

Tributylphosphate in the In-Tank Precipitation Process Facilities

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TRIBUTYLPHOSPHATE IN THE IN-TANK PRECIPITATION PROCESS FACILITIES (U)

SUMMARY

A material balance investigation and evaluation of n-tributylphosphate (TBP) recycle throughout ITP and its carryover to DWPF was performed. Criticality and DWPF-related issues were determined to pose no adverse consequences due to TBP addition. Effects of decomposition products were also considered. Flammability of 1-butanol, a TBP decomposition product, in Tank 22 was investigated. Calculations show that Tank 22 would be ventilated with air at a rate sufficient to maintain a 1-butanol concentration (volume %) well below 25 % of the lower flammability limit (LFL) for 1-butanol.

Tributylphosphate will not accumulate in Tanks 48, 50, or 22 if added at concentrations up to 100 mg/L. Additionally, no significant quantities of TBP will be carried over to Tank 49 or further downstream. All soluble decomposition products are expected to be cycled from Tank 22 to Tank 48 and ultimately removed from the process in the decontaminated salt solution (DSS) waste stream. Since only minimal TBP and TBP decomposition products (e.g., dibutyl- and monobutylphosphate, 1-butanol, and phosphate) are expected to be carried over to Tank 49, there should be no effect on DWPF. Evaluation of material balance data in conjunction with uranium solubility experiments indicates no criticality problems will occur. Data indicate that ventilation of Tank 22 will prevent the TBP decomposition product, 1-butanol, from accumulating at a rate sufficient to produce a flammable concentration (at initial TBP feed concentrations of 100 mg/L). Further calculation has determined that in the event of loss of ventilation in Tank 22, the time to reach LFL for 1-butanol would be 18.5 days.

INTRODUCTION

In-Tank Precipitation (ITP) is a process designed to remove soluble cesium and strontium from highly alkaline, salt solutions.¹ This is accomplished as a batch process in Tank 48 by precipitation and absorption using sodium tetrphenylborate (NaTPB) and monosodium titanate (MST). The cesium- and strontium-containing solids are concentrated to 10 weight percent by filtration. The resulting decontaminated salt solution filtrate, DSS, is processed through stripping columns to remove benzene formed by the radiolytic decomposition of NaTPB. The filtrate is stored temporarily in hold tanks and

eventually is transferred to Tank 50 for processing into Saltstone. Second and third batches are processed in the same manner in the presence of the previous batch's concentrated solids. The accumulated cesium- and strontium-containing solids are washed and filtered to remove residual, soluble salts. The resulting spent wash water filtrate is also processed through the stripping columns to remove benzene and temporarily stored in hold tanks before eventually being sent to Tank 22 where it is mixed with spent wash water from the Late Wash Facility. The contents of Tank 22 are recycled to Tank 48 for use in the precipitation and concentration batch processes during the next ITP process cycle. The three precipitation and concentration batches and the washing process constitute one cycle.

The ITP benzene stripping columns have been observed to experience large pressure differentials across their structured packing.^{2,3} The pressure differentials are the result of filtrate foaming within the columns. TBP (n-tributylphosphate) is an effective anti-foaming agent for the highly caustic salt solution filtrate and alleviates the pressure differential in the columns.^{4,5} The Interim Waste Technology Section (IWTS) of the Savannah River Technology Center (SRTC) was requested (HLE-TTR-93040)⁶ to evaluate potential adverse effects of TBP addition to the ITP process. Specifically, the concerns to be addressed included recycle of TBP throughout ITP, carryover to the Defense Waste Processing Facility (DWPF), and the disposal of TBP-containing decontaminated salt solution by Saltstone.

Several individual safety-related documents have been prepared which address differing aspects of TBP usage.⁷⁻¹³ These documents were prepared by IWTS personnel and are related to TBP usage in Cold Chemical Testing. These documents are not necessarily applicable to normal ITP operation but are still relevant and may be informative. The documents describe chemical degradation of TBP,⁷ consequences of addition of benzene stripper test solution to Tank 48,⁸ allowable amounts of TBP in the ITP Feed and Hold Tanks,⁹ TBP vapor pressure,¹⁰ benzene and 1-butanol deflagration pressure calculations,^{11,12} and hydrogen generation from the radiolysis of TBP.¹³

This document reports the results obtained from the investigation and evaluation of TBP recycle throughout ITP and its carryover to DWPF. A separate evaluation¹⁴ of the disposal of TBP-containing decontaminated salt solution by Saltstone is being conducted by the Waste Disposal and Environmental Development Group of the IWTS. In addition, a materials of construction compatibility investigation is being conducted by the Equipment Engineering Section of the SRTC.¹⁵

DISCUSSION

To assess and evaluate the effect of TBP on ITP facilities, the flow path of TBP was determined and the expected concentration of TBP in the facilities was calculated. The flow path of TBP is readily identified.¹ However, several factors are capable of influencing TBP concentration. These factors include varying facility volumes, solubility of TBP in the respective solutions and relatedly the degree of mixing or entrainment of insoluble materials in the solutions, hydrolysis of TBP, and radiolysis of TBP. Each of these factors are discussed in further detail later in this section. Based upon the maximum concentration of TBP expected in each facility, flammability, criticality, and DWPF-related issues are evaluated in this document.

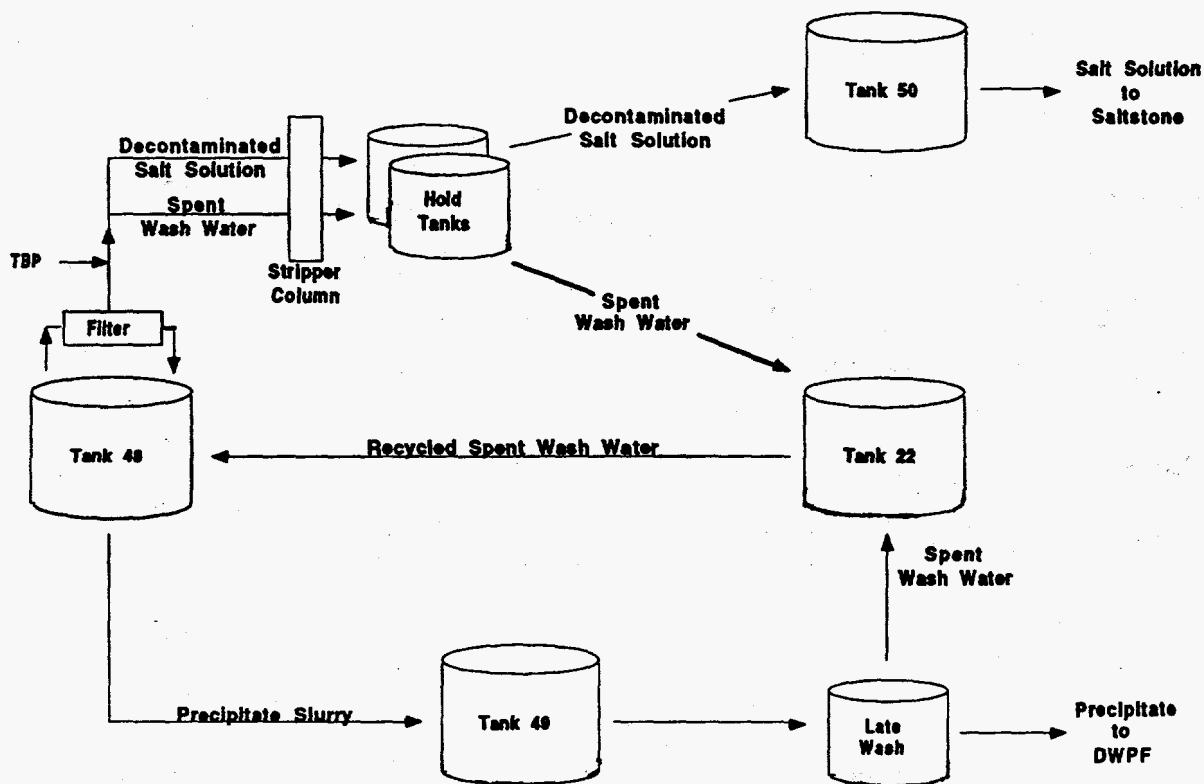
Tributylphosphate Flow Path and Recycle

A schematic diagram of ITP is shown in Figure 1. The waste flow throughout the process is indicated on the diagram. As noted earlier, removal of soluble cesium and strontium from highly caustic, salt solutions is accomplished by precipitation and absorption in Tank 48.¹ The cesium- and strontium-containing solids are concentrated to 10 weight percent by filtration and the resulting DSS filtrate is processed through stripping columns to remove benzene. The filtrate is stored temporarily in hold tanks and eventually is transferred to Tank 50 for processing into Saltstone. Second and third batches are processed within Tank 48 in the presence of the first batch's concentrated solids. After three batches have been precipitated, the accumulated solids are washed and filtered to remove residual, soluble salts. The resulting spent wash water filtrate is also processed through the stripping columns to remove benzene and then temporarily stored in hold tanks. Eventually the spent wash water is sent to Tank 22 where it is mixed with

spent wash water from the Late Wash Facility. The three precipitation and concentration batches and the washing process constitute one cycle. At this point, the 10 weight percent precipitate slurry contained in Tank 48 is transferred to Tank 49 for storage. Ultimately, the contents of Tank 49 will be processed through the Late Wash Facility and sent on to DWPF for processing. During the precipitate's processing in the Late Wash Facility, spent wash water will be generated and sent to Tank 22 and mixed with Tank 48 spent wash water. The contents of Tank 22 are eventually recycled for use in the precipitation and concentration batch processes during the next ITP process cycle within Tank 48.

Due to the large pressure differentials within the ITP benzene stripping columns, TBP will be added to the ITP process at a location downstream from the cross flow filters (in the filtrate) but prior to the benzene stripping columns. During the ITP cycle, TBP will be added to both the DSS filtrate and the spent wash water filtrate. TBP added to the DSS filtrate during the concentration steps of the three precipitation batches will be transferred to Tank 50 and processed into Saltstone. There is a possibility that some residual TBP will remain in the filtrate hold tanks. The exact quantity is difficult to predict and will be a function of entrainment during transfer from the tanks. Tributylphosphate added to the spent wash water filtrate during the washing phase of the cycle will be sent to Tank 22. Since the contents of Tank 22 will be recycled to Tank 48 during the precipitation steps of the next cycle, TBP will also be recycled and thereby mixed with the contents of Tank 48. Depending upon the concentration, solubility, and rate of decomposition of TBP in Tanks 22 and 48, a mechanism exists whereby TBP could be sent to Tank 49 and ultimately to DWPF.

Figure 1. Schematic of the In-Tank Precipitation process facilities and waste flow path.



Material Balance

The effect of TBP upon ITP facilities is directly dependent upon the concentration of TBP within the respective facilities. There are several factors which can influence TBP concentration. The primary ones include varying facility volumes, solubility of TBP in the respective solutions, hydrolysis of TBP, and radiolysis of TBP. Each of these is further discussed in detail in the paragraphs that follow.

Solubility of Tributylphosphate

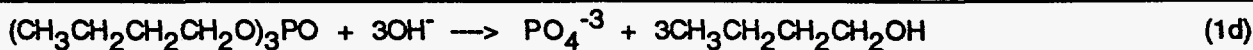
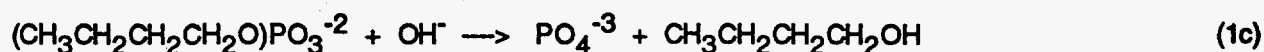
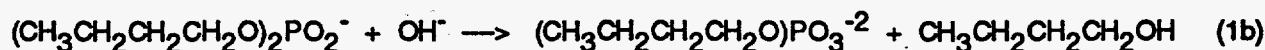
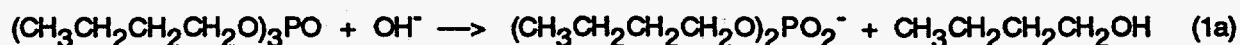
The solubility of TBP in DSS simulant was experimentally determined to be 1.1 mg/L at room temperature.¹⁶ The solubility of TBP in wash water simulant was determined to be 16.0 mg/L at room temperature.¹⁶ Compositions of the simulated DSS and wash water are listed in Table I. As a check of the solubility test method, the solubility of TBP in water at room temperature was determined to be 385 mg/L.¹⁶ The solubility of TBP in water is reported in the literature to be 380 mg/L at 22°C.¹⁷

Table I. Composition of DSS and washwater simulants.

| <u>Chemical</u> | <u>DSS Simulant (moles/liter)</u> | <u>Wash Water Simulant (moles/liter)</u> |
|-------------------------------|---------------------------------------|--|
| hydroxide | 1.48 | 1.38 |
| aluminate | 0.31 | 0.07 |
| nitrate | 1.74 | 0.38 |
| nitrite | 0.67 | 0.31 |
| carbonate | 0.16 | 0.04 |
| sulfate | 0.14 | 0.03 |
| oxalate | 0.015 | 0.004 |
| tetraphenylborate (saturated) | 0.002 | 0.01 |
| Total Sodium | 4.83 | 2.30 |

Hydrolysis of Tributylphosphate

Tributylphosphate hydrolyzes in the presence of strong alkaline solutions.¹⁸ Products of the reaction are dibutylphosphate (DBP) and 1-butanol. Further hydrolysis of DBP results in the formation of monobutylphosphate (MBP) and 1-butanol. Hydrolysis of MBP yields phosphate and 1-butanol as reaction products. These reactions are shown below in equations 1a - 1d. The first order rate constant for hydrolysis of TBP at 30°C is reported as 0.007 hr⁻¹.¹⁸ Dibutylphosphate is reported to be considerably more resistant than TBP to alkaline hydrolysis.¹⁸



The hydrolysis of TBP in both DSS and wash water has not been accurately determined due to the low solubility of TBP in the salt solutions.¹⁹ Analysis of the experimental data gave hydrolysis rate constants for TBP which were approximately one order of magnitude larger than that reported above. The difference in the values may be associated with the degree of mixing and hydrolysis that may occur at the interface of the two solutions. Additionally, some experimental error was expected due to both the low total and soluble TBP concentrations being tested. Due to the low precision, the experimental rate constants are not considered valid absolute numbers. However, since the experimental rate constants are reasonably close to, but larger than, the referenced value listed above, they support the use of the referenced rate constant as a reasonable yet conservative value for calculating the material balance for

TBP in ITP. For facilities containing solutions with TBP concentrations in excess of the solubility limit, a rate of hydrolysis was calculated assuming a steady state solubility limit concentration for TBP and the above listed rate constant (i.e. hydrolysis only occurs in the bulk aqueous phase and not at the interface of the two solutions).

