CSTF Flammability Control Program

Program Description Document

PREPARED BY:

2/29/16

H. Bui, Tank Farm Process Safety and Regulatory Engineering / Signature Date

REVIEWED BY:

C. M. Ridgway 2/29/16

Design Verification by Document Review
C. M. Ridgeway, Flowsheet Development and Facility Integration Engineering / Signature Date

APPROVED BY:

Helen Boyd 3/1/16

H. P. Boyd, Tank Farm Process Safety and Regulatory Engineering Manager / Signature Date

3-1-16

T. H. Huff., Program Review Committee Chairman / Signature Date

3/2/16

E. Patten or delegate, Tank Farm / ETP Facility Manager / Signature Date

3/1/2016

J. S. Contardi, Tank Farm Facility Engineering Manager / Signature Date

Summary of Revisions

	Revisions 1-19	See Revision 23 for Summary
2/11/13	Revision 20	Revised to support Type I/II/IV Waste Tank Grouting consistent with DSA Revision HLW-CRF-12012, Rev. 0. References to "Removed From Service Mode" have been deleted. The requirements to enter "Closure Mode" have been updated to reflect DSA revision HLW-CRF-12012, Rev. 0. Inserted a description of methodology used to determine sludge/salt height of a waste tank in Section 5.0. Updated best management practices for a Very Slow Generation tank to ensure compliance with NFPA 69. Methodology to remain NFPA 69 compliant during grouting operations has been included to support F-FHA-F-00018 and F-FHA-F-00055 as amended by F-DCF-H-000641.
7/2/2013	Revision 21	Revised to correct file conversion error that occurred in Revision 20. Revised list in Section 4.5 to match DSA Section 5.5.4.2.44.2.
1/31/2014	Revision 22	The following changes are to match DSA Revision 15. Revised list in Section 4.5 to match DSA, Section 5.5.2.4 Revised wording in Section 6.2.2 to match DSA, Section 3.4.2.11.1, page 3.4-220 Sections 4.5 and 6.5 revised to include SCDHEC Wastewater Permit requirements with respect to waste tank lowest leak site
7/31/2014	Revision 23	Incorporated changes and improvements identified in 2013-CTS-004168: • Updated Section 6 with additional equations required for performance of flammability calculations as listed in the DSA and reference documents. • Updated to align with the revision to Manual S4 Procedure ENG.36 • Flammable transient limits were added to Section 6.5.1 • Variable names were made more consistent with the DSA Added Table of Contents Added list of acronyms Discusses declaration of PISA PI-2014-0007 Introduced term LFL_{OC} to differentiate from composite LFL (CLFL) Removed use of CLFL for waste tanks other than Tank 50 Added Section 5.1 Implementation Actions associated with the inputs in Section 5 Identified in Section 5.0 where the organic contribution was accounted for in

		the flammability calculations Clarified in Section 6.1 how the SAV can be varied Removed organic correction from the initial hydrogen concentration (y_0) Clarified for Tank 50 the hydrogen concentration associated with an SAV of 60% Removed division of CLFL from equations to return a value in volume percent hydrogen rather than %CLFL Rearranged equations throughout to better reflect use in actual calculations and WCS. Provided guidance on equilibrium hydrogen concentration for Slow and Rapid tanks, including impacts to initial hydrogen concentration for Gas Release Mode and seismic evaluations as well as determination of turnovers. Added Equation # 25 for clarity Revised requirement for vapor space turnovers for Tank 50 Revised Section 6.3.2 to update how cascading releases of hydrogen are accounted for once GRM is entered Updated Implementation Actions in Section 6.3.3 to address compensatory actions for PI-2014-00007 Added reference to how the dissolution water skid (DWS) meets the DSA requirements for continuous makeup Added values for fill limits in Section 6.5 Added Implementation Action in Section 6.5.1 for the discovery of a new leaksite Decreased hydrogen monitoring limits in Section 6.8 to account for organics and align with hydrogen monitoring application in the field. Added Sections 8.4 and 10.0 Added References 11 and 63-72
4/8/2015	Revision 24	Added Reference U-ESS-G-00002 to replace discussion of PISA. Updated slurry pump and SMP discussion in trapped gas sections to include CSMPs consistent with DSA revision. Clarified initial hydrogen concentration for Tank 50 for gas release evaluations. Updated how to calculate NO_2 portion of Hmix as 0.5*[NO_2] Clarified application of Flammable Transient Limit. Added implementation actions to Section 6.8.1 for riser grouting consistent with Reference 61.

		Deleted requirement to take technical work documents for grouting to FOSC. Added Reference 73. Replaced Reference 71. Previous Reference 71 was a repeat of Reference 10. Updated references. Condensed Summary of Revisions section.
10/26/15	Revision 25	Deleted cascading release of gas in Section 4.4 Added units for Zabetakis attenuation factor Deleted dry sludge Tank 15 in Section 6.1.2. Added requirements for liquid additions in Sections 6.1.1, 6.1.3, 6.2.3, and 6.4.3. Deleted Mechanical Cleaning Mode or Type IV Waste Tank Mechanical Cleaning equipment in Sections 2.0, 4.0, 4.7, 6.6, and 6.9. Clarified that salt removal activities are prohibited for Type I/II Acidic and Non-Acidic Chemical Cleaning Waste Tanks. Added requirements for spray washing to meet continuous makeup capability. Clarified insignificant hydrogen release in Sections 6.3 and 6.4. Credited Pump Run Program in Section 6.3 and Salt Dissolution/Interstitial Liquid Removal Program in Section 6.4. Revised wording to match DSA in Sections 4.2, 6.2, 6.2.3, 6.3.2, 6.7.1. Clarified in Sections 6.1.1 and 6.2.1 that hydrogen generation rate calculations excluding waste tanks entering Closure Mode do not need to include analytical uncertainties. Clarified in Section 6.8.1 that analytical uncertainty shall be included when comparing hydrogen generation rate against the limit. Clarified maximum missing waste in Section 6.2.1. Added Ref. DSA Section 3.4.2.11.1 to methodology for Gas Release Mode evaluation in Sections 6.3.1 and 6.4.1. Clarified in Sections 6.3.2 and 6.4.2 that 72 scfm and 15,000 gals of MMW should be considered in Gas Release Mode. Clarified in Sections 5.0, 5.1, 6.1.1, that supernate temperature limits cannot exceed 100°C. Removed 1st bullet from Gas Release Mode assumptions about using actual release rates. Added requirements to verify vapor space hydrogen concentration for Very Slow tanks in Sections 6.3.1, 6.4.1. Clarified methodology used in Gas Release Mode evaluation in Section 6.4.2. Added examples of organic sources in Section 6.9. Flagged SAC requirements throughout the document. Reformatted and updated references.
2/2016	**Rev. 26**	**Added Tanks 1-4 and 7-12 to Siphon Limits in Sections 4.5 and 6.5.** **Listed Tanks 5, 6, and 16 as "Closed" and added a note for Tank 12 on "Maximum Fill Limit to Protect Waste Tank Overflow" in Section 6.5.** **Added discussion/table in Maximum Fill Limit to Protect Siphon through Cooling Coils in Section 6.5** **Replaced WCS1.5 with WCS in Section 6.5.1.4** **Updated References**

LIST OF ACRONYMS

AC	Administrative Control
CLFL	Composite Lower Flammability Limit
CSMP	Commercial Submersible Mixer Pump
CSTF	Concentration, Storage, and Transfer Facility
DOE	Department of Energy
DSA	Documented Safety Analysis
DWS	Dissolution Water Skid
ERD	High Level Waste Emergency Response Data and Waste Tank Data
ESP	Extended Sludge Processing
GRM	Gas Release Mode
HLLCP	High Liquid Level Conductivity Probe
LFL	Lower Flammability Limit
NFPA	National Fire Protection Association
OA	Oxalic Acid
PDD	Program Description Document
SAC	Specific Administrative Control
SAV	Safety Analysis Value
SCDHEC	South Carolina Department of Health and Environmental Control
SCFM	Standard Cubic Feet per Minute
SMP	Submersible Mixer Pump
STP	Standard Temperature and Pressure
TSR	Technical Safety Requirement
WCS	Waste Characterization System

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1.0 PURPOSE

The purpose of this Program Description Document (PDD) is to provide guidance to Engineering personnel for implementing controls contained in the Documented Safety Analysis (DSA) programs and Technical Safety Requirements (TSR) Administrative Controls. This document is not a Safety Basis Document.

This PDD describes the implementation plan for the Concentration, Storage, and Transfer Facilities (CSTF) Flammability Control Program, including the following ancillary programs provided for by the CSTF DSA [Ref. 1]:

Waste Tank Quiescent Time Program (SAC),

Pump Run Program (SAC),

Bulk Salt Dissolution/Interstitial Liquid Removal Program (SAC),

Tank Fill Limits (SAC), and

Oil Control Program (AC)

Additional controls deemed necessary by program management are also described, such as F-ESR-H-00140, "Flammability Requirements and Controls of LWDP Waste Storage Tanks." **[Ref. 57]**

This PDD provides background information and describes attributes of the Flammability Control Program in sufficient detail such that procedures implementing flammability control can be developed.

2.0 SCOPE

Evaluation of the Safety of the Situation (ESS): Vulnerabilities Associated with Gas Release Mode Evaluations and Application of Trapped Gas Release Information for Sludge (Potential Inadequacy of the Safety Analysis PI-2014-0007) was approved in September 2014 with implementation complete in October 2014 and compensatory measures listed in this ESS impact Sections 6.2 and 6.3 of this PDD. Compensatory measures in U-ESS-G-00002 supersede the requirements of this PDD for the affected sections.

The safety function of the CSTF Flammability Control Program is to protect the anticipated times to reach the Lower Flammability Limit (LFL) in individual waste tanks, thereby preventing waste tank explosions. Throughout this Flammability Control Program PDD, the following terms are used with regard to flammability limits:

- LFL: Lower Flammability Limit – the minimum concentration of fuel (i.e. hydrogen, Isopar® L, and/or trace organics) in air such that combustion will occur if an ignition source is present. LFL refers generically to a flammable condition (i.e., LFL_{OC} or CLFL).

- LFL_{25C}: LFL of hydrogen gas at 25°C – 4.0% by volume [Ref. 1].
- LFL_T: Temperature corrected LFL for hydrogen (Eq. # 3B)
- CLFL: Composite LFL – This represents the point at which the vapor space is flammable due to a combination of combustible vapors. In the case of Tank 50, this includes Isopar® L and trace organics.
- LFL_{OC}: Temperature and organic corrected LFL for hydrogen – Hydrogen concentration at LFL, including contribution from trace organics for all tanks other than Tank 50 (Eq. # 3). For Tank 50, LFL_{OC} (Eq. # 3A) represents the hydrogen concentration at CLFL, including the contributions from both trace organics and Isopar® L (i.e. LFL_{OC} = 43.8% of the LFL for hydrogen [Ref. 42])

Tank 48 is outside the scope of the Flammability Control Program; flammable vapor requirements for Tank 48 are contained in Chapter 18 of the DSA. Tanks in inactive locations (e.g., Tank 16) or reclassified as a radiological facility (e.g., Tanks 17, 18, 19, and 20) are excluded from the Flammability Control Program requirements of the DSA and TSR. This PDD does not address these tanks any further.

Tanks in Closure Mode [Ref. 6] are excluded from the Flammability Control Program requirements of the DSA and TSR after the flammability-related Mode entry prerequisites are met [Ref. 1], however separate requirements (i.e., NFPA 69) for waste tanks in Closure Mode are outlined in this PDD. The prerequisites for entering the Closure Mode are described in this PDD.

A "Chemical Cleaning Tank" is defined as a tank in Acidic Chemical Cleaning Mode. The attributes of the Flammability Control Program that apply to tanks in Acidic Chemical Cleaning Mode are: tracking the time to LFL in the High Level Waste Emergency Response Data and Waste Tank Data (ERD) (3 days [Ref. 56]) and classifying these tanks as Priority II Acidic Chemical Cleaning Tanks. Other than these attributes, the calculations and methodology prescribed in this Program are not applicable to tanks in Acidic Chemical Cleaning Mode. The corrosion induced hydrogen generation rate for tanks in Acidic Chemical Cleaning Mode is 4.3E-05 $ft^3/min/ft^2$ for tank surfaces contacted by oxalic acid (OA). The basis for this rate is discussed in the Corrosion Control PDD [Ref. 8]. This rate is used in Reference 56 to determine the bounding purge flow requirements and time to LFL for Chemical Cleaning Tanks.

Corrosion induced hydrogen generation from oxalic acid is assumed to contribute to the total flammable vapor concentration after 70 days contact with carbon steel for oxalic acid concentrations ≤ 4 wt.% [Ref. 1]. The Waste Tank Chemical Cleaning Program [TSR SAC 5.8.2.53] implements controls to prevent corrosion induced hydrogen generation in the transfer facilities, as well as transfers to unintended waste tanks. These controls ensure that: the oxalic acid concentration is ≤ 4 wt.%, the transfer is only permitted through evaluated facilities, the waste temperature must be ≤ 60 °C and ensuring that waste is neutralized within 60 days. These controls are not within the scope of the CSTF Flammability Control Program.

3.0 TSR HYDROGEN CONCENTRATION LIMIT

For activities where entry into Gas Release Mode (GRM) is required (refer to Sections 6.3.1 and 6.4.1), the TSR hydrogen concentration limits (considering only radiolytic hydrogen generation) shall be established by the Flammability Control Program and shall ensure the minimum time to LFL, defined by the tank classification, is maintained [Ref. 1]. TSR hydrogen concentration limits (measured) are established by the Flammability Control Program according to the safety analysis limit or value designation of a given tank (not applicable (NA) for Tank 50, as no hydrogen monitoring of that tank vapor space is required [Refs. 1,6]). Safety analysis values (SAVs), not including instrument uncertainty and organic contributions, cannot be less than 25% LFL and cannot exceed 60% LFL. In order to determine the TSR hydrogen concentration limit, which shall be documented in the ERD, the designated SAV is reduced to account for potential organics and instrument uncertainty. Additionally, for tanks that require entry into GRM, an alarm setpoint will be required to ensure the TSR hydrogen concentration limit is not exceeded [Refs 1,2]. The TSR hydrogen concentration limit will be designated in the ERD (excluding Tank 50, Chemical Cleaning Tanks, and Closure Tanks). Once the ERD is approved, this will drive the revision of the Instrument Scaling and Setpoint Document, which will allow implementation of the required indicated hydrogen concentration reading and/or alarm setpoint in the facility. References 3, 4, and 52 provide instrument uncertainty values for a range in various SAVs, which are employed to determine the TSR hydrogen concentration limit (i.e., indicated hydrogen reading) and/or alarm setpoint.

When not in GRM, portable monitors [References 5, 50, and 51] are used to measure the hydrogen concentration of the tank vapor space for Rapid Generation Tanks and Slow Generation Tanks while in Operation Mode or Non-Acidic Chemical Cleaning Mode and tanks in Acidic Chemical Cleaning Mode. The instrument uncertainty value selected in the development of the TSR hydrogen concentration limit where portable monitors are utilized shall be the highest uncertainty value for the available portable monitoring equipment used in the Tank Farm. For example, the MSA Model 261 multigas monitor has a larger uncertainty than the MSA Watchman multigas monitor or the RKI Eagle 2 multigas monitor. The uncertainty value for the Model 261 would be selected for determining the TSR hydrogen concentration limit. This permits any one of the three instruments to be used for manually monitoring hydrogen concentration per the TSRs.

For tanks in GRM, Operation Mode and Non-Acidic Chemical Cleaning Mode, the Flammability Control Program shall establish the TSR hydrogen concentration limit such that the minimum time to reach the LFL is maintained based on the vapor space volume protected by the waste tank High Liquid Level Conductivity Probe (HLLCP) [Ref. 1]. The TSR hydrogen concentration limits shall be on an individual tank basis and shall consider any proposed activities having the potential to release trapped gas (e.g., sludge agitation, bulk salt dissolution, interstitial liquid removal) [Ref. 1]. Tanks in Acidic Chemical Cleaning Mode will require minimum purge flow and a prescribed HLLCP setting to maintain the assumed initial hydrogen concentration that will protect 3 days to reach the LFL.

4.0 BACKGROUND

The CSTF Flammability Control Program applies to all waste storage tanks (except as described in Section 2.0) due to the presence of hydrogen and potentially flammable organic vapors. Waste tank flammability classifications shall be determined and documented in the ERD using the methodology in the program for tanks in Gas Release Mode, Operation Mode, and Non-Acidic Chemical Cleaning Mode. Tanks in Non-Acidic Chemical Cleaning Mode shall be subject to the same Flammability Control Program controls as tanks in Operation Mode.

The calculations and methodology prescribed in this Program are not applicable to tanks in Acidic Chemical Cleaning Mode. Tanks in Acidic Chemical Cleaning Mode must meet minimum purge flow requirements to maintain a minimum of 3 days to reach the LFL [Ref. 56].

For Tanks in Acidic Chemical Cleaning Mode, the waste tanks shall be classified as Chemical Cleaning Tanks and the time to LFL is not calculated: the time to LFL was determined in Reference 56 to be three days (accounting for radiolytic hydrogen generation, corrosion induced hydrogen generation, and the release of trapped gas from 10,000 gallons of sludge). Once a waste tank meets the requirements to exit Acidic Chemical Cleaning Mode, the tank may change Mode, the waste tank will be reclassified (Rapid Generation, Slow Generation, Very Slow Generation) and the Routine Flammability Controls apply.

Spray washing in Acidic Chemical Cleaning Mode does not contribute additional corrosion-induced hydrogen beyond that generated during batch additions of oxalic acid [Ref. 1].

Administrative controls will be implemented through this program to control mixing devices, bulk salt dissolution, interstitial liquid removal, and free supernate removal operations to limit hydrogen releases into a tank vapor space. The control requirements are separated into the following general categories:

- Loss of Ventilation Flammability Control Program
- Seismic Flammability Control Program
- Sludge Hydrogen Release Activities
- Salt Removal Activities
- Tank Fill Limits
- Closure Mode
- Non-Acidic Chemical Cleaning Mode

The following sections describe the program attributes for the general categories and provide the Technical Safety Requirement (TSR) [Ref. 6] and DSA Chapter 5 Administrative Control (AC) and Specific Administrative Control (SAC) references, where applicable.

4.1 LOSS OF VENTILATION FLAMMABILITY CONTROL PROGRAM

The Flammability Control Program does not apply to loss of ventilation for Tanks in Acidic Chemical Cleaning Mode, with the exception of tracking the flammability status in the ERD [Ref. 2]. Tanks in Acidic Chemical Cleaning Mode will require minimum purge flow to protect the time to LFL in Reference 56. The purge flow analysis includes the release of trapped gas during Acidic Chemical Cleaning. Response times to loss of ventilation for tanks in Acidic Chemical Cleaning Mode are prescribed by LCOs 3.8.15 and 3.8.18 for the tank primary and annulus, respectively [Ref. 6]. The Flammability Control Program does not apply to loss of ventilation for waste tanks in Closure Mode. Requirements for waste tanks in Closure Mode are given in Section 6.8.

A Flammability Control Program addressing loss of ventilation shall be established. The program shall include the following minimum attributes:

- Ensure that it takes a minimum of seven days upon loss of waste tank forced ventilation (excluding the effects of post-seismic trapped gas release and waste tanks in Acidic Chemical Cleaning Mode) for the tank bulk vapor space to increase from the safety analysis limit (value) to 100% of the LFL (CLFL for Tank 50). [TSR SAC 5.8.2.27.a]

- Determine and track the time to LFL (CLFL for Tank 50) for waste tanks in order to determine the individual waste tank flammability classification (Rapid Generation Tank, Slow Generation Tank, Very Slow Generation Tank, Chemical Cleaning Tank). Document the waste tank flammability classification for each waste tank in the ERD [Ref. 2]. [TSR SAC 5.8.2.27.a]

4.2 SEISMIC FLAMMABILITY CONTROL PROGRAM

The Seismic Flammability Control Program methodology does not apply to tanks in Acidic Chemical Cleaning Mode, with the exception of tracking the emergency response priority in the ERD [Ref. 2]. Tanks in Acidic Chemical Cleaning Mode have been determined to reach the LFL in 3 days [Ref. 56]. Acidic Chemical Cleaning Tanks shall be included in the number of tanks that can reach the LFL in less than seven days following a seismic event. Waste tanks in Closure Mode are also excluded from the Seismic Flammability Control Program methodology. Due to the low waste volume, there is negligible impact to time to LFL for trapped gas release.

