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CSTF Corrosion Control Program

Program Description Document

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Summary of Revisions

2/14/03 -	Revision 0; Initial Issue
3/5/03 -	Revision 1; Addition of "Sampling Methodology" reference [75]; new wording regarding output documents.
5/7/03 -	Revision 2; Addition of wording to allow engineering evaluations to extend the 45 day limit on restoring chemistry in a waste tank. Change to Table 5 to better clarify meaning; Rewording of sentences describing temperature monitoring to show that evaporator drop tank's supernate phase temperature monitoring has been excluded
11/17/04	Revision 3; Addition to allow 30 day grace period for sample frequency and time allowance for sample analysis and results incorporation into WCS; Addition of sample analysis tracking in the ERD.

Glossary of Terms

Active Waste Tank – a tank that has received a waste transfer within the past year, is available to receive a waste transfer at any time, or is being slurried

Inactive Waste Tank – a tank that has not received a waste transfer within the past year, nor is in the process of being slurried

Slurried Waste Tank – a tank that has had slurry pumps/mixers operate for a minimum of 3 hours at or above the minimum speed within the previous 30 days

Receiver Waste Tank –an active tank that is not slurried, undergoing salt processing, nor is an evaporator feed or drop tank.

Salt Processing Tank – a tank undergoing processes designed for the ultimate removal of salt from the tank inventory (eg., salt dissolution, interstitial liquid removal, etc.)

Dry Waste Tank – a tank that contains salt and/or sludge, but has an inadequate amount of free supernate to allow sampling for analysis

ERD – Emergency Response Datasheet (N-ESR-G-00001)

WCS – Waste Characterization System
(WG08/Waste8/HLCATS/WCSystem/WCSystem)

Stress Corrosion Cracking (SCC) – cracking caused by the simultaneous presence of tensile stress, a specific corrosive medium, and sufficiently high temperature

Nitrate SCC – cracking due to sodium nitrate and the other two factors

Caustic SCC – cracking due to sodium hydroxide and the other two factors

Pitting – an extremely localized intense form of corrosion that may result in perforation with only a small amount of general wall thinning of the structure. Failures often occur suddenly.

1.0 SAFETY FUNCTION

The safety function of the CSTF Corrosion Control Program is to ensure that all safety related equipment in the tank farms is protected against corrosion, both stress corrosion cracking and pitting, so as to preserve the integrity of each component. Most of the controls listed in this document deal solely with the condition of a waste tank; however, since this program controls the chemistry and temperature of all waste in the tank farms, it protects all safety-related equipment in the tank farms' transfer paths from corrosion. In addition, controls are listed which protect the evaporator tube bundle in the event the tube bundle is not covered by waste.

This program does not necessarily but can, as directed by management, apply to tanks in the "Removed From Service" mode. This program does not apply to "Closed" tanks.

2.0 PURPOSE

The purpose of this program description document is to provide background information and describe the key attributes of the CSTF Corrosion Control Program.

3.0 KEY ATTRIBUTES

In order to protect the safety-related equipment, there are several attributes of this program that are necessary; they are as follows:

1. **Temperature** – the corrosion control program sets temperature limits, which, if followed, will ensure that corrosion degradation, is minimized.
   - Based on tank chemistry
   - Specific for each phase (i.e., sludge/salt, supernate, and steel wall)
   - Temperature is periodically checked using representative thermocouples placed in various places in each waste phase within the waste tanks

2. **Chemistry** – the corrosion control program requires minimum concentrations of inhibitor to be present for corresponding amounts of corrosive species in waste to prevent corrosion.
   - Actual tank chemistry is obtained through periodic sampling – sampling schedule based on tank chemistry / use of tank is specified by the program
   - Tank-to-tank transfers are evaluated to ensure chemistry is kept within limits
   - Water Additions to Waste Tanks – the corrosion control program sets limits on how much water can be added to a waste tank over certain time intervals based on the concentration of the inhibitor in the tank
   - Microbiologically Induced Corrosion (MIC) – this program addresses the potential for and lists mitigative actions to preclude MIC.

- Evaporator Tube Bundles – this program ensures that the evaporator tube bundles are kept from conditions that would lead to corrosion.

- Chromate Cooling Water – this program outlines the method to minimize the failure of cooling coils due to corrosion.

3. **Humidity** – the corrosion control program requires the operation of annulus ventilation in order to keep the annulus dry.
   - Steam is supplied to the pre-heater so that dry air is circulated through the annulus.
   - A conductivity probe, or an acceptable alternate (e.g., dip tube), in each annulus alerts operations if any liquid is detected in the annulus

4.0 BACKGROUND

The Corrosion Control Program is included in a list of general controls in Section 3.4.1.5.6 of the Documented Safety Analysis. The current Corrosion Control Program, established in G-TRT-G-00003, Appendix 6 [66], has been preserved in this document, although the means of implementation have been changed slightly.

The time limits given for the completion of a compensatory action or the monitoring frequency are all based on the desire to stop the initiation of corrosive reactions when possible and retard corrosion if it is initiated, while at the same time realizing the time needed to perform various corrective actions. Since the end results of corrosion are grave, the corrective actions to remove an environment conducive to corrosion from the tank farm must be pursued with speed and diligence. With this philosophy in mind, the time limits were established, based on the estimated time that various actions could reasonably be performed.

Temperature Control

Note that the temperature limits given below do not account for uncertainties in temperature, however the limits are not precise enough to cause concern over instrument uncertainty.

The supernate temperature limits were established to prevent the initiation of stress corrosion cracking and pitting of the tank walls and cooling coils and to minimize the propagation of cracks that are already present. The maximum salt/sludge and steel wall temperature limits were established to maintain a liquid phase, which contains sufficient corrosion inhibitors, in continuous contact with the tank wall. The temperature limits dictated by this program are more restrictive than those required to maintain the structural integrity of the tank [67], although other factors may necessitate even lower temperature limits.

Waste tank contents are considered to exist in three phases: supernate, sludge, and salt. The supernate phase consists of water, dissolved material (primarily dissolved salts such as $NaNO_2$, $NaNO_3$, and NaOH), and suspended particles (including sludge particles suspended due to slurry pump/mixer operation). The sludge phase consists of settled sludge particles and interstitial supernate. The salt phase consists of the precipitated solid salts and interstitial supernate.

The basis for the temperature limits is discussed in-depth in Reference 1. In order to ensure temperature monitoring is available, the Corrosion Control Program requires that there be at least one functional TC to monitor each applicable waste phase and the steel wall for waste tanks, **with the exception of the supernate phase in evaporator drop tanks.** The TC monitoring the steel wall temperature for Type I, II, and III tanks must be within three feet of the bottom knuckle weld (this requirement is not applicable to Type IIIA tanks).

Introducing a New Supernate Phase

When a new supernate phase is established in a sludge or salt tank, the requirement to have at least one functional TC for the new supernate phase shall be met within 5 days after sufficient liquid has been added to the tank to cover the lowest available thermocouple. The determination that sufficient liquid has been added to cover the lowest available thermocouple (and therefore the 5-day period to perform the monitoring has started) may be made by direct measurement of tank liquid level or by evaluation of liquid volumes added to the tank (e.g., from tanker trucks, IW tank, waste transfer).

There is no requirement to stop liquid additions at the point where the lowest thermocouple is just under the liquid surface in order to perform applicable monitoring. It is preferable to continue liquid additions until a process-related stable stopping point is reached. Filling the tank with several hundred thousand gallons (as part of the initial addition or a subsequent addition) prior to performing the applicable thermocouple monitoring is acceptable as long as temperature of the liquid added is below the supernate temperature limit expected to exist after the additions.

Concentrated Supernate Limits

The recommended supernate temperature limits in Table 1 are for concentrated wastes (i.e., nitrate concentration greater than 1 molar) and are dependent on the molar concentration ratio (R) of the inhibitor species (e.g., nitrite and hydroxide) to the corrosive species (e.g., nitrate). For concentrated wastes, the ratio (R) of the hydroxide and nitrite concentrations to the nitrate concentration was observed to be an indicator of waste corrosivity [2]. Stress corrosion cracking is the primary degradation mechanism for this case. From Table 1 it is shown that the two limits are 70°C when R is less than 2.0 (except when the nitrate concentration is between 2.75 M and 5.5 M, then the boiling point is the limit) and the boiling

point when R is greater than 2.0. These limits are based on extensive laboratory testing and analysis of process history [3]. Due to the various waste tank compositions, the boiling point temperature differs from tank to tank. However, over a significant concentration range the boiling point differs by only a few degrees. An equation was developed to calculate the boiling point given the total molarity of the waste [3].

$$T_{bp}\,(^{\circ}C) = 100 + (\text{total molarity}) * 1.03\,^{\circ}C\text{-liter/mole} \qquad (1)$$

For cases where R was greater than 2.0, the equation was utilized to determine the average boiling point for the nitrate concentration ranges 1 to 2.75 molar and 2.75 to 5.5 molar. The 5.5 to 8.5 molar nitrate concentration range was not considered due to solubility limitations. The boiling point was calculated in the following manner. It was assumed that since the primary components of the waste were nitrate, nitrite, and hydroxide, that the sum of these three molar concentrations could be utilized to determine the total molarity. The boiling point temperature was first determined at the lower end of the concentration range assuming that R was 2. For example, if the nitrate concentration is 1 molar, the sum of the hydroxide and nitrite concentrations would be 2 molar, and thus the total molarity would be 3 molar. Substituting this value into Equation 1 gives a calculated boiling point of 103°C. Performing a similar calculation using a nitrate concentration of 2.75 M, an estimated boiling point of 108°C is obtained. The average of these two temperatures is 105°C. A temperature of 105°C was determined to be an acceptable limit for wastes within this supernate concentration range. The same assumptions and calculations were made for the nitrate concentration between 2.75 to 5.5 M. In this case the average estimated boiling point was 112°C.