For informational purposes, three graphs have been prepared based upon the literature rate for decomposition of TBP-containing solutions (Figures 2a, 2b and 2c). The graphs depict batch solutions in which no volume changes are occurring and where hydrolysis of soluble TBP is the only mechanism whereby TBP is removed. Figures 2a and 2b represent the hydrolysis of both 100 mg/L and 40 mg/L TBP-containing solutions. Both figures show the expected rate of decomposition for solutions with initial TBP concentrations greater than the TBP solubility limit. Figure 2a shows the rate of decomposition for solutions with a solubility limit of 16.0 mg/L (simulating Tank 22 wash water). Figure 2b shows the expected rate of decomposition for solutions with a TBP solubility limit of 1.1 mg/L (simulating Tank 50 DSS). The rate of decomposition is linear initially and is based upon maintaining the solubility limit concentration of TBP in the aqueous phase. Once enough TBP is decomposed to reduce the TBP concentration to below its solubility limit, TBP is decomposed logarithmically as predicted for a first order decomposition. This logarithmic decomposition is shown in expanded detail in Figure 2c. Figure 2c represents the hydrolysis of a solution with an initial TBP concentration of 16.0 mg/L (again simulating Tank 22 wash water).

Radiolysis of Tributylphosphate

Information regarding the radiolysis of TBP in alkaline salt solutions has not been reported. However, radiolysis of pure TBP has been reported.²⁰⁻²⁴ Radiolysis products (with their respective G-values) include dibutylphosphate (2.44 molecules/100 eV), monobutylphosphate (0.14 molecules/100 eV),

Figure 2a. Concentration of TBP based upon hydrolysis of both a 100 mg/L and 40 mg/L TBP-containing solution with a TBP solubility of 16.0 mg/L. The graphs represent the expected rate of decomposition for Tank 22 wash water.

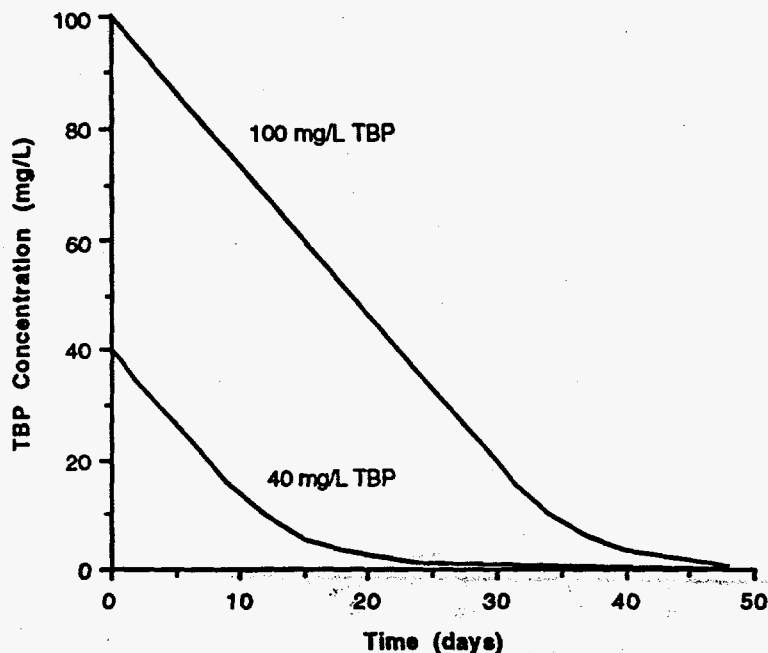


Figure 2b. Concentration of TBP based upon hydrolysis of both a 100 mg/L and 40 mg/L TBP-containing solution with a TBP solubility limit of 1.1 mg/L. The graphs represent the expected rate of decomposition for Tank 50 DSS.

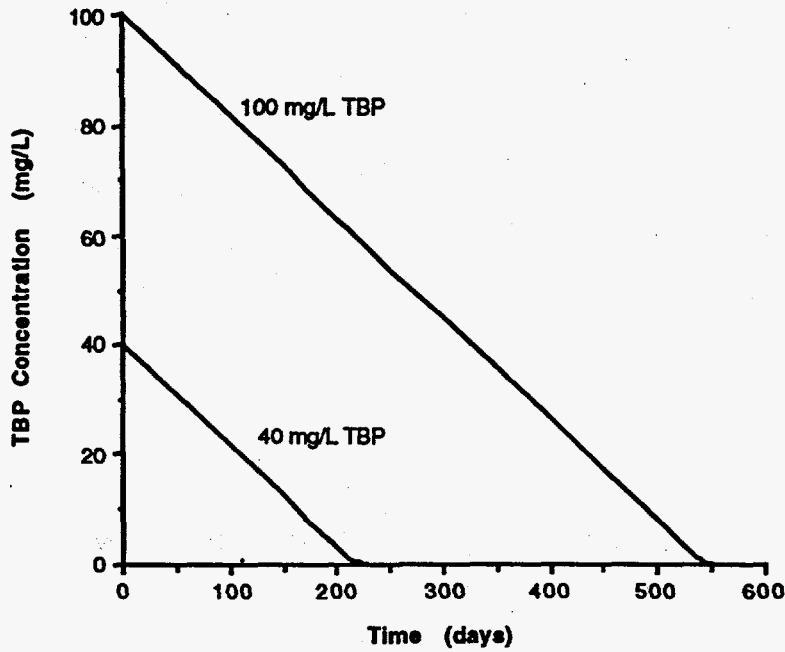
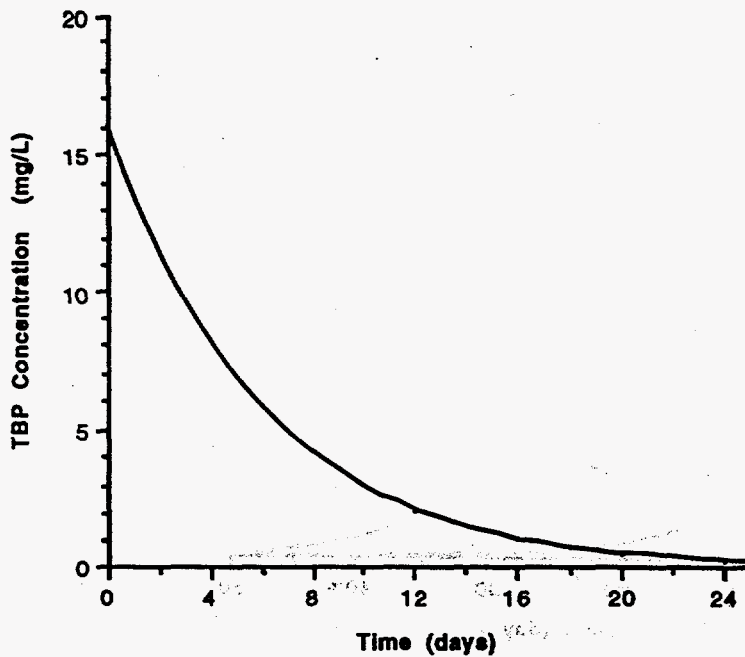


Figure 2c. Concentration of TBP based upon hydrolysis of a solution with an initial TBP concentration equal to the TBP solubility limit (16.0 mg/L simulating Tank 22 wash water).



hydrogen (1.73 molecules/100 eV), and various 3 and 4 carbon atom decomposition compounds including 1-butanol, butane, propane, etc. (cumulative value for all of these species is 0.65 molecules/100 eV).

Material Balance Calculations

A material balance was performed for the addition of TBP to the ITP facilities. The material balance was calculated for the addition of two TBP concentrations (40 mg/L and 100 mg/L). In each case, the TBP material balance was based upon the ITP flow sheet representing the ITP process with late wash.¹ The TBP material balance was determined for a period of three cycles. The data obtained for cycle 2 and cycle 3 were identical, indicating that there was no "roll-over" effect (i.e., no TBP was accumulating in any facility from one cycle to the next). The material balance data are contained in Appendices A and B at the end of this document. The only facilities factored into the material balance are Tanks 48, 22, and 50. The hold tanks and Tank 49 were not considered since no dilution or concentration activities occur within these facilities. There is a possibility that some residual TBP will remain in the filtrate hold tanks. The exact quantity is difficult to predict and will be a function of entrainment during transfer from the tanks. Retention of residual TBP in the hold tanks was not accounted for in this material balance due to the difficulty involved in predicting actual amounts involved.

The material balance was calculated using the above information regarding solubility and hydrolysis. Furthermore, a few conservative yet reasonable assumptions were made in order to obtain the material balance. These assumptions included the following:

- Late Wash spent wash water is sent to Tank 22 at the average rate of of 2809 gallons per day. It is assumed that this spent late wash water is similar in composition to Tank 48 spent wash water and will not change TBP solubility in Tank 22 significantly.
- TBP is not introduced into Tank 48 until the second cycle since the contents of Tank 22 used in the precipitation steps of cycle 1 do not contain TBP. TBP is not introduced into Tank 22 until the washing stage of cycle 1.
- TBP quantities (both decomposed and remaining) are calculated for the end of each step and are based upon the remaining TBP concentration data from the step immediately preceding it.
- Only soluble TBP will be recycled from Tank 22 to Tank 48 since any insoluble TBP would remain in a layer on the surface of the wash water in Tank 22. For information purposes, if all of the TBP (assuming 100 mg/L case) transferred to Tank 22 during one cycle were collected as a layer on the surface, it would be less than 0.010 inch thick.
- Hydrolysis of TBP in Tank 22 is not diffusion controlled (i.e., a TBP solubility limit concentration is maintained in the aqueous phase when TBP is present above the solubility limit).
- The only TBP degradation product produced, which is expected to be soluble to any appreciable degree, is 1-butanol.²⁵ The recycle of the other degradation products (dibutylphosphate and monobutylphosphate) is expected to be similar to that of TBP and should be minimal.^{26,27}
- Radiolytic decomposition of TBP in Tank 48 was not accounted for since very little TBP was recycled to Tank 48 and the amount which is recycled is rapidly decomposed and removed by filtration and washing.
- Decomposition of TBP within Tank 50 was not calculated. The actual concentration of TBP in Tank 50 will be less than the TBP addition concentration due to the addition of ETF evaporator concentrate to the DSS filtrate. This will further serve to dilute the TBP. Decomposition of TBP in Tank 50 will be slow (relative to Tank 22) due to the low solubility of TBP in DSS (Figure 2a vs. 2b). The effect of TBP in Saltstone is the subject of another document.¹⁴

The material balances yield the same observations for both 40 mg/L and 100 mg/L TBP addition concentrations. A summary of these observations follows:

- Tributylphosphate is not accumulated from one cycle to the next cycle.
- 99 % of the TBP added to Tank 22 is decomposed within the tank.
- Only small amounts of TBP (<1 mg/L) will be recycled from Tank 22 into Tank 48.
- All TBP which is recycled from Tank 22 to Tank 48 is eventually decomposed or filtered off.

Data contained in the TBP material balances in Appendices A and B have been summarized in Table II below. Only the most important and pertinent information is provided due to the large quantity of data generated. In addition to the table, a graph representing the TBP concentration in Tank 22 was prepared using the material balance TBP concentration data contained in Appendices A and B. The graph represents a time period of three cycles in the ITP process (the data for the first cycle represents initial start-up). As can be seen in Figure 3, the maximum TBP concentration is less than 15.4 mg/L and 6.2 mg/L for the 100 mg/L and 40 mg/L TBP feed rates, respectively.

Table II. Summary of TBP material balance data contained in Appendices A and B. The material balance data were prepared for TBP additions at 40 mg/L and 100 mg/L.

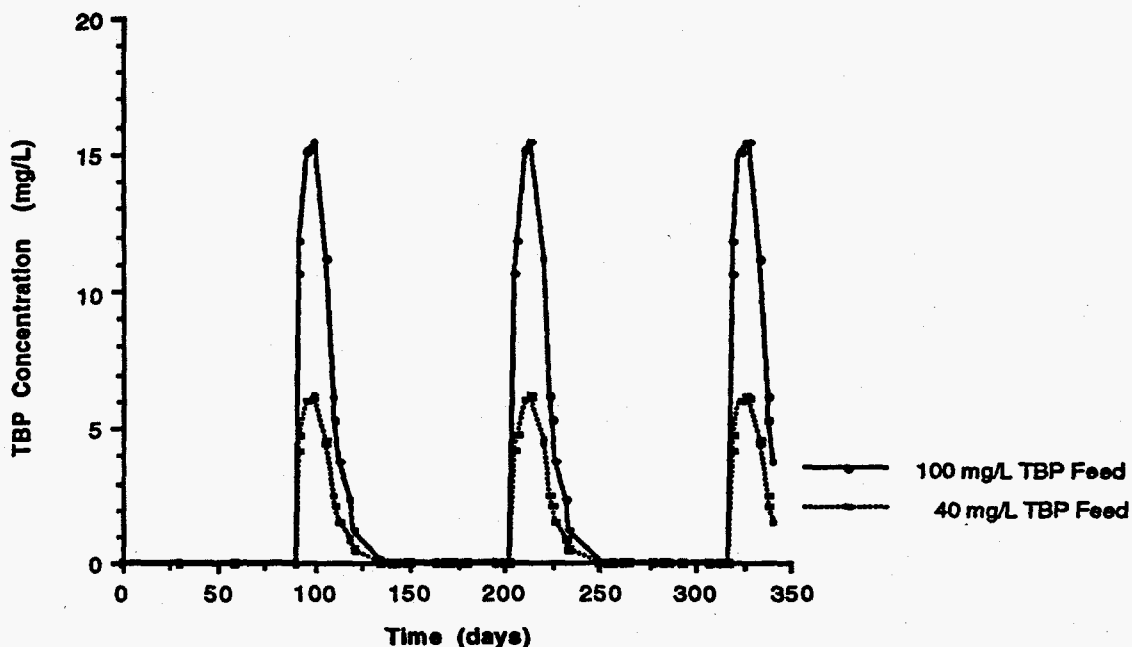
| Tank Feature | TBP Addition Concentration | |
|---|----------------------------|-----------|
| | 40 mg/L | 100 mg/L |
| Tank 22 (per cycle) | | |
| maximum TBP Concentration: | 6.2 mg/L | 15.4 mg/L |
| Amount of TBP decomposed per cycle: | 49.9 Kg | 125 Kg |
| Tank 48 (per cycle) | | |
| maximum TBP Concentration: | 0.2 mg/L | 0.6 mg/L |
| amount of TBP recycled to (from Tank 22): | 743 g | 1860 g |
| TBP transferred to Tank 49 | 0 g | 0 g |
| Tank 50 (per batch) | | |
| maximum amount of TBP: | 127 Kg | 317 Kg |

Criticality Issues - The Effect of TBP on Solubility of Uranium and Loading onto MST

A review of possible impacts of TBP and TBP hydrolysis products (i.e., DBP and MBP) on nuclear criticality safety in the ITP process identified the following; (1) increase solubility of uranium, (2) increase loading of uranium onto MST, and (3) accumulation of fissile material in a separate layer or TBP residue in the Filtrate Hold Tanks or Tank 22. Since TBP and DBP are known to be complexants for metal ions, the addition of TBP could alter the distribution of fissile material in the ITP process. For example, addition of TBP could increase the solubility of uranium resulting in a high chemical potential for loading onto MST. Although data in dilute caustic/carbonate solution suggest that the solubility would not be increased, there was no definitive data at higher salt solutions.

