CSTF Flammability Control Program

Program Description Document

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Summary of Revisions

<table>
<thead>
<tr>
<th>Revisions</th>
<th>Date</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-19</td>
<td></td>
<td>See Revision 23 for Summary</td>
</tr>
<tr>
<td>20-26</td>
<td></td>
<td>See Revision 26 for Summary</td>
</tr>
<tr>
<td>6/2016</td>
<td>Rev. 27</td>
<td>Total rewrite, no revision bars included</td>
</tr>
<tr>
<td>10/2016</td>
<td>Rev. 28</td>
<td>Section 4.1.2.3 – Clarified initial hydrogen concentration for spontaneous time to LFL</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Section 4.1.3.1 Variable H'EQ Calculation – Clarified H’eq is compared with 2.5% of the LFL_T in lieu of 2.5% of the LFL25C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Section 4.2.1.2.1 Clarified Seismic Quiescent Time determination when y0(Seismic) &lt; LFLOC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Section 4.3.1.2 Clarified verification of 2.5% of the LFL25C prior to starting the prime mover</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Section 4.3.2.2 Variable Hmix Calculation – Revised wording to match DSA</td>
</tr>
<tr>
<td>11/2016</td>
<td>Rev. 29</td>
<td>Section 2.0 – Recognized Tank 12 as radiological facility</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Section 3.0 – Recognized continuous purge ventilation for Very Slow Generation Tanks is sufficient to account for dissolved hydrogen release from steam jetted transfers. Clarified the criteria to consider sludge as slurried sludge.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Section 4.3.1 – Modified requirement associated with applicability of Free Supernate Removal Hydrogen Release Rate Limits – changed 36 hours to 48 hours</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Section 4.4 – Removed Tank 12 from waste tanks under Tank Fill Limits Program</td>
</tr>
<tr>
<td>9/2017</td>
<td>Rev. 30</td>
<td>Section 1.0 – Added other Safety Basis controls defined in WSRC-IM-94-10 Section 3.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Section 4.0 – Added wording to acknowledge the Interim Safety Basis requirements supersede the ones in the DSA and TSR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Added Section 4.8 - Added ESS compensatory measures 2.2.1, 2.2.6, 2.2.8, 2.2.9 and implementation actions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Updated References</td>
</tr>
<tr>
<td>11/2017</td>
<td>Rev. 31</td>
<td>Section 4.3 – Corrected typographical errors on pages 86 thru 88</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Section 4.3.2.2 – Revised wording on page 105 to match DSA Section 3.4.1.5.3.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Section 4.8 – Added ESS compensatory measure 2.2.18 and associated implementation actions to implement U-ESS-G-00007, Rev. 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Updated References</td>
</tr>
<tr>
<td>Date</td>
<td>Rev.</td>
<td>Changes</td>
</tr>
<tr>
<td>--------</td>
<td>------</td>
<td>---------</td>
</tr>
</tbody>
</table>
| 2/2018 | Rev. 32 | Section 4.2.3 – Added reference for mixing efficiency used in vapor space turnovers calculation  
Section 4.3.2 – Removed 242-16F evaporator from service  
Update References |
| 5/2019 | Rev. 33 | Section 3.0 – Added terminology for Dissolution Water Skid System and waste tank mixing devices  
Section 4.1.2.2.1 – Updated Tank 50 maximum radiolytic hydrogen generation rate  
Section 4.2.1.1 – Clarified Quiescent Time Program still applicable to those tanks that have inter-mixed waste layers. Recognized SBP operation can create slurried sludge from settled sludge.  
Section 4.2.4 – Added items 13 to clarify SBPs to not be credited for any Quiescent Times  
Section 4.3 – Added SBP Operation Program to minimize sludge entrainment during SBP operation.  
Section 4.3.2.1 – Inserted a paragraph to discuss how to treat inter-mixed waste layers in GRM evaluation  
Section 4.3.2.2 – Updated variable $V_{\text{solids}}$ calculation  
Section 4.3.2.3 – Revised to enable saltcake dissolution with mixing eductors and waste tank mixing devices in Gas Release Mode  
Section 4.3.2.4 – Added 2nd person verification of mixing eductor turntable operation  
Section 4.4 – Updated Tank Fill Limits  
Section 4.7 – Added temperatures the compressor oils evaluated.  
Section 9.0 – Updated references |
| 11/2019 | Rev. 34 | Section 3.0 – Updated definition for bulk saltcake layer, free supernate removal, saltcake interstitial liquid removal and saltcake well mining  
Section 4.2.1.1 – Added Reference 61  
Section 4.3 – Clarified Gas Release Program attribute applicability (including exclusions for some process transitions)  
Section 4.3.1.2 – Added action 8 to address unintended interstitial liquid removal during a free supernate removal  
Section 4.3.2 – Updated insignificant hydrogen release activities  
Section 4.3.2.1 – Recognized saltcake interstitial liquid removal using transfer jets without requiring enter GRM and added Reference 61  
Section 4.3.2.2 – Recognized vapor space volume using actual waste contents/inventory and clarified bulk saltcake dissolution with supernate coverage  
Section 4.3.2.4 – Updated action 13, added actions 15 thru 18  
Section 9.0 – Updated references |
# List of Acronyms

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC</td>
<td>Administrative Control</td>
</tr>
<tr>
<td>CLFL</td>
<td>Composite Lower Flammability Limit</td>
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<tr>
<td>CSMP</td>
<td>Commercial Submersible Mixer Pump</td>
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<tr>
<td>CSTF</td>
<td>Concentration, Storage, and Transfer Facility</td>
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<tr>
<td>DOE</td>
<td>Department of Energy</td>
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<tr>
<td>DSA</td>
<td>Documented Safety Analysis</td>
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<tr>
<td>DWS</td>
<td>Dissolution Water Skid</td>
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<tr>
<td>ERD</td>
<td>High Level Waste Emergency Response Data and Waste Tank Data</td>
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<tr>
<td>ESP</td>
<td>Extended Sludge Processing</td>
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<tr>
<td>ESS</td>
<td>Evaluation of the Safety of the Situation</td>
</tr>
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<td>GRM</td>
<td>Gas Release Mode</td>
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<td>HLLCP</td>
<td>High Liquid Level Conductivity Probe</td>
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<tr>
<td>ISB</td>
<td>Interim Safety Basis</td>
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<tr>
<td>JCO</td>
<td>Justification for Continued Operation</td>
</tr>
<tr>
<td>LFL</td>
<td>Lower Flammability Limit</td>
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<tr>
<td>MCU</td>
<td>Modular Caustic Side Solvent Extraction Unit</td>
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<tr>
<td>NFPA</td>
<td>National Fire Protection Association</td>
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<tr>
<td>OA</td>
<td>Oxalic Acid</td>
</tr>
<tr>
<td>PDD</td>
<td>Program Description Document</td>
</tr>
<tr>
<td>PISA</td>
<td>Potential Inadequacy in the Safety Analysis</td>
</tr>
<tr>
<td>SAC</td>
<td>Specific Administrative Control</td>
</tr>
<tr>
<td>SAV</td>
<td>Safety Analysis Value</td>
</tr>
<tr>
<td>SCDHEC</td>
<td>South Carolina Department of Health and Environmental Control</td>
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<tr>
<td>SCFM</td>
<td>Standard Cubic Feet per Minute</td>
</tr>
<tr>
<td>SBP</td>
<td>Submersible Blender Pump</td>
</tr>
<tr>
<td>SMP</td>
<td>Submersible Mixer Pump</td>
</tr>
<tr>
<td>S/RID</td>
<td>Standards/Requirements Identification Document</td>
</tr>
<tr>
<td>STP</td>
<td>Standard Temperature and Pressure</td>
</tr>
<tr>
<td>TSR</td>
<td>Technical Safety Requirements</td>
</tr>
</tbody>
</table>
WCS  Waste Characterization System
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table of Contents</td>
<td>6</td>
</tr>
<tr>
<td>1.0 Purpose</td>
<td>8</td>
</tr>
<tr>
<td>2.0 Scope</td>
<td>8</td>
</tr>
<tr>
<td>3.0 Terminology And Inputs</td>
<td>9</td>
</tr>
<tr>
<td>3.1 Implementation Actions</td>
<td>21</td>
</tr>
<tr>
<td>4.0 Program Description</td>
<td>22</td>
</tr>
<tr>
<td>4.1 Flammability Control Program</td>
<td>22</td>
</tr>
<tr>
<td>4.1.1 Background</td>
<td>22</td>
</tr>
<tr>
<td>4.1.2 Time to LFL</td>
<td>24</td>
</tr>
<tr>
<td>4.1.2.1 Waste Tank Flammability Classification</td>
<td>24</td>
</tr>
<tr>
<td>4.1.2.2 Time to LFL Methodology</td>
<td>25</td>
</tr>
<tr>
<td>4.1.2.2.1 Radiolytic Time to LFL</td>
<td>28</td>
</tr>
<tr>
<td>4.1.2.2.2 Spontaneous Time to LFL</td>
<td>35</td>
</tr>
<tr>
<td>4.1.2.3 Waste Tank Flammability Classification Determination</td>
<td>40</td>
</tr>
<tr>
<td>4.1.2.4 Implementation Actions</td>
<td>43</td>
</tr>
<tr>
<td>4.1.3 Seismic Time to LFL</td>
<td>45</td>
</tr>
<tr>
<td>4.1.3.1 Seismic Time To LFL Methodology</td>
<td>45</td>
</tr>
<tr>
<td>4.1.3.2 Implementation Actions</td>
<td>53</td>
</tr>
<tr>
<td>4.2 Quiescent Time</td>
<td>54</td>
</tr>
<tr>
<td>4.2.1 Quiescent Time Program</td>
<td>54</td>
</tr>
<tr>
<td>4.2.1.1 Background</td>
<td>54</td>
</tr>
<tr>
<td>4.2.1.2 Quiescent Time Program Methodology</td>
<td>58</td>
</tr>
<tr>
<td>4.2.1.2.1 Seismic Release Protection</td>
<td>58</td>
</tr>
<tr>
<td>4.2.1.2.2 Spontaneous Liberation Protection</td>
<td>70</td>
</tr>
<tr>
<td>4.2.2 National Fire Protection Association Spontaneous Quiescent Time</td>
<td>73</td>
</tr>
<tr>
<td>4.2.3 Gas Release Mode Quiescent Time</td>
<td>79</td>
</tr>
<tr>
<td>4.2.4 Implementation Actions</td>
<td>85</td>
</tr>
<tr>
<td>4.3 Gas Release Program</td>
<td>87</td>
</tr>
<tr>
<td>4.3.1 Free Supernate Removal Activities</td>
<td>87</td>
</tr>
<tr>
<td>4.3.1.1 Free Supernate Removal Methodology</td>
<td>91</td>
</tr>
<tr>
<td>4.3.1.2 Implementation Actions</td>
<td>92</td>
</tr>
<tr>
<td>4.3.2 Sludge Agitation, Bulk Saltcake Dissolution, and Saltcake Interstitial Liquid Removal Activities</td>
<td>96</td>
</tr>
<tr>
<td>4.3.2.1 Initial Gas Release Evaluation For Sludge Agitation, Bulk Saltcake Dissolution, and Saltcake Interstitial Liquid Removal Activities</td>
<td>98</td>
</tr>
<tr>
<td>4.3.2.2 Evaluation Of Gas Release</td>
<td>101</td>
</tr>
</tbody>
</table>
4.3.2.2 Gas Release Methodology For Sludge Agitation, Bulk Saltcake Dissolution, and Interstitial Liquid Removal Activities
4.3.2.3 Gas Release Mode Sludge Agitation, Bulk Saltcake Dissolution, and Saltcake Interstitial Liquid Removal Activities
4.3.2.4 Implementation Actions
4.4 Tank Fill Limits Program
4.4.1 Implementation Actions
4.5 Waste Tanks in Acidic Chemical Cleaning Mode
4.5.1 Implementation Actions
4.6 Closure Mode
4.6.1 Implementation Actions
4.7 Oil Control Program
4.7.1 Implementation Actions
4.8 Interim Safety Basis Requirements
4.8.1 Implementation Actions

5.0 Output Documentation

6.0 Best Management Practice
6.1 Gas Release Mode
6.2 Time to LFL Methodology
6.3 Chemical Cleaning Program
6.4 Contingency Storage
6.5 Quiescent Time Program

7.0 Uncertainties And Conservatisms
7.1 Seismic Time to LFL Methodology
7.2 Quiescent Times Methodology

8.0 Deviations

9.0 References
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), Technical Safety Requirements (TSR) Administrative Controls, or other Interim Safety Basis (ISB) documents defined by WSRC-IM-94-10 Section 3.0 (e.g., Justification for Continued Operation (JCO), Potential Inadequacy in the Safety Analysis (PISA), and Evaluation of the Safety of the Situation (ESS)). 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),
- Gas Release Program (SAC),
- Tank Fill Limits Program (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. 35]

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

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.

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 reclassified as a radiological facility (e.g., Tanks 5, 6, 12, 16 thru 20) are excluded from the Flammability Control Program requirements of the DSA and TSR. This PDD does not address these tanks any further.

Waste Tanks in Closure Mode (see Section 3.0) 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.

Waste Tanks in Acidic Chemical Cleaning Mode (see Section 3.0) are excluded from the Flammability Control Program with the exception of tracking the waste tank flammability status
3.0 TERMINOLOGY AND INPUTS

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

- **LFL25C**: LFL of hydrogen gas at 25°C – 4.0% by volume [Ref. 1].

- **LFLT**: Temperature corrected LFL for hydrogen.

- **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.

- **LFLOC**: Temperature and organic corrected LFL for hydrogen – Hydrogen concentration at LFL, including contribution from trace organics for all waste tanks other than Tank 50. For Tank 50, LFLOC represents the hydrogen concentration at CLFL, including the contributions from both trace organics and Isopar® L (i.e. LFLOC = 43.8% of the LFL for hydrogen at 43°C [Ref. 24]).

- **[NOeff]**: Sum of nitrate concentration and one-half nitrite concentration.

- **Organics**: For the purpose of flammability calculations, organics is used to describe any flammable vapor other than hydrogen that may contribute to the LFL (CLFL for Tank 50) [Ref. 1].

- **Isopar® L**: An organic solvent used in the treatment of radioactive waste in the Modular Caustic Side Solvent Extraction Unit (MCU) and may be present in Tank 50 due to potential carryover from MCU transfers. Isopar® L is an isoparaffin diluent which is a mixture of branched chain hydrocarbons, designated Isopar® L by the vendor. Although the solvent used in the MCU contains other organics, Isopar® L is the only MCU organic of analytical concern on flammable vapor generation and energy contribution to an explosion. The masses and vapor pressures of the other MCU solvent organic components are small enough to discount [Ref. 1].

- **Sludge**: Insoluble metal oxide/hydroxide compounds.

- **Supernate**: An aqueous solution containing dissolved sodium salts.

- **Saltcake**: A solids phase of dissolved sodium salts as a result of evaporation process.
Hydrogen: Hydrogen (H₂) is the primary flammable gas of concern in the CSTF. The primary source of hydrogen is the radiolytic decomposition of water except during Acidic Chemical Cleaning of Type I/II Waste Tanks where hydrogen generation from corrosion of carbon steel is an additional source.

Dissolved hydrogen: Hydrogen gas that is retained in the supernate [Ref. 1].

Trapped hydrogen gas: Hydrogen gas that is retained in sludge or saltcake [Ref. 1].

Saltcake or Sludge Soundings: Saltcake/slime soundings, also known as steel tape saltcake/sludge soundings, consist of placing a manual tape with a metal wafer (or spike) at one end through the tank riser to measure the saltcake/sludge level. As the metal wafer (or spike) touches the saltcake/sludge, an average from multiple readings is taken, and the saltcake/sludge level is determined [Ref. 1].

Turbidity Meters: Turbidity meters are portable instruments that may be used to determine the suspended sludge level via clarified supernate in the waste tanks. A turbidity meter consists of a battery, an ohmmeter, a photoresistor, and a light source. The turbidity meter measures sludge level by using light resistance to determine the amount of suspended solids in the solution. Sludge has a larger amount of suspended solids than supernate, so as the meter passes sludge/supernate interface, the amount of light that passes through the solution will decrease. The photoresistor detects the amount of light passing through a solution and provides an output that is measured on the ohmmeter [Ref. 1].

Supernate Coverage: A layer of liquid (i.e., free supernate) which covers the bulk saltcake layer in a waste tank. This layer can range in depth from many feet of liquid to as little as an inch of liquid covering the saltcake, so long as only small saltcake peaks (height and base measures in inches, not feet) and salt on cooling coils are visible above the liquid surface. These small saltcake volumes above the liquid layer are acceptable because: 1) they release an insignificant volume of hydrogen as the interstitial liquid drains from the exposed saltcake and 2) they would release an insignificant volume of hydrogen if dissolved by an influent liquid [Ref. 41].

Concentrated Supernate: Supernate which has an average bulk concentration greater than or equal to 9.6M Na OR has an average bulk density of greater than or equal to 1.45 g/mL. The saturation limits are indicative of general chemical tendencies, and not finite thresholds above which abrupt changes are expected. Thus, use of nominal values is acceptable and does not need to include analytical uncertainty [Ref. 1].

Dilute Supernate: Any supernate which does NOT meet the above criteria for Concentrated Supernate [Ref. 1].

Mixing Eductor: Mixing eductors (e.g., Low Volume Mixing Jets (LVMJs)) are submerged in the tank liquid near the saltcake layer. Mixing eductors are designed to promote saltcake dissolution via mixing. This is accomplished by discharging the water added through a
nozzle, entraining the liquid above the waste tank bulk saltcake layer through an eductor assembly at a ratio of 4 gallons of the waste tank liquid to 1 gallon of water added [Ref. 41].

- **Dissolution Water Skid System:** The in-tank components (e.g., eductors, piping) of the system are inserted through the tank risers. These components extend near the saltcake layer and provide uniform mixing of the free liquid during water addition. System components (e.g., water skid, supply tanks) are arranged to the side of the tank top depending on the available space near the location of the risers used for eductor insertion. The system uses well water to feed the supply tanks.

- **Waste Tank Mixing Devices:** The term “waste tank mixing devices” is used to describe any of the following: slurry pumps (any type), CSMPs, SBPs, or SMPs. The waste tank mixing devices are used to agitate the sludge. They may also be used to mix liquid within a waste tank to perform saltcake dissolution.

- **Bulk Saltcake Layer:** When supernate is present in a waste tank above saltcake, the bulk saltcake layer is the saltcake level in the tank as determined by measurement or engineering evaluation. When supernate coverage is being removed from a waste tank containing saltcake, the bulk saltcake layer is the level within a waste tank where supernate coverage is at its minimum; further liquid removal will uncover sufficient saltcake requiring consideration as interstitial liquid removal (e.g., uncovered salt peaks’ height and base measurement transitions from inches to feet). **Saltcake mounds located within a 20 ft radius from the center of the evaporator concentrate receipt riser in Tank 30, Tank 37, and Tank 38 are excluded from consideration as part of the bulk saltcake layer** [Ref. 1].

  Tanks 30, 37, and 38 are the only waste tanks that may be used as evaporator concentrate receipt tanks. Other waste tanks may be used to receive evaporator concentrate; however, they may not utilize the exclusion of saltcake mounds under evaporator concentrate receipt risers from consideration as part of the bulk saltcake layer.

- **Sludge Agitation:** A process of mixing sludge (excluding insignificant sludge agitation activities in Section 4.3.2) using waste tank mixing devices [Ref. 1].

- **Free Supernate Removal:** Free supernate removal is the process of removing liquid from above the solids layers (i.e., saltcake, sludge) in a waste tank. For activities involved with free supernate removal over saltcake (including pumping/jetting liquid from below the saltcake surface), the activity is considered free supernate removal provided the bulk saltcake layer has supernate coverage [Ref. 1].

- **Bulk Saltcake Dissolution:** Bulk saltcake dissolution is the process of dissolving saltcake (excluding insignificant bulk saltcake dissolution activities in Section 4.3.2) by adding liquid to a waste tank and/or mixing liquid within a waste tank (via waste tank mixing devices, mixing eductor, or waste tank recirculation transfer pumps associated with waste tank recirculation) [Ref. 1].
• Saltcake Interstitial Liquid Removal: Saltcake interstitial liquid removal is the process of removing interstitial liquid from bulk saltcake (excluding insignificant interstitial liquid removal activities in Section 4.3.2), with the liquid level in the waste tank at or below the bulk saltcake layers, by pumping/jetting liquid from below the saltcake surface. 

Bumping/jetting liquid from below the saltcake surface where the bulk saltcake layer has supernate coverage is not considered saltcake interstitial liquid removal [Ref. 1].

• Saltcake Well Mining: Saltcake well mining, considered as a bulk saltcake dissolution, is the process of dissolving saltcake, usually to allow insertion of equipment such as a pump/jet for saltcake interstitial liquid removal [Ref. 1].

• Waste Tanks in Gas Release Mode (GRM): Waste tanks are required to enter GRM prior to sludge agitation, bulk saltcake dissolution or saltcake interstitial liquid removal activities if the GRM evaluation shows that the release of hydrogen due to sludge agitation, bulk saltcake dissolution or saltcake interstitial liquid removal activities will cause the waste tank vapor space to exceed the Gas Release Criteria (see Section 4.3.2.1).

• Waste Tanks in Operation Mode: When in Operation Mode, liquid transfers in and out of the waste tanks are allowed. Sludge agitation, bulk saltcake dissolution, and saltcake interstitial liquid removal activities in the waste tanks are allowed provided the activities do not have the potential to cause the waste tank vapor space to exceed the Gas Release Criteria stated in Section 4.3.2.1. Chemical cleaning transfers are allowed into the waste tanks. Direct oxalic acid receipt to the waste tanks is prohibited. For more information, see Reference 6 Section 1.6.

• Waste Tanks in Acidic Chemical Cleaning Mode: Only Type I/II waste tanks are allowed to enter Acidic Chemical Cleaning Mode. Waste tanks in Acidic Chemical Cleaning Mode are allowed to store waste and operate chemical cleaning process provided:
  o Inhalation dose potential of waste is less than or equal to 3.98E+8 rem/gallon
  o Sludge remaining in the waste tank is less than or equal to 10,000 gallons
  For more information, see Reference 6 Section 1.6.

• Acidic Spray Washing: It is part of the chemical cleaning process to remove waste material from the tank walls and internal equipment and may be spray washed using oxalic acid, inhibited water or well water. Spray washing between acid sludge dissolution treatments can be conducted as needed [Ref. 1]. Acidic spray washing uses oxalic acid for spray washing activities.

• Waste Tanks in Non-Acidic Chemical Cleaning Mode: Only Type I/II waste tanks are allowed to enter Non-Acidic Chemical Cleaning Mode. Waste Tanks in Non-Acidic Chemical Cleaning Mode are allowed to store waste provided:
  o Inhalation dose potential of waste less than or equal to 3.98E+8 rem/gallon,
  o Sludge remaining in the waste tank less than or equal to 10,000 gallons,
  o pH of waste contents (e.g., waste from previous chemical cleaning operations has been neutralized) greater than or equal to 7.
  For more information, see Reference 6 Section 1.6.
Waste Tanks in Closure Mode: Only Type I, II and IV waste tanks are allowed to enter Closure Mode. Waste Tanks in Closure Mode are allowed to store waste provided:

- Inhalation dose potential of waste less than or equal to 1.0E+12 rem,
- Radiolytic hydrogen generation rate less than or equal to 0.5 ft³/hr evaluated at 25°C with a NO_{eff} equal to zero.

For more information, see Reference 6 Section 1.6.

Extended Sludge Processing (ESP) Sludge Slurry Waste Tank: A waste tank with a total radiolytic hydrogen generation greater than 19.6 ft³/hr and less than or equal to 65.3 ft³/hr. Only Waste Tanks 40 and 51 may be an ESP Sludge Slurry Waste Tank [Ref. 1].

Hydrogen Concentration Safety Analysis Value (SAV): The Flammability Control Program establishes the hydrogen concentration SAV for a given tank (excluding Very Slow Generation Tanks, Tank 50 [as no hydrogen monitoring is required], waste tanks in Acidic Chemical Cleaning Mode and waste tanks in Closure Mode), when the waste tank is in GRM, Operation Mode, and Non-Acidic Chemical Cleaning Mode, such that the minimum time to reach the LFL is maintained based on the vapor space volume protected by the waste tank HLLCP [Ref. 1]. The hydrogen concentration SAVs, not including instrument uncertainty and organic contributions, cannot be less than 25% LFL and cannot exceed 60% LFL for hydrogen. The hydrogen concentration SAVs 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 saltcake dissolution, interstitial liquid removal) [Ref. 1].

TSR Hydrogen Concentration LFL Limit: TSR hydrogen concentration LFL limit (measured) is established by the Flammability Control Program according to the hydrogen concentration SAV designation of a given tank (excluding Tank 50, Very Slow Generation Tanks, waste tanks in Acidic Chemical Cleaning Mode, and waste tanks in Closure Mode). The TSR hydrogen concentration LFL limit shall be based on an individual tank basis and shall consider any proposed activities having the potential to release trapped gas (e.g., sludge agitation, bulk saltcake dissolution, and interstitial liquid removal). To determine the TSR hydrogen concentration LFL limit, the designated SAV is reduced to account for potential organics and instrument uncertainty [Ref. 1]. The TSR hydrogen concentration LFL limit will be designated in the ERD (excluding waste tanks discussed above). 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 in the facility. References 3, 4, and 31 provide instrument uncertainty values for a range of various SAVs, which are employed to determine the TSR hydrogen concentration LFL limit (i.e., indicated hydrogen reading).

When the waste tanks are not in GRM, portable monitors [Refs. 5, 29, and 30] are used to measure the waste tank vapor space for comparison against the TSR hydrogen concentration LFL limits for Rapid Generation Tanks and Slow Generation Tanks while in Operation Mode or Non-Acidic Chemical Cleaning Mode, and waste tanks in Acidic Chemical Cleaning Mode. The instrument uncertainty value selected in the development of the TSR hydrogen concentration LFL 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 LFL limit. This permits any one of the three instruments to be used for manually monitoring hydrogen concentration per the TSRS.

For activities where entry into GRM is required (refer to Section 4.3.2.3), the TSR hydrogen concentration LFL limits, established by the Flammability Control Program, shall ensure the minimum time to LFL, defined by the tank classification, is maintained [Ref. 1].

- High Liquid Level Conductivity Probes (HLLCP): In order to detect high waste levels in the primary tank, conductivity probes, with an associated control room alarm, are installed in each waste tank, and suspended at, or below, the desired maximum fill level [Ref. 1].

- Time to LFL: The time it takes for the hydrogen in the waste tank vapor space to reach the LFLOC from an assumed initial hydrogen concentration.

- Radiolytic Time to LFL (excluding Tank 50): This is the time for the hydrogen concentration to go from SAV (nominally 25% the LFLT) to the LFLOC. The time to LFL is calculated based on the waste tank volume protected by the waste tank HLLCP setpoint (and Tank Fill Limits Program [see Section 4.4], flammable vapor contributions from trace organics, and radiolytic hydrogen generation, considering atmospheric breathing rate only.

- Radiolytic Time to LFL (Tank 50): This is the time for the hydrogen concentration to go from 3.8% of the LFLT to the LFLOC. The time to LFL is calculated based on the waste tank volume protected by the waste tank HLLCP setpoint (and Tank Fill Limits Program [see Section 4.4], flammable vapor contributions from radiolytic hydrogen generation, considering atmospheric breathing rate only.

- Spontaneous Time to LFL (excluding Tank 50): This is the time for the hydrogen concentration to go from 25% the LFLT to the LFLOC. The time to LFL is calculated based on the actual/projected waste tank level, flammable vapor contributions from trace organics, trapped gas release from slurried sludge, and radiolytic hydrogen generation, considering atmospheric breathing rate only.

- Spontaneous Time to LFL (Tank 50): This is the time for the hydrogen concentration to go from 3.8% of the LFLT to the LFLOC. The time to LFL is calculated based on the actual/projected waste tank level, flammable vapor contributions from trapped gas release from slurried sludge and radiolytic hydrogen generation, considering atmospheric breathing rate only.

- Rapid Generation Tanks: Rapid Generation Tanks are waste tanks that have the time to reach the LFLOC greater than or equal to 7 days and less than 28 days following a loss of ventilation.

- Slow Generation Tanks: Slow Generation Tanks are waste tanks that have the time to reach the LFLOC greater than or equal to 28 days following a loss of ventilation.
• **Very Slow Generation Tanks**: Very Slow Generation Tanks are waste tanks that never reach LFL\textsubscript{OC}.

• **Seismic Time to LFL**: For Rapid and Slow Generation Tanks, it is the time it takes for the hydrogen concentration to go from 2.5\% of the LFL\textsubscript{T} (3.8\% of the LFL\textsubscript{T} for Tank 50) or radiolytic hydrogen equilibrium concentration, accounting for minimum ventilation flow, whichever is higher, to the LFL\textsubscript{OC} following a seismic event. For Very Slow Generation Tanks, it is the time it takes for the hydrogen concentration to go from the radiolytic hydrogen equilibrium concentration, accounting for atmospheric breathing, to the LFL\textsubscript{OC} following a seismic event [Ref. 1]. Seismic time to LFL is calculated based on the actual/projected waste tank level, flammable vapor contributions from trace organics, trapped gas release from solids (e.g., saltcake, settled sludge, slurried sludge), and radiolytic hydrogen generation.

• **Priority 1 Tanks**: Waste tanks that can reach 100\% of the LFL\textsubscript{OC} in less than 24 hours assuming no ventilation and including the effects of post-seismic trapped gas release.

• **Priority 2 Tanks**: Waste tanks that can reach 100\% of the LFL\textsubscript{OC} in greater than or equal to 24 hours and less than 7 days assuming no ventilation and including the effects of post-seismic trapped gas release, and waste tanks in the Acidic Chemical Cleaning Mode.

• **Quiescent Time**: It is the allowable time between waste tank mixing device operations such that the hydrogen released from the applicable settled sludge and/or slurried sludge does not cause the waste tank vapor space to exceed the applicable Quiescent Time criteria.