Sludge/Salt/Steel Wall Limits

The temperature limits (see Table 2) for the salt and sludge phases (T_{ss}) and the steel wall (T_w) are based on maintaining a liquid phase, containing inhibitors, at the tank wall. The composition of the interstitial liquid in the salt and/or sludge, and hence the liquid which is in contact with the bottom and wall of the primary, is not completely known. However, laboratory tests and analysis of actual interstitial liquid have shown that for saltcake the R ratio is much greater than 2 [4]. The interstitial liquid present in sludge has also been characterized [5]. In general, the nitrate concentration in the supernate above the sludge was greater than that observed in the sludge interstitial liquid. It is likely that the nitrate concentration decreased due to ionizing radiation that converts the nitrate to the inhibitor species nitrite. Thus as the sludge ages, the R factor of the interstitial liquid increases indicating a decrease in the corrosivity of the liquid. For these reasons the temperature limits for the salt/sludge and the steel wall is the boiling point for a particular waste concentration.

The tank steel wall temperature limits apply to Type I, II, III and IIIA tanks. If the temperature were greater than the solution boiling point, it would be possible to produce nitrate-rich salt deposits on the tank wall [6]. As the waste ages and cools, there could be gradual intrusion of water vapor or supernate into the deposit. The resulting solution may have high local concentrations of nitrate ion. The effects of this condition on either nitrate or hydroxide stress corrosion cracking cannot be predicted or simulated because of its complexity. The maximum temperature limits prevent the occurrence of this phenomenon.

The static head of the waste above the location of the thermocouples that measure T_{ss} and T_w elevates the boiling point temperature above the atmospheric supernate boiling point temperature [7]. The boiling point temperature elevation is calculated on the basis of the volume and the specific gravity of the waste in each tank [8]. The Clausius-Clapeyron equation relates the boiling point elevation to the static head pressure due to the liquid depth. In general, most of the concentrated wastes (nitrate > 1 molar) have a specific gravity greater than 1.25. If a tank contains 120 inches of free supernate, the total pressure at a level 120 inches below the top of the supernate due to the liquid head, assuming a specific gravity of 1.25, is 20.1 psia. Substituting this pressure into the Clausius-Clapeyron equation, a boiling point elevation of 10°C is calculated. Therefore, it is recommended that the temperature limit for T_{ss} and T_w be determined not only by the supernate boiling point temperature but also the depth of free supernate. If the depth of free supernate is greater than 120 inches, the temperature, T_{ss} and T_w, limits shall be 10°C greater than the boiling point of the supernate. Depending on the composition of the supernate, these temperatures would be either 115°C or 122°C. If the depth of free supernate is less than 120 inches, T_{ss} and T_w limits shall remain the same as the boiling point of the supernate. In many cases, this is a conservative approach (i.e., the boiling point is actually higher) as the amount of free supernate in a tank is much greater than 120 inches. If the temperatures measured by the thermocouples rise to near these boiling point values, a more rigorous calculation should be performed. This calculation would involve determining the exact position of the thermocouple relative to the waste level. The boiling point elevation can be determined accurately from the Clausius-Clapeyron equation. The simplified approach to be implemented eliminates the difficulty of determining the elevation difference between the top of the supernate and the thermocouple that is being utilized to measure the temperature.

Supernate and Sludge/Steel Wall Temperature Limits for Supernate with Low Nitrate Concentrations

At nitrate concentrations less than 1 molar the predominant corrosion mechanism is pitting. There are two regions of the tank where pitting is a concern. The first region occurs at the vapor/liquid interface. Here a thin wetted film forms on the tank wall above the liquid level [9]. This film absorbs carbon dioxide that reacts with the hydroxide to form carbonate and bicarbonate. Unless there is sufficient hydroxide or nitrite in the bulk waste to replenish this film with inhibitors by diffusion processes, this layer becomes uninhibited and pitting results.

The second area is in the walls in contact with the bulk liquid. Depletion of hydroxide is slower in the bulk liquid than for the thin film, however, given enough time it will occur here also. Tanks that have a small volume of waste or low hydroxide concentration are most susceptible to inhibitor depletion [10]. The temperature limits are summarized in Table 3.

There are two schemes for inhibiting nitrate induced pitting: 1) sodium hydroxide alone, or 2) sodium nitrite with a minimum hydroxide level. If the hydroxide concentration is greater than 1 molar the sodium hydroxide scheme has been selected. Laboratory tests have shown that no pitting is observed in simulated dilute waste that contains greater than 1 molar hydroxide [11, 12]. A theoretical model also demonstrated that a minimum hydroxide concentration of 1 M is sufficient to maintain a minimum pH of 12 in the wetted film region [9]. At high hydroxide concentrations stress corrosion cracking may become a concern. In hot caustic solutions carbon steel may become susceptible to caustic stress corrosion cracking.

Laboratory testing was performed in simulated wastes that contained between 1 to 8 molar sodium hydroxide, 0.02 to 1.0 molar sodium nitrate, and at temperatures between 50 to 100°C [13, 14]. The results of the tests demonstrated that the presence of a small amount of nitrate was enough to prevent caustic cracking within these environmental conditions. If less than 0.02 molar nitrate is present there is a potential for caustic cracking at high temperatures. Therefore, for nitrate concentrations less 0.02 molar the temperature limits were set at 60°C. If the hydroxide concentration exceeds 8 molar, the carbon steel may again become susceptible to caustic stress corrosion cracking. Therefore, for this case, the temperature limits are also 60°C. Otherwise a temperature of 100°C may be utilized for the temperature limits. The temperature limits for tanks that meet these hydroxide concentration conditions were based on the criteria that the liquid would always have sufficient inhibitor to prevent attack at temperatures less than 40°C. The establishment of these corrosion inhibitor concentration criterion determines when inhibitor additions shall be performed. The 40°C temperature is sufficiently above the normal operating temperature (i.e., 18 to 32°C) of the tanks which contain dilute waste, while at the same time not resulting in the addition of excess inhibitor.

The primary aggressive species in dilute solutions is the nitrate anion [15], although at very dilute nitrate concentrations, the chloride or sulfate ion may become the aggressive species [16]. There are four possible conditions in the dilute waste: 1) the waste has aggressive anion concentrations less than 0.01 molar, 2) nitrate is the aggressive species, 3) chloride is the aggressive species, and 4) sulfate is the aggressive species. From these equations the minimum ratio of the nitrite to aggressive species, A, can be calculated for a waste at 40°C. These ratios and the constant values for each condition, MIN, are shown below.

A <0.01 M: $[NO_2^-] = 0.0161$ (2)

Nitrate: $[NO_2^-]/[NO_3^-] = 1.61$ (3)

Chloride: $[NO_2^-]/[Cl^-]^{1.34} = 287$ (4)

Sulfate: $[NO_2^-]/[SO_4^{=}]^{0.84} = 1.77$ (5)

A review of these equations showed that if any one of these requirements is violated, then inhibitor shall be added to the waste. The maximum value obtained from these equations determines the minimum nitrite concentration. The amount of nitrite added to the waste shall correspond to the value from the equation in which the requirement was violated, or if more than one requirement was violated, the value from the equation which calculates the largest nitrite concentration.

The sludge phase limits discussed above are primarily for tanks that have concentrated waste. For tanks with dilute waste that contains sludge the sludge/salt temperature limit is 75°C. The concern is that areas of localized high temperature will develop and result in regions that are uninhibited against pitting. Laboratory tests have shown that as long as the temperature in the lower region of the tank is less than 75°C and the bulk supernate concentration of the aggressive anion is greater than 0.01 M no pitting occurs [17].

Slurried Waste Tank Limits

Table 4 applies only to slurried waste tanks. The bases for the temperature limits in Table 4 are primarily the same as the bases for Table 3. The only difference between the two tables is the supernate temperature limit when the hydroxide concentration is less than or equal to 1 molar.

Waste removal operations have significant impact on the chemistry and temperature of the supernate. During these operations an inhibited solution, either inhibited water or dilute supernate from another waste tank, is added to the tank undergoing waste removal. This mixture is then agitated with a single or multiple slurry pumps. The supernate chemistry will be impacted as sludge particles are suspended, salts are dissolved, and interstitial liquid from the sludge is mixed with the inhibited solution. The temperature of the supernate will also gradually rise as mechanical energy from the pump is dissipated in the waste tank. The temperature limit for the bulk supernate during slurry pump operation shall be 75°C for supernate with a nitrate concentration less than 1 molar and a hydroxide concentration less than or equal to 1 molar. Laboratory tests showed that if the bulk solution is inhibited with greater than 0.01 molar sodium hydroxide, pitting does not occur below this temperature [17]. The agitation also prevents the occurrence of inhibitor depletion in the thin film above the liquid vapor interface [9]. The supernate in a waste tank is considered to be adequately mixed for the application of these higher temperature limits after at least one slurry pump is operated at or above its normal minimum speed for at least 3 continuous hours in the past 30 days (turntable is not required to be rotating). The 3-hour operating

time period is based on past operational experience, which indicates that the surface of the liquid is sufficiently agitated within the first 3 hours of pump operation (seen on videotapes of slurry pump operation as well as past experience with Tank 8). Once the pump operations have ceased, the temperature limit for the supernate shall remain at 75°C for no longer than 30 days, as pit growth would be assumed to be minimal for this period. However, after 30 days the tank shall be considered to have returned to a "non-slurried" condition. Temperature limits will then be governed by the chemistry of the waste per Tables 1 through 3 of this control program as appropriate [18].

Over the years, the supernate in several waste tanks has been allowed to evaporate, leaving either a saltcake or sludge layer phase. Although there is no supernate above, these phases may contain interstitial liquid that may cause a corrosion concern. Due to the various mechanisms of concentration and depletion that can occur in the interstitial liquid, the composition of the interstitial liquid is difficult to predict. A conservative estimate of the interstitial liquid concentration is that it has the same composition as the supernate that was above the sludge or salt layer prior to the time when the tank became "dry". The actual hydroxide concentration of the interstitial liquid is probably higher due to evaporation of the water from the interstitial liquid. Therefore, the composition results from the most recent sample that was obtained will be utilized to estimate the composition of the interstitial liquid, and hence to determine the temperature limits. Based on these compositions, Table 2 shall be utilized to determine the sludge/salt phase and steel wall temperature limits in dry waste tanks. If the tanks are re-wetted, an engineering evaluation shall be performed to determine the new temperature limits.