A set of tests were conducted to determine the effect of adding 50-500 ppm of tributylphosphate on the solubility of uranium in a concentrated salt solution. The salt solution test had a $[Na^+]$ of 4.3 molar and was comprised of the following salts; sodium hydroxide (2.0 M), sodium nitrate (1.0 M), sodium nitrite (0.1 M), sodium aluminate (0.33 M), sodium sulfate (0.40 M), and sodium carbonate (0.02 M). This solution was

Figure 3. Concentration of TBP in Tank 22 over three ITP process cycles.



previously selected for use in batch loading tests with monosodium titanate (MST) because of its high solubility for uranium and plutonium relative to the range of salt solution compositions which will be processed in ITP.²⁸

Analytical results are presented in Table III. The results indicated that the presence of 50.9 and 508 ppm (w/w) of TBP does not affect the solubility of uranium in concentrated salt solution. Thus, the addition of TBP would not be expected to increase the amount of uranium released to saltstone through ITP. The decreasing solubility with time is attributed to changes in the phase of the uranium and the composition of the salt solution²⁹ (i.e. with time the form of uranium is changing to a less soluble form, and the salt solution composition also is changing such that it decreases the solubility of any particular uranium phase). It is also possible that the undissolved and/or precipitated uranium is dissolving in an excess TBP phase. However, if uranium were dissolving into an excess TBP phase, it would be expected that the rate of change in the uranium concentration would be different for the bottles with TBP than that without TBP. The uranium dissolved in the TBP phase would provide an additional source of uranium for dissolution into the aqueous phase. This should alter the rate of decrease in uranium concentration. Since this was not observed, it is concluded that the uranium is not dissolving in an excess TBP phase.

TBP is a neutral molecule, and therefore, should not exhibit a significant tendency to adsorb onto the MST. If adsorption would occur, it will be through the polar phosphate end of the molecule. Since this is also the portion which complexes with uranium to form a more soluble compound than the uncomplexed uranium form, the loading of uranium onto the MST cannot be increased because the uranium complexing sites are tied up with the MST (probably by hydrogen bonding). Therefore, it is concluded that the use of TBP in ITP as a defoaming agent will not impact the solubility of uranium or the loading of uranium onto the monosodium titanate.

Flammability Issues

Flammability of TBP in any of the process tanks is of no concern due to its extremely low vapor pressure.¹⁰ The flashpoint of pure TBP is 193°C. However, the flammability of TBP degradation products is of

Table III. Uranium Concentrations of Test Solutions.

| Elapsed Time (days) | Average Uranium Concentration (mg/L) ^a | | |
|---------------------|---|---------------------------|--------------------------|
| | No TBP ^b | 50.9 ppm TBP ^c | 508 ppm TBP ^c |
| 1 | 12.4 ± 0.21 | 13.0 ± 0.17 | 12.8 ± 0.25 |
| 2 | 10.8 ± 0.071 | 11.0 ± 0.43 | 10.8 ± 0.26 |
| 7 | 7.81 ± 0.40 | 8.32 ± 0.19 | 8.44 ± 0.28 |
| 14 | 6.89 ± 0.21 | 6.98 ± 0.15 | 7.01 ± 0.18 |
| 28 | 5.99 ± 0.40 | 5.95 ± 0.20 | 6.18 ± 0.25 |

^aUranium concentrations were determined by kinetic phosphorescence spectroscopy.

^bAverage and standard deviation of duplicate measurements.

^cAverage and standard deviation of duplicate measurements for replicate tests.

concern. In particular, the two degradation products which were investigated are hydrogen and 1-butanol. Hydrogen is formed from the radiolysis of TBP. Previous calculations showed that a TBP concentration of 4000 mg/L was necessary in Tank 48 in order to generate a 1.0 % increase in hydrogen formation.¹³ Given that the TBP concentration in Tank 48 is expected to be less than 1 mg/L, hydrogen formation from the radiolysis of TBP does not pose any flammability concerns. Radiolysis of TBP in the other facilities (e.g., Tank 22) is of little concern due to both the low TBP concentration and the low levels of radioactivity.

Tank 22 will contain the largest quantity of TBP and TBP decomposition products and therefore is of greatest concern for 1-butanol flammability. Calculations based upon the addition of 100 mg/L TBP show that 125 kg of TBP are decomposed in Tank 22 during one process cycle. Additional calculations based upon this amount in conjunction with the rate of hydrolysis of TBP have been performed. These calculations are presented in Appendix C and indicate that under worst case conditions (as listed in Appendix C), ventilation of Tank 22 would prevent the TBP decomposition product, 1-butanol, from accumulating at a rate sufficient to produce a flammable concentration. The data indicate that under these conditions, 1-butanol would be produced at a volume % concentration of 0.015 %. The LFL for 1-butanol is 1.45 %.³⁰ Current ITP OSR limits are set at 25% of the composite LFL for Tank 22.³¹ Further calculation has determined that in the event of loss of ventilation in Tank 22, the time to reach LFL for 1-butanol would be 18.5 days.

Flammability of 1-butanol in Tanks 48 and 49 will be less likely for a few reasons: (1) less TBP and TBP decomposition products are present, (2) both tanks are inerted with nitrogen, and (3) both tanks will be ventilated with nitrogen at a rate equivalent to that of Tank 22 with air. Once design is completed, the TBP injection system should be more adequately investigated with regards to flammability issues. Also, the potential for flammability in the filtrate hold tanks should be more thoroughly investigated once a more accurate determination is made regarding the amount of residual TBP that will remain in the filtrate hold tanks. The filtrate hold tanks are maintained with a maximum oxygen content (MOC) of 3.6 %. The MOC for 1-butanol is not readily available.

DWPF Issues

The material balance described previously indicates that no TBP will remain further downstream than Tank 48. Therefore, TBP itself should have no direct impact on DWPF facilities. Furthermore, any soluble (or insoluble) TBP degradation products (e.g., phosphate, 1-butanol, etc.) which will be transported from Tank 22 into Tank 48 (exact quantities will depend upon their respective solubilities) should eventually be removed from Tank 48 in the DSS filtrate during the concentration steps. Any additional residual

degradation products will be removed during the washing portion of the ITP cycle. Therefore, only extremely small amounts of TBP and TBP degradation products will likely be transported to Tank 49. Again, processing of the precipitate slurry in the Late Wash facility would further serve to remove and reduce (by approximately a factor of 10) the TBP and TBP degradation products in the unlikely event that any of the materials were still present.

In addition to the material balance, experiments have been conducted by the Defense Waste Processing Technology Section (DWPT) of the SRTC examining the effects of using TBP as a defoaming agent in DWPF.³² Results indicate that TBP is ineffective in controlling foam. For informational purposes, there would be some concern associated with formation of a red-oil in the SRAT/SME if excess amounts of nitric acid were to be added and if TBP were to be present that far into the process. However, this should not be a problem since TBP is not expected to be present downstream from Tank 48.

CONCLUSION

Based upon a TBP addition concentration of 100 mg/L or less, the material balance data and all relevant information indicate that TBP will not accumulate in Tanks 22, 48, or 50. Furthermore, no TBP will be carried over to Tank 49 or further downstream. All soluble decomposition products are expected to be recycled from Tank 22 to Tank 48 and ultimately removed from the process in the DSS waste stream. Since no TBP or TBP decomposition products (i.e., DBP, MBP, 1-butanol, and phosphate) are expected to be recycled to Tank 49, there should be no effect on DWPF. Evaluation of the material balance data in conjunction with uranium solubility experiments indicates no criticality problems will occur. Effects of decomposition products were also considered. Flammability of 1-butanol in Tank 22 was investigated. It was determined that Tank 22 would be ventilated with air at a rate sufficient to maintain a 1-butanol concentration (volume %) well below 25 % of the LFL for 1-butanol (based upon a TBP feed addition of 100 mg/L). Further calculation determined that in the event of loss of ventilation in Tank 22, the time to reach LFL for 1-butanol would be 18.5 days.

QUALITY ASSURANCE

All work was conducted in accordance with the SRL Quality Assurance Program. Experimental work was performed in accordance with Task Technical Plans WSRC-RP-93-766 "Salt Solution Foaming Characteristics Technical Task Plan" and WSRC-RP-93-1010 "Task Technical Plan to Evaluate the Solubility of Tributylphosphate in ITP Salt Solutions". Salt solutions were prepared from reagent grade chemicals. Chemical analyses were performed by the Analytical Development Section of SRTC.

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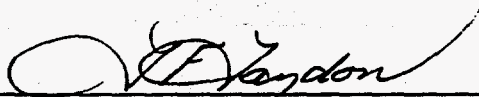
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Technical review performed by:



D. D. Walker, Bldg. 773-A



DWPT Technical Representative

APPENDIX A

The material balance for the addition of 40 mg/L TBP in Tanks 48, 50, and 22 is shown below.

| | | |
|-------------------------------|----------------|-------------------------------|
| Concentration of TBP Added: | 40 mg/L | |
| TPB Solubility in DSS: | 1.1 mg/L | |
| TPB Solubility in Wash Water: | 16.0 mg/L | |
| DSS TBP Hydrolysis Rate: | 0.184 mg/L·day | (If [TBP] > solubility limit) |
| TBP Hydrolysis Rate Constant: | 0.17 /day | (If [TBP] < solubility limit) |

| Process | | | Tank 48 - Cycle 1 | | | | |
|-----------------------|---------------|----------------------|---------------------------|-----------------|-----------------------|-------------------|------------------------|
| Step | Timing (days) | Volume Change (Kgal) | Volume of Contents (Kgal) | TBP Decomp. (g) | Total TBP Decomp. (g) | Remaining TBP (g) | Remaining [TBP] (mg/L) |
| Batch # 1 | | | | | | | |
| Transfer SS | 5.9 | 630 | 630 | 0 | 0 | 0 | 0.0 |
| Transfer RWW | 1.6 | 217 | 847 | 0 | 0 | 0 | 0.0 |
| Add Misc. Soln. | 14.1 | 40.1 | 887.1 | 0 | 0 | 0 | 0.0 |
| Filter to 7.5 wt % | 4.9 | <i>813.5</i> | 73.6 | 0 | 0 | 0 | 0.0 |
| Filter to 10 wt % | 0.2 | <i>18.4</i> | 55.2 | 0 | 0 | 0 | 0.0 |
| Stop/Start | 2.9 | - | 55.2 | 0 | 0 | 0 | 0.0 |
| Batch # 2 | | | | | | | |
| Transfer SS | 5.9 | 630 | 685.2 | 0 | 0 | 0 | 0.0 |
| Transfer RWW | 1.6 | 217 | 902.2 | 0 | 0 | 0 | 0.0 |
| Add Misc. Soln. | 14.0 | 27 | 929.2 | 0 | 0 | 0 | 0.0 |
| Filter to 7.5 wt % | 4.9 | <i>806.7</i> | 122.5 | 0 | 0 | 0 | 0.0 |
| Filter to 10 wt % | 0.4 | <i>30.6</i> | 91.9 | 0 | 0 | 0 | 0.0 |
| Stop/Start | 2.9 | - | 91.9 | 0 | 0 | 0 | 0.0 |
| Batch # 3 | | | | | | | |
| Transfer SS | 5.9 | 630 | 721.9 | 0 | 0 | 0 | 0.0 |
| Transfer RWW | 1.6 | 217 | 938.9 | 0 | 0 | 0 | 0.0 |
| Add Misc. Soln. | 14.0 | 27 | 965.9 | 0 | 0 | 0 | 0.0 |
| Filter to 7.5 wt % | 4.8 | <i>798.6</i> | 167.3 | 0 | 0 | 0 | 0.0 |
| Filter to 10 wt % | 0.6 | <i>40.2</i> | 127.1 | 0 | 0 | 0 | 0.0 |
| Stop/Start | 3.9 | - | 127.1 | 0 | 0 | 0 | 0.0 |
| Wash Cycle | | | | | | | |
| Wash | 2.5 | 50 | 127.1 | 0 | 0 | 0 | 0.0 |
| Add NaOH | 0.5 | 8 | 127.1 | 0 | 0 | 0 | 0.0 |
| Wash | 3.5 | 70 | 127.1 | 0 | 0 | 0 | 0.0 |
| Add NaOH | 0.4 | 6 | 127.1 | 0 | 0 | 0 | 0.0 |
| Wash | 3.2 | 65 | 127.1 | 0 | 0 | 0 | 0.0 |
| Add NaNO ₂ | 0.5 | 8 | 127.1 | 0 | 0 | 0 | 0.0 |
| Wash | 5.2 | 125 | 127.1 | 0 | 0 | 0 | 0.0 |
| Sample | 3.5 | - | 127.1 | 0 | 0 | 0 | 0.0 |
| Transfer Slurry | 0.9 | 130 | 0 | 0 | 0 | 0 | 0.0 |
| Stop | 2.1 | - | 0 | 0 | 0 | 0 | 0.0 |

SS = Salt Solution

RWW = Recycled Wash Water

Italicized volume changes indicate removal from Tank 48.

Non-italicized volume changes indicate additions to Tank 48.

The wash cycle volume changes do not cause volume level changes in Tank 48 since the washwater and inhibitor solutions are added and removed simultaneously.

The volume of the contents in Tank 22 is incrementally increased by Late washwater at the rate of 2809 gallons per day.

APPENDIX A (continued)

| | | |
|-------------------------------|----------------|-------------------------------|
| Concentration of TBP Added: | 40 mg/L | |
| TPB Solubility in DSS: | 1.1 mg/L | |
| TPB Solubility in Wash Water: | 16.0 mg/L | |
| RWW TBP Hydrolysis Rate: | 2.679 mg/L-day | (If [TBP] > solubility limit) |
| TBP Hydrolysis Rate Constant: | 0.17 /day | (If [TBP] < solubility limit) |

| Process | | | Tank 22 - Cycle 1 | | | | |
|-----------------------|---------------|----------------------|---------------------------|-----------------|-----------------------|-------------------|------------------------|
| Step | Timing (days) | Volume Change (Kgal) | Volume of Contents (Kgal) | TBP Decomp. (g) | Total TBP Decomp. (g) | Remaining TBP (g) | Remaining [TBP] (mg/L) |
| Batch # 1 | | | | | | | |
| Transfer SS | 5.9 | 630 | 668 | 0 | 0 | 0 | 0.0 |
| Transfer RWW | 1.6 | 217 | 455 | 0 | 0 | 0 | 0.0 |
| Add Misc. Soln. | 14.1 | 40.1 | 495 | 0 | 0 | 0 | 0.0 |
| Filter to 7.5 wt % | 4.9 | <i>813.5</i> | 508 | 0 | 0 | 0 | 0.0 |
| Filter to 10 wt % | 0.2 | <i>18.4</i> | 508 | 0 | 0 | 0 | 0.0 |
| Stop/Start | 2.9 | - | 517 | 0 | 0 | 0 | 0.0 |
| Batch # 2 | | | | | | | |
| Transfer SS | 5.9 | 630 | 534 | 0 | 0 | 0 | 0.0 |
| Transfer RWW | 1.6 | 217 | 321 | 0 | 0 | 0 | 0.0 |
| Add Misc. Soln. | 14.0 | 27 | 361 | 0 | 0 | 0 | 0.0 |
| Filter to 7.5 wt % | 4.9 | <i>806.7</i> | 374 | 0 | 0 | 0 | 0.0 |
| Filter to 10 wt % | 0.4 | <i>30.6</i> | 375 | 0 | 0 | 0 | 0.0 |
| Stop/Start | 2.9 | - | 384 | 0 | 0 | 0 | 0.0 |
| Batch # 3 | | | | | | | |
| Transfer SS | 5.9 | 630 | 400 | 0 | 0 | 0 | 0.0 |
| Transfer RWW | 1.6 | 217 | 188 | 0 | 0 | 0 | 0.0 |
| Add Misc. Soln. | 14.0 | 27 | 227 | 0 | 0 | 0 | 0.0 |
| Filter to 7.5 wt % | 4.8 | <i>798.6</i> | 240 | 0 | 0 | 0 | 0.0 |
| Filter to 10 wt % | 0.8 | <i>40.2</i> | 242 | 0 | 0 | 0 | 0.0 |
| Stop/Start | 3.9 | - | 253 | 0 | 0 | 0 | 0.0 |
| Wash Cycle | | | | | | | |
| Wash | 2.5 | 50 | 310 | 2596 | 2596 | 4974 | 4.2 |
| Add NaOH | 0.5 | 8 | 320 | 498 | 3094 | 5687 | 4.7 |
| Wash | 3.6 | 70 | 399 | 7240 | 10334 | 9045 | 6.0 |
| Add NaOH | 0.4 | 6 | 408 | 647 | 10981 | 9307 | 6.0 |
| Wash | 3.2 | 65 | 480 | 7963 | 18944 | 11185 | 6.2 |
| Add NaNO ₂ | 0.5 | 8 | 490 | 999 | 19942 | 11398 | 6.1 |
| Wash | 6.2 | 125 | 632 | 19622 | 39564 | 10701 | 4.5 |
| Sample | 3.5 | - | 642 | 4665 | 44229 | 6036 | 2.5 |
| Transfer Slurry | 0.9 | 130 | 646 | 827 | 45055 | 5209 | 2.1 |
| Stop | 2.1 | - | 651 | 1515 | 46571 | 3694 | 1.5 |

SS = Salt Solution

RWW = Recycled Wash Water

Italicized volume changes indicate removal from Tank 48.