The Flammability Control Program is credited with tracking the time to reach LFL following a seismic event. The program shall include the following attributes:

- Engineering, using the flammable vapor release methodology of the DSA, shall:
    - Ensure that it takes a minimum of 7 days upon loss of waste tank forced ventilation (excluding the effects of post seismic trapped gas release and excluding Chemical Cleaning Tanks) for the tank bulk vapor space to increase from the safety analysis limit to 100% of the LFL (CLFL for Tank 50) [TSR SAC 5.8.2.27.a]

- Determine, track, and ensure that only 7 waste tanks can reach 100% of the LFL in less than 24 hours assuming no ventilation and including the effects of post-seismic trapped gas release. [TSR SAC 5.8.2.27.a]

- Determine, track, and ensure that only 14 waste tanks can reach 100% of the LFL in less than seven days including [TSR SAC 5.8.2.27.a]:

  - Effects of post seismic trapped gas release, assuming no ventilation

  - Number of waste tanks in Acidic Chemical Cleaning Mode

- Programmatic controls shall be established to ensure a path forward is provided to DOE (addressing the additional risk and recovery time) if a transfer required to mitigate a waste tank leak causes additional waste tanks (more than 14) to have the potential to become flammable in less than seven days. Because the transfer is mitigating a degraded condition (i.e., placing the facility in a safer condition), the path forward is not required to be provided to DOE prior to initiating the transfer. [TSR AC 5.8.2.27.c].

- Waste tank mixing devices shall be periodically operated to limit the amount of trapped gas that could be released during a seismic event, such that the waste tank does not become flammable in less than 7 days following a seismic event. These controls shall be applicable to a waste tank following the initial depletion of trapped gas from the waste as a result of mixing operations. The program shall determine the quiescent period and shall be based on the actual waste contents/inventory (considering incoming transfers) and the hydrogen retention/release and flammable vapor criteria/methodologies discussed in the DSA, Sections 3.4.1.5.3 and 3.4.2.11.1. For waste tanks receiving transfers from a sending vessel greater than or equal to 15,000 gallons or has continuous makeup capability, the actual waste contents/inventory shall be adjusted to account for the maximum volume associated with a Transfer Error Event (i.e., 15,000 gallons). If the liquid batch source is less than 15,000 gallons and does not have continuous makeup capability, the actual waste contents/inventory shall be adjusted to account for the maximum total volume of the batch source. The liquid source system shall be considered to have continuous makeup capability if the system has an automatic or manual fill provision that is not electrically or mechanically isolated. This program does not apply to waste tanks that have an infinite calculated seismic quiescent time. The program shall also address the requirements for declaring hydrogen depletion success for a given tank quadrant (e.g., waste tank mixing device run times and speeds, number of pumps required to perform the safety function). The program shall also address the requirements in the event that hydrogen depletion success is not attained. The methodology for these requirements is discussed in the DSA, Section 3.4.2.11.1. [TSR SAC 5.8.2.28]

4.3 SLUDGE HYDROGEN RELEASE ACTIVITIES

The Flammability Control Program does not apply to the release of hydrogen from sludge for tanks in Acidic Chemical Cleaning Mode or Closure Mode. The purge flow analysis for tanks in Acidic Chemical Cleaning Mode included the release of trapped gas from the

maximum allowed sludge heel volume [Ref. 56]. For waste tanks in Closure Mode, operation of waste tank mixing devices is prohibited.

Programmatic controls shall be implemented to ensure that:

- Prior to initiating sludge agitation using waste tank mixing devices, determine if the activity will cause the waste tank to enter Gas Release Mode. [TSR SAC 5.8.2.29.a]

- Planned operation of waste tank mixing devices limits the release of trapped hydrogen such that the bulk vapor space concentration does not exceed the SAV defined by the Flammability Control Program, assuming a loss of ventilation. The Pump Run Program will ensure that the waste tank bulk vapor space hydrogen concentration is less than or equal to the initial value assumed in the hydrogen release Engineering Evaluation. The methodology used to determine the adequate number of vapor space turnovers and/or the hydrogen concentration shall be consistent with the requirements of Chapter 5 of the DSA. [TSR SAC 5.8.2.29.b]

- When a tank is in GRM, the operation of waste tank mixing devices shall be controlled such that the waste tank vapor space does not result in exceeding the hydrogen concentration safety analysis limit. [TSR SAC 5.8.2.29.c]

- Determine the waste tank hydrogen concentration LFL limit and document the value in the ERD [Ref. 2] (NA for Tank 50, as no hydrogen monitoring of that tank vapor space is required [Refs. 1,6]), excluding waste tanks in Acidic Chemical Cleaning Mode and Closure Mode. The hydrogen concentration LFL value stated in the ERD [Ref. 2] shall account for potential organics and instrument uncertainties. [TSR SAC 5.8.2.27.b]

4.4 SALT REMOVAL ACTIVITIES

Bulk salt dissolution and removal of interstitial liquid from saltcake are prohibited for tanks in Acidic Chemical Cleaning Mode. Transfers of waste into and out of a waste tank in Closure Mode are prohibited and liquid additions permitted for a tank in Closure Mode are those which are considered insignificant salt removal activities. Therefore, controls for Salt Removal Activities do not apply to tanks in Acidic Chemical Cleaning Mode or Closure Mode.

Controls shall be established to ensure that:

- Prior to initiating bulk salt dissolution/interstitial liquid removal activities, determine if the activity will cause the waste tank to enter Gas Release Mode. [TSR SAC 5.8.2.30.a]

- Bulk salt dissolution and interstitial liquid removal from saltcake activities limit the planned release of trapped hydrogen such that the bulk vapor space concentration does not exceed the SAV defined by the Flammability Control Program, assuming a loss of ventilation. The methodology used to determine the necessary controls (e.g., amount/rate of liquid addition, liquid removal rate) shall be based on the hydrogen

retention/release methodology/flammability controls for saltcake discussed in the DSA, Sections 3.4.1.5.3 and 3.4.2.11.1. The methodology used to determine the adequate number of vapor space turnovers changes and/or the hydrogen concentration shall be consistent with the requirements of Chapter 5 of the DSA. [TSR SAC 5.8.2.30.b]

- When a tank is in Gas Release Mode, the rate at which salt is dissolved or interstitial liquid is removed from saltcake shall be controlled such that the waste tank vapor space does not result in exceeding the hydrogen concentration safety analysis limit. [TSR SAC 5.8.2.30.c]

- Determine the waste tank hydrogen concentration LFL limit and document the value in the ERD [Ref. 2] (NA for Tank 50, as no hydrogen monitoring of that tank vapor space is required [Refs. 1,6]), excluding waste tanks in Acidic Chemical Cleaning Mode and Closure Mode. The hydrogen concentration LFL value stated in the ERD [Ref. 2] shall account for potential organics and instrument uncertainties. [TSR SAC 5.8.2.27.b]

4.5 TANK FILL LIMITS

This section is not applicable to waste tanks in Acidic Chemical Cleaning Mode or Closure Mode. The maximum fill levels for tanks in Acidic Chemical Cleaning Mode were determined based on the equilibrium liquid level in the tank annulus following a tank wall breach, and were used to determine the minimum required purge flow [Refs. 56,1]. These fill levels will be protected by the HLLCP setpoint [Ref. 6]. Waste tanks in Closure Mode are intentionally being filled with grout and are not protected by a fill limit. Waste tank overflow is considered not possible for a Closure waste tank and the flammability is not protected by a fill limit, but by the methods described in Section 6.8.

Programmatic controls shall be implemented to ensure that:

CST Engineering shall determine the Waste Tank Fill Limit for applicable waste tanks and document the values in the ERD [Ref. 2]. The values stated in the ERD shall account for the maximum volume associated with a transfer error event [i.e., 15,000 gallons] (excluding tanks in Non-Acidic Chemical Cleaning Mode) and instrument uncertainties, [TSR SAC 5.8.2.44] unless the SCDHEC Construction Permit [Ref. 62] criterion is bounding (i.e., results in the lowest setpoint value). The published value shall be based on the most conservative of the following:

- Maximum Fill Limit (maximum tank level that protects initial conditions/assumptions used in the accident analysis)

- Overflow Limits (these limits also protect assumptions associated with tank wall exposed area)

- Structural Integrity Fill Limit

- Siphon Limits for **Waste** Tanks 1**-4 and 7-1**2

- Flammable Transient Limits Due to Trapped Gas Release
- Flammability Level (used for time to LFL [CLFL for Tank 50] calculations)
- Maximum annulus equilibrium liquid level (following a tank wall breach) for waste tanks in Non-Acidic Chemical Cleaning Mode
- Lowest Leak Site (SCDHEC Construction Permit Requirement, see section 6.5)

4.6 DELETED

4.7 DELETED

4.8 CLOSURE MODE

The parameters defining the Closure Mode are documented in Chapter 5 of the DSA [Ref. 1]. This PDD describes the flammability-related Mode entry prerequisites for entering the Closure Mode in Section 6.8.

4.9 NON-ACIDIC CHEMICAL CLEANING MODE

The parameters defining the Non-Acidic Chemical Cleaning Mode are documented in Chapter 5 of the DSA [Ref. 1]. Non-Acidic Chemical Cleaning Mode is applicable to Type I and II waste storage tanks. Routine Flammability controls apply to tanks in Non-Acidic Chemical Cleaning Mode.

5.0 INPUTS

The inputs used for the CSTF Flammability Control Program include the following:

- Vapor space and trapped gas temperature limits used in the flammability calculations may use the supernate temperature limits protected by the Corrosion Control Program [Ref. 8], not to exceed 100°C [Ref. 1]. As an alternative to using the corrosion control supernate temperature limits, an engineering evaluation may be performed to set maximum flammability temperature limits (refer to Reference 9). These temperature limits are used to correct the flammability calculations to account for temperature variations. For inactive, dry tanks with no specified supernate temperature limit, a maximum temperature limit of 75°C shall be used for the flammability calculations [Ref. 55]. For evaporator drop tanks during evaporator operation (and 7 days following the termination of evaporator operation), the corrosion supernate temperature limits are suspended [Ref. 8]. However, during this period, the corrosion supernate temperature limits for drop tanks are applied to drop tanks for flammability calculations. For Tank 50, 43ºC is to be used for the flammability calculations (the bulk supernate temperature limit is 43ºC [Refs. 1, 42].

- Unless otherwise noted, dissolved hydrogen contributions are not considered because of the following:

- Typical of waste tanks, small temperature increases correspond to insignificant amounts of dissolved hydrogen released.

- Waste agitation from seismic motion will release insignificant, if any, quantities of dissolved hydrogen, per the DSA, Section 3.4.1.5.3.

- Dissolved hydrogen release due to mixer operation is not a prompt release, per the DSA, Section 3.4.1.5.3.

- Organic flammability contributions due to trace organics are considered bounded by 5% of the LFL for hydrogen, except for Tank 50, which includes contributions from Isopar® L (51.2% of the CLFL at 43°C) in addition to the 5% of the LFL [Ref. 42] due to trace organics. The Waste Acceptance Criteria Program [TSR SAC 5.8.2.15] shall ensure that waste streams received into the facility are sufficiently characterized to demonstrate compliance with the organic contribution to flammable vapors (evaluated at 100 °C). The organic contribution is accounted for in the time to LFL calculations. Within CSTF, very minor, if any, organics are added (e.g., defoamers for evaporators) and are fully covered by the 5% LFL assigned for organics by the following programs:

  - The Chemical Inventory Control Program shall provide control over new materials brought into the facility. [TSR AC 5.8.2.17]

  - The Oil Control Program shall be established to prevent the introduction (e.g., via air compressors,) of significant flammable vapors from lubricating or hydraulic oil into analyzed spaces (e.g., evaporator pots, evaporator cells, transfer facilities, waste tanks, and waste tank annuli) [Ref. 1]. This program is described in Section 6.9. [TSR AC 5.8.2.45]

  The contribution from organics for waste tanks is included in the temperature and organic-corrected LFL (LFL_{OC}). The 5% contribution to the hydrogen LFL from trace organics is evaluated at 25°C, which is conservative compared to the Waste Acceptance Criteria requirement of 100°C.

- Flammability calculation inputs are dependent on the Waste Characterization System (WCS) Administrative Program [Ref. 10]. The input parameters and corresponding outputs for the flammability control program calculations are revised at the frequency that the WCS database is updated. Such updates capture the Flammability Control Program requirements through the ERD linking procedure (SW11.6-SVP-ERD).

- Salt/sludge height is calculated based on measurement by salt/sludge soundings or turbidity meters (for sludge), or determined per engineering evaluation. Engineering shall identify the methodology for salt/sludge height determination. Engineering evaluations for salt/sludge height determination should consider the following as applicable for the specific waste tank: visual inspection, process knowledge (e.g., transfer history, operational conditions), historical salt/sludge height indications, and waste tank sample results [Ref. 1].

5.1 IMPLEMENTATION ACTIONS

1. Supernate temperature limits imposed by the Corrosion Control Program [Ref. 8] shall be used in flammability calculations, with the following exceptions:

    a. Alternative temperature limits may be set by engineering evaluation

    b. Inactive, dry tanks with no specified supernate temperature limit shall use 75°C for flammability calculations

    c. Tank 50 shall use 43°C for flammability calculations

    d. The limits cannot exceed 100°C [Ref. 1].

2. Flammability calculations shall account for the contribution of 5% of the hydrogen LFL due to trace organics, except for Tank 50. Tank 50 shall account for contributions from Isopar® L (51.2% of the CLFL at 43°C) in addition to the 5% of the LFL due to trace organics

3. Solids volume shall be calculated based on measurements obtained using salt/sludge soundings or turbidity meters (for sludge), or determined per engineering evaluation

6.0 PROGRAM DESCRIPTION

6.1 LOSS OF VENTILATION FLAMMABILITY CONTROL PROGRAM

This section is not applicable to tanks in Acidic Chemical Cleaning Mode or Closure Mode. Tanks in Acidic Chemical Cleaning Mode and Closure Mode are evaluated by a separate methodology, as outlined in Sections 6.7 and 6.8 respectively.

The objective of this section is to describe the administrative control requirements to evaluate the mixture of flammable gases in the waste tank vapor space such that, upon loss of ventilation, at least seven days are available before the waste tank reaches 100% LFL (100% CLFL for Tank 50), considering radiolytic hydrogen generation.

The Flammability Control Program shall provide administrative controls to determine and track the time to LFL for each waste tank, including administrative control of tank contents and operations. Rapid and Slow flammability classifications are designated according to the time it takes to go from the tank's SAV to 100% of the LFL (100% CLFL for Tank 50). For hydrogen release due to planned activities, the SAV must be a minimum of 25% to a maximum of 60% of the LFL. The SAV may be increased within the range of 25% to 60% to allow for a larger hydrogen release, but will reduce the time to LFL upon loss of ventilation in the waste tank. The SAV (and therefore the allowable trapped gas release) must be set such that the minimum times to LFL for Rapid and Slow tanks are protected. A Very Slow Generation flammability classification designates tanks that reach their equilibrium concentration at less than 100% LFL (100% CLFL for Tank 50); therefore, the

times to LFL are infinite (and therefore the SAV is not applicable) and Very Slow Generation Tanks are exempt from ventilation requirements (except for best management practice as discussed in Section 8.2). However, during free supernate removal in Very Slow Generation Tanks, specific volumes of saltcake (see Section 6.4) and settled sludge (see Section 6.3) will cause the vapor space to reach 100% LFL (100% CLFL for Tank 50); therefore, free supernate removal from waste tanks with these specific volumes is prohibited (See Sections 6.3 and 6.4).

Dissolved gas releases from jetted transfers and free liquid removal are not considered in the loss of ventilation time to LFL.

Hydrogen is naturally buoyant in air and diffuses readily; therefore, hydrogen released to vapor spaces from radiolytic decomposition and corrosion is assumed to be well mixed (i.e., no hydrogen layering) and only bulk hydrogen concentrations are considered.

6.1.1 TIME TO LFL METHODOLOGY

The DSA recognizes atmospheric breathing as a realistic transport mechanism for flammable vapors in the loss of normal tank ventilation. The following equation, derived from the hydrogen vapor space concentration equation in Ref. 1, Section 3.4.1.1.2, provides the Flammability Control Program time to LFL equation which accounts for the effects of atmospheric breathing:

Eq. # 1.

$$\text{Time to LFL} = \frac{-\ln\left[\dfrac{LFL_{OC} - \dfrac{Q_{H2}}{Q_{H2}+Q}}{y_0 - \dfrac{Q_{H2}}{Q_{H2}+Q}}\right]}{\dfrac{Q_{H2}+Q}{V_V}}$$

Where,

Time to LFL	=	Time it takes for the hydrogen concentration to go from the initial hydrogen concentration (y_0) to the temperature and organic corrected hydrogen concentration at 100% LFL (LFL_{OC}), hours
LFL_{OC}	=	Temperature and organic corrected hydrogen concentration at 100% LFL (Eq. # 3) for all waste tanks except Tank 50. Due to the contribution of trace organics of up to 5% of the CLFL, and Isopar of up to 51.2% of the CLFL, LFL_{OC} for Tank 50 at 100% CLFL is calculated to be 43.8% of the CLFL (i.e., 43.8% of the hydrogen LFL at 43°C) [Ref. 42], vol. frac.
y_0	=	Initial hydrogen concentration (defined by the designated tank specific SAV), including temperature

correction (Eq. # 2), vol. frac.

Q_{H2}	=	Temperature corrected hydrogen generation rate, ft^3/hr (Eq. # 12)
Q	=	Atmospheric breathing rate, ft^3/hr (Eq. # 13)
V_V	=	Vapor space volume protected by HLLCP level, ft^3 (Eq. # 14)

Time to LFL is calculated in units of hours.

VARIABLE y_0 CALCULATION (USED IN EQ. # 1)

The initial hydrogen concentration, corrected for temperature, is determined by using the Burgess – Wheeler correlation, as follows:

Eq. # 2. $$y_0 = y_{0(25C)} \cdot [1 - A \cdot (T - 25)]$$

Where,

y_0	=	Initial hydrogen concentration (defined by the designated tank specific SAV), including temperature correction, vol. frac.
$y_{0(25C)}$	=	Initial hydrogen concentration at 25°C, defined by the designated tank specific SAV (3.8% of LFL_{25C} for Tank 50 [Ref. 1]), vol. frac.
A	=	Empirical coefficient (Zabetakis attenuation factor), (i.e., 0.0011 per Ref. 1), $^oC^{-1}$
T	=	Temperature at which LFL is to be evaluated in °C (43°C for Tank 50) [Refs. 1,42]

For Tank 50, the purge flow is shown to be able to maintain the vapor space ≤ 60% of the CLFL when Tank 50 is classified as a Slow or Rapid tank. Because Tank 50 is assumed to have 51.2% of the CLFL due to Isopar® L and 5% due to trace organics, the concentration of hydrogen that can be maintained is 60%-51.2%-5% = 3.8% [Refs. 1,42]. Therefore, a hydrogen concentration of 3.8% corresponds to a total combustible vapor concentration equal to 60% of the CLFL, which is the SAV for Tank 50.

The values used in the temperature correction calculations are the supernate temperature limits designated by the Corrosion Control Program [Ref. 8], except for Tank 50. The values cannot exceed 100°C [Ref. 1]. For Tank 50, 43ºC is to be used for flammability calculations (the bulk supernate temperature limit is 43ºC [Refs. 1,42]).

As an alternative to using supernate temperature limits, an engineering evaluation may be performed to set maximum temperature limits, not to exceed 100°C [Ref. 1] (refer to Reference 9). The vapor space temperature is assumed to be the same as the supernate phase.

VARIABLE LFL_{OC} CALCULATION (USED IN EQ. # 1)

The LFL for hydrogen is 4.0% by volume (0.04-volume fraction) at room temperature conditions (i.e., 25°C). Since the LFL is temperature dependent, the LFL is adjusted for the various temperature conditions found in the CSTF using the Burgess – Wheeler Law [Ref. 1] The Burgess-Wheeler Law provides an empirical correlation to correct the LFL to account for temperature variations. The Burgess – Wheeler correlation is documented in Section 3.4.1.1.2 of the DSA.