The temperature at the tank exterior surface will be held at least 5°C below the boiling point of the solution. This temperature differential accounts for the maximum temperature drop across the steel wall of < 1°C [20]. This applies only to Types I, II, III and IIIA waste tanks since the Type IV tanks do not have steel wall thermocouples. The waste in Type IV tanks are low heat and therefore do not present a credible potential to boil waste; controls placed by the DSA on the waste entering Type IV tanks will ensure that this remains true. In addition, other required thermocouples in Type IV waste tanks will be monitored to ensure that waste does not reach its boiling point.

Chemistry Control

The corrosion inhibitor limits (hydroxide and nitrite) in Table 5 were established to minimize or prevent the corrosion of waste tank walls and cooling coils. The limits are based on experimental data developed at SRS. Samples of the waste are taken periodically to determine whether or not the tank is within the corrosion inhibitor limits (see Table 6 and Table 7). The bases for determining the sampling frequency is discussed as well as the requirements for sampling after a waste transfer.

The application of these corrosion inhibitor limits have successfully stabilized and minimized the stress corrosion cracking (SCC) of waste tank carbon steel walls experienced in the early days of SRS and pitting identified in laboratory tests somewhat later. These are the two major corrosion failure modes expected in SRS waste tanks and cooling coils. Since controlled inhibitor addition began in the mid-1970's, there have been no reports of SCC or evidence of it in the stress-relieved Type III and IIIA tanks. The frequency of cooling coil failures has also been minimized (although it is possible that not all cooling coil failures are related to the waste chemistry).

Compliance with these limits may not totally eliminate the potential for cracking of a waste tank. Cracking may occur below the specified temperature as result of concentrations of NO_3^-, NO_2^- and OH^- within the specified limits because of flaws in the metal, stress concentrations, or crevice formations. Cracking may also occur as a result of other corrosion mechanisms involving unknown contaminants that could conceivably be in a waste stream.

The chemistry controls ensure that SCC and pitting of the waste tank walls and cooling coils are stabilized, minimized and/or prevented. Corrosion control by addition of chemical inhibitors is the primary means of corrosion mitigation and also the result of continuously diligent and effective research over approximately 40 years. Table 5 summarizes the corrosion inhibitor limits. The primary corrosion inhibitors that are utilized are sodium hydroxide and sodium nitrite, while the primary aggressive species is the nitrate anion. The next sections describe the bases for each of the limits. Temperature limits associated with the various waste chemistries are described in the temperature control section of this document.

Limits 1 to 3 (Table 5):

Carbon steel exposed to alkaline solutions has a low general corrosion rate [21]. However, the presence of the nitrate anion may induce various forms of localized attack (i.e., SCC, pitting, etc.) even in these environments. It has been postulated that cracks are initiated at carbon present in the solid solution or Fe_3C at the grain boundary [22]. Cracks propagate along the grain boundaries of a material as the tensile stress maintains a crevice where the solution remains aggressive towards the metal. The corrosion rate is influenced by the nitrate reduction kinetics as shown in the equation below [23].

$$NO_3^- + H_2O + 2e^- = NO_2^- + 2\,OH^- \quad (1)$$

Nitrate is more easily reduced as the solution becomes more acidic. Work at the Naval Research Laboratory has shown that during cracking the solution at the crack tip is approximately pH 3 [24], which is significantly different from the bulk pH. Equation 1 shows that adding hydroxide and/or nitrite anions will reverse the equilibrium of the reduction reaction. Therefore, these anions are useful corrosion inhibitors. Laboratory tests on carbon steel were performed to determine the appropriate combination of inhibitors that would prevent the

initiation of new cracks and mitigate the propagation of the current cracks [25-27]. Limits 1 to 3 are based on these tests.

As the NO_3^- concentration increases from 1 to 2.75 M, the susceptibility to nitrate SCC increases, and higher concentrations of inhibitors are required [28]. The inhibitor concentration is directly proportional to the nitrate concentration. The presence of = 0.3 M OH^- and = 1.1 M of $OH^- + NO_2^-$ will inhibit nitrate cracking in wastes containing 2.75 to 5.5 M NO_3^-. From 5.5 to 8.5 M NO_3^-, inhibitors at = 0.6 M OH^- and = 1.1 M of $OH^- + NO_2^-$ will be sufficient to prevent nitrate SCC.

Limits 4 and 5 (Table 5):

The nitrite and hydroxide minima are specified to minimize the potential for pitting corrosion of the carbon steel tank walls and cooling coils. The inhibitor concentration limits are based on either hydroxide alone or nitrite with a minimum pH level to inhibit pitting [29-32]. The discontinuity between the 3 and 4 hydroxide limits is due to a change in corrosion mode from SCC to pitting corrosion, and to the conservative approach taken for 4 and 5 to account for the limitations in the available data on which the standard can be based.

Pitting has not been a problem at hydroxide concentrations greater than 1 molar in over 40 years of experience in the tanks. No pitting is observed at 1 molar hydroxide ion for any of the diluted waste solutions tested [33,34]. A theoretical model indicates that a hydroxide minimum of 1.0 M is sufficient to maintain a minimum pH of 12 in most of the aqueous film [35]. Lower hydroxide concentrations in the film are probably sufficient to protect the steel, especially when nitrite is present. However, there are not sufficient data available to specify a lower hydroxide ion concentration in the bulk solution that will provide adequate protection throughout the film.

The nitrite minimum is based on the concentration required to inhibit pitting of the tank wall or cooling coils in an aqueous film which has reached a steady state pH [29, 31, 32, 36]. The nitrite requirements include a 50% safety margin to account for both the increased requirements when processing worst-case (most corrosive) salt solution, for local variations in waste composition and for differences between actual waste and the laboratory simulants.

The inhibitor levels specified in limits 4 and 5 are based on the aqueous phase reaching steady-state with respect to the absorption of atmospheric carbon dioxide. Alkaline solutions absorb and react with carbon dioxide to produce bicarbonate and carbonate [37]. The steady state pH depends on the initial hydroxide and carbonate levels in the waste and carbon dioxide concentration in the air. The lowest steady-state pH which has been tested is pH = 10.3 [32, 38] and is the minimum specified for all nitrate concentrations below 1 molar. At nitrate concentrations between 0.02 to 1.0 molar, the nitrite concentrations specified by in 4b are sufficient to inhibit corrosion only if the solution pH does

not fall below the steady state value of 10.3 [29]. A pH lower than this could put the tank in a regime where adequate protection against pitting is not provided by the nitrite level specified in 4b and 5b [29].

The inhibitor requirements specified in limits 4 and 5 are based on a supernate temperature of 40°C (see background of temperature control). Pitting of carbon steel is worse at temperatures greater than the maximum allowable and greater concentrations of inhibitors would be required for prevention.

In general, the nitrate anion is the aggressive species that causes pitting. However, in very dilute solutions, sulfate or chloride, may become the species that is aggressive [39]. Minimum nitrite concentrations as a function of chloride or sulfate concentration in the supernate are represented by limits 4c and 4d, respectively. A review of limits 4b-d demonstrated that the solution is always inhibited if it contains the maximum value of nitrite calculated from the three equations [40]. For example, if the nitrite concentrations calculated from each equation are 0.5, 0.01, and 0.04 molar for nitrate, chloride and sulfate, respectively, the minimum nitrite required for the supernate would be 0.5 molar. Therefore, the maximum value obtained from limits 4b, 4c, or 4d shall be utilized to determine the minimum nitrite concentration required to inhibit a dilute solution. Similarly, if the nitrate concentration is less than 0.02 molar, the maximum value obtained from **limits 5b if the concentrations of the nitrate, chloride, and sulfate anions are not known, or 5c, 5d or 5e shall be utilized to determine the minimum nitrite concentration required if the concentrations of these constituents are known.**

pH limit (Table 5):

This limit ensures that waste from other areas on site, that would rapidly corrode a carbon steel tank or cooling coils if not thoroughly mixed with waste already in the tank, is not routinely added to the waste tanks [41]. Waste that is acidic (pH < 7), could cause severe corrosion damage to parts of the waste tank or cooling coils when it comes in contact before being mixed with alkaline tank contents. The waste acceptance plan has specified pH 9.5 to allow a safety factor above pH 7 to account for field measurements, which although accurate, may not be precise. The limit does not apply to raw water (pH 4 to 5) used for line flushing.

Sampling Frequencies (Tables 6 and 7):

The sample frequencies in Table 6 are set based on a statistical analysis of the historical corrosion chemistry sample data of the tanks in each category [51] and on an understanding of mechanisms that may change the concentrations of either aggressive or inhibitor species (e.g., hydroxide depletion) [50]. The frequencies in Table 6 may be used for any tank. Tanks that have a sample history of at least 15 samples since the last inter-tank transfer OR since waste was last slurried in the tank, may qualify for further extension of sampling frequency as described in the Notes for Table 6 and as specified in Table 7.

A 30 day grace period is permitted in the sample frequency specified in Tables 6 and 7. Sampling results shall be incorporated into the Waste Characterization System (WCS) within 90 days of the date the sample was taken. A 30 day grace period is permitted in the time allowance for sample result incorporation into WCS. A sampling methodology has been documented that describes the types and locations of various samples needed to comply with this and other PDDs [75].

1. Active Tanks

1.a. Evaporator Feed and Drop Tanks

The sample frequency for active evaporator feed and drop tanks shall not exceed 6 months. The relatively frequent transfers into these tanks from several different sources (canyons, DWPF, etc.) may result in significant changes in the corrosion chemistry that need to be trended. Models for hydroxide depletion indicate that for dilute solutions (i.e., nitrate concentration is less than 1 molar) the hydroxide concentration can deplete to the steady state pH level of 9.5-10.3 within 3 to 6 months [50]. Therefore tanks with these composition ranges shall be sampled every 3 months. Models for hydroxide depletion in tanks with concentrated wastes (nitrate greater than 1 molar and hydroxide greater than or equal to 2.35 molar) indicate that at high hydroxide concentrations will take more than 5 years to attain the steady state pH level [50]. Therefore a six-month sample frequency that will monitor changes in the chemistry due to waste transfers will be sufficient for the more concentrated wastes.