• **t\textsubscript{seismic}**: Seismic Quiescent Time – The Seismic Quiescent Time protects the waste tank vapor space from reaching LFL\textsubscript{OC} in less than 7 days post-seismic event (due to trapped gas released from settled sludge and slurried sludge, and subsequent radiolytic hydrogen production) [Ref. 1].

• **t\textsubscript{spontaneous}**: Spontaneous Quiescent Time - This quiescent time protects the waste tank flammability classification during a spontaneous release event [Ref. 1].

• **t\textsubscript{NFPA}**: National Fire Protection Association (NFPA) Spontaneous Quiescent Time – The NFPA Quiescent Time protects the waste tank vapor space from reaching 60\% of LFL\textsubscript{T} due to spontaneous release of trapped hydrogen gas from slurried sludge.

• **t\textsubscript{GRM}**: GRM Quiescent Time – The GRM Quiescent Time protects the waste tank vapor space from exceeding the GRM criteria.

• **Q\textsubscript{H2}**: Temperature corrected hydrogen generation rate – Volumetric flow rate of hydrogen generated from the radiolytic decomposition of water.

• **H\textsubscript{mix}**: Fraction of hydrogen in the gas trapped in saltcake, settled sludge or slurried sludge.
• \( Q_{\text{ATM}} \): Atmospheric breathing rate – Volumetric flow rate of air breathing through the opening size of a waste tank (e.g., riser plugs, penetrations). \( Q_{\text{ATM}} \) is calculated using the waste tank vapor space volume protected by the HLLCP setpoint.

• \( Q'_{\text{ATM}} \): Atmospheric breathing rate – Volumetric flow rate of air breathing through the opening size of a waste tank (e.g., riser plugs, penetrations). \( Q'_{\text{ATM}} \) is calculated using the waste tank vapor space volume based on the actual/projected waste tank level.

• \( V_{V} \): Waste tank vapor space volume – Vapor space volume protected by HLLCP setpoint.

• \( V'_{V} \): Waste tank vapor space volume – Vapor space volume calculated based on the actual/projected waste tank level.

• \( H_{\text{eq}} \): Hydrogen concentration at equilibrium conditions with hydrogen generated from radiolytic decomposition of water, considering atmospheric breathing, calculated using the waste tank vapor space volume protected by the HLLCP setpoint.

• \( H_{\text{eq}}(\text{Rapid/Slow}) \): Vapor space hydrogen concentration at equilibrium conditions with hydrogen generation from radiolytic decomposition of water for Rapid and Slow Generation Tanks. \( H_{\text{eq}}(\text{Rapid/Slow}) \) is calculated accounting for DSA purge ventilation flow (e.g., 72 \( \text{ft}^3/\text{min} \) for Rapid Generation Tanks or 45 \( \text{ft}^3/\text{min} \) for Slow Generation Tanks).

• \( H'_{\text{eq}} \): Vapor space hydrogen concentration at equilibrium conditions with hydrogen generated from radiolytic decomposition of water. \( H'_{\text{eq}} \) is calculated using the actual waste tank vapor space volume, accounting for atmospheric breathing.

• \( C \): Pressure correction factor – An expansion factor that accounts for the effect of pressure on trapped bubble gas release.

• \( P_{\text{avg}} \): Hydrostatic head pressure.

• \( F_{R} \): Volume fraction of trapped gas released from solids layer (e.g., saltcake, settled sludge, slurried sludge).

• \( G_{S} \): Volume fraction of trapped bubble gas in solids layer (e.g., saltcake, settled sludge, slurried sludge).

• \( T_{G} \): Concentration of trapped hydrogen gas released from solids layer (e.g., saltcake, settled sludge, slurried sludge).

• \( T_{GSS} \): Concentration of trapped hydrogen released from slurried sludge.
- **VT**: Total tank vapor space volume (empty tank).

- **MMW**: Missing waste volume to account for maximum volume associated with a Transfer Error event.

- **IU**: Instrument uncertainty attributed to the HLLCP.

- **y₀**: Initial hydrogen concentration in the waste tank vapor space at temperature T.

- **y₀(25°C)**: Initial hydrogen concentration in the waste tank vapor space at 25°C.

- **y₀(seismic)**: Initial hydrogen concentration in the waste tank vapor space following a seismic event.

- **Vₓ solids**: Volume of solids layer (e.g., saltcake, slurried sludge or settled sludge) in the waste tank.

- **Vₓ solids pump**: Volume of solids layers below the pump/jet suction.

- **HR**: Percentage of hydrogen generated that is retained in the slurried sludge.

- **Lₓ HLLCP**: Level of HLLCP setpoint.

- **Lₓ tank**: Level of waste (actual or projected).

- **ΔVₓ H₂**: Volume of trapped hydrogen gas released per inch of free supernate removed.

- **Ff**: Nominal waste tank fill factor - The nominal waste tank fill factors (i.e., 2,710 gal/in for Type I waste tanks; 3,500 gal/in for Type II waste tanks; 3,510 gal/in for Type III/IIIA waste tanks; 3,540 gal/in for Type IV waste tanks) may be used to calculate the waste volumes to support implementation of DSA Administrative Controls (e.g., Flammability Control Program) [Ref. 1]. For more detailed values of waste tank volumes as a function of waste tank fill height, see Reference 41.

- 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. 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 temperature limit of 75°C shall be used for the flammability calculations [Ref. 33]. 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 flammability supernate temperature limits are applied to these tanks for flammability calculations. For Tank 50, the bulk supernate temperature limit of 43°C is to be used for the flammability calculations [Refs. 1, 24].

• Unless otherwise noted, dissolved hydrogen contributions are not considered because of the following [Ref. 1]:
  o Typical of waste tanks, small temperature increases correspond to insignificant amounts of dissolved hydrogen released.
  o Waste agitation from seismic motion will release insignificant, if any, quantities of dissolved hydrogen.
  o Dissolved hydrogen release due to mixer operation is not a prompt release.
  o The minimum ventilation flow rates required for Rapid and Slow Generation Tanks (i.e., 45 scfm and 72 scfm) account for dissolved hydrogen release from steam jetted transfers (excluding Tank 50, Type I/II Chemical Cleaning Waste Tank, and Tanks 40 and 51 when classified as ESP Sludge Slurry Waste Tanks).

  o Continuous purge by the waste tank ventilation system (minimum flow rate of 45 scfm) on Very Slow Generation Tanks (excluding Tank 50, Type I/II Chemical Cleaning Waste Tank, and Tanks 40 and 51 when classified as ESP Sludge Slurry Waste Tanks) is sufficient to account for dissolved hydrogen release when receiving steam jetted transfers.

• 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. 24] 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:

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

  o 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 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 4.7. [TSR AC 5.8.2.45]

The contribution from organics for waste tanks is included in the temperature and organic-corrected LFL (LFLOC). 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 is updated. Such updates capture the Flammability Control Program requirements through the ERD linking procedure [Ref. 55].

- A waste tank may contain both types of sludge layers, settled sludge and slurried sludge; however, a slurried sludge layer cannot exist beneath a settled sludge layer. Each sludge type is defined below [Ref. 1]:
  - Settled sludge: sludge meeting the following criteria shall be considered settled sludge:
    - Sludge that has not been mixed (see discussion below) for greater than or equal to 15 years
    - Sludge receipts into a waste tank received greater than or equal to 15 years (see discussion below)
  - Slurried sludge: sludge meeting the following criteria shall be considered slurried sludge:
    - Sludge that has been mixed (see discussion below) less than 15 years ago.
    - Sludge receipts into a waste tank received less than 15 years ago, except as discussed below.

Sludge received during DWPF recycle transfers, Canyon transfers or transfers from settled sludge waste tanks with the transfer device suction at or above the sludge layer can be considered to be settled sludge immediately (due to limited quantities), provided both of the following criteria apply:

- No waste tank mixing device operation (which created slurried sludge) occurred in the receipt tank in the 15 years prior to the date the sludge was received, or after the date of receipt.
- No slurried sludge was received into the waste tank within the past 15 years.

Operating a mixing device in a waste tank is considered to create slurried sludge from any settled sludge within the zone of influence of the mixing device, after the mixing device has operated for a cumulative total of 10 days with turntable rotating and indication of sludge mixing. Additionally, sludge that has been within the zone of influence of an operating waste tank mixing device (i.e., based on tank cross sectional area and sludge disturbance depth as defined in Section 4.3.2.2 Variable $V_{\text{solids}}$ Calculation for settled sludge agitation) will be considered slurried sludge, irrespective of requirements previously stated, if any mixing device in the waste tank is lowered. Sludge that does not fully meet one of these criteria may continue to be considered settled sludge. If any waste tank mixing device is lowered prior to 10-day mixing operation, the affected sludge layer within the zone of influence of the waste tank mixing device (prior to lowering) shall be considered slurried sludge [Ref. 1].

For waste tanks that are undergoing initial sludge agitation, multiple waste tank mixing devices will typically be used to ensure a sludge layer within a waste tank (or entire
sludge inventory) has been slurried (and thus be considered slurried sludge). However, a process upset under certain waste tank conditions (e.g., failure of slurry pumps / CSMPs during slurrying with a remaining single slurry pump / CSMP operated for cumulative total of 10 days), could result in only a portion of the sludge layer to become slurried sludge. Engineering evaluation can be performed to estimate the amount of slurried sludge created by this process upset [Ref. 1].

For waste transfers that do not meet the Sludge Carryover Criteria defined in the Sludge Carryover Minimization (SCOM) Program, a methodology has been developed to estimate the volume of sludge entrained during the transfers [Ref. 9]. Alternatively, an engineering evaluation can be performed to determine the sludge transfer volume. The type of sludge transferred (i.e., settled sludge vs. slurried sludge) is determined by the criteria previously defined.

Supernate transfers (transfers that meet the Sludge Carryover Minimization Program) from one waste tank into another waste tank do not contain sludge for the purpose of determining slurried sludge receipts.

- Saltcake, settled sludge, slurried sludge, and liquid level can be determined by measurement, visual inspection, or by engineering evaluation. Engineering shall identify the selected methodology. Soundings provide direct measurement using a tape with a wafer (for settled sludge) or a spike (for saltcake) by comparison to the known elevation of the riser being used. Turbidity meters provide direct measurement of the slurried sludge level using the scattered light meter by comparison to the known elevation of the riser being used. Visual inspections may be by direct observation or via camera by comparison to the known waste tank component elevations. Use of an engineering evaluation for saltcake / settled sludge / slurried sludge level determination shall address applicable parameters described below. Tank liquid level can be measured by reel tape, radar, etc. These values (saltcake, settled sludge, slurried sludge, and liquid level) are used to determine waste tank characteristics for calculation of hydrogen generation rate and amount of trapped gas retained/released.

When selected, engineering evaluations for saltcake / settled sludge / slurried sludge level determination shall address the following attributes, as applicable, for the specific waste tank:

- Process knowledge (e.g., transfer history, operational conditions)
- Historical saltcake / settled sludge / slurried sludge level determinations
- Waste tank sample results
- Uniformity of the solids level (saltcake / settled sludge / slurried sludge), as described below

It is recognized that the solids layer (i.e., saltcake, settled sludge, slurried sludge) level within a waste tank may not be at a uniform level across the tank (e.g., layer slopes downward from one side of the tank). The engineering evaluation shall consider this in determining the solids layer volume from the level determination. Although the highest measured or visually determined value may be used to define the level of the entire layer, this may produce an
unreasonably conservative value for use in flammability evaluations. Known parameters of the layer (e.g., approximate slope of a settled sludge layer, mapping) may be utilized to estimate a more reasonable actual volume of the layer.

3.1 IMPLEMENTATION ACTIONS

1. Supernate temperature limits imposed by the Corrosion Control Program [Ref. 8] may be used in flammability calculations, with the following exceptions:
   - Alternative temperature limits may be set by engineering evaluation
   - Inactive, dry tanks with no specified supernate temperature limit shall use 75°C for flammability calculations [Ref. 33]
   - Tank 50 shall use 43°C for flammability calculations [Ref. 24]
   - 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 CLFL due to trace organics [Ref. 24].

3. Solids (e.g., saltcake, settled sludge, slurried sludge) volume/height shall be calculated based on measurements obtained using salt/sludge soundings or turbidity meters (for sludge), or determined per engineering evaluation and shall be tracked in WCS [Ref. 11], as applicable [Ref. 1].

4. Prior to a sludge slurry transfer, an engineering evaluation shall be performed to estimate the volume of settled sludge/slurried sludge entrained during the transfer. The methodology to estimate the volume of settled sludge/slurried sludge transferred is provided in the SCOM Program PDD [Ref. 9]. As an alternative to using this methodology, an engineering evaluation may be performed by using the following attributes, as applicable [Ref. 1]:
   - Engineering principles (e.g., fluid flow mechanics)
   - Engineering modeling (e.g., Computational Fluid Dynamics)
   - Equipment characteristics (e.g., pump curves, suction orientation)
   - Process knowledge (e.g., weight percent solids from sample at a specific level)

5. After completion of a sludge slurry transfer, a re-baseline of the waste tank solids layers (e.g., settled sludge, slurried sludge, saltcake) may be performed. The resulting levels of settled sludge and slurried sludge may be input into WCS [Ref. 11] to provide an updated waste tank flammability status [Ref. 1].

6. The date slurried sludge is received in a waste tank or the date settled sludge becomes slurried sludge shall be tracked in WCS [Ref. 11].
4.0 PROGRAM DESCRIPTION

Section 4.8 lists ISB requirements other than those in the DSA and TSR. The ISB requirements supersede the requirements of this PDD for the affected sections.

4.1 FLAMMABILITY CONTROL PROGRAM

4.1.1 BACKGROUND

The primary flammable vapor of concern in the CSTF is hydrogen. The primary source of hydrogen is the radiolytic decomposition of water except during Chemical Cleaning of Type I/II Waste Tanks where hydrogen generation from corrosion of carbon steel is an additional source. Hydrogen can be released directly into the vapor space or can be retained in the waste. The retained hydrogen is either captured in the supernate (i.e., dissolved hydrogen) or in the saltcake/sludge (i.e., trapped hydrogen). The dissolved hydrogen is continuously released from the supernate, with the rate being dependent on the supernate characteristics (e.g., temperature, chemistry). The dissolved hydrogen release from the supernate due to supernate agitation, mixer operation, and seismic motion is not considered a significant independent hydrogen source and therefore is not credible in the absence of ventilation (see Section 3.0). Trapped hydrogen gas is assumed to be released from sludge when the sludge is agitated (e.g., seismic event, waste tank mixing device operation), the static head pressure on the sludge is reduced (e.g., free supernate removal), or the spontaneous liberation of gas bubbles from the slurried sludge layer occurs. Trapped hydrogen gas is assumed to be released from saltcake during saltcake dissolution, during seismically initiated agitation (due to mobilization from liquid sloshing), during saltcake interstitial liquid removal, or from the reduction in static pressure (e.g., free supernate removal). The trapped hydrogen gas release rates are dependent on the characteristics of the saltcake/sludge and the cause of the release [Ref. 1]. Hydrogen is naturally buoyant in air and diffuses readily; therefore, hydrogen released to vapor spaces from radiolytic decomposition and corrosion as discussed above is assumed to be well mixed (i.e., no hydrogen layering) and only bulk hydrogen concentrations are considered.

The CSTF Flammability Control Program applies to all waste tanks (except as described in Section 2.0) due to the presence of hydrogen and potentially flammable organic vapors. Waste tank flammability classifications and waste tanks that can reach 100% of the LFL in less than 7 days assuming no ventilation and including the effects of post seismic trapped gas release 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 Flammability Control Program does not apply to loss of ventilation for waste tanks in Acidic Chemical Cleaning Mode, with the exception of tracking the flammability status and 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 and will require minimum purge flow to protect the initial hydrogen concentration of 25% of the LFL in the tank vapor space [Ref. 34]. 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.
Acidic Chemical Cleaning Tanks shall be included in the number of tanks that can reach the LFL in less than 7 days following a seismic event.

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 4.6. Due to the low waste volume, there is negligible impact to time to LFL for trapped gas release.

The Flammability Control Program is established to protect the assumed time to LFL (CLFL for Tank 50) in individual waste tanks upon loss of ventilation and minimizes the number of tanks that can become flammable in 24 hours or 7 days assuming no ventilation and including the effects of post-seismic trapped gas release. The program shall include the following attributes [Ref. 6]:

- 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 Tanks, Slow Generation Tanks, Very Slow Generation Tanks, Chemical Cleaning Tanks). Document the waste tank flammability classification for each waste tank in the ERD (N-ESR-G-00001). [TSR SAC 5.8.2.27.a]

- Determine the waste tank hydrogen concentration SAV and hydrogen concentration LFL limit, excluding Tank 50, Very Slow Generation Tanks, and waste tanks in Acidic Chemical Cleaning Mode. The hydrogen concentration LFL limit shall be based on the hydrogen concentration SAV and shall account for potential organics and instrument uncertainties. Document the waste tank hydrogen concentration LFL limit for each waste storage tank in the ERD (N-ESR-G-00001). [TSR SAC 5.8.2.27.b]

- Ensure that it takes a minimum of 7 days upon loss of waste tank forced ventilation (based on the methodology for waste tank flammability classification) for the tank bulk vapor space to reach 100% of the LFL (CLFL for Tank 50), excluding Very Slow Generation Tanks, and waste tanks in Acidic Chemical Cleaning Mode. [TSR SAC 5.8.2.27.c].

- 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. Document the waste tank prioritization results in the ERD (N-ESR-G-00001). [TSR SAC 5.8.2.27.d]

- Determine, track, and ensure that only 14 waste tanks can reach 100% of the LFL in less than 7 days including [TSR SAC 5.8.2.27.e]:
  - Effects of post-seismic trapped gas release, assuming no ventilation
  - Number of waste tanks in Acidic Chemical Cleaning Mode

  Document the waste tank prioritization results in the ERD (N-ESR-G-00001) [Ref. 2].

Waste tank priorities are defined based on the time for the hydrogen concentration in the vapor space to reach 100% of the LFL assuming no ventilation and including the effects of post-seismic trapped gas release. Priority 1 refers to waste tanks that may become flammable
in less than 24 hours. Priority 2 refers to waste tanks that have greater than or equal to 24 hours but less than 7 days to become flammable. Waste tanks that are in Acidic Chemical Cleaning Mode are also classified as Priority 2 (as these waste tanks have an assumed time to LFL of three days).

- 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 7 days. The path forward is not required to be provided to DOE prior to initiating the transfer. [TSR A/C 5.8.2.27.f]

4.1.2 TIME TO LFL

4.1.2.1 WASTE TANK FLAMMABILITY CLASSIFICATION

The waste tank flammability classifications are designated according to the time it takes to reach 100% of the temperature and organic corrected LFL for hydrogen, \( \text{LFL}_{\text{OC}} \), following a loss of ventilation by the following criteria [Ref. 1]:

- Rapid Generation Tanks are waste tanks that have a time to reach the \( \text{LFL}_{\text{OC}} \) of less than 28 days following a loss of ventilation.
- Slow Generation Tanks are waste tanks (excluding Very Slow Generation Tanks) that have a time to reach the \( \text{LFL}_{\text{OC}} \) of greater than or equal to 28 days following a loss of ventilation.
- The time to LFL is determined as the lower of the radiolytic time to LFL or the spontaneous time to LFL.
  - Waste tanks excluding Tank 50
    - Radiolytic Time to LFL is the time it takes for the waste tank vapor space to go from the hydrogen concentration SAV (nominally 25% of the temperature corrected LFL \( \text{LFL}_{T} \)) to the \( \text{LFL}_{\text{OC}} \). The time to LFL is calculated based on the vapor space volume protected by the waste tank HLLCP setpoint (and Tank Fill Limits Program), flammable vapor contributions from trace organics and radiolytic hydrogen generation, considering atmospheric breathing rate only.
    - Spontaneous Time to LFL is the time it takes for the waste tank vapor space to go from 25% of the \( \text{LFL}_{T} \) to the \( \text{LFL}_{\text{OC}} \). The time to LFL is calculated based on the actual/projected waste contents and vapor space volume, flammable vapor contributions from trace organics, trapped gas release from slurried sludge, and radiolytic hydrogen generation, considering atmospheric breathing rate only.
  
  For Rapid and Slow Generation Tanks, the SAV is nominally set at 25% of the \( \text{LFL}_{T} \). For planned gas release activities, the SAV may be increased within a range of 25% to 60% to allow for a larger hydrogen release, but it will reduce the time to LFL upon loss of ventilation in the waste tank. The SAV must be set such that the minimum times to LFL for Rapid and Slow Generation Tanks are protected.
  - Tank 50
Radiolytic Time to LFL has been determined to go from 3.8% of the LFL$_T$ to the LFLOC. The tank time to LFL is calculated based on the vapor space volume protected by the waste tank HLLCP setpoint (and Tank Fill Limits Program), flammable vapor contribution from radiolytic hydrogen generation, considering atmospheric breathing rate only.

Spontaneous Time to LFL has been determined to go from 3.8% of the LFL$_T$ to the LFLOC. The time to LFL is calculated based on the actual/projected waste contents and vapor space volume, and flammable vapor contributions from trapped gas release from slurried sludge and radiolytic hydrogen generation, considering atmospheric breathing rate only.

For Tank 50, the purge flow is shown to be able to maintain the vapor space less than or equal to 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 in Tank 50 is 60% - 51.2% - 5% = 3.8% [Refs. 1, 24]. Therefore, a hydrogen concentration of 3.8% corresponds to a total vapor space flammable concentration of 60% of the CLFL.

- Very Slow Generation Tanks are waste tanks whose times to reach the LFLOC (i.e., radiolytic time to LFL and spontaneous time to LFL) are infinite and must meet both of the following criteria.
  - Radiolytic Time to LFL has been determined to never reach the LFLOC at equilibrium conditions. The tank classification is calculated based on the vapor space volume protected by the waste tank HLLCP setpoint (and Tank Fill Limits Program), and flammable vapor contribution from Isopar® L (Tank 50 only), trace organics, and radiolytic hydrogen generation, considering atmospheric breathing rate only.
  - Spontaneous Time to LFL has been determined to never reach the LFLOC at equilibrium conditions. The tank classification is calculated based on the actual/projected waste contents and vapor space volume, and flammable vapor contributions from Isopar® L (Tank 50 only), trace organics, trapped gas release from slurried sludge, and radiolytic hydrogen generation, considering atmospheric breathing rate only.

Waste tanks for which the time to LFL has the potential to fluctuate above and below one of the waste tank flammability classification criteria may remain classified at the more restrictive flammability classification. For example, waste tanks with the time to LFL of 28.5 days may remain classified as Rapid Generation Tanks.

4.1.2.2 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 Reference 1, Section 3.4.1.1.2, provides the Flammability
Control Program time to LFL equation which accounts for the effects of atmospheric breathing:

\[
\text{Time to LFL} = -\ln\left(\frac{LFL_{OC} - \frac{Q_{H2}}{Q_{H2} + Q_{ATM}}}{y_0 - \frac{Q_{H2}}{Q_{H2} + Q_{ATM}}}\right)\]

Eq. #1

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 (100% of the CLFL for Tank 50), hours
- **\(y_0\)** = Initial hydrogen concentration, including temperature correction, vol. frac.
- **\(LFL_{OC}\)** = Temperature and organic corrected hydrogen concentration at 100% LFL 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 (100% CLFL – 51.2% CLFL – 5% CLFL) or 43.8% of the hydrogen LFL at 43°C [Ref. 24], vol. frac.
- **\(Q_{H2}\)** = Temperature corrected hydrogen generation rate, ft\(^3\)/hr
- **\(Q_{ATM}\)** = Atmospheric breathing rate, ft\(^3\)/hr
- **\(V_V\)** = Vapor space volume, ft\(^3\)

Both the radiolytic time to LFL and the spontaneous time to LFL can be determined using Equation 1. Calculations of the variables listed in Equation 1 are provided in Section 4.1.2.2.1 for radiolytic time to LFL or Section 4.1.2.2.2 for spontaneous time to LFL.

The radiolytic and spontaneous times to LFL calculated using Equation 1 may return an error, due to attempting to calculate the natural log of a negative number, or return a negative time to LFL depending on the conditions of the indicated waste tank. The bullets below can be used to determine the waste tank times to LFL, if the waste tank conditions are met, prior to applying Equation 1 for time to LFL calculations.

- Radiolytic Time to LFL
For radiolytic time to LFL calculation, $\frac{Q_{H_2}}{Q_{H_2} + Q_{ATM}}$ is defined as $Heq$ (see Variable $Heq$ Calculation in Section 4.1.2.2.1). Substituting $Heq$ for $\frac{Q_{H_2}}{Q_{H_2} + Q_{ATM}}$ into Equation 1 yields

$$-\ln \left[ \frac{LFL_{OC} - H_{eq}}{y_0 - H_{eq}} \right]$$

Time to LFL = $\frac{Q_{H_2} + Q_{ATM}}{V_V}$

- $H_{eq} < LFL_{OC}$: the waste tank vapor space never becomes flammable. The waste tank radiolytic time to LFL is infinite and Equation 1 is not required.
- $H_{eq} > LFL_{OC}$ and $H_{eq} > y_0$: the waste tank time to LFL can be determined using Equation 1 and the methodology in Section 4.1.2.2.1.
- $H_{eq} > LFL_{OC}$ and $H_{eq} < y_0$: this condition never exists since $y_0 < LFL_{OC}$

**Spontaneous Time to LFL**

In the spontaneous time to LFL calculation, the waste tank vapor space is calculated based on the actual/projected waste tank level. $Q_{ATM}$ and $V_V$ in Equation 1 are replaced with $Q'_{ATM}$ and $V'_{V}$. The initial hydrogen concentration is defined as the summation of the assumed initial hydrogen concentration plus the trapped gas released from slurried sludge, which is $y_0 + TGSS$ and $\frac{Q_{H_2}}{Q_{H_2} + Q_{ATM}}$ is defined as $H'_{eq}$ (see Variable $y_0$ Calculation, Variable TGSS Calculation, and Variable $H'_{eq}$ Calculation in Section 4.1.2.2.2).

Equation 1 becomes the following equation after substituting $y_0 + TGSS$ for $y_0$, $H'_{eq}$ for $\frac{Q_{H_2}}{Q_{H_2} + Q_{ATM}}$ and $V'_{V}$ for $V_V$ into Equation 1.

$$-\ln \left[ \frac{LFL_{OC} - H'_{eq}}{y_0 + TGSS - H'_{eq}} \right]$$

Time to LFL = $\frac{Q_{H_2} + Q_{ATM}}{V'_V}$

- $H'_{eq} + TGSS < LFL_{OC}$, the waste tank vapor space never reaches flammable condition. The waste tank spontaneous time to LFL is infinite and Equation 1 is not required.
- $H'_{eq} < LFL_{OC}$ and $H'_{eq} < y_0 + TGSS$
  - If $y_0 + TGSS < LFL_{OC}$, the waste tank vapor space never reaches flammable condition. The waste tank spontaneous time to LFL is infinite and Equation 1 is not required.
  - If $y_0 + TGSS \geq LFL_{OC}$, the waste tank spontaneous time to LFL is immediate and Equation 1 is not required.
- $H'_{eq} > LFL_{OC}$ and $H'_{eq} > y_0 + TGSS$
If \( y_0 + TGSS < LFLOC \), the waste tank spontaneous time to LFL can be determined using Equation 1 and the methodology in Section 4.1.2.2.2.

If \( y_0 + TGSS \geq LFLOC \), the waste tank spontaneous time to LFL is immediate and Equation 1 is not required.

- \( H'_{eq} > LFLOC \) and \( H'_{eq} < y_0 + TGSS \)  
  Since \( y_0 + TGSS > H'_{eq} \) and \( H'_{eq} > LFLOC \), \( y_0 + TGSS > LFLOC \). The waste tank spontaneous time to LFL is immediate and Equation 1 is not required.

- \( H'_{eq} < LFLOC \) and \( H'_{eq} > y_0 + TGSS \)  
  Since \( y_0 + TGSS < H'_{eq} \) and \( H'_{eq} < LFLOC \), \( y_0 + TGSS < LFLOC \). The waste tank spontaneous time to LFL is infinite and Equation 1 is not required.

### 4.1.2.2.1 Radiolytic Time to LFL

The waste tank radiolytic time to LFL is calculated using Equation 1 in Section 4.1.2.2. Calculations of variables \( y_0 \), \( LFLOC \), \( QH2 \), \( QATM \) and \( Vv \) in Equation 1 are provided in this section. All variables/equations provided in this section are only applicable to this section unless otherwise noted.

**VARIABLE \( y_0 \) CALCULATION – Radiolytic Time To LFL**

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, including temperature correction, vol. frac.
- \( y_{0(25C)} \) = Initial hydrogen concentration at 25°C, vol. frac.
  
Waste tanks excluding Tank 50: nominally 25% but can go up 60% of the LFL for hydrogen at 25°C (LFL for hydrogen at 25°C is 0.04 vol. frac.)

Tank 50: 3.8% of the LFL for hydrogen at 25°C

- \( A \) = Empirical coefficient (Zabetakis attenuation factor), (i.e., 0.0011 per Ref. 1), °C⁻¹

- \( T \) = Temperature at which LFL is to be evaluated in °C (43°C for Tank 50) (see Variable T Calculation)
VARIABLE T CALCULATION

The vapor space temperature is assumed to be the same as the supernate phase. Vapor space temperatures 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]. For Tank 50, the bulk supernate temperature limit of 43°C is to be used for flammability calculations [Refs. 1, 24].

As an alternative to using supernate temperature limits, an engineering evaluation may be performed to set maximum temperature limits. This temperature cannot exceed 100°C [Ref. 1]. These temperature limits are used to correct the flammability calculations to account for temperature variations.

VARIABLE LFLOC CALCULATION

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.