Non-italicized volume changes indicate additions to Tank 48.

The wash cycle volume changes do not cause volume level changes in Tank 48 since the washwater and inhibitor solutions are added and removed simultaneously.

The volume of the contents in Tank 22 is incrementally increased by Late washwater at the rate of 2809 gallons per day.

APPENDIX A (continued)

Concentration of TBP Added: 40 mg/L
 TPB Solubility in DSS: 1.1 mg/L
 TPB Solubility in Wash Water: 16.0 mg/L
 DSS TBP Hydrolysis Rate: 0.184 mg/L-day (If [TBP] > solubility limit)
 TBP Hydrolysis Rate Constant: 0.17 /day (If [TBP] < solubility limit)

| Process | | | Tank 50 - Cycle 1 | | | | |
|-----------------------|---------------|----------------------|---------------------------|-----------------|-----------------------|-------------------|------------------------|
| Step | Timing (days) | Volume Change (Kgal) | Volume of Contents (Kgal) | TBP Decomp. (g) | Total TBP Decomp. (g) | Remaining TBP (g) | Remaining [TBP] (mg/L) |
| Batch # 1 | | | | | | | |
| Transfer SS | 5.9 | 630 | | | | | |
| Transfer RWW | 1.6 | 217 | | | | | |
| Add Misc. Soln. | 14.1 | 40.1 | | | | | |
| Filter to 7.5 wt % | 4.9 | <i>813.5</i> | 813.5 | | | 1.23E+05 | 40.0 |
| Filter to 10 wt % | 0.2 | <i>18.4</i> | 831.9 | | | 1.26E+05 | 40.0 |
| Stop/Start | 2.9 | - | 831.9 | | | 1.26E+05 | 40.0 |
| Contents to Saltstone | | | | | | | |
| Batch # 2 | | | | | | | |
| Transfer SS | 5.9 | 630 | | | | | |
| Transfer RWW | 1.6 | 217 | | | | | |
| Add Misc. Soln. | 14.0 | 27 | | | | | |
| Filter to 7.5 wt % | 4.9 | <i>806.7</i> | 806.7 | | | 1.22E+05 | 40.0 |
| Filter to 10 wt % | 0.4 | <i>30.6</i> | 837.3 | | | 1.27E+05 | 40.0 |
| Stop/Start | 2.9 | - | 837.3 | | | 1.27E+05 | 40.0 |
| Contents to Saltstone | | | | | | | |
| Batch # 3 | | | | | | | |
| Transfer SS | 5.9 | 630 | | | | | |
| Transfer RWW | 1.6 | 217 | | | | | |
| Add Misc. Soln. | 14.0 | 27 | | | | | |
| Filter to 7.5 wt % | 4.8 | <i>798.6</i> | 798.6 | | | 1.21E+05 | 40.0 |
| Filter to 10 wt % | 0.6 | <i>40.2</i> | 838.8 | | | 1.27E+05 | 40.0 |
| Stop/Start | 3.9 | - | 838.8 | | | 1.27E+05 | 40.0 |
| Contents to Saltstone | | | | | | | |
| Wash Cycle | | | | | | | |
| Wash | 2.5 | 50 | | | | | |
| Add NaOH | 0.6 | 8 | | | | | |
| Wash | 3.6 | 70 | | | | | |
| Add NaOH | 0.4 | 6 | | | | | |
| Wash | 3.2 | 65 | | | | | |
| Add NaNO2 | 0.5 | 8 | | | | | |
| Wash | 6.2 | 125 | | | | | |
| Sample | 3.5 | - | | | | | |
| Transfer Slurry | 0.9 | 130 | | | | | |
| Stop | 2.1 | - | | | | | |

SS = Salt Solution

RWW = Recycled Wash Water

Italicized volume changes indicate removal from Tank 48.

Non-italicized volume changes indicate additions to Tank 48.

The wash cycle volume changes do not cause volume level changes in Tank 48 since the washwater and inhibitor solutions are added and removed simultaneously.

The volume of the contents in Tank 22 is incrementally increased by Late washwater at the rate of 2809 gallons per day.

APPENDIX A (continued)

| | | |
|-------------------------------|----------------|-------------------------------|
| Concentration of TBP Added: | 40 mg/L | |
| TPB Solubility in DSS: | 1.1 mg/L | |
| TPB Solubility in Wash Water: | 16.0 mg/L | |
| DSS TBP Hydrolysis Rate: | 0.184 mg/L-day | (If [TBP] > solubility limit) |
| TBP Hydrolysis Rate Constant: | 0.17 /day | (If [TBP] < solubility limit) |

| Process | | | Tank 48 - Cycle 2 | | | | |
|-----------------------|---------------|----------------------|---------------------------|-----------------|-----------------------|-------------------|------------------------|
| Step | Timing (days) | Volume Change (Kgal) | Volume of Contents (Kgal) | TBP Decomp. (g) | Total TBP Decomp. (g) | Remaining TBP (g) | Remaining [TBP] (mg/L) |
| Batch # 1 | | | | | | | |
| Transfer SS | 5.9 | 630 | 630 | 0 | 0 | 0 | 0.0 |
| Transfer RWW | 1.6 | 217 | 847 | 0 | 0 | 743 | 0.2 |
| Add Misc. Soln. | 14.1 | 40.1 | 887.1 | 671 | 671 | 73 | 0.0 |
| Filter to 7.5 wt % | 4.9 | <i>813.5</i> | 73.6 | 70 | 741 | 0 | 0.0 |
| Filter to 10 wt % | 0.2 | <i>18.4</i> | 55.2 | 0 | 741 | 0 | 0.0 |
| Stop/Start | 2.9 | - | 55.2 | 0 | 741 | 0 | 0.0 |
| Batch # 2 | | | | | | | |
| Transfer SS | 5.9 | 630 | 685.2 | 0 | 741 | 0 | 0.0 |
| Transfer RWW | 1.6 | 217 | 902.2 | 0 | 741 | 4 | 0.0 |
| Add Misc. Soln. | 14.0 | 27 | 929.2 | 3 | 744 | 0 | 0.0 |
| Filter to 7.5 wt % | 4.9 | <i>806.7</i> | 122.5 | 0 | 744 | 0 | 0.0 |
| Filter to 10 wt % | 0.4 | <i>30.6</i> | 91.9 | 0 | 744 | 0 | 0.0 |
| Stop/Start | 2.9 | - | 91.9 | 0 | 744 | 0 | 0.0 |
| Batch # 3 | | | | | | | |
| Transfer SS | 5.9 | 630 | 721.9 | 0 | 744 | 0 | 0.0 |
| Transfer RWW | 1.6 | 217 | 938.9 | 0 | 744 | 0 | 0.0 |
| Add Misc. Soln. | 14.0 | 27 | 965.9 | 0 | 744 | 0 | 0.0 |
| Filter to 7.5 wt % | 4.8 | <i>798.6</i> | 167.3 | 0 | 744 | 0 | 0.0 |
| Filter to 10 wt % | 0.6 | <i>40.2</i> | 127.1 | 0 | 744 | 0 | 0.0 |
| Stop/Start | 3.0 | - | 127.1 | 0 | 744 | 0 | 0.0 |
| Wash Cycle | | | | | | | |
| Wash | 2.5 | 50 | 127.1 | 0 | 744 | 0 | 0.0 |
| Add NaOH | 0.5 | 8 | 127.1 | 0 | 744 | 0 | 0.0 |
| Wash | 3.5 | 70 | 127.1 | 0 | 744 | 0 | 0.0 |
| Add NaOH | 0.4 | 6 | 127.1 | 0 | 744 | 0 | 0.0 |
| Wash | 3.2 | 65 | 127.1 | 0 | 744 | 0 | 0.0 |
| Add NaNO ₂ | 0.5 | 8 | 127.1 | 0 | 744 | 0 | 0.0 |
| Wash | 6.2 | 125 | 127.1 | 0 | 744 | 0 | 0.0 |
| Sample | 3.5 | - | 127.1 | 0 | 744 | 0 | 0.0 |
| Transfer Slurry | 0.9 | 130 | 0 | 0 | 744 | 0 | 0.0 |
| Stop | 2.1 | - | 0 | 0 | 744 | 0 | 0.0 |

SS = Salt Solution

RWW = Recycled Wash Water

Italicized volume changes indicate removal from Tank 48.

Non-italicized volume changes indicate additions to Tank 48.

The wash cycle volume changes do not cause volume level changes in Tank 48 since the washwater and inhibitor solutions are added and removed simultaneously.

The volume of the contents in Tank 22 is incrementally increased by Late washwater at the rate of 2809 gallons per day.

APPENDIX A (continued)

| | | |
|-------------------------------|----------------|-------------------------------|
| Concentration of TBP Added: | 40 mg/L | |
| TPB Solubility in DSS: | 1.1 mg/L | |
| TPB Solubility in Wash Water: | 16.0 mg/L | |
| RWW TBP Hydrolysis Rate: | 2.679 mg/L·day | (If [TBP] > solubility limit) |
| TBP Hydrolysis Rate Constant: | 0.17 /day | (If [TBP] < solubility limit) |

| Process | | | Tank 22 - Cycle 2 | | | | |
|-----------------------|---------------|----------------------|---------------------------|-----------------|-----------------------|-------------------|------------------------|
| Step | Timing (days) | Volume Change (Kgal) | Volume of Contents (Kgal) | TBP Decomp. (g) | Total TBP Decomp. (g) | Remaining TBP (g) | Remaining [TBP] (mg/L) |
| Batch # 1 | | | | | | | |
| Transfer SS | 5.9 | 630 | 659 | 1407 | 1407 | 2287 | 0.9 |
| Transfer RWW | 1.6 | 217 | 455 | 1096 | 2503 | 804 | 0.5 |
| Add Misc. Soln. | 14.1 | 40.1 | 495 | 722 | 3225 | 82 | 0.0 |
| Filter to 7.5 wt % | 4.9 | <i>813.5</i> | 506 | 45 | 3270 | 37 | 0.0 |
| Filter to 10 wt % | 0.2 | <i>18.4</i> | 506 | 1 | 3271 | 36 | 0.0 |
| Stop/Start | 2.9 | - | 517 | 13 | 3285 | 22 | 0.0 |
| Batch # 2 | | | | | | | |
| Transfer SS | 5.9 | 630 | 534 | 14 | 3298 | 9 | 0.0 |
| Transfer RWW | 1.6 | 217 | 321 | 5 | 3303 | 2 | 0.0 |
| Add Misc. Soln. | 14.0 | 27 | 361 | 2 | 3305 | 0 | 0.0 |
| Filter to 7.5 wt % | 4.9 | <i>806.7</i> | 374 | 0 | 3305 | 0 | 0.0 |
| Filter to 10 wt % | 0.4 | <i>30.6</i> | 375 | 0 | 3305 | 0 | 0.0 |
| Stop/Start | 2.9 | - | 384 | 0 | 3305 | 0 | 0.0 |
| Batch # 3 | | | | | | | |
| Transfer SS | 5.9 | 630 | 400 | 0 | 3305 | 0 | 0.0 |
| Transfer RWW | 1.6 | 217 | 188 | 0 | 3305 | 0 | 0.0 |
| Add Misc. Soln. | 14.0 | 27 | 227 | 0 | 3305 | 0 | 0.0 |
| Filter to 7.5 wt % | 4.9 | <i>798.6</i> | 240 | 0 | 3305 | 0 | 0.0 |
| Filter to 10 wt % | 0.6 | <i>40.2</i> | 242 | 0 | 3305 | 0 | 0.0 |
| Stop/Start | 9.9 | - | 253 | 0 | 3305 | 0 | 0.0 |
| Wash Cycle | | | | | | | |
| Wash | 2.5 | 50 | 310 | 2596 | 5901 | 4974 | 4.2 |
| Add NaOH | 0.5 | 8 | 320 | 498 | 6400 | 5687 | 4.7 |
| Wash | 3.5 | 70 | 399 | 7240 | 13639 | 9045 | 6.0 |
| Add NaOH | 0.4 | 6 | 406 | 647 | 14286 | 9307 | 6.0 |
| Wash | 3.2 | 65 | 480 | 7963 | 22249 | 11185 | 6.2 |
| Add NaNO ₂ | 0.5 | 8 | 490 | 999 | 23248 | 11398 | 6.1 |
| Wash | 6.2 | 125 | 632 | 19622 | 42870 | 10701 | 4.5 |
| Sample | 3.5 | - | 642 | 4665 | 47534 | 6036 | 2.5 |
| Transfer Slurry | 0.9 | 130 | 646 | 827 | 48361 | 5209 | 2.1 |
| Stop | 2.1 | - | 651 | 1515 | 49876 | 3694 | 1.5 |

SS = Salt Solution

RWW = Recycled Wash Water

Italicized volume changes indicate removal from Tank 48.

Non-italicized volume changes indicate additions to Tank 48.

The wash cycle volume changes do not cause volume level changes in Tank 48 since the washwater and inhibitor solutions are added and removed simultaneously.

The volume of the contents in Tank 22 is incrementally increased by Late washwater at the rate of 2809 gallons per day.