1.b. Fresh Canyon Waste Receiver with Nitrate Concentration Greater Than or Equal to 1 Molar

Fresh canyon waste receivers were separated out as a special case waste receiver. Previous service history show that these tanks, in addition to having relatively lower inhibitor concentrations compared to other waste receivers, also historically have higher temperatures. The higher temperatures result in a greater susceptibility to corrosion degradation mechanisms. Therefore, the sample frequency shall not exceed 12 months. If the hydroxide concentration is less than 3 M, or the total inhibitor concentration is less than 4 M, the tanks will be sampled on a 6 month frequency.

1.c. Receivers with Nitrate Concentration Less Than 1 Molar

The ratio of the concentration of nitrate to nitrite typically determines whether dilute wastes are within corrosion chemistry limits. The statistical analysis of the historical sample data was utilized to establish the frequencies shown in Table 2.6.2-2. The hydroxide depletion models were reviewed to confirm that these frequencies were adequate. If the hydroxide concentration is less than 2.35 M, depletion models indicate that the steady state pH may be attained within a year [50]. Therefore the 3 and 6-month frequencies are justified. On the other hand, if

the hydroxide concentration was greater than 2.35 M, it will take more than 5 years to attain the steady state pH. Therefore, the 12-month frequency is justified. Dilute wastes may also be inhibited with 1 molar sodium hydroxide per Table 5. Models for hydroxide depletion predict that solutions with high hydroxide concentrations (greater than or equal to 2.35 molar) will take more than 5 years to attain the steady state pH [50]. An exception to these frequencies may occur at very dilute solutions (i.e., nitrate concentrations on the order of 0.01 M). If the chloride or sulfate species becomes the aggressive species rather than the nitrate, the sample frequency will be 3 months. Which species is aggressive can be determined by calculating the minimum nitrite level for each of these species and then determining which species requires the maximum amount of nitrite. The equations for the minimum nitrite calculations are shown in Table 5. The nitrate will be the most aggressive species except in some rare cases of dilute waste.

1.d. Receivers with Nitrate Concentration Greater Than or Equal to 1 Molar

Inhibition of concentrated wastes (nitrate greater than or equal to 1 molar) is achieved with a minimum hydroxide concentration and the combination of hydroxide and nitrite concentrations (see Table 5). Statistical analysis of the sample data was utilized to determine the frequencies based on the risk of being outside the corrosion chemistry controls [51]. The hydroxide depletion models were reviewed to confirm that these frequencies were adequate. If the hydroxide concentration is less than 2.35 M, depletion models suggest that the steady state pH may be attained within a year. Therefore 6 months is an adequate sample frequency. For hydroxide concentrations greater than or equal to 2.35 M, the steady state pH level will not be attained for more than 5 years [50]. Therefore these tanks may be sampled on a 12 or 24 month basis as determined by Table 6.

1.e. Slurried Tanks

Due to the potential for changing the concentration during slurrying operations, samples shall be taken once a month to verify that the waste remains within corrosion chemistry, unless an engineering evaluation shows that a longer frequency is acceptable.

1.f. Salt Processing Tanks

The study of conditions present in tanks containing salt was instrumental in forming the basis for this program. Therefore, all limits listed in this program apply to salt processing tanks as if they were any other active tank. Salt processes are those operations taken to prepare for and perform salt disposition and may include, but are not limited to, salt dissolution and interstitial liquid removal.

2. **Inactive Tanks**

2.a. Receivers with Nitrate Concentration Less Than 1 Molar

Inactive tanks have not received any transfers for over a year. Thus any change in the supernate chemistry would be due to hydroxide depletion. The ratio of the concentration of nitrate to nitrite typically determines whether dilute wastes are within corrosion chemistry limits. The statistical analysis of the historical sample data was utilized to establish the frequencies shown in Table 6. The hydroxide depletion models were reviewed to confirm that these frequencies were adequate. If the hydroxide concentration is less than 2.35 M, depletion models indicate that the steady state pH may be attained within a year [50]. Given that there are no transfers into the tank within a year, the 6 and 12 month frequencies are justified. On the other hand, if the hydroxide concentration was greater than 2.35 M, it will take more than 5 years to attain the steady state pH. Therefore, the 24 month frequency is justified. Dilute wastes may also be inhibited with 1 molar sodium hydroxide per Table 5. Models for hydroxide depletion predict that solutions with high hydroxide concentrations (greater than or equal to 2.35 molar) will take more than 5 years to attain the steady state pH [50]. An exception to these frequencies may occur at very dilute solutions (i.e., nitrate concentrations on the order of 0.01 M). If the chloride or sulfate species becomes the aggressive species rather than the nitrate, the sample frequency will be 3 months. Which species is aggressive can be determined by calculating the minimum nitrite level for each of these species and then determining which species requires the maximum amount of nitrite. The equations for the minimum nitrite calculations are shown in Table 5. The nitrate will be the most aggressive species except in some rare cases of dilute waste.

2.b. Receivers with Nitrate Concentration Greater Than or Equal to 1 Molar

Inactive tanks have not received any transfers for over a year. Thus any change in the supernate chemistry would be due to hydroxide depletion. Inhibition of concentrated wastes (nitrate greater than or equal to 1 molar) is achieved with a minimum hydroxide concentration and the combination of hydroxide and nitrite concentrations (see Table 5).

Statistical analysis of the sample data was utilized to determine the frequencies based on the risk of being outside the corrosion chemistry controls [51]. The hydroxide depletion models were reviewed to confirm that these frequencies were adequate. If the hydroxide concentration is less than 2.35 M, depletion models suggest that the steady state pH may be attained within a year. Given that there have not been any transfers into this tank for over a year, 12 months is an adequate sample frequency. For hydroxide concentrations greater than or equal to 2.35 M the steady state pH level will not be attained for over 5 years [50]. Therefore these tanks may be sampled on a 24 or 48 month basis depending on the results of the statistical analysis and/or the guidelines established in Table 6.

3. Exceptions to the Sample Frequency Rules

1) Once the bulk waste in a tank has been removed as part of the closure process, an engineering evaluation shall be performed to determine if the tank may be

excluded from the sampling requirements shown in Table 6 and, in effect, fall outside the control of this program.

2) If a waste tank has been sampled 15 times since the last inter-tank transfer or since waste was slurried in the tank AND the statistical capability of the tank to meet minimum corrosion inhibitor limits (Sigma Level) can be established [44], the sample frequency for that tank may be determined using Table 7. If the frequency is extended using this provision, the extension will be documented in the ERD.

Vapor Space Corrosion

The possibility of corrosion occurring above the highest waste phase in the tank is a reality, although this phenomena has never been observed on the tank wall in any SRS waste tanks. Video inspections of the tanks and all other utilized monitoring activities have produced no evidence that corrosion in the vapor space of our tanks has taken place or is inevitable. Additionally, the required inhibitor levels and temperature controls for the waste in the tanks protects the tank wall near the vapor/liquid interface. SRS has insufficient data regarding corrosion above this point in a tank to understand the corrosion mechanisms that would take place, largely because this type of corrosion has never been observed; this lack of knowledge precludes the site from enforcing any meaningful preventative or mitigative controls. However, SRS is in the process of studying vapor space corrosion so that future controls may be proposed to prevent this corrosion possibility.

Water Additions

Small volumes of uninhibited water and aqueous solutions are occasionally added to the waste tanks. This program allows the addition of up to 3,000 gallons of water (e.g., flush water, uninhibited water, spring water, well water, and all other forms of water available to the tank farm) to a tank within 30 days without any corrective action. This is based on the fact that in the waste tanks, an addition of 3,000 gallons or less of water does not significantly change the inhibitor concentration of that tank's supernate, and within the given time, the inhibitor concentration from the supernate in the tank will diffuse into the water that has been added. In order to ensure this limit is not exceeded, the levels of each inactive tank will be evaluated every 30 days to ensure no unplanned addition of more than 1 inch occurred.

In order for water to be considered inhibited, it must be verified to contain greater than 0.01 M hydroxide and 0.011 M nitrite. All other water additions are considered uninhibited.

Small volumes of uninhibited water and aqueous solutions are occasionally added to the waste tanks. Sources of these additions include rainwater, sump solutions, transfer line flush water, and decontamination solutions. These additions

generally do not significantly alter the bulk chemistry of the waste already present in the tank. However, these additions increase the risk of corrosion near the vapor liquid interface. The difference in the densities of water and high level waste result in inadequate mixing of these solutions. Water additions to the tank are likely to separate and form a thin layer on top of the more dense bulk waste. During this time, solute concentrations in this layer are assumed to increase by diffusion only from the bulk waste. Because the water additions are likely to have pHs in the near-neutral range, the potential for corrosion does exist for a period of time before the concentration of inhibitors such as hydroxide and nitrite reach protective values in this added layer. Near-neutral pHs are well below the pH of 10 required to inhibit against pitting corrosion in pure water and the pH of 14 required for solutions containing corrosive anions, such as nitrate, sulfate, or chloride [53]. Water additions will remain corrosive until the required inhibitor concentrations are satisfied by diffusion from the bulk supernate into the addition layer. The inhibitor requirements for this layer were established as either 1M sodium hydroxide or a combination of 0.01M sodium hydroxide and 0.011 M sodium nitrite. These levels of inhibitor have been shown to prevent pitting attack in dilute wastes [5]. Although pit initiation and growth rates for carbon steel in alkaline solutions are not well established, the experience of cooling coil failures during sludge removal operations in the 1960s suggests that pit growth rates may be as high as 0.15 in/month [54]. Some period of time is required to initiate pits, and some pits may repassivate upon the establishment of inhibiting conditions. Diffusion calculations were performed to determine the largest water addition for which the required inhibitor concentrations are achieved at the top of the layer in a reasonable time frame.