Using the same basis as the y_0 calculation (Eq. #2), the LFL, corrected for organic and temperature, is determined by using the Burgess – Wheeler correlation and subtracting the organic contribution, as follows for all tanks except for Tank 50:

Eq. # 3. $$LFL_{OC} = LFL_{25C} \cdot [1 - A \cdot (T - 25)] - OC$$

Where,

LFL_{OC}	=	LFL corrected for organic contribution and temperature, vol. frac.
LFL_{25C}	=	LFL at 25°C, (i.e., 0.04-volume fraction), vol. frac.
OC	=	The organic contribution equivalent hydrogen concentration (i.e., 5% of LFL_{25C} (0.002-volume fraction) for all tanks except Tank 50), vol. frac.
A	=	Empirical coefficient (Zabetakis attenuation factor), (i.e., 0.0011 per Ref. 1), $^{o}C^{-1}$
T	=	Temperature at which LFL is to be evaluated in °C (43°C for Tank 50) [Refs. 1,42]

Trace organics may account for up to 5% of the hydrogen LFL in a waste tank. For Tank 50, Isopar® L may contribute up to 51.2% of the CLFL at 43°C [Ref. 42]. This is in addition to the 5% of the CLFL due to trace organics, for a total of 56.2% of the CLFL [Ref. 42]. This results in a hydrogen concentration of 43.8% of the CLFL at 43°C (i.e. if the hydrogen concentration in Tank 50 reaches 43.8% of the LFL for hydrogen at 43°C, the vapor space is assumed to be flammable) [Ref. 42]. For Tank 50, the LFL_{OC} is calculated using Eq. # 3A:

Eq. # 3A. $$LFL_{OC} = 43.8\% \cdot LFL_{25C} \cdot [1 - A \cdot (43 - 25)]$$

Where,

LFL_{OC}	=	LFL corrected for organic contribution and temperature, vol. frac.
LFL_{25C}	=	LFL at 25°C, (i.e., 0.04-volume fraction), vol. frac.
A	=	Empirical coefficient (Zabetakis attenuation factor), (i.e., 0.0011 per Ref. 1), $^{o}C^{-1}$

To only account for a temperature correction to the hydrogen LFL (no organic contribution) the equation would become

Eq. # 3B. $$LFL_T = LFL_{25C} \cdot [1 - A \cdot (T - 25)]$$

Where,

LFL_T	=	LFL corrected for temperature, vol. frac.
LFL_{25C}	=	LFL at 25°C, (i.e., 0.04-volume fraction), vol. frac.
A	=	Empirical coefficient (Zabetakis attenuation factor), (i.e., 0.0011 per Ref. 1), $^oC^{-1}$
T	=	Temperature at which LFL is to be evaluated in °C (43°C for Tank 50) [Refs. 1,42]

VARIABLE Q_{H2} (USED IN EQ. # 1)

The methodology used to calculate the total hydrogen generation rate (x_{H2}) is taken from Section 3.4.1.1.2 of the DSA and is the sum of the contribution from the radiolytic hydrogen generation and corrosion induced hydrogen generation. The radiolytic hydrogen generation rate equations are based on experimental data that has had margin added (10%) [Ref. 74]. Therefore, the hydrogen generation rate calculations excluding waste tanks entering Closure Mode do not need to include additional analytical uncertainty [Ref. 1]. This total generation rate is:

Eq. # 4. $$x_{H2} = x_{RAD} + x_{CORR}$$

Where:

x_{H2}	=	Total generation rate of hydrogen, ft³/hr
x_{RAD}	=	Radiolytic hydrogen generation rate, ft³/hr
*x_{CORR}	=	Corrosion induced hydrogen generation rate, ft³/hr

*Applicable to waste tanks in Acidic Chemical Cleaning Mode, where the bounding rate is: 4.3E-05 ft³ / min-ft² (Eq. # 10)

The radiolytic hydrogen generation rate at 25 °C is determined using the following equation:

Eq. # 5. $$x_{RAD} = \frac{R_{\beta/\gamma} H_{\beta/\gamma} + R_\alpha H_\alpha}{10^6}$$

Where:

x_{RAD}	=	Radiolytic hydrogen generation rate at 25°C, ft³/hr

$R_{\beta/\gamma}$ = Volume (ft^3) of hydrogen generated per MBTU (10^6 British Thermal Unit) of heat added from beta or gamma decay

$H_{\beta/\gamma}$ = Heat generated by beta and gamma decay, BTU/hr

R_α = Volume (ft^3) of hydrogen generated per MBTU of heat added from alpha decay

H_α = Heat generated by alpha decay, BTU/hr

The 10^6 in the denominator converts MBTU to BTU.

The values of R_α and $R_{\beta/\gamma}$ are dependent on the concentration of nitrate and nitrite in the waste and are given by the equations:

Eq. # 6. $$R_\alpha = 134.7 - 82.3*(NO_{eff})^{1/3} - 13.6*(NO_{eff})^{2/3} + 11.8*(NO_{eff})$$

Eq. # 7. $$R_{\beta/\gamma} = 48.36 - 52.78*(NO_{eff})^{1/3} + 14.1*(NO_{eff})^{2/3} + 0.572*(NO_{eff})$$

Where:

R_α = Volume (ft^3) of hydrogen generated per MBTU of heat added from alpha decay

$R_{\beta/\gamma}$ = Volume (ft^3) of hydrogen generated per MBTU (10^6 British Thermal Unit) of heat added from beta or gamma decay

NO_{eff} = The nitrate concentration plus one-half the nitrite concentration (where concentrations are in units of mol/L)

The effective ion concentration (NO_{eff}) of the tank supernate is equal to the nitrate concentration plus one-half of the nitrite concentration. To address the potential for inadvertent transfers to the tanks, the NO_{eff} is diluted by the addition of 15,000 gallons of uninhibited water to account for maximum missing waste. As an alternative to using 15,000 gallons of uninhibited water, an engineering evaluation may be performed to evaluate the impact of an inadvertent transfer of 15,000 gallons of supernate from each waste tank on NO_{eff} [Ref. 39].

The heat generated by alpha and beta/gamma decay is determined by the equations:

Eq. # 8. $$H_\alpha = \sum_i Q_i * A_i$$

Eq. # 9. $$H_{\beta/\gamma} = \sum_j Q_j * A_j$$

Where:

H_α = Total heat generated by alpha decay, BTU/hr

Q_i	=	Heat generated per curie for each isotope that decays by alpha, BTU/Ci-hr
A_i	=	Total activity of each isotope that decays by alpha, Ci
$H_{\beta/\gamma}$	=	Total heat generated by beta or gamma decay, BTU/hr
Q_j	=	Heat generated per curie for each isotope that decays by beta or gamma, BTU/Ci-hr
A_j	=	Total activity of each isotope that decays by beta or gamma, Ci

At a minimum the following isotopes must be considered when calculating the total heat: Sr-90, Y-90, Cs-137, Ba-137m, Ce-144, Pu-238, Pu-239, Am-241, Cm-244 [Ref. 1].

The corrosion induced hydrogen generation rate is determined using the following equation:

Eq. # 10. x_{CORR} = Area Contacted x Rate

Where:

x_{CORR}	=	Corrosion induced hydrogen generation rate, ft^3/hr
Area Contacted	=	Surface area in contact with acidic waste, ft^2
Rate	=	Corrosion induced hydrogen generation rate per area, $ft^3/hr\text{-}ft^2$ (Ref. 1, Section 3.4.1.5.5)

If corrosion induced hydrogen generation is not a contributor, x_{CORR} is zero and the equation becomes:

Eq. # 11. $x_{H2} = x_{RAD}$

Where:

x_{H2}	=	Total generation rate of hydrogen at 25°C, ft^3/hr
x_{RAD}	=	Radiolytic hydrogen generation rate at 25°C, ft^3/hr

The maximum hydrogen generation rates are provided below in addition to the tank flammability requirements (e.g. a Slow Generation Tank must have at least 28 days to LFL, following a loss of ventilation, and have a total radiolytic hydrogen generation rate less than or equal to the value stated below) [Ref. 1]:

- The maximum radiolytic hydrogen generation rate for a Rapid Generation Tank (excluding the third, fourth, and fifth bulleted items below) is 19.6 ft^3/hr. This total tank radiolytic hydrogen generation rate, in addition to the dissolved hydrogen release

rate associated with transfers, is utilized for determining the required ventilation purge rate.

- The maximum radiolytic hydrogen generation rate for a Slow Generation Tank (excluding the third, fourth, and fifth bulleted items below) is 8.1 ft^3/hr. This total tank radiolytic hydrogen generation rate, in addition to the dissolved hydrogen release rate associated with transfers, is utilized for determining the required ventilation purge rate.
- The maximum radiolytic hydrogen generation rate for Tanks 40 and 51, when classified as an ESP Sludge Slurry Waste Tank, is 65.3 ft^3/hr. This total tank radiolytic hydrogen generation rate is utilized for determining the required ventilation purge rate.
- The maximum radiolytic hydrogen generation rate for Tank 50 (when classified as either a Rapid or Slow Generation Tank) is 5.9E-02 ft^3/hr . This total tank radiolytic hydrogen generation rate is utilized for determining the required ventilation purge rate.
- The maximum radiolytic hydrogen generation rate for Type IV tanks is 3.2 ft^3/hr. This total tank radiolytic hydrogen generation rate, in addition to the dissolved hydrogen release rate associated with transfers, is utilized for determining the required ventilation purge rate.

Many of the accidents are assumed to occur at elevated temperatures; therefore, the radiolytic hydrogen generation rate is corrected for the higher temperatures using the Temperature Corrected Hydrogen Generation Rate methodology in Section 3.4.1.1.2 of the DSA.

Eq. # 12.
$$Q_{H2} = x_{H2} * \frac{(T + 273)}{(T_i + 273)}$$

Where:

Q_{H2}	=	Temperature corrected hydrogen generation rate, ft^3/hr
x_{H2}	=	Total hydrogen generation rate at temperature T_i, ft^3/hr
T	=	Temperature at which Q_{H2} is to be evaluated, ^oC
T_i	=	Base temperature which Q_{H2} is to be compared against, ^oC (typically 25°C [Ref. 66])

The values used in the temperature correction calculations are the supernate temperature limits designated by the Corrosion Control Program, not to exceed 100°C [Refs. 8,1]. For Tank 50, 43ºC is to be used for flammability calculations (the bulk supernate temperature limit is 43ºC [Refs. 1,42]). As an alternative to using supernate temperature limits, an engineering evaluation may be performed to set maximum temperature limits (refer to Reference 9). Time to LFL evaluations assume that the waste is at equilibrium for hydrogen retention, therefore all the hydrogen generated is assumed to be released into the waste tank vapor space.

Application of the Corrosion Control Program dip sample analysis for the effective ion concentration (NO_{eff}) values applied to supernate, sludge, and salt layers is a conservative practice, which minimizes the number of samples required to satisfy both Corrosion and Flammability Control Programs. Alternatively, variable depth samples can be used in conjunction with Corrosion Control samples to offer a more representative analysis of NO_{eff} of the bulk supernate for flammability purposes and are acceptable for use in the Flammability Control Program evaluations. This will be especially true of waste tanks where supernate stratification is suspected (e.g. evaporator feed tanks, drop and vent tanks, low density transfer into high density waste tanks, and rainwater in-leakage into waste tanks). The variable depth samples used in flammability calculations will be subject to the same requirements (i.e., sample frequency and grace period) as the dip sample analysis in the Corrosion Control Program (refer to Reference 8).

The scavenger concentration, NO_{eff}, used in dry salt tanks and sludge tanks without a supernate cover is based on the most recent sample results. As the evaporation process occurs in a salt/sludge tank, the supernate layer above the salt/sludge increases in salt concentration as the liquid level recedes into the salt/sludge phase as interstitial liquid. Evaporation tends to increase NO_{eff} in the remaining liquid. Therefore, using the latest sample results is conservative.

VARIABLE Q CALCULATION (USED IN EQ. # 1)

Atmospheric breathing reduces the hydrogen buildup in the vapor space and is therefore credited in this program. No specific controls for atmospheric breathing are required, since the design of the cell covers, penetrations, riser plugs, etc., is such that the locations crediting atmospheric breathing will have more than enough of such extremely small openings [Ref. 1]. The atmospheric breathing assumptions and methodology are established in the DSA, Section 3.4.1.5.5. The correlation for atmospheric breathing rate is determined using the following equation:

Eq. # 13. $$Q = \left[\frac{\text{mean atm. fluctuation}}{1013\ \text{mbar}}\right] \cdot \frac{V_V}{24\ \text{hrs/day}}$$

Where,

Q	=	Atmospheric breathing rate, ft^3/hr
mean atm. fluctuation	=	Mean pressure fluctuation, 5 mbar/day (Ref. 64)
V_V	=	Vapor space volume as determined in Eq. # 14 (Vv' for seismic calculations in Eq. # 21), ft^3

VARIABLE V_V CALCULATION (USED IN EQ. # 1)

The High Liquid Level Conductivity Probe (HLLCP) setpoint is credited for protecting the vapor space volume used to determine loss of ventilation time to LFL and flammability classification. Although the actual waste level will be less than the HLLCP, the use of the setpoint provides a

conservative basis utilizing credited level detection equipment. The following equation is the vapor space volume calculation, in cubic feet:

Eq. # 14. $V_V = [V_T - (\text{Flammability Level} \cdot \text{Ff})] \cdot 0.1336\ \text{ft}^3 / \text{gal}$

Where,

Vv	=	Vapor space volume protected by HLLCP setpoint, ft^3
V_T	=	Total tank vapor space volume (empty tank), gal
Flammability Level	=	Establishes the credited vapor volume used to protect the Tank Classification, in. (see Eq. # 27)
Ff	=	Fill factor, gal/in

The adjusted fill factor is applied as an algorithm to reflect varying fill factors that adjust the established tank calibrations as a result of the displaced volume of the support cone in the upper part of the tank, as applicable [Refs. 13,14]. The nominal fill factor [Ref. 1] may be used to calculate the waste volume. Application of the nominal fill factor in this way is conservative because the fill factor overestimates the waste volume. The Flammability Level accounts for maximum missing waste volume and instrument uncertainty [Ref. 1]. The instrument uncertainty values are based on conductivity probe uncertainty calculations [Ref. 15].

6.1.2 FLAMMABILITY CLASSIFICATION METHODOLOGY

The flammability classifications are designated according to the time it takes to go from the SAV to 100% of the LFL_{OC} following a loss of ventilation:

- Rapid Generation Tanks - Waste storage tanks that have been determined to go from the SAV to 100% of the LFL_{OC} in less than 28 days following a loss of ventilation. For Tank 50, the SAV will be 60% CLFL; this is an equivalent hydrogen concentration of 3.8% of the LFL_T for hydrogen, accounting for 51.2% of the CLFL due to Isopar® L and 5% of the CLFL due to trace organics [Ref. 1].

- Slow Generation Tanks - Waste storage tanks that have been determined to go from the SAV to 100% of the LFL_{OC} in greater than or equal to 28 days following a loss of ventilation. For Tank 50, the SAV will be 60% CLFL; this is an equivalent hydrogen concentration of 3.8% of the LFL_T for hydrogen, accounting for 51.2% of the CLFL due to Isopar® L and 5% of the CLFL due to trace organics [Ref. 1].

- Very Slow Generation Tanks - Waste storage tanks that have been determined to never reach 100% of the LFL_{OC}, considering atmospheric breathing.

The above classifications only pertain to tanks where there is no sludge agitation and/or salt removal activities taking place (i.e., tanks not in Gas Release Mode). Requirements and considerations for tanks undergoing sludge agitation or salt removal activities are addressed

in Sections 6.3 and 6.4, respectively. All flammability classifications are based on the time to LFL calculations using Eq. # 1.

VERY SLOW GENERATION TANKS

Very Slow Generation Tanks are shown by calculation to never reach 100% of the LFL_{OC}. The total hydrogen concentration at equilibrium conditions with hydrogen production from radiolytic decomposition is represented in the following equation:

Eq. # 15. $$H_{eq} = \frac{Q_{H2}}{Q_{H2} + Q} \cdot 100\%$$

Where,

H_{eq}	=	Volume % hydrogen concentration at equilibrium
Q_{H2}	=	Total hydrogen volumetric evolution rate, ft^3/hr
Q	=	Atmospheric breathing rate, ft^3/hr (see Eq. # 13) [By substituting ventilation flow rate for Q, the hydrogen concentration at steady state equilibrium is determined for Slow and Rapid Generation Tanks when accounting for ventilation. See "Variable Equilibrium Concentration Calculation" in Section 6.2.1.]

The equilibrium concentration is expressed in units of volume %, but it can be expressed in units of % LFL_{OC} if the equation is divided by LFL_{OC}. Heq can also be expressed as a volume fraction if the equation is not multiplied by 100%.

No forced ventilation is required for the purposes of flammability by the DSA for Very Slow tanks. Normal tank breathing will ensure that the tank vapor space is maintained below 100% of LFL_{OC}.

Best management practice will be to require ventilation (installed or portable) to operate on Very Slow Generation Tanks while undergoing jetted transfer receipts (due to steam used in a steam jet transfer) because of the potential of dissolved hydrogen contributions above the hydrogen equilibrium to result in greater than, or equal to, 100% of LFL_{OC}. The exhaust fan shall be operating and aligned for the duration of the transfer.

The calculated hydrogen concentration shall reach equilibrium conditions for Very Slow Generation Tanks at less than 100% of the LFL_{OC}, by definition. However, during free supernate removal in Very Slow Generation Tanks, specific volumes of saltcake/settled sludge will cause the vapor space to reach 100% LFL_{OC}; therefore, free supernate removal from the tanks that contain greater than these specified volumes of saltcake/settled sludge is prohibited. (Sections 6.3 and 6.4)

6.1.3 IMPLEMENTATION ACTIONS

1. The tank flammability classification shall be determined in an engineering evaluation or in the WCS database governed by the WCS Administrative Program. [TSR SAC 5.8.2.27.a]

2. The tank flammability classifications shall be documented in the ERD. [TSR SAC 5.8.2.27.a]

3. Planned operations (e.g., waste tank to waste tank transfers) shall be pre-evaluated to determine the impact on the hydrogen generation rate, time to LFL, and tank flammability classifications for the affected process areas (e.g., sending and receiving tanks) as part of the Evaluated Transfer Approval Form (ETAF) process [Ref. 11, Tab Electronic SW11.1].

4. If the evaluated activity results in a tank flammability classification change to a more restrictive status (SLOW to RAPID, VERY SLOW to RAPID, VERY SLOW to SLOW), then the status will be updated in the ERD and implemented in the facility via the ERD linking procedure (SW11.6-SVP-ERD) prior to initiation of the planned activity.

5. If the projected time to LFL results in less than seven days or the maximum hydrogen generate rate is exceeded, then the evaluated activity shall not be performed.

6. Liquid additions to the waste tanks shall be pre-evaluated to determine the impact on the hydrogen generation rate, time to LFL, and flammability classification of the affected waste tanks using WCS or an engineering evaluation.

7. Ventilation shall be required during jetted transfer receipts for Very Slow Generation Tanks as part of the ETAF process [Ref. 11, Tab Electronic SW11.1].

8. Periodically, the flammability classifications of all waste tanks will be reviewed to determine if any are at risk of an unexpected flammability classification change due to fluctuations in sample results. If a tank is identified by this review, recommendations (e.g., chemical additions, lowering probe heights, etc.) shall be provided to the facility to avoid this risk (See Section 8.2).

9. The equilibrium flammable gas concentration for Very Slow Generation Tanks shall be determined in an engineering evaluation or in the WCS database. Very Slow Generation Tanks with a calculated equilibrium flammable gas concentration greater than 60% LFL_{OC} shall be identified in the ERD [Ref. 2] or in an engineering evaluation.

10. Tanks in Non-Acidic Chemical Cleaning Mode are not permitted to exceed Gas Release Criteria.

6.2 SEISMIC FLAMMABILITY CONTROL PROGRAM

This section is not applicable to tanks in Acidic Chemical Cleaning Mode. Tanks in Acidic Chemical Cleaning Mode are evaluated by a separate methodology, as outlined in Section 6.7. Waste tanks in Closure Mode are also excluded from the Seismic Flammability Control Program methodology. Due to the low waste volume, there is negligible impact to time to LFL for trapped gas release.

The Flammability Control Program shall provide administrative controls to determine and track the seismic time to LFL for each waste tank, including administrative control of tank contents and operations. Programmatic controls shall be established to ensure that the number of tanks capable of becoming flammable following a seismic event (including the effects of post seismic trapped gas release and the number of tanks in Acidic Chemical Cleaning Mode) within specified time periods shall be within the restrictions of the TSR/DSA [Refs. 1,22]. Programmatic controls shall be established to ensure a path forward is provided to DOE (addressing the additional risk and recovery time) if a transfer that is required to mitigate a waste tank leak causes additional waste tanks to have the potential to become flammable in less than seven days. Because the transfer is mitigating a degraded condition (i.e., placing the facility in a safer condition), the path forward is not required to be provided to DOE prior to initiating the transfer.

6.2.1 SEISMIC TIME TO LFL METHODOLOGY

The methodology for determining the seismic time to LFL is consistent with the methodology presented in the Time to LFL Methodology (Section 6.1.1), with the exception of the following assumptions:

- The initial concentration, y_0, shall be the steady state hydrogen equilibrium concentration including the effects of post seismic trapped gas release and shall be designated by the term y_0(Seismic) (see Eq. # 16)

- The vapor space volume, Vv, shall be dependent on the actual or projected tank fill level and is designated Vv' (see Eq.# 21)

- 15,000 gallons of maximum missing waste shall be evaluated for the receipt tank prior to transfers (assuming the maximum missing waste is the transfer material) if a sending vessel is greater than or equal to 15,000 gallons or has continuous makeup capability. If the liquid batch source is less than 15,000 gallons and does not have continuous makeup capability, the maximum total volume of the batch source shall be used to account for the maximum volume associated with a Transfer Error event. The liquid source system shall be considered to have continuous makeup capability if the system has an automatic or manual fill provision that is not electrical or mechanically isolated.