- **Waste tanks excluding Tank 50:** Using the same basis as the y0 calculation (Equation 2), the LFL, corrected for organics and temperature, is determined by using the Burgess – Wheeler correlation and subtracting the organic contribution, as follows:

\[
\text{Eq. #3} \quad \text{LFL}_{OC} = \text{LFL}_{25C} \cdot \left[1 - A \cdot (T - 25)\right] - \text{OC}
\]

Where:

\[
\text{LFL}_{OC} = \text{LFL for hydrogen corrected for organic contribution and temperature, vol. frac.} \\
\text{LFL}_{25C} = \text{LFL for hydrogen at 25°C, (i.e., 0.04-volume fraction), vol. frac.} \\
\text{OC} = \text{The organic contribution equivalent hydrogen concentration (i.e., 5% of LFL}_{25C} (0.002-volume fraction)), vol. frac.} \\
A = \text{Empirical coefficient (Zabetakis attenuation factor), (i.e., 0.0011 per Ref. 1), }^\circ\text{C}^{-1} \\
T = \text{Temperature at which LFL is to be evaluated in }^\circ\text{C (see Variable T Calculation)}
\]

- **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, LFLOC for Tank 50 at 100% of the CLFL is calculated to be 43.8% of the CLFL at 43°C or 43.8% of the LFL for hydrogen at 43°C [Ref. 24].
Eq. #4  \[ \text{LFL}_{OC} = \frac{43.8}{100} \cdot \text{LFL}_{25C} \cdot [1 - A \cdot (43 - 25)] \]

Where:

\[
\begin{align*}
\text{LFL}_{OC} & = \text{LFL for hydrogen corrected for organic contribution and temperature, vol. frac.} \\
\text{LFL}_{25C} & = \text{LFL for hydrogen at } 25^\circ \text{C, (i.e., 0.04-volume fraction), vol. frac.} \\
A & = \text{Empirical coefficient (Zabetakis attenuation factor), (i.e., 0.0011 per Ref. 1), } ^{\circ}\text{C}^{-1}
\end{align*}
\]

**VARIABLE \( q_{H2} \) CALCULATION**

The methodology used to calculate the total hydrogen generation rate \( q_{H2} \) 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 (excluding acidic spray washing activities since the acid does not remain in contact with vertical tank surfaces for longer than 48 hours). The radiolytic hydrogen generation rate equations are based on experimental data that has had margin added (10%) [Ref. 50]. 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. #5  \[ q_{H2} = q_{RAD} + q_{CORR} \]

Where:

\[
\begin{align*}
q_{H2} & = \text{Total generation rate of hydrogen, ft}^3/\text{hr} \\
q_{RAD} & = \text{Radiolytic hydrogen generation rate, ft}^3/\text{hr} \\
q_{CORR} & = \text{Corrosion induced hydrogen generation rate, ft}^3/\text{hr}
\end{align*}
\]

*Applicable to waste tanks in Acidic Chemical Cleaning Mode, where the bounding rate is: 4.3E-05 ft³ / min-ft² (Equation 11)

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

Eq. #6  \[ q_{RAD} = \frac{R_{\beta/\gamma} \cdot H_{\beta/\gamma} + R_a \cdot H_a}{10^6} \]

Where:

\[
\begin{align*}
q_{RAD} & = \text{Radiolytic hydrogen generation rate at } 25^\circ \text{C, ft}^3/\text{hr} \\
R_{\beta/\gamma} & = \text{Volume (ft}^3\) \text{ of hydrogen generated per MBTU (10}^6\text{ British Thermal Unit) of heat added from beta or gamma decay} \\
H_{\beta/\gamma} & = \text{Heat generated by beta and gamma decay, BTU/hr}
\end{align*}
\]
The values of $R_\alpha$ and $R_{\beta/\gamma}$ are dependent on the concentration of nitrate and nitrite in the waste and are given by Equations 7 and 8.

Eq. #7  \[
R_\alpha = 134.7 - 82.3 [\text{NO}_{\text{eff}}]^{1/3} - 13.6 [\text{NO}_{\text{eff}}]^{2/3} + 11.8 [\text{NO}_{\text{eff}}]
\]

Eq. #8  \[
R_{\beta/\gamma} = 48.36 - 52.78 [\text{NO}_{\text{eff}}]^{1/3} + 14.1 [\text{NO}_{\text{eff}}]^{2/3} + 0.572 [\text{NO}_{\text{eff}}]
\]

Where:

$R_\alpha$ = 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

$\text{NO}_{\text{eff}}$ = The nitrate concentration ([NO$_3^-$]) plus one-half the nitrite concentration ([NO$_2^-$]) \((\text{NO}_{\text{eff}}) = [\text{NO}_3^-] + \frac{1}{2}[\text{NO}_2^-]\), where concentrations are in units of mol/L.

The effective ion concentration ([NO$_{\text{eff}}$]) 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 $\text{NO}_{\text{eff}}$ 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 $\text{NO}_{\text{eff}}$ [Ref. 23].

Application of the Corrosion Control Program dip sample analysis for $\text{NO}_{\text{eff}}$ values applied to supernate (including interstitial in the 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 $\text{NO}_{\text{eff}}$ 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 [Ref. 8].

The $\text{NO}_{\text{eff}}$ used in dry salt tanks is based on the most recent sample results. As the evaporation process occurs in a salt tank, the supernate layer above the salt increases in salt concentration as
the liquid level recedes into the salt phase as interstitial liquid. Evaporation tends to increase [NO$_{eff}$] in the remaining liquid. Therefore, using the latest sample results is conservative.

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

Eq. #9 \[ H_a = \sum_i Q_i \cdot A_i \]

Eq. #10 \[ H_{\beta/\gamma} = \sum_j Q_j \cdot A_j \]

Where:

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

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. #11 \[ x_{\text{CORR}} = \text{Area Contacted} \cdot \text{Rate} \]

Where:

\begin{align*}
x_{\text{CORR}} &= \text{Corrosion induced hydrogen generation rate, ft}^3/\text{hr} \\
\text{Area Contacted} &= \text{Surface area in contact with acidic waste, ft}^2 \\
\text{Rate} &= \text{Corrosion induced hydrogen generation rate per area, ft}^3/\text{hr-ft}^2 (\text{Reference 1 Section 3.4.1.5.5 gives value in ft}^3/\text{min-ft}^2. \text{ Multiply by 60 min/hr to get in units of ft}^3/\text{hr-ft}^2.)
\end{align*}

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

Eq. #12 \[ x_{\text{H}_2} = x_{\text{RAD}} \]

Where:

\begin{align*}
x_{\text{H}_2} &= \text{Total generation rate of hydrogen at 25°C, ft}^3/\text{hr} \\
x_{\text{RAD}} &= \text{Radiolytic hydrogen generation rate at 25°C, ft}^3/\text{hr}
\end{align*}
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 ft³/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 ft³/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 ft³/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 2.8 ft³/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 ft³/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. #13

\[ Q_{H2} = x_{H2} \frac{(T + 273)}{(T_i + 273)} \]

Where:

- \( Q_{H2} \) = Temperature corrected hydrogen generation rate, ft³/hr
- \( x_{H2} \) = Total hydrogen generation rate at temperature \( T_i \), ft³/hr
- \( T \) = Temperature at which \( Q_{H2} \) is to be evaluated, °C (see Variable \( T \) Calculation)
- \( T_i \) = Initial temperature at standard pressure of 1 atm, °C (e.g., 25°C [Ref. 1])

Variable \( Q_{H2} \) Calculation is applicable in other sections as noted.
VARIABLE $Q_{ATM}$ CALCULATION - RADIOLYTIC TIME TO LFL

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 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:

$$Q_{ATM} = \left(\frac{\text{mean atm. fluctuation}}{1013}\right) \cdot \frac{V_v}{24}$$

Where:

- $Q_{ATM}$ = Atmospheric breathing rate, ft³/hr
- mean atm. fluctuation = Mean pressure fluctuation, 5 mbar/day [Ref. 41]
- $V_v$ = Vapor space volume protected by HLLCP setpoint, ft³, (see Variable $V_v$, Calculation)
- 24 = Conversion factor from days to hours
- 1013 = Standard atmospheric pressure, mbar

VARIABLE $V_v$ CALCULATION - RADIOLYTIC TIME TO LFL

The vapor space volume credited in calculating the radiolytic time to LFL following a loss of ventilation is the vapor space volume protected by the waste tank HLLCP setpoint, adjusted for instrument uncertainty and maximum missing waste. The following equation is the vapor space volume calculation, in cubic feet:

$$V_v = 0.13368 \left[V_T - (L_{HLLCP} + IU) \cdot F_f - \text{MMW}\right]$$

Where:

- $V_v$ = Vapor space volume, ft³
- $V_T$ = Total tank vapor space volume (empty tank), gallons
- 0.13368 = Conversion factor from gallons to ft³
- $L_{HLLCP}$ = HLLCP setpoint, inches
- $F_f$ = Nominal waste tank fill factor, gal/in, (see Section 3.0)
- MMW = Maximum missing waste, equal to 15,000 gallons, to account for maximum volume associated with a Transfer Error event, gallons. MMW will be equal to 0 if the waste tanks are in Non-Acidic Chemical Cleaning Mode
- IU = Uncertainty attributed to HLLCP, inches
**VARIABLE $H_{eq}$ CALCULATION - RADIOLYTIC TIME TO LFL**

The total hydrogen concentration at equilibrium conditions with hydrogen production from radiolytic decomposition, considering atmospheric breathing only, is used to determine whether the waste tank vapor space reaches a flammable condition at the steady state hydrogen concentration. The equilibrium hydrogen concentration for radiolytic time to LFL is represented in the following equation:

$$\begin{align*}
\text{Eq. #16} \quad H_{eq} &= \frac{Q_{H2}}{Q_{H2} + Q_{ATM}}
\end{align*}$$

Where:

- $H_{eq} = \text{Hydrogen concentration at equilibrium, vol. frac.}$
- $Q_{H2} = \text{Total hydrogen volumetric evolution rate, ft}^3/\text{hr} \text{ (see Variable } Q_{H2} \text{ Calculation)}$
- $Q_{ATM} = \text{Atmospheric breathing rate, ft}^3/\text{hr} \text{ (see Variable } Q_{ATM} \text{ Calculation)}$

$H_{eq}$ will be used to determine whether the waste tanks can be designated as Very Slow Generation Tanks.

**4.1.2.2.2 SPONTANEOUS TIME TO LFL**

The waste tank spontaneous time to LFL is calculated in the same manner as the radiolytic time to LFL with changes to the initial hydrogen concentration, the waste tank vapor space volume based on the actual/projected tank level, and the flammable vapor contributions. Equation 1 in Section 4.1.2.2 can be used to determine the spontaneous time to LFL. Calculations of variables $\text{LFL}_{OC}$ and $Q_{H2}$ in Equation 1 can be found in Section 4.1.2.2.1. This section presents the equations used to calculate variables $y_0$, $Q_{ATM}$ and $V_v$. Since $V_v$ is based on actual/projected waste tank level, $Q_{ATM}$ and $V_v$ in Equation 1 will be replaced with $Q'_{ATM}$ and $V'_{v}$. All variables/equations provided in this section are only applicable to this section unless otherwise noted.

**VARIABLE $y_0$ CALCULATION – SPONTANEOUS TIME TO LFL**

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

$$\begin{align*}
\text{Eq. #17} \quad y_0 &= y_{0(25C)} \cdot \left[1 - A \cdot (T - 25)\right] + TG_{ss}
\end{align*}$$

Where:

- $y_0 = \text{Initial hydrogen concentration, including temperature correction, and trapped gas release from slurried sludge, vol. frac.}$
- $y_{0(25C)} = \text{Initial hydrogen concentration at 25°C, vol. frac.}$
Waste tanks excluding Tank 50: 25% of the LFL for hydrogen at 25°C (LFL for hydrogen at 25°C is 0.04 vol. frac.)

Tank 50: 3.8% of the LFL for hydrogen at 25°C

\[ A = \text{Empirical coefficient (Zabetakis attenuation factor), (i.e., 0.0011 per Ref. 1), } ^\circ\text{C}^{-1} \]

\[ T = \text{Temperature at which LFL is to be evaluated in } ^\circ\text{C (43°C for Tank 50) (see Variable T Calculation in Section 4.1.2.2.1)} \]

\[ TG_{SS} = \text{Volume fraction of trapped hydrogen gas released from slurried sludge, vol. frac. (see Variable TG}_{SS} \text{ Calculation below)} \]

**VARIABLE TG\(_{SS}\) CALCULATION – SPONTANEOUS TIME TO LFL**

The vapor space hydrogen concentration due to trapped gas release from slurried sludge is determined as follows:

\[ TG_{SS} = \frac{V_{SS} \cdot G_{S} \cdot H_{mix} \cdot C \cdot F_{R}}{V'_{V}} \]

Where:

\[ TG_{SS} = \text{Volume fraction of hydrogen released from slurried sludge, vol. frac.} \]

\[ V_{SS} = \text{Volume of slurried sludge, gallons (see Variable } V_{SS} \text{ Calculation)} \]

\[ G_{S} = \text{Volume fraction of trapped bubble gas, vol. frac. (see Variable } G_{S} \text{ Calculation)} \]

\[ H_{mix} = \text{Volume fraction of hydrogen in trapped gas, vol. frac. (see Variable } H_{mix} \text{ Calculation)} \]

\[ C = \text{Pressure correction factor (see Variable } C \text{ Calculation)} \]

\[ F_{R} = \text{Volume fraction of trapped gas release (see Variable } F_{R} \text{ Calculation)} \]

\[ V'_{V} = \text{Vapor space volume using actual/projected waste tank level, gallons (see Variable } V'_{V} \text{ Calculation)} \]

**VARIABLE V\(_{SS}\) CALCULATION – SPONTANEOUS TIME TO LFL**

All the slurried sludge in the waste tank is considered to release hydrogen during a spontaneous liberation event and is used in determination of \( TG_{SS} \) [Ref. 1].

**VARIABLE G\(_{S}\) CALCULATION – SPONTANEOUS TIME TO LFL**

The maximum percentage of trapped bubble gas in slurried sludge is 20% by volume (0.20 volume fraction) [Ref. 1].

**VARIABLE H\(_{mix}\) CALCULATION**

In waste tanks with known chemistry and heat loads, equations below which relate empirical
data (i.e., nitrite and nitrate concentrations) to the radiolytic decay heat may be used to calculate the fraction of hydrogen in the trapped bubble gas up to a maximum of 75% [Refs. 1, 48]. Otherwise, the hydrogen percent in trapped gas is determined as follows:

- 75% in waste tanks that contain slurried sludge (0.75 volume fraction)
- 50% in other waste tanks (e.g. tanks containing saltcake or settled sludge) (0.50 volume fraction)

Eq. #19 \( \text{H}_{\text{Mix}} = \text{H}_{\text{NO}_3} \cdot F_{\text{NO}_3} \cdot G_{\text{NO}_3} + \text{H}_{\text{NO}_2} \cdot F_{\text{NO}_2} \cdot G_{\text{NO}_2} \)

Where:

- \( \text{H}_{\text{Mix}} \) = Hydrogen fraction in trapped gas (multiply by 100 to get in terms of percent)
- \( \text{H}_{\text{NO}_3} \) = Fraction of hydrogen in the gas produced by radiolysis of nitrate (see Equation 20)
- \( \text{H}_{\text{NO}_2} \) = Fraction of hydrogen in the gas produced by radiolysis of nitrite (see Equations 21, 22)
- \( F_{\text{NO}_3} \) = Fraction of nitrate in the supernate (see Equation 23)
- \( F_{\text{NO}_2} \) = Fraction of nitrite in the supernate (see Equation 24)
- \( G_{\text{NO}_3} \) = Hydrogen generation correction factor for \( \text{NO}_3 \) to account for nitrate/nitrite interaction in mixed solution (see Equation 25)
- \( G_{\text{NO}_2} \) = Hydrogen generation correction factor for \( \text{NO}_2 \) to account for nitrate/nitrite interaction in mixed solution (see Equation 26)

Eq. #20 \( \text{H}_{\text{NO}_3} = 0.0242[\text{NO}_3]^3 - 0.076[\text{NO}_3]^2 - 0.2101[\text{NO}_3] + 0.69 \), for \([\text{NO}_3] \geq 0 \text{M}\)

Eq. #21 \( \text{H}_{\text{NO}_2} = 1.0213[\text{NO}_2]^2 - 1.2235[\text{NO}_2] + 0.9821 \), for \([\text{NO}_2] < 1 \text{M}\)

Eq. #22 \( \text{H}_{\text{NO}_2} = 0.035[\text{NO}_2] + 0.74 \), for \([\text{NO}_2] \geq 1 \text{M}\)

Eq. #23 \( F_{\text{NO}_3} = [\text{NO}_3] / ([\text{NO}_3] + [\text{NO}_2]) \)

Eq. #24 \( F_{\text{NO}_2} = [\text{NO}_2] / ([\text{NO}_3] + [\text{NO}_2]) \)

Eq. #25 \( G_{\text{NO}_3} = g_{\text{Mix}} / g_{\text{NO}_3} \)

Eq. #26 \( G_{\text{NO}_2} = g_{\text{Mix}} / g_{\text{NO}_2} \)

Where:

- \([\text{NO}_3]\) = Nitrate concentration in supernate, mol/L
- \([\text{NO}_2]\) = Nitrite concentration in supernate, mol/L
- \(g_{\text{Mix}}\) = Hydrogen generation correction factor based on the concentration of \( \text{NO}_{\text{eff}} \) (see Equations 27 thru 30 with \([\text{NO}_{\text{eff}}]\) in place of \([\text{NO}_3]\))
- \(g_{\text{NO}_3}\) = Hydrogen generation correction factor based on the concentration of \( \text{NO}_3 \) (see Equations 27 thru 30)
\( g_{NO_2} \) = Hydrogen generation correction factor based on the concentration of NO\(_2\) (see Equations 27 thru 30 with 0.5*\([NO_2]\) in place of \([NO_3]\))

Eq. #27 \( g_{NO_3} = G_{\alpha NO_3} \cdot a_{hf} + G_{\beta/\gamma NO_3} \cdot (1-a_{hf}) \)

Eq. #28 \( G_{\alpha NO_3} = 1.3 - 0.79 \ [NO_3]^{1/3} - 0.13 \ [NO_3]^{2/3} + 0.11 \ [NO_3] \)

Eq. #29 \( G_{\beta/\gamma NO_3} = 0.466 - 0.51[NO_3]^{1/3} + 0.14[NO_3]^{2/3} + 0.0055[NO_3] \)

Eq. #30 \( a_{hf} = (H_{\alpha sludge} + H_{\alpha salt})/(H_{\beta/\gamma sludge} + H_{\alpha sludge} + H_{\beta/\gamma salt} + H_{\alpha salt}) \)

Where:

- \( G_{\alpha NO_3} \) = Hydrogen yield in molecules per 100 electron volts of radiation produced by alpha radiation
- \( G_{\beta/\gamma NO_3} \) = Hydrogen yield in molecules per 100 electron volts of radiation produced by beta/gamma radiation
- \( a_{hf} \) = Fraction of radiolytic heat rate that is contributed to alpha radiation
- \( H_{\beta/\gamma sludge} \) = Heat generated by beta and gamma decay in the sludge, Btu/hr
- \( H_{\alpha sludge} \) = Heat generated by alpha decay in the sludge, Btu/hr
- \( H_{\beta/\gamma salt} \) = Heat generated by beta and gamma decay in the salt, Btu/hr
- \( H_{\alpha salt} \) = Heat generated by alpha decay in the salt, Btu/hr

Eq. #31 \( [NO_{eff}] = [NO_3] + \frac{1}{2}[NO_2] \)

Where:

- \( [NO_{eff}] \) = Effective ion concentration, mol/L
- \( [NO_3] \) = Nitrate concentration in supernate, mol/L
- \( [NO_2] \) = Nitrite concentration in supernate, mol/L

For sludge/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) may be used to determine the hydrogen concentration in trapped gas for Gas Release evaluations [Ref. 16].

Variable \( H_{mix} \) Calculation is applicable in other sections as noted.

**VARIABLE C CALCULATION – SPONTANEOUS TIME TO LFL**

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 (\( C = \frac{P_{avg}}{P_{atm}} \)). The expansion correction is determined from the following head pressure equation [Ref. 14]:

\( \)
Eq. #32 \[ p_{\text{avg}} = \left( \sum_{a=2}^{n} \rho_a \cdot g \cdot h_a \right) + \frac{1}{2} \rho_1 \cdot g \cdot h_1 + p_{\text{atm}} \]

Where:
- \( p_{\text{avg}} \) = Hydrostatic head pressure, atm
- \( n \) = Number of layers above slurried sludge,
- \( \rho_a \) = Density of layer material, kg/m³
- \( \rho_1 \) = Density of the slurried sludge layer material, kg/m³
- \( h_a \) = Height of layer material, m
- \( h_1 \) = Height of the slurried sludge layer, m
- \( g \) = Standard acceleration of gravity (9.81 m/s²)
- \( p_{\text{atm}} \) = Atmospheric pressure, atm
- \( X \) = 101325, Pa/atm

**VARIABLE \( F_R \) CALCULATION – SPONTANEOUS TIME TO LFL**

The percentage of trapped gas released from the slurried sludge due to spontaneous release is 100% (1.00 volume fraction).

**VARIABLE \( H'_\text{eq} \) CALCULATION – SPONTANEOUS TIME TO LFL**

The equilibrium hydrogen concentration for spontaneous time to LFL is calculated in the same manner as the equilibrium hydrogen concentration for radiolytic time to LFL except the waste tank vapor space is determined using the actual/projected waste tank level.

Eq. #33 \[ H'_{\text{eq}} = \frac{Q_{H2}}{Q_{H2} + Q'_{\text{ATM}}} \]

Where:
- \( H'_{\text{eq}} \) = Hydrogen concentration at equilibrium, vol. frac.
- \( Q_{H2} \) = Total hydrogen volumetric evolution rate, ft³/hr (see Variable \( Q_{H2} \) Calculation in Section 4.1.2.2.1)
- \( Q'_{\text{ATM}} \) = Atmospheric breathing rate, ft³/hr (see Variable \( Q'_{\text{ATM}} \) Calculation)

\( H'_{\text{eq}} \) will be used to determine whether the waste tanks can be designated as Very Slow Generation Tanks.

**VARIABLE \( Q'_{\text{ATM}} \) CALCULATION – SPONTANEOUS TIME TO LFL**

The correlation for atmospheric breathing rate for spontaneous time to LFL calculation is similar to the atmospheric breathing rate for radiolytic time to LFL calculation except the waste tank vapor space is determined using the actual/projected waste tank level.
Eq. #34  \[ Q'_{\text{ATM}} = \left[ \frac{\text{mean atm. fluctuation}}{1013} \right] \times \frac{V'_V}{24} \]

Where:

- \( Q'_{\text{ATM}} \) = Atmospheric breathing rate, ft\(^3\)/hr
- mean atm. fluctuation = Mean pressure fluctuation, 5 mbar/day [Ref. 41]
- \( V'_V \) = Vapor space volume based on actual/projected waste tank level, ft\(^3\), (see Variable \( V'_V \) Calculation)
- 24 = Conversion factor from days to hours
- 1013 = Standard atmospheric pressure, mbar

**VARIABLE \( V'_V \) CALCULATION – SPONTANEOUS TIME TO LFL**

The vapor space volume used to calculate the spontaneous time to LFL is based on the actual or projected waste level. The calculations account for the maximum missing waste volume when considering incoming transfers. The following equation is the vapor space volume calculation, in ft\(^3\).

Eq. #35  \[ V'_V = 0.13368 \left[ V_T - (L_{\text{tank}} \times Ff) - \text{MMW} \right] \]

Where:

- \( V'_V \) = Vapor space volume based on actual/projected waste tank level, ft\(^3\)
- \( V_T \) = Total tank vapor space volume (empty tank), gallons
- 0.13368 = Conversion factor from gals to ft\(^3\)
- \( L_{\text{tank}} \) = Actual/projected level, inches
- \( Ff \) = Nominal waste tank fill factor, gal/in (see Section 3.0)
- \( \text{MMW} \) = Missing waste volume, gallons (to be accounted for in the receipt tank for incoming transfers, see discussion below)

The waste tank level shall be adjusted to account for the maximum volume associated with a Transfer Error event (i.e., 15,000 gallons) for waste tanks receiving transfers from a sending vessel 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 waste tank level shall be adjusted to account for the maximum volume of the batch source. The liquid batch 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.

**4.1.2.3 WASTE TANK FLAMMABILITY CLASSIFICATION DETERMINATION**

The methodology in determining the radiolytic time to LFL and the spontaneous time to LFL is detailed in Section 4.1.2.2. The steps below can be used to as guidelines in determination of the waste tank flammability classification.
a. Calculate volume fraction of hydrogen concentration at equilibrium (H\textsubscript{eq}) due to radiolytic hydrogen generation, using the vapor space volume protected by the waste tank HLLCP (see Section 4.1.2.2.1 Variable H\textsubscript{eq} Calculation).

b. Calculate volume fraction of hydrogen concentration at equilibrium (H'\textsubscript{eq}) due to radiolytic hydrogen generation, using the actual/projected waste tank level to determine the vapor space volume (see Section 4.1.2.2.2 Variable H'\textsubscript{eq} Calculation).

c. Calculate volume fraction of trapped hydrogen gas released from slurried sludge (TGSS), (see Section 4.1.2.2.2 Variable TGSS Calculation).

d. Calculate the temperature and organic corrected hydrogen concentration at 100% of the LFL (LFL\textsubscript{OC}) (see Section 4.1.2.2.1 Variable LFL\textsubscript{OC} Calculation).

e. If H\textsubscript{eq} < LFL\textsubscript{OC} AND (H'\textsubscript{eq} + TGSS) < LFL\textsubscript{OC}, then the waste tank can be designated as a Very Slow Generation Tank.

f. If step e above is not met, then:
   • Waste tanks excluding Tank 50
     o Radiolytic time to LFL:
       ▪ If H\textsubscript{eq} < LFL\textsubscript{OC}, radiolytic time to LFL is infinite. Go to step g.
       ▪ If the condition above is not met, then calculate the radiolytic time to LFL starting from the SAV (nominally 25% of the LFL\textsubscript{T}). Calculations are based on the vapor space volume protected by the waste tank HLLCP setpoint (and Tank Fill Limits Program) and flammable vapor contributions from trace organics and radiolytic hydrogen generation, considering atmospheric breathing only (see Section 4.1.2.2.1).
     
     o Spontaneous time to LFL:
       ▪ If (H'\textsubscript{eq} + TGSS) < LFL\textsubscript{OC}, spontaneous time to LFL is infinite. Go to step g.
       ▪ If H'\textsubscript{eq} < (y\textsubscript{0} + TGSS) < LFL\textsubscript{OC}, spontaneous time to LFL is infinite. Go to step g.
       ▪ If (y\textsubscript{0} + TGSS) < H'\textsubscript{eq} < LFL\textsubscript{OC}, spontaneous time to LFL is infinite. Go to step g.
       ▪ If (y\textsubscript{0} + TGSS) ≥ LFL\textsubscript{OC}, spontaneous time to LFL is immediate. Go to step g.
       ▪ If the conditions above are not met, then calculate the spontaneous time to LFL starting from 25% of the LFL\textsubscript{T}. Calculations are based on actual/projected waste level and flammable vapor contributions from trapped hydrogen gas released from slurried sludge, trace organics and radiolytic hydrogen generation, considering atmospheric breathing only (see Section 4.1.2.2.2).
     
   * y\textsubscript{0} can be determined using Equation 2 in Section 4.1.2.2.1. For spontaneous time to LFL calculation, y\textsubscript{0}(25\textdegree C) is equal to 25% of the LFL for hydrogen at 25\textdegree C (LFL for hydrogen at 25\textdegree C is 0.04 vol. frac.).
   
   • Tank 50
     o Radiolytic time to LFL:
       ▪ If H\textsubscript{eq} < LFL\textsubscript{OC}, radiolytic time to LFL is infinite. Go to step g.
       ▪ If not, then calculate the radiolytic time to LFL starting from 3.8% of the LFL\textsubscript{T}. Calculations are based on the vapor space volume protected by the waste tank HLLCP setpoint (and Tank Fill Limits Program) and flammable vapor contributions from radiolytic hydrogen generation, considering atmospheric breathing only (see Section 4.1.2.2.1).
     
     o Spontaneous time to LFL:
       ▪ If (H'\textsubscript{eq} + TGSS) < LFL\textsubscript{OC}, spontaneous time to LFL is infinite. Go to step g.
       ▪ If H'\textsubscript{eq} < (y\textsubscript{0} + TGSS) < LFL\textsubscript{OC}, spontaneous time to LFL is infinite. Go to step g.
       ▪ If (y\textsubscript{0} + TGSS) < H'\textsubscript{eq} < LFL\textsubscript{OC}, spontaneous time to LFL is infinite. Go to step g.
If \((y_0 + TGSS) \geq LFLoc\), spontaneous time to LFL is immediate. Go to step g.

If not, then calculate the spontaneous time to LFL starting from 3.8% of the LFLT. Calculations are based on actual/projected waste content and flammable vapor contributions from trapped hydrogen gas released from slurried sludge and radiolytic hydrogen generation, considering atmospheric breathing only (see Section 4.1.2.2.2).

* \(y_0\) can be determined using Equation 2 in Section 4.1.2.2.1. For spontaneous time to LFL calculation, \(y_0(25^\circ C)\) is equal to 3.8% of the LFL for hydrogen at 25°C (LFL for hydrogen at 25°C is 0.04 vol. frac.).

g. Waste tank flammability classification determination

- If radiolytic time to LFL is infinite \((H_{eq} < LFLOC)\) and spontaneous time to LFL is infinite \(((y_0 + TGSS) < LFLOC AND H'_{eq} < LFLOC)\), the waste tank can be designated as a Slow or Rapid Generation Tank.
- If radiolytic time to LFL is infinite \((H_{eq} < LFLOC)\) and spontaneous time to LFL is immediate \(((y_0 + TGSS) \geq LFLOC)\), the waste tank can be designated as a Slow or Rapid Generation Tank. The Spontaneous Liberation Protection Program will protect the waste tank vapor space from reaching 100% LFL in less than the time protected by the waste tank flammability classification.
- If radiolytic time to LFL is infinite and spontaneous time to LFL is a numeric value, the waste tank flammability classification will be determined based on the spontaneous time to LFL.
  - If spontaneous time to LFL \(\geq 28\) days, the tank can be designated as a Slow or Rapid Generation Tank.
  - If 7 days \(\leq\) spontaneous time to LFL \(< 28\) days, the tank shall be designated as a Rapid Generation Tank.
  - If spontaneous time to LFL \(< 7\) days, the waste tank flammability classification shall be determined based on the time to LFL protected by the Spontaneous Liberation Protection Program. If the program protects 7 days, the waste tank shall be designated as a Rapid Generation Tank. If the program protects 28 days, the waste tank can be designated as a Rapid or Slow Generation Tank.
- If radiolytic time to LFL is a numeric value and spontaneous time to LFL is infinite, the waste tank flammability classification will be designated based on the radiolytic time to LFL.
  - If radiolytic time to LFL \(\geq 28\) days, the tank can be designated as a Slow or Rapid Generation Tank.
  - If 7 days \(\leq\) radiolytic time to LFL \(< 28\) days, the tank shall be designated as a Rapid Generation Tank.
  - If radiolytic time to LFL \(< 7\) days, the waste tank configuration must be changed to increase the waste tank radiolytic time to LFL to \(\geq 7\) days (e.g., lower HLLCP, reduce the tank supernate temperature, adjust tank chemistry, reduce SAV, reduce waste level). Once the option(s) is selected, go back to step a to re-calculate the waste tank times to LFL.
- If radiolytic time to LFL is a numeric value and spontaneous time to LFL is immediate, the waste tank flammability classification will be designated based on the radiolytic time to LFL. The Spontaneous Liberation Protection Program will protect the waste tank
vapor space from reaching 100% LFL in less than the time protected by the waste tank flammability classification defined by the radiolytic time to LFL.