APPENDIX A (continued)

| | | |
|-------------------------------|----------------|-------------------------------|
| Concentration of TBP Added: | 40 mg/L | |
| TPB Solubility in DSS: | 1.1 mg/L | |
| TPB Solubility in Wash Water: | 16.0 mg/L | |
| DSS TBP Hydrolysis Rate: | 0.184 mg/L-day | (If [TBP] > solubility limit) |
| TBP Hydrolysis Rate Constant: | 0.17 /day | (If [TBP] < solubility limit) |

| Process | | | Tank 50 - Cycle 2 | | | | |
|-----------------------|---------------|----------------------|---------------------------|-----------------|-----------------------|-------------------|------------------------|
| Step | Timing (days) | Volume Change (Kgal) | Volume of Contents (Kgal) | TBP Decomp. (g) | Total TBP Decomp. (g) | Remaining TBP (g) | Remaining [TBP] (mg/L) |
| Batch # 1 | | | | | | | |
| Transfer SS | 5.9 | 630 | | | | | |
| Transfer RWW | 1.6 | 217 | | | | | |
| Add Misc. Soln. | 14.1 | 40.1 | | | | | |
| Filter to 7.5 wt % | 4.9 | <i>813.5</i> | 813.5 | | | 1.23E+05 | 40.0 |
| Filter to 10 wt % | 0.2 | <i>18.4</i> | 831.9 | | | 1.26E+05 | 40.0 |
| Stop/Start | 2.9 | - | 831.9 | | | 1.26E+05 | 40.0 |
| Contents to Saltstone | | | | | | | |
| Batch # 2 | | | | | | | |
| Transfer SS | 5.9 | 630 | | | | | |
| Transfer RWW | 1.6 | 217 | | | | | |
| Add Misc. Soln. | 14.0 | 27 | | | | | |
| Filter to 7.5 wt % | 4.9 | <i>806.7</i> | 806.7 | | | 1.22E+05 | 40.0 |
| Filter to 10 wt % | 0.4 | <i>30.6</i> | 837.3 | | | 1.27E+05 | 40.0 |
| Stop/Start | 2.9 | - | 837.3 | | | 1.27E+05 | 40.0 |
| Contents to Saltstone | | | | | | | |
| Batch # 3 | | | | | | | |
| Transfer SS | 5.9 | 630 | | | | | |
| Transfer RWW | 1.6 | 217 | | | | | |
| Add Misc. Soln. | 14.0 | 27 | | | | | |
| Filter to 7.5 wt % | 4.9 | <i>798.6</i> | 798.6 | | | 1.21E+05 | 40.0 |
| Filter to 10 wt % | 0.6 | <i>40.2</i> | 838.8 | | | 1.27E+05 | 40.0 |
| Stop/Start | 3.0 | - | 838.8 | | | 1.27E+05 | 40.0 |
| Contents to Saltstone | | | | | | | |
| Wash Cycle | | | | | | | |
| Wash | 2.5 | 50 | | | | | |
| Add NaOH | 0.6 | 8 | | | | | |
| Wash | 3.6 | 70 | | | | | |
| Add NaOH | 0.4 | 6 | | | | | |
| Wash | 3.2 | 65 | | | | | |
| Add NaNO ₂ | 0.5 | 8 | | | | | |
| Wash | 6.2 | 125 | | | | | |
| Sample | 3.5 | - | | | | | |
| Transfer Slurry | 0.9 | 130 | | | | | |
| Stop | 2.1 | - | | | | | |

SS = Salt Solution

RWW = Recycled Wash Water

Italicized volume changes indicate removal from Tank 48.

Non-italicized volume changes indicate additions to Tank 48.

The wash cycle volume changes do not cause volume level changes in Tank 48 since the washwater and inhibitor solutions are added and removed simultaneously.

The volume of the contents in Tank 22 is incrementally increased by Late washwater at the rate of 2809 gallons per day.

APPENDIX A (continued)

| | | |
|-------------------------------|----------------|-------------------------------|
| Concentration of TBP Added: | 40 mg/L | |
| TPB Solubility in DSS: | 1.1 mg/L | |
| TPB Solubility in Wash Water: | 16.0 mg/L | |
| DSS TBP Hydrolysis Rate: | 0.184 mg/L-day | (If [TBP] > solubility limit) |
| TBP Hydrolysis Rate Constant: | 0.17 /day | (If [TBP] < solubility limit) |

| Process | | | Tank 48 - Cycle 3 | | | | |
|-----------------------|---------------|----------------------|---------------------------|-----------------|-----------------------|-------------------|------------------------|
| Step | Timing (days) | Volume Change (Kgal) | Volume of Contents (Kgal) | TBP Decomp. (g) | Total TBP Decomp. (g) | Remaining TBP (g) | Remaining [TBP] (mg/L) |
| Batch # 1 | | | | | | | |
| Transfer SS | 5.9 | 630 | 630 | 0 | 0 | 0 | 0.0 |
| Transfer RWW | 1.6 | 217 | 847 | 0 | 0 | 743 | 0.2 |
| Add Misc. Soln. | 14.1 | 40.1 | 887.1 | 671 | 671 | 73 | 0.0 |
| Filter to 7.5 wt % | 4.9 | <i>813.5</i> | 73.6 | 70 | 741 | 0 | 0.0 |
| Filter to 10 wt % | 0.2 | <i>18.4</i> | 55.2 | 0 | 741 | 0 | 0.0 |
| Stop/Start | 2.9 | - | 55.2 | 0 | 741 | 0 | 0.0 |
| Batch # 2 | | | | | | | |
| Transfer SS | 5.9 | 630 | 685.2 | 0 | 741 | 0 | 0.0 |
| Transfer RWW | 1.6 | 217 | 902.2 | 0 | 741 | 4 | 0.0 |
| Add Misc. Soln. | 14.0 | 27 | 929.2 | 3 | 744 | 0 | 0.0 |
| Filter to 7.5 wt % | 4.9 | <i>806.7</i> | 122.5 | 0 | 744 | 0 | 0.0 |
| Filter to 10 wt % | 0.4 | <i>30.6</i> | 91.9 | 0 | 744 | 0 | 0.0 |
| Stop/Start | 2.9 | - | 91.9 | 0 | 744 | 0 | 0.0 |
| Batch # 3 | | | | | | | |
| Transfer SS | 5.9 | 630 | 721.9 | 0 | 744 | 0 | 0.0 |
| Transfer RWW | 1.6 | 217 | 938.9 | 0 | 744 | 0 | 0.0 |
| Add Misc. Soln. | 14.0 | 27 | 965.9 | 0 | 744 | 0 | 0.0 |
| Filter to 7.5 wt % | 4.8 | <i>798.6</i> | 167.3 | 0 | 744 | 0 | 0.0 |
| Filter to 10 wt % | 0.6 | <i>40.2</i> | 127.1 | 0 | 744 | 0 | 0.0 |
| Stop/Start | 3.9 | - | 127.1 | 0 | 744 | 0 | 0.0 |
| Wash Cycle | | | | | | | |
| Wash | 2.5 | 50 | 127.1 | 0 | 744 | 0 | 0.0 |
| Add NaOH | 0.5 | 8 | 127.1 | 0 | 744 | 0 | 0.0 |
| Wash | 3.5 | 70 | 127.1 | 0 | 744 | 0 | 0.0 |
| Add NaOH | 0.4 | 6 | 127.1 | 0 | 744 | 0 | 0.0 |
| Wash | 3.2 | 65 | 127.1 | 0 | 744 | 0 | 0.0 |
| Add NaNO ₂ | 0.5 | 8 | 127.1 | 0 | 744 | 0 | 0.0 |
| Wash | 6.2 | 125 | 127.1 | 0 | 744 | 0 | 0.0 |
| Sample | 3.5 | - | 127.1 | 0 | 744 | 0 | 0.0 |
| Transfer Slurry | 0.9 | 130 | 0 | 0 | 744 | 0 | 0.0 |
| Stop | 2.1 | - | 0 | 0 | 744 | 0 | 0.0 |

SS = Salt Solution

RWW = Recycled Wash Water

Italicized volume changes indicate removal from Tank 48.

Non-italicized volume changes indicate additions to Tank 48.

The wash cycle volume changes do not cause volume level changes in Tank 48 since the washwater and inhibitor solutions are added and removed simultaneously.

The volume of the contents in Tank 22 is incrementally increased by Late washwater at the rate of 2809 gallons per day.

APPENDIX A (continued)

| | | |
|-------------------------------|----------------|-------------------------------|
| Concentration of TBP Added: | 40 mg/L | |
| TPB Solubility in DSS: | 1.1 mg/L | |
| TPB Solubility in Wash Water: | 16.0 mg/L | |
| RWW TBP Hydrolysis Rate: | 2.679 mg/L-day | (If [TBP] > solubility limit) |
| TBP Hydrolysis Rate Constant: | 0.17 /day | (If [TBP] < solubility limit) |

| Process | | | Tank 22 - Cycle 3 | | | | |
|-----------------------|---------------|----------------------|---------------------------|-----------------|-----------------------|-------------------|------------------------|
| Step | Timing (days) | Volume Change (Kgal) | Volume of Contents (Kgal) | TBP Decomp. (g) | Total TBP Decomp. (g) | Remaining TBP (g) | Remaining [TBP] (mg/L) |
| Batch # 1 | | | | | | | |
| Transfer SS | 5.9 | 630 | 669 | 1407 | 1407 | 2287 | 0.9 |
| Transfer RWW | 1.6 | 217 | 455 | 1096 | 2503 | 804 | 0.5 |
| Add Misc. Soln. | 14.1 | 40.1 | 495 | 722 | 3225 | 82 | 0.0 |
| Filter to 7.5 wt % | 4.9 | <i>813.5</i> | 508 | 45 | 3270 | 37 | 0.0 |
| Filter to 10 wt % | 0.2 | <i>18.4</i> | 509 | 1 | 3271 | 36 | 0.0 |
| Stop/Start | 2.9 | - | 517 | 13 | 3265 | 22 | 0.0 |
| Batch # 2 | | | | | | | |
| Transfer SS | 5.9 | 630 | 534 | 14 | 3296 | 9 | 0.0 |
| Transfer RWW | 1.6 | 217 | 321 | 5 | 3303 | 2 | 0.0 |
| Add Misc. Soln. | 14.0 | 27 | 361 | 2 | 3305 | 0 | 0.0 |
| Filter to 7.5 wt % | 4.9 | <i>806.7</i> | 374 | 0 | 3305 | 0 | 0.0 |
| Filter to 10 wt % | 0.4 | <i>30.6</i> | 375 | 0 | 3305 | 0 | 0.0 |
| Stop/Start | 2.9 | - | 364 | 0 | 3305 | 0 | 0.0 |
| Batch # 3 | | | | | | | |
| Transfer SS | 5.9 | 630 | 400 | 0 | 3305 | 0 | 0.0 |
| Transfer RWW | 1.6 | 217 | 188 | 0 | 3305 | 0 | 0.0 |
| Add Misc. Soln. | 14.0 | 27 | 227 | 0 | 3305 | 0 | 0.0 |
| Filter to 7.5 wt % | 4.9 | <i>798.6</i> | 240 | 0 | 3305 | 0 | 0.0 |
| Filter to 10 wt % | 0.6 | <i>40.2</i> | 242 | 0 | 3305 | 0 | 0.0 |
| Stop/Start | 3.9 | - | 253 | 0 | 3305 | 0 | 0.0 |
| Wash Cycle | | | | | | | |
| Wash | 2.5 | 50 | 310 | 2596 | 5901 | 4974 | 4.2 |
| Add NaOH | 0.6 | 8 | 320 | 498 | 6400 | 5687 | 4.7 |
| Wash | 3.5 | 70 | 399 | 7240 | 13639 | 9045 | 6.0 |
| Add NaOH | 0.4 | 6 | 406 | 647 | 14286 | 9307 | 6.0 |
| Wash | 3.2 | 65 | 480 | 7963 | 22249 | 11185 | 6.2 |
| Add NaNO ₂ | 0.5 | 8 | 490 | 999 | 23248 | 11398 | 6.1 |
| Wash | 6.2 | 125 | 632 | 19622 | 42870 | 10701 | 4.5 |
| Sample | 3.5 | - | 642 | 4665 | 47534 | 6036 | 2.5 |
| Transfer Slurry | 0.9 | 130 | 646 | 827 | 48361 | 5209 | 2.1 |
| Stop | 2.1 | - | 651 | 1515 | 49876 | 3694 | 1.6 |

SS = Salt Solution

RWW = Recycled Wash Water

Italicized volume changes indicate removal from Tank 48.

Non-italicized volume changes indicate additions to Tank 48.

The wash cycle volume changes do not cause volume level changes in Tank 48 since the washwater and inhibitor solutions are added and removed simultaneously.

The volume of the contents in Tank 22 is incrementally increased by Late washwater at the rate of 2809 gallons per day.

APPENDIX A (continued)

| | | |
|-------------------------------|----------------|-------------------------------|
| Concentration of TBP Added: | 40 mg/L | |
| TPB Solubility in DSS: | 1.1 mg/L | |
| TPB Solubility in Wash Water: | 16.0 mg/L | |
| DSS TBP Hydrolysis Rate: | 0.184 mg/L-day | (If [TBP] > solubility limit) |
| TBP Hydrolysis Rate Constant: | 0.17 /day | (If [TBP] < solubility limit) |

| Process | | | Tank 50 - Cycle 3 | | | | |
|-----------------------|---------------|----------------------|---------------------------|-----------------|-----------------------|-------------------|------------------------|
| Step | Timing (days) | Volume Change (Kgal) | Volume of Contents (Kgal) | TBP Decomp. (g) | Total TBP Decomp. (g) | Remaining TBP (g) | Remaining [TBP] (mg/L) |
| Batch # 1 | | | | | | | |
| Transfer SS | 5.9 | 630 | | | | | |
| Transfer RWW | 1.5 | 217 | | | | | |
| Add Misc. Soln. | 14.1 | 40.1 | | | | | |
| Filter to 7.5 wt % | 4.9 | <i>813.5</i> | 813.5 | | | 1.23E+05 | 40.0 |
| Filter to 10 wt % | 0.2 | <i>18.4</i> | 831.9 | | | 1.26E+05 | 40.0 |
| Stop/Start | 2.9 | - | 831.9 | | | 1.26E+05 | 40.0 |
| Contents to Saltstone | | | | | | | |
| Batch # 2 | | | | | | | |
| Transfer SS | 5.9 | 630 | | | | | |
| Transfer RWW | 1.6 | 217 | | | | | |
| Add Misc. Soln. | 14.0 | 27 | | | | | |
| Filter to 7.5 wt % | 4.9 | <i>806.7</i> | 806.7 | | | 1.22E+05 | 40.0 |
| Filter to 10 wt % | 0.4 | <i>30.6</i> | 837.3 | | | 1.27E+05 | 40.0 |
| Stop/Start | 2.9 | - | 837.3 | | | 1.27E+05 | 40.0 |
| Contents to Saltstone | | | | | | | |
| Batch # 3 | | | | | | | |
| Transfer SS | 5.9 | 630 | | | | | |
| Transfer RWW | 1.6 | 217 | | | | | |
| Add Misc. Soln. | 14.0 | 27 | | | | | |
| Filter to 7.5 wt % | 4.8 | <i>798.6</i> | 798.6 | | | 1.21E+05 | 40.0 |
| Filter to 10 wt % | 0.6 | <i>40.2</i> | 838.8 | | | 1.27E+05 | 40.0 |
| Stop/Start | 3.9 | - | 838.8 | | | 1.27E+05 | 40.0 |
| Contents to Saltstone | | | | | | | |
| Wash Cycle | | | | | | | |
| Wash | 2.5 | 50 | | | | | |
| Add NaOH | 0.5 | 8 | | | | | |
| Wash | 3.5 | 70 | | | | | |
| Add NaOH | 0.4 | 6 | | | | | |
| Wash | 3.2 | 65 | | | | | |
| Add NaNO ₂ | 0.5 | 8 | | | | | |
| Wash | 6.2 | 125 | | | | | |
| Sample | 3.5 | - | | | | | |
| Transfer Slurry | 0.9 | 130 | | | | | |
| Stop | 2.1 | - | | | | | |

SS = Salt Solution

RWW = Recycled Wash Water

Italicized volume changes indicate removal from Tank 48.