- Post seismic trapped gas release assumes no gas retention (the hydrogen generated is equal to the hydrogen released into the waste tank vapor space). The methodology is limited to settled sludge and saltcake waste tanks. Seismic Time to LFL Methodology

for slurried tanks is governed by the Seismic Quiescent Time Program specified in Section 6.2.2.

VARIABLE y_0 (SEISMIC) CALCULATION (USED IN EQ. # 1)

The initial concentration used in the seismic time to LFL equation shall include the steady state hydrogen equilibrium concentration accounting for ventilation, (except for Very Slow Generation Tanks, which shall assume the hydrogen equilibrium without ventilation) and the effects of post seismic trapped gas release. Free release is inherently accounted for in the seismic time to LFL calculation based on the inclusion of the hydrogen generation rate term. To determine the seismic time to LFL, y_0(Seismic) is then substituted for y_0 in Eq. # 1.

Eq. # 16. $$y_0(\text{Seismic}) = \text{Equil. Conc.} + \text{TG}$$

Where,

y_0(Seismic)	=	Initial hydrogen concentration in the vapor space following a seismic event, vol. frac. H_2
Equil. Conc	=	initial concentration at steady state hydrogen equilibrium in units of vol. frac. H_2 • higher of 2.5% of LFL_T using Eq. # 3B, or as specified in engineering evaluation for a Rapid or Slow Generation Tank • equilibrium concentration using Eq. # 15 for a Very Slow Tank, accounting for the actual vapor space volume, Vv'
TG	=	Hydrogen concentration due to trapped gas release in units of vol. frac. H_2 (see Eq. # 17)

For a Rapid or Slow tank, the engineering evaluation (by hand or in the WCS database) should account for the hydrogen concentration at equilibrium with operating ventilation at an appropriate flow rate (i.e. minimum required purge flow for the tank given the flammability classification) as described in the following section.

VARIABLE EQUILIBRIUM CONCENTRATION CALCULATION (USED IN EQ. # 16)

For Rapid and Slow Generation Tanks, the initial hydrogen concentration at the time of a seismic event is assumed to be at steady state hydrogen equilibrium accounting for ventilation (minimum required purge flow for the applicable flammability classification) (excluding Tank 50). The steady state hydrogen equilibrium (H_{eq}) is calculated using Eq. #15, substituting the atmospheric breathing term, Q, with the DSA minimum purge ventilation flow rate. This value is compared to 2.5% of LFL_T and the greater of the two is used as Equil. Conc. in Eq. # 16. For Very Slow Generation Tanks, the initial hydrogen concentration at the time of a seismic event is assumed to be at steady state hydrogen

equilibrium accounting for atmospheric breathing (Eq. # 15) using the actual vapor space volume (Vv'). When not classified as Very Slow, use 3.8% LFL_T for Tank 50.

VARIABLE TG CALCULATION (USED IN EQ # 16)

The contribution of post seismic trapped gas from salt and sludge is additive. The following equation is used to determine the vapor space hydrogen concentration due to trapped gas release from sludge or salt under post seismic conditions [Ref. 22]. Each contributing phase shall be added together to determine the total seismic initial concentration:

Eq. # 17.
$$TG = \frac{V_{solids} \cdot G_s \cdot H_{mix} \cdot C \cdot F_R}{Vv'} \cdot 100\%$$

Where,

TG	=	Trapped hydrogen released during a seismic event, vol%
V_{solids}	=	volume of sludge or salt in the tank that is available to liberate hydrogen, ft^3
G_s	=	fraction of trapped bubble gas
H_{mix}	=	hydrogen fraction in trapped gas
C	=	pressure correction (see Eq. # 20)
F_R	=	Trapped gas release fraction
Vv'	=	Vapor space volume using actual or projected waste level, ft^3 (see Eq. # 21)

TG is expressed in units of volume % hydrogen, or can be expressed in % LFL_{OC} if Equation # 17 is divided by the LFL_{OC}. TG can also be expressed in terms of volume fraction if not multiplied by 100%.

VARIABLE V_{SOLIDS} (USED IN EQ. # 17)

All insoluble solids are considered to be sludge for the purposes of trapped gas retention. The DSA, Section 3.4.1.5.3, establishes the following input for determining the volume of sludge or salt affected due to seismic agitation:

- For tanks not under a Quiescent Time Program, the tank sludge is assumed to be settled sludge, and therefore the entire sludge volume is used
- For tanks under a Quiescent Time Program, the sludge is slurried sludge and the entire sludge volume is included in releasing hydrogen during a seismic event
- For salt tanks, the volume of salt available to liberate hydrogen is equal to the least of the following: the salt depth, the free liquid depth (depth of liquid above salt) or 40 inches. If there is no free liquid above the salt layer, no trapped gas is released from salt

VARIABLE G_S (USED IN EQ. # 17)

The DSA, Section 3.4.1.5.3, establishes the following input for determining the percent of trapped bubble gas:

- For sludge tanks under a Quiescent Time Program, the trapped bubble gas volume percent is 20%
- For sludge tanks not under a Quiescent Time Program, the trapped bubble gas volume percent is 10%
- For salt tanks, the trapped bubble gas volume percent is 11%

VARIABLE H_{MIX} (USED IN EQ. # 17)

The percent hydrogen in trapped gas values are established in the DSA, Section 3.4.1.5.3 and are as follows:

- 75% in pump tanks
- 75% in waste tanks with low nitrate concentrations (e.g. tanks that are not in evaporator service or do not contain salt cake)
- 50% in other waste tanks (e.g. salt tanks and evaporator system tanks)

In waste tanks with known chemistry and heat loads, equations which relate empirical data (i.e., nitrite and nitrate concentrations) to the radiolytic decay heat are used in lieu of the above values [Refs. 1, 72].

Eq. # 18. $$H_{Mix} = H_{NO3} * F_{NO3} * G_{NO3} + H_{NO2} * F_{NO2} * G_{NO2}$$

Where,

H_{Mix}	=	Hydrogen fraction in trapped gas (multiply by 100 to get in terms of percent)
H_{NO3}	=	Fraction of hydrogen in the gas produced by radiolysis of nitrate
H_{NO2}	=	Fraction of hydrogen in the gas produced by radiolysis of nitrite
F_{NO3}	=	Fraction of nitrate in the supernate
F_{NO2}	=	Fraction of nitrite in the supernate
G_{NO3}	=	Hydrogen generation correction factor for NO_3 to account for nitrate/nitrite interaction in mixed solution
G_{NO2}	=	Hydrogen generation correction factor for NO_2 to account for nitrate/nitrite interaction in mixed solution

Eq. # 18A. $H_{NO3} = 0.0242[NO_3]^3 - 0.076[NO_3]^2 - 0.2101[NO_3] + 0.69$, for $[NO_3] \geq 0M$

Where,

$[NO_3]$ = Nitrate concentration in supernate, mol/L

Eq. # 18B. $H_{NO2} = 1.0213[NO_2]^2 - 1.2235[NO_2] + 0.9821$, for $[NO_2] < 1M$

Eq. # 18C. $H_{NO2} = 0.035[NO_2] + 0.74$, for $[NO_2] \geq 1M$

Where,

$[NO_2]$ = Nitrite concentration in supernate, mol/L

Eq. # 18D. $F_{NO3} = [NO_3] / ([NO_3] + [NO_2])$

Eq. # 18E. $F_{NO2} = [NO_2] / ([NO_3] + [NO_2])$

Eq. # 18F. $G_{NO3} = G^{Mix} / G^{NO3}$

Eq. # 18G. $G_{NO2} = G^{Mix} / G^{NO2}$

Where,

F_{NO3}	=	Fraction of nitrate in the supernate
F_{NO2}	=	Fraction of nitrite in the supernate
G_{NO3}	=	Hydrogen generation correction factor for NO_3 to account for nitrate/nitrite interaction in mixed solution
G_{NO2}	=	Hydrogen generation correction factor for NO_2 to account for nitrate/nitrite interaction in mixed solution
$[NO_3]$	=	Nitrate concentration in supernate, mol/L
$[NO_2]$	=	Nitrite concentration in supernate, mol/L
G^{Mix}	=	Hydrogen generation correction factor based on the concentration of NO_{eff}
G^{NO3}	=	Hydrogen generation correction factor based on the concentration of NO_3
G^{NO2}	=	Hydrogen generation correction factor based on the concentration of NO_2

Eq. # 18H. $G^{NO3} = G_{\alpha NO3} * f_\alpha + G_{\beta/\gamma\ NO3} * (1-f_\alpha)$

Where,

G^{NO3}	=	Hydrogen generation correction factor based on the concentration of NO_3
$G_{\alpha NO3}$	=	Hydrogen yield in molecules per 100 electron volts of radiation produced by alpha radiation

$G_{\beta/\gamma NO3}$ = Hydrogen yield in molecules per 100 electron volts of radiation produced by beta/gamma radiation

f_α = Fraction of radiolytic heat rate that is contributed to alpha radiation

Eq. # 18I. $G_{\alpha NO3} = 1.3 - 0.79 * [NO_3]^{1/3} - 0.13 * [NO_3]^{2/3} + 0.11 * [NO_3]$

Eq. # 18J. $G_{\beta/\gamma NO3} = 0.466 - 0.51*[NO_3]^{1/3} + 0.14*[NO_3]^{2/3} + 0.0055*[NO_3]$

Eq. # 18K. $f_\alpha = (H_{\alpha sludge} + H_{\alpha salt})/(H_{\beta/\gamma sludge} + H_{\alpha sludge} + H_{\beta/\gamma salt} + H_{\alpha salt})$

Where,

$G_{\alpha NO3}$ = Hydrogen yield in molecules per 100 electron volts of radiation produced by alpha radiation

$G_{\beta/\gamma NO3}$ = Hydrogen yield in molecules per 100 electron volts of radiation produced by beta/gamma radiation

f_α = Fraction of radiolytic heat rate that is contributed to alpha radiation

$[NO_3]$ = Nitrate concentration in supernate, mol/L

$H_{\beta/\gamma salt}$ = Heat generated by beta and gamma decay in the salt, Btu/hr

$H_{\beta/\gamma sludge}$ = Heat generated by beta and gamma decay in the sludge, Btu/hr

$H_{\alpha salt}$ = Heat generated by alpha decay in the salt, Btu/hr

$H_{\alpha sludge}$ = Heat generated by alpha decay in the sludge, Btu/hr

G^{NO2} is determined using equations # 18H - # 18K above with $0.5*[NO_2]$ in place of $[NO_3]$.

G^{Mix} is determined using equations # 18H - # 18K above with $[NO_{eff}]$ in place of $[NO_3]$

Eq. # 19. $[NO_{eff}] = [NO_3] + ½[NO_2]$

Where,

$[NO_{eff}]$ = Effective ion concentration, mol/L

$[NO_3]$ = Nitrate concentration in supernate, mol/L

$[NO_2]$ = Nitrite concentration in supernate, mol/L

VARIABLE C CALCULATION (USED IN EQ. # 17)

The expansion factor is used for predicting the effect of pressure on trapped bubble gas release due to agitation. The relationship between the expansion factor and the head pressure is linear ($C = P_{avg}/P_{atm}$). The expansion correction is determined from the following head pressure equation (Ref. 22):

Eq. # 20. $$P_{avg} = \sum_{a=2}^{n} \frac{\rho_a g h_a}{X} + \frac{1}{2}\frac{\rho_1 g h_1}{X} + p_{atm}$$

Where,

P_{avg}	=	Hydrostatic head pressure, atm
n	=	Number of layers in the waste tank, excluding bottom layer
ρ_a	=	Density of layer material, kg/m³
ρ_1	=	Density of the bottom layer material, kg/m³
h_a	=	Height of layer, m
h_1	=	Height of the portion of the bottom layer from which hydrogen can be released, m
g	=	Gravitational force, m/s^2
p_{atm}	=	Atmospheric pressure, atm
X	=	101325, Pa/atm

VARIABLE F_R CALCULATION (USED IN EQ. # 17)

The DSA, Section 3.4.1.5.3, establishes the following input for determining the release percentage due to seismic agitation:

- The trapped hydrogen release percentage from waste tank settled sludge (i.e., tanks not under a Quiescent Time Program) after a seismic event is equal to the following equation:

$$\frac{\text{total waste level (in)}}{400} * 50\%$$

- The trapped hydrogen release percentage from waste tank slurried sludge (i.e., tanks under a Quiescent Time Program) after a seismic event is 100%

- The trapped hydrogen release percentage from waste tank salt after a seismic event is 50% of the affected salt volume (defined by V_{solids}).

VARIABLE VV' CALCULATION (USED IN EQ # 17)

The vapor space volume used to calculate the seismic time to LFL is based on the actual or projected waste level. The calculations account for the maximum missing waste volume only when pre-evaluating a transfer. This is accomplished by reducing the vapor space volume and adjusting the chemistry by 15,000 gallons (assuming the maximum missing waste is the material to be transferred). The following equation is the vapor space volume calculation, in cubic feet:

Eq. # 21. $Vv' = [VT - (Level_A * Ff + MMW)] * 0.1336\ ft^3/gal$

Where,

Vv'	=	Vapor space volume based on the actual or projected waste level, ft^3
VT	=	Total tank vapor space volume (empty tank), gal
$Level_A$	=	Actual or projected waste level, in
MMW	=	Maximum missing waste volume, gal (pre-evaluated to be accounted for in the receipt tank during a transfer)
Ff	=	Fill factor, gal/in

The adjusted fill factor is applied as an algorithm to reflect varying fill factors that adjust the established tank calibrations as a result of the displaced volume of the support cone in the upper part of the tank, as applicable [Refs. 13,14]. The nominal fill factor [Ref. 1] may be used to calculate the waste volume. Application of the nominal fill factor in this way is conservative because the fill factor overestimates the waste volume.

6.2.2 SEISMIC QUIESCENT TIME PROGRAM

The Quiescent Time Program is a periodic pump/mixer run program required to safely manage the trapped hydrogen that may be retained within the sludge of some tanks. Tanks are placed under a Quiescent Time Program after successful initial sludge mixing (i.e., hydrogen depletion) is accomplished. Initial sludge mixing is achieved upon completion of an adequate number of fully inserted waste tank mixing devices running non-indexed or turntable operating for a cumulative period of ten days [Ref. 23]. At this point, operation of the waste tank mixing devices will not achieve any additional trapped hydrogen release from settled sludge disturbance. Operation of the pump/mixer liberates hydrogen retained within the waste resulting in elevated flammable vapor concentrations in the vapor space. A periodic slurry pump run program has been implemented to safely manage the inventory of flammable vapors that may be retained within the waste. An integral part of this program is to determine the maximum time that a tank can remain undisturbed and still not retain sufficient hydrogen to cause the tank's vapor space to reach the LFL_{OC} within seven days if a hydrogen release event were to occur. This time, referred to as the seismic quiescent time, is calculated based upon the following conservative inputs and assumptions:

- The hydrogen generation rate equations in Section 6.1.1 are used to determine the amount of hydrogen generated during the seismic quiescent period.
- The seismic quiescent time is the allowable time between tank agitation such that the hydrogen released during a seismic event does not cause the waste tank vapor space to reach the LFL_{OC} within seven days (radiolytic hydrogen and trapped hydrogen release) assuming the hydrogen concentration in the vapor space is initially at 25% LFL_T (3.8% LFL_T for Tank 50) for Rapid and Slow Generation Tanks, or at the higher of 25% LFL_T (3.8% LFL_T for Tank 50) or equilibrium for Very Slow

Generation Tanks.

- The amount of hydrogen retained in the slurried sludge layer during the quiescent period is dependent upon the depth of the sludge layer. For waste tanks with a slurried sludge depth of less than or equal to 90 inches, 50% of the hydrogen generated is retained in the sludge. For waste tanks with a slurried sludge depth greater than 90 inches, 100% of the hydrogen generated is retained in the sludge [Ref. 1].
- Post seismic trapped gas release time to LFL portion of seismic calculation release percentage is assumed to be 100%. The methodology is limited to a release period of seven days.

After initially slurrying the entire inventory of sludge in a waste tank, the Seismic Quiescent Time Program will be applied to that tank. Operational experiences have demonstrated that retained gas is released when adequate mixing occurs (i.e., after successful completion of an 8 hour pump/mixer run (4 hour pump run for the three pumps in Tank 50) [Ref. 1] at maximum allowable speed with evidence of adequate sludge mixing [e.g., camera inspection, motor loading with acceptable ranges]). If less than the required number of waste tank mixing devices are available for use, prior gas release data can be used to permit the operation of less than the required number of waste tank mixing devices to deplete the tank's trapped hydrogen inventory. For example, for a waste tank, it has been demonstrated that a single slurry pump or a single Commercial Submersible Mixer Pump (CSMP) is capable of depleting at least 25% of the retained hydrogen inventory in the waste tank [Refs. 1,73]. Thus, the trapped gas inventory can be removed with four pumps operating in a manner that ensures adequate mixing. Likewise, the effect of a non-operational pump is that it could leave up to 25% of the tank content inadequately mixed, retaining the trapped gas inventory. Empirical trapped gas release data, which is baselined with a 4 pump run for 8 hours, from the tank under consideration or an engineering evaluation utilizing an effective cleaning radius may be evaluated to permit operation of less than four waste tank mixing devices and still claim adequate mixing occurs to deplete the tank's trapped hydrogen inventory. Reference 38 demonstrates that a single SMP operated at a maximum allowable speed theoretically has sufficient mixing capability to deplete at least 50% of the waste tank's retained hydrogen inventory. Reference 38 also demonstrates that the trapped gas inventory in the waste tank can be removed with two or three SMPs (depending on waste tank type and SMP riser location) operating in a manner that ensures adequate mixing. The effect of a non-operational SMP is that it could leave up to 50% of the tank contents inadequately mixed. Empirical trapped gas release data from the tank under consideration or an engineering evaluation utilizing effective cleaning radius may be evaluated to permit operation other than that described above and still claim adequate mixing occurs.

6.2.2.1 SEISMIC QUIESCENT TIME METHODOLOGY

The methodology for determining the seismic quiescent time is consistent with the methodology presented in the Seismic Time to LFL Methodology, with the exception of the following assumptions:

- The initial concentration, y_0, shall be the initial hydrogen concentration (25% LFL_T (3.8% LFL_T for Tank 50) for Rapid and Slow Generation Tanks, or at the higher of

25% LFL_T (3.8% LFL_T for Tank 50) or equilibrium for Very Slow Generation Tanks) including the effects of post seismic trapped gas release and shall be designated by the variable name, y_0 (Seismic)' (see Eq. # 22).

- 25% LFL_T (3.8% LFL_T for Tank 50) is used for the initial hydrogen concentration for seismic quiescent time (y_{0s}) instead of the SAV because if the latter were used, this would be double counting the effects of the trapped gas contribution mentioned above.
- The trapped gas contribution, TG, shall be a function of time (see Eq. # 24).

VARIABLE y_0 (SEISMIC)' CALCULATION (USED IN EQ #1)

The initial hydrogen concentration (y_{0s}) is added to the trapped gas contribution (TG) to determine the post seismic initial hydrogen concentration, y_0 (Seismic)':

Eq. # 22. y_0 (Seismic)' = y_{0s} + TG

y_{0s} shall be calculated using Eq. # 3B, with 25% LFL_T (3.8% LFL_T for Tank 50) for Rapid and Slow Generation Tanks, or the higher of 25% LFL_T (3.8% LFL_T for Tank 50) or the equilibrium hydrogen concentration for Very Slow Generation Tanks. y_0(Seismic)' shall be substituted into Equation # 1 to determine the time to LFL. The time to LFL shall be greater than or equal to seven days to satisfy the requirement inherent to the purpose of determining the quiescent time.

VARIABLE TG CALCULATION (USED IN EQ. # 22)

Upon depletion of the hydrogen inventory due to pump agitation, the trapped gas inventory is a function of time (i.e., at time equal zero, the trapped gas inventory equals zero) until the maximum inventory is retained per the trapped gas methodology in the DSA, Section 3.4.1.5.3.