If this limit (3,000 gallons) is exceeded or it is anticipated that it will be exceeded, an engineering evaluation for directions or remedial actions shall be performed as soon as practical [52]. The engineering evaluation will consider variables such as the bulk concentration of the waste in the tank, the source of the uninhibited water, and recent additions of uninhibited water to the tank in its recommendation.

Humidity Control

Based on a review of SRS meteorological data, obtained from the onsite weather services of the Atmospheric Technology Group, including the dew point temperatures in the tank farm over the time period from 2000 to 2002, it was concluded that if the lowest tank steel-wall temperature is above 40°C, steam is not required to protect the annulus. This review discovered that typically, the dew point does not go above 80°F. No recorded dew point over the past two years exceeded 100°F. Therefore, if the tank's lowest steel wall temperature is above 40°C (104°F), no condensation should occur in the annulus. However, if liquid is detected (from rainwater, etc.) in the annulus, steam shall be, if the steam supply is functional, supplied to the annulus until it is dried, regardless of the temperature of the tank wall.

For tanks with a low heat generation rate, continuous operation of the annulus ventilation system with steam on prevents condensation from forming on the exterior of the primary tank wall and the secondary pan or wall of double-walled tanks as well as evaporating any standing liquid from the annulus pan. Heat, provided by the steam, is utilized in the system to raise the temperature of the air, causing the relative humidity to decrease, and thus minimizes the potential for condensation. The presence of water in the annulus may cause significant corrosion of the tank walls. Occasionally the annulus ventilation system needs to be shutdown for repairs to supporting systems such as low pressure steam. This program places limits on the time which the annulus ventilation system may be shutdown. Provisions have also been made to operate the fans if steam is not available. During continuous operation in this mode, there is a risk that there will be periods of time when condensation and rainwater will accumulate and therefore over time the integrity of the tank will degrade due to corrosion. Long term operation in this mode is not recommended. The only limitation of utilizing the annulus fans with no steam is that the tank wall temperature must be greater than the nil-ductility transition temperature (NDTT) (see [67]). For tanks with a high heat generation rate, continuous operation of the annulus ventilation system (without steam on) removes excess heat from the tank. Due to the high temperatures near the bottom of these tanks, water typically would evaporate rapidly and be removed due to the circulation of the air.
The purpose of this requirement is to prevent corrosion degradation of the exterior primary wall, the secondary pan, and the secondary wall of the double wall tanks. The degradation may result in an inadvertent release of radioactive material to the surrounding environment. Operation of the annulus ventilation in high heat tanks lowers the temperature of the primary steel and thus minimizes the potential for corrosion degradation of the steel or thermal degradation of the concrete. The annulus conductivity probe, a safety-significant instrument detects standing liquid in the annulus. Operation of the annulus air with steam will evaporate the water and prevent corrosion of tank steel. After 30 to 40 years of operation with steam, insignificant degradation of the tank walls has occurred. Operation of the ventilation fans with no steam will evaporate some of the moisture and reduce the potential for production of nitric acid and is therefore better than not operating the fans at all. However, there is a risk that there will be periods of the year when condensation and rainwater will accumulate in the annulus, and therefore over time the integrity of the tank will degrade due to corrosion.

For tanks that have a low heat generation rate, continuous operation of the annulus ventilation system in the past has prevented excessive general corrosion of the primary or secondary tank walls. The intent of this program is to prevent shut-down of the tank annulus ventilation systems for extended time periods. The annulus ventilation system, operated with steam, provides warm air to the annulus that minimizes the accumulation of moisture. Moisture in the annulus causes four concerns for the annulus integrity, (i) for cracked tanks, the moisture will dissolve salt deposits covering the leaksites and allows for intrusion of waste into the tank annulus [55], (ii) for all tanks, radiolysis of the air produces NO_2 gas which reacts with the moisture to produce the highly corrosive nitric acid [56], (iii) for all

tanks, microbiologically induced corrosion (MIC) may initiate [57], and (iv) for all tanks, corrosion products may hide defects and therefore prevent the detection of changes in the tank wall surface by tank inspection.

Several Type I tanks and all of the Type II tanks have leaked waste through cracks into the annulus. The warm air circulating through the annulus evaporated the water from the waste and formed salt deposits that plugged the cracks and prevented further leakage. Inspections have shown that when the annulus ventilation is turned off, these deposits begin to dissolve and leakage of waste into the annulus resumes [55]. The dissolution of the salt deposits is likely due to the formation of condensation on the tank walls as the air cools. Although the waste should be inhibited when it enters the annulus, dilution due to rainwater intrusion or reaction with carbon dioxide may change the chemistry of the leaked waste significantly from that of the waste inside the tank. Thus a new corrosive condition may be created.

Moisture by itself will cause general corrosion. Accelerated general corrosion may occur due to air radiolysis. This mechanism is initiated by gamma rays that irradiate the annulus air to produce NO_2 gas [58]. A nitric acid solution will form wherever air containing NO_2 is in contact with moisture. The reaction producing the nitric acid is:

$$2\,NO_2(g) + H_2O = HNO_2 + H^+ + NO_3^- \qquad (1)$$

If it is assumed that the dose rate is 1000 R/hr (a representative value for the annulus air [59]), and the volume of air in the annulus is approximately 23,000 ft^3, the production of NO_2 gas is 1.9×10^{-8} atm/hr. Assuming that equilibrium is instantaneously established, the pH of the standing water may reach 2.9 within 1 hour. At this pH, carbon steel corrodes at a rate of approximately 40-50 mils per year [60]. If these conditions were allowed to persist significant wall thinning may occur. This mechanism was observed to occur in the reactor process room at SRS [61]. Inspections of the annular space to date have not revealed indications of excessive general corrosion [62] even with occasional steam and blower outages. There are several possible explanations for the lack of observed general corrosion. First, the rate at which the nitric acid production reaction occurs in cold dilute solutions may be slow [63], and therefore, the reaction may not attain equilibrium rapidly. Second, the contents of the tank may have contributed sufficient heat to maintain the temperature of the annulus air above the ambient temperature. Condensate would not form under these conditions. Third, the above calculations assume that the air in the annulus is stagnant. A small air flow in the annulus may dilute the NO_2 concentration sufficiently. Fourth, in tanks that have salt deposits, the condensate or standing water may contain other dissolved salts. The presence of these dissolved salts would likely decrease the absorption of the NO_2 gas into the water and the formation of nitric acid.

A final consideration is the potential for MIC. MIC was observed in the annulus pan during construction of the Type III tanks [57]. Wet, stagnant conditions were ideal for initiating pits beneath the microbes. The solution to the problem was to

run warm annulus air to remove the moisture that sustains the microbes and the corrosion reaction. Maintaining warm air in the annulus minimizes the potential that this mechanism will initiate new pits or reinitiate pits that are present.

Given that the Type I and II tanks are older and have experienced more degradation, the allowable time period for an outage is 30 days. Also should defects form (i.e., pits or cracks), the structure will be more susceptible to brittle fracture due to the high nil-ductility transition temperature of the steel used for these tanks. Moisture build-up in the Type III and IIIA tanks is also undesirable. However, the lack of any known leaksites and the superior materials and fabrication procedures used for these tanks allows for a longer allowable outage period.

There are situations where steam is not available to heat the ambient air prior to entering the waste tanks. If steam is not available, the annulus fans may be turned on in order to evaporate moisture as long as the tank walls remain above the low operating temperature limit on the roundsheets. The minimum temperature limit on the roundsheets ensures that the tank wall temperature remains above the minimum nil-ductility transition temperature (NDTT) value (see [67]) by a sufficient margin. The temperature limit minimizes the potential for brittle fracture of the tank walls. Portable fans may also be utilized in this situation. Due to the convection of the air, some undetermined amount of moisture (which depends on the temperature and relative humidity of the ambient air and the heat generated by the tank) will be evaporated. Additionally the air flow will reduce the concentration NO_2 in the annulus that was produced by radiolysis. Therefore, although corrosion would occur due to moisture, it would not be accelerated by nitric acid. However, there will be time periods during the year when condensation will accumulate in the annulus. This mode of operation is not ideal, however, it may be utilized on an interim basis.

In addition to moisture due to condensation, rainwater leaks into the annulus through risers and other penetrations such as transfer lines. Conductivity probes are set near the floor of the waste tank annulus to detect the presence of liquids. The probes should be located as near as practical to the annulus floor to minimize the accumulation of liquid. In some situations, debris or waste prevents the probe from being placed directly on the annulus floor. Two benefits are realized by minimizing the accumulation of liquid: 1) the potential for deflagration or the accumulation of flammable gases is reduced, and 2) long-term corrosion degradation of the pan, annulus floor, annulus wall or primary tank is mitigated or prevented. The first benefit reduces the risk of releasing a radioactive dose to the public. Given that this is the more immediate concern of the two, the level that the probe is set above the annulus floor (in the presence of debris or accumulated waste) will be based on this consideration. The second benefit maintains the structural integrity of safety class structures over an extended period of time. The maximum probe height settings are described in the TSRs.

Circulation of warm air will evaporate rainwater and prevent the possibility of corrosion. For example, a test was performed that showed that operating the annulus ventilation at 2200 CFM, with an inlet temperature of 96°C, would evaporate approximately 10 gallons of liquid per hour [64]. In the event that steam is not available to heat the ambient air, the ventilation fans or portable ventilation fans shall be operated to evaporate the water. Although the drying capacity of the air is significantly decreased during periods of time when the humidity is above 50%, blowing air across the accumulated water will evaporate water as long as the ambient air is below 100% relative humidity. The tank steel wall temperature shall be monitored also to ensure that it does not go below the minimum value i.e., the NDTT.

For tanks with a high heat generation rate, circulation of air that has not been pre-heated with steam has been utilized to cool the waste tank steel. Cooling the waste tank in this manner minimizes the potential for corrosion degradation of the steel (see Temperature Control) or thermal degradation of the concrete (see Structural Integrity Program). Typically the heat from the high heat tanks in combination with air convection will evaporate water from the annulus in a relatively short period of time.

