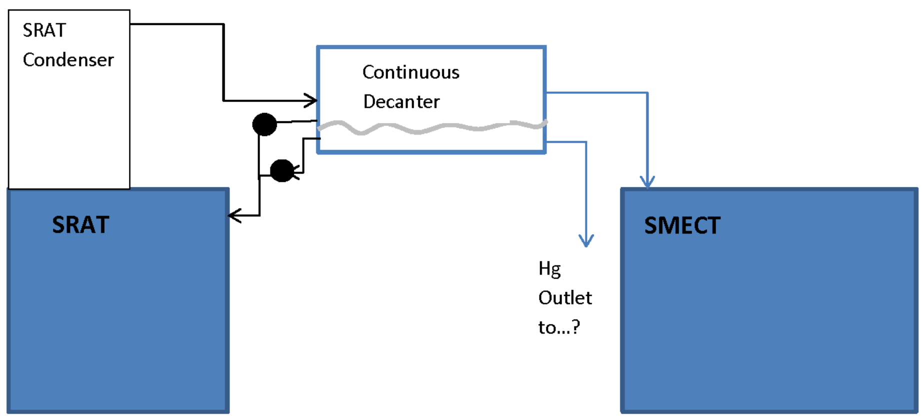
Refluxing prior to concentrating poses some operational risks. Further studies need to be done to understand the risk.

Combinations

*Identify which of the other options could be deployed in parallel with this option.*

Any options facilitating removal of mercury from the MWWT.

**Option 18 c - Use a continuous gravity Hg decanter instead of the MWWT Hg transfer pump**. This would remove elemental Hg as soon as it is collected in the MWWT without operator intervention. If the disposal requirements allow direct disposal of Hg as drained from the MWWT without further decontamination, this would also avoid pumping and processing the mercury in the mercury purification cell. This option involves canyon design and processing details that would need to be resolved.




Evaluation Data:

1. Mercury Removal Capability

A continuous gravity decanter would be effective at removing mercury from the process assuming the mercury collects in appreciable amounts in the MWWT. This option does not provide a mercury removal route for deposits that are already present or may collect in other process vessels.

2. Ease of Disposal

Using the mercury samples from the SMECT, SRAT, and MWWT as a guide line, the mercury removed via this option would most likely be the dirtiest form relative to isolated mercury from the SRAT or SMECT.

3. Operability

This option requires minimal operator load. Operation of a continuous gravity decanter requires little operator intervention, although, the removal of mercury from the decanter would involve some operator action.

4. Maintainability

The decanter separates the contents of the MWWT based on density (like the current sump design) and involves no moving parts.

5. Deployment Schedule

Given the design, procurement, fabrication, and installation restraints around adding a new vessel the deployment of this option would most likely be greater than one year.

6. Outage Window Duration

This option could be implemented within a regular outage window. This estimate is based on the amount of time required to replace the MWWT during a previous outage.

7. Technical Maturity

While a gravity decanter has not been used in DWPF for this specific application, the concept of separating stream contents continuously by density difference is well established.

Combinations

This option is compatible with options: 6-12, 17, 19, 21, 24-28

Option - 19. Add more acid to SRAT

Typically, excess acid is added to the SRAT by way of multiplying the total moles of acid required by a stoichiometric factor, which is required to accommodate variations in the chemical and rheological properties of sludge macrobatches. During sludge batch simulant flowsheet testing, a stoichiometric acid window is determined based upon protection of assumptions in the safety basis, namely, nitrite destruction (which determines the minimum acid requirement), and hydrogen and ammonia generation (which determine the maximum acid requirement). Processing issues (i.e. transport issues, mercury recovery, etc.) are a secondary concern when adjusting the acid stoichiometry and only affect the stoichiometric acid window within the bounds of the safety basis. During a macrobatch, minor adjustments can be made to the acid stoichiometry within the stoichiometric window to help control chemical processing.

The recommended stoichiometry per SRNL for SB8 is 110-126%. Early batches in SB8 did not show issues with hydrogen generation and nitrite was sufficiently destroyed so the stoichiometry remained at the lower end of 110-115%. This has resulted in 250-350 gallons of formic and 85-150 gallons of nitric added to each SRAT batch. Since SB6, we have used 115% for the stoichiometry parameter but have used higher stoichiometry in the past based on the chemistry of those particular sludge batches: SB4-5 (130%), SB3 (155%), SB2 (125%-180%), S1b (137.5%), SB1a (125%).