The following equation demonstrates the time dependence of the trapped hydrogen inventory:

Eq. # 23. $$G_s * H * C = \frac{\left(\frac{H_R}{100}\right) * Q_{H2} * t}{V_{solids}}$$

Where,

Gs	=	fraction of trapped bubble gas
H	=	Hydrogen fraction in trapped gas
C	=	pressure correction
t	=	Time, hours
Q_{H2}	=	Temperature corrected hydrogen generation rate defined in Section 6.1.1, ft^3/hr
H_R	=	Percentage of hydrogen generated that is retained in slurried sludge and is consistent with the methodology presented in

Reference 1. For waste tanks with slurried sludge depth greater than 90 inches with a settling period of 20 days or less, H_R is 100%. For waste tanks with slurried sludge depth less than or equal to 90 inches with a settling period of 20 days or less, H_R is 50% [Ref. 34]. If the slurried sludge depth is not measured within 20 days, H_R is 100%.

All other variables are defined in Section 6.2.1. The pressure correction, C, is included in the time dependent hydrogen inventory equation because the hydrogen generation rate already calculates the ambient pressure effects due to the application of the ideal gas law in Section 3.4.1.1.2 of the DSA.

The trapped gas contribution to LFL (Eq. # 24) shall then be calculated by substituting Equation # 23 for the hydrogen inventory, $G_s * H * C$.

The following equation is used to determine the vapor space hydrogen concentration as a function of time due to trapped gas release from sludge under post seismic conditions:

Eq. # 24. $$TG = \frac{V_{solids} * \left(\frac{(H_R/100) * Q_{H2} * t}{V_{solids}} \right) * F_R}{Vv'} \cdot 100\%$$

Eq. # 24 is expressed in units of volume %, but it can be expressed in units of % LFL_{OC} if the equation is divided by LFL_{OC}. TG can also be expressed as a volume fraction if not multiplied by 100%.

Eq. # 24 is substituted into Eq. # 22, which provides the initial hydrogen concentration, y_0, for Eq. # 1, where Time to LFL shall be greater than, or equal to, seven days. The equations may be rearranged to solve for quiescent time, t, since all other variables are known. The evaluation for determining quiescent time is shown below in Eq. # 25 where TG is in terms of volume fraction hydrogen (may be expressed in units of fraction of LFL_{OC} if the equation is divided by LFL_{OC}).

Eq. # 25. $$t_Q = \frac{Vv'}{\frac{H_R}{100} * Q_{H2} * F_R} * \left(\frac{LFL_{OC} - \frac{Q_{H2}}{Q_{H2} + Q}}{e^{-7*24*\left(\frac{Q_{H2}+Q}{Vv'}\right)}} - y_{0s} + \frac{Q_{H2}}{Q_{H2} + Q} \right) / 24$$

Where:

t_Q	=	Quiescent time, days
Q_{H2}	=	Temperature corrected hydrogen generation rate, ft^3/hr
Q	=	Atmospheric breathing rate, ft^3/hr
H_R	=	Percentage of hydrogen generation that is retained in slurried

		sludge
y_{0s}	=	Initial hydrogen concentration for seismic quiescent time, vol. frac,
F_R	=	Trapped gas release fraction
Vv'	=	Vapor space volume using actual or projected waste tank level, ft^3
LFL_{OC}	=	Temperature and organic corrected hydrogen concentration at 100% LFL (see Eq. # 3 or Eq. # 3A for Tank 50), vol. frac
7	=	Minimum time to LFL, days
24	=	Conversion factor from days to hours

6.2.3 IMPLEMENTATION ACTIONS

Evaluation of the Safety of the Situation (ESS): Vulnerabilities Associated with Gas Release Mode Evaluations and Application of Trapped Gas Release Information for Sludge (PISA PI-2014-0007) was approved in September 2014 with implementation complete in October 2014 and compensatory measures listed in this ESS impact Sections 6.2 and 6.3 of this PDD. Compensatory measures in U-ESS-G-00002 supersede the requirements of this PDD for the affected sections.

1. The seismic time to LFL shall be determined using an engineering evaluation or the WCS database governed by the WCS Administrative Program [Ref. 10]. [TSR SAC 5.8.2.27.a]

2. Planned operations (e.g., waste tank to waste tank transfers) shall be pre-evaluated to determine the impact on the seismic time to LFL and the seismic quiescent time for the affected process areas (e.g., sending and receiving tanks) as part of the ETAF process [Ref. 11, Tab Electronic SW11.1].

3. If the projected numbers of tanks capable of becoming flammable following a seismic event (including the effects of post seismic trapped gas release and number of waste tanks in Acidic Chemical Cleaning Mode) within specified time periods are not within the restrictions of the TSR, then the evaluated activity shall not be performed. [TSR SAC 5.8.2.27.a]

4. Liquid additions to the waste tanks shall be pre-evaluated to determine the impact on the seismic time to LFL and the seismic quiescent time for the affected waste tanks using WCS or an engineering evaluation.

5. For waste tanks receiving transfers from a sending vessel greater than or equal to 15,000 gallons or has continuous makeup capability, the actual or projected waste

tank level shall be adjusted to account for the maximum volume associated with a Transfer Error event (i.e., 15,000 gallons). If the liquid batch source is less than 15,000 gallons and does not have continuous makeup capability, the actual or projected waste tank level shall be adjusted to account for the maximum volume of the batch source. The liquid source system shall be considered to have continuous makeup capability if the system has an automatic or manual fill provision that is not electrical or mechanically isolated. If the projected level of the affected waste tank including the liquid addition and the batch source exceed the waste tank operating level, the batch source volume can be reduced to protect the operating level, if desired.

6. A path forward shall be provided to DOE (addressing the additional risk and recovery time) if a transfer required to mitigate a tank leak causes additional tanks (more than 14) to have the potential to become flammable in less than seven days. Because the transfer is mitigating a degraded condition (i.e., placing the facility in a safer condition), the path forward is not required to be provided to DOE prior to initiating the transfer. [TSR AC 5.8.2.27.c]

7. The Quiescent Time Program quiescent time shall be determined using an engineering evaluation or the WCS database to ensure that waste tank mixing devices will be periodically operated to limit the amount of trapped gas that could be released during a seismic event. [TSR SAC 5.8.2.28]

8. The Quiescent Time Program quiescent time shall be tracked by CST Operations to ensure that waste tank mixing devices will be periodically operated within the specified quiescent time to limit the amount of trapped gas that could be released during a seismic event.

9. The emergency response priority classification shall be determined by the seismic time to LFL. Response priorities shall be, in order of decreasing priority: Priority 1 Tanks (seismic time to LFL < 24 hours), Priority 2 Acidic Chemical Cleaning Tanks (tank primary, then annulus), then remaining Priority 2 Tanks (seismic time to LFL < 7 days).

6.3 SLUDGE HYDROGEN RELEASE ACTIVITIES

This section is not applicable to tanks in Acidic Chemical Cleaning Mode or Closure Mode. Tanks in Acidic Chemical Cleaning Mode are evaluated by a separate methodology, as outlined in Section 6.7. For waste tanks in Closure Mode, operation of waste tank mixing devices is prohibited.

Hydrogen bubbles can become trapped in the sludge layer over time and subsequently released. The amount of trapped hydrogen released is dependent upon the characteristics of the sludge and the release initiator (i.e., agitation source). The amount of trapped hydrogen released from sludge varies depending on the agitation source (e.g., waste tank mixing device operation, seismic event) and the agitator height (for waste tank mixing devices) [Refs. 53,73], or from the reduction in static pressure (e.g., free supernate removal).

INSIGNIFICANT SLUDGE MIXING ACTIVITIES

Some activities in waste storage tanks have the potential to disturb limited quantities of sludge. These activities are not considered to result in significant sludge mixing. Examples of these activities are provided in the DSA, Section 3.4.2.11.1, and include the following:

- Rotation of waste tank mixing device turntables
- Sludge sampling
- Inserting tank components below the sludge layer (e.g., riser mining tools, pumps, caissons, etc.)
- Removing tank components from below the sludge layer
- Air blowing transfer jets that have a suction below the sludge layer
- Operating transfer pumps or jets that have a suction below the sludge layer
- Transfers into the waste tank (regardless of downcomer location)
- Flushing of transfer pumps or jets
- Riser mining in a settled sludge tank

In general, if activities in waste storage tanks are physically limited by design to disturb a localized region of sludge (i.e., not assumed to release significant quantities of trapped gas), then these activities are judged to involve insignificant sludge mixing.

AIR OR STEAM SPARGING

Air or steam sparging activities do not require additional sludge agitation evaluation per the DSA, Section 3.4.1.5.3, because the action that causes the release also serves to mitigate the release (through dilution or purging) and the net effect is insignificant in comparison to other hydrogen release mechanisms.

FREE SUPERNATE REMOVAL

Aged settled sludge in waste tanks accumulates radiolytic gas bubbles, which connect into networks as they mature. Ordinarily, these networks release gas slowly by percolation. However, removing free liquid reduces the hydrostatic head, causing the bubbles to expand and release at a rate proportional to the liquid removal rate.

Based on the hydrogen release rates in Reference 1 and Reference 24 and a maximum transfer rate of 250 gpm, the following free supernate removal activities are prohibited[1]:

- Waste transfers (including siphon potential) associated with free supernate removal from a Type III/IIIA settled sludge tank with a sludge inventory greater than 250 inches when the tank is classified as a Slow Generation Tank.

- Waste transfers (including siphon potential) associated with free supernate removal from a settled sludge tank with a sludge inventory greater than 80 inches when the tank is classified as a Very-Slow Generation Tank.

6.3.1 SLUDGE AGITATION GAS RELEASE MODE EVALUATION

Prior to planned sludge agitation, an initial evaluation shall be performed to determine whether entry into the Gas Release Mode will be required. (Tank 50 is prohibited from entering into Gas Release Mode. Tanks in Gas Release Mode are prohibited from receiving Chemical Cleaning transfers [Ref. 1]). When this initial evaluation (using the methodology of DSA, Sections 3.4.1.5.3 and 3.4.2.11.1) shows that the release of hydrogen due to agitation will not cause the vapor space to exceed the following gas release criteria (accounting for atmospheric breathing only), no specific controls regarding planned sludge agitation are required (other than Routine Flammability Controls and Pump Run Program)[1]:

- Become flammable in less than 7 days for a tank classified as a Rapid Generation Tank (due to trapped gas release plus radiolytic hydrogen generation; for Tank 50, due to trapped gas release, radiolytic hydrogen generation, and flammable vapor contributions from Isopar® L / trace organics [Ref. 1])
- Become flammable in less than 28 days for a tank classified as a Slow Generation Tank (due to trapped gas release plus radiolytic hydrogen generation; for Tank 50, due to trapped gas release, radiolytic hydrogen generation, and flammable vapor contributions from Isopar® L / trace organics [Ref. 1])
- Become flammable for a tank classified as a Very-Slow Generation Tank (due to trapped gas release plus radiolytic hydrogen generation; for Tank 50, due to trapped gas release, radiolytic hydrogen generation, and flammable vapor contributions from Isopar® L / trace organics [Ref. 1])
- Exceed 60% of the temperature-corrected LFL for hydrogen (due only to trapped gas release)

Tanks may be reclassified, based on the engineering evaluation, to meet the above criteria[1]. For example, an evaluation determines that, for a Slow Generation Tank, the assumed trapped gas release from the planned sludge agitation results in reaching 50% of the LFL_T and the subsequent radiolytic hydrogen production causes the tank to become flammable in 25 days. In this case, the tank would exceed the criteria above unless it is reclassified as a Rapid Generation Tank (with the associated Routine Flammability Controls and Pump Run Program).

The hydrogen concentration due to trapped gas release is added to the initial concentration to determine the total hydrogen concentration, H_2Total, in the waste tank vapor space due to non-seismic agitation:

Eq. # 26. $H_2Total = H_2Initial + TG$

Where,

H2Total = Total hydrogen concentration in the waste tank vapor space due to non-seismic agitation, vol. frac.

H_2Initial = Initial hydrogen concentration, vol. frac. This can be determined accounting for an adequate number of vapor space turnovers (as determined in an engineering evaluation) and/or by comparing the tank LFL reading (cannot measure for Tank 50) to a reading obtained using a known LFL concentration (see Variable H2 Initial Calculation below). For Very Slow Generation Tanks, the equilibrium hydrogen concentration (H_{eq}, Eq. # 15) can be used as the initial concentration if the calculated trapped gas release does not cause the tank to exceed 95% LFL_{OC} and the equilibrium hydrogen concentration is equal to or greater than 2.5% of LFL_{25C} for hydrogen.

TG = Hydrogen concentration due to trapped gas release (Using Eq. # 17 or Eq. # 24 and inputs provided below), vol. frac.

VARIABLE H2 INITIAL CALCULATION (USED IN EQ. # 26)

An adequate number of vapor space turnovers (and/or comparing the tank LFL reading to a reading obtained using a known LFL concentration) establishes the initial hydrogen concentration in the tank vapor space as low as practical when desired. This assumes that the tank is under conditions that do not cause significant hydrogen release (e.g., no incoming jetted transfers or sludge agitation activities) and accounts for radiolytic hydrogen generation. Vapor space turnovers (and/or comparing the tank LFL reading to a reading obtained using a known LFL concentration) are not required for the insignificant sludge mixing activities listed in Section 6.3). The time to complete an adequate number of vapor space turnovers is determined based on the best estimate of the actual vapor space volume. The ventilation shall be operable to perform an adequate number of vapor space turnovers with downtime not exceeding 12 cumulative hours from start to completion. A 12 hour downtime will not significantly impact this initial concentration prior to sludge agitation activities because of the conservative assumptions used in the vapor space calculations (e.g., low mixing efficiency, high initial hydrogen concentration).

Flammability evaluations shall use the maximum of 2.5% of LFL_{25C} for hydrogen or a value based on the steady state hydrogen equilibrium concentration accounting for ventilation operation as the initial condition where vapor space turnovers are employed for Rapid and Slow Generation Tanks (excluding Tank 50). The steady state hydrogen equilibrium concentration (H_{eq}) is calculated using Eq. # 15, substituting the atmospheric breathing term, Q, with the DSA minimum purge ventilation flow rate (minimum required purge flow for the applicable flammability classification). This value is compared to 2.5% of LFL_{25C} and the greater of the two is used as H_2Initial in Eq. # 26. If H_{eq} is used, it should be increased by an appropriate amount to balance the allowable trapped gas release against the number of vapor space turnovers required, as determined by an engineering evaluation. For Tank 50, 3.8% LFL_T should be used when not classified as Very Slow.

For Very Slow Generation Tanks, H_{eq}, accounting for atmospheric breathing only (Eq. # 15), **can be used as the** initial hydrogen concentration if the calculated trapped gas release does

not cause the tank vapor space to exceed 95% LFL_{OC} and H_{eq} is equal to or greater than 2.5% of LFL_{25C} for hydrogen. No vapor space turnovers are required for the initial trapped gas release activity if the equilibrium hydrogen concentration is used as the initial condition for Very Slow Generation Tanks. For each subsequent trapped gas release activity (e.g., after a pump is lowered), vapor space turnovers (and/or comparing the tank LFL reading to a reading obtained using a known LFL concentration) shall be required to ensure the waste tank bulk vapor space hydrogen concentration is less than or equal to H_{eq} assumed in the hydrogen release engineering evaluation.

The required number of vapor space turnovers for each tank will be documented in the ERD [Ref. 2]. In order to determine the adequate number of vapor space turnovers required to reduce the hydrogen concentration from the safety analysis limit to less than or equal to the assumed initial concentration [i.e. the maximum of 2.5% of LFL_{25C} for hydrogen or H_{eq} (including additional percent increase determined by an engineering evaluation) or H_{eq} or 3.8% LFL_T for Tank 50], the methodology of Reference 25 shall be employed (assuming a mixing efficiency of 0.2 and accounting for radiolytic hydrogen generation). However, vapor space turnovers and/or comparing the tank LFL reading to a reading obtained using a known LFL concentration can be employed to reduce the initial concentration below the assumed initial concentration. If the latter option is used (not applicable to Tank 50), the methodology to determine the flammable vapor concentration shall be consistent with the requirements of Reference 7. Because the initial hydrogen concentration for Tank 50 cannot be measured, and hydrogen monitoring is not required for Tank 50, vapor space turnovers cannot be calculated if Tank 50 is Slow or Rapid since the assumed initial hydrogen concentration is the same as the SAV (3.8% LFL_T). As a Very Slow waste tank, vapor space turnovers can be used in Tank 50 to reduce the equilibrium concentration to 3.8% LFL_T if necessary. Vapor space turnover requirements for Tank 50, when necessary, will have to be met by ACTUAL vapor space turnovers, using the calculation in the ERD [Ref. 2] to determine the "Ventilation Time (hr)" to achieve this.

VARIABLE TG CALCULATION (USED IN EQ. # 26)

The methodology for determining the vapor space hydrogen concentration due to trapped gas release from sludge under non-seismic conditions is consistent with the methodology presented in the Seismic Flammability Control Program (Eq. # 17 or Eq. # 24) except as noted below. For tanks not under a Quiescent Time Program, the trapped gas calculation evaluated under equilibrium conditions shall utilize the trapped bubble gas and the hydrogen percent assumptions from Eq. # 17 and the Seismic Time to LFL Methodology in Section 6.2.1 (except as noted below in the remainder of Section 6.3.1). For tanks under a Quiescent Time Program, the trapped hydrogen inventory is time dependent and can utilize Eq. # 24 and the Seismic Quiescent Time Methodology in Section 6.2.2 (except as noted below in the remainder of Section 6.3.1).

For sludge tanks where water or inhibitor is added, the time for the water or inhibitor to diffuse into the interstitial liquid (5-10 years depending on particle size, density gradients and temperature gradients) is considered so long that the percent hydrogen in trapped gas is assumed to be unchanged; therefore, current chemistry (i.e., chemistry prior to the water/inhibitor addition) may be used to determine the hydrogen concentration in trapped gas for Sludge Agitation Gas Release Mode evaluations [Ref. 27].

VARIABLE V_{SOLIDS} (USED IN EQ. # 17 OR EQ. # 24)

All insoluble solids are considered to be sludge for the purposes of trapped gas retention. The DSA, Section 3.4.1.5.3 and References 53 and 73 establish the following input for determining the volume of sludge affected due to non-seismic agitation:

- The trapped hydrogen release percentage for sludge agitation is 100% of the tank cross sectional area (accounting for sludge disturbance depth) if the agitation source is a single SMP, multiple slurry pumps, or multiple CSMPs and the tank is not under a Quiescent Time Program. The trapped hydrogen release percentage for sludge agitation is 50% of the tank cross sectional area (accounting for sludge disturbance depth) if the agitation source is a single slurry pump or a single CSMP, and the tank is not under a Quiescent Time Program. The sludge disturbance depth for releasing trapped gas is the sludge 24 inches below the bottom of the waste tank mixing device and the entire depth of the sludge above the bottom of the mixing device for all pumps but the quad-volute slurry pumps. The quad-volute slurry pumps release the entire depth of sludge regardless of the installation height.
- The trapped hydrogen release percentage is 100% of the entire tank inventory if the tank is under a Quiescent Time Program, even if the agitation source is a single slurry pump.

VARIABLE F_R (USED IN EQ. # 17 OR EQ. # 24)

For the purposes of initially determining if the sludge agitation activity requires Gas Release Mode controls, the release percentage is assumed to be per the DSA, Section 3.4.1.5.3 as shown in the "Variable V_{SOLIDS}" section immediately above.

VARIABLE VV CALCULATION (USED IN EQ. # 17 OR EQ. # 24)

The HLLCP shall be used to protect the vapor space volume in the initial sludge agitation evaluations to determine if entry into Gas Release Mode will be required (see Eqs. # 14 and # 27).

6.3.2 GAS RELEASE MODE PUMP RUN PROGRAM AND QUIESCENT TIME

For planned sludge agitation activities where the percent LFL could exceed 60% or the minimum time to LFL is not met for the tank classification, based on the guidelines presented for the initial evaluation, the waste tank Gas Release Mode shall be declared prior to agitation. Once it is determined that a tank will enter Gas Release Mode, programmatic controls shall be established to ensure that operation of waste tank mixing devices limit the planned release of trapped gases such that the vapor space does not exceed the hydrogen concentration limit determined by the Flammability Control Program. Requirements during slurry pump operation associated with Gas Release Mode are documented in Section 3.4.2.11.1 of the DSA.

If the hydrogen inventory accumulated in the sludge between hydrogen depletion activities provides the potential to exceed 60% LFL for hydrogen (or the SAV for hydrogen) upon instantaneous release, a tank must enter Gas Release Mode prior to the hydrogen depletion

activity. The ERD shall report the time allowed between hydrogen depletion activities such that Gas Release Mode would not have to be entered (typically labeled in the ERD as "Frequency to Run Slurry Pumps to stay out of Gas Release Mode"). However, once Gas Release Mode is entered, a pump run time will be reported in the ERD so that when pumps are run 60% LFL for hydrogen (or the SAV for hydrogen) will not be exceeded (typically labeled in the ERD as "Pump Run Q-Time with no start/stop Pump Operation Controls"). If an evaluation is performed which credits the operational attributes listed in Section 9.0 (all or some combination), the pump run time may be extended up to the seismic quiescent time as long as hydrogen releases are limited such that the TSR hydrogen concentration limit is not exceeded in the vapor space at any time during the agitation activity.