Evaporator Tube Bundle Corrosion Controls

In order to prevent corrosion of the evaporator tube bundles, it is required that they either be submerged in waste or in inhibited water. The basis document for the corrosion control program recommends that the tube bundle not be left uncovered for more than 30 days (Ref. 65). During the period of time when the evaporator is not operating, the pot shall have a pH greater than 12, as calculated by the following formulas. During normal operation, the tube bundles are covered with waste that is sufficiently inhibited to prevent corrosion.

The amount of inhibitor needed to raise the pH in the evaporator pot to above 12 is very minimal. The 2F and 2H evaporators require approximately 11 gallons of 50 wt% caustic to raise the pH to 13; in the 3H, it takes approximately 53 gallons. The following equation yields the volume of 50 wt% caustic that is necessary to be added to increase the pH of the pot contents to 13.

$$(0.1 * (\text{gallons in pot})) / 19 = x \text{ gallons caustic} \qquad (1)$$

This equation determines the gallons of 50 wt% caustic that need to be added by taking the product of the desired concentration of 0.1 M (pH 13) and the gallons in the pot and dividing this product by the concentration of the 50 wt% caustic (19 M).

Credit may be given for the waste left in the evaporator pot, if it is sufficient to bring the pH of the pot over the minimum of 12, and the lance is operating when the water addition to the waste is made. To calculate whether the waste is sufficient to inhibit, use the free hydroxide concentration of the evaporator feed tank, multiply it by the expected volume of the waste left in the pot; then, divide by the total volume of the liquid in the pot. This

number is the actual free hydroxide concentration in the pot. If this value is above 0.01 M, the waste left in the cone is sufficient to inhibit the pot. If not, the addition of caustic as described above must be completed within 30 days.

The intent of this program is to ensure that the tube bundle in the evaporator pot is submerged in an inhibited solution very quickly after going into an extended shutdown. This minimizes the chances for the initiation of corrosion on the tube bundle. This basis document was written specifically for the 2H and 2F evaporators, but a later evaluation [70] confirmed that this control can be extended to the 3H evaporator as well.

Prevention of MIC (Microbiologically Influenced Corrosion) in Transfer Lines and Evaporator Systems

MIC has not been observed in any of the tank farm systems; however some conditions at SRS do cause concern over the possibility of MIC occurring. The conditions that cause MIC concerns are stagnant water, low pH (pH<10.5), temperatures less than 100°F, presence of organic matter, and the absence of a biocide [68]. On occasion, uninhibited water is used in the tank farm, primarily for flushing transfer lines after a transfer, which could produce conditions that would encourage MIC.

In order to prevent conditions that would be favorable to MIC, transfer lines shall be vented and drained after each transfer. If there are known "low" points in the transfer line (as identified in the Structural Integrity Program), and that line needs to be flushed, that line must be flushed with inhibited water (pH>12) unless another waste transfer is planned within the next 5 days. A five-day maximum on the time that uninhibited water can remain stagnant in a transfer line has a technical basis combined with engineering prudence [68].

The evaporator tube bundle must also be protected against failure due to MIC. However, the high temperatures of the steam in the tube bundle kill all the microbiological entities that could cause this form of corrosion, so no further controls need to be placed on the system.

Cooling Coil Corrosion Protection

The cooling coils in each of the waste tanks are protected against corrosion from the exterior by the inhibitor and temperature requirements required for each of the waste tanks in this program. The interior of the cooling coils is protected against corrosion by the chromate that is in the cooling water. Periodic testing (at least every 3 months) of the chromate cooling water for the appropriate levels of chromate (greater than 450 ppm) coupled with a required flush of all isolated chromate cooling coils every 3 months will ensure that the cooling coils are sufficiently protected against internal corrosion. 450 ppm must be ensured every 3 months, because within 3 months it is possible to decay down to approximately 200 ppm, which is the level needed to prevent corrosion.

A decision to not protect a certain cooling coil by the Facility Manager shall exempt that cooling coil from the requirements of this program, provided the coil is removed from service.

The supports for the cooling coils that are in a waste phase are also protected by the temperature and chemistry controls on the waste in each tank. The vapor space corrosion section of this program is applicable to the supports for the cooling coils that are in the vapor space of the tank.

5.0 PROGRAM DESCRIPTION

The output documents generated by this PDD shall ensure independent verification or validation of results and conclusions. Output documents include, but are not limited to, calculations, procedures and technical reports.

Grace periods are allowed for operational flexibility. Good operating practice would dictate that grace periods are not to be relied upon as routine extensions of the specified interval.

Calculations issued as output documents shall be confirmed Type I calculations in accordance with the requirements of the E7 Manual, Procedure 2.31. Technical Reports issued as output documents shall comply with the requirements of E7 Manual, Procedure 3.60. Assumptions and recommendations from these reports shall be addressed in the Design Authority Technical Review (DATR) written against the Proposed Activity. Additionally, the output documents will be included in the USQ review process against the Proposed Activity per Manual 11Q, Procedure 1.05.

1. Temperature Control

Thermocouples

A functional thermocouple in each waste phase is required for all waste tanks, **with the exception of the supernate phase in evaporator drop tanks**. In addition, a functional thermocouple is needed to monitor the steel wall temperature on all Type I, II, III, and IIIA waste tanks; Tanks 1-15 and 29-34 also require a steel wall thermocouple within 3 feet of the bottom knuckle weld.

Annually, an instrument loop calibration must be completed for the thermocouples in each waste tank. This is to ensure that the thermocouples are functioning properly. In addition, the steel wall thermocouples for Tank 1-15 and 29-34 must be checked bi-annually to ensure they are still attached to the tank wall within 3 feet of the bottom knuckle weld.

If a transfer into or out of a tank results in a waste phase containing no functional TC, the TC in the adjacent phase may be used if it is determined to be representative (similar to or hotter than). The only exception is for evaporator drop tanks during evaporator operations. During this time, the supernate temperature limits do not apply to these tanks. [Basis: The evaporator drop tanks are excluded from supernate temperature requirements during evaporator operation due to the fact that the liquid/air interface during this time is moving (not stagnant), the evaporator is actually concentrating caustic in the drop tank,

the liquid that is dropping is not boiling , and past experience shows that evaporator bottoms have been used to actually stop corrosion (evaporator bottoms were transferred to Tank 11 in the late 1960s in order to mitigate cooling coil failures [74]). However, the temperature limits do apply when the tank is no longer functioning as a drop tank, but rather as a storage tank (7 days following the termination of evaporator operation).

Roundsheets, ticklers, or PassPort will be used to prompt and record the temperature readings. Loop calibrations will be prompted by PassPort.

Temperature Limits

The following tables provide temperature limits, dependant upon the concentration of nitrate and inhibitors.

Table 1. Maximum Temperature Limits For Supernate (T_{sup}) With Nitrate Concentrations Greater Than Or Equal To 1 Molar (M)* (*Applicable to slurried and non-slurried waste tanks*)

Nitrate (M)	R<2	R>2
$1.0 \leq [NO_3^-] \leq 2.75$	70°C	105°C
$2.75 < [NO_3^-] \leq 5.5$	105°C	112°C
$5.5 < [NO_3^-] \leq 8.5$	70°C	**

T_{sup} = supernate temperature

$R = \{[NO_2^-] + [OH^-]\} / [NO_3^-]$

*For the most recent concentrations of nitrate, nitrite and hydroxide in each tank, review WCS

**Due to the liquid solubility limitations it is not possible to have these supernate compositions.

Table 2. Maximum Temperature Limits For The Sludge/Salt and Steel Wall (T_{ss}, T_w) With Nitrate Concentrations Greater Than Or Equal To 1 Molar (M)*.
(*Applicable to slurried and non-slurried tanks*)

Supernate Concentration	R < 2		R ≥ 2	
Nitrate (M)	Liquid Level < 120 inches	Liquid Level ≥ 120 inches	Liquid Level < 120 inches	Liquid Level ≥ 120 inches
$1.0 \leq [NO_3^-] \leq 2.75$	$T_{ss} = 105^oC$ $T_w = 100^oC$	$T_{ss} = 115^oC$ $T_w = 110^oC$	$T_{ss} = 105^oC$ $T_w = 100^oC$	$T_{ss} = 115^oC$ $T_w = 110^oC$
$2.75 < [NO_3^-] \leq 5.5$	$T_{ss} = 105^oC$ $T_w = 100^oC$	$T_{ss} = 115^oC$ $T_w = 110^oC$	$T_{ss} = 112^oC$ $T_w = 107^oC$	$T_{ss} = 122^oC$ $T_w = 117^oC$
$5.5 < [NO_3^-] \leq 8.5$	$T_{ss} = 105^oC$ $T_w = 100^oC$	$T_{ss} = 115^oC$ $T_w = 110^oC$	**	**

T_w = Waste tank steel wall temperature

T_{ss} = Temperature of the salt of sludge phase

*For the most recent concentrations of nitrate, nitrite, and hydroxide in each tank, review WCS.

**Due to liquid solubility limitations it is not possible to have these supernate compositions.

Table 3. Temperature Limits For Non-Slurried Waste Tanks With Nitrate Concentrations Less Than 1 Molar (M)*.

Supernate Concentration	T_{sup}		T_{ss}, T_w	
Hydroxide (M)	$[NO_3^-] \leq 0.02$ M	0.02 M < $[NO_3^-] < 1$ M	$[NO_3^-] \leq 0.02$ M	0.02 M < $[NO_3^-] < 1$ M
$0.01 < [OH^-] \leq 1$	40°C	40°C	$T_{ss} = 75^oC$ $T_w = 70^oC$	$T_{ss} = 75^oC$ $T_w = 70^oC$
$1 < [OH^-] \leq 8$	60°C	100°C	$T_{ss} = 60^oC$ $T_w = 55^oC$	$T_{ss} = 100^oC$ $T_w = 95^oC$
$[OH^-] > 8$	60°C	60°C	$T_{ss} = 60^oC$ $T_w = 55^oC$	$T_{ss} = 60^oC$ $T_w = 55^oC$

*For the most recent concentrations of nitrate, nitrite, and hydroxide in each tank, review WCS.