Historically in experiments, higher quantities of acid result in higher recovery yield of mercury. The method is thought to be that more acid would destroy nitrite faster leading to a more neutral state in the DWTT. Spending a longer amount of time in a more neutral state during concentration will cause more mercury to precipitate in the MWWT and carry less over to the SMECT.

**Note: These have been completed under the assumption that more acid could be added. However, due to calculations related to PISA compensatory actions using current formic acid addition levels, higher acid is not a viable solution as it would provide unaccounted for hydrogen generation.**

**1. Mercury Removal Capability**

*The greater the ability of the option to remove mercury, the more favorable the option. Describe how effectively the option can remove mercury and present its limitations.*

In theory, more acid will lead to more mercury precipitating in the MWWT due to reaching a more neutral phase sooner. It is unknown what additional quantity of mercury will precipitate. It does not remove mercury directly but rather transfers more of it to the MWWT instead of remaining in the SRAT and downstream processes.

**2. Ease of Disposal**

*The more easily the form of mercury captured is to dispose of, the more favorable the option. (e.g. clean elemental mercury is preferable). Describe what form the captured mercury will be, e.g. elemental, dirty, amalgam etc. and how easy it is to dispose of the material. Identify which add on options (i through v can be used)*

No mercury removed with this change. More mercury could potentially be gathered in the DWTT.

**3. Operability**

*The less operator load, (e.g., fewer operations, fewer actions), the more preferable. Describe briefly the operations needed to complete the removal process and estimate if this is a difficult (complex) or easy (simple) operation to perform*

No removal

**4. Maintainability**

*The easier to maintain (e.g. no moving parts, long component design life), the more preferable. Describe what the maintenance of the deployed option will entail.*

Chemical change, no maintenance involved.

**5. Deployment Schedule**

*The shorter the duration from receiving notice to proceed to complete deployment, the more preferable. Provide an estimate of how long from the authorization to proceed, the deployment could be complete and operational.*

Acid requirements can be altered for each individual batch.

**6. Outage Window Duration**

*The shorter the outage window needed to deploy the option, the more preferable. Provide an estimate of the outage window(s) if any needed to deploy the option.*

No outage required for this change. We are authorized for SB8 to target a stoichiometry between 110-126%. We currently target 110% for batches containing PRFT and 115% for non-PRFT batches.

**7. Technical Maturity**

*The more technically mature the more preferred the option. Provide an estimate of technical maturity e.g. TRL or identify the aspect of the option requiring the greatest amount of development.*

Calculations associated with compensatory measures for ongoing PISAs have been developed using assumptions on current formic acid addition quantities. Adding more acid would provide additional hydrogen generation not accounted for in these calculations and is not a viable option.

**Combinations**

*Identify which of the other options could be deployed in parallel with this option.*

Any options facilitating removal of mercury from the MWTT.

Option 21 - Use mercury removal resin in RCT

There are currently no locations within the facility in which mercury accumulates in appreciable amounts, thus precluding the ability to consistently remove mercury from the process. There are two primary mechanisms which currently limit accumulation: incompatible chemistry and/or mechanical interferences. The chemistry of the RCT is favorable for mercury accumulation since normal processing of condensate requires adjustment of the heel to ensure the contents remain at an elevated pH. The primary limitation of accumulation in the RCT is due to residence time of the condensate and consistent vessel agitation, which maintain suspension (and subsequent transfer to the Tank Farm) of mercury.

This option is similar to Option #12 (Ion Exchange Column on SMECT Sample Loop), but would locate the unit operation inside the RCT vessel. Additionally, the RCT chemistry is different (RCT high pH versus SMECT low pH). The option would require modification of the vessel to incorporate a removable basket/strainer such that Duolite GT-73 resin would contact the condensate. Efficiency will depend upon contact time and resin. Will require resin change-out and either disposal, or a storage vessel (Catalyst Make-up Tank?) and subsequent unit operation for resin-recovery.

Evaluation Data:

1. Mercury Removal Capability

Assuming the resin of choice is Duolite GT-73, the removal efficiency of mercury from the waste stream is expected to be significantly less than that of Option #12 for two reasons: 1)the form of mercury in high pH environment is less conducive to removal (compared to dissolved mercury at low pH), and 2)the contact time may be limited.