Non-italicized volume changes indicate additions to Tank 48.

The wash cycle volume changes do not cause volume level changes in Tank 48 since the washwater and inhibitor solutions are added and removed simultaneously.

The volume of the contents in Tank 22 is incrementally increased by Late washwater at the rate of 2809 gallons per day.

APPENDIX B

The material balance for the addition of 100 mg/L TBP in Tanks 48, 50, and 22 is shown below.

| | | |
|-------------------------------|----------------|-------------------------------|
| Concentration of TBP Added: | 100 mg/L | |
| TPB Solubility In DSS: | 1.1 mg/L | |
| TPB Solubility in Wash Water: | 16.0 mg/L | |
| DSS TBP Hydrolysis Rate: | 0.184 mg/L·day | (If [TBP] > solubility limit) |
| TBP Hydrolysis Rate Constant: | 0.17 /day | (If [TBP] < solubility limit) |

| Process | | | Tank 48 - Cycle 1 | | | | |
|--------------------|---------------|----------------------|---------------------------|-----------------|-----------------------|-------------------|------------------------|
| Step | Timing (days) | Volume Change (Kgal) | Volume of Contents (Kgal) | TBP Decomp. (g) | Total TBP Decomp. (g) | Remaining TBP (g) | Remaining [TBP] (mg/L) |
| Batch # 1 | | | | | | | |
| Transfer SS | 5.9 | 630 | 630 | 0 | 0 | 0 | 0.0 |
| Transfer RWW | 1.6 | 217 | 847 | 0 | 0 | 0 | 0.0 |
| Add Misc. Soln. | 14.1 | 40.1 | 887.1 | 0 | 0 | 0 | 0.0 |
| Filter to 7.5 wt % | 4.9 | <i>813.5</i> | 73.6 | 0 | 0 | 0 | 0.0 |
| Filter to 10 wt % | 0.2 | <i>18.4</i> | 55.2 | 0 | 0 | 0 | 0.0 |
| Stop/Start | 2.9 | - | 55.2 | 0 | 0 | 0 | 0.0 |
| Batch # 2 | | | | | | | |
| Transfer SS | 5.9 | 630 | 685.2 | 0 | 0 | 0 | 0.0 |
| Transfer RWW | 1.6 | 217 | 902.2 | 0 | 0 | 0 | 0.0 |
| Add Misc. Soln. | 14.0 | 27 | 929.2 | 0 | 0 | 0 | 0.0 |
| Filter to 7.5 wt % | 4.9 | <i>806.7</i> | 122.5 | 0 | 0 | 0 | 0.0 |
| Filter to 10 wt % | 0.4 | <i>30.6</i> | 91.9 | 0 | 0 | 0 | 0.0 |
| Stop/Start | 2.9 | - | 91.9 | 0 | 0 | 0 | 0.0 |
| Batch # 3 | | | | | | | |
| Transfer SS | 5.9 | 630 | 721.9 | 0 | 0 | 0 | 0.0 |
| Transfer RWW | 1.6 | 217 | 938.9 | 0 | 0 | 0 | 0.0 |
| Add Misc. Soln. | 14.0 | 27 | 965.9 | 0 | 0 | 0 | 0.0 |
| Filter to 7.5 wt % | 4.8 | <i>798.6</i> | 167.3 | 0 | 0 | 0 | 0.0 |
| Filter to 10 wt % | 0.8 | <i>40.2</i> | 127.1 | 0 | 0 | 0 | 0.0 |
| Stop/Start | 3.9 | - | 127.1 | 0 | 0 | 0 | 0.0 |
| Wash Cycle | | | | | | | |
| Wash | 2.5 | 50 | 127.1 | 0 | 0 | 0 | 0.0 |
| Add NaOH | 0.5 | 8 | 127.1 | 0 | 0 | 0 | 0.0 |
| Wash | 3.5 | 70 | 127.1 | 0 | 0 | 0 | 0.0 |
| Add NaOH | 0.4 | 6 | 127.1 | 0 | 0 | 0 | 0.0 |
| Wash | 3.2 | 65 | 127.1 | 0 | 0 | 0 | 0.0 |
| Add NaNO2 | 0.5 | 8 | 127.1 | 0 | 0 | 0 | 0.0 |
| Wash | 6.2 | 125 | 127.1 | 0 | 0 | 0 | 0.0 |
| Sample | 3.5 | - | 127.1 | 0 | 0 | 0 | 0.0 |
| Transfer Slurry | 0.9 | 130 | 0 | 0 | 0 | 0 | 0.0 |
| Stop | 2.1 | - | 0 | 0 | 0 | 0 | 0.0 |

SS = Salt Solution

RWW = Recycled Wash Water

Italicized volume changes indicate removal from Tank 48.

Non-italicized volume changes indicate additions to Tank 48.

The wash cycle volume changes do not cause volume level changes in Tank 48 since the washwater and inhibitor solutions are added and removed simultaneously.

The volume of the contents in Tank 22 is incrementally increased by Late washwater at the rate of 2809 gallons per day.

APPENDIX B (continued)

| | | |
|-------------------------------|----------------|-------------------------------|
| Concentration of TBP Added: | 100 mg/L | |
| TPB Solubility in DSS: | 1.1 mg/L | |
| TPB Solubility in Wash Water: | 16.0 mg/L | |
| RWW TBP Hydrolysis Rate: | 2.679 mg/L·day | (If [TBP] > solubility limit) |
| TBP Hydrolysis Rate Constant: | 0.17 /day | (If [TBP] < solubility limit) |

| Process | | | Tank 22 - Cycle 1 | | | | |
|-----------------------|---------------|----------------------|---------------------------|-----------------|-----------------------|-------------------|------------------------|
| Step | Timing (days) | Volume Change (Kgal) | Volume of Contents (Kgal) | TBP Decomp. (g) | Total TBP Decomp. (g) | Remaining TBP (g) | Remaining [TBP] (mg/L) |
| Batch # 1 | | | | | | | |
| Transfer SS | 5.9 | 630 | 669 | 0 | 0 | 0 | 0.0 |
| Transfer RWW | 1.6 | 217 | 455 | 0 | 0 | 0 | 0.0 |
| Add Misc. Soln. | 14.1 | 40.1 | 495 | 0 | 0 | 0 | 0.0 |
| Filter to 7.5 wt % | 4.9 | <i>813.5</i> | 508 | 0 | 0 | 0 | 0.0 |
| Filter to 10 wt % | 0.2 | <i>18.4</i> | 509 | 0 | 0 | 0 | 0.0 |
| Stop/Start | 2.9 | - | 517 | 0 | 0 | 0 | 0.0 |
| Batch # 2 | | | | | | | |
| Transfer SS | 5.9 | 630 | 534 | 0 | 0 | 0 | 0.0 |
| Transfer RWW | 1.6 | 217 | 321 | 0 | 0 | 0 | 0.0 |
| Add Misc. Soln. | 14.0 | 27 | 361 | 0 | 0 | 0 | 0.0 |
| Filter to 7.5 wt % | 4.9 | <i>806.7</i> | 374 | 0 | 0 | 0 | 0.0 |
| Filter to 10 wt % | 0.4 | <i>30.6</i> | 375 | 0 | 0 | 0 | 0.0 |
| Stop/Start | 2.9 | - | 384 | 0 | 0 | 0 | 0.0 |
| Batch # 3 | | | | | | | |
| Transfer SS | 5.9 | 630 | 409 | 0 | 0 | 0 | 0.0 |
| Transfer RWW | 1.6 | 217 | 188 | 0 | 0 | 0 | 0.0 |
| Add Misc. Soln. | 14.0 | 27 | 227 | 0 | 0 | 0 | 0.0 |
| Filter to 7.5 wt % | 4.8 | <i>798.6</i> | 240 | 0 | 0 | 0 | 0.0 |
| Filter to 10 wt % | 0.6 | <i>40.2</i> | 242 | 0 | 0 | 0 | 0.0 |
| Stop/Start | 3.9 | - | 253 | 0 | 0 | 0 | 0.0 |
| Wash Cycle | | | | | | | |
| Wash | 2.5 | 50 | 310 | 6490 | 6490 | 12435 | 10.6 |
| Add NaOH | 0.5 | 8 | 320 | 1246 | 7736 | 14217 | 11.8 |
| Wash | 3.5 | 70 | 389 | 18099 | 25835 | 22613 | 16.0 |
| Add NaOH | 0.4 | 6 | 406 | 1617 | 27452 | 23267 | 15.1 |
| Wash | 3.2 | 65 | 480 | 19906 | 47358 | 27963 | 15.4 |
| Add NaNO ₂ | 0.5 | 8 | 490 | 2497 | 49856 | 28494 | 15.4 |
| Wash | 5.2 | 125 | 632 | 49055 | 98911 | 26751 | 11.2 |
| Sample | 3.5 | - | 642 | 11662 | 110572 | 15090 | 6.2 |
| Transfer Slurry | 0.9 | 130 | 646 | 2066 | 112639 | 13023 | 5.3 |
| Stop | 2.1 | - | 651 | 3788 | 116427 | 9235 | 3.8 |

SS = Salt Solution

RWW = Recycled Wash Water

Italicized volume changes indicate removal from Tank 48.

Non-italicized volume changes indicate additions to Tank 48.

The wash cycle volume changes do not cause volume level changes in Tank 48 since the washwater and inhibitor solutions are added and removed simultaneously.

The volume of the contents in Tank 22 is incrementally increased by Late washwater at the rate of 2809 gallons per day.

APPENDIX B (continued)

| | | |
|-------------------------------|----------------|-------------------------------|
| Concentration of TBP Added: | 100 mg/L | |
| TPB Solubility in DSS: | 1.1 mg/L | |
| TPB Solubility in Wash Water: | 16.0 mg/L | |
| DSS TBP Hydrolysis Rate: | 0.184 mg/L·day | (If [TBP] > solubility limit) |
| TBP Hydrolysis Rate Constant: | 0.17 /day | (If [TBP] < solubility limit) |

| Process | | | Tank 50 - Cycle 1 | | | | |
|-----------------------|---------------|----------------------|---------------------------|-----------------|-----------------------|-------------------|------------------------|
| Step | Timing (days) | Volume Change (Kgal) | Volume of Contents (Kgal) | TBP Decomp. (g) | Total TBP Decomp. (g) | Remaining TBP (g) | Remaining [TBP] (mg/L) |
| Batch # 1 | | | | | | | |
| Transfer SS | 5.9 | 630 | | | | | |
| Transfer RWW | 1.6 | 217 | | | | | |
| Add Misc. Soln. | 14.1 | 40.1 | | | | | |
| Filter to 7.5 wt % | 4.9 | <i>813.5</i> | 813.5 | | | 3.08E+05 | 100.0 |
| Filter to 10 wt % | 0.2 | <i>18.4</i> | 831.9 | | | 3.15E+05 | 100.0 |
| Stop/Start | 2.9 | - | 831.9 | | | 3.15E+05 | 100.0 |
| Contents to Saltstone | | | | | | | |
| Batch # 2 | | | | | | | |
| Transfer SS | 5.9 | 630 | | | | | |
| Transfer RWW | 1.6 | 217 | | | | | |
| Add Misc. Soln. | 14.0 | 27 | | | | | |
| Filter to 7.5 wt % | 4.9 | <i>806.7</i> | 806.7 | | | 3.05E+05 | 100.0 |
| Filter to 10 wt % | 0.4 | <i>30.6</i> | 837.3 | | | 3.17E+05 | 100.0 |
| Stop/Start | 2.9 | - | 837.3 | | | 3.17E+05 | 100.0 |
| Contents to Saltstone | | | | | | | |
| Batch # 3 | | | | | | | |
| Transfer SS | 5.9 | 630 | | | | | |
| Transfer RWW | 1.6 | 217 | | | | | |
| Add Misc. Soln. | 14.0 | 27 | | | | | |
| Filter to 7.5 wt % | 4.8 | <i>798.6</i> | 798.6 | | | 3.02E+05 | 100.0 |
| Filter to 10 wt % | 0.8 | <i>40.2</i> | 838.8 | | | 3.17E+05 | 100.0 |
| Stop/Start | 3.9 | - | 838.8 | | | 3.17E+05 | 100.0 |
| Contents to Saltstone | | | | | | | |
| Wash Cycle | | | | | | | |
| Wash | 2.5 | 50 | | | | | |
| Add NaOH | 0.6 | 8 | | | | | |
| Wash | 3.6 | 70 | | | | | |
| Add NaOH | 0.4 | 6 | | | | | |
| Wash | 3.2 | 65 | | | | | |
| Add NaNO ₂ | 0.5 | 8 | | | | | |
| Wash | 6.2 | 125 | | | | | |
| Sample | 3.5 | - | | | | | |
| Transfer Slurry | 0.9 | 130 | | | | | |
| Stop | 2.1 | - | | | | | |

SS = Salt Solution

RWW = Recycled Wash Water

Italicized volume changes indicate removal from Tank 48.

Non-italicized volume changes indicate additions to Tank 48.

The wash cycle volume changes do not cause volume level changes in Tank 48 since the washwater and inhibitor solutions are added and removed simultaneously.

The volume of the contents in Tank 22 is incrementally increased by Late washwater at the rate of 2809 gallons per day.