Table 4. Temperature Limits For SLURRIED WASTE TANKS* With Nitrate Concentrations Less Than 1 Molar (M)**.

Supernate Concentration	T_{sup}		T_{ss}, T_w	
Hydroxide (M)	$[NO_3^-] \leq 0.02$ M	0.02 M < $[NO_3^-]$ < 1 M	$[NO_3^-] \leq 0.02$ M	0.02 M < $[NO_3^-]$ < 1 M
$0.01 < [OH^-] \leq 1$	75°C	75°C	T_{ss} = 75°C T_w = 70°C	T_{ss} = 75°C T_w = 70°C
$1 < [OH^-] \leq 8$	60°C	100°C	T_{ss} = 60°C T_w = 55°C	T_{ss} = 100°C T_w = 95°C
$[OH^-] > 8$	60°C	60°C	T_{ss} = 60°C T_w = 55°C	T_{ss} = 60°C T_w = 55°C

*A waste tank is considered slurried (for corrosion control purposes) for a period starting when one or more slurry pumps/mixers have operated at or above minimum speed for 3 hours and extending up to 30 days after the pumps/mixers are shutdown. SLURRIED WASTE TANKS with nitrate concentration greater than or equal to 1 M are subject to the limits in Tables 1 and 2.

**For the most recent concentrations of nitrate, nitrite, and hydroxide in each tank, review WCS.

An engineering evaluation or an approved operating plan for a particular waste tank can exempt a tank from these temperature controls. The evaluation or operating plan must provide justification for the relaxation of controls and must be properly reviewed and approved.

Compensatory Measures

The following required actions are designed to ensure that the time period over which a waste tank is susceptible to corrosion is minimized.

1. If the temperature of the waste in a tank exceeds the limits established in Tables 1, 2, 3, and 4, with the exception of the supernate temperature limits for evaporator drop tanks during evaporator operations, the following shall occur:
   A. CST Engineering shall be notified by CSTO of the condition within 24 hours if Operations is unable to bring the temperature within limits before this time is expired.
   B. CST Engineering shall provide, within 5 days of notification, an evaluation that includes suggested actions needed to bring the tank temperature into compliance with Tables 1, 2, 3, and 4. The evaluation shall also include the expected time needed to perform necessary actions. If slurry pumps/mixers are in operation at the time the condition is recognized, Engineering shall assess whether they should continue operation. If the temperature is restored within the limits listed in Tables

1-4 before the 5 days have expired, engineering does not have to provide an evaluation.

2. If the thermocouple for the supernate, salt, and/or sludge phases is not functional, or if the thermocouple for the steel wall is not functional (or the magnetic thermocouple attached to the outside of the primary tank wall of Tanks 1-15 or 29-34 becomes detached), the following actions shall occur: (Only applies to Type I, II, III, and IIIA waste tanks, excluding evaporator drop tanks during evaporator operation)
   A. The thermocouple shall be restored to functionality, or an alternate (e.g., a representative one in an adjacent phase) thermocouple shall be used to monitor the temperature of the affected waste phase or steel wall within 7 days after the condition is noticed. The normal monitoring frequency shall continue with the alternate thermocouple if the thermocouple is not restored.
   B. If slurry pumps/mixers are in operation at the time of the thermocouple's failure, CST Engineering shall be notified to provide guidance on whether operation of the slurry pumps/mixers should continue.
   C. A functional wall temperature thermocouple shall be restored in the affected waste phase/tank steel wall within 45 days.

3. If there are no functional or representative thermocouples available in a Type IV waste tank, the following actions shall occur:
   A. CST Engineering shall be notified if there are any slurry pumps/mixers in operation in the affected tank. Engineering shall provide guidance as to whether or not the slurry pumps/mixers should remain in operation.
   B. A representative thermocouple shall be functional in the tank within 30 days.

Monitoring Frequencies

1. For active Type I, II, III, and IIIA tanks and for inactive Type I, II, III, and IIIA tanks with heat loads greater than 0.10 Btu/hr/gal (A heat load of 0.10 Btu/hr/gal in a waste tank, conservatively assuming the waste has the properties of water and that there is no external heat removal, can produce a 5°C rise in temperature in a month), verify that the tank waste (supernate, salt/sludge, as applicable) and/or steel wall temperatures are no greater than the maximum limits tabulated in Tables 1, 2, 3, and 4 every 7 days or every shift during slurry pump operation (unless an engineering evaluation justifies a longer frequency). The temperature monitoring frequency of each tank will be shown in the ERD.

2. For inactive Type I, II, III, and IIIA tanks with heat loads less than 0.10 Btu/hr/gal, verify that the tank waste (supernate, salt/sludge, as applicable) and/or steel wall temperatures are no greater than the maximum limits tabulated in Tables 1, 2, 3, and 4 every 30 days (unless an engineering

evaluation justifies a longer frequency). The temperature monitoring frequency of each tank will be shown in the ERD.

3. For Type IV tanks, verify that the tank waste temperatures (supernate, salt, and sludge, as applicable) are no greater than the maximum temperature limits as listed in Tables 1, 2, 3, and 4 every month, unless an engineering evaluation justifies a longer frequency (e.g., Tanks 18 and 19 have been removed from temperature requirements due to engineering evaluations [71], [72], [73]).

4. Perform an instrument loop calibration of thermocouples for each tank every year.

5. For the active Type I, II, III, and IIIA tanks and inactive Type I, II, III, and IIIA tanks with heat loads above 0.10 Btu/hr/gal, ensure that the thermocouples used for reporting temperatures in each waste phase are reading representative phase temperatures every 3 months.

6. For the inactive Type I, II, III, and IIIA tanks with heat loads below 0.10 Btu/hr/gal, ensure that the thermocouples used for reporting temperatures in each waste phase are reading representative phase temperatures every year.

7. Inspect the steel wall TCs for Tanks 1-15 and 29-34 and verify that they are attached to the steel primary wall within 3 feet of the bottom knuckle weld every 2 years.

8. Prior to each waste transfer and prior to operating slurry pumps, which have changed height, verify that there will be a functional, or functional alternate, thermocouple for each resulting waste phase. Operating (WTS, WTE) procedures shall ensure the compliance with this requirement.

9. Every 30 days, verify that tanks categorized as slurried waste tanks have had a slurry pump/mixer in operation for at least 3 continuous hours at or above the minimum speed within the previous 30 days.

2. Chemistry Control

Chemistry Limits

In order to prevent corrosion, the appropriate amount of inhibitor must be present in the tank to sufficiently balance the nitrate concentration. The following table, Table 5, shows the required concentration of either hydroxide or nitrite for the corresponding amount of nitrate in the waste tanks.

Table 5. Minimum Corrosion Inhibitor Concentration Limits

Applicability	Limit		Parameter	Minimum Needed	Units
$5.5 < [NO_3^-] \leq 8.5$ M	1		$[OH^-]$	0.6	Molar
			$[OH^-] + [NO_2^-]$	1.1	Molar
$2.75 < [NO_3^-] \leq 5.5$ M	2		$[OH^-]$	0.3	Molar
			$[OH^-] + [NO_2^-]$	1.1	Molar
$1.0 \leq [NO_3^-] \leq 2.75$ M	3		$[OH^-]$	$0.1[NO_3^-]$	Molar
			$[OH^-] + [NO_2^-]$	$0.4[NO_3^-]$	Molar
$0.02 < [NO_3^-] < 1.0$ M AND $[OH^-] < 1.0$ M	4	4a	$[OH^-]$	1.0	Molar
			OR		
		4b	$[NO_2^-]$	$0.038x[NO_3^-]x10^{1.64}$	Molar
		4c	AND $[NO_2^-]$	$6.11\ EXP[1.64+1.34xlog[Cl^-]]$	Molar
		4d	AND $[NO_2^-]$	$0.04\ EXP[1.64+0.84xlog[SO_4^{-2}]]$	Molar
			AND pH	10.3	pH Units
$[NO_3^-] \leq 0.02$ M AND $[OH^-] < 1.0$ M	5	5a	$[OH^-]$	1.0	Molar
			OR		
		5b	$[NO_2^-]$ (if $[Cl^-]$, $[SO_4^{-2}]$ is not known)	0.03318	Molar
			OR		
		5c	$[NO_2^-]$	$0.038x[NO_3^-]x10^{1.64}$	Molar
		5d	AND $[NO_2^-]$	$6.11\ EXP[1.64+1.34xlog[Cl^-]]$	Molar
		5e	AND $[NO_2^-]$	$0.04\ EXP[1.64+0.84xlog[SO_4^{-2}]]$	Molar
			AND pH	10.3	pH Units
Influents to waste tanks from other areas on site.*			pH	9.5	pH Units

* Waste Acceptance Criteria provides the means for controlling the pH of influents to the tank farm. These influents do not include rainwater, raw water flushes, etc.

Sampling Schedule

In order to assure that the chemistry in each tank stays within the limits given in Table 5, every tank's supernate must be sampled periodically. A 30 day grace period is permitted in meeting this frequency. Table 6 identifies the frequency with which a tank must be sampled, based on that tank's status and last known chemistry. If a tank has been sampled 15 times since receiving waste in a waste tank to waste tank transfer and the statistical capability of the tank to meet the minimum corrosion inhibitor limits (Sigma Level) can be established, the sample frequency shall be determined from Table 7. In either case, the sample frequency for each tank shall be noted in the ERD. The PassPort system, or its equivalent, shall be utilized to ensure that the samples are taken to meet the requirements of this section.