- If radiolytic time to LFL ≥ 28 days, the tank can be designated as a Slow or Rapid Generation Tank.
- If 7 days ≤ radiolytic time to LFL < 28 days, the tank shall be designated as a Rapid Generation Tank.
- If radiolytic time to LFL < 7 days, the waste tank configuration must be changed to increase the waste tank radiolytic time to LFL to ≥ 7 days (e.g., lower HLLCP, reduce the tank supernate temperature, adjust tank chemistry, reduce SAV, reduce waste level). Once the option(s) is selected, go back to step a to re-calculate the waste tank times to LFL.

- If both the radiolytic time to LFL and spontaneous time to LFL are numeric values, then the lower of the radiolytic time to LFL or the spontaneous time to LFL (named time to LFL below) will be used to determine the waste tank flammability classification.
  - If time to LFL ≥ 28 days, the tank can be designated as a Slow or Rapid Generation Tank.
  - If 7 days ≤ time to LFL < 28 days, the tank shall be designated as a Rapid Generation Tank.
  - If time to LFL < 7 days, then
    - If radiolytic time to LFL < 7 days, the waste tank configuration must be changed to increase the waste tank radiolytic time to LFL to ≥ 7 days (e.g., lower HLLCP, reduce the tank supernate temperature, adjust tank chemistry, reduce SAV, reduce waste level). Once the option(s) is selected, go back to step a to re-calculate the waste tank times to LFL. If the spontaneous time to LFL is also < 7 days, the Spontaneous Liberation Protection Program will protect the waste tank vapor space from reaching 100% LFL in less than the time protected by the waste tank flammability classification defined by the radiolytic time to LFL.
    - If 7 days ≤ radiolytic time to LFL < 28 days, and spontaneous time to LFL< 7 days, the tank shall be designated as a Rapid Generation Tank. The Spontaneous Liberation Protection Program will protect the waste tank vapor space from reaching 100% LFL in less than the time protected by the waste tank flammability classification defined by the radiolytic time to LFL.
    - If radiolytic time to LFL ≥ 28 days, and spontaneous time to LFL< 7 days, the tank can be designated as a Rapid or Slow Generation Tank. The Spontaneous Liberation Protection Program will protect the waste tank vapor space from reaching 100% LFL in less than the time protected by the waste tank flammability classification.

### 4.1.2.4 IMPLEMENTATION ACTIONS

1. The waste tank flammability classification shall be determined using WCS [Ref. 11] or an engineering evaluation and shall be documented in the ERD. [TSR SAC 5.8.2.27.a]

2. The waste tank hydrogen concentration SAV (excluding Tank 50, Very Slow Generation Tanks, Closure Waste Tanks and Acidic Chemical Cleaning Mode Waste Tanks) shall be determined in WCS [Ref. 11] or an engineering evaluation. The TSR hydrogen concentration LFL limit shall be based on the hydrogen concentration SAV and account for
potential organics and instrument uncertainties and shall be documented in the ERD. [TSR SAC 5.8.2.27.b]

3. Liquid additions to a waste tank (e.g., water additions, waste 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) [TSR SAC 5.8.2.27.a].

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 [Ref. 55] prior to initiation of the planned activity. [TSR SAC 5.8.2.27.a]

5. If the projected radiolytic time to LFL results in less than seven days or the maximum hydrogen generation rate is exceeded, then the evaluated activity shall not be performed. [TSR SAC 5.8.2.27.c]

6. As a result of pre-transfer evaluation (e.g., transfers, sludge or salt removal) or a change in the waste tank configuration (e.g., chemistry, solids level), it may be necessary to change the HLLCP setpoint to protect the desired tank classification. In these cases, an engineering evaluation shall determine the new HLLCP setting, taking into account maximum missing waste, and instrument uncertainty. When the engineering evaluation requires lowering the HLLCP setpoint of a Type III/IIIA waste tank, additional consideration of the volume of contingency space should be applied (See Section 6.4). The HLLCP setpoint shall be updated in WCS [Ref. 11] and the ERD upon completion of the field work.

7. Ventilation is required on Very Slow Generation Tanks while receiving steam jetted transfers because of the potential of dissolved hydrogen contributions above the equilibrium resulting in greater than, or equal to, 100% of the LFLOC. Operation of the exhaust fan shall be maintained for the duration of the transfer.

8. The Electronic Transfer Approval Form (ETAF) shall address ventilation system requirements during jetted transfer receipts for Very Slow Generation Tanks.

9. 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 waste 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 6.2).

10. For Very Slow Generation Tanks not containing slurried sludge, the equilibrium flammable hydrogen concentration \([H_{eq}]\) shall be calculated based on the vapor space volume protected by HLLCP, using WCS [Ref. 11] or an engineering evaluation. Those waste tanks with \(H_{eq} > 60%\) LFLOC shall be identified in the ERD.

11. For Very Slow Generation Tanks containing slurried sludge, the equilibrium flammable hydrogen concentrations (\([H_{eq}]\) and \([H_{eq}']\)) shall be calculated based on the vapor space volume protected by HLLCP and based on the actual/projected waste level, respectively,
using WCS [Ref. 11] or an engineering evaluation. Those waste tanks with \( \text{H}_{eq} > 60\% \) OR \( \text{(H’}_{eq} + \text{TGSS}) > 60\% \) LFL\(_{OC}\) shall be identified in the ERD.

### 4.1.3 Seismic Time to LFL

#### 4.1.3.1 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 4.1.2.2). This section provides all the equations used in determining the seismic time to LFL except those used in determining the temperature corrected hydrogen generation rate (\( Q_{H2} \)) and the volume fraction of hydrogen trapped in sludge and salt (\( H_{mix} \)), which can be found in Section 4.1.2.2.1 Variable \( Q_{H2} \) Calculation and in Section 4.1.2.2.2 Variable \( H_{mix} \) Calculation, respectively. Calculations of variables listed in this section are only applicable to this section unless otherwise noted. The waste tank seismic time to LFL can be determined using the following equation:

\[
\text{Seismic Time to LFL} = \left( \frac{\text{LFL}_{OC} - \frac{Q_{H2}}{Q_{H2} + Q_{ATM}}}{\frac{y_{0,\text{seismic}}}{Q_{H2} + Q_{ATM}} - \frac{Q_{H2}}{Q_{H2} + Q_{ATM}}} \right) - \ln \left( \frac{Q_{H2} + Q_{ATM}}{V'} \right)
\]

Eq. #36  Seismic Time to LFL = 

Where:

- **Seismic Time to LFL** = It is the time for the hydrogen concentration in the waste tank vapor space to go from \( y_{0,\text{seismic}} \) to the LFL\(_{OC}\) following a seismic event.
- **\( y_{0,\text{seismic}} \)** = Initial hydrogen concentration in the waste tank vapor space following a seismic event, vol. frac. (see Variable \( y_{0,\text{seismic}} \) Calculation).
- **LFL\(_{OC}\)** = Temperature and organic corrected hydrogen concentration at 100% LFL (100% CLFL Tank 50) (see Variable LFL\(_{OC}\) Calculation).
- **\( Q_{H2} \)** = Temperature corrected hydrogen generation rate, ft\(^3\)/hr (see Variable \( Q_{H2} \) Calculation in Section 4.1.2.2.1).
- **\( Q'\)\(_{ATM}\)** = Atmospheric breathing rate, ft\(^3\)/hr (see Variable \( Q'\)\(_{ATM}\) Calculation).
- **\( V'\)** = Vapor space volume based on actual/projected waste tank level, ft\(^3\) (see Variable \( V'\) Calculation).

The seismic time to LFL calculated using Equation 36 may return an error, due to attempting to calculate the natural log of a negative number, or return a negative seismic time to LFL depending on the conditions of the indicated waste tank. The bullets below can be used to
determine the waste tank seismic time to LFL, if the waste tank conditions are met, prior to applying Equation 36 for seismic time to LFL calculation.

\[
\frac{Q_{H2}}{Q_{H2} + Q_{ATM}}
\]

in Equation 36 is defined as \( H'_{eq} \) (see Variable \( H'_{eq} \) Calculation below). Substituting \( H'_{eq} \) for \( \frac{Q_{H2}}{Q_{H2} + Q_{ATM}} \) into Equation 36 yields

\[
\text{Seismic Time to LFL} = \frac{\ln \left[ \frac{LFL_{OC} - H'_{eq}}{y_{0,seismic} - H'_{eq}} \right]}{\frac{Q_{H2} + Q_{ATM}}{V_V}}
\]

- **\( H'_{eq} < LFL_{OC} \) and \( H'_{eq} < y_{0,seismic} \)**
  - If \( y_{0,seismic} < LFL_{OC} \), the waste tank vapor space never reaches flammable condition. The waste tank seismic time to LFL is infinite and Equation 36 is not required.
  - If \( y_{0,seismic} \geq LFL_{OC} \), the waste tank seismic time to LFL is immediate and Equation 36 is not required.

- **\( H'_{eq} > LFL_{OC} \) and \( H'_{eq} > y_{0,seismic} \)**
  - If \( y_{0,seismic} < LFL_{OC} \), the waste tank seismic time to LFL can be determined using the methodology described in this section.
  - If \( y_{0,seismic} \geq LFL_{OC} \), the waste tank seismic time to LFL is immediate and Equation 36 is not required.

- **\( H'_{eq} > LFL_{OC} \) and \( H'_{eq} < y_{0,seismic} \)**
  Since \( y_{0,seismic} > H'_{eq} \) and \( H'_{eq} > LFL_{OC} \), \( y_{0,seismic} > LFL_{OC} \). The waste tank seismic time to LFL is immediate and Equation 36 is not required.

- **\( H'_{eq} < LFL_{OC} \) and \( H'_{eq} > y_{0,seismic} \)**
  Since \( y_{0,seismic} < H'_{eq} \) and \( H'_{eq} < LFL_{OC} \), \( y_{0,seismic} < LFL_{OC} \). The waste tank seismic time to LFL is infinite and Equation 36 is not required.

**VARIABLE \( y_{0,seismic} \) CALCULATION – SEISMIC TIME TO LFL**

The initial concentration used in the seismic time to LFL equation shall include the steady state hydrogen equilibrium concentration accounting for minimum ventilation, (except for Very Slow Generation Tanks, which shall assume the hydrogen equilibrium with atmospheric breathing) and the effects of post seismic trapped gas release. \( y_{0,seismic} \) is then determined using the expression below.
Eq. #37 \[ y_{0,\text{seismic}} = \text{Equil. Conc.} + \text{TG} \]

Where:

\[ y_{0,\text{Seismic}} \] = Initial hydrogen concentration in the vapor space following a seismic event, vol. frac.

\[ \text{Equil. Conc} \] = Initial hydrogen concentration in units of vol. frac.

- **Rapid or Slow Generation Tanks**: higher of 2.5% of LFT (3.8% of LFT for Tank 50) (see Variable LFT Calculation), or steady state hydrogen equilibrium (see Variable \( H_{\text{eq}} \) Calculation), accounting for the minimum DSA purge flow rate

- **Very Slow Generation Tanks**: higher of 2.5% of LFT (3.8% of LFT for Tank 50) (see Variable LFT Calculation), or steady state hydrogen equilibrium concentration (see Variable \( H_{\text{eq}} \) Calculation), accounting for atmospheric breathing

\[ \text{TG} \] = Hydrogen concentration due to trapped gas release in units of vol. frac. \( \text{H}_2 \) (see Variable TG Calculation)

**VARIABLE LFL_{OC} CALCULATION**

- **Waste tanks excluding Tank 50**: The LFL, corrected for organic and temperature, is determined by using the Burgess – Wheeler correlation and subtracting the organic contribution, as follows:

\[ \text{Eq. } \#38 \quad \text{LFL}_{\text{OC}} = \text{LFL}_{25C} \cdot [1 - A \cdot (T - 25)] - \text{OC} \]

Where:

\[ \text{LFL}_{\text{OC}} \] = LFL for hydrogen corrected for organic contribution and temperature, vol. frac.

\[ \text{LFL}_{25C} \] = LFL for hydrogen at 25°C, (i.e., 0.04-volume fraction), vol. frac.

\[ \text{OC} \] = The organic contribution equivalent hydrogen concentration (i.e., 5% of \( \text{LFL}_{25C} \) (0.002-volume fraction)), vol. frac.

\[ A \] = Empirical coefficient (Zabetakis attenuation factor), (i.e., 0.0011 per Ref. 1), °C⁻¹

\[ T \] = Temperature at which LFL is to be evaluated in °C [Refs. 1, 24]

- **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, \( \text{LFL}_{\text{OC}} \) for Tank 50 at 100% of the CLFL is calculated to be 43.8% of the CLFL at 43°C or 43.8% of the LFL for hydrogen at 43°C [Ref. 24].
Eq. #39 \[ \text{LFL}_{OC} = \frac{43.8}{100} \cdot \text{LFL}_{25C} \cdot [1 - A \cdot (43 - 25)] \]

Where:

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

**VARIABLE LFL\(_T\)** CALCULATION – SEISMIC TIME TO LFL

LFL for hydrogen can be corrected for temperature. Using the Burgess - Wheeler correlation, the temperature corrected LFL for hydrogen, LFL\(_T\), is determined as follows:

Eq. #40 \[ \text{LFL}_T = \text{LFL}_{25C} \cdot [1 - A \cdot (T - 25)] \]

Where:

- \( \text{LFL}_T \) = LFL corrected for temperature, vol. frac.
- \( \text{LFL}_{25C} \) = 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, °C\(^{-1}\))
- \( T \) = Temperature at which LFL is to be evaluated in °C [Refs. 1, 24]

**VARIABLE H\(_{eq}\)** CALCULATION – SEISMIC TIME TO LFL

For Rapid and Slow Generation Tanks, steady state hydrogen equilibrium accounting for ventilation (minimum required purge flow for the applicable flammability classification) may be used as the assumed initial hydrogen concentration at the time of a seismic event. The steady state hydrogen equilibrium (H\(_{eq}\) (Rapid/Slow)) is calculated using the following equation:

Eq. #41 \[ H_{eq} (\text{Rapid/Slow}) = \frac{Q_{H2}}{Q_{H2} + 60 (Q_{\text{purge}})} \]

Where:

- \( H_{eq} (\text{Rapid/Slow}) \) = Hydrogen concentration at equilibrium for Rapid and Slow Generation Tanks, vol. frac.
- \( Q_{H2} \) = Total hydrogen volumetric evolution rate, ft\(^3\)/hr. (see Variable \( Q_{H2} \) in Section 4.1.2.2.1)
- \( Q_{\text{purge}} \) = Minimum purge flow rate, ft\(^3\)/min
= 72 ft³/min for Rapid tanks
= 45 ft³/min for Slow tanks

60 = Conversion factor from mins to hours

The \( H_{eq} \) (Rapid/Slow) value is compared to 2.5\% of the LFL \( T \) (3.8\% of the LFL \( T \) for Tank 50) and the greater of the two is used as Equil. Conc. in Equation 37.

For Very Slow Generation Tanks, steady state hydrogen equilibrium accounting for atmospheric breathing may be used as the assumed initial hydrogen concentration at the time of a seismic event and is represented in the equation below:

\[
\text{Eq. \#42} \quad H'_{eq} = \frac{Q_{H2}}{Q_{H2} + Q'_{ATM}}
\]

Where:

\( H'_{eq} \) = Hydrogen concentration at equilibrium for Very Slow Generation Tanks, vol. frac.

\( Q_{H2} \) = Total hydrogen volumetric evolution rate, ft³/hr (see Variable \( Q_{H2} \) in Section 4.1.2.2.1)

\( Q'_{ATM} \) = Atmospheric breathing rate, ft³/hr (see Variable \( Q'_{ATM} \) Calculation)

The \( H'_{eq} \) value is compared to 2.5\% of the LFL \( T \) (3.8\% of the LFL \( T \) for Tank 50) and the greater of the two is used as Equil. Conc. in Equation 37.

**VARIABLE Q'\text{ATM} \text{ CALCULATION – SEISMIC TIME TO LFL}**

The atmospheric breathing assumptions and methodology are established in Reference 1 Section 3.4.1.5.5. The atmospheric breathing rate is determined as follows:

\[
\text{Eq. \#43} \quad Q'_{ATM} = \frac{\text{Mean atm. fluctuation}}{1013} \cdot \frac{V'_{v}}{24}
\]

Where:

\( Q'_{ATM} \) = Atmospheric breathing rate, ft³/hr

Mean atm. fluctuation = Mean pressure fluctuation, 5 mbar/day [Ref. 41]

\( V'_{v} \) = Vapor space volume based on the actual/projected waste tank level, ft³ (see Variable \( V'_{v} \) Calculation)

24 = Conversion factor from days to hours

1013 = Standard atmospheric pressure, mbar

**VARIABLE TG \text{CALCULATION – SEISMIC TIME TO LFL}**

The contribution of post seismic trapped gas released from saltcake, settled sludge, and slurried sludge is additive. The following equation is used to determine the vapor space hydrogen
concentration due to trapped gas release from each layer (i.e., saltcake, settled sludge, and slurried sludge) under post seismic conditions [Ref. 14]. Each contributing phase (i.e., trapped gas release from saltcake, trapped gas release from settled sludge, and trapped gas release from slurried sludge) shall have a separate value of trapped hydrogen gas released (TG) and these values are added together to determine the total seismic initial concentration:

\[ TG = \frac{V_{\text{solids}} \cdot G_s \cdot H_{\text{mix}} \cdot C \cdot F_R}{V_v} \]

Where,

\( TG = \) Trapped hydrogen released during a seismic event, vol. frac.
\( V_{\text{solids}} = \) Volume of saltcake, slurried sludge or settled sludge in the tank that is available to liberate hydrogen, ft\(^3\) (see Variable \( V_{\text{SOLIDS}} \) Calculation)
\( G_s = \) Fraction of trapped bubble gas, vol. frac. (see Variable \( G_s \) Calculation)
\( H_{\text{mix}} = \) Hydrogen fraction in trapped gas (see Section 4.1.2.2.2 Variable \( H_{\text{mix}} \) Calculation)
\( C = \) Pressure correction (see Variable \( C \) Calculation)
\( F_R = \) Trapped gas release fraction, vol. frac. (see Variable \( F_R \) Calculation)
\( V_v = \) Vapor space volume using actual or projected waste level, ft\(^3\) (see Variable \( V_v \) Calculation)

**VARIABLE \( V_{\text{SOLIDS}} \) CALCULATION – SEISMIC TIME TO LFL**

All insoluble solids are considered to retain trapped gas for the purposes of trapped gas retention. The DSA, Section 3.4.1.5.3, establishes the following input for determining the volume of solids layers (i.e., saltcake, slurried sludge and settled sludge) affected due to seismic event. The volume of the solids layers is determined by multiplying the affected depth (in) by the applicable waste tank fill factor (gal/in).

- Saltcake
  - Waste tanks containing saltcake without free liquid above the salt layer
    - No trapped gas is released from salt
  - The saltcake depth/region that becomes mobilized during a seismic event and is available to liberate hydrogen is equal to the least of the following:
    - Depth of the saltcake
    - Depth of total overlying waste level (including settled sludge, slurried sludge, and supernate) above the saltcake
    - 40 inches

- Settled Sludge
  - The volume of settled sludge available to liberate hydrogen is equal to zero if the sludge contains an overlying saltcake layer greater than 40 inches.
The volume of settled sludge available to liberate hydrogen following a seismic event is proportional to the height of the settled sludge layer and the overlying waste layer above it:

Settled sludge volume (gals) = \frac{\text{Settled sludge layer (inches)} \times \text{Total overlying waste layer (inches)}}{400 \text{ inches}}

Where: Total overlying waste level = Depth of total overlying waste level (including saltcake, slurried sludge, and supernate) above the settled sludge layer. Saltcake below the settled sludge layer does not contribute to the total settled sludge volume.

- Slurried Sludge: The volume of slurried sludge that is available to liberate hydrogen is the entire slurried sludge volume in the waste tank.

**VARIABLE G S CALCULATION – SEISMIC TIME TO LFL**

The DSA, Section 3.4.1.5.3, establishes the following input for determining the percentage of trapped bubble gas available to be released as follows:

- For waste tanks containing slurried sludge, the percentage of trapped bubble gas volume is 20% (0.20 volume fraction) of the volume of slurried sludge.

- For waste tanks containing settled sludge, the percentage of trapped bubble gas volume is 10% (0.10 volume fraction) of the volume of settled sludge.

- For waste tanks containing saltcake, the percentage of trapped bubble gas volume is 11% (0.11 volume fraction) of the volume of salt.

**VARIABLE C CALCULATION – SEISMIC TIME TO LFL**

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 \( C = \frac{P_{\text{avg}}}{P_{\text{atm}}} \). The expansion correction is determined from the following head pressure equation [Ref. 14]:

\[
\text{Eq. #45} \quad P_{\text{avg}} = \left( \sum_{a=2}^{n} \frac{\rho_a \cdot g \cdot h_a}{X} \right) + \frac{1}{2} \frac{\rho_1 \cdot g \cdot h_1}{X} + P_{\text{atm}}
\]

Where:

- \( P_{\text{avg}} \) = Hydrostatic head pressure, atm
- \( n \) = Number of layers above the evaluated layer
- \( \rho_a \) = Density of layer above the evaluated layer material, kg/m³
- \( h_a \) = Height of layer above the evaluated layer, m
- \( \rho_1 \) = Density of the evaluated layer material, kg/m³
- \( h_1 \) = Height of the evaluated layer, m
\[ g = \text{Standard acceleration of gravity (9.81 m/s}^2) \]
\[ p_{\text{atm}} = \text{Atmospheric pressure, atm} \]
\[ X = 101325, \text{ Pa/atm} \]

**VARIABLE FR CALCULATION – SEISMIC TIME TO LFL**

The DSA, Section 3.4.1.5.3, establishes the following input for determining the trapped gas release percentage from each solids layer (i.e., saltcake, slurried sludge, and settled sludge) due to seismic event:

- Saltcake layer: 50% (0.50 volume fraction) of the trapped gas is released from the affected saltcake layer
- Slurried sludge layer: 100% (1.00 volume fraction) of the trapped gas is released from the affected slurried sludge layer within a waste tank (even if saltcake and/or settled sludge layers are present)
- Settled sludge layer: 50% (0.50 volume fraction) of the trapped gas is released from the affected settled sludge layer

The affected solids layer is defined in Section Variable VSOLIDS Calculation.

**VARIABLE V'V CALCULATION – SEISMIC TIME TO LFL**

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 when considering incoming transfers. The following equation is the vapor space volume calculation, in cubic feet:

Eq. #46
\[ V'_{V} = 0.13368 \left[ V_T - (L_{\text{tank}} \cdot Ff) - \text{MMW} \right] \]

Where,
\[ V'_{V} = \text{Vapor space volume using actual/projected waste tank level, ft}^3 \]
\[ V_T = \text{Total tank vapor space volume (empty tank), gallons} \]
\[ L_{\text{tank}} = \text{Actual or projected waste level, inches} \]
\[ 0.13368 = \text{Conversion factor from gallons to ft}^3 \]
\[ Ff = \text{Nominal waste tank fill factor, gal/in (see Section 3.0)} \]
\[ \text{MMW} = \text{Maximum missing waste volume, gallons (to be accounted for in the receipt tank for incoming transfers, see discussion below)} \]

For waste tanks receiving transfers from a sending vessel greater than or equal to 15,000 gallons or has continuous makeup capability, MMW is equal to 15,000 gallons. If the sending vessel is less than 15,000 gallons and does not have continuous makeup capability, MMW is equal to the volume of the vessel. 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. In lieu of using the actual/projected waste contents, the evaluation may be based upon the vapor space volume protected by the Tank Fill Limits Program. Liquid additions to the waste tank from DWS do not have continuous makeup capability.

### 4.1.3.2 IMPLEMENTATION ACTIONS

1. The seismic time to LFL shall be determined using WCS [Ref. 11] or an engineering evaluation. [TSR SAC 5.8.2.27.d, 5.8.2.27.e]

2. The emergency response priority classification (Priority 1 and Priority 2) shall be determined by the seismic time to LFL. Response priorities shall be, in the 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).

3. Ensure that only 7 waste tanks can reach 100% of the LFLOC in less than 24 hours assuming no ventilation and including the effects of post-seismic trapped gas release. Document these waste tanks as Priority 1 in the ERD [TSR SAC 5.8.2.27.d]

4. Ensure that only 14 waste tanks can reach 100% of the LFLOC in less than 7 days including:
   - Effects of post-seismic trapped gas release, assuming no ventilation
   - Number of waste tanks in Acidic Chemical Cleaning Mode.
   Document these waste tanks as Priority 1 and Priority 2, as applicable, in the ERD [TSR SAC 5.8.2.27.e].

5. Liquid additions to a waste tank (e.g., water additions, waste transfers) shall be pre-evaluated to determine the impact on the seismic time to LFL for the affected waste tanks using WCS [Ref. 11] or an engineering evaluation. [TSR SAC 5.8.2.27.d, 5.8.2.27.e]

6. If the projected number of waste 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) is greater than 7 Priority 1 tanks or a total of 14 Priority 1 and 2 tanks, then the evaluated activity shall not be performed. [TSR SAC 5.8.2.27.d, 5.8.2.27.e]

7. 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.f]
4.2 QUIESCENT TIME

4.2.1 QUIESCENT TIME PROGRAM

4.2.1.1 BACKGROUND

The Quiescent Time Program does not apply to Type I/II Acidic Chemical Cleaning Waste Tanks or Closure Waste Tanks. The Quiescent Time Program is applicable to waste tanks that contain slurried sludge. The program is also applicable to waste tanks that contain settled sludge, if the waste tank was placed under the Seismic Release Protection portion of the Quiescent Time Program. Depending on whether the waste tank has completed full sludge inventory initial trapped gas depletion via mixing operations or contains a partial layer of slurried sludge as a direct result of sludge agitation via waste tank mixing devices or receipt of slurried sludge via a transfer, the Waste Tank Quiescent Time Program is divided into two sub-programs: Seismic Release Protection and Spontaneous Liberation Protection [Ref. 1].

- **Seismic Release Protection Program** – The Seismic Release Protection Program protects the waste tank vapor space from reaching 100% LFL in less than 7 days following a seismic event. Waste tanks will be placed under the Seismic Release Protection Program after successful initial full inventory sludge mixing (i.e., hydrogen depletion). Initial full inventory sludge mixing is achieved upon completion of an adequate number of fully inserted waste tank mixing devices operating (with the turntable operating) for a cumulative period of 10 days. The criteria are also applied to waste tanks that contain a saltcake layer beneath the sludge layer. In this case, the saltcake level is used in determining the depth of the fully inserted waste tank mixing devices. Additionally, waste tanks containing no sludge (even if saltcake is present) will be placed under the program after receiving slurried sludge via a transfer.

Once placed under the Seismic Release Protection, the waste tanks will remain in the program even if the slurried sludge in the waste tanks becomes settled sludge after meeting the settled sludge criteria (see Section 3.0). The waste tanks may exit the program only when the program is no longer applicable due to waste tank conditions (e.g., waste tanks entering Chemical Cleaning Mode [Type I/II Acidic Chemical Cleaning Waste Tanks], or Closure Mode [Closure Waste Tanks], waste tanks with all settled sludge/slurried sludge layers removed).

- **Spontaneous Liberation Protection Program** – The Spontaneous Liberation Protection Program protects the waste tank vapor space from reaching 100% LFL in less than the time protected by the waste tank flammability classification, following a spontaneous release event. Waste tanks will be placed under the Spontaneous Liberation Protection Program when the waste tanks contain a slurried sludge layer as a direct result of sludge agitation via waste tank mixing devices or receipt of slurried sludge via a transfer (including waste tanks in the Seismic Release Protection Program).

Waste tanks placed under the Spontaneous Liberation Protection Program will remain in the program until the program is no longer applicable due to waste tank conditions (e.g., waste tanks entering Chemical Cleaning Mode [Type I/II Acidic Chemical Cleaning Waste Tanks]...
or Closure Mode [Closure Waste Tanks], slurried sludge layer becomes settled sludge, slurried sludge layers removed). Waste tanks may be removed from the Spontaneous Liberation Protection Program if the slurried sludge in the waste tanks becomes settled sludge after meeting the settled sludge criteria (see Section 3.0).

The Waste Tank Quiescent Time Program shall require the following to protect assumed times to LFL (CLFL for Tank 50) excluding waste tanks in Acidic Chemical Cleaning Mode or Closure Mode:

- Determine and track waste tanks required to be in the Waste Tank Quiescent Time Program and document in the ERD (N-ESR-G-00001). [TSR SAC 5.8.2.28.a]

- Waste tanks under the Seismic Release Protection Program shall be controlled to ensure that the waste tanks will not reach 100% of the LFL (CLFL for Tank 50) (due to trapped gas release from the settled sludge/slurried sludge and subsequent radiolytic hydrogen production) in less than 7 days following a seismic event. [TSR SAC 5.8.2.28.b]

- Waste tanks under the Spontaneous Liberation Protection Program shall be controlled to ensure that the minimum time to LFL (CLFL for Tank 50) is maintained defined by the waste tank flammability classification (see Section 4.1.2.1). [TSR SAC 5.8.2.28.c]

Waste tanks are controlled to ensure the applicable criteria discussed above are not exceeded, by one or both of the following methods [Ref. 1]:

- Periodically operate waste tank mixing devices in the applicable sludge layer to limit the amount of trapped gas that can be released.