The Gas Release Mode Pump Run Program shall document an evaluation using a similar methodology to the Sludge Agitation Gas Release Mode evaluation (refer to Section 6.3.1); however, several assumptions may be modified once Gas Release Mode is declared; examples are:

- The DSA minimum required ventilation flow rate (e.g., 72 scfm) shall be used in calculations using the first level of control (ventilation) in order to protect the SAV for the hydrogen concentration
- Hydrogen release may be considered depending on the operational attributes (e.g., number of pumps run)
- Actual waste temperature may be used.
- Actual waste height (considering incoming transfer) may be used to credit the vapor space volume and shall be adjusted to account for the maximum amount of waste associated with a Transfer Error Event (i.e., 15,000 gallons). If the liquid batch source is less than 15,000 gallons and does not have continuous makeup capability, the actual waste contents/inventory shall be adjusted to account for the maximum total volume of the batch source. The liquid source system shall be considered to have continuous makeup capability if the system has an automatic or manual fill provision that is not electrically or mechanically isolated

6.3.3 IMPLEMENTATION ACTIONS

Evaluation of the Safety of the Situation (ESS): Vulnerabilities Associated with Gas Release Mode Evaluations and Application of Trapped Gas Release Information for Sludge (PISA PI-2014-0007) was approved in September 2014 with implementation complete in October 2014 and compensatory measures listed in this ESS impact Sections 6.2 and 6.3 of this PDD. Compensatory measures in U-ESS-G-00002 supersede the requirements of this PDD for the affected sections.

1. Operation procedures shall address the requirement to perform an adequate number of vapor space turnovers and/or to compare the tank LFL reading to a reading obtained using a known LFL concentration prior to sludge agitation activities. [TSR SAC 5.8.2.29.b]

2. Prior to sludge agitation, an engineering evaluation shall be performed to determine if Gas Release Mode controls are required. The evaluation shall determine the number of vapor space turnovers required to reduce the hydrogen concentration from the safety analysis limit to less than or equal to the initial value assumed in the hydrogen release engineering evaluation. [TSR SAC 5.8.2.29.a & 5.8.2.29.b]

3. If required, the Gas Release Mode Pump Run Program is implemented to limit the vapor space hydrogen concentration.

4. Prior to free supernate removal (including siphon potential) from a Type III/IIIA Slow Generation Tank, it shall be verified that the tank does not contain a settled sludge inventory greater than 250 inches as part of the ETAF process (Ref. 11, Tab Electronic SW11.1). [TSR SAC 5.8.2.43.k]

5. Prior to free supernate removal (including siphon potential) from a Very Slow Generation Tank, it shall be verified that the tank does not contain a settled sludge inventory greater than 80 inches as part of the ETAF process (Ref. 11, Tab Electronic SW11.1). [TSR SAC 5.8.2.43.l]

6.4 SALT REMOVAL ACTIVITIES

Bulk salt dissolution and removal of interstitial liquid from saltcake are prohibited for tanks in Acidic Chemical Cleaning Mode. Transfers of waste into and out of a waste tank in Closure Mode are prohibited and liquid additions permitted for a tank in Closure Mode are those which are considered insignificant salt removal activities. Therefore, controls for Salt Removal Activities do not apply to tanks in Acidic Chemical Cleaning Mode or Closure Mode.

Trapped hydrogen is assumed to be released from salt during bulk salt dissolution, interstitial liquid removal, agitation (e.g., seismic event, slurry pump/mixer operation), or from the reduction in static pressure (e.g., free supernate removal). Bulk salt dissolution is the process of dissolving salt by adding liquid to the tank. Bulk salt dissolution is typically performed by liquid addition alone, although in some cases the liquid addition may be accompanied by slurry pump/mixer operation [Ref. 1]. Interstitial liquid removal from bulk saltcake is performed by pumping liquid from a well in the saltcake. Removing interstitial liquid will release hydrogen from the saltcake where the interstitial liquid is removed.

Salt removal activities include salt well mining. Salt well mining is the dissolving of a limited amount of salt, usually to allow insertion of equipment such as a pump for interstitial liquid removal. The volume of the well to be mined will determine the amount of hydrogen that can be released. The controls specified for waste tanks undergoing planned bulk salt dissolution also apply to salt well mining.

INSIGNIFICANT SALT REMOVAL ACTIVITIES

Some activities in waste storage tanks have the potential to release limited quantities of hydrogen. These activities are not considered to result in significant hydrogen release.

Examples of these activities include the following:

- Salt sampling
- Removing tank components from below the salt layer
- Air blowing transfer jets that have a suction below the salt layer
- Transfers into salt tanks with small exposed salt peaks (height and base in inches not feet) / exposed salt on cooling coils and tank wall
- Dilute liquid additions to free supernate over saltcake
- Flushing of equipment in a salt tank including vent demister and reheater
- Sample rinsing
- Filling purge condenser seal leg
- Routine evaporator operation (which includes the introduction of dilute (unsaturated) supernate into the Evaporator Systems as described in Reference 63)
- Transfers out of a tank that expose salt peaks/mounds (height and base in inches not feet)
- Transfers out of a tank that expose salt on cooling coils

In general, if activities in waste storage tanks disturb a limited quantity of salt (e.g., small salt peaks) or dissolve salt with a limited ability to retain hydrogen (e.g., surface salt on cooling coils), then these activities are judged to result in an insignificant hydrogen release and are not considered bulk salt removal activities. However, when performing these activities during salt removal activities, the amount of hydrogen released from these "insignificant release" activities shall be considered in the engineering evaluation.

AIR OR STEAM SPARGING

Air or steam sparging activities do not require additional bulk salt dissolution/ interstitial liquid removal evaluation per the DSA, Section 3.4.1.5.3, because the action that causes the release also serves to mitigate the release (through dilution or purging) and the net effect is insignificant in comparison to other hydrogen release mechanisms.

FREE SUPERNATE REMOVAL

Submerged saltcake in waste tanks accumulate radiolytic gas bubbles, which connect into networks as they mature. Ordinarily these networks release gas slowly by percolation. However, removing free liquid reduces the hydrostatic head, causing the bubbles to expand and release at a rate proportional to the liquid removal rate. At the same time, the tank vapor space volume is increasing due to liquid removal.

Based on the hydrogen release rates in Reference 1 and Reference 24 and a maximum transfer rate of 250 gpm, the following free supernate removal activities are prohibited[1]:

- Waste transfers (including siphon potential) associated with free supernate removal from

a Type III/IIIA salt tank with an equivalent saltcake inventory greater than 330 inches when the tank is classified as a Slow Generation Tank.

- Waste transfers (including siphon potential) associated with free supernate removal from a salt tank with an equivalent saltcake inventory greater than 150 inches when the tank is classified as a Very-Slow Generation Tank.

With the exception of the above prohibitions, the minimum time to reach the LFL defined by the tank flammability classification is not impacted as free supernate is removed; therefore, no specific controls (other than the Routine Flammability Controls in DSA Section 3.4.2.11.1) are required during free supernate removal over saltcake[1].

6.4.1 SALT REMOVAL GAS RELEASE MODE EVALUATION

Prior to planned salt removal activities (e.g., bulk salt dissolution with or without agitation, salt mining, interstitial liquid removal), an initial evaluation shall be performed to determine whether entry into the Gas Release Mode will be required. (Tank 50 is not allowed to enter into Gas Release Mode [Ref. 1]). When this initial evaluation (using the methodology of the DSA, Section 3.4.1.5.3 and 3.4.2.11.1) shows that the release of hydrogen due to salt removal activities will not cause the vapor space to exceed the following gas release criteria (accounting for atmospheric breathing only), no specific controls regarding planned salt removal activities are required (other than Routine Flammability Controls and Salt Dissolution/Interstitial Liquid Removal Program) [Ref. 1].

- Become flammable in less than 7 days for a tank classified as a Rapid Generation Tank (due to trapped gas release plus radiolytic hydrogen generation; for Tank 50, due to trapped gas release, radiolytic hydrogen generation, and flammable vapor contributions from Isopar® L / trace organics [Ref. 1])
- Become flammable in less than 28 days for a tank classified as a Slow Generation Tank (due to trapped gas release plus radiolytic hydrogen generation; for Tank 50, due to trapped gas release, radiolytic hydrogen generation, and flammable vapor contributions from Isopar® L / trace organics [Ref. 1])
- Become flammable for a tank classified as a Very-Slow Generation Tank (due to trapped gas release plus radiolytic hydrogen generation; for Tank 50, due to trapped gas release, radiolytic hydrogen generation, and flammable vapor contributions from Isopar® L / trace organics [Ref. 1])
- Exceed 60% of the temperature-corrected LFL for hydrogen (due only to trapped gas release)

Tanks may be reclassified, based on the engineering evaluation, to meet the above criteria [Ref. 1]. For example, an evaluation determines that, for a Slow Generation Tank, the assumed trapped gas release from the salt removal activities results in reaching 50% of the LFL_T and the subsequent radiolytic hydrogen production causes the tank to become flammable in 25 days. In this case, the tank would exceed the criteria above unless it is reclassified as a Rapid Generation Tank (with the associated Routine Flammability Controls and Salt Dissolution/Interstitial Liquid Removal Program).

Using the total vapor space hydrogen concentration equation (Eq. # 26), the hydrogen concentration due to trapped gas release is added to the initial concentration to determine the total hydrogen concentration in the waste tank vapor space due to non-seismic trapped gas release.

VARIABLE H_2 INITIAL CALCULATION (USED IN EQ. # 26)

An adequate number of vapor space turnovers (and/or comparing the tank LFL reading to a reading obtained using a known LFL concentration) establishes the initial hydrogen concentration in the tank vapor space as low as practical when desired. This accounts for only radiolytic hydrogen generation, with the tank not undergoing activities that release significant quantities of hydrogen. Vapor space turnovers (and/or comparing the tank LFL reading to a reading obtained using a known LFL concentration) are not required for the insignificant salt removal activities listed in Section 6.4, or when an engineering evaluation shows that the trapped gas release is acceptable without reduction in initial LFL concentration (e.g., for Very Slow Generation Tanks). The time to complete an adequate number of vapor space turnovers is determined based on the best estimate of the actual vapor space volume. The ventilation shall be operable to perform an adequate number of vapor space turnovers with downtime not exceeding 12 cumulative hours from start to completion. A 12 hour downtime will not significantly impact this initial concentration prior to salt removal activities because of the conservative assumptions used in the vapor space calculations (e.g., low mixing efficiency, high initial hydrogen concentration).

Flammability evaluations shall use the maximum of 2.5% of LFL_{25C} for hydrogen or a value based on the steady state hydrogen equilibrium concentration accounting for ventilation operation as the initial condition where vapor space turnovers are employed for Rapid and Slow Generation Tanks (excluding Tank 50). The steady state hydrogen equilibrium concentration (H_{eq}) is calculated using Eq. # 15, substituting the atmospheric breathing term, Q, with the DSA minimum purge ventilation flow rate (minimum required purge flow for the applicable flammability classification). This value is compared to 2.5% of LFL_{25C} and the greater of the two is used as H_2 Initial in Eq. # 26. If H_{eq} is used, it should be increased by an appropriate amount to balance the allowable trapped gas release against the number of vapor space turnovers required, as determined by an engineering evaluation. For Tank 50, 3.8% LFL_T should be used when not classified as Very Slow.

For Very Slow Generation Tanks, H_{eq}, accounting for atmospheric breathing only (Eq. # 15), can be used as the initial condition if the calculated trapped gas release does not cause the tank vapor space to exceed 95% LFL_{OC} and H_{eq} is equal to or greater than 2.5% of LFL_{25C} for hydrogen. No vapor space turnovers are required for the initial trapped gas release activity if the equilibrium hydrogen concentration is used as the initial condition for Very Slow Generation Tanks. For each subsequent trapped gas release activity (e.g., dissolution batch is added to the tank), vapor space turnovers (and/or comparing the tank LFL reading to a reading obtained using a known LFL concentration) shall be required to ensure the waste tank bulk vapor space hydrogen concentration is less than or equal to H_{eq} assumed in the hydrogen release engineering evaluation.

The required number of vapor space turnovers for each tank will be documented in the ERD [Ref. 2]. In order to determine the adequate number of vapor space turnovers required to

reduce the hydrogen concentration from the safety analysis limit to less than or equal to the assumed initial concentration [i.e. the maximum of 2.5% of LFL_{25C} for hydrogen or H_{eq} (including additional percent increase determined by an engineering evaluation) or H_{eq} or 3.8% LFL_T for Tank 50], the methodology of Reference 25 shall be employed (assuming a mixing efficiency of 0.2 and accounting for radiolytic hydrogen generation). However, vapor space turnovers and/or comparing the tank LFL reading to a reading obtained using a known LFL concentration can be employed to reduce the initial concentration below the assumed initial concentration. If the latter option is used (not applicable to Tank 50), the methodology to determine the flammable vapor concentration shall be consistent with the requirements of Reference 7. Because the initial hydrogen concentration for Tank 50 cannot be measured, and hydrogen monitoring is not required for Tank 50, the vapor space turnovers cannot be calculated if Tank 50 is Slow or Rapid since the assumed initial hydrogen concentration is the same as the SAV (3.8% LFL_T). As a Very Slow waste tank, vapor space turnovers can be used in Tank 50 to reduce the equilibrium concentration to 3.8% LFL_T if necessary. Vapor space turnover requirements for Tank 50, when necessary, will have to be met by ACTUAL vapor space turnovers, using the calculation in the ERD[2] to determine the "Ventilation Time (hr)" to achieve this.

VARIABLE TG CALCULATION (USED IN EQ. # 26)

The methodology for determining the vapor space hydrogen concentration due to trapped gas release from salt under non-seismic conditions is determined using the trapped gas release equation presented in the Seismic Time to LFL Methodology (Eq. # 17) except as noted below in the remainder of Section 6.4.1.

For tanks where the interstitial liquid has been drained from the salt, there is no pressure correction term (i.e., only atmospheric pressure is exerted on the saltcake).

For salt tanks where water or inhibitor is added, the time for the water or inhibitor to diffuse into the interstitial liquid (5-10 years depending on particle size, density gradients and temperature gradients) is considered so long that the percent hydrogen in trapped gas is assumed to be unchanged; therefore, current chemistry (i.e., chemistry prior to the water/inhibitor addition) shall be used to determine the hydrogen concentration in trapped gas for Salt Removal Gas Release Mode evaluations [Ref. 27]

VARIABLE V_{SOLIDS} (USED IN EQ. # 17)

SALT DISSOLUTION WITHOUT WASTE TANK MIXING DEVICES

The trapped hydrogen released due to bulk salt dissolution is equivalent to the gas trapped in the volume of salt dissolved, where the water to saltcake dissolution ratio is 1 gallon of water dissolves 1 gallon of salt [Ref. 1].

For bulk salt dissolution, the amount of salt dissolved in the affected tank is equal to the smaller of the total volume of salt in the waste tank or the volume of the dissolution water source tank which will be used for bulk salt dissolution. If the volume of the dissolution water source tank to be used for bulk salt dissolution is used to estimate the volume of salt dissolved, the water source must not have the capability for continuous makeup.

The liquid source system shall be considered to have continuous makeup capability if the

system has an automatic or manual fill provision that is not electrically or mechanically isolated. The electrical or mechanical isolation shall contain two independent means of isolation (e.g., two isolation valves; one isolation valve and open disconnect for liquid source transfer pump). A dissolution water skid (DWS) is commonly used as a method for introducing water into a waste tank for salt dissolution. The liquid source system for the DWS contains solenoid actuated valves, controlled by a Programmable Logic Controller (PLC) which is equivalent to electrical or mechanical isolation for the purposes of continuous makeup (Ref. 1, Section 3.4.1.5.2).

During bulk salt dissolution operations, in-tank mixing eductors (Hooper Jets) shall not be considered slurry pump/mixing devices. Operation of in-tank mixing eductors will not increase the hydrogen release above that resulting from the 1 gallon of water which dissolves 1 gallon of salt. In-tank mixing eductors are installed above the salt layer, but below the supernate layer, and discharge water at a low flow rate parallel to the saltcake surface. The result of this discharge is a sub-saturated plume that is distributed across the saltcake surface. Because the water is discharged at a low flow rate into a supernate layer, disturbance of the salt layer is not appreciable. Thus, the use of in-tank mixing eductors shall not be considered to increase the hydrogen release above that resulting from the release of trapped gas in the volume of salt dissolved (i.e., assuming 1 gallon of water dissolves 1 gallons of salt) [Ref. 54].

SALT DISSOLUTION WITH WASTE TANK MIXING DEVICES

The trapped hydrogen release percentage for bulk salt dissolution due to slurry pump/mixer operation is 100% of the tank cross sectional area (accounting for salt disturbance depth) if the agitation source is a single SMP, multiple slurry pumps, or multiple CSMPs. The trapped hydrogen release percentage for bulk salt dissolution due to waste tank mixing device operation is 50% of the tank cross sectional area (accounting for salt disturbance depth) if the agitation source is a single slurry pump or a single CSMP. The salt disturbance depth for releasing trapped gas is the salt 24 inches below the bottom of the waste tank mixing device and the entire depth of the salt above the bottom of the mixing device for all pumps but the quad-volute slurry pumps. The quad-volute slurry pumps release the entire depth of salt regardless of the installation height [Refs. 1,53,73].

When evaluating trapped hydrogen releases due to bulk salt dissolution with mixing, the larger of the two salt volumes discussed above (i.e., salt dissolved [1 gallon of water equals 1 gallon of salt dissolved] or salt disturbed due to mixing device operation) is used [Ref. 1,53]

INTERSTITIAL LIQUID REMOVAL

For interstitial liquid removal, the amount of salt available to liberate hydrogen in the affected tank is the volume of salt above the pump suction elevation. The pump suction elevation must be defined by a technical baseline document governing the pump installation.

SALT WELL MINING

For salt well mining, the amount of hydrogen released is equal to the amount of hydrogen trapped in the volume of salt to be mined.

VARIABLE F_R (USED IN EQ. # 17)

For the purposes of initially determining if the salt removal activity requires Gas Release Mode controls, the release percentage is assumed to be per the DSA, Section 3.4.1.5.3 as shown in the "Variable V_{SOLIDS}" section immediately above.

VARIABLE VV CALCULATION (USED IN EQ. # 17)

For salt removal activities, the HLLCPs are used to protect the vapor space volume in the initial salt removal evaluations to determine if entry into Gas Release Mode is required (see Eq. # 14).

6.4.2 GAS RELEASE MODE BULK SALT DISSOLUTION/INTERSTITIAL LIQUID REMOVAL PROGRAM

For planned salt removal activities where the percent LFL could exceed 60% or the minimum time to LFL is not met for the applicable flammability classification of the waste tank, based on the guidelines presented for the initial evaluation, Gas Release Mode shall be declared prior to bulk salt dissolution/interstitial liquid removal activities. Requirements during salt removal activities associated with Gas Release Mode are documented in Section 3.4.2.11.1 of the DSA. Programmatic controls shall be established to ensure that bulk salt dissolution and interstitial liquid removal activities are controlled to limit the planned release of trapped gases such that the vapor space does not exceed the hydrogen concentration limit determined by the Flammability Control Program [Ref. 1].

The Bulk Salt Dissolution/Interstitial Liquid Removal Program shall document an evaluation using a similar methodology to the Salt Removal Gas Release Mode evaluation (refer to Section 6.4.1); however, several assumptions may be modified once Gas Release Mode is declared; examples are:

- The DSA minimum required ventilation flow rate (e.g., 72 scfm) shall be used in calculations using the first level of control (ventilation) in order to protect the SAV for the hydrogen concentration [TSR SAC 5.8.2.30.c]
- Hydrogen release may be considered depending on the salt removal operational attributes. The methodology used to determine the necessary controls shall be based on the hydrogen retention/release criteria/methodology for waste as discussed in DSA Section 3.4.1.5.3. [TSR SAC 5.8.2.30.c]
- Actual waste temperature may be used
- Actual waste height (considering incoming transfer) may be used to credit the vapor space volume and shall be adjusted to account for the maximum amount of waste associated with a Transfer Error Event (i.e., 15,000 gallons) if the waste tank receives a liquid batch volume of greater than or equal to 15,000 gallons or if the liquid source system has continuous makeup capability (i.e., the system has an automatic or manual fill provision that is not electrically or mechanically isolated). If the liquid batch source is less than 15,000 gallons and does not have continuous makeup capability, the actual waste contents/inventory shall be adjusted to account for the maximum total volume of the batch source. [TSR SAC 5.8.2.30.c]

- Interstitial liquid removal releases trapped gas from the drained portion of saltcake [Ref. 37] prior to bulk salt dissolution may be used

6.4.3 IMPLEMENTATION ACTIONS

1. CSTF Operations procedures shall address the requirement to perform an adequate number of vapor space turnovers and/or to compare the tank LFL reading to a reading obtained using a known LFL concentration prior to salt removal activities. [TSR SAC 5.8.2.30.b]

2. Prior to salt removal activities, an engineering evaluation shall be performed to determine if Gas Release Mode controls are required. The evaluation shall determine the number of vapor space turnovers required to reduce the hydrogen concentration from the safety analysis limit to less than or equal to the initial value assumed in the hydrogen release engineering evaluation. [TSR SAC 5.8.2.30.a and 5.8.2.30.b]

3. If required, the Gas Release Mode Bulk Salt Dissolution/Interstitial Liquid Removal Program is implemented to limit the vapor space hydrogen concentration.