Table 6. Sample Frequency For Waste Tanks

Status	Category	Inhibitor Levels	Frequency
ACTIVE WASTE TANKS	Evaporator Feed and Drop Tanks	If $[NO_3^-] < 1M$ or $[OH^-] < 2.35$ M or [S] < 3 M	3 months
		If $[NO_3^-] \geq 1M$ or $[OH^-] \geq 2.35$ M or [S] ≥ 3 M	6 months
	Fresh Canyon Waste Receiver with Nitrate Concentration Greater Than or Equal to 1 M	[OH-] < 3 M or [S] < 4 M	6 months
		[OH-] ≥ 3 M or [S] ≥ 4 M	12 months
	Receiver with Nitrate Concentration Less Than 1 M	[NO2-]/[NO3-] < 3.4 OR [OH-] < 0.02 M	3 months
		3.4 ≤ [NO2-]/[NO3-] < 4.8 AND 0.02 M ≤ [OH-] < 2.35 M	6 months
		[NO2-]/[NO3-] ≥ 4.8 M OR [OH-] ≥ 2.35 M	12 months
	Receiver with Nitrate Concentration Greater Than or Equal to 1 M	[OH-] < 2.35 M or [S] < 3 M	6 months
		2.35 M ≤ [OH-] < 3 M AND 3 M ≤ [S] < 4 M	12 months
		[OH-] ≥ 3 M OR [S] ≥ 4 M	24 months
	Slurried Tank	N/A	1 month AND Within 1 month after slurry pumps or mixers are stopped
INACTIVE WASTE TANKS	Nitrate Concentration Less Than 1 Molar	$[NO_2^-]/[NO_3^-] < 3.4$ OR $[OH^-] < 0.02$ M	6 months
		$3.4 \leq [NO_2^-]/[NO_3^-] < 4.8$ AND $0.02 \text{ M} \leq [OH^-] < 2.35$ M	12 months
		$[NO_2^-]/[NO_3^-] \geq 4.8$ M OR $[OH^-] \geq 2.35$ M	24 months
	Nitrate Concentration Greater Than or Equal to 1 Molar	$[OH^-] < 2.35$ M or [S] < 3 M	12 months
		$2.35 \text{ M} \leq [OH^-] < 3$ M AND 3 M ≤ [S] < 4 M	24 months
		$[OH^-] \geq 3$ M or [S] ≥ 4 M	48 months

Table 7. Sample Frequency for Waste Tanks Based on Statistical Analysis	
Active Tanks and Inactive Tanks with Nitrate Concentrations Less Than or Equal to 1 Molar	
Sigma Level	Frequency
0 - 2.99	3 months
3.00 - 3.49	6 months
3.50 - 3.99	12 months
4.00 or greater	24 months
Inactive Tanks with Nitrate Concentrations Greater Than 1 Molar	
Sigma Level	Frequency
0 - 2.99	6 months
3.00 - 3.49	12 months
3.50 - 3.99	24 months
4.00 or greater	48 months

If the sample frequency is increased such that the next required sample is past due, then the next sample should be scheduled within a grace period of 30 days from the date that the new sample frequency is noted in the ERD. The sampling frequency for a slurried tank can be extended only by an engineering evaluation. This evaluation must discuss the possible risks of extending the frequency and must provide adequate justification of the risks. The Facility Manager's concurrence with this evaluation shall provide the necessary authority to extend that tank's sampling frequency.

An engineering evaluation may be performed to allow the exclusion of a tank undergoing waste removal activities from this sampling frequency schedule. Such an evaluation must demonstrate that the risk of corrosion in the tank is minimal and explain any actions needed to retain the integrity of the waste tank (i.e., inhibitor additions). This evaluation should estimate the amount of corrosion that would occur during the time period between its exit from the sampling schedule until it is closed. If the evaluation shows that the tank wall integrity will not be lost during the anticipated time frame, that tank can be exempted from the program. The evaluation should also discuss the need to increase annulus leak detection monitoring. The concurrence of the Facility Manager on such an evaluation will automatically exempt that tank from the sampling frequencies shown above. If any of the assumptions (i.e., timeframe, chemistry, etc.) change after the evaluation is written, the tank must be re-evaluated using the new conditions to determine whether it is still safe to remove the sampling frequency requirements.

The Extended Sludge Processing (ESP) (i.e., Tanks 40 and 51) tanks may fall under the category of "slurried" by the strict definition of this term; however, because these tanks are well characterized and all incoming streams are known, these tanks are treated as "receiver" tanks rather than "slurried" tanks.

Tanks that are deemed exempt from the sampling program will be labeled in WCS as "Empty" only for purposes of this program and after they are officially closed, they will be labeled as "Closed". Any tank with either of these two labels will be exempt from the sampling requirements of this program.

Water Additions to Waste Tanks

During normal operations of the tank farms, water must be added occasionally to a waste tank as a result of some form of flushing. These water additions could potentially change the chemistry of the waste tank and present a possibility for the chemistry to fall outside the limits set in Table 5. If more than 3,000 gallons of water are to be added to a tank, an engineering evaluation shall be completed. This evaluation should discuss the ramifications of adding large amounts of water to the tank and should also provide any necessary compensatory measures such as sampling or chemical additions. If the receipt tank has a specific gravity higher than 1.20, the evaluation should also discuss the possibility of stratification, and provide guidance on restoring the chemistry within the established limits.

Compensatory Measures

The following actions are required in order to minimize the risk of corrosion in a waste tank.

1. If the hydroxide and/or nitrite concentrations are outside the corrosion inhibitor limits shown in Table 5 the following actions shall be taken:

   A. CSTE shall provide CSTO guidance regarding the continuance of waste transfers and the continued operation of slurry pumps/mixers. This guidance shall be given within 24 hours.
   B. The chemistry in the tank shall be restored and/or verified to be within the tank chemistry limits within 45 days, unless an extension is justified by an engineering evaluation. This action may require the addition of corrosion inhibitors and/or a re-sampling of the supernate in the affected tank. CSTE shall provide direction concerning chemical additions and the re-sampling of the supernate.

2. If the liquid level in an inactive waste tank increases by greater than 1 inch during the period of 30 days (checked once every 30 days), not related to transfers, Engineering shall provide an evaluation to determine the need for any remedial action within 5 days.

3. For additions of water greater than 3,000 gallons, an engineering evaluation shall be provided prior to the execution of the water addition.

4. Waste tank corrosion samples shall be pulled at the frequency specified in Tables 6 and 7 and tracked in the ERD. A 30 day grace period is applicable for this. This 30 day grace period is also applicable when an increase in sample frequency results in a sample which is overdue. If the 30 day grace period will not be met engineering shall specify remedial actions and required timing.

5. Completion of corrosion sample analysis with the results incorporated into WCS is required within 90 days of the date that the sample was pulled and shall be tracked in the ERD. A 30 day grace period is applicable to this requirement. If the 30 day grace period will not be met engineering shall specify remedial actions and required timing.

Monitoring Frequencies

The following monitoring activities are required to ensure that each tank complies with the chemistry limits established in Table 5 and is monitored in accordance with Tables 6 & 7.

1. Each tank that contains liquid waste shall be periodically sampled in accordance with Tables 6 & 7. The sample frequency dictated by Tables 6 & 7 shall be shown in the ERD. The ERD must be updated when these frequencies change.

2. Prior to each waste tank to waste tank transfer, verify that the corrosion inhibitors of the receiving tank will remain within the limits established in Table 5 after the transfer is completed.

3. Humidity Control – Annulus Ventilation

Steam Supply to Ventilation

Steam shall be supplied to the annulus ventilation pre-heater in order to heat the air in the annulus. By heating the air in the annulus, the risk of corrosion due to condensation is eliminated. Every week (7 days) a check shall be made to ensure that each annulus ventilation system is receiving steam and that each annulus ventilation system is operating.

If the steel wall temperature of the tank is above 40°C (lowest steel wall temperature reading), there is no requirement for the operation of steam, unless liquid is detected in the annulus. In the event liquid is detected, steam shall be used until the annulus is dried.

Compensatory Measures

1. If the annulus ventilation is not in operation or steam is not supplied to the annulus pre-heater and the tank steel-wall temperature is below 40°C, these

conditions shall be corrected within 30 days for the Types I and II tanks and within 90 days for the Types III and IIIA tanks. If no steam is available, the ventilation, if available and to the extent practical, shall be operated continuously (as long as the tank wall temperature is above the low operating limit on the roundsheets).

2. If liquid is detected in the annulus or if the annulus does not contain a functional conductivity probe, the following action shall be taken:
   If liquid is verified to be in the annulus, the ventilation system shall be operated; also, ensure that steam is supplied to the annulus pre-heater. This action shall be completed within 24 hours.

4. Evaporator Tube Bundle Corrosion Control

The evaporator tube bundle shall be submerged in an inhibited solution, as defined in the background section of this program, within 30 days of the removal of waste from the evaporator pot.

Compensatory Measures

If more than 30 days elapse before the tube bundle is submerged in an inhibited liquid (as defined in the background section of this program), an engineering evaluation shall be performed and documented detailing the necessary measures to ensure that corrosion has not jeopardized the integrity of the tube bundle.

5. Prevention of Microbiologically Influenced Corrosion (MIC) in Transfer Lines and Evaporator Systems

Transfer lines and evaporator systems must be protected from conditions that could lead to MIC. The following measures ensure that these conditions do not occur.

Compensatory Measures

1. If there is a known "low" point in a transfer line, as shown in the SI program, and a flush is intended, use inhibited water (pH>12) to flush that transfer line, unless another waste transfer is planned through that line within the next 5 days. If a line is flushed with uninhibited well water because another transfer is anticipated and that anticipated transfer does not occur, the line shall be flushed with inhibited water before the 5 days have expired.

6. Cooling Coil Corrosion Control

Cooling coils must be protected, both from the interior and exterior, from corrosion. The exterior of the cooling coils is protected by the chemistry and temperature limits imposed on the waste in each waste tank. The following compensatory measures and monitoring activities are intended to reduce the failure of cooling coils due to internal corrosion.

Compensatory Measures

1. All functional, isolated cooling coils shall be flushed with chromate cooling water every 3 months.

Monitoring Frequencies

1. Chromate cooling water shall be sampled every 90 days to ensure that the chromate level in the water is sufficient to inhibit corrosion (>450 ppm).

Acknowlegements

Large portions of this report are adapted from the current corrosion control program, G-TRT-G-00003, Appendix 6. Evaporator controls are adapted from G-TRT-G-00003, Appendix 16.

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