2. Ease of Disposal

Presumably, disposal options already exist for loaded Duolite GT-73.

3. Operability

Operability for this option will depend upon the frequency of resin change-out required to maintain efficiency. Since the unit is located inside the vessel, an interruption in waste water processing would be required to execute basket removal, resin retrieval and replacement, and re-installation. Operability during normal operations (mercury removal while processing waste water) is minimal.

4. Maintainability

Since there are no moving parts associated with this option, maintainability is minimal.

5. Deployment Schedule

Deployment potentially requires R&D (to determine appropriate design requirements to maximize removal efficiency) as well as subsequent design work and fabrication/procurement to install a basket or column into the vessel. Deployment is expected to be > 18 months.

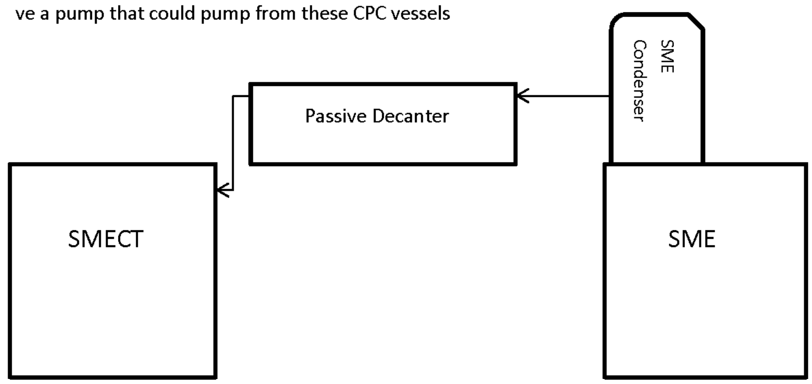
6. Outage Window Duration
The outage to implement the design is on the order of weeks, and could potentially be implemented within an existing (extended) outage window.

7. Technical Maturity
The use of Duolite GT-73 for mercury removal is fairly mature. The efficiency of this particular option would likely require R&D to maximize placement of the resin inside the vessel, and may identify flowsheet changes required to improve efficiency.

Combinations
Note: This particular option may be more appropriately replaced by an alternative to Option #12 in which the ammonia scrubbers are utilized as the removal point. In this case, the saddles might be replaced with resin and the ammonia scrubbers become the “basket”. Avoids design work and likely improves removal efficiency due to chemistry of SMECT and constant recycle flow of liquid through scrubbers.

24. Passive decanter as part of SME overheads

- Description:
    - Since there is some mercury stripping in the SME cycle similar to the SRAT cycle, a decanter similar to the MWWT would be beneficial for the SME as well. This would help keep the mercury from the acidic chemistry in the SMECT and in turn help keep the mercury from returning to the tank farm. This would need to be properly sized to make sure the mercury has adequate time to settle to the sump as it has been suggested that the MWWT could be sized better to be more efficient.
- Benefits:
    - Having an additional decanter for the SME would keep the mercury from the SMECT which is one transfer from going back to tank farm. Assuming the condensate from the SME is fairly neutral; keeping the mercury in this decanter assuming it is properly sized would seem like an easy task.
- Problems / setbacks:
    - An additional tank that would take up resources from design, engineering, and procurement.
    - Very little space inside of the CPC
    - Procurement times on a tank could be lengthy
    - Could potentially cost lots of money.
    - If the MWWT doesn't work effectively, what makes us think this vessel will?
    - Have to tie this vessel into the MTH and be able to pump to the MWWT. If it is not sized exactly like the MWWT, might need a new pump design which could incorporate additional large costs.
    - ve a pump that could pump from these CPC vessels



Evaluation Data:

1. Mercury Removal Capability

The effectiveness of this option depends on if the chemistry in the SME produces mercury that will collect at the bottom of a decanter. This option does not facilitate removal of mercury from other process vessels.

2. Ease of Disposal

The form of mercury isolated with this option is unknown.

3. Operability

The operability of this option depends on the method chosen to extract mercury from the passive decanter. These methods could be anything from pumping decanted mercury to the MWWT, to installing a drain in the mercury sump for continuous removal. The former requires considerable operator intervention while the latter little to no oversight.

4. Maintainability

The decanter itself would have no moving parts and would require minimal maintenance. However, the overall maintainability depends on the method chosen to remove mercury from the decanter.

5. Deployment Schedule

This option would require a lengthy deployment schedule due to the logistics of adding a new tank into the canyon.