- Maintain waste tank configuration (e.g., waste level, slurried sludge level) to limit the amount of trapped gas that can be released and ensure adequate waste tank vapor space volume.

An integral part of the Quiescent Time Program (i.e., Seismic Release Protection Program and Spontaneous Liberation Protection Program) is to determine the maximum time that the applicable settled/slurried sludge can remain undisturbed and still not retain sufficient hydrogen to cause the tank vapor space to exceed the applicable criteria if a hydrogen release event were to occur (e.g., earthquake). The maximum time, referred to as the quiescent time, is calculated based upon the following conservative inputs [Ref. 1]:

- The quiescent time starts from the end of the last successful hydrogen depletion operation (waste tank mixing device operation) or the time that the program became applicable to the start of the next hydrogen depletion operation.

For waste tanks that receive transfers of slurried sludge that causes the waste tank to be placed in the Spontaneous Liberation Protection Program and/or Seismic Release Protection Program, the quiescent time starts at the end of the transfer.
For waste tanks that are undergoing initial sludge agitation using waste tank mixing devices (Spontaneous Liberation Protection), the quiescent time starts from the end of successful sludge agitation for an affected sludge layer. Successful sludge agitation occurs upon completion of an adequate number of waste tank mixing devices operating within acceptable times/speeds (with the turntable operating) for a cumulative period of 10 days. At this point the affected sludge layer within the zone of influence of the waste tank mixing devices (i.e., based on tank cross sectional area and sludge disturbance depth) is considered slurried sludge. If sludge agitation is stopped prior to completion of successful sludge agitation, the sludge is still considered settled sludge. If any waste tank mixing device is lowered, the affected sludge layer within the zone of influence of the waste tank mixing devices (based on the mixing device location prior to lowering) shall be considered slurried sludge [Ref. 1].

- The quiescent time is the allowable time between waste tank mixing device operation such that the hydrogen released from the applicable settled sludge/slurried sludge does not cause the tank vapor space to exceed the following criteria:
  - For Seismic Release Protection Program
    - Reach $L_{FLoc}$ in less than 7 days following a seismic event (due to trapped gas release from the settled sludge /slurried sludge and subsequent radiolytic hydrogen production).
  - For Spontaneous Liberation Protection Program
    - Reach $L_{FLoc}$ in less than 7 days for Rapid Generation Tanks (due to Isopar® L (Tank 50 only), trace organics, trapped gas release from slurried sludge, and radiolytic hydrogen generation).
    - Reach $L_{FLoc}$ in less than 28 days for Slow Generation Tanks (due to Isopar® L (Tank 50 only), trace organics, trapped gas release from slurried sludge, and radiolytic hydrogen generation).
    - Reach $L_{FLoc}$ for Very Slow Generation Tanks (due to Isopar® L (Tank 50 only), trace organics, trapped gas release from slurried sludge, and radiolytic hydrogen generation).

Trapped gas release is only considered from the applicable sludge layers (i.e., settled sludge/slurried sludge for Seismic Release Protection; slurried sludge for Spontaneous Liberation Protection). Other solids layers above (e.g., saltcake), or below (saltcake and/or settled sludge) the applicable sludge layer are not controlled as part of the Quiescent Time Program. The solids layers will be considered in determining/tracking the post-seismic trapped gas release seismic time to LFL (Section 4.1.3)

After successfully slurrying the entire sludge layer or entire tank contents, the Quiescent Time Program becomes applicable to that tank. Following the initial trapped gas depletion (via mixing operations), hydrogen depletion for the affected slurried sludge layer can be declared to be successful for a given tank quadrant if adequate mixing occurs.

- For Tank 50, Reference 52 demonstrates that adequate solids mixing of the tank occurs after successful completion of a 4-hour pump run at maximum allowable speed with three slurry pumps (assuming of two of the three pumps are the quad-volute slurry pumps and the Tank
50 solids content is less than or equal to 20 wt%). Reference 52 also demonstrates that a single slurry pump (standard or quad-volute) is capable of depleting approximately 33% of the retained hydrogen inventory in the tank. The effect of a non-operational pump is that it could leave up to 33% of the tank contents inadequately mixed, retaining the trapped gas inventory.

- For the remaining waste tanks, operational experiences and analysis performed in Reference 49 for CSMPs have demonstrated that adequate mixing occurs after successful completion of an 8 hour slurry pump/CSMP operation at maximum allowable speed with evidence of adequate sludge mixing (e.g., camera inspection, motor loading within acceptable ranges). For a waste tank, it has been demonstrated that a single slurry pump/CSMP is capable of depleting at least 25% of the retained hydrogen inventory in the waste tank or slurried sludge layer. Thus, the trapped gas inventory can be removed with four slurry pumps/CSMPs 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. Information on CSMP flow rates and the calculated effective cleaning radius is provided in Reference 49. Reference 22 demonstrates that a single SMP operated for an 8-hour period at maximum allowable speed theoretically has sufficient mixing capability to deplete at least 50% of the retained hydrogen inventory in the tank or slurried sludge layer. Depending on waste tank type and SMP riser location, the trapped gas inventory in the tank or slurried sludge layer can be removed by two or three SMPs operating in a manner that ensures adequate mixing [Ref. 22]. The effect of a non-operational SMP is that it could leave up to 50% of the tank or slurried sludge layer contents inadequately mixed, retaining trapped gas inventory (regardless of whether two or three SMPs are required for 100% depletion).

- There have been no operational experiences or studies to determine when adequate mixing occurs after completion of an SBP run. Therefore, operation of the SBPs cannot be used to credit any DSA or non-DSA defined Quiescent Times.

- 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 to deplete the trapped hydrogen inventory in the tank or slurried sludge layer.

It is recognized under certain waste tank conditions during a process upset associated with typical initial sludge agitation processing plans, only a portion of the sludge layer may become slurried sludge within a waste tank. Additionally, cases could occur where the entire sludge layer may not be actually mixed (e.g., due to limited number of waste tank mixing devices operated in the sludge layer), but the layer is considered slurried sludge based on the discussion in Section 3.0 and inputs in Section 4.3.2.2 for sludge agitation. For example, operation of only one SMP (or two slurry pumps/SBPs/CSMPs) for a cumulative period of 10 days is assumed to cause the entire sludge layer (100% cross sectional area) to become slurried sludge. However, the entire sludge layer would not actually be mixed as the settled sludge agitation input is a conservative maximum value for sludge disturbance. The requirements for declaring hydrogen depletion success (stated above), assume an entire layer or entire tank contain slurried sludge (or contain sludge that was actually mixed) and would not be applicable to these scenarios. Should this
situation occur (where only a portion of a sludge layer is considered slurried sludge or a portion of the sludge layer is actually mixed), an engineering evaluation shall be completed to determine the requirements for hydrogen depletion for this waste tank. The evaluation shall consider the location of the waste tank mixing device(s) used for hydrogen depletion in relationship to the area of slurried sludge (or portion of the sludge layer that is actually mixed), and determine the resulting trapped gas depletion/retention percentage.

Tank 26 waste removal performed its first CSMP mixing campaign in February 2019. A sludge sounding performed following a 10-day mixing campaign of all four CSMPs indicated the sludge was disturbed lower in the tank than was expected (i.e., a 32.4-inch disturbance depth versus the 24-inch DSA disturbance depth input). A review of Tank 26 process history indicated that the tank served as the 242-16F evaporator feed tank and canyon receipt tank, having a history of containing highly concentrated supernate, resulting in a waste layer containing a mixture of salt and sludge [Ref. 60, Action 4]. For waste tanks with the potential to contain inter-mixed sludge/salt waste layers, the more conservative waste layer should be assumed for gas release and quiescent time evaluations [Ref. 61].

### 4.2.1.2 QUIESCENT TIME PROGRAM METHODOLOGY

The initial hydrogen concentration, \( y_0 \), shall be 25% of the LFL\(_T\) (3.8% of the LFL\(_T\) for Tank 50) for Rapid and Slow Generation Tanks, or at the higher of 25% of the LFL\(_T\) (3.8% of the LFL\(_T\) for Tank 50) or steady state hydrogen equilibrium accounting for atmospheric breathing using the actual vapor space volume (\( H_{eq} \)) for Very Slow Generation Tanks. Use of the initial hydrogen concentration is considered acceptable for Seismic Release or Spontaneous Liberation Protection due to the following:

- For waste tanks which require continuous waste tank ventilation (i.e., Rapid and Slow Generation Tanks), the ventilation system is adequate to maintain the radiolytic hydrogen concentration less than 25% of the LFL\(_T\).

- For waste tanks which do not require continuous waste tank ventilation (i.e., Very Slow Generation Tanks), the initial hydrogen concentration may exceed 25% of the LFL\(_T\). Use of the higher of 25% of the LFL\(_T\) (3.8% LFL\(_T\) for Tank 50) or steady state hydrogen equilibrium accounting for atmospheric breathing using the actual vapor space volume is needed to protect the assumed initial hydrogen concentration for the waste tanks.

The initial hydrogen concentration \( y_0 \) is added to the trapped gas contribution (TG) from the applicable sludge layer(s) to determine the post seismic initial hydrogen concentration, \( y_0 \) (Seismic).

\[
y_0(\text{Seismic}) = y_0 + TG
\]

### 4.2.1.2.1 SEISMIC RELEASE PROTECTION

Upon depletion of the hydrogen inventory due to pump agitation, the trapped hydrogen gas inventory retained in the slurried sludge is a function of time (i.e., at time equal zero, the trapped gas inventory equals zero) until the maximum retained hydrogen value is reached. The trapped gas release during a seismic event for calculation of Seismic Quiescent Time is a summation of the retained hydrogen in the slurried sludge and in any settled sludge. Trapped gas release from
The waste tank will require a Seismic Quiescent Time if $y_0(\text{Seismic}) \geq \text{LFLOC}$. From Equation 47, $y_0(\text{Seismic})$ is defined as the summation of the initial hydrogen concentration plus the trapped hydrogen gas released from the settled sludge and slurried sludge layer. Therefore, the Seismic Quiescent Time is required for the waste tank if

$$y_0 + T_{\text{settled}} + T_{\text{slurried}} \geq \text{LFLOC} \quad \text{or} \quad \text{Eq. #48} \quad y_0 + \frac{H_{\text{mix}}}{V'} \left[ (V_{\text{solids}} \cdot G_s \cdot C \cdot F_R)_{\text{settled}} + (V_{\text{solids}} \cdot G_s \cdot C \cdot F_R)_{\text{slurried}} \right] \geq \text{LFLOC}$$

Where:

- $\text{LFLOC} =$ Temperature and organic corrected hydrogen concentration at 100% LFL, vol. frac. (see Variable LFLOC Calculation)
- $y_0 =$ Initial hydrogen concentration, 25% of the LFL$_T$ (3.8% of the LFL$_T$ for Tank 50) for Rapid and Slow Generation Tanks, or at the higher of 25% LFL$_T$ (3.8% of the LFL$_T$ for Tank 50) or $H'_\text{eq}$ for Very Slow Generation Tanks, vol. frac. For $H'_\text{eq}$, see Variable $H'_\text{eq}$ Calculation
- $H_{\text{mix}} =$ Fraction of hydrogen in trapped gas, determined using equations in Section 4.1.2.2 Variable $H_{\text{mix}}$ Calculation
- $G_s =$ Fraction of trapped bubble gas (see Variable $G_s$ calculation)
- $V_{\text{solids}} =$ Volume of settled sludge/slurried sludge in the tank that is available to liberate hydrogen, ft$^3$ (see Variable $V_{\text{solids}}$ Calculation)
- $F_R =$ Fraction of trapped gas release from slurried/settled sludge (see Variable $F_R$ Calculation)
- $C =$ Pressure correction (see Variable $C$ Calculation)
- $V'_v =$ Vapor space volume using actual or projected waste tank level, ft$^3$ (see Variable $V'_v$ Calculation)

Equation 51, 52, 53 or 54 will be used to calculate the Seismic Quiescent Time as applicable.

If $y_0(\text{Seismic}) < \text{LFLOC}$, the following two bullets may be used to determine whether the waste tank Seismic Quiescent Time will be infinite.

The waste tank Seismic Quiescent Time will become infinite if one of the criteria below is met:
- The waste tank vapor space never becomes flammable (i.e., hydrogen concentration at equilibrium plus retained hydrogen gas released from slurried sludge/settled sludge is less than LFLOC).
H_{\text{eq}} + T G_{\text{settled}} + T G_{\text{slurried}} < \text{LFL}_{OC} \quad \text{or}

\text{Eq. } #49 \quad \frac{Q_{H2}}{Q_{H2} + Q_{\text{ATM}}} + \frac{H_{\text{mix}}}{V'} \cdot [(V_{\text{solids}} \cdot G_s \cdot C \cdot F_{\text{R}})_{\text{settled}} + (V_{\text{solids}} \cdot G_s \cdot C \cdot F_{\text{R}})_{\text{slurried}}] < \text{LFL}_{OC}

Where:

\text{LFL}_{OC} = \text{Temperature and organic corrected hydrogen concentration at 100\% LFL, vol. frac. (see Variable LFL}_{OC} \text{ Calculation)}

Q_{H2} = \text{Temperature corrected hydrogen generation rate, ft}^3/\text{hr} (\text{see Section 4.1.2.2.1 Variable Q}_{H2} \text{ Calculation)}

Q'_{\text{ATM}} = \text{Atmospheric breathing rate, ft}^3/\text{hr} (\text{see Variable Q'}_{\text{ATM}} \text{ Calculation)}

H_{\text{mix}} = \text{Fraction of hydrogen in trapped gas, determined using equations in Section 4.1.2.2.2 Variable H}_{\text{mix}} \text{ Calculation)}

G_s = \text{Fraction of trapped bubble gas (see Variable } G_s \text{ calculation)}

V_{\text{solids}} = \text{Volume of settled sludge/slurried sludge in the tank that is available to liberate hydrogen, ft}^3 (\text{see Variable } V_{\text{solids}} \text{ Calculation)}

F_{\text{R}} = \text{Fraction of trapped gas release from slurried/settled sludge (see Variable } F_{\text{R}} \text{ Calculation)}

C = \text{Pressure correction (see Variable } C \text{ Calculation)}

V'_{V} = \text{Vapor space volume using actual or projected waste tank level, ft}^3 (\text{see Variable } V'_{V} \text{ Calculation)}

- \ln \left[ \frac{\text{LFL}_{OC} \cdot \frac{Q_{H2}}{Q_{H2} + Q_{\text{ATM}}}}{y_0 + \frac{H_{\text{mix}}}{V'} \cdot [(V_{\text{solids}} \cdot G_s \cdot C \cdot F_{\text{R}})_{\text{settled}} + (V_{\text{solids}} \cdot G_s \cdot C \cdot F_{\text{R}})_{\text{slurried}}] - \frac{Q_{H2}}{Q_{H2} + Q_{\text{ATM}}} \right] \geq (7) \cdot (24)

Where:

\text{LFL}_{OC} = \text{Temperature and organic corrected hydrogen concentration at 100\% LFL, vol. frac. (see Variable LFL}_{OC} \text{ Calculation)}

Q_{H2} = \text{Temperature corrected hydrogen generation rate, ft}^3/\text{hr} (\text{see Section 4.1.2.2.1 Variable Q}_{H2} \text{ Calculation)}

Q'_{\text{ATM}} = \text{Atmospheric breathing rate, ft}^3/\text{hr}, (\text{see Variable } Q'_{\text{ATM}} \text{ Calculation)}

y_0 = \text{Initial hydrogen concentration, 25\% of the LFL}_{T} (3.8\% of the } \text{LFL}_{T} \text{ for Tank 50) for Rapid and Slow Generation Tanks, or at the higher of 25\% LFL}_{T} (3.8\% of the } \text{LFL}_{T} \text{ for Tank 50) or } H'_{\text{eq}} \text{ for Very Slow Generation Tanks), vol. frac.}

H_{\text{mix}} = \text{Fraction of hydrogen in trapped gas, determined using equations in Section 4.1.2.2.2 Variable } H_{\text{mix}} \text{ Calculation)

G_s = \text{Fraction of trapped bubble gas (see Variable } G_s \text{ calculation)}
If none of the criteria above is met, the waste tank Seismic Quiescent Time is required. The Seismic Quiescent Time equation is derived as below.

- Waste tank with $H'_{eq} \geq LFL_{OC}$ ($H'_{eq}$: hydrogen concentration at equilibrium [for calculation, see Variable $H'_{eq}$ Calculation]; $LFL_{OC}$: temperature and organic corrected hydrogen concentration at 100% LFL, vol. frac. [for calculation, see Variable $LFL_{OC}$ Calculation])

The time dependence of the trapped hydrogen inventory for slurried sludge is demonstrated below:

$$G_s \cdot H_{mix} \cdot C = \frac{HR_{100} \cdot Q_{H2} \cdot t}{V_{solids}}$$

The trapped gas contribution is then calculated by substituting the hydrogen inventory, $(G_s \cdot H_{mix} \cdot C)$ into Equation 44 to yield:

$$TG_{slurried} = \frac{V_{solids} \cdot HR_{100} \cdot Q_{H2} \cdot t \cdot FR}{V_{V}'}$$

The equation is then simplified and becomes the below equation.

$$TG_{slurried} = \frac{HR_{100} \cdot Q_{H2} \cdot FR \cdot t}{V_{V}'}$$

Where:

- $TG_{slurried} = \text{Volume fraction of hydrogen retained in slurried sludge, vol. frac}$
- $t = \text{Time trapped gas retained in slurried sludge since the last hydrogen depletion, hours}$
- $Q_{H2} = \text{Temperature corrected hydrogen generation rate, ft}^3/\text{hr}$
- $HR = \text{Percentage of hydrogen generated that is retained in slurried sludge}$
If the waste tank contains a settled sludge layer, the amount of hydrogen gas released from the settled sludge during a seismic event is:

\[ \text{TG}_{\text{settled}} = \frac{V_{\text{solids}} \cdot G_s \cdot H_{\text{mix}} \cdot C \cdot F_R}{V'_v} \]

Where:

- \( \text{TG}_{\text{settled}} \) = Hydrogen released from settled during a seismic event, vol. frac.
- \( V_{\text{solids}} \) = Volume of settled sludge in the tank that is available to liberate hydrogen, ft\(^3\)
- \( G_s \) = Fraction of trapped bubble gas, vol. frac.
- \( H_{\text{mix}} \) = Hydrogen fraction in trapped gas
- \( C \) = Pressure correction
- \( F_R \) = Fraction of trapped gas release from settled sludge
- \( V'_v \) = Vapor space volume using actual or projected waste level, ft\(^3\)

Substituting the slurried sludge and settled sludge trapped gas equations to the post seismic initial hydrogen concentration equation (Equation 47), \( y_0(\text{Seismic}) \), yields:

\[ y_0(\text{Seismic}) = y_0 + \text{TG}_{\text{slurried}} + \text{TG}_{\text{settled}} = y_0 + \left( \frac{H_R}{100} \right) \cdot Q_{H_2} \cdot F_R \cdot t \frac{V_{\text{solids}} \cdot G_s \cdot H_{\text{mix}} \cdot C \cdot F_R}{V'_v} \]

Where:

- \( y_0(\text{Seismic}) \) = Post seismic initial hydrogen concentration, vol. frac.
- \( y_0 \) = Initial hydrogen concentration, vol. frac., 25% of the LFL (3.8% of the LFL\(_T\) for Tank 50) for Rapid and Slow Generation Tanks, or at the higher of 25% of the LFL\(_T\) (3.8% of the LFL\(_T\) for Tank 50) and for \( H'_{\text{eq}} \) Very Slow Generation Tanks

\( y_0(\text{Seismic}) \) is then substituted into the time to LFL equation (Equation 1 in Section 4.1.2.2). To ensure the waste tank vapor space does not reach the LFL\(_{OC}\) less than 7 days (due to trapped hydrogen release), the waste tank time to LFL shall be at least 7 days.

\[ \text{Time to LFL} = \frac{-\ln \left( y_0 + \left( \frac{H_R}{100} \right) \cdot Q_{H_2} \cdot F_R \cdot t \frac{V_{\text{solids}} \cdot G_s \cdot H_{\text{mix}} \cdot C \cdot F_R}{V'_v} \right) + V_{\text{solids}} \cdot G_s \cdot H_{\text{mix}} \cdot C \cdot F_R}{Q_{H_2} + Q'_{\text{ATM}}} \leq 7 \text{ days} \]

Rearranging the equation to solve for quiescent time, \( t_{\text{seismic}} \) (\( t \) in equation above becomes \( t_{\text{seismic}} \)) for waste tanks containing slurried sludge and settled sludge layers, yields:
If the waste tank contains slurried sludge but no settled sludge layer, $t_{seismic}$ becomes:

$$t_{seismic} = \frac{1}{24} \frac{H_R}{100} \frac{Q_{H_2}}{Q_{H_2} \cdot F_{R, slurried}} \left( e^{-\frac{(Q_{H_2} + Q_{ATM})}{V_{V}}} \right) - y_0 \left( \frac{Q_{H_2}}{Q_{H_2} + Q_{ATM}} \right)$$

Where:

- $t_{seismic}$ = Seismic Quiescent Time, days
- $LFL_{OC}$ = Temperature and organic corrected hydrogen concentration at 100% LFL, vol. frac. (see Variable $LFL_{OC}$ Calculation)
- $Q_{H_2}$ = Temperature corrected hydrogen generation rate, ft³/hr (see Section 4.1.2.2.1 Variable $Q_{H_2}$ Calculation)
- $Q_{ATM}$ = Atmospheric breathing rate, ft³/hr, (see Variable $Q_{ATM}$ Calculation)
- $H_{mix}$ = Fraction of hydrogen in trapped gas, determined using equations in Section 4.1.2.2.2 Variable $H_{mix}$ Calculation
- $G_s$ = Fraction of trapped bubble gas (see Variable $G_s$ calculation)
- $V_{solids}$ = Volume of settled sludge in the tank that is available to liberate hydrogen, ft³ (see Variable $V_{solids}$ Calculation)
- $F_{R, slurried}$ = Fraction of trapped gas release from slurried sludge (see Variable $F_{R, slurried}$ calculation)
- $F_{R, settled}$ = Fraction of trapped gas release from settled sludge (see Variable $F_{R, settled}$ calculation)
- $H_R$ = Percentage of hydrogen generation that is retained in slurried sludge (see Variable $H_R$ Calculation)
- $y_0$ = Initial hydrogen concentration, 25% of the LFLₜ (3.8% of the LFLₜ for Tank 50) for Rapid and Slow Generation Tanks, or at the higher of 25% of the LFLₜ (3.8% of the LFLₜ for Tank 50) or $H_{eq}$ for Very Slow Generation Tanks, vol. frac. For $H_{eq}$ calculation, see Variable $H_{eq}$ Calculation
- $V'_{V}$ = Vapor space volume using actual or projected waste tank level, ft³, (see Variable $V'_{V}$ Calculation)
- $7$ = Minimum time between waste tank mixing device operation such that the waste tank vapor space will not become flammable, days
24 = Conversion factor from hours to days
C = Pressure correction (see Variable C Calculation)

- **Waste tanks with** $H_{eq} < LFL_{OC}$ ($H_{eq}$: hydrogen concentration at equilibrium [for calculation, see Variable $H_{eq}$ Calculation]; $LFL_{OC}$: temperature and organic corrected hydrogen concentration at 100% LFL, vol. frac. [for calculation, see Variable $LFL_{OC}$ Calculation])

The time dependence of the trapped gas inventory in the slurried and settled sludge to reach $LFL_{OC}$ when the waste tank contains both the slurried and settled sludge layers is displayed in the expression below.

$$y_0(\text{Seismic}) = y_0 + TG_{slurried} + TG_{settled} = y_0 + \frac{(H_R/300)Q_{H2}t\cdot F_{R,slurried}}{V_v'} + \frac{V_{solids}G_S H_{mix} C F_{R,settled}}{V_v'} = LFL_{OC}$$

Where:

- $y_0(\text{Seismic})$ = Post seismic initial hydrogen concentration, vol. frac.
- $y_0$ = Initial hydrogen concentration, 25% of the $LFL_T$ (3.8% of the $LFL_T$ for Tank 50) for Rapid and Slow Generation Tanks, or at the higher of 25% of the $LFL_T$ (3.8% of the $LFL_T$ for Tank 50) or $H_{eq}$ for Very Slow Generation Tanks), vol. frac.
- $H_R$ = Percentage of hydrogen generation that is retained in slurried sludge
- $Q_{H2}$ = Temperature corrected hydrogen generation rate, ft³/hr
- $t$ = Time trapped gas retained in slurried/settled sludge since the last hydrogen depletion, hours
- $V_v'$ = Vapor space volume using actual or projected waste tank level, ft³
- $V_{solids}$ = Volume of settled sludge that is available to liberate hydrogen, ft³
- $G_S$ = Fraction of trapped bubble gas, vol. frac.
- $H_{mix}$ = Fraction of hydrogen in trapped gas
- $C$ = Pressure correction
- $F_{R,slurried}$ = Fraction of trapped gas release from slurried sludge
- $F_{R,settled}$ = Fraction of trapped gas release from settled sludge
- $LFL_{OC}$ = Temperature and organic corrected hydrogen concentration at 100% LFL, vol. frac.

To calculate the Seismic Quiescent Time, $t_{seismic}$, for waste tanks containing slurried sludge and settled sludge, the above equation is rearranged to solve for $t$ and becomes Equation 53.
Eq. #53  \[ t_{\text{seismic}} = \frac{1}{24} \cdot \left( \frac{\text{HR}}{100} \right)_{\text{QH}_2-F_{R,\text{slurried}}} \cdot \left( \text{LFL}_{\text{OC}} - y_0 - \frac{V_{\text{solids}} \cdot G_S \cdot H_{\text{mix}} \cdot C \cdot F_{R,\text{settled}}}{V'_V} \right) \]

Where:

\( t_{\text{seismic}} \) = Seismic Quiescent Time, days

\( \text{LFL}_{\text{OC}} \) = Temperature and organic corrected hydrogen concentration at 100% LFL, vol. frac. (see Variable LFL_{OC} Calculation)

\( y_0 \) = Initial hydrogen concentration, 25% of the LFL\(_T\) (3.8% of the LFL\(_T\) for Tank 50) for Rapid and Slow Generation Tanks, or at the higher of 25% of the LFL\(_T\) (3.8% of the LFL\(_T\) for Tank 50) or \( H'_{\text{eq}} \) for Very Slow Generation Tanks), vol. frac. For LFL\(_T\) and \( H'_{\text{eq}} \) calculations, see Variable LFL\(_T\) Calculation and Variable \( H'_{\text{eq}} \) Calculation, respectively

\( V_{\text{solids}} \) = Volume of settled sludge that is available to liberate hydrogen, ft\(^3\) (see Variable \( V_{\text{solids}} \) Calculation)

\( G_S \) = Fraction of trapped bubble gas, vol. frac. (see Variable \( G_S \) Calculation)

\( H_{\text{mix}} \) = Fraction of hydrogen in trapped gas, determined using equations in Section 4.1.2.2.2 Variable \( H_{\text{mix}} \) Calculation

\( C \) = Pressure correction (see Variable \( C \) Calculation)

\( F_{R,\text{slurried}} \) = Fraction of trapped gas release from slurried sludge (see Variable \( F_{R} \) Calculation)

\( F_{R,\text{settled}} \) = Fraction of trapped gas release from settled sludge (see Variable \( F_{R} \) Calculation)

\( V'_V \) = Vapor space volume using actual or projected waste tank level, ft\(^3\) (see Variable \( V'_V \) Calculation)

\( H_R \) = Percentage of hydrogen generation that is retained in slurried sludge (see Variable \( H_R \) Calculation)

\( \text{QH}_2 \) = Temperature corrected hydrogen generation rate, ft\(^3\)/hr (see Section 4.1.2.2.1 Variable \( \text{QH}_2 \) Calculation)

\( 24 \) = Conversion factor from hours to days

For waste tanks containing slurried sludge but no settled sludge layer, the Seismic Quiescent Time is calculated using Equation 54.

Eq. #54  \[ t_{\text{seismic}} = \frac{1}{24} \cdot \left( \frac{\text{HR}}{100} \right)_{\text{QH}_2-F_{R,\text{slurried}}} \cdot (\text{LFL}_{\text{OC}} - y_0) \]

Where:

\( t_{\text{seismic}} \) = Seismic Quiescent Time, days

\( \text{LFL}_{\text{OC}} \) = Temperature and organic corrected hydrogen concentration at 100% LFL for all waste tanks, vol. frac. (see Variable LFL_{OC} Calculation)
\[ y_0 = \text{Initial hydrogen concentration, 25\% of the LFL}_T \text{ (3.8\% of the LFL}_T \text{ for Tank 50) for Rapid and Slow Generation Tanks, or at the higher of 25\% of the LFL}_T \text{ (3.8\% of the LFL}_T \text{ for Tank 50) or H'}_{\text{eq}} \text{ for Very Slow Generation Tanks), vol. frac. For LFL}_T \text{ and H'}_{\text{eq}} \text{ calculations, see Variable LFL}_T \text{ Calculation and Variable H'}_{\text{eq}} \text{ Calculation, respectively} \]

\[ V'_v = \text{Vapor space volume using actual or projected waste tank level, ft}^3 \text{ (see Variable } V'_v \text{ Calculation)} \]

\[ H_R = \text{Percentage of hydrogen generation that is retained in slurried sludge (see Variable } H_R \text{ Calculation)} \]

\[ Q_{H2} = \text{Temperature corrected hydrogen generation rate, ft}^3/\text{hr (see Section 4.1.2.2.1 Variable } Q_{H2} \text{ Calculation)} \]

\[ F_{R,\text{slurried}} = \text{Fraction of trapped gas release from slurried sludge (see Variable } F_R \text{ Calculation)} \]

\[ 24 = \text{Conversion factor from hours to days} \]

When the number of waste tank mixing devices available to liberate the retained trapped gas is less than the number of waste tank mixing devices required (e.g., only 3 slurry pumps instead of 4 slurry pumps), the generic methodology defined in Reference 45 can be used to calculate the adjusted Seismic Quiescent Time.