4. Planned operations (e.g., waste tank to waste tank transfers) shall be pre-evaluated to ensure bulk salt dissolution does not occur for the affected process areas (e.g., receiving tanks) as part of the ETAF process [Ref. 11, Tab Electronic SW11.1], without an engineering evaluation (excluding Insignificant Salt Removal Activities listed in Section 6.4).

5. Planned operations (e.g., waste tank to waste tank transfers) shall be pre-evaluated to ensure interstitial liquid removal does not occur for the affected process areas (e.g., sending tanks) as part of the ETAF process [Ref. 11, Tab Electronic SW11.1], without an engineering evaluation.

6. Prior to free supernate removal (including siphon potential) from a Type III/IIIA Slow Generation Tank, it shall be verified that the tank does not contain an equivalent saltcake inventory greater than 330 inches as part of the ETAF process [Ref. 11, Tab Electronic SW11.1]. [TSR SAC 5.8.2.43.k]

7. Prior to free supernate removal (including siphon potential) from a Very Slow Generation Tank, it shall be verified that the tank does not contain an equivalent saltcake inventory greater than 150 inches as part of the ETAF process (Ref. 11, Tab Electronic SW11.1). [TSR SAC 5.8.2.43.l]

8. Liquid additions to the waste tanks shall be pre-evaluated using WCS or an engineering evaluation (excluding Insignificant Salt Removal Activities listed in Section 6.4 and excluding planned salt removal activities which require a separate engineering evaluation) to ensure bulk salt dissolution does not occur from dissolution of exposed bulk salt in the receipt tank

9. Bulk salt dissolution and interstitial liquid removal activities in Type I/II Acidic Chemical Cleaning Waste Tanks and Non-Acidic Chemical Cleaning Waste Tanks are prohibited [Ref. 1].

6.5 TANK FILL LIMITS

This section is not applicable to tanks in Acidic Chemical Cleaning Mode or Closure Mode. As a Best Management Practice, the fill level for tanks in Acidic Chemical Cleaning Mode will be documented in the ERD as described in Section 8.3. Waste tanks in Closure Mode are intentionally being filled with grout and are not protected by a fill limit. Waste tank overflow is considered not possible for a Closure waste tank and the flammability is not protected by a fill limit, but by the methods described in Section 6.8.

Tank fill limits are imposed for each waste tank. The tank fill limit will incorporate the lowest fill limit imposed by all programs of the DSA and CSTFs SCDHEC Construction Permit [Ref. 62].

The DSA credits a maximum waste storage tank level for the most restrictive of the following considerations:

- Maximum Fill Limit (maximum tank level that protects initial conditions/assumptions used in the accident analysis)
- Overflow Limits (these limits also protect assumptions associated with tank wall exposed area)
- Structural Integrity Fill Limit
- Siphon Limits for **Waste** Tanks 1**-4 and 7-12**
- Flammable Transient Limits Due to Trapped Gas Release
- Flammability Level (used for time to LFL [CLFL for Tank 50] calculations)
- Maximum annulus equilibrium liquid level (following a tank wall breach) for waste tanks in Non-Acidic Chemical Cleaning Mode

Additionally (outside of DSA requirements), the following should be considered once waste removal begins on a waste tank.

- Lowest Leak Site (SCDHEC Construction Permit Requirement)

The tank fill limit shall account for the maximum amount of waste associated with a Transfer Error event (i.e., 15,000 gallons) excluding waste tanks in Non-Acidic Chemical Cleaning Mode, and associated instrument uncertainties, unless the SCDHEC Construction Permit criterion remains bounding (i.e., results in the lowest setpoint value). The SCDHEC Construction Permit does not require consideration of the maximum amount of waste associated with a Transfer Error event (i.e., 15,000 gallons).

The following fill limits do not include maximum missing waste or instrument uncertainty. When comparing an HLLCP setpoint to these limits, maximum missing waste and instrument uncertainty should be accounted for unless otherwise noted below.

MAXIMUM FILL LIMIT BASED ON TANK TYPE TO PROTECT INITIAL CONDITIONS/ASSUMPTIONS IN ACCIDENT ANALYSES

This is the maximum tank level that protects initial conditions/assumptions used in the Aerosolization, Waste Tank Annulus Explosion, Waste Tank/Pump Tank Overheating, and Waste Tank Wall Failure events [Ref. 1].

The maximum fill limits for each waste tank type are listed in Table 3.4-2 of the DSA.

Waste Tank Type	Maximum Fill Limit (inches)
Type I	276
Type II	306
Type III/IIIA	372
Type IV	386

MAXIMUM FILL LIMIT TO PROTECT WASTE TANK OVERFLOW

This is the level at which the tank would physically overflow (typically through a sidewall penetration) [Refs. 29 and 67].

Tank	Tank Type	Fill Limit (inches)
1F	I	275.9
2F	I	279.2
3F	I	280.0
4F	I	280.3
5F	I	**Closed**
6F	I	**Closed**
7F	I	278.2
8F	I	279.5
9H	I	277.2
10H	I	276.4
11H	I	280.0
12H	I	**See note***
13H-15H	II	316.2
16H	II	**Closed**
17F-20F	IV	Closed
21H-24H	IV	382.7
25F	IIIA	374.2
26F	IIIA	375.5
27F	IIIA	373.5
28F	IIIA	373.6
29H-32H, 33F, 34F	III	378.6

35H-37H	IIIA	378.0
38H	IIIA	375.4
39H	IIIA	373.9
40H	IIIA	374.5
41H	IIIA	373.8
42H	IIIA	374.4
43H	IIIA	373.6
44F, 45F	IIIA	373.9
46F	IIIA	373.8
47F	IIIA	373.5
48H	IIIA	375.5
49H	IIIA	374.3
50H	IIIA	375.5
51H	IIIA	375.0

***Tank 12 is in Closure Mode. The tank is being filled with grout and thus is not protected by a Waste Tank Overflow Limit.**

MAXIMUM FILL LIMIT TO PROTECT MAXIMUM WALL STRESS (TYPE I AND II TANKS)

This is the level at which the tank wall stresses would exceed a maximum allowed value (limiting for only Type I and II tanks) [Refs. 30, 31, and 68]. This level is dependent on the specific gravity (SpG) of the waste contents. The SpG may be determined by calculating a composite SpG for the tank under evaluation, reflective of the tank conditions regarding sludge, salt, and supernate volumes and associated SpG in each represented phase.

Type I Tanks

Specific Gravity (SpG)	Allowable Fill Levels (inches)		
	Unflawed Tanks- with or without Submersible Mixing Pump (SMP)	Flawed Tanks-no SMP	Flawed Tanks- with operating SMP
1.00	276	276	276
1.20	276	276	276
1.40	276	276	276
1.50	276	276	256
1.56	276	276	246
1.58	276	271	242
1.60	274	266	237
1.80	244	237	211
2.00	222	213	190
2.20	203	198	177

Type II Tanks

Specific Gravity	Allowable Fill Level (inches)	
	Unflawed Tanks-	Flawed Tanks

	with or without SMP	
1.00	306	306
1.20	306	306
1.40	306	302
1.50	306	302
1.60	306	302*
1.80	277	268*
2.00	253	242*
2.20	234	232

*Operation of SMP not included for SpG of 1.6 through 2.0

MAXIMUM FILL LIMIT TO PREVENT SIPHON THROUGH COOLING COILS (TANKS 1-4 AND 7-12)

This is the level above which it would be physically possible to siphon waste from the tank through the cooling coils (for **Waste** Tanks 1-4 and 7-12). Based on the **maximum tank liquid level with respect to the Chromate Cooling Water System valve house header high point, the maximum fill limit to prevent siphon through cooling coils for Waste Tanks 1-4 and 7-12, determined in Ref. 75, is presented in the table below.**

Tank	Fill Limit (inches)
1F	245
2F	246
3F	243
4F	243
7F	246
8F	242
9H	249
10H	244
11H	252
12H	See note*

***Tank 12 is in Closure Mode and thus isolated from the Chromate Water System. Therefore, a siphon fill limit is not calculated for this tank.**

MAXIMUM FILL LIMIT BASED ON FLAMMABLE TRANSIENT ASSUMPTIONS

This is the level required to protect flammable transient assumptions for waste tank trapped gas releases [Refs. 32, 33, 49]. To protect flammable transient assumptions, waste tank HLLCPs shall include the following criteria for setpoint determination (in inches from the bottom of the tank) from Ref. 1, Section 3.4.2.11.1. These fill limits are applicable to waste tanks undergoing trapped gas release activities (Sections 6.3 and 6.4).

- Tanks under the Waste Tank Quiescent Time Program and salt tanks without mixing devices

Tank Type	I	II	III/IIIA	IV
HLLCP Setpoint (max)	274	304	376	411

- Tanks not under the Waste Tank Quiescent Time Program that have a calculated percent hydrogen in the bubble gas (H_{mix}) of less than or equal to 37.5%

Tank Type	I	II	III/IIIA	IV
HLLCP Setpoint (max) – Mixer Discharge totally clear of sludge and salt	274	304	376	411
HLLCP Setpoint (max) – Mixer Discharge partially or fully submerged in sludge or salt	215	245	317	397

- Tanks not under the Waste Tank Quiescent Time Program that have a calculated percent hydrogen in the bubble gas (H_{mix}) of greater than 37.5%

Tank Type	I	II	III/IIIA	IV
HLLCP Setpoint (max) – Mixer Discharge totally clear of sludge and salt	254	284	356	411
HLLCP Setpoint (max) – Mixer Discharge partially or fully submerged in sludge or salt	136	166	238	318

With the above limitations in place, the potential flammable gas transients in the tank vapor space are short-lived or virtually non-existent for realistically analyzed waste tank operating conditions.

MAXIMUM FILL LIMIT BASED ON TIME TO LFL (CLFL FOR TANK 50)

The Flammability Level establishes the tank level above which the vapor space is credited for time to LFL calculations. The Flammability Level is directly related to the HLLCP setting by the following:

Eq. # 27. Flammability Level = HLLCP + MMW + instrument uncertainty

Where,

Flammability Level = Establishes the credited vapor volume used to protect the Tank Classification (Section 6.1.1) and Gas Release Mode evaluations (Sections 6.3.1 and 6.4.1), in

HLLCP = High liquid level conductivity probe setpoint, in
MMW = Maximum missing waste volume divided by the fill factor, in

instrument uncertainty = Uncertainty attributed to HLLCP, in

The adjusted fill factor is applied as an algorithm to reflect varying fill factors that adjust the established tank calibrations as a result of the displaced volume of the support cone in the upper part of the tank, as applicable [Refs. 13,14]. The nominal fill factor [Ref. 1] may be used to calculate the waste volume. Application of the nominal fill factor in this way is conservative because the fill factor overestimates the waste volume. The instrument uncertainty values are based on the HLLCP setpoint uncertainty calculations [Ref. 15]. The HLLCP set point shall be documented in the ERD.

As a result of pre-evolution time to LFL evaluations (e.g., transfers, sludge or salt removal) it may be necessary to change the HLLCP height to protect the desired Tank Classification. In these cases, an engineering evaluation shall document the new HLLCP setting, taking into account maximum missing waste, instrument uncertainty, analytical analysis uncertainty, and any additional margin deemed appropriate to protect the Tank Classification desired. When the engineering evaluation requires the lowering of the HLLCP setpoint of a Type III/IIIA waste tank, an additional consideration of the volume of contingency space should be applied (See Section 8.4). The WCS database shall be revised with the new HLLCP set point upon completion of the field work.

For saturated salt solutions, the potential for salt-precipitation exists when the temperature is decreased. As the temperature decreases, the solubility of the nitrate and nitrite ion decreases in the liquid phase. This decrease in the concentration of nitrate and nitrite cause the time to LFL to decrease, which may result in the need to lower the HLLCP.

MAXIMUM ANNULUS EQUILIBRIUM LIQUID LEVEL

This is the level to protect maximum annulus equilibrium liquid level (following a tank wall breach) for Type I/II waste tanks in Non-Acidic Chemical Cleaning Mode. The tank fill limits of less than or equal to 63.8 inches [Type I] and 64.8 inches [Type II] provide controls to protect a maximum annulus equilibrium liquid level following a tank wall breach [Ref. 1]. These fill limits are not required to account for maximum missing waste [Ref. 1].

LOWEST LEAK SITE

In addition, the SCDHEC Construction Permit requires that once waste removal begins on a tank with a leak or crack and the waste is removed to a level below the lowest known leak or crack, that level shall become the maximum operating level of the tank and shall not be exceeded unless the exceedance is a temporary result of the waste removal process [Ref. 62]. The locations of known leaksites are documented in Reference 65.

6.5.1 IMPLEMENTATION ACTIONS

1. The most limiting of the maximum fill levels for each individual waste tank shall be determined in the WCS database, which is governed by the WCS Administrative Program [Ref. 10].

2. The WCS database shall verify that the HLLCP set point protects the most limiting of the maximum fill levels [accounting for Maximum Missing Waste (except waste tanks in Non-Acidic Chemical Cleaning Mode) and instrument uncertainty] for each individual waste tank.

3. Current HLLCP set points shall be documented in the ERD [Ref. 2].

4. Proposed HLLCP set points that support planned operations (e.g., waste tank to waste tank transfers) shall be compared against the waste tank fill limits and documented by an engineering evaluation or by the WCS database.

5. The WCS database and the ERD [Ref. 2] shall be updated with the new HLLCP set point after the field work to set the HLLCP at the proposed set point is complete and prior to the planned activity.

6. Tank Farm influents shall be updated in the WCS database as determined by the Waste Characterization System Program Description Document [Ref. 10] to ensure that the HLLCP is adjusted at the appropriate height in the tank to maintain greater than 7 days to LFL and tank classification.

7. Waste tank to waste tank transfers shall be pre-evaluated to protect fill limits.

8. The Waste Tank Structural Integrity Cognizant Engineering function shall maintain a reference document(s) of current overflow limits (all waste tanks), structural integrity limits (all waste tanks), and lowest known leak sites (all waste tanks).

9. The WCS database owner shall be notified upon discovery of a new leaksite and current HLLCP setpoints shall be compared to the leaksite location and adjusted if necessary.

6.6 DELETED

6.7 WASTE TANKS IN ACIDIC CHEMICAL CLEANING MODE

The Chemical Cleaning process involves two distinct modes: Acidic Chemical Cleaning and Non-Acidic Chemical Cleaning. Non-Acidic Chemical Cleaning Mode will typically be entered following completion of Acidic Chemical Cleaning in the waste tank. However, a tank may possibly transition between the two modes several times during a chemical cleaning campaign in some circumstances. The treatment tank will enter Acidic Chemical Cleaning Mode prior to the transfer of oxalic acid into the tank; acid may be added at up to a 20:1 volume ratio at a maximum concentration of 8 wt.% oxalic acid to sludge. The tank may enter Non-Acidic Chemical Cleaning Mode once the entry requirements are met. Routine flammability controls apply to tanks in Non-Acidic Chemical Cleaning Mode.

Only Type I and Type II waste tanks (except Tanks 1, 5 and 6) are allowed to enter Acidic Chemical Cleaning Mode. The tanks in Acidic Chemical Cleaning Mode will be required to have a minimum purge ventilation flow rate with flow indication [Refs. 1,56]. These flow rates maintain the hydrogen concentration in the waste tank below 25% of the LFL, and ensure at least 3 days to LFL in the event that ventilation is lost. The time to LFL in the

annulus due to a leak during Acidic Chemical Cleaning is 3.25 days [Ref. 45]. Because of the minimum purge flow requirement, additional vapor space turnovers are not required. In addition, the maximum heights are specified for the HLLCPs in tanks in Acidic Chemical Cleaning Mode [Ref. 56].

Spray washing may be conducted in Acidic Chemical Cleaning Mode as part of the waste tank chemical cleaning evolution. Liquid additions shall be limited to those from batch sources less than or equal to 8,000 gallons total volume that do not have a continuous makeup capability. The liquid source system shall be considered to have continuous makeup capability if the system has an automatic or manual fill provision that is not electrically or mechanically isolated. The electrical or mechanical isolation shall contain two independent means of isolation (e.g., two isolation valves; one isolation valve and open disconnect for liquid source transfer pump) [Ref. 1]. Spray washing does not contribute additional hydrogen beyond that generated during batch additions of oxalic acid [Ref. 1].

6.7.1 IMPLEMENTATION ACTIONS

The following requirements shall be met prior to placing a waste tank in Acidic Chemical Cleaning Mode:

1. The tank shall be classified as a Chemical Cleaning Tank in the ERD [Ref. 2]
2. If the projected numbers of tanks capable of becoming flammable following a seismic event (including the effects of post seismic trapped gas release and number of waste tanks in Chemical Cleaning Mode) within 7 days are not within the restrictions of the TSR, then the evaluated activity shall not be performed. [TSR AC 5.8.2.27.a]
3. A path forward shall be provided to DOE (addressing the additional risk and recovery time) if a transfer required to mitigate a waste tank leak causes additional waste tanks (more than 14) to have the potential to become flammable in less than seven days. Because the transfer is mitigating a degraded condition (i.e., placing the facility in a safer condition), the path forward is not required to be provided to DOE prior to initiating the transfer. [TSR AC 5.8.2.27.c]
4. The emergency response priority classification shall be determined by the time to LFL. Response priorities shall be, in order of decreasing priority: Priority 1 Tanks (seismic time to LFL < 24 hours), Priority 2 Acidic Chemical Cleaning Tanks (tank primary, then annulus), then remaining Priority 2 Tanks (seismic time to LFL < 7 days).
5. Bulk salt dissolution and removal of interstitial liquid from saltcake are prohibited.

6.8 CLOSURE MODE

A requirement for tanks in the Closure Mode (only applies to Type I, II, and IV waste tanks) is that the radiolytic hydrogen generation rate shall be less than or equal to 0.5 ft^3/hr evaluated at 25°C with an NO_{eff} equal to zero [Ref. 1]. Using the Radiolytic Hydrogen Generation Model outlined in Section 3.4.1.1.2 of the DSA [Ref. 1], the radiolytic hydrogen generation rate can be calculated.

An evaluation was performed on the flammability of Type I, II and IV waste storage tanks during grouting operations [Ref. 58]. The evaluation used a maximum vapor space temperature of 100°C. The maximum vapor space temperature in an inactive dry tank is 75°C so using a higher vapor space temperature provides conservatism in the results. A radiolytic hydrogen generation rate of 0.63 ft^3/hr was determined to be the maximum rate at which a Type I, II, or IV waste storage tank can remain at or above 10 days time to LFL at the primary waste tank historical maximum waste level with a vapor space temperature of 100°C. This corresponds to a radiolytic hydrogen generation rate of 0.5 ft^3/hr evaluated at 25°C which is consistent with the temperature used to evaluate the LFL of hydrogen (See Section 6.1.1).

During waste tank grouting, the organic content of the components that will comprise the grout will contribute insignificant quantities to the flammable vapor space concentration. As such, the contribution from trace organics (5% LFL for hydrogen) assumed in waste tanks undergoing grouting will bound any volatile releases from the grout [Ref. 59].

Once the flammability-related Closure Mode entry prerequisites have been met for a waste storage tank, the HLLCP is not required for flammability controls in a tank that has been declared a Closure Waste Tank [Ref. 1].

Even though Closure Mode contains no other DSA requirements for flammable vapors, compliance with codes and standards (i.e., National Fire Protection Association (NFPA) Standard 69 [Ref. 20]) continues to apply until grouting is complete. As such, flammable vapor control will be maintained by: a) operating forced ventilation, or b) sampling the vapor space to determine flammable vapor concentrations, or c) a combination of a and b. A methodology for compliance is contained in the FTF and HTF Fire Hazard Analyses [Refs. 60,61] and is defined in the following paragraphs along with the implementation items of Section 6.8.1.