6. Outage Window Duration

Installing a passive decanter would most likely require a longer than average outage time.

7. Technical Maturity

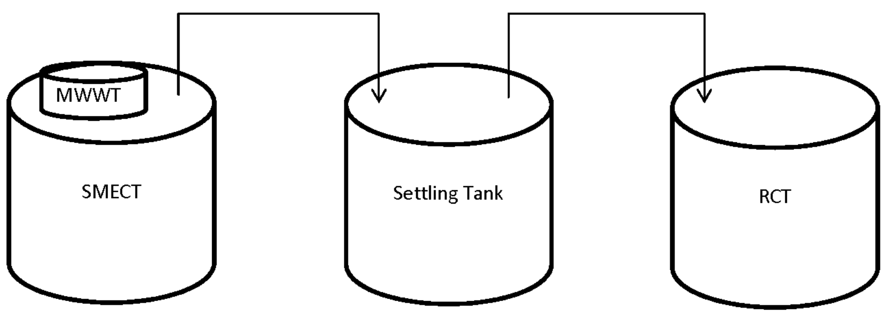
Decanter separation schemes are widely used, however this technology is not currently applied for mercury separation within DWPF.

Combinations

This option is compatible with options: 1-12, 16, 17, 18c, 19, 21, 25-28

25. Install settling tank (after pumping out of SMECT)

- Description:
  - Installing a settling tank after the SMECT, but before the RCT might give the advantage of allowing any dissolved up mercury to settle back down and separate from rest of the waste. This would then make additional removal area for mercury.
- Benefits:
  - Using this could potentially allow for the settling tank to remove more mercury from the system that otherwise would have went to the RCT and then to the tank farm. Could do similar chemistry that the RCT receives and caustically adjust so that the mercury could potentially drop out or precipitate out.
- Problems / setbacks:
  - The reason the RCT is continuously mixed is to avoid solids building in the tank and to help purge. If you did not agitate your settling tank, could potentially have large amounts of solids buildup in this tank and create 'Dirty mercury'.
  - Room for another vessel, especially one as large as the SMECT would be near impossible.
  - Believe that they have been trying to procure another vessel similar to the CPC vessels for a few years now and have yet to be successful. Long implementation time.
  - Big vessel = big money
  - Not sure with this amount of money that the return investment would be there for what little you could potentially gain.
  - Would once again have to have a pump that could pump from these CPC vessels




Evaluation Data:

1. Mercury Removal Capability

*Could help recover some mercury that is potentially leaving the SMECT and let it settle in the settling tank. Only issue is that sludge solids would also settle in the tank.*

2. Ease of Disposal

*If adjusted like the RCT, we would expect the Hg to be in elemental form, but it could be similar to what is in the MWWT since there will be some solids present and settling with the mercury. Additionally, would either need a pump or another tank to hold collected mercury.*

3. Operability

*This should be very simple to do. Easy to adjust caustically in the settling tank instead of the RCT and let mercury settle out before transferring to the RCT. Just another transfer process.*

4. Maintainability

*No moving parts and if tank is created out of correct materials, should have no reason to believe that it won't last for a very long time.*

5. Deployment Schedule

*This would probably take a long time to install and procure all necessary items. Vessels take a long time to procure and there is limited space in the canyon to install something such as this. Typical SMECT size is about 6k gallons so this vessel would need to hold at least this amount plus some for chemical adjustments. One other solution could be to use a Salt Cell vessel. In this case it would require only jumpers.*

6. Outage Window Duration

*This would take a long time to install since you are inserting another vessel. Space must be made in the canyon and all new jumpers from SMECT to settling tank to RCT.*

7. Technical Maturity

*This option has a long way to go technically. Sludge settling in the tank would present a problem with sludge/mercury combinations that we are currently presented with in the MWWT. May help remove some from the stream this way, but does not help us process mercury if we needed it 'clean'.*

Combinations

Could be used with multiple other options.

Option 26 - Filtration and IX downstream of RCT

There are currently no locations within the facility in which mercury accumulates in appreciable amounts, thus precluding the ability to consistently remove mercury from the process. There are two primary mechanisms which currently limit accumulation: incompatible chemistry and/or mechanical interferences. The chemistry of the RCT is favorable for mercury accumulation since normal processing of condensate requires adjustment of the heel to ensure the contents remain at an elevated pH. The primary limitation of accumulation in the RCT is due to residence time of the condensate and consistent vessel agitation, which maintain suspension (and subsequent transfer to the Tank Farm) of mercury.