**VARIABLE LFL_{OC} CALCULATION – QUIESCENT TIME PROGRAM**

- **Waste tanks excluding Tank 50**

The temperature and organic corrected hydrogen concentration at 100\% LFL is calculated as follows:

\[ \text{LFL}_{OC} = \text{LFL}_{25C} \cdot [1 - A \cdot (T - 25)] - \text{OC} \]

Where:

\[ \text{LFL}_{OC} = \text{LFL for hydrogen corrected for organic contribution and temperature, vol. frac.} \]

\[ \text{LFL}_{25C} = \text{LFL for hydrogen at } 25^\circ\text{C, (i.e., 0.04-volume fraction), vol. frac.} \]

\[ \text{OC} = \text{The organic contribution equivalent hydrogen concentration (i.e., 5\% of LFL}_{25C} \text{ (0.002-volume fraction)), vol. frac.} \]

\[ A = \text{Empirical coefficient (Zabetakis attenuation factor), (i.e., 0.0011 per Ref. 1), } \text{C}^{-1} \]

\[ T = \text{Temperature at which LFL is to be evaluated in } ^\circ\text{C} \]

- **Tank 50**: Due to the contribution of trace organics of up to 5\% of the CLFL, Isopar of up to 51.2\% of the CLFL, LFL_{OC} for Tank 50 at 100\% of the CLFL is calculated to be 43.8\% of the LFL at 43^\circ\text{C} [Ref. 24]. Therefore, the LFL_{OC} is calculated using the equation below:
Eq. #56  
\[ \text{LFL}_{\text{OC}} = \frac{43.8}{100} \cdot \text{LFL}_{25C} \cdot [1 - A \cdot (43 - 25)] \]

Where:
- \( \text{LFL}_{\text{OC}} \) = LFL for hydrogen corrected for organic contribution and temperature, vol. frac.
- \( \text{LFL}_{25C} \) = LFL for hydrogen at 25°C, (i.e., 0.04-volume fraction), vol. frac.
- \( A \) = Empirical coefficient (Zabetakis attenuation factor), (i.e., 0.0011 per Ref. 1), °C⁻¹

**VARIABLE LFL\(_T\) CALCULATION – QUIESCENT TIME PROGRAM**

LFL for hydrogen can be corrected for temperature. Using the Burgess - Wheeler correlation, the temperature corrected LFL for hydrogen, \( \text{LFL}_T \), is determined as follows:

Eq. #57  
\[ \text{LFL}_T = \text{LFL}_{25C} \cdot [1 - A \cdot (T - 25)] \]

Where:
- \( \text{LFL}_T \) = LFL for hydrogen corrected for temperature, vol. frac.
- \( \text{LFL}_{25C} \) = LFL for hydrogen at 25°C, (i.e., 0.04-volume fraction), vol. frac.
- \( A \) = Empirical coefficient (Zabetakis attenuation factor), (i.e., 0.0011 per Ref. 1), °C⁻¹
- \( T \) = Temperature at which LFL is to be evaluated in °C [Refs. 1, 24]

**VARIABLE Q\(_{\text{ATM}}\) CALCULATION – QUIESCENT TIME PROGRAM**

The atmospheric breathing assumptions and methodology are established in Reference 1 Section 3.4.1.5.5. The atmospheric breathing rate is determined as follows:

Eq. #58  
\[ Q'_{\text{ATM}} = \frac{\text{mean atm. fluctuation}}{1013} \cdot \frac{V'_V}{24} \]

Where:
- \( Q'_{\text{ATM}} \) = Atmospheric breathing rate, ft³/hr
- \( \text{Mean atm. fluctuation} \) = Mean pressure fluctuation, 5 mbar/day [Ref. 41]
- \( V'_V \) = Vapor space volume, ft³, based on the actual/projected waste tank level (see Variable \( V'_V \) Calculation)
- \( 24 \) = Conversion factor from days to hours
- \( 1013 \) = Standard atmospheric pressure, mbar
VARIABLE $H'_{eq}$ CALCULATION – QUIESCENT TIME PROGRAM

The steady state hydrogen equilibrium accounting for atmospheric breathing using the actual vapor space volume can be calculated using the equation below.

Eq. #59

$$H'_{eq} = \frac{Q_{H2}}{Q_{H2} + Q_{ATM}}$$

Where:

$H'_{eq}$ = Hydrogen concentration at equilibrium for Very Slow Generation Tanks, vol. frac.

$Q_{H2}$ = Total hydrogen volumetric evolution rate, ft$^3$/hr (see Variable $Q_{H2}$ in Section 4.1.2.2.1)

$Q'_{ATM}$ = Atmospheric breathing rate, ft$^3$/hr (see Variable $Q'_{ATM}$ Calculation)

VARIABLE $V'_{V}$ CALCULATION – QUIESCENT TIME PROGRAM

The vapor space volume is based on the actual or projected waste level. The calculations account for the maximum missing waste volume when considering incoming transfers. The following equation is the vapor space volume calculation, in cubic feet:

Eq. #60

$$V'_{V} = 0.13368 \left[ V_T - (L_{tank} \cdot Ff) - MMW \right]$$

Where:

$V'_{V}$ = Vapor space volume based on the actual/projected waste tank level, ft$^3$

$V_T$ = Total tank vapor space volume (empty tank), gallons

$L_{tank}$ = Actual or projected waste level, inches

0.13368 = Conversion factor from gallons to ft$^3$

$Ff$ = Nominal waste tank fill factor, gal/in (see Section 3.0)

$MMW$ = Maximum missing waste volume, gallons (to be accounted for in the receipt tank for incoming transfers, see discussion below)

For waste tanks receiving transfers from a sending vessel greater than or equal to 15,000 gallons or has continuous makeup capability, $MMW$ is equal to 15,000 gallons. If the sending vessel is less than 15,000 gallons and does not have continuous makeup capability, $MMW$ is equal to the volume of the vessel. 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. In lieu of using the actual/projected waste contents, the evaluation may be based upon the vapor space volume protected by the Tank Fill Limits Program. Liquid additions to the waste tank from DWS do not have continuous makeup capability.
**VARIABLE C CALCULATION – QUIESCENT TIME PROGRAM**

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 ($C = \frac{P_{avg}}{P_{atm}}$). The expansion correction is determined from the following head pressure equation [Ref. 14]:

\[
P_{avg} = \left( \sum_{a=2}^{n} \frac{\rho_a \cdot g \cdot h_a}{X} \right) + \frac{1}{2} \frac{\rho_1 \cdot g \cdot h_1}{X} + p_{atm}
\]

Where:

- $P_{avg}$ = Hydrostatic head pressure, atm
- $n$ = Number of layers above the evaluated settled/slurried sludge layer
- $\rho_a$ = Density of layer material above the evaluated settled/slurried sludge layer, kg/m³
- $\rho_1$ = Density of the evaluated settled/slurried sludge material, kg/m³
- $h_a$ = Height of layer above the evaluated settled/slurried sludge layer, m
- $h_1$ = Height of the evaluated settled/slurried sludge layer, m
- $g$ = Standard acceleration of gravity ($9.81 \text{ m/s}^2$)
- $p_{atm}$ = Atmospheric pressure, atm
- $X$ = 101325, Pa/atm

**VARIABLE HR CALCULATION – QUIESCENT TIME PROGRAM**

The percentage of hydrogen generated that is retained in the slurried sludge ($H_R$) is based on the depth of the slurried sludge (until the maximum retained hydrogen value is reached as determined using the maximum trapped bubble gas volume and associated hydrogen percent in trapped gas).

- If the slurried sludge depth is less than 40 inches, 25% of the hydrogen generated is retained.
- If the slurried sludge depth is greater than or equal to 40 inches and less than 90 inches, 50% of the hydrogen generated is retained.
- If the slurried sludge depth is greater than or equal to 90 inches and less than 110 inches, 75% of the hydrogen generated is retained.
- If the slurried sludge depth is greater than or equal to 110 inches, 100% of the hydrogen generated is retained.

**VARIABLE FR CALCULATION – SEISMIC QUIESCENT TIME PROGRAM**

The percentage of trapped gas released from the slurried sludge is 100% (1.00 volume fraction).

The percentage of trapped gas released from the affected settled sludge layer is 50% (0.50 volume fraction).
**VARIABLE $V_{\text{solids}}$ CALCULATION – SEISMIC QUIESCENT TIME PROGRAM**

All the slurried sludge in the waste tank is considered to release hydrogen during a seismic event.

For waste tanks that contain a saltcake layer of greater than 40 inches overlying settled sludge, the saltcake layer has high enough shear strengths to resist mobilization and gas release from settled sludge during a seismic event. Therefore, the trapped gas release from the settled sludge layer is 0%.

Otherwise, the volume of settled sludge available to liberate hydrogen during a seismic event is proportional to the height of the settled sludge layer and the overlying waste layer above it.

\[
\text{Settled sludge volume (gals)} = \frac{\text{Settled sludge layer (inches)} + \text{Total overlying waste layer (inches)}}{400 \text{ inches}}
\]

Where: Total overlying waste level = Depth of total overlying waste level (including saltcake, slurried sludge, and supernate) above the settled sludge layer

**VARIABLE $G_s$ CALCULATION – QUIESCENT TIME PROGRAM**

The maximum percentage of trapped bubble gas released from slurried sludge is 20% by volume (0.20 volume fraction) [Ref. 1].

The maximum percentage of trapped bubble gas released from settled sludge is 10% by volume (0.10 volume fraction) [Ref. 1].

**4.2.1.2.2 SPONTANEOUS LIBERATION PROTECTION**

Waste tanks under Spontaneous Liberation Protection shall maintain the minimum spontaneous time to LFL (CLFL for Tank 50) defined by the waste tank flammability classification. Equations used to calculate the spontaneous time to LFL are provided in Section 4.1.2.2.2. Once the spontaneous time to LFL is calculated, the Spontaneous Quiescent Times for waste tanks under the Spontaneous Liberation Protection Program can be determined using the guidelines below. If a Spontaneous Quiescent Time is required, and thus requires waste tank mixing devices to be run, the quiescent time only considers hydrogen depletion to occur in the slurried sludge layer. If additional solids layers will be impacted by the pump run, the additional trapped hydrogen release must be considered in an associated gas release evaluation.

- If the waste tank is designated as a Very Slow Generation Tank, the waste tank has an infinite Spontaneous Quiescent Time.
- If the spontaneous time to LFL $\geq$ 28 days and the waste tank is designated as a Slow or Rapid Generation Tank, then waste tank has an infinite Spontaneous Quiescent Time.
- If 7 days $\leq$ spontaneous time to LFL $< 28$ days and the waste tank is designated as a Rapid Generation Tank, then waste tank has an infinite Spontaneous Quiescent Time.
- If 7 days $\leq$ spontaneous time to LFL $< 28$ days and the waste tank is designated as a Slow Generation Tank, then the waste tank must be reclassified as RAPID or Spontaneous Quiescent Time shall be required. The Spontaneous Quiescent Time will be calculated in the same manner as the Seismic Quiescent Time (see Section 4.2.1.2.1) except only trapped
gas release from slurried sludge is considered and the time it takes for the waste tanks to become flammable is 28 days. Equation 52 in Section 4.2.1.2.1 in which 7-day time to LFL is replaced with 28-day time to LFL (see Equation 62 below) can be used to determine the Spontaneous Quiescent Time. Calculations of those variables in Equation 62 except \( Q_{H2} \) can be found in Section 4.2.1.2.1. Variable \( Q_{H2} \) calculation is presented in Section 4.1.2.2.1.

\[
\text{Eq. #62} \quad t_{\text{spontaneous}} = \frac{1}{24} \frac{H_R}{100} Q_{H2} F_{R,slurried} \left( \frac{LFL_{OC} - \frac{Q_{H2}}{Q_{H2} + Q_{ATM}}}{e^{-(28/24)\left(\frac{Q_{H2} + Q_{ATM}}{V_v}\right)}} - y_0 + \frac{Q_{H2}}{Q_{H2} + Q_{ATM}} \right)
\]

Where:

- \( t_{\text{spontaneous}} \) = Spontaneous Quiescent Time, days
- \( LFL_{OC} \) = Temperature and organic corrected hydrogen concentration at 100% LFL, vol. frac. (see Section 4.2.1.2.1 Variable \( LFL_{OC} \) Calculation)
- \( Q_{H2} \) = Temperature corrected hydrogen generation rate, ft³/hr (see Section 4.1.2.2.1 Variable \( Q_{H2} \) Calculation)
- \( Q'_{ATM} \) = Atmospheric breathing rate, ft³/hr, (see Section 4.2.1.2.1 Variable \( Q'_{ATM} \) Calculation)
- \( H_R \) = Percentage of hydrogen generation that is retained in slurried sludge (see Section 4.2.1.2.1 Variable \( H_R \) Calculation)
- \( y_0 \) = Initial hydrogen concentration, vol. frac. \( y_0 \) is equal to 3.8% of the LFLT for Tank 50 and 25% of the LFLT for other waste tanks (For LFLT calculation, see Variable LFLT Calculation in Section 4.2.1.2.1)
- \( F_{R,slurried} \) = Fraction of trapped gas released from slurried sludge (see Section 4.2.1.2.1 Variable \( F_R \) Calculation)
- \( V'_{v} \) = Vapor space volume using actual or projected waste tank level, ft³, (see Section 4.2.1.2.1 Variable \( V'_{v} \) Calculation)
- 28 = Minimum time to LFL, days, required for a Slow tank with spontaneous time to LFL less than 28 days
- 24 = Conversion factor from days to hours

- If spontaneous time to LFL < 28 days (excluding immediate spontaneous time to LFL) and the waste tank is designated as a Slow Generation Tank, a Spontaneous Quiescent Time shall be required. Equation 62 above can be used to determine the Spontaneous Quiescent Time for the waste tank.

- If spontaneous time to LFL < 7 days (excluding immediate spontaneous time to LFL) and the waste tank is designated as a Rapid Generation Tank, a Spontaneous Quiescent Time shall be required. Equation 52 in Section 4.2.1.2.1, which is Equation 63 below, can be used to determine the Spontaneous Quiescent Time for the waste tank. Calculation of variable \( Q_{H2} \) in Equation 63 is provided in Section 4.1.2.2.1. Other variable calculations are provided in Section 4.2.1.2.1.
Eq. #63  \[ t_{\text{spontaneous}} = \frac{1}{24} \cdot \frac{V'}{V_y} \cdot \frac{H_R}{100} \cdot Q_{H2} \cdot F_{R,\text{slurried}} \]

\[
\left( \frac{LFL_{OC} - \frac{Q_{H2}}{Q_{H2} + Q_{ATM} \cdot \frac{V'}{V_y}}}{e^{-\frac{7}{24}\left(\frac{Q_{H2} + Q_{ATM}}{V_y}\right)}} \right) - y_0 + \frac{Q_{H2}}{Q_{H2} + Q_{ATM} \cdot \frac{V'}{V_y}} \]

Where:

- \( t_{\text{spontaneous}} \) = Spontaneous Quiescent Time, days
- \( LFL_{OC} \) = Temperature and organic corrected hydrogen concentration at 100% LFL, vol. frac. (see Section 4.2.1.2.1 Variable LFL_{OC} Calculation)
- \( Q_{H2} \) = Temperature corrected hydrogen generation rate, ft³/hr (see Section 4.1.2.2.1 Variable \( Q_{H2} \) Calculation)
- \( Q'_{ATM} \) = Atmospheric breathing rate, ft³/hr, (see Section 4.2.1.2.1 Variable \( Q'_{ATM} \) Calculation)
- \( H_R \) = Percentage of hydrogen generation that is retained in slurried sludge (see Section 4.2.1.2.1 Variable \( H_R \) Calculation)
- \( y_0 \) = Initial hydrogen concentration, vol. frac. \( y_0 \) is equal to 3.8% of the LFL_{T} for Tank 50 and 25% of the LFL_{T} for other waste tanks (For LFL_{T} calculation, see Variable LFL_{T} Calculation in Section 4.2.1.2.1)
- \( F_{R,\text{slurried}} \) = Fraction of trapped gas released from slurried sludge (see Section 4.2.1.2.1 Variable \( F_R \) Calculation)
- \( V'_{V} \) = Vapor space volume using actual or projected waste tank level, ft³, (see Section 4.2.1.2.1 Variable \( V'_{V} \) Calculation)
- \( 7 \) = Minimum time to LFL, days
- \( 24 \) = Conversion factor from days to hours

- If spontaneous time to LFL is immediate and \( H'_{eq} \geq LFL_{OC} \) (\( H'_{eq} \): hydrogen concentration at equilibrium [for calculation, see Section 4.2.1.2.1 Variable \( H'_{eq} \) Calculation]; \( LFL_{OC} \): temperature and organic corrected hydrogen concentration at 100% LFL, vol. frac. [for calculation, see Section 4.2.1.2.1 Variable \( LFL_{OC} \) Calculation]), then
  - If the waste tank is designated as a Slow Generation Tank, the waste tank Spontaneous Quiescent Time can be determined using Equation 62.
  - If the waste tank is designated as a Rapid Generation Tank, the waste tank Spontaneous Quiescent Time can be determined using Equation 63.

- If spontaneous time to LFL is immediate and \( H'_{eq} < LFL_{OC} \) (\( H'_{eq} \): hydrogen concentration at equilibrium [for calculation, see Section 4.2.1.2.1 Variable \( H'_{eq} \) Calculation]; \( LFL_{OC} \): temperature and organic corrected hydrogen concentration at 100% LFL, vol. frac. [for calculation, see Section 4.2.1.2.1 Variable \( LFL_{OC} \) Calculation]), the Spontaneous Quiescent Time can be determined using Equation 54 in Section 4.2.1.2.1, which is Equation 64 below. Calculation of variable \( Q_{H2} \) in Equation 64 is provided in Section 4.1.2.2.1. Other variable calculations are provided in Section 4.2.1.2.1.
\[
\text{Eq. #64 } \quad t_{\text{spontaneous}} = \frac{1}{24} \left[ \frac{V'_{V} H_{R}}{Q_{H2} F_{R,\text{slurried}}} \right] (LFL_{OC} - y_{0})
\]

Where:

- \( t_{\text{spontaneous}} \): Spontaneous Quiescent Time, days
- \( LFL_{OC} \): Temperature and organic corrected hydrogen concentration at 100% LFL, vol. frac. (see Section 4.2.1.2.1 Variable LFLOC Calculation)
- \( y_{0} \): Initial hydrogen concentration, 25% of the LFL \((3.8\% \text{ of the LFL for Tank 50})\) for Rapid and Slow Generation Tanks, or at the higher of 25% of the LFL \((3.8\% \text{ of the LFL for Tank 50})\) or \(H'_{eq}\) for Very Slow Generation Tanks), vol. frac. For LFL and \(H'_{eq}\) calculations, see Section 4.2.1.2.1 Variable LFLT Calculation and Variable \(H'_{eq}\) Calculation, respectively
- \( V'_{V} \): Vapor space volume using actual or projected waste tank level, ft\(^3\) (see Section 4.2.1.2.1 Variable V'V Calculation)
- \( H_{R} \): Percentage of hydrogen generation that is retained in slurried sludge (see Section 4.2.1.2.1 Variable \(H_{R}\) Calculation)
- \( Q_{H2} \): Temperature corrected hydrogen generation rate, ft\(^3\)/hr (see Section 4.1.2.2.1 Variable \(Q_{H2}\) Calculation)
- \( F_{R,\text{slurried}} \): Fraction of trapped gas released from slurried sludge (see Section 4.2.1.2.1 Variable \(F_{R}\) Calculation)
- 24: Conversion factor from hours to days

When the number of waste tank mixing devices available to liberate the retained trapped gas is less than the number of waste tank mixing devices required (e.g., only 3 slurry pumps instead of 4 slurry pumps), the generic methodology defined in Reference 45 can be used to calculate the adjusted Spontaneous Quiescent Time.

**4.2.2 National Fire Protection Association Spontaneous Quiescent Time**

National Fire Protection Association (NFPA) code (NFPA 69 “Explosion Prevention System”) was written to provide guidance in the installation of specific systems for the prevention of explosion. This code is applied to the Tank Farm waste tanks to aid in the control of explosion potential as required per the Standards/Requirements Identification Document (SRID) Section FA-12 “Fire Protection” [Ref. 35].

To quote Reference 35, “The combustible concentration shall be maintained at or below 25 percent of the lower flammability limit unless the following conditions apply: (1) Where automatic instrumentation with safety interlocks is provided, the combustible concentration shall be permitted to be maintained at or below 60% of the lower flammability limit.” The flammable limit of 25% of the LFL is established to allow ample time for appropriate actions to take place to prevent the trapped vapors from escalating to a condition where they can become flammable. Purge ventilation systems are installed in the Tank Farm waste tanks to maintain the waste tank vapor space at or below 25% of the LFL. According to Reference 35, given an equivalence of
protection obtained by instituting administrative controls versus installing automatic interlocks for controlling the tanks flammable gas concentration at or below 60% of the LFL, the hydrogen concentration in the waste tank vapor space can be maintained at or below 60% of the LFL_T and therefore meets the requirements defined in NFPA 69. To implement the administrative actions, the configuration of the waste tanks containing slurried sludge should be altered (e.g., reduce the tank level/slurried sludge level) to limit the amount of trapped gas released during a spontaneous liberation event or the waste tank mixing devices should be periodically operated, if required, to release the hydrogen gas trapped in the slurried sludge. The quiescent time requiring the waste tank mixing devices to be operated periodically in the waste tanks containing slurried sludge to limit the trapped gas release from the slurried sludge from causing the waste tank vapor space to exceed 60% of the LFL_T is defined as NFPA Spontaneous Quiescent Time Program. The NFPA Spontaneous Quiescent Time Program is not part of the DSA defined Quiescent Time Program. If an NFPA Spontaneous Quiescent Time is required, and thus requires waste tank mixing devices to be run, the Spontaneous Quiescent Time only considers hydrogen depletion to occur in the slurried sludge layer. If additional solids layers will be impacted by the pump run, the additional trapped hydrogen release must be considered in an associated gas release evaluation.

Upon hydrogen inventory depletion due to waste tank mixing device operation, a portion of hydrogen gas generated from the radiolytic decomposition of water becomes trapped in the slurried sludge. The amount of hydrogen gas retained in the slurried sludge is a function of time until it reaches the maximum inventory (determined based on the maximum trapped bubble gas volume [20% of the affected slurried sludge] and the associated hydrogen percent in trapped gas [determined in Section 4.1.2.2.2 Variable H_{mix} Calculation]). Calculations of variables provided in this section are only applicable to this section unless otherwise noted.

The NFPA Spontaneous Quiescent Time will be infinite for a waste tank when the total trapped hydrogen gas (y_0 + T_{GSS}) released into the waste tank vapor space is less than or equal to 60% of the LFL_T as expressed below.

$$\text{Eq. \#65} \quad (y_0 + T_{GSS}) \leq 0.6 \times \text{LFL}_T$$

Where:

- **y_0** = Initial hydrogen concentration, vol. frac., (see Variable y_0 Calculation)
- **T_{GSS}** = Hydrogen concentration due to trapped hydrogen gas release from slurried sludge, vol. frac., (see Variable T_{GSS} Calculation)
- **LFL_T** = LFL corrected for temperature (see Variable LFL_T Calculation)

The NFPA Spontaneous Quiescent Time will be infinite for a Very Slow waste tank when the total trapped gas (y_0 + T_{GSS}) released into the waste tank vapor space is less than the LFLOC. For LFLOC, see Variable LFLOC Calculation in Section 4.2.1.2.1.

If the total trapped gas release exceeds 60% of the LFL_T, the waste tank configuration must be altered (e.g., reduce waste level, adjust supernate chemistry) or mixing devices must be
periodically operated to limit the volume of trapped gas released from the slurried sludge layer so the resulting hydrogen concentration in the waste tank vapor space is less than or equal to 60% of the LFL_T. The NFPA Spontaneous Quiescent Time and is calculated as follows:

\[ t_{\text{NFPA Qtime}} = \frac{(y_{60\%} - y_0) \cdot V'_v \cdot 1}{24} \]

Where:
- \( t_{\text{NFPA Qtime}} \) = NFPA Quiescent Time, days
- \( y_{60\%} \) = Hydrogen concentration at 60% of the LFL_T, vol. frac., equal to 0.60 * LFL_T, for LFL_T see Variable LFLT Calculation
- \( y_0 \) = Initial hydrogen concentration, vol. frac. (see Variable \( y_0 \) Calculation)
- \( V'_v \) = Vapor space volume based on actual/projected tank level, ft^3 (see Variable \( V'_v \) Calculation)
- \( F_R \) = Volume fraction of trapped release (see Variable \( F_R \) Calculation)
- 24 = Conversion factor from hours to days
- \( Q_{H2} \) = Temperature corrected hydrogen generation rate, ft^3/hr (see Section 4.1.2.2.1 Variable \( Q_{H2} \) Calculation)
- \( H_R \) = Percentage of hydrogen generation that is retained in slurried sludge (See Variable \( H_R \) Calculation)

When the number of waste tank mixing devices available to liberate the retained trapped gas is less than the number of waste tank mixing devices required (e.g., only 3 slurry pumps instead of 4 slurry pumps), the generic methodology defined in Reference 45 can be used to calculate the adjusted NFPA Quiescent Time.

**VARIABLE TGSS CALCULATION – NFPA SPONTANEOUS QUIESCENT TIME**

The vapor space hydrogen concentration due to trapped gas release from slurried sludge is determined as follows:

\[ TGSS = \frac{V_{ss} \cdot G_s \cdot H_{mix} \cdot C \cdot F_R}{V'_v} \]

Where:
- \( V_{ss} \) = Volume of slurried sludge, gallons (see Variable \( V_{ss} \) Calculation)
- \( G_s \) = Volume fraction of trapped bubble gas, vol. frac. (see Variable \( G_Ss \) Calculation)
- \( H_{mix} \) = Volume fraction of hydrogen in trapped gas, vol. frac. (see Variable \( H_{mix} \) Calculation in Section 4.1.2.2.2)
- \( C \) = Pressure correction factor (see Variable \( C \) Calculation)
F<sub>R</sub> = Volume fraction of trapped gas release (see Variable F<sub>R</sub> Calculation)

V<sub>V</sub> = Vapor space volume using actual/projected waste tank level, gallons (see Variable V<sub>V</sub> Calculation)

TG<sub>SS</sub> = Volume fraction of hydrogen released from slurried sludge, vol. frac.

**VARIABLE V<sub>ss</sub> CALCULATION – NFPA SPONTANEOUS QUIESCENT TIME**

All the slurried sludge in the waste tank is considered to release hydrogen during a spontaneous liberation event and is used in determination of TG<sub>SS</sub> [Ref. 1].

**VARIABLE G<sub>s</sub> CALCULATION – NFPA SPONTANEOUS QUIESCENT TIME**

The maximum percentage of trapped bubble gas in slurried sludge is 20% by volume (0.20 volume fraction) [Ref. 1].

**VARIABLE F<sub>R</sub> CALCULATION – NFPA SPONTANEOUS QUIESCENT TIME**

The percentage of trapped gas released from the slurried sludge due to spontaneous release is 100% (1.00 volume fraction)

**VARIABLE C CALCULATION – NFPA SPONTANEOUS QUIESCENT TIME**

The expansion factor is used for predicting the effect of pressure on trapped bubble gas release. The relationship between the expansion factor and the head pressure is linear (C = P<sub>avg</sub>/P<sub>atm</sub>). The expansion correction is determined from the following head pressure equation [Ref. 14]:

\[
\text{Eq. #68} \quad P_{\text{avg}} = \left( \sum_{a=2}^{n} \frac{\rho_a \cdot g \cdot h_a}{X} \right) + \frac{1}{2} \frac{\rho_1 \cdot g \cdot h_1}{X} + P_{\text{atm}}
\]

Where:

- \( P_{\text{avg}} \) = Hydrostatic head pressure, atm
- \( n \) = Number of layers above the evaluated slurried sludge layer,
- \( \rho_a \) = Density of layer material above the evaluated slurried sludge layer, kg/m³
- \( \rho_1 \) = Density of the evaluated slurried sludge layer material, kg/m³
- \( h_a \) = Height of layer above the evaluated slurried sludge layer, m
- \( h_1 \) = Height of the evaluated slurried sludge layer, m
- \( g \) = Standard acceleration of gravity (9.81 m/s²)
- \( P_{\text{atm}} \) = Atmospheric pressure, atm
- \( X \) = 101325, Pa/atm
**VARIABLE $H_R$ CALCULATION – NFPA SPONTANEOUS QUIESCENT TIME**

The percentage of hydrogen generated that is retained in the slurried sludge ($H_R$) is based on the depth of the slurried sludge (until the maximum retained hydrogen value is reached as determined using the maximum trapped bubble gas volume and associated hydrogen percent in trapped gas).

- If the slurried sludge depth is less than 40 inches, 25% of the hydrogen generated is retained.
- If the slurried sludge depth is greater than or equal to 40 inches and less than 90 inches, 50% of the hydrogen generated is retained.
- If the slurried sludge depth is greater than or equal to 90 inches and less than 110 inches, 75% of the hydrogen generated is retained.
- If the slurried sludge depth is greater than or equal to 110 inches, 100% of the hydrogen generated is retained.

**VARIABLE $LFLT$ CALCULATION - NFPA SPONTANEOUS QUIESCENT TIME**

LFL for hydrogen can be corrected for temperature. Using the Burgess - Wheeler correlation, the temperature corrected LFL for hydrogen, $LFLT$, is determined as follows:

Eq. #69

$$LFLT = LFL_{25C} \cdot [1 - A \cdot (T - 25)]$$

Where:

$LFLT$ = LFL for hydrogen corrected for temperature, vol. frac.

$LFL_{25C}$ = LFL for hydrogen at 25°C, (i.e., 0.04-volume fraction), vol. frac.