From S-CLC-H-01248, a waste tank with a radiolytic hydrogen generate rate meeting the Closure Mode pre-requisite cannot reach an equilibrium condition of 100% of the LFL_{OC} so long as the tank level is less than 60 inches for a Type I tank, less than 140 inches for a Type II tank or less than 230 inches for a Type IV tank. Until grout is added to the tank, reducing the available vapor space volume, a Closure Mode tank will contain a small waste volume which will yield a much lower tank level than the values above. Since, by definition, a Very Slow Generation waste tank must also not reach equilibrium at 100% of the LFL_{OC}, it is reasonable to use the methodology described in Section 8.2 for Closure Mode waste tanks until grout fill is initiated.

While adding grout to the primary tank and annulus, it is expected that forced ventilation will be operated in order to provide radiological contamination control for the displaced vapor space. This will simultaneously provide flammable vapor control. When grout addition is not actively in progress, the ventilation system can continue to be operated or periodic flammable vapor sampling can be performed.

Once the primary tank (or annulus) is filled to the base of the risers, an alternate strategy is required. At this point in the process, each riser (primary or annulus) can be considered a stand-alone location for flammable vapor accumulation. However, the hydrogen being

generated by the waste will have to diffuse through 20+ vertical feet of grout to reach the riser openings. It is reasonably conservative to assume that the diffused hydrogen will be distributed equally among the available risers, i.e., the flammable vapor concentration in any one riser will be comparable to all risers of that location (primary or annulus). Based on this approach, at least one unfilled riser for each applicable location (primary and/or annulus) shall be sampled periodically to monitor for flammable vapor concentrations. Additionally, any riser that is about to be grouted shall also be monitored prior to grout pouring; the riser sampled for grouting can be used to satisfy the requirement for that location/period. Measured flammable vapor concentrations < 10% LFL require no action. If the measured value is >10% LFL but less than 20% LFL, prior to grouting a monitoring frequency must be established to ensure that the riser vapor space does not exceed 20% without recognition of the hazard. If the measured value is ≥20% LFL but less than 55% LFL, compensatory measures determined by an engineering evaluation shall be carried out to reduce the flammable vapor concentration prior to grouting [Ref. 61]. If ventilation is utilized as the compensatory measure, successful removal shall be confirmed via follow-up sampling. Risers with a measured flammable vapor concentration ≥ 55% LFL shall be ventilated to remove flammable vapors. Successful removal shall be confirmed via follow-up sampling prior to further activity. If any riser is found to be ≥55% LFL, other unfilled risers for that location (primary or annulus) shall be sampled and action taken based on the values above.

During riser grout pouring, continuous vapor space monitoring is not required; however if grout pouring is interrupted prior to filling the riser, vapor space monitoring is required if the duration of the interruption is greater than 8 hours. If the riser is found to be greater than or equal to 20% LFL, action should be taken based on the values above.

6.8.1 IMPLEMENTATION ACTIONS

1. Prior to placing a waste storage tank in Closure Mode, an engineering evaluation shall be performed to ensure the flammability-related Mode entry prerequisites for Closure Mode are met. For hydrogen generation rate requirement, an analytical uncertainty of 2 Sigma shall be included when comparing against the hydrogen generation rate limit.

2. The flammability status of the waste tank shall be classified as Closure in the ERD. Conductivity Probe Height/Fill Limit, Hydrogen Analyzer Limit and Number of Required Turnovers are not applicable to a tank in Closure Mode.

3. From the time when a waste tank is declared in Closure Mode until grout pouring is initiated, the waste tank shall be treated as a Very Slow Generation waste tank and shall be ventilated/monitored as described in Section 8.2.

4. Prior to initiating grouting operations, perform an engineering evaluation to determine the following (not applicable to riser grouting):

    a. minimum purge flow required to maintain a flammable vapor concentration below 20% LFL during grouting

b. required time for response to a loss of ventilation (e.g. restoration of ventilation or periodic flammable vapor sampling)

5. Prior to initiating grouting, monitor the vapor space to ensure that the flammable vapor concentration is less than 20% LFL. If the result is greater than or equal to 20% LFL, operate forced ventilation until the flammable vapor concentration is less than 20% LFL (not applicable to riser grouting).

6. When grouting of a Closure Waste Tank is initiated, the following shall be performed for the primary tank and its annulus until each of these locations is completely filled to ensure that flammable vapor concentration remains below 20% LFL:

   b. Ventilate the location with forced ventilation

   OR

   c. Perform periodic flammable vapor sampling

   If ventilation is being used to satisfy this attribute and ventilation flow is lost, initiate periodic flammable vapor sampling until forced ventilation is restored (not applicable to riser grouting).

7. Upon completion of bulk (non-riser) grouting perform the following for unfilled risers:

   a. Sample one primary and one annulus riser for flammable vapor concentration weekly. If riser grouting is to be performed, the riser to be grouted may count as one of the risers sampled (annulus or primary)

      - If measured vapor concentration is less than 20% of the LFL, no action is required.

      - If vapor concentration is greater than or equal to 20% of the LFL, a compensatory measure, as defined in an engineering evaluation, shall be performed to bring the concentration below 20%.

        - Additionally, other unfilled risers in that location (primary or annulus) shall be sampled to determine flammable vapor concentration. Compensatory measures shall be performed for each riser found with a concentration above 20% LFL.

   b. If data shows the flammable vapor concentration remains below 10% LFL, the frequency of sampling may be decreased based on an engineering evaluation.

8. For riser grouting, perform the following:

   a. Prior to grouting of a riser, sample the flammable vapor concentration.

- If the grouting concentration is less than 10% LFL grouting can proceed with daily monitoring.

- If the concentration is between 10% and 20% LFL, a monitoring frequency must be established to ensure that the riser vapor space does not exceed 20% without recognition of the hazard. Grouting may proceed with established monitoring frequency.

- If the concentration is greater than or equal to 20% LFL but less than 55%, perform an engineering evaluation to determine compensatory actions to reduce flammable vapor concentration.

- If the measured flammable vapor concentration is equal to or greater than 55% LFL, perform the following:

    - Ventilate riser with forced ventilation. Perform a follow-up sample of that riser after ventilating to ensure LFL <20%.

    - Sample all other unfilled risers for that location (primary or annulus) and perform required actions defined above for any riser with a measured concentration ≥20% LFL

b. If grouting is interrupted prior to filling the riser perform the following actions:

- If interruption duration is less than 8 hours, no action is required and grouting may proceed.

- If interruption duration is greater than 8 hours, monitoring of vapor space concentration shall be completed and actions performed as stated in (a) to ensure the flammable vapor concentration is < 20% LFL before grout pouring can continue.

6.9 OIL CONTROL PROGRAM

Programmatic controls through the Oil Control Program shall be established to prevent the introduction (e.g. via air compressors, transfer pumps, waste tank mixing devices) of significant flammable vapors (≥5% LFL at 100ºC [Ref. 36]) from lubricating or hydraulic oil into analyzed spaces (e.g., evaporator pots, evaporator cells, transfer facilities, waste tanks, and waste tank annuli) [Ref. 1]. Reference 36 lists the currently evaluated compressor lubrication oils that can be used in the facility without causing these analyzed vapor spaces to exceed their 5% LFL requirement. In addition, Reference 71 evaluates a lubrication oil specific for use in CSMPs. In order to prevent unevaluated lubricating or hydraulic oils from being used in the facility, certain implementation actions have been established to control the introduction of new lubricating or hydraulic oils within the facility.

6.9.1 IMPLEMENTATION ACTIONS

1. For installed facility compressors, the model work orders for F and H Tank Farm's preventive maintenance shall ensure the use of approved lube oils.

2. For portable compressors, the preventive maintenance program for these compressors shall ensure that only approved lube oils are used. The facility shall ensure that only those compressors serviced under an appropriate PM program are used in the facility.

3. The lubricating or hydraulic oils from the equipment that can enter the vapor spaces of the Tank Farm equipment shall be evaluated to ensure an oil is selected that does not cause the analyzed vapor spaces to exceed the 5% LFL requirement mentioned above.

7.0 OUTPUT DOCUMENTATION

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.

Calculations issued as output documents shall be confirmed calculations in accordance with the requirements of the E7 Manual, Procedure 2.31A. 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 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.

8.0 BEST MANAGEMENT PRACTICE

8.1 GAS RELEASE MODE

Best management practice will be to limit releases such that the vapor space remains below the TSR hydrogen concentration limit (i.e., as documented in the ERD), which accounts for potential organics and instrument uncertainty according to the designated SAV, by controlling slurry pump (or other mixing device) operation procedures. The best management practice, which includes the use of calculations, is to ensure that the TSR hydrogen concentration interlocks and alarm set points (second level of control) are not activated. Additionally, for tanks that require entry into Gas Release Mode, the pump run and interstitial removal/bulk salt dissolution programs will require an alarm setpoint, which considers alarm setpoint increment limitations to ensure the TSR hydrogen concentration limit is not exceeded [Refs. 1,2]. The TSR hydrogen concentration limit will be designated in the ERD. Once the ERD is approved, this will drive the revision of the Instrument Scaling and Setpoint Document, which will allow implementation of the required indicated hydrogen concentration reading and/or alarm setpoint in the facility. References 3, 4, and 52 provide instrument uncertainty values for a range in various SAVs, which are employed to determine the TSR hydrogen concentration limit (i.e., indicated hydrogen reading) and/or alarm setpoint.

The methodology described in Sections 6.3 and 6.4 must be followed during all gas release activities in sludge and salt.

8.2 TIME TO LFL METHODOLOGY

The hydrogen generation rate equations used in the DSA [Ref. 1] are functions of both radiolytic heat load, and concentration of nitrate and nitrite anions. There is analytical uncertainty on chemical and radiological composition measurements as reported from laboratories [Ref. 44]. The potential effect of these uncertainties is that the calculated time to LFL could change by about 30%. In addition to the conservatisms already contained within the assumptions of DSA, the tank classification and time to LFL are periodically reviewed against the following criteria to mitigate the potential for tank classification change due to these analytical uncertainties [Ref. 46]:

RAPID GENERATION TANKS with less than 10 days time to LFL

SLOW GENERATION TANKS with less than 36 days time to LFL

VERY SLOW GENERATION TANK with an equilibrium hydrogen concentration greater than 65% LFL_{OC} (70% LFL_{OC} or 85% CLFL for Tank 50)[†].

If any tank is found to meet the above criteria during periodic reviews [Ref. 46], additional actions are recommended (these actions are not requirements) in order to mitigate this vulnerability of a tank classification change (e.g., chemical additions, lowering HLLCP height, removing waste, etc.).

Additional conservatism is available in the hydrogen generation rate based on a comparison of predicted hydrogen generation rate, and measured hydrogen generation rates based on measurements in waste tanks [Ref. 47]. The analysis showed that WCS consistently overpredicts the hydrogen generation rate; especially, in high heat waste tanks (which are the most critical). The observed generation rates measured by gas chromatographs in the non-slurried, high-heat waste tanks (see data in Table 3 of Ref. 47) are 4-9 times less than the WCS calculated hydrogen generation rates. This observed conservatism in calculated hydrogen generation rate is due, possibly, to a combination of several factors; including, passive ventilation, radiation leakage from the tanks, radiation absorption by solids, and/or systematic conservatism in heat load or R-value estimates.

Best management practice will be to limit the Very Slow Generation designation to tanks that reach equilibrium at less than 95% of the LFL_{OC}. For a Very Slow Generation tank that is found to reach equilibrium at or above 60% of the LFL_{OC} (Eq. # 3), the tank shall undergo quarterly ventilation operation using an installed or portable ventilation system (i.e., for a duration of 12 vapor space turnovers with downtime not exceeding 12 cumulative hours from start to completion). As an alternative to ventilation operation, the tank vapor space may be verified to be less than 60% of the LFL. Tank 50, at a minimum of once per year, shall undergo periodic ventilation operation using an installed or portable ventilation system (i.e.,

[†] It is calculated based on a reduction of 30% uncertainty from 43.8 %CLFL for hydrogen plus 56.2 % CLFL for Isopar® L/organics (~ 0.70 * 43.8 %CLFL + 56.2 %CLFL).

for a duration of 12 vapor space turnovers with downtime not exceeding 12 cumulative hours from start to completion). See Eq. # 15 in order to calculate the equilibrium hydrogen concentration for Tank 50.

8.3 CHEMICAL CLEANING PROGRAM

As a Best Management Practice, the hydrogen LFL limit of 12% should be entered in the ERD for tanks in Acidic Chemical Cleaning Mode. This is a set value for all Chemical Cleaning Tanks based on the purge flow protecting 25% of the LFL [Ref. 56]. This value is not determined using the methodology in this Program, and is not required to be entered in the ERD by the TSRs. However, it should be included in the ERD for clarification.

In addition, the conductivity probe height / tank fill limit for tanks in Acidic Chemical Cleaning Mode should be entered in the ERD [Ref. 2]. This is a set value (61 in. for Type I Tanks, 63 in. for Type II Tanks) [Ref. 6], and was used in the purge flow analysis for Chemical Cleaning Tanks. Although not required to be entered in the ERD by the TSRs, it should be included in the ERD for clarification.

8.4 CONTINGENCY STORAGE

DOE Manual 435.1-1 describes the commitment to have spare capacity with adequate capabilities to receive the largest volume of waste contained in any one storage vessel, pretreatment facility or treatment facility [Ref. 70]. This commitment is implemented by the ETAF process (Ref. 11, Tab Electronic SW11.1); however, when performing a flammability calculation where the HLLCP setpoint is required to be lowered on a Type III/IIIA waste tank, the group responsible for the ETAF process should be notified of the new setpoint to ensure adequate contingency storage is available once the HLLCP is lowered.

9.0 UNCERTAINTIES AND CONSERVATISMS

9.1 SEISMIC TIME TO LFL METHODOLOGY

There are conservatisms associated with the seismic time to LFL methodology; including:

- 100% of the hydrogen generated after the seismic event will not be in the waste tank vapor space after the seismic event. When part of the trapped gas in salt and sludge layers is released after the seismic event, some of the hydrogen generated will tend to be retained to restore the trapped gas inventory to the maximum quantities achieved prior to the seismically induced release.

- Measured (actual) hydrogen generation rates in high-heat waste tanks are significantly less than calculated (theoretical) hydrogen generation rates [Ref. 47].

- The equations used to determine the radiolytic hydrogen generation rate are based on experimental data that has margin added [Ref. 74].

No additional uncertainty allowances are applied to the seismic time to LFL methodology because of these large conservatisms.

9.2 SLUDGE PUMP RUN AND SEISMIC QUIESCENT TIMES

There are several conservatisms that exist in the calculation of Pump Run and Seismic quiescent times (related to tanks under a Quiescent Time Program) including:

- All gas is released instantaneously upon operation of slurry pumps, or a seismic event. This is conservative because actual gas release is known to be a time-dependent phenomenon. Additionally, it has been observed that the tank level in Tank 51 continues to decrease for some time after a slurry pump run is completed; indicating that it takes time for gas bubbles to be released from large waste depths.
- Gas is retained in a step-wise fashion: 50% retention for an inventory of 90 inches of sludge, and less; and 100% retention for an inventory of greater than 90 inches [Ref. 1]. Actual data shows retention to be a 2nd order polynomial function of sludge depth [Ref. 34].
- Ventilation system operation during slurry pump operation serves to limit the vapor space flammable gas concentration significantly below the SAV, and TSR hydrogen concentration limits. Routine slurry pump runs with ventilation operating cause the vapor space to reach only 5-10% of the LFL_{OC} [Ref. 44].
- 100% of the hydrogen generated after the pump operation or seismic event will not be in the waste tank vapor space. When the trapped gas in sludge is released after the pump run or seismic event, some of the hydrogen being generated will tend to be retained to restore the trapped gas inventory to the quantities achieved prior to the release.
- The equations used to determine the radiolytic hydrogen generation rate are based on experimental data that has margin added [Ref. 74].

Additional conservatism is included in tanks that are not in GRM. The frequency to run pumps to stay out of GRM implemented in the ERD [Ref. 2] is based on the vapor space protected by the HLLCP. Due to these large conservatisms, no additional uncertainty needs to be incorporated into the calculated quiescent times. Slight changes in calculated quiescent times as a result of analytical uncertainty in sample results are incorporated in the ERD [Ref. 2] as new data is input into the WCS database.

10.0 DEVIATIONS

Proposed deviations from the requirements as described by this PDD shall be evaluated as deemed appropriate. The proposed deviation shall be reviewed by the Program Review Committee (PRC). Furthermore, acceptance of the deviation and evaluation and any required compensatory actions shall require documented approval of the PRC.

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ENGINEERING TECHNICAL REPORT CHECKLIST / VERIFICATION BY DOCUMENT REVIEW

S4-ENG.51 Form

Report Number: WSRC-TR-2003-00087 Revision: 26

Report Title: CSTF Flammability Control Program-Program Description Document

The following checklist is used to ensure technical reports are complete and in compliance with Manual E7. Add any notes or comments to the end of the checklist with the item number.

Item No.	Item	Yes / No N/A*	Comments Use continuation page at end of form if more space is needed
	Version / Format		
1	If revising an existing report, are you starting with the latest, approved version of the report obtained from DCR?	Yes	
2	Are all of the pages properly labeled with Report Number, Revision Number, and Sequential Page Number?	Yes	
3	Are the Subject and Purpose clearly stated and do they meet the end users needs?	Yes	
	References		
4	Are all References properly documented within the report and can they be easily verified within Document Control, on-line, or within the library, etc.? If reference documents are not readily available, are they attached?	Yes	
5	Have the correct design bases documents been identified (e.g., Codes, Standards, DOE Orders, SRR Requirements, Regulatory Requirements)?	Yes	
	Open Items / Input		
6	Is there a reference/source for each input?	Yes	
7	Do the identified references/sources fully support the inputs?	Yes	
8	Are all assumptions used to support the report individually listed?	N/A	No assumptions
9	Is there a justification written for each assumption that includes a technical basis?	N/A	No assumptions

* Double click and Delete will make field blank.

ENGINEERING TECHNICAL REPORT CHECKLIST / VERIFICATION BY DOCUMENT REVIEW

S4-ENG.51 Form

Item No.	Item	Yes / No N/A*	Comments Use continuation page at end of form if more space is needed
	Open Items / Input - continued		
10	Do the justifications adequately support the assumptions?	N/A	No assumptions
11	If the report has open items, is there a method identified to track them?	N/A	No open items
	Results / Conclusions		
12	Are the results of the report consistent with the input and assumptions?	Yes	
13	Do the results of the report affect any other technical documents?	N/A	These will be identified as part of the implementation checklist.
14	Do the results substantiate the conclusion?	Yes	
	Approvals		
15	Does the document identify the method of verification, if applicable, and does it have a signature block for the verifier/checker?	Yes	
Items 16-28 are only to be completed when Verificaiton by Document Review is being performed. The verifier assures the technical accuracy of the document by performing administrative and mathematical checks as appropriate, and by evaluating the modification against the following questions:			
16	Were the inputs correctly selected and identified?	Yes	
17	Are the assumptions made in the performance of the design or analytical activity adequately described and reasonable?	N/A	No assumptions
18	When necessary, are the assumptions identified for subsequent re-verification when the detailed design activities are completed?	N/A	No assumptions
19	Were appropriate design or analytical methods and computer programs used?	Yes	
20	Were the design or analytical inputs correctly incorporated into the design, analysis or evaluation?	Yes	
21	Have engineering actions required to support risk handling strategies been verified?	Yes	The HLLCP probe in Tank 8 will need to be lowered to comply with new siphon limits.
22	Is the design output reasonable compared to the design or analytical inputs?	Yes	Changes made support HLW-CRF-15008

* Double click and Delete will make field blank.

ENGINEERING TECHNICAL REPORT CHECKLIST / VERIFICATION BY DOCUMENT REVIEW

S4-ENG.51 Form

Item No.	Item	Yes / No N/A*	Comments Use continuation page at end of form if more space is needed
23	Are the necessary design inputs for interfacing organizations specified in the design documents or in supporting procedures or instructions?	N/A	Affected procedures will be identified as part of the implementation checklist.
24	Have suitable materials, parts, processes, and inspection and testing criteria been specified?	N/A	
25	Have existing and potential workplace hazards been identified, evaluated, and controls incorporated for the risk to worker injury or illness?	N/A	
26	Was a review conducted to confirm that there are no interferences with other ongoing or planned modifications?	Yes	Some discussion occurred in PRC. This is completed as part of the implementation checklist.
27	Have engineering judgments been identified, technically justified, and supported?	Yes	
28	Have design optimization strategies been considered/met (e.g., appropriate tailoring of requirements, design attributes, and operating strategies)?	No	

Item No. Cont.	Comments Continuation

Checker / Verifier: Christine Ridgeway / Christine Ridgeway 2/25/16
Circle function, both if applicable — Print — Signature — Date

Verifier:** _____ / _____ _____
** Only if different than above — Print — Signature — Date

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