This option is similar to Option #12 (Ion Exchange Column on SMECT Sample Loop) with different chemistry (RCT high pH versus SMECT low pH). Eliminates need to accumulate mercury in the RCT, which could prove difficult. This option would require design and fabrication of a recycle loop containing in-line filtration elements and an ion exchange column with Duolite GT-73. Efficiency will depend upon contact time and resin. Will require resin change-out and either disposal, or a storage vessel (Catalyst Make-up Tank?) and subsequent unit operation for resin-recovery.

1. Mercury Removal Capability

Assuming the resin of choice is Duolite GT-73, the removal efficiency of mercury from the waste stream is expected to be improved over Option #21 (due to the recycle piping and subsequent contact exposure), but less than that of Option #12 (due to the form of mercury in high pH environment being less conducive to removal compared to dissolved mercury at low pH).

2. Ease of Disposal

Presumably, disposal options already exist for loaded Duolite GT-73.

3. Operability

Operability for this option will depend upon the frequency of resin change-out required to maintain efficiency. An interruption in waste water processing may be required to execute resin retrieval and replacement, but should improve over Option #21 since the unit is external to the vessel. Operability during normal operations (mercury removal while processing waste water) is minimal.

4. Maintainability

A recirculation pump will be required as part of the design, thus maintainability is marginally reduced over Option #21.

5. Deployment Schedule

Deployment potentially requires R&D (to determine appropriate design requirements to maximize removal efficiency) as well as subsequent design work and fabrication/procurement to install recirculation loop, ion exchange column, and filters. Deployment is expected to be > 18 months.

6. Outage Window Duration

The outage to implement the design is on the order of weeks, and could potentially be implemented within an existing (extended) outage window.

7. Technical Maturity

The use of Duolite GT-73 for mercury removal is fairly mature. The efficiency of this particular option would likely require R&D to maximize configuration of the recirculation loop setup, and may identify flowsheet changes required to improve efficiency.

Combinations

Note: This particular option may be more appropriately replaced by an alternative to Option #12 in which the ammonia scrubbers are utilized as the removal point. In this case, the saddles might be replaced with resin and the ammonia scrubbers become the "exchange column". Avoids design work and likely improves removal efficiency due to chemistry of SMECT.

Option 27 - Change operating mode of RCT to allow decanting

There are currently no locations within the facility in which mercury accumulates in appreciable amounts, thus precluding the ability to consistently remove mercury from the process. There are two primary mechanisms which currently limit accumulation: incompatible chemistry and/or mechanical interferences. The chemistry of the RCT is favorable for mercury accumulation since normal processing of condensate requires adjustment of the heel to ensure the contents remain at an elevated pH. The primary limitation of accumulation in the RCT is due to residence time of the condensate and consistent vessel agitation, which maintain suspension (and subsequent transfer to the Tank Farm) of mercury.

Since the chemistry of the RCT (high pH) is likely favorable for mercury accumulation in the RCT sump, the idea is to adapt how the RCT is processed to optimize the potential for accumulation of mercury in the RCT sump. Examples include securing agitation with the exception of chemical additions (beginning of RCT) and prior to transfer (end of RCT). Concern would be whether or not agitation re-suspends sludge solids (without re-suspending mercury) to prevent accumulation. Change in processing strategy may need to be mode dependent. Likely inefficient, and would need to be supported by testing to determine the optimal operating conditions for mercury accumulation.

Evaluation Data:

1. Mercury Removal Capability

*As mentioned above, this is likely inefficient. Key here would be settling time in the RCT. The more time Hg is allowed to settle, the more potential Hg that could be recovered from the stream. Not sure that Hg is going to settle out of solution. Maybe take a harder look at tank 22 (DWPF recycle) solids to see if this indeed occurs. Longer wait times could potentially affect canister production.*

2. Ease of Disposal

*Do not know which form the Hg would present itself in. It is likely that it would be relatively clean elemental mercury since both the SMECT and OGCT (main RCT sources) are of low pH fairly clean streams, but caustic adjustments could make unknown interactions.*

3. Operability

*This could be a fairly simple exercise. Add liquids from sources as usual, but turn off agitator and let solids settle. Then, turn on agitator so that solids get pulled back into solution, but Hg stays in the sump of the vessel (if that is possible). May need some VFD motor on agitator to pull this off.*