$A$ = Empirical coefficient (Zabetakis attenuation factor), (i.e., 0.0011 per Ref. 1), °C$^{-1}$

$T$ = Temperature at which LFL is to be evaluated in °C [Refs. 1, 24]

**VARIABLE $y_0$ CALCULATION - NFPA SPONTANEOUS QUIESCENT TIME**

The initial hydrogen concentration in the vapor space, $y_0$, for Rapid and Slow Generation Tanks is assumed to be the higher of 2.5% of the $LFL_{25C}$ or a value based on the steady state hydrogen equilibrium concentration accounting for ventilation operation. Use of an initial hydrogen concentration of 2.5% of the $LFL_{25C}$ is considered acceptable due to the fact that the waste tank purge ventilation systems are adequate to maintain the radiolytic hydrogen concentration less than 2.5% of the $LFL_{25C}$ as evidenced by numerous years of waste tank operations and vapor space hydrogen monitoring. For Tank 50, 3.8% of the $LFLT$ should be used when not classified as Very Slow.

For Very Slow Generation Tanks, the hydrogen concentration at equilibrium ($H'_{eq}$), accounting for atmospheric breathing only, can be used as the initial hydrogen concentration if the calculated
trapped gas release does not cause the waste tank vapor space to exceed the LFL_{OC}. For \( H_{eq} \) calculation, see Variable \( H_{eq} \) calculation.

**VARIABLE \( H_{eq} \) CALCULATION - NFPA SPONTANEOUS QUIESCENT TIME**

For Rapid and Slow Generation Tanks (excluding Tank 50), the initial hydrogen concentration prior to waste tank mixing device operation is assumed to be at steady state hydrogen equilibrium accounting for ventilation (minimum required purge flow for the applicable flammability classification). For Tank 50, the initial hydrogen concentration is 3.8% of the LFL_{T}. The steady state hydrogen equilibrium (\( H_{eq \ (Rapid/Slow)} \)) is calculated using the following equation:

\[
H_{eq \ (Rapid/Slow)} = \frac{Q_{H2}}{Q_{H2} + 60 \cdot (Q_{purge})}
\]

Where:

\( H_{eq \ (Rapid/Slow)} \) = Hydrogen concentration at equilibrium, vol. frac.
\( Q_{H2} \) = Total hydrogen volumetric evolution rate, \( \text{ft}^3/\text{hr} \) (see Variable \( Q_{H2} \) in Section 4.1.2.2.1)
\( Q_{purge} \) = Purge flow rate, \( \text{ft}^3/\text{min} \)

- 72 \( \text{ft}^3/\text{min} \) for Rapid tanks; 45 \( \text{ft}^3/\text{min} \) for Slow tanks; 188 \( \text{ft}^3/\text{min} \) for Tanks 40 and 51 when classified as Rapid; In lieu of using the DSA purge flow rates, actual ventilation flow rate may be used

The \( H_{eq \ (Rapid/Slow)} \) value is compared to 2.5% of the LFL_{25C} (excluding Tank 50) and the greater of the two is used as \( y_0 \) in Equation 65 and Equation 66. For Very Slow Generation Tanks, the initial hydrogen concentration is assumed to be at steady state hydrogen equilibrium accounting for atmospheric breathing and is calculated using the expression below:

\[
H_{eq} = \frac{Q_{H2}}{Q_{H2} + Q_{ATM}}
\]

Where:

\( H_{eq} \) = Hydrogen concentration at equilibrium, vol. frac.
\( Q_{H2} \) = Total volumetric hydrogen generation rate, \( \text{ft}^3/\text{hr} \) (see Variable \( Q_{H2} \) Calculation in Section 4.1.2.2.1)
\( Q_{ATM} \) = Atmospheric breathing rate, \( \text{ft}^3/\text{hr} \) (see Variable \( Q_{ATM} \) Calculation)

**VARIABLE \( Q_{ATM} \) CALCULATION - NFPA SPONTANEOUS QUIESCENT TIME**

The atmospheric breathing assumptions and methodology are established in Reference 1 Section 3.4.1.5.5. The atmospheric breathing rate is determined as follows:
**Variable \( V'_v \) Calculation - NFPA Spontaneous Quiescent Time**

The vapor space volume is based on the actual or projected waste level. The calculations account for the maximum missing waste volume when considering incoming transfers. The following equation is the vapor space volume calculation, in cubic feet:

\[
V'_v = 0.13368 \times \left[ V_T - (L_{tank} \cdot F_f) - MMW \right]
\]

Where:

- \( V'_v \) = Vapor space volume based on actual/projected tank level, ft\(^3\)
- \( V_T \) = Total tank vapor space volume (empty tank), gallons
- \( L_{tank} \) = Actual or projected waste level, inches
- 0.13368 = Conversion factor from gallons to ft\(^3\)
- \( F_f \) = Nominal waste tank fill factor, gal/in (see Section 3.0)
- \( MMW \) = Maximum missing waste volume, gallons (to be accounted for in the receipt tank for incoming transfers, see discussion below)

For waste tanks receiving transfers from a sending vessel greater than or equal to 15,000 gallons or has continuous makeup capability, MMW is equal to 15,000 gallons. If the sending vessel is less than 15,000 gallons and does not have continuous makeup capability, MMW is equal to the volume of the vessel. 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. In lieu of using the actual/projected waste contents, the evaluation may be based upon the vapor space volume protected by the Tank Fill Limits Program. Liquid additions to the waste tank from DWS do not have continuous makeup capability.

**4.2.3 Gas Release Mode Quiescent Time**

The Gas Release Mode (GRM) Quiescent Time is defined as the frequency to run the waste tank mixing devices in the waste tanks under Quiescent Time Program to prevent the waste tank vapor space hydrogen concentrations (protected by the HLLCP setpoint) from exceeding the GRM criteria in Section 4.3.2.1. The Gas Release Mode Quiescent Time is not part of the DSA defined
Quiescent Time Program. If a GRM Quiescent Time is required, and thus requires waste tank mixing devices to be run, the GRM Quiescent Time only considers hydrogen depletion to occur in the slurried sludge layer. If additional solids layers will be impacted by the pump run, the additional trapped hydrogen release must be considered in an associated gas release evaluation.

The GRM Quiescent Time may be exceeded; however, the waste tank configuration must be changed (e.g., lower HLLCP, adjust supernate chemistry) or GRM must be entered prior to mixing device operation to control the hydrogen release to less than or equal to the SAV. The methodology to calculate the GRM Quiescent Time for waste tanks in GRM is similar to the methodology used in determining the GRM Quiescent Time (for waste tank not in GRM) except the vapor space for waste tanks in GRM can be calculated using the actual/projected tank levels.

The GRM Quiescent Time will be infinite for a Rapid or Slow Generation Tank if the total trapped hydrogen gas \((y_0 + TG)\) released into the waste tank vapor space is less than or equal to the SAV (not to exceed 60% of the LFLT), as seen below.

\[
(y_0 + TG) \leq SAV
\]

Where:

- \(y_0\) = Initial hydrogen concentration, vol. frac., (see Variable \(y_0\) Calculation)
- \(TG\) = Hydrogen concentration due to trapped gas release, vol. frac., (see Variable \(TG\) Calculation)
- \(SAV\) = Safety Analysis Value used to protect radiolytic time to LFL, nominally equal to 25% LFLT, but can go up to 60% LFLT (see Variable LFLT Calculation). For Tank 50, it is equal to 3.8% of the LFLT.

The GRM Quiescent Time will be infinite for a Very Slow Generation Tank if the total trapped hydrogen \((y_0 + TG)\) released into the tank vapor space is less than the LFLOC and the trapped hydrogen gas \(TG\) is less than or equal to 60% of the LFLT. For LFLT and LFLOC, see Variable LFLT Calculation and Variable LFLOC Calculation, respectively, in Section 4.2.1.2.1.

\[
(y_0 + TG) < LFLOC \text{ AND } TG \leq 60\% \text{ LFLT}
\]

The GRM Quiescent Time will be infinite for Tank 50 when classified as a Very Slow Generation Tank if the total trapped hydrogen \((y_0 + TG)\) released into the tank vapor space is less than LFLOC. For LFLT and LFLOC, see Variable LFLT Calculation and Variable LFLOC Calculation, respectively, in Section 4.2.1.2.1.

If the total trapped gas release exceeds the SAV or the GRM Quiescent Time is not infinite for a Very Slow Generation Tank, the waste tank configuration must be altered (e.g. reduce HLLCP, adjust chemistry) or mixing devices must be periodically operated to limit the volume of trapped
gas retained in the slurried sludge layer. The frequency to run the waste tank mixing devices to stay out of GRM is calculated as follows:

Eq. #76  
\[ t_{\text{GRM}} = \frac{(y_{\text{SAV}} - y_0) \cdot V_v \cdot \frac{H_R}{100}}{F_R \cdot Q_{\text{H2}} \cdot \frac{H_R}{100} \cdot \frac{1}{24}} \]  
for Rapid or Slow Generation Tanks

Eq. #77  
\[ t_{\text{GRM}} = \frac{y_{\text{SAV}} \cdot V_v \cdot \frac{H_R}{100}}{F_R \cdot Q_{\text{H2}} \cdot \frac{H_R}{100} \cdot \frac{1}{24}} \]  
for Very Slow Generation Tanks

Where:
- \( t_{\text{GRM}} \) = Frequency to run waste tank mixing devices to stay out of Gas Release Mode, days
- \( y_{\text{SAV}} \) = Hydrogen concentration at the SAV, vol. frac., equal to SAV * LFL\(_T\) for Rapid and Slow Generation Tanks (excluding Tank 50). For Very Slow Generation Tanks (excluding Tank 50), \( y_{\text{SAV}} \) is equal to 60% of the LFL\(_T\). For Tank 50, \( y_{\text{SAV}} \) is equal to 3.8% of the LFL\(_T\) when classified as a Rapid or Slow Generation Tank and equal to LFL\(_{OC}\) when classified as a Very Slow Generation Tank. For LFL\(_T\), LFL\(_{OC}\), see Variable LFL\(_T\) Calculation and Variable LFL\(_{OC}\) Calculation, respectively, in Section 4.2.1.2.1
- \( y_0 \) = Initial hydrogen concentration, vol. frac. (see Variable \( y_0 \) Calculation)
- \( V_v \) = Vapor space volume, ft\(^3\) (see Variable \( V_v \) Calculation)
- \( F_R \) = Volume fraction of trapped gas release (see Variable \( F_R \) Calculation)
- 24 = Conversion factor from hours to days
- \( Q_{\text{H2}} \) = Temperature corrected hydrogen generation rate, ft\(^3\)/hr (see Section 4.1.2.2.1 Variable \( Q_{\text{H2}} \) Calculation)
- \( H_R \) = Percentage of hydrogen generation that is retained in slurried sludge, (see Section 4.2.2 Variable \( H_R \) Calculation)

When the number of waste tank mixing devices available to liberate the retained trapped gas is less than the number of waste tank mixing devices required (e.g., only 3 slurry pumps instead of 4 slurry pumps), the generic methodology defined in Reference 45 can be used to calculate the adjusted GRM Quiescent Time.

**VARIABLE \( y_0 \) CALCULATION - GRM QUIESCENT TIME**

The initial hydrogen concentration in the vapor space, \( y_0 \), of the Rapid and Slow Generation Tanks is assumed to be the higher of 2.5% of the LFL\(_{25C}\) or a value based on the steady state hydrogen equilibrium concentration accounting for ventilation operation (\( H_{\text{eq(Rapid/Slow)}} \)). For \( H_{\text{eq(Rapid/Slow)}} \) calculation, see Variable \( H_{\text{eq}} \) Calculation below. If \( H_{\text{eq(Rapid/Slow)}} \) is used as initial hydrogen concentration, 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. An adequate number of vapor space turnovers (and/or comparing the tank LFL 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 the assumed initial hydrogen concentration in the hydrogen release evaluation. For Tank 50, vapor space turnovers will be required to reduce the initial hydrogen concentration from 3.8%
of the LFL to the higher of 2.5% of the LFL25C or $H_{eq}(\text{Rapid/Slow})$ when not classified as a Very Slow Generation Tank.

For Very Slow Generation Tanks, the greater of 2.5% of the LFL25C or $H_{eq}$, accounting for atmospheric breathing only (see Equation 82), can be used as the initial hydrogen concentration if the calculated trapped gas release does not cause the tank vapor space to exceed the LFLOC. If using $H_{eq}$ as the initial hydrogen concentration causes the waste tank vapor space to exceed the LFLOC upon releasing the trapped hydrogen, 2.5% of the LFL25C may be used as the initial hydrogen concentration; however, vapor space turnovers or hydrogen monitoring shall be required prior to each trapped gas release activity to ensure the waste tank bulk vapor space hydrogen concentration is less than or equal to 2.5% of the LFL25C. For $H_{eq}$ calculation, see Variable $H_{eq}$ calculation.

The required number of vapor space turnovers for each tank will be documented in the ERD [Ref. 2]. The methodology specified in Reference 15 with a mixing efficiency of 0.2 shall be employed to determine the adequate number of vapor space turnovers. The mixing efficiency of 0.2 is based on the recommended value from NFPA 69 Annex D for the ventilation system arrangement (single exhaust opening, non-positive supply ventilation system) [Ref. 13]. However, vapor space turnovers and/or comparing the tank LFL reading to a reading obtained using a known LFL concentration can be employed to 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. 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 will be performed in Tank 50, when classified as a Rapid or Slow tank, to reduce the initial hydrogen concentration from 3.8% of the LFL to the higher of 2.5% of the LFL25C or $H_{eq}(\text{Rapid/Slow})$. As a Very Slow waste tank, vapor space turnovers can be used in Tank 50 to reduce the equilibrium concentration to 2.5% of the LFL25C 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 – GRM QUIESCENT TIME**

The vapor space hydrogen concentration due to trapped gas release from slurried sludge is determined as follows:

$$\text{Eq. #78} \quad \text{TG} = \frac{V_{\text{solids}} \cdot G_s \cdot H_{mix} \cdot C \cdot F_R}{V_V}$$

Where:

$V_{\text{solids}}$ = Volume of slurried sludge, gallons (see Variable $V_{\text{solids}}$ Calculation)

$G_s$ = Volume fraction of trapped bubble gas, vol. frac. (see Variable $G_s$ Calculation)

$H_{mix}$ = Volume fraction of hydrogen in trapped gas, vol. frac. (see Variable $H_{mix}$ Calculation in Section 4.1.2.2.2)
C = Pressure correction factor (see Variable C Calculation)

FR = Volume fraction of trapped gas release (see Variable FR Calculation)

VV = Vapor space volume protected by HLLCP setpoint, gallons (see Variable Vv Calculation below for waste tanks not entering GRM)


**VARIABLE VSOLIDS CALCULATION – GRM QUIESCENT TIME**

All the slurried sludge in the waste tank is considered to release hydrogen [Ref. 1].

**VARIABLE GS CALCULATION – GRM QUIESCENT TIME**

The maximum percentage of trapped bubble gas released from slurried sludge is 20% by volume (0.20 volume fraction) [Ref. 1].

**VARIABLE FR CALCULATION – GRM QUIESCENT TIME**

The percentage of trapped gas released from the slurried sludge is 100% (1.00 volume fraction)

**VARIABLE C CALCULATION – GRM QUIESCENT TIME**

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 = Pavg/Patm). The expansion correction is determined from the following head pressure equation [Ref. 14]:

\[
P_{\text{avg}} = \left( \sum_{a=2}^{n} \rho_a \cdot g \cdot h_a \right) + \frac{1}{2} \frac{\rho_1 \cdot g \cdot h_1}{X} + P_{\text{atm}}
\]

Where:

- Pavg = Hydrostatic head pressure, atm
- n = Number of layers above the evaluated slurried sludge layer,
- \( \rho_a \) = Density of layer material above the evaluated slurried sludge layer, kg/m³
- \( \rho_1 \) = Density of the evaluated slurried sludge layer material, kg/m³
- \( h_a \) = Height of layer above the evaluated slurried sludge layer, m
- \( h_1 \) = Height of the evaluated slurried sludge layer, m
- g = Standard acceleration of gravity (9.81 m/s²)
- P_atm = Atmospheric pressure, atm
- X = 101325, Pa/atm
**VARIABLE V<sub>V</sub> CALCULATION – GRM QUIESCENT TIME**

The HLLCP is credited in the evaluation to determine whether entry into GRM will be required prior to sludge agitation, bulk saltcake dissolution or saltcake interstitial liquid removal activities in a waste tank. The GRM Quiescent Time is to protect the vapor space hydrogen concentration for the waste tank from exceeding the Gas Release Criteria. Therefore, the GRM Quiescent Time shall be calculated based on the waste tank vapor space protected by the HLLCP setpoint. The following equation is the vapor space volume calculation in units of ft<sup>3</sup>.

\[
V_v = 0.13368 \left( V_T - (L_{HLLCP} + IU) \times Ff - MMW \right)
\]

Where:
- \(V_v\) = Vapor space volume based on HLLCP setpoint, ft<sup>3</sup>
- \(V_T\) = Total tank vapor space volume (empty tank), gallons
- \(L_{HLLCP}\) = Level of HLLCP setpoint, inches
- \(Ff\) = Nominal waste tank fill factor, gal/in (see Section 3.0)
- \(MMW\) = Maximum volume associated with a Transfer Error event, equal to 15,000 gallons
- \(IU\) = Uncertainty attributed to HLLCP, inches [see Ref. 12]
- 0.13368 = Conversion factor from gallons to ft<sup>3</sup>

**VARIABLE H<sub>eq</sub> CALCULATION - GRM QUIESCENT TIME**

For Rapid and Slow Generation Tanks, steady state hydrogen equilibrium accounting for ventilation (minimum required purge flow for the applicable flammability classification) may be used as the assumed initial hydrogen concentration prior to waste tank mixing device operation. The steady state hydrogen equilibrium (\(H_{eq}^{(Rapid/Slow)}\)) is calculated using the following equation:

\[
H_{eq}^{(Rapid/Slow)} = \frac{Q_{H2}}{Q_{H2} + 60 \times (Q_{purge})}
\]

Where:
- \(H_{eq}^{(Rapid/Slow)}\) = Hydrogen concentration at equilibrium, vol. frac.
- \(Q_{H2}\) = Total hydrogen volumetric evolution rate, ft<sup>3</sup>/hr (see Variable \(Q_{H2}\) in Section 4.1.2.2.1)
- \(Q_{purge}\) = Minimum purge flow rate, ft<sup>3</sup>/min
  - 72 ft<sup>3</sup>/min for Rapid tanks
  - 45 ft<sup>3</sup>/min for Slow tanks
- 60 = Conversion factor from mins to hours

The \(H_{eq}^{(Rapid/Slow)}\) value is compared to 2.5% of the LFL<sub>25C</sub> and the greater of the two is used as \(y_0\) in Equations 74 and 76.
For Very Slow Generation Tanks, steady state hydrogen equilibrium accounting for atmospheric breathing may be used as the assumed initial hydrogen concentration and is calculated using the expression below:

\[ H_{eq} = \frac{Q_{H2}}{Q_{H2} + Q_{ATM}} \]

Where:

- \( H_{eq} \) = Hydrogen concentration at equilibrium, vol. frac.
- \( Q_{H2} \) = Total volumetric hydrogen generation rate, ft\(^3\)/hr (see Variable \( Q_{H2} \) Calculation in Section 4.1.2.2.1)
- \( Q_{ATM} \) = Atmospheric breathing rate, ft\(^3\)/hr (see Variable \( Q_{ATM} \) Calculation)

The \( H_{eq} \) value is compared to 2.5% of the LFL\(_{25C}\) and the greater of the two is used as \( y_0 \) in Equation 75.

**VARIABLE \( Q_{ATM} \) CALCULATION - GRM QUIESCENT TIME**

The atmospheric breathing assumptions and methodology are established in Reference 1 Section 3.4.1.5.5. The atmospheric breathing rate is determined as follows:

\[ Q_{ATM} = \frac{\text{mean atm. fluctuation}}{1013} \times \frac{V_V}{24} \]

Where:

- \( Q_{ATM} \) = Atmospheric breathing rate, ft\(^3\)/hr
- \( \text{mean atm. fluctuation} \) = Mean pressure fluctuation, 5 mbar/day [Ref. 41]
- \( V_V \) = Vapor space volume, ft\(^3\), based on HLLCP level (see Variable \( V_V \) Calculation)
- \( 24 \) = Conversion factor from days to hours
- \( 1013 \) = Standard atmospheric pressure, mbar

### 4.2.4 IMPLEMENTATION ACTIONS

1. The Seismic Release Protection Quiescent Time and Spontaneous Liberation Protection Quiescent Time shall be determined using WCS [Ref. 11] or an engineering evaluation and documented in the ERD. [TSR SAC 5.8.2.28.a]

2. The NFPA 69 Quiescent Time and GRM Quiescent Time shall be determined using WCS [Ref. 11] or an engineering evaluation and documented in the ERD.

3. The Quiescent Time Program (Seismic Release Protection) shall be tracked by CST Operations to ensure that waste tanks will not reach LFL\(_{OC}\) in less than 7 days following a
4. The Quiescent Time Program (Spontaneous Liberation Protection) shall be tracked by CST Operations to ensure that the minimum time to LFL (CLFL for Tank 50) defined by the waste tank flammability classification is maintained. [TSR SAC 5.8.2.28.c]

5. Operating procedures shall address the requirement to perform an adequate number of vapor space turnovers and/or compare the tank LFL reading to a reading obtained using a known LFL concentration to ensure the waste tank bulk vapor space hydrogen concentration is less than or equal to the value assumed in WCS [Ref. 11] or in an engineering evaluation prior to initiating waste tank mixing devices operation. If the flammable vapor concentration method (i.e., comparing the tank LFL reading) is implemented, the methodology used to determine the flammable vapor concentration shall be consistent with the requirements of Ref. 7.

6. Transferring slurried sludge into a non-quiescent time waste tank will require the receipt tank to be placed into the quiescent time. [TSR SAC 5.8.2.28.a]

7. When transferring settled/slurried sludge between quiescent time waste tanks, a pre-evaluation shall be performed to determine quiescent time impacts for the waste tanks. [TSR SAC 5.8.2.28.a]

8. If the evaluated activity results in a non-conservative change in the quiescent time (e.g., a reduction of allowable time between tank agitation) or tank flammability classification (e.g., SLOW to RAPID, VERY SLOW to RAPID), the projected changes will be updated in the ERD and implemented in the facility via the ERD linking procedure [Ref. 55] prior to initiation of the planned activity. The quiescent time will be re-evaluated and re-updated in the ERD once the activity is complete.

9. The ERD shall track the GRM Quiescent Time for waste tanks under Quiescent Time Program to protect the waste tanks from exceeding the Gas Release Criteria stated in Section 4.3.2.1.

10. Trapped gas release activities in Tank 50 that could exceed the Tank 50 Gas Release Criteria (see Section 4.3.2.1) are prohibited. Therefore, Tank 50 is prohibited from entering GRM. The GRM Quiescent Time for Tank 50 must be infinite. If not infinite, the tank GRM Quiescent Time must not be exceeded.

11. Prior to initiation of operation of mixing devices in a settled sludge layer at each waste tank mixing device height, an evaluation shall be performed to determine the waste tank’s Quiescent Time (assuming completion of 10 days of mixing). The results of this evaluation will be documented in the ERD prior to starting the mixing devices. In the event the 10 day mixing time is not completed, the waste tank’s Quiescent Time will be reverted back to prior condition and a new ERD will be issued. [TSR SAC 5.8.2.28.a]
12. If a waste tank mixing device is lowered prior to completion of successful sludge agitation, the affected sludge layer within the zone of influence of the waste tank mixing devices (based on the mixing device location prior to lowering) shall be considered slurried sludge [Ref. 1].

13. There have been no operational experiences or studies to determine when adequate mixing occurs after completion of an SBP run. Therefore, operation of the SBPs cannot be used to credit any DSA or non-DSA defined Quiescent Times.

4.3 GAS RELEASE PROGRAM

The Gas Release Program does not apply to Type I/II Acidic Chemical Cleaning Waste Tanks or waste tanks in Closure Mode. Information in this section pertaining to bulk saltcake dissolution and saltcake interstitial liquid removal activities does not apply to Type I/II Non-Acidic Chemical Cleaning Waste Tanks. Bulk saltcake dissolution and saltcake interstitial liquid removal activities in Type I/II Non-Acidic Chemical Cleaning Waste Tanks are prohibited.

The Gas Release Program is not applicable to operational activities in waste tanks that have the potential to release insignificant amounts of hydrogen and do not require an engineering evaluation. The Gas Release Program has the following applicability related to those unintended transitions that may occur between certain activities:

- Unintended transition between free supernate removal and saltcake interstitial liquid removal. The controls associated with free supernate removal provide adequate protection for a trapped gas release, and the controls associated with saltcake interstitial liquid removal in Gas Release Program are not required for this unintended transition.

- Water or dilute supernate addition onto exposed saltcake after unintended transition between free supernate removal and saltcake interstitial liquid removal. The controls associated with bulk saltcake dissolution in the Gas Release Program are not required for this activity following the unintended transition.

Although certain controls in the Gas Release Program are not required for these activities if associated with unintended transition, once the facility becomes cognizant of the actual condition the facility shall follow the appropriate controls for subsequent activities. For example, if the facility recognizes that actual saltcake level would indicate that saltcake interstitial liquid removal activity is occurring versus free supernate removal activity, then subsequent activities related to this process shall follow controls associated with saltcake interstitial liquid removal.

The Gas Release Program provides safety functions to protect hydrogen concentrations assumed for the waste tank bulk vapor space during the following planned operational activities:

- Free Supernate Removal

- Sludge Agitation

- Bulk saltcake dissolution

- Saltcake Interstitial Liquid Removal
The Gas Release Program shall utilize the following requirements to protect hydrogen concentrations assumptions in the waste tank bulk vapor space during waste tank mixing device operation, bulk saltcake dissolution, saltcake interstitial liquid removal or free supernate removal.

- Prior to initiating sludge agitation (using waste tank mixing devices), bulk saltcake dissolution, or saltcake interstitial liquid removal activities, determine if the activity will cause the waste tank to enter Gas Release Mode [TSR SAC 5.8.2.29.a]

- Prior to initiating sludge agitation (using waste tank mixing devices), bulk saltcake dissolution, or saltcake interstitial liquid removal activities, ensure the waste tank bulk vapor space hydrogen concentration is less than or equal to the initial value assumed in the hydrogen release engineering evaluation (by verifying adequate number of tank vapor space turnovers, verifying vapor space hydrogen concentration, or combination of the preceding two methodologies). [TSR SAC 5.8.2.29.b]

- For waste tanks in Gas Release Mode undergoing sludge agitation (using waste tank mixing devices), bulk saltcake dissolution, or saltcake interstitial liquid removal activities, the activity shall be controlled to maintain the waste tank bulk vapor space hydrogen concentration less than or equal to the safety analysis value and maintain the minimum time to LFL defined by the waste tank flammability classification. [TSR SAC 5.8.2.29.c]

- Prior to initiating free supernate removal activities (excluding Very Slow Generation Tanks), ensure the waste tank bulk vapor space hydrogen concentration is less than or equal to 2.5% of the LFL (by verifying adequate number of tank vapor space turnovers, verifying vapor space hydrogen concentration, or combination of the preceding two methodologies). [TSR SAC 5.8.2.29.d]

- Prior to initiating free supernate removal activities, ensure that the resultant free supernate hydrogen release rate is less than or equal to the limits of Table 1 for the associated waste tank type and flammability classification. [TSR SAC 5.8.2.29.e]

### Table 1: Free Supernate Removal Hydrogen Release Rate Limits by Waste Tank Flammability Classification

<table>
<thead>
<tr>
<th>Tank Type</th>
<th>Waste Tank Flammability Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rapid Generation Tank</td>
</tr>
<tr>
<td>Type I</td>
<td>HR(_{FSR}) ≤ 187</td>
</tr>
<tr>
<td>Type II</td>
<td>HR(_{FSR}) ≤ 226</td>
</tr>
<tr>
<td>Type III/IIIA</td>
<td>HR(_{FSR}) ≤ 223</td>
</tr>
<tr>
<td>Type IV</td>
<td>HR(_{FSR}) ≤ 233</td>
</tr>
</tbody>
</table>
The Free Supernate Removal Hydrogen Release Rate Limits stated above were derived in Reference 53 to ensure that free supernate removal activities will maintain the minimum time to LFL (CLFL for Tank 50) defined by the waste tank flammability classification (and associated minimum ventilation flow rate requirements) [Ref. 1].