APPENDIX B (continued)

| | | |
|-------------------------------|----------------|-------------------------------|
| Concentration of TBP Added: | 100 mg/L | |
| TPB Solubility In DSS: | 1.1 mg/L | |
| TPB Solubility in Wash Water: | 16.0 mg/L | |
| DSS TBP Hydrolysis Rate: | 0.184 mg/L·day | (if [TBP] > solubility limit) |
| TBP Hydrolysis Rate Constant: | 0.17 /day | (if [TBP] < solubility limit) |

| Process | | | Tank 48 - Cycle 2 | | | | |
|-----------------------|---------------|----------------------|---------------------------|-----------------|-----------------------|-------------------|------------------------|
| Step | Timing (days) | Volume Change (Kgal) | Volume of Contents (Kgal) | TBP Decomp. (g) | Total TBP Decomp. (g) | Remaining TBP (g) | Remaining [TBP] (mg/L) |
| Batch # 1 | | | | | | | |
| Transfer SS | 5.9 | 630 | 630 | 0 | 0 | 0 | 0.0 |
| Transfer RWW | 1.6 | 217 | 847 | 0 | 0 | 1859 | 0.6 |
| Add Misc. Soln. | 14.1 | 40.1 | 887.1 | 1677 | 1677 | 182 | 0.1 |
| Filter to 7.5 wt % | 4.9 | <i>813.5</i> | 73.6 | 176 | 1852 | 1 | 0.0 |
| Filter to 10 wt % | 0.2 | <i>18.4</i> | 55.2 | 0 | 1852 | 0 | 0.0 |
| Stop/Start | 2.9 | - | 55.2 | 0 | 1852 | 0 | 0.0 |
| Batch # 2 | | | | | | | |
| Transfer SS | 5.9 | 630 | 685.2 | 0 | 1852 | 0 | 0.0 |
| Transfer RWW | 1.6 | 217 | 902.2 | 0 | 1852 | 9 | 0.0 |
| Add Misc. Soln. | 14.0 | 27 | 929.2 | 8 | 1860 | 1 | 0.0 |
| Filter to 7.5 wt % | 4.9 | <i>806.7</i> | 122.5 | 1 | 1861 | 0 | 0.0 |
| Filter to 10 wt % | 0.4 | <i>30.6</i> | 91.9 | 0 | 1861 | 0 | 0.0 |
| Stop/Start | 2.9 | - | 91.9 | 0 | 1861 | 0 | 0.0 |
| Batch # 3 | | | | | | | |
| Transfer SS | 5.9 | 630 | 721.9 | 0 | 1861 | 0 | 0.0 |
| Transfer RWW | 1.6 | 217 | 938.9 | 0 | 1861 | 0 | 0.0 |
| Add Misc. Soln. | 14.0 | 27 | 965.9 | 0 | 1861 | 0 | 0.0 |
| Filter to 7.5 wt % | 4.9 | <i>798.6</i> | 167.3 | 0 | 1861 | 0 | 0.0 |
| Filter to 10 wt % | 0.6 | <i>40.2</i> | 127.1 | 0 | 1861 | 0 | 0.0 |
| Stop/Start | 3.9 | - | 127.1 | 0 | 1861 | 0 | 0.0 |
| Wash Cycle | | | | | | | |
| Wash | 2.5 | 50 | 127.1 | 0 | 1861 | 0 | 0.0 |
| Add NaOH | 0.5 | 8 | 127.1 | 0 | 1861 | 0 | 0.0 |
| Wash | 3.5 | 70 | 127.1 | 0 | 1861 | 0 | 0.0 |
| Add NaOH | 0.4 | 6 | 127.1 | 0 | 1861 | 0 | 0.0 |
| Wash | 3.2 | 65 | 127.1 | 0 | 1861 | 0 | 0.0 |
| Add NaNO ₂ | 0.5 | 8 | 127.1 | 0 | 1861 | 0 | 0.0 |
| Wash | 6.2 | 125 | 127.1 | 0 | 1861 | 0 | 0.0 |
| Sample | 3.5 | - | 127.1 | 0 | 1861 | 0 | 0.0 |
| Transfer Slurry | 0.9 | 130 | 0 | 0 | 1861 | 0 | 0.0 |
| Stop | 2.1 | - | 0 | 0 | 1861 | 0 | 0.0 |

SS = Salt Solution

RWW = Recycled Wash Water

Italicized volume changes indicate removal from Tank 48.

Non-italicized volume changes indicate additions to Tank 48.

The wash cycle volume changes do not cause volume level changes in Tank 48 since the washwater and inhibitor solutions are added and removed simultaneously.

The volume of the contents in Tank 22 is incrementally increased by Late washwater at the rate of 2809 gallons per day.

APPENDIX B (continued)

| | | |
|-------------------------------|----------------|-------------------------------|
| Concentration of TBP Added: | 100 mg/L | |
| TPB Solubility in DSS: | 1.1 mg/L | |
| TPB Solubility in Wash Water: | 16.0 mg/L | |
| RWW TBP Hydrolysis Rate: | 2.679 mg/L-day | (If [TBP] > solubility limit) |
| TBP Hydrolysis Rate Constant: | 0.17 /day | (If [TBP] < solubility limit) |

| Process | | | Tank 22 - Cycle 2 | | | | |
|-----------------------|---------------|----------------------|---------------------------|-----------------|-----------------------|-------------------|------------------------|
| Step | Timing (days) | Volume Change (Kgal) | Volume of Contents (Kgal) | TBP Decomp. (g) | Total TBP Decomp. (g) | Remaining TBP (g) | Remaining [TBP] (mg/L) |
| Batch # 1 | | | | | | | |
| Transfer SS | 5.9 | 630 | 669 | 3517 | 3517 | 5718 | 2.3 |
| Transfer RWW | 1.6 | 217 | 435 | 2739 | 6256 | 2011 | 1.2 |
| Add Misc. Soln. | 14.1 | 40.1 | 495 | 1806 | 8062 | 205 | 0.1 |
| Filter to 7.5 wt % | 4.9 | <i>813.5</i> | 509 | 112 | 8175 | 92 | 0.0 |
| Filter to 10 wt % | 0.2 | <i>18.4</i> | 509 | 3 | 8178 | 89 | 0.0 |
| Stop/Start | 2.9 | - | 517 | 34 | 8211 | 56 | 0.0 |
| Batch # 2 | | | | | | | |
| Transfer SS | 5.9 | 630 | 534 | 34 | 8246 | 21 | 0.0 |
| Transfer RWW | 1.6 | 217 | 321 | 12 | 8257 | 6 | 0.0 |
| Add Misc. Soln. | 14.0 | 27 | 361 | 5 | 8262 | 1 | 0.0 |
| Filter to 7.5 wt % | 4.9 | <i>806.7</i> | 374 | 0 | 8263 | 0 | 0.0 |
| Filter to 10 wt % | 0.4 | <i>30.6</i> | 375 | 0 | 8263 | 0 | 0.0 |
| Stop/Start | 2.9 | - | 394 | 0 | 8263 | 0 | 0.0 |
| Batch # 3 | | | | | | | |
| Transfer SS | 5.9 | 630 | 409 | 0 | 8263 | 0 | 0.0 |
| Transfer RWW | 1.6 | 217 | 198 | 0 | 8263 | 0 | 0.0 |
| Add Misc. Soln. | 14.0 | 27 | 227 | 0 | 8263 | 0 | 0.0 |
| Filter to 7.5 wt % | 4.8 | <i>798.6</i> | 240 | 0 | 8263 | 0 | 0.0 |
| Filter to 10 wt % | 0.6 | <i>40.2</i> | 242 | 0 | 8263 | 0 | 0.0 |
| Stop/Start | 3.9 | - | 253 | 0 | 8263 | 0 | 0.0 |
| Wash Cycle | | | | | | | |
| Wash | 2.5 | 50 | 319 | 6490 | 14753 | 12435 | 10.8 |
| Add NaOH | 0.5 | 8 | 320 | 1246 | 15999 | 14217 | 11.8 |
| Wash | 3.5 | 70 | 399 | 18099 | 34098 | 22613 | 15.0 |
| Add NaOH | 0.4 | 6 | 406 | 1617 | 35715 | 23267 | 15.1 |
| Wash | 3.2 | 65 | 480 | 19906 | 55622 | 27963 | 15.4 |
| Add NaNO ₂ | 0.5 | 8 | 490 | 2497 | 58119 | 28494 | 15.4 |
| Wash | 6.2 | 125 | 632 | 49055 | 107174 | 26751 | 11.2 |
| Sample | 3.5 | - | 642 | 11662 | 118835 | 15090 | 6.2 |
| Transfer Slurry | 0.9 | 130 | 645 | 2066 | 120902 | 13023 | 5.3 |
| Stop | 2.1 | - | 651 | 3788 | 124690 | 9235 | 3.8 |

SS = Salt Solution

RWW = Recycled Wash Water

Italicized volume changes indicate removal from Tank 48.

Non-italicized volume changes indicate additions to Tank 48.

The wash cycle volume changes do not cause volume level changes in Tank 48 since the washwater and inhibitor solutions are added and removed simultaneously.

The volume of the contents in Tank 22 is incrementally increased by Late washwater at the rate of 2809 gallons per day.

APPENDIX B (continued)

| | | |
|-------------------------------|----------------|-------------------------------|
| Concentration of TBP Added: | 100 mg/L | |
| TPB Solubility in DSS: | 1.1 mg/L | |
| TPB Solubility in Wash Water: | 16.0 mg/L | |
| DSS TBP Hydrolysis Rate: | 0.184 mg/L·day | (If [TBP] > solubility limit) |
| TBP Hydrolysis Rate Constant: | 0.17 /day | (If [TBP] < solubility limit) |

| Process | | | Tank 50 - Cycle 2 | | | | |
|-----------------------|---------------|----------------------|---------------------------|-----------------|-----------------------|-------------------|------------------------|
| Step | Timing (days) | Volume Change (Kgal) | Volume of Contents (Kgal) | TBP Decomp. (g) | Total TBP Decomp. (g) | Remaining TBP (g) | Remaining [TBP] (mg/L) |
| Batch # 1 | | | | | | | |
| Transfer SS | 5.9 | 630 | | | | | |
| Transfer RWW | 1.6 | 217 | | | | | |
| Add Misc. Soln. | 14.1 | 40.1 | | | | | |
| Filter to 7.5 wt % | 4.9 | <i>813.5</i> | 813.5 | | | 3.08E+05 | 100.1 |
| Filter to 10 wt % | 0.2 | <i>18.4</i> | 831.9 | | | 3.15E+05 | 100.1 |
| Stop/Start | 2.9 | - | 831.9 | | | 3.15E+05 | 100.1 |
| Contents to Saltstone | | | | | | | |
| Batch # 2 | | | | | | | |
| Transfer SS | 5.9 | 630 | | | | | |
| Transfer RWW | 1.6 | 217 | | | | | |
| Add Misc. Soln. | 14.0 | 27 | | | | | |
| Filter to 7.5 wt % | 4.9 | <i>806.7</i> | 806.7 | | | 3.05E+05 | 100.0 |
| Filter to 10 wt % | 0.4 | <i>30.6</i> | 837.3 | | | 3.17E+05 | 100.0 |
| Stop/Start | 2.9 | - | 837.3 | | | 3.17E+05 | 100.0 |
| Contents to Saltstone | | | | | | | |
| Batch # 3 | | | | | | | |
| Transfer SS | 5.9 | 630 | | | | | |
| Transfer RWW | 1.6 | 217 | | | | | |
| Add Misc. Soln. | 14.0 | 27 | | | | | |
| Filter to 7.5 wt % | 4.9 | <i>798.6</i> | 798.6 | | | 3.02E+05 | 100.0 |
| Filter to 10 wt % | 0.6 | <i>40.2</i> | 838.8 | | | 3.17E+05 | 100.0 |
| Stop/Start | 3.9 | - | 838.8 | | | 3.17E+05 | 100.0 |
| Contents to Saltstone | | | | | | | |
| Wash Cycle | | | | | | | |
| Wash | 2.5 | 50 | | | | | |
| Add NaOH | 0.5 | 8 | | | | | |
| Wash | 3.5 | 70 | | | | | |
| Add NaOH | 0.4 | 6 | | | | | |
| Wash | 3.2 | 65 | | | | | |
| Add NaNO ₂ | 0.5 | 8 | | | | | |
| Wash | 6.2 | 125 | | | | | |
| Sample | 3.5 | - | | | | | |
| Transfer Slurry | 0.9 | 130 | | | | | |
| Stop | 2.1 | - | | | | | |

SS = Salt Solution

RWW = Recycled Wash Water

Italicized volume changes indicate removal from Tank 48.

Non-italicized volume changes indicate additions to Tank 48.

The wash cycle volume changes do not cause volume level changes in Tank 48 since the washwater and inhibitor solutions are added and removed simultaneously.

The volume of the contents in Tank 22 is incrementally increased by Late washwater at the rate of 2809 gallons per day.

APPENDIX B (continued)

| | | |
|-------------------------------|----------------|-------------------------------|
| Concentration of TBP Added: | 100 mg/L | |
| TPB Solubility In DSS: | 1.1 mg/L | |
| TPB Solubility in Wash Water: | 16.0 mg/L | |
| DSS TBP Hydrolysis Rate: | 0.184 mg/L·day | (if [TBP] > solubility limit) |
| TBP Hydrolysis Rate Constant: | 0.17 /day | (if [TBP] < solubility limit) |

| Process | | | Tank 48 - Cycle 3 | | | | |
|-----------------------|---------------|----------------------|---------------------------|-----------------|-----------------------|-------------------|------------------------|
| Step | Timing (days) | Volume Change (Kgal) | Volume of Contents (Kgal) | TBP Decomp. (g) | Total TBP Decomp. (g) | Remaining TBP (g) | Remaining [TBP] (mg/L) |
| Batch # 1 | | | | | | | |
| Transfer SS | 5.9 | 630 | 630 | 0 | 0 | 0 | 0.0 |
| Transfer RWW | 1.6 | 217 | 847 | 0 | 0 | 1859 | 0.6 |
| Add Misc. Soln. | 14.1 | 40.1 | 887.1 | 1677 | 1677 | 182 | 0.1 |
| Filter to 7.5 wt % | 4.9 | <i>813.5</i> | 73.6 | 176 | 1852 | 1 | 0.0 |
| Filter to 10 wt % | 0.2 | <i>18.4</i> | 55.2 | 0 | 1852 | 0 | 0.0 |
| Stop/Start | 2.9 | - | 55.2 | 0 | 1852 | 0 | 0.0 |
| Batch # 2 | | | | | | | |
| Transfer SS | 5.9 | 630 | 695.2 | 0 | 1852 | 0 | 0.0 |
| Transfer RWW | 1.6 | 217 | 912.2 | 0 | 1852 | 9 | 0.0 |
| Add Misc. Soln. | 14.0 | 27 | 939.2 | 8 | 1860 | 1 | 0.0 |
| Filter to 7.5 wt % | 4.9 | <i>806.7</i> | 122.5 | 1 | 1861 | 0 | 0.0 |
| Filter to 10 wt % | 0.4 | <i>30.6</i> | 91.9 | 0 | 1861 | 0 | 0.0 |
| Stop/Start | 2.9 | - | 91.9 | 0 | 1861 | 0 | 0.0 |
| Batch # 3 | | | | | | | |
| Transfer SS | 5.9 | 630 | 721.9 | 0 | 1861 | 0 | 0.0 |
| Transfer RWW | 1.6 | 217 | 938.9 | 0 | 1861 | 0 | 0.0 |
| Add Misc. Soln. | 14.0 | 27 | 965.9 | 0 | 1861 | 0 | 0.0 |
| Filter to 7.5 wt % | 4.8 | <i>798.6</i> | 167.3 | 0 | 1861 | 0 | 0.0 |
| Filter to 10 wt % | 0.6 | <i>40.2</i> | 127.1 | 0 | 1861 | 0 | 0.0 |
| Stop/Start | 3.8 | - | 127.1 | 0 | 1861 | 0 | 0.0 |
| Wash Cycle | | | | | | | |
| Wash | 2.5 | 50 | 127.1 | 0 | 1861 | 0 | 0.0 |
| Add NaOH | 0.5 | 8 | 127.1 | 0 | 1861 | 0 | 0.0 |
| Wash | 3.5 | 70 | 127.1 | 0 | 1861 | 0 | 0.0 |
| Add NaOH | 0.4 | 6 | 127.1 | 0 | 1861 | 0 | 0.0 |
| Wash | 3.2 | 65 | 127.1 | 0 | 1861 | 0 | 0.0 |
| Add NaNO ₂ | 0.5 | 8 | 127.1 | 0 | 1861 | 0 | 0.0 |
| Wash | 6.2 | 125 | 127.1 | 0 | 1861 | 0 | 0.0 |
| Sample | 3.5 | - | 127.1 | 0 | 1861 | 0 | 0.0 |
| Transfer Slurry | 0.9 | 130 | 0 | 0 | 1861 | 0 | 0.0 |
| Stop | 2.1 | - | 0 | 0 | 1861 | 0 | 0.0 |

SS = Salt Solution

RWW = Recycled Wash Water

Italicized volume changes indicate removal from Tank 48.