4. Maintainability

*This would be fairly easy to maintain as it is the current system, just differences in when DWPF runs the RCT agitator and when DWPF transfers the liquid from the RCT to TF.*

5. Deployment Schedule

*I could not imagine that this option would take a long time to develop. The longest potential time could be spent on SRNL testing whether it were possible to suspend almost all of the sludge solids without suspending settled Hg back into solution and sending it back to tank farm. Also would need the mobile Hg pump to get Hg from the RCT to desired endpoint location.*

6. Outage Window Duration
*This should not require an outage unless DWPF found a 'sweet spot' in agitator power to suspend sludge and not Hg and had to replace agitator motor or install a VFD motor so that tuning of agitator could be possible.*

7. Technical Maturity
*Not very technically mature. This option may not settle any Hg out and if it does, is it even possible to suspend only sludge solids and not Hg using the agitator? SRNL testing must be done to evaluate this. Even if SRNL says it can be done, at what rate does DWPF run its agitator? No camera or other clues about whether just Hg is staying on bottom, but bubbler might give somewhat of an indication.*

Combinations
*Wide variety of combos, discuss among group.*

**Removal of Mercury from DWPF Vessels Pro-Forma**

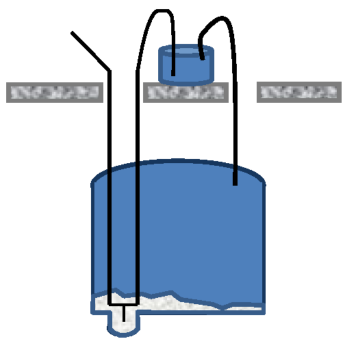
**<u>Option 28</u>**

**<u>Title:</u>** Utilize jet eductor pump and temporary bucket

**<u>Originator:</u>** Andy Tisler

**<u>Description:</u>**

Utilize a jet eductor pump in the SMECT's (or any other process vessel's) mercury sump to pump any mercury that is in the tank into a temporary storage vessel. This will clean the vessel of any accumulated mercury. The temporary storage vessel would drain back into the tank and the mercury would be retained in the vessel. Once the temporary storage vessel is either full of mercury or no more mercury exists to pump, the storage vessel can be relocated to an area to be dispositioned.



Evaluation Data:

1. Mercury Removal Capability

Utilizing this temporary transfer system, it will remove any mercury that has accumulated in the vessel sumps.

2. Ease of Disposal

The mercury removed from the system should be in a clean state. The temporary storage vessels will have to be characterized and disposed, which should not be difficult as the mercury removed should be clean.

## Removal of Mercury from DWPF Vessels Pro-Forma

3. Operability

Actions to operate the system include removing the currently installed transfer system, installing the jet temporarily, locating the temporary storage vessel where the jet can discharge into it as well as having an overflow back to the vessel. Once the system is installed, the mercury is transferred into the temporary storage vessel.

Operating this temporary transfer system could become difficult if it is not designed for personnel to be near it during operations.

4. Maintainability

This system is extremely simple to operate. There are no moving parts, only connections to a high pressure water source.

5. Deployment Schedule

Anticipate design effort taking 6-8 weeks
Fabrication of system – 8 weeks
Testing of system (mock- up) 6 weeks
Final fabrication and ready to deploy 6 weeks

6. Outage Window Duration

The system could be deployed during any outage window. Operation of the system should take less than a shift per tank (provided the temporary storage container can handle the amount of mercury anticipated).

7. Technical Maturity

The use of water to transfer material has been proven in radiation environments. TRL would be a 9.

Combinations

This option should be considered with any other option that caused mercury to be deposited in the bottom of a vessel.

## Appendix C – Option Scoring

| Ideal mode | | DIRECT | DIRECT | DIRECT | DIRECT | DIRECT | DIRECT | DIRECT |
|---|---|---|---|---|---|---|---|---|
| Alternative | Total | Hg Removal Capability (L: .382) | Ease of Disposal (L: .041) | Operability (L: .170) | Maintainability (L: .152) | Deployment Schedule (L: .071) | Outage Window Duration (L: .071) | Technical Maturity (L: .114) |
| 2-Re-establish Existing System | .732 | .7 | 1 | .875 | .5 | .5 | .9 | .875 |
| 3-Pump SMECT to MAWT | .714 | .7 | 1 | .875 | .5 | .5 | .85 | .75 |
| 4-Pump MWWT to SMECT to MAWT | .701 | .7 | .375 | .8 | .6 | .75 | .75 | .75 |
| 6-SRAT cnds to SMECT to MWWT | .634 | .6 | .375 | .8 | .5 | .6 | .7 | .75 |
| 7-Develop Dip/Scoop & Pull from SMECT | .429 | .2 | .15 | .2 | .75 | .9 | .5 | .875 |
| 8-Use Centrifugal Separator | .352 | .3 | .375 | .2 | .4 | .5 | .5 | .5 |
| 10-Diss Hg in SMECTwith pH change (acid) | .648 | .8 | .5 | .4 | .8 | .25 | .5 | .7 |
| 11-Raise pH Collect in SMECT pump out | .748 | .75 | 1 | .875 | .5 | .5 | .9 | .85 |
| 12-IX Column at SMECT Sample Loop | .554 | .4 | .5 | .6 | .8 | .6 | .5 | .7 |
| 16-Add Coalescer to MWWT | .000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 17-Reflux at Beginning of Boiling in SRAT | .000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 18c-Gravity Decanter Instead of MWWT | .584 | .4 | .375 | .7 | .9 | .4 | .5 | .85 |
| 21-Mercury Removal Resin in RCT | .560 | .75 | .5 | .3 | .6 | .15 | .3 | .7 |
| 24-Passive Decanter SME Overheads | .000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 25-Settling Tank after pumping out SMECT | .399 | .25 | .375 | .3 | .9 | .1 | .2 | .7 |
| 26-Filtration and IX after RCT | .608 | .85 | .5 | .4 | .6 | .15 | .35 | .6 |
| 27-Allow Decanting in RCT | .491 | .25 | .375 | .3 | .9 | .6 | 1 | .7 |
| 28-Jet Eductor and Temporary Bucket | .518 | .6 | .375 | .3 | .6 | .55 | .5 | .5 |

## Appendix D – Compatibility Grid

| Option | 2-Re-establsh existing system | 3-Pump from SMECT to MAWT | 4-Pump from MWWT to SMECT then SMECT to MAWT | 6-Routing SRAT Condensate to SMECT then pump SMECT mercury to MWWT | 7-Develop a new dip/scoop to pull out of SMECT | 8-Use Centrifugal Separator | 10-Dissolve mercury in SMECT using pH change (with acid) and remove dissolved mercury using mercury resin | 11-Collect elemental mercury in SMECT using pH change (increase) and pump (to purification, storage or amalgamation) | 12-IX column at SMECT sample loop | 16-Add coalescer to MWWT | 17-Reflux at beginning of boiling in SRAT | 18c-Use a continuous gravity Hg decanter instead of the MWWT Hg transfer pump | 21-Use mercury removal resin in RCT | 24-Passive decanter as part of SME overheads | 25-Install settling tank (after pumping out of SMECT) | 26-Filtration and IX after RCT | 27-Change operating mode of RCT to allow decanting | 28-Utilize Jet Eductor and Temporary Bucket |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2-Re-establsh existing system | | √ | √ | √ | X | If Returned to SMECT Sump | X | √ | √ | √ | √ | X | √ | √ | √ | √ | √ | Use Jet Eductor only |
| 3-Pump from SMECT to MAWT | √ | | √ | Route SRAT Condensate to SMECT | X | If Returned to SMECT Sump | X | √ | √ | √ | √ | X | √ | √ | √ | √ | √ | Use Jet Eductor only |
| 4-Pump from MWWT to SMECT then SMECT to MAWT | √ | √ | | Route SRAT Condensate to SMECT | X | If Returned to SMECT Sump | X | √ | √ | √ | √ | X | √ | √ | √ | √ | √ | Use Jet Eductor only |
| 6-Routing SRAT Condensate to SMECT then pump SMECT mercury to MWWT | | | | | | | | | | | | | | | | | | |
| 7-Develop a new dip/scoop to pull out of SMECT | | | | | | | | | | | | | | | | | | |
| 8-Use Centrifugal Separator | | | | | | | | | | | | | | | | | | |
| 10-Dissolve Hg in SMECT using pH change (with acid) and remove dissolved Hg using resin | | | | | | | | | | | | | | | | | | |
| 11-Collect Hg in SMECT using pH (increase) and pump (to purification, storage or amalgamation) | √ | √ | √ | √ | X | If Returned to SMECT Sump | X | | √ | √ | √ | X | √ | √ | √ | √ | √ | Use Jet Eductor only |
| 12-IX column at SMECT sample loop | | | | | | | | | | | | | | | | | | |
| 16-Add coalescer to MWWT | | | | | | | | | | | | | | | | | | |
| 17-Reflux at beginning of boiling in SRAT | | | | | | | | | | | | | | | | | | |
| 18c-Use a continuous gravity Hg decanter instead of the MWWT Hg transfer pump | | | | | | | | | | | | | | | | | | |
| 21-Use mercury removal resin in RCT | | | | | | | | | | | | | | | | | | |
| 24-Passive decanter as part of SME overheads | | | | | | | | | | | | | | | | | | |
| 25-Install settling tank (after pumping out of SMECT) | | | | | | | | | | | | | | | | | | |
| 26-Filtration and IX after RCT | | | | | | | | | | | | | | | | | | |
| 27-Change operating mode of RCT to allow decanting | | | | | | | | | | | | | | | | | | |
| 28-Utilize Jet Eductor and Temporary Bucket | | | | | | | | | | | | | | | | | | |