Non-italicized volume changes indicate additions to Tank 48.

The wash cycle volume changes do not cause volume level changes in Tank 48 since the washwater and inhibitor solutions are added and removed simultaneously.

The volume of the contents in Tank 22 is incrementally increased by Late washwater at the rate of 2809 gallons per day.

APPENDIX B (continued)

| | | |
|-------------------------------|----------------|-------------------------------|
| Concentration of TBP Added: | 100 mg/L | |
| TPB Solubility in DSS: | 1.1 mg/L | |
| TPB Solubility in Wash Water: | 16.0 mg/L | |
| RWW TBP Hydrolysis Rate: | 2.679 mg/L-day | (If [TBP] > solubility limit) |
| TBP Hydrolysis Rate Constant: | 0.17 /day | (If [TBP] < solubility limit) |

| Process | | | Tank 22 - Cycle 3 | | | | |
|-----------------------|---------------|----------------------|---------------------------|-----------------|-----------------------|-------------------|------------------------|
| Step | Timing (days) | Volume Change (Kgal) | Volume of Contents (Kgal) | TBP Decomp. (g) | Total TBP Decomp. (g) | Remaining TBP (g) | Remaining [TBP] (mg/L) |
| Batch # 1 | | | | | | | |
| Transfer SS | 5.9 | 630 | 568 | 3517 | 3517 | 5718 | 2.3 |
| Transfer RWW | 1.6 | 217 | 455 | 2739 | 6256 | 2011 | 1.2 |
| Add Misc. Soln. | 14.1 | 40.1 | 495 | 1806 | 8062 | 205 | 0.1 |
| Filter to 7.5 wt % | 4.9 | <i>813.5</i> | 508 | 112 | 8175 | 92 | 0.0 |
| Filter to 10 wt % | 0.2 | <i>18.4</i> | 509 | 3 | 8178 | 89 | 0.0 |
| Stop/Start | 2.9 | - | 517 | 34 | 8211 | 56 | 0.0 |
| Batch # 2 | | | | | | | |
| Transfer SS | 5.9 | 630 | 534 | 34 | 8246 | 21 | 0.0 |
| Transfer RWW | 1.6 | 217 | 321 | 12 | 8257 | 6 | 0.0 |
| Add Misc. Soln. | 14.0 | 27 | 361 | 5 | 8262 | 1 | 0.0 |
| Filter to 7.5 wt % | 4.9 | <i>806.7</i> | 374 | 0 | 8263 | 0 | 0.0 |
| Filter to 10 wt % | 0.4 | <i>30.6</i> | 375 | 0 | 8263 | 0 | 0.0 |
| Stop/Start | 2.9 | - | 384 | 0 | 8263 | 0 | 0.0 |
| Batch # 3 | | | | | | | |
| Transfer SS | 5.9 | 630 | 400 | 0 | 8263 | 0 | 0.0 |
| Transfer RWW | 1.6 | 217 | 188 | 0 | 8263 | 0 | 0.0 |
| Add Misc. Soln. | 14.0 | 27 | 227 | 0 | 8263 | 0 | 0.0 |
| Filter to 7.5 wt % | 4.9 | <i>798.6</i> | 240 | 0 | 8263 | 0 | 0.0 |
| Filter to 10 wt % | 0.6 | <i>40.2</i> | 242 | 0 | 8263 | 0 | 0.0 |
| Stop/Start | 3.9 | - | 253 | 0 | 8263 | 0 | 0.0 |
| Wash Cycle | | | | | | | |
| Wash | 2.5 | 50 | 310 | 6490 | 14753 | 12435 | 10.6 |
| Add NaOH | 0.6 | 8 | 320 | 1246 | 15999 | 14217 | 11.8 |
| Wash | 3.6 | 70 | 399 | 18099 | 34098 | 22613 | 15.0 |
| Add NaOH | 0.4 | 6 | 406 | 1617 | 35715 | 23267 | 15.1 |
| Wash | 3.2 | 65 | 480 | 19906 | 55622 | 27963 | 15.4 |
| Add NaNO ₂ | 0.5 | 8 | 490 | 2497 | 58119 | 28494 | 15.4 |
| Wash | 6.2 | 125 | 632 | 49055 | 107174 | 26751 | 11.2 |
| Sample | 3.5 | - | 642 | 11662 | 118835 | 15090 | 6.2 |
| Transfer Slurry | 0.9 | 130 | 646 | 2066 | 120902 | 13023 | 5.3 |
| Stop | 2.1 | - | 651 | 3788 | 124690 | 9235 | 3.8 |

SS = Salt Solution

RWW = Recycled Wash Water

Italicized volume changes indicate removal from Tank 48.

Non-italicized volume changes indicate additions to Tank 48.

The wash cycle volume changes do not cause volume level changes in Tank 48 since the washwater and inhibitor solutions are added and removed simultaneously.

The volume of the contents in Tank 22 is incrementally increased by Late washwater at the rate of 2809 gallons per day.

APPENDIX B (continued)

| | | |
|-------------------------------|----------------|-------------------------------|
| Concentration of TBP Added: | 100 mg/L | |
| TPB Solubility in DSS: | 1.1 mg/L | |
| TPB Solubility in Wash Water: | 16.0 mg/L | |
| DSS TBP Hydrolysis Rate: | 0.184 mg/L-day | (if [TBP] > solubility limit) |
| TBP Hydrolysis Rate Constant: | 0.17 /day | (if [TBP] < solubility limit) |

| Process | | | Tank 50 - Cycle 3 | | | | |
|-----------------------|---------------|----------------------|---------------------------|-----------------|-----------------------|-------------------|------------------------|
| Step | Timing (days) | Volume Change (Kgal) | Volume of Contents (Kgal) | TBP Decomp. (g) | Total TBP Decomp. (g) | Remaining TBP (g) | Remaining [TBP] (mg/L) |
| Batch # 1 | | | | | | | |
| Transfer SS | 5.9 | 630 | | | | | |
| Transfer RWW | 1.6 | 217 | | | | | |
| Add Misc. Soln. | 14.1 | 40.1 | | | | | |
| Filter to 7.5 wt % | 4.9 | <i>813.5</i> | 813.5 | | | 3.08E+05 | 100.1 |
| Filter to 10 wt % | 0.2 | <i>18.4</i> | 831.9 | | | 3.15E+05 | 100.1 |
| Stop/Start | 2.9 | - | 831.9 | | | 3.15E+05 | 100.1 |
| Contents to Saltstone | | | | | | | |
| Batch # 2 | | | | | | | |
| Transfer SS | 5.9 | 630 | | | | | |
| Transfer RWW | 1.6 | 217 | | | | | |
| Add Misc. Soln. | 14.0 | 27 | | | | | |
| Filter to 7.5 wt % | 4.9 | <i>806.7</i> | 806.7 | | | 3.05E+05 | 100.0 |
| Filter to 10 wt % | 0.4 | <i>30.6</i> | 837.3 | | | 3.17E+05 | 100.0 |
| Stop/Start | 2.9 | - | 837.3 | | | 3.17E+05 | 100.0 |
| Contents to Saltstone | | | | | | | |
| Batch # 3 | | | | | | | |
| Transfer SS | 5.9 | 630 | | | | | |
| Transfer RWW | 1.6 | 217 | | | | | |
| Add Misc. Soln. | 14.0 | 27 | | | | | |
| Filter to 7.5 wt % | 4.8 | <i>798.6</i> | 798.6 | | | 3.02E+05 | 100.0 |
| Filter to 10 wt % | 0.6 | <i>40.2</i> | 838.8 | | | 3.17E+05 | 100.0 |
| Stop/Start | 3.9 | - | 838.8 | | | 3.17E+05 | 100.0 |
| Contents to Saltstone | | | | | | | |
| Wash Cycle | | | | | | | |
| Wash | 2.5 | 50 | | | | | |
| Add NaOH | 0.5 | 8 | | | | | |
| Wash | 3.5 | 70 | | | | | |
| Add NaOH | 0.4 | 6 | | | | | |
| Wash | 3.2 | 65 | | | | | |
| Add NaNO ₂ | 0.5 | 8 | | | | | |
| Wash | 6.2 | 125 | | | | | |
| Sample | 3.5 | - | | | | | |
| Transfer Slurry | 0.9 | 130 | | | | | |
| Stop | 2.1 | - | | | | | |

SS = Salt Solution

RWW = Recycled Wash Water

Italicized volume changes indicate removal from Tank 48.

Non-italicized volume changes indicate additions to Tank 48.

The wash cycle volume changes do not cause volume level changes in Tank 48 since the washwater and inhibitor solutions are added and removed simultaneously.

The volume of the contents in Tank 22 is incrementally increased by Late washwater at the rate of 2809 gallons per day.

APPENDIX C

Flammability calculations concerning 1-butanol in ITP facilities.

Tank 22

Use worst case conditions for basis:

- TBP is added at a concentration of 100 mg/L. The total amount of TBP added to Tank 22 is 125 kg per cycle. (TBP will likely be injected at a maximum concentration of 40 mg/L).
- The volume of wash water contained in Tank 22 is at its maximum (668 kgal based upon the material balance) resulting in the minimum volume of vapor space. (The volume of wash water in Tank 22 is expected to range between 188 and 668 kgal per cycle).
- TBP decomposes completely to 1-butanol and phosphate whereby each hydrolysis step occurs at the same rate (conservative since DBP and MBP hydrolyze at a slower rate than TBP). Therefore, 3 times as many moles of 1-butanol are formed per mole of TBP decomposed over any given period of time.
- The maximum rate of TBP decomposition occurs when the TBP concentration is equal to or greater than its solubility limit.
- All 1-butanol which is produced is vaporized instantaneously. (The solubility of 1-butanol in water is 7.35 g/100g and 1-butanol will likely be soluble to a similar extent in wash water).³³

Relevant information:

- The LFL for 1-butanol is 1.45 % in air.³⁰
- Tank 22 is ventilated with air at a nominal rate of 300 scfm (8500 l/min).³⁴
- The first-order rate constant, k, for the hydrolysis of TBP is 0.007 hr⁻¹ (0.17 day⁻¹).¹⁸

Rate of TBP hydrolysis for concentrations ≥ 16.0 mg/L (solubility limit):

$$\ln \frac{[\text{TBP}]}{[\text{TBP}]_0} = -kt$$

$$[\text{TBP}] = [\text{TBP}]_0 e^{-kt}$$

$$[\text{TBP}] = (16.0)e^{-.007(1 \text{ hr})}$$

$$[\text{TBP}] = 15.89 \text{ mg/L}$$

$$\Delta[\text{TBP}]/\text{time} = (16.0 - 15.89) / 1 \text{ hr}$$

$$\text{rate of TBP hydrolysis} = 0.11 \text{ mg/L soln} \cdot \text{hr}$$

Volume % 1-butanol produced per minute:

$$\frac{0.11 \text{ mg}}{\text{L soln} \cdot \text{hr}} \times \frac{1 \text{ g}}{1000 \text{ mg}} \times \frac{1 \text{ mole TBP}}{266.3 \text{ g TBP}} \times \frac{3 \text{ moles 1-butanol}}{1 \text{ mole TBP}} \times \frac{1 \text{ hr}}{60 \text{ min}} =$$

$$= 2.1 \times 10^{-8} \text{ moles 1-butanol / L soln} \cdot \text{min}$$

Using the Ideal Gas Law, $PV = nRT$, allows for the conversion of moles 1-butanol produced per minute to volume of 1-butanol produced per minute.

$$V = \frac{(2.1 \times 10^{-8} \text{ moles/L soln} \cdot \text{min})(0.08205 \text{ L} \cdot \text{atm/mole} \cdot \text{K})(298 \text{ K})}{1 \text{ atm}}$$

$$V = 5.1 \times 10^{-7} \text{ L 1-butanol / L soln} \cdot \text{min}$$

Assuming Tank 22 contains 668 kgal (2,528,000 L) of wash water, the amount of 1-butanol produced per minute would be:

$$V = (5.1 \times 10^{-7} \text{ L 1-butanol / L soln} \cdot \text{min})(2,528,000 \text{ L soln})$$

$$V = 1.3 \text{ L 1-butanol / min}$$

Given the ventilation air flow of Tank 22 is 8500 L / min, then the volume % of 1-butanol capable of being produced would be:

$$\text{Volume \% 1-butanol} = \frac{1.3 \text{ L 1-butanol / min}}{8500 \text{ L air / min}} \times 100 \%$$

$$\text{Volume \% 1-butanol} = 0.015 \%$$

This is 1.0 % of the LFL for 1-butanol. Based upon the rate of volume of 1-butanol produced per minute, the time to reach LFL would be 18.5 days in the event ventilation was lost.

Distribution:

86001

11/27/75

- G. T. Wright, 5002H
- H. M. Handfinger, 5002H
- J. P. Morin, 719-4A
- R. G. Croley, 241-120H
- R. K. Roosa, 241-121H
- J. N. Brooke, 241-119H
- R. A. Scaggs, 703-H
- W. B. Van Pelt, 241-152H
- C. L. Leung, 241-154H
- J. E. Marra, 703-H
- M. C. Chandler, 703-H
- D. A. Pervis, 241-121H
- G. K. Georgetown, 703-H
- T. P. Gaughan, 241-152H
- W. L. Tamosaitis, 773-A
- M. K. Gupta, 992W-1
- J. P. Bibler, 773-A
- D. D. Walker, 773-A
- D. T. Hobbs, 773-A
- R. F. Swingle, 773-A
- J. F. McGlynn, 676-T
- D. J. McCabe, 676-T
- L. L. Kilpatrick, 676-T
- M. L. Meyer, 676-1T
- R. H. Hsu, 773-43A
- C. A. Langton, 773-43A
- L. F. Landon, 704-T
- J. C. Marek, 704-T
- M. A. Baich, 704-T
- WT-LWG Files, 773-A
- TIM, 703-43A

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