X Cannot be combined with this option as an add on

√ May be combined with this option as an add on

Part of Recommended Option

Add on to Recommended Option

Not Recommended add on to Recommended Option

**Appendix E – Risk Assessment Premortem Results**

| Risk ID | Risk | Handling Strategy |
|---|---|---|
| 1 | Mercury Pump may not lift from SMECT (if severe, buildup of mercury in SMECT could cause structural issues) | • Mock up Test<br>• Identify design improvements (e.g. educator, scoop etc.)<br>• Obtain uncontaminated pump and hands on test (e.g. Salt Cell pump) |
| 2 | Purification System clogs | • Optimize operations (steps)<br>• Examine system to identify what is causing this issue (ongoing)<br>• Identify options for cleaning system<br>• Review other options (add ons) that may help |
| 3 | No antifoam allowed (reduces efficiency) | • Accept |
| 4 | Equipment is obsolete (breaks and no replacement is available) | • Perform RAMI<br>• Identify obsolete parts/design review<br>• Redesign as needed<br>• Work with testing and mockup |
| 5 | Sludge Batch chemistry not compatible | • Factor into Sludge Batch preparation and planning<br>• Factor into Sludge Batch qualification |
| 6 | Mercury still goes to Tank Farm (e.g. increasing pH does not precipitate sufficient mercury or organic mercury is not captured or other phenomena) | • Investigate/deploy RCT options<br>• Investigate options downstream<br>• Monitor |
| 7 | Reflux does not precipitate | • Accept |
| 8 | Reflux causes carryover (potential for larger SRAT batch size in future) | • Operational changes to improve (without impacting throughput) |
| 9 | Mercury Pump/Line plugs | • Evaluate and if necessary re-design and incorporate in testing |

| Risk ID | Risk | Handling Strategy |
|---|---|---|
| | | and mockup<br>• Incorporate identified design improvements<br>• Have spares available |
| 10 | Impacts processing time/throughput | • Evaluate other add on options not employed and mature and deploy those showing promise |
| 11 | Scrubber operation is impacted (e.g. raising pH causes ammonium nitrate to collect in header) | • Limit pH as practical<br>• Implement Alternate Reductant flowsheet early |
| 12 | pH increase causes unforeseen chemistry impact | • Factor into Sludge Batch preparation and planning<br>• Factor into Sludge Batch qualification |
| 13 | Existing system cannot be recovered | • Determine early if existing system cannot be recovered and repair/re-design/procure/install equipment as necessary |
| 14 | Frequent equipment failure is encountered | • Mock up<br>• Provide spare parts<br>• Minimize operating impacts |
| 15 | Purification System overfills (5 gals max) | • Ensure alternate storage/disposal is available |
| 16 | Mercury (e.g. dirty mercury) does not migrate to sump (if not removed could also cause pumps and jumpers to plug) | • Identify options that could help mitigate, e.g. slope of trough/scoop options |
| 17 | Captured mercury has no disposal path | • Accept and if encountered develop a new disposal strategy |
| 18 | Lack of agitation in SMECT impacts mercury removal (mixing) | • Accept- Current sample indicates this is not a problem |