- Prior to operation of a waste tank mixing device in a waste tank containing only slurried sludge (for a mixing device that has not been operated within 180 days), ensure the waste tank level is within the limits of Table 2 to ensure adequate vapor space volume for flammable transients. [TSR SAC 5.8.2.29.f]

### Table 2: Waste Tank Level Limitations for Flammable Transients – Slurried Sludge

| Waste Tank Conditions (for \(H_{\text{mix}}\) determination, see Section 4.1.2.2.2 Variable \(H_{\text{mix}}\) Calculation) | Waste Tank Type and Maximum Level (in inches from the bottom of the tank) |
|---|---|---|---|---|
| \(H_{\text{mix}} \leq 37.5\%\) and waste tank mixing device discharge totally clear of sludge | I | II | III/IIIA | IV |
| 274 | 304 | 376 | 411 |
| \(H_{\text{mix}} \leq 37.5\%\) and waste tank mixing device discharge partially or fully submerged in sludge | 215 | 245 | 317 | 397 |
| \(H_{\text{mix}} > 37.5\%\) and waste tank mixing device discharge totally clear of sludge | 254 | 284 | 356 | 411 |
| \(H_{\text{mix}} > 37.5\%\) and waste tank mixing device discharge partially or fully submerged in sludge | 136 | 166 | 238 | 318 |

For trapped gas releases associated with mechanically disturbing waste, the potential flammable transients in the tank vapor space are short-lived (less than 3 minutes) [Ref. 18]. Transfers into waste tanks are not normally occurring during waste tank mixing device operation. Additionally, it would take at least 60 minutes to transfer the entire assumed maximum missing waste volume (assuming transfer flow rate of 250 gpm); therefore, the waste tank level limitations for flammable transient given in Table 2 do not need to be adjusted for the maximum volume associated with a Transfer Error event (i.e., 15,000 gallons) or instrument uncertainties.
Prior to operation of a waste tank mixing device in a waste tank containing saltcake, settled sludge, or any combination of saltcake, settled sludge, or slurried sludge, ensure the waste tank level is within the limits of Table 3 to ensure adequate vapor space volume for flammable transients. [TSR SAC 5.8.2.29.g]

Table 3: Waste Tank Level Limitations for Flammable Transients – Saltcake, Settled Sludge or Any Combination of Saltcake, Settled Sludge, or Slurried Sludge

<table>
<thead>
<tr>
<th>Waste Tank Conditions (for $H_{\text{mix}}$ determination, see Section 4.1.2.2.2 Variable $H_{\text{mix}}$ Calculation)</th>
<th>Waste Tank Type and Maximum Level (in inches from the bottom of the tank)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I</td>
</tr>
<tr>
<td>$H_{\text{mix}} \leq 37.5%$ and waste tank mixing device discharge totally clear of saltcake and sludge</td>
<td>274</td>
</tr>
<tr>
<td>$H_{\text{mix}} \leq 37.5%$ and waste tank mixing device discharge partially or fully submerged in saltcake or sludge</td>
<td>215</td>
</tr>
<tr>
<td>$H_{\text{mix}} &gt; 37.5%$ and waste tank mixing device discharge totally clear of saltcake and sludge</td>
<td>254</td>
</tr>
<tr>
<td>$H_{\text{mix}} &gt; 37.5%$ and waste tank mixing device discharge partially or fully submerged in saltcake or sludge</td>
<td>136</td>
</tr>
</tbody>
</table>

For trapped gas releases associated with mechanically disturbing waste, the potential flammable transients in the tank vapor space are short-lived (less than 3 minutes) [Ref. 18]. Transfers into waste tanks are not normally occurring during waste tank mixing device operation. Additionally, it would take at least 60 minutes to transfer the entire assumed maximum missing waste volume (assuming transfer flow rate of 250 gpm); therefore, the waste tank level limitations for flammable transient given in Table 3 do not need to be adjusted for the maximum volume associated with a Transfer Error event (i.e., 15,000 gallons) or instrument uncertainties.

As stated in Section 3.0, waste tank mixing devices refers to any of the following: slurry pumps (any type), SMPs, SBPs, or CSMPs.

The SBP Operation Program shall ensure the entrained waste has less than or equal to 1 wt% sludge solids. The program shall at a minimum include the following attributes during SBP operation [TSR SAC 5.8.2.58]:

For trapped gas releases associated with mechanically disturbing waste, the potential flammable transients in the tank vapor space are short-lived (less than 3 minutes) [Ref. 18]. Transfers into waste tanks are not normally occurring during waste tank mixing device operation. Additionally, it would take at least 60 minutes to transfer the entire assumed maximum missing waste volume (assuming transfer flow rate of 250 gpm); therefore, the waste tank level limitations for flammable transient given in Table 3 do not need to be adjusted for the maximum volume associated with a Transfer Error event (i.e., 15,000 gallons) or instrument uncertainties.
The suction of the SBP shall be a minimum of 152 inches from the sludge layer.
The speed of the SBP shall be less than or equal to 860 rpm.

Additional controls shall be implemented as necessary to minimize the amount of sludge solids in suspension during SBP operations based on evaluation of the following phenomena:

- Tank agitation
- Effects of receiving waste transfers

4.3.1 FREE SUPERNATE REMOVAL ACTIVITIES

Prior to a planned free supernate removal activity, an engineering evaluation shall be performed to verify that the resultant release of hydrogen due to the activity is less than or equal to the hydrogen release rate limits provided in Table 1 for the associated waste tank type and waste tank flammability classification.

The initial hydrogen concentration used for the derivation of the free supernate removal hydrogen release rate limits is assumed to be 2.5% of the LFL$_{25^\circ C}$, excluding Very Slow Generation Tanks. Therefore, prior to initiating free supernate removal activities, the waste tank bulk vapor space shall be ventilated for an adequate number of vapor space turnovers to reduce the hydrogen concentration from the SAV to less than or equal to 2.5% of the LFL$_{25^\circ C}$ or shall be verified by hydrogen monitoring to be less than or equal to 2.5% of the LFL$_{25^\circ C}$ or combining the two preceding methodologies. Free supernate removal cannot be performed in Tank 50 when classified as a Rapid or Slow Generation Tank. Transfers from Tank 50 when classified as a Rapid or Slow Generation Tank should occur within 48 hours of successful trapped hydrogen depletion by sludge agitation.

The bulk vapor space hydrogen concentration shall be verified to be less than or equal to 2.5% of the LFL$_{25^\circ C}$ within 4 days prior to initiating of free supernate removal activities [Ref. 43]. Due to the conservative inputs and assumptions (e.g., bounding sludge slurry radiolytic hydrogen generation rate, minimum purge ventilation flow rate) used in establishing the Free Supernate Removal Hydrogen Release Rate Limits and the requirements of continuous operation of purge ventilation system for Slow and Rapid Generation Tanks, verification within 4 days is considered acceptable. The data sheets in Reference 56 provide the portable LFL monitor sampling results for Tanks 30, 32, 35, 36, 37, 39, 40, 41, 42, 43, and 51 when classified as Rapid Generation Tanks from 5/26/15 thru 8/3/15. As can be seen from the data sheets, at no time was a value above 0% of the LFL recorded for Tanks 30, 32, 35, 36, 37, 41, 43, and 51. Tanks 39 and 42 LFL monitor sampling results were recorded at 1% and 2% one time, respectively. Tank 40 LFL monitor sampling results only went up to 5% of the LFL during and after completion of slurry pump operations. The data sets indicated that when no trapped gas release activities performed in the waste tanks the bulk vapor space hydrogen concentration in the waste tanks remained well below 2.5% of the LFL$_{25^\circ C}$.

For Very Slow Generation Tanks, the methodology to establish the hydrogen release rate limits is conservatively based on no ventilation flow during free supernate removal. The vapor space is segregated into two parts corresponding to the initial vapor space volume and the additional vapor space volume created from the removal of free supernate out of the tank. Given this
approach, the hydrogen concentration in the waste tank bulk vapor space generated by radiolysis or liberated during free supernate removal is maintained to be less than LFL.

The limits derived for free supernate removal activities maintain the waste tank flammability classification for time to LFL (CLFL for Tank 50), but do not necessarily protect the hydrogen concentration SAV established by the Flammability Control Program. However, excluding Very Slow Generation Tanks, the hydrogen concentration does not exceed 60% of the LFL during the free supernate removal activity.

Waste tank flammability classification may be reclassified, based on the engineering evaluation, to meet the above criteria. For example, an evaluation determines that, for a Type I and Slow Generation Tank, the assumed hydrogen release due to the free supernate removal activity exceeds the hydrogen release rate limit of 163 gallons per inch of liquid removed, but is less than the limit for a Type I Rapid Generation Tank. In this case, the tank is at risk for becoming flammable in less than 28 days during the free supernate removal activity and should be reclassified as a Rapid Generation Tank.

For waste tanks undergoing sludge agitation using waste tank mixing devices concurrent with the outgoing transfer (or had undergone sludge agitation within 48 hours prior to completion of the transfer), trapped gas release from the slurried sludge layer may be discounted from the evaluation if hydrogen depletion success has been accomplished by the criteria/methodology in Section 4.2.1.1.

4.3.1.1 FREE SUPERNATE REMOVAL METHODOLOGY

A transfer of free supernate out of the tank lowers the hydrostatic pressure on the saltcake and/or sludge layers. The term “sludge” refers to both settled sludge and slurried sludge. A reduction in hydrostatic pressure, $\Delta P$, on the saltcake and/or sludge layers is accompanied by a reduction in the moles of gas, $\Delta n$, trapped in the saltcake and/or sludge layers at constant volume and temperature according to the Ideal Gas Law.

$$\Delta n = \frac{\Delta P \cdot V}{R \cdot T}$$

Where:

- $\Delta n$ = Moles of trapped gas, moles
- $R$ = Gas constant, $\frac{gal \cdot atm}{mol \cdot K}$
- $V$ = Volume of trapped gas, gallons
- $T$ = Temperature of trapped gas, Kelvin

The moles of hydrogen in the trapped gas, $\Delta n_{H_2}$, released due to head reduction in the waste tank during free supernate removal can be expressed as:
\[ \Delta n_{H_2} = \frac{\Delta P \cdot V_{H_2}}{R \cdot T_{solids}} \]

Where:
- \( \Delta n_{H_2} \) = Moles of hydrogen in the trapped gas, moles
- \( \Delta P \) = Hydrostatic pressure reduction, atm
- \( V_{H_2} \) = Volume of hydrogen in trapped gas, gallons
- \( T_{solids} \) = Temperature of salt and/or sludge layers, Kelvin
- \( R \) = Gas constant, \( \frac{gal \cdot atm}{mol \cdot K} \)

The volume of hydrogen, \( V_{H_2} \), in the trapped gas in the saltcake and/or sludge layers is calculated in the equation below.

\[ V_{H_2} = V_{solids} \cdot G_s \cdot H_{mix} \]

Where:
- \( V_{H_2} \) = Volume of hydrogen in trapped gas, gallons
- \( V_{solids} \) = Volume of saltcake and/or sludge layer, gallons
- \( G_s \) = Fraction of trapped bubble gas, vol. frac.
- \( H_{mix} \) = Fraction of hydrogen in trapped gas, vol. frac.

Substituting \( V_{H_2} \) into \( \Delta n_{H_2} \) yields

\[ \Delta n_{H_2} = \frac{\Delta P \cdot V_{solids} \cdot G_s \cdot H_{mix}}{R \cdot T_{solids}} \]

Releasing the moles of hydrogen (i.e, \( \Delta n_{H_2} \)) results in a hydrogen release volume, \( \Delta V_{H_2} \), of:

\[ \Delta V_{H_2} = \frac{R \cdot T_{H_2} \cdot \Delta n_{H_2}}{P_{atm}} \]

Where:
- \( \Delta V_{H_2} \) = Volume of hydrogen released, gallons
- \( P_{atm} \) = Ambient pressure, atm
- \( R \) = Gas constant, \( \frac{gal \cdot atm}{mol \cdot K} \)
- \( T_{H_2} \) = Temperature of trapped hydrogen gas, Kelvin

Substituting \( \Delta n_{H_2} \) into \( \Delta V_{H_2} \) yields the following expression for \( \Delta V_{H_2} \).
\[ \Delta V_{H_2} = \frac{T_{H_2} \cdot \Delta P \cdot V_{\text{solids}} \cdot G_s \cdot H_{\text{mix}}}{T_{\text{solids}} \cdot P_{\text{atm}}} \]

Where:
- \( \Delta V_{H_2} \) = Volume of hydrogen released, gallons
- \( T_{H_2} \) = Temperature of trapped hydrogen gas, Kelvin
- \( \Delta P \) = Hydrostatic pressure reduction, atm
- \( V_{\text{solids}} \) = Volume of saltcake and/or sludge layer, atm
- \( G_s \) = Fraction of trapped bubble gas, vol. frac.
- \( H_{\text{mix}} \) = Fraction of hydrogen in trapped gas, vol. frac.
- \( T_{\text{solids}} \) = Temperature of saltcake and/or sludge layer, Kelvin
- \( P_{\text{atm}} \) = Ambient pressure, atm

Hydrostatic pressure reduction, \( \Delta P \), per inch of liquid removed is expressed in the following equation:

\[ \Delta P = \frac{0.0254 \cdot (\rho \cdot g)}{1.01325 \times 10^5} \]

Where:
- \( \Delta P \) = Hydrostatic pressure reduction, atm
- \( \rho \) = Density of liquid removed, kg/m\(^3\)
- \( g \) = Standard acceleration of gravity (9.81 m/s\(^2\))
- 0.0254 = Conversion factor from inches to meters
- 1.01325E+05 = Conversion factor from atms to Pa (N/m\(^2\))

Due to heat generated from the radionuclides present in the salt and sludge layers, the salt and sludge temperature (\( T_{\text{solids}} \)) is higher than the ambient temperature (\( T_{H_2} \)). Increasing the \( T_{\text{solids}} \) value in the \( \Delta V_{H_2} \) equation above reduces the volume of hydrogen released due to free supernate removal. For conservatism, it is assumed that \( T_{\text{solids}} \) is equal to \( T_{H_2} \). The volume of trapped hydrogen gas released per inch of free supernate removal for each applicable solids layer is given by the following expression after combining the \( \Delta V_{H_2} \) and \( \Delta P \) equations and simplifying the resultant equation.

Eq. #84

\[ \Delta V_{H_2} = \frac{0.0254 \cdot (\rho \cdot g \cdot V_{\text{solids}} \cdot G_s \cdot H_{\text{mix}})}{1.01325 \times 10^5 \cdot P_{\text{atm}}} \]

Where:
- \( \Delta V_{H_2} \) = Volume of trapped hydrogen gas released per inch of free liquid removed, gallons
- \( \rho \) = Density of liquid removed, kg/m\(^3\)
- \( g \) = Standard acceleration of gravity (9.81 m/s\(^2\))
The total volume of hydrogen released per inch of free supernate removal is a summation of the volumes of hydrogen released per inch of free supernate removal from each applicable solids layer. The total volume is then compared against Table 1 for the applicable waste tank type and flammability classification.

Reference 17 calculates the volume of dissolved hydrogen release per inch of free supernate removal during a steam jetted transfer. For waste tanks undergoing free supernate removal activity concurrent with receiving a steam jetted transfer, the total volume of hydrogen gas released per inch of free liquid removed is the volume of dissolved hydrogen released due to steam jetted transfers (obtained from Ref. 17) in addition to the volume of hydrogen released due to free supernate removal (calculated from Equation 84) [Ref. 43].

\[
\Delta V_{total H_2} = \frac{0.0254}{1.01325 \times 10^5} \cdot \frac{\rho \cdot g \cdot H_{mix}}{P_{atm}} \cdot \sum^n_1 (V_{solids} \cdot G_s) + \Delta V_{dissolved H_2}
\]

Where:
- \(\Delta V_{total H_2}\) = Total volume of hydrogen gas released per inch of liquid removed due to free supernate removal and steam jetted transfers, gallons
- \(\rho\) = Density of liquid removed, \(\text{kg/m}^3\)
- \(g\) = Standard acceleration of gravity (9.81 \(\text{m/s}^2\))
- 0.0254 = Conversion factor from inches to meters
- 1.01325E+05 = Conversion factor from atms to \(\text{Pas} \ (\text{N/m}^2)\)
- \(n\) = Number of solids layers
- \(V_{solids}\) = Volume of saltcake, settled sludge or slurried sludge layer below the affected waste removed, gallons (see discussion below)
- \(G_s\) = Fraction of trapped bubble gas in solids layers, vol. frac., equal to 0.11 if in saltcake; 0.10 if in sludge; 0.20 if in slurried sludge
- \(H_{mix}\) = Fraction of hydrogen in trapped gas, vol. frac. For \(H_{mix}\) calculation see Section 4.1.2.2.2 Variable \(H_{mix}\) Calculation
- \(P_{atm}\) = Ambient pressure, atm
The total hydrogen volume, $\Delta V_{total H_2}$, is then compared against Table 1 for the applicable waste tank type and flammability classification.

For waste tanks undergoing sludge agitation using waste tank mixing devices concurrent with the outgoing transfer (or had undergone sludge agitation within 48 hours of completion of the transfer), trapped gas release from the slurried sludge layer may be discounted from the evaluation if hydrogen depletion success had been accomplished by the criteria/methodology in Section 4.2.1.1 (e.g., completion of 8-hour slurry pump/CSMP operation at maximum allowable speed with evidence of adequate sludge mixing). The 48-hour period (for a waste tank that had previously undergone sludge agitation) is based on engineering judgement. This time period is considered reasonably conservative since sludge slurry would need sufficient time for the sludge solids to settled (via the free settling phase) and generate/retain any appreciable radiolytic hydrogen [Ref. 1].

### 4.3.1.2 Implementation Actions

1. Operating procedures shall address the requirement to perform an adequate number of vapor space turnovers and/or compare the tank LFL reading to a reading obtained using a known LFL concentration to ensure the waste tank bulk vapor space hydrogen concentration is less than or equal to 2.5% of the LFL$_{25C}$ prior to initiating free supernate removal activities excluding Very Slow Generation Tanks. Operating procedures shall address the requirement to have second person verification of vapor space turnovers time and/or comparison of the hydrogen concentration reading to the hydrogen concentration acceptance value. If the flammable vapor concentration method (i.e., comparing the tank LFL reading) is implemented, the methodology used to determine the flammable vapor concentration shall be consistent with the requirements of Reference 7. [TSR SAC 5.8.2.29.d]

2. Prior to initiating free supernate removal activities, the bulk vapor space hydrogen concentration for the waste tanks shall be verified to be less than or equal to 2.5% of the LFL$_{25C}$ per one of the following methods:
   a) By performing the verification in the respective transfer procedure prior to, but as close as practicable, to starting the prime mover
   OR
   b) By performing the verification via procedure (e.g., roundsheets) and subsequently confirming in the respective transfer procedure, as close as practicable to starting the prime mover, that the verification was performed within 4 days of the same shift (e.g., day 1 day shift to day 5 day shift) provided the following requirements are met [Ref. 43]:
      - No additional trapped gas release activities (e.g., waste tank mixing device operation, bulk saltcake dissolution) have occurred in the tank since the bulk vapor space hydrogen
concentration was verified to be less than or equal to 2.5% of the LFL$_{25C}$.

- No hydrogen releasing activities have been performed in the waste tank since the bulk vapor space hydrogen concentration was verified to be less than or equal to 2.5% of the LFL$_{25C}$, except the following activities [Ref. 43]:
  - Flushing of transfer pumps or jets. In tanks where the highest solids layer is slurried sludge, the separation distance between the transfer pump/jet suction and the slurried sludge layer must meet the requirements of the SCOM Program PDD [Ref. 9] to be considered an insignificant hydrogen releasing activity. In tanks where the highest solids layer is settled sludge or saltcake, there is no minimum separation criteria required to perform flushing.
  - Flushing of ventilation system components
  - Sample rinsing
  - Flushing of waste level measurement devices (e.g., reel tape, radar, steel tape, turbidity meter, salt spike, wafer)
  - Filling the purge condenser seal leg
  - Lifting the evaporator pot to the associated drop tank
  - Limited duration (5 minutes or less) operation of transfer pump in recirculation in a waste tank containing saltcake

For those activities involving a very small quantity of water (e.g., several gallons per activity), the performance of the activities is not limited, individually or in combination with other activities, between the initial hydrogen verification check and the start of the free supernate removal activity. These activities are sample rinsing, flushing of waste level measurement devices (e.g., reel tape, radar, steel tape, turbidity meter, salt spike, wafer).

The following activities are considered to individually result in insignificant hydrogen release. These allowed activities are flushing of transfer pumps or jets when the separation distance between the transfer pump/jet suction and the slurried sludge layer meets the requirements of the SCOM Program PDD, flushing of ventilation system components, filling purge condenser seal leg, lifting the evaporator pot to the associated drop tank, and limited duration (5 minutes or less) operation of transfer pump in recirculation in a salt tank. If multiple activities from this list are to be performed (or the same activity is performed multiple times), any previously performed initial hydrogen concentration verification check is considered invalid, and a new check must be performed prior to initiating free supernate removal. The only exception to this involves lifting the evaporator pot to the drop tank. If this activity is in progress when the initial hydrogen concentration verification is performed, then that activity can continue, and one additional activity from the above list (i.e., flushing of transfer pumps or jets, flushing of ventilation system components, filling purge condenser seal leg, or limited duration [5 minutes or less] operation of transfer pump in recirculation in a salt tank) can be performed without invalidating the previous initial hydrogen concentration verification.

- Purge ventilation system has been continuously operating in the waste tanks since the bulk vapor space hydrogen concentration was verified to be less than or equal to 2.5% of the LFL$_{25C}$.
3. The time to complete an adequate number of vapor space turnovers should be determined based on the best estimate of the actual vapor space volume.

4. The required number of vapor space turnovers for each waste tank shall be determined using WCS [Ref. 11] or an engineering evaluation and documented in the ERD. The methodology used to calculate the number of vapor space turnovers is specified in Reference 15, with a mixing efficiency of 0.2. The mixing efficiency of 0.2 is based on the recommended value from NFPA 69 Annex D for the ventilation system arrangement (single exhaust opening, non-positive supply ventilation system) [Ref. 13].

5. Prior to initiating free supernate removal activities (e.g., waste tank to waste tank transfers, waste tank to outside facility transfers), an engineering evaluation shall be completed to demonstrate that the resultant free supernate hydrogen release rate is less than or equal to the respective limits provided in Table 1. Calculation of the free supernate hydrogen release rate for waste tank to waste tank transfers can be performed in WCS [Ref. 11] as part of the ETAF process. [TSR SAC 5.8.2.29.e]

6. Prior to performing a transfer associated with the Evaporator Feed Pumps (e.g., Tank 32 to 242-25H Evaporator, Tank 43 to 242-16H Evaporator), transfers from waste tanks to outside facilities (e.g., Tank 49 to 512-S, Tank 50 to Saltstone), operations personnel shall verify the activity is approved in the ERD (N-ESR-G-00001).

7. Trapped gas release from slurried sludge may be discounted from the calculation of volume of trapped gas released per inch of free supernate removal provided the following conditions are met:
   • Hydrogen depletion is successfully accomplished in the waste tanks, based on criteria in Section 4.2.1.1.
   • Free supernate removal activities shall be completed within 48 hours upon completion of hydrogen depletion.

8. If recognition of an unintended saltcake interstitial liquid removal activity has occurred during a free supernate removal activity, then immediately shut down the transfer.

4.3.2 SLUDGE AGITATION, BULK SALTCAKE DISSOLUTION, AND SALTCAKE INTERSTITIAL LIQUID REMOVAL ACTIVITIES
Hydrogen bubbles can become trapped in the solids layers (i.e., settled sludge, saltcake, and slurried sludge) over time and subsequently released. The amount of trapped hydrogen released is dependent upon the characteristics of the solids layers (e.g., settled sludge or slurried sludge) and the release initiator (e.g., waste tank mixing device operation, hydrostatic head pressure reduction due to free supernate removal, transfer pump operation for the purpose of recirculation).

INSIGNIFICANT SLUDGE MIXING, BULK SALTCAKE DISSOLUTION, AND
SALTCAKE INTERSTITIAL LIQUID REMOVAL ACTIVITIES

Some operational activities have the potential to release insignificant amounts of hydrogen (excluding spontaneous liberation events). **For these activities, a hydrogen release evaluation and Gas Release Program controls are not required.** These activities listed below are divided into three categories: sludge agitation, saltcake dissolution, and saltcake interstitial liquid removal. These activities are considered insignificant hydrogen release activities for the specific category identified, but may be considered a significant hydrogen release activity for a different category (or may be considered free supernate removal or a flammable transient concern). Examples of these insignificant hydrogen release activities are provided in the DSA, Section 3.4.2.11.1, and include the following:

- **Sludge Agitation (activity applied to settled and slurried sludge unless otherwise noted)**
  - Rotation of waste tank mixing device turntables
  - Limited duration operation (less than or equal to five minutes) of a waste tank mixing device for operational/maintenance testing (does not apply to a waste tank containing slurried sludge)
  - Sludge sampling
  - Sample rinsing
  - Inserting/removing tank components below the sludge layer (e.g., riser mining tools, pumps, caissons, etc.)
  - Riser mining in a sludge tank
  - 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)
  - Waste sparging (air or steam)
  - Flushing of transfer pumps or jets
  - Flushing of ventilation system components (e.g., demister, reheater) and level monitoring equipment (e.g., reel tape)
  - Filling purge condenser seal leg

Sludge agitation activities stated above, if performed in slurried sludge, may cause a spontaneous liberation event; however, no hydrogen release evaluation is required for the activity. Routine Flammability Controls and the Spontaneous Liberation Protection portion of the Waste Tank Quiescent Time Program ensure waste tanks maintain the minimum time to LFL (CLFL for Tank 50) defined by the waste tank flammability classification. These controls are adequate to ensure spontaneous liberation events would not be a concern in these waste tanks.

In general, if activities in waste storage tanks disturb a localized region of sludge, then these activities are judged to result in an insignificant hydrogen release.
• **Bulk Saltcake Dissolution**
  - Bearing water leaks from pressurized pump columns (e.g., slurry pump, telescoping transfer pump) during transfers into a waste tank
  - Limited duration operation (less than or equal to 5 minutes) of a waste tank mixing device or transfer pump (waste tank recirculation) for operational/maintenance testing
  - Transfers out of a salt tank (including transfers with a siphon break on the transfer pump/jet discharge line)
  - Recirculation to the feed tank from the 242-16H evaporator feed pump
  - Evaporator operations associated with concentrated waste being transferred (siphoning/lifting/pump-outs) to the evaporator drop tank (including concurrent transfers)
  - **Transfers into an evaporator drop tank (Tank 30, Tank 37, and Tank 38 only) with an exposed saltcake mound present (located within a 20 ft radius from the center of the evaporator concentrate receipt riser)**
  - Transfers into salt tanks with exposed salt on cooling coils / exposed salt on waste tank wall (height and base in inches not feet)
  - Flushing of equipment in a salt tank
  - Flushing of ventilation system components (e.g., demister, re heater) and level monitoring equipment (e.g., reel tape)
  - Sample rinsing
  - Salt sampling
  - Removing tank components from below the salt layer
  - Filling purge condenser seal leg

• **Saltcake Interstitial Liquid Removal**
  - Limited duration operation (less than or equal to 5 minutes) of a transfer pump for operational/maintenance testing
  - 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 tanks disturb a limited quantity of saltcake (e.g., small salt peaks) or remove interstitial liquid from a limited quantity of saltcake, then these activities are judged to result in an insignificant hydrogen release and are not considered bulk saltcake dissolution, or saltcake interstitial liquid 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.

**In addition to the operational activities that have the potential to release insignificant**
amounts of hydrogen (described above), hydrogen releases may also be associated with the unintended transitions between certain activities. These unintended transitions may be related to uncertainty in saltcake level determinations used to set the thresholds between free supernate removal and saltcake interstitial liquid removal. These transitions/activities include the following:

- Unintended transition between free supernate removal and saltcake interstitial liquid removal. This activity is considered to release insignificant additional hydrogen. The controls associated with free supernate removal provide adequate protection for a trapped gas release, and the controls associated with saltcake interstitial liquid removal in Gas Release Program are not required for this unintended transition.

- Water or dilute supernate addition onto exposed saltcake after unintended transition between free supernate removal and saltcake interstitial liquid removal. This activity, following the unintended transition, is considered to release insignificant amounts of hydrogen. The controls associated with bulk saltcake dissolution in the Gas Release Program are not required for this activity following the unintended transition.

4.3.2.1 INITIAL GAS RELEASE EVALUATION FOR SLUDGE AGITATION, BULK SALTCAKE DISSOLUTION, AND SALTCAKE INTERSTITIAL LIQUID REMOVAL ACTIVITIES

Prior to planned sludge agitation, bulk saltcake dissolution, or saltcake interstitial liquid removal activities, an initial evaluation shall be performed to determine whether entry into the Gas Release Mode will be required. Bulk saltcake dissolution and saltcake interstitial liquid removal activities in Type I/II Acidic Chemical Cleaning Waste Tanks and Type I/II Non-Acidic Chemical Cleaning waste tanks are prohibited. Sludge agitation activities that could exceed Gas Release Criteria are prohibited in Type I/II Non-Acidic Chemical Cleaning waste tanks. Tank 50 is not allowed to enter into Gas Release Mode [Ref. 1]. Tanks in Gas Release Mode are prohibited from receiving Chemical Cleaning transfers [Ref. 6]. Saltcake interstitial liquid removal activities using a transfer jet that could exceed the Gas Release Criteria below are not permitted. When this initial evaluation shows that the release of hydrogen due to sludge agitation, bulk saltcake dissolution, or saltcake interstitial liquid 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 trapped gas release activities are required (other than Routine Flammability Controls and Gas Release Program) [Ref. 1]:

- Become flammable in less than 7 days for a Rapid Generation Tank (due to flammable vapor contributions from Isopar® L [Tank 50 only], trace organics, trapped gas release and radiolytic hydrogen generation) [Ref. 1].

- Become flammable in less than 28 days for a Slow Generation Tank (due to flammable vapor contributions from Isopar® L [Tank 50 only], trace organics, trapped gas release and radiolytic hydrogen generation) [Ref. 1].

- Become flammable for a tank classified as a Very-Slow Generation Tank (due to flammable vapor contributions from Isopar® L [Tank 50 only], trace organics, trapped gas release and radiolytic hydrogen generation) [Ref. 1].
Tanks may be reclassified, based on the engineering evaluation, to meet the above criteria. For example, an evaluation determines that, for a Slow Generation Tank, the assumed trapped gas release from the planned sludge agitation, bulk saltcake dissolution, or saltcake interstitial liquid removal activities results in reaching 50% of the LFL 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 Gas Release Program).

Tank 26 waste removal performed its first CSMP mixing campaign in February 2019. A sludge sounding performed following a 10-day mixing campaign of all four CSMPs indicated the sludge was disturbed lower in the tank than was expected (i.e., a 32.4-inch disturbance depth versus the 24-inch DSA disturbance depth input). A review of Tank 26 process history indicated that the tank served as the 242-16F evaporator feed tank and canyon receipt tank, having a history of containing highly concentrated supernate, resulting in a waste layer containing a mixture of salt and sludge [Ref. 60, Action 4]. For waste tanks with the potential to contain inter-mixed sludge/salt waste layers, the more conservative waste layer should be assumed for gas release and quiescent time evaluations [Ref. 61].

4.3.2.2 Gas Release Methodology for Sludge Agitation, Bulk Saltcake Dissolution, and Interstitial Liquid Removal Activities

Variable H2 Total Calculation – Initial GRM Evaluation

The hydrogen concentration due to trapped gas release is added to the initial concentration to determine the total hydrogen concentration, H2Total, in the waste tank vapor space due to sludge agitation, bulk saltcake dissolution or interstitial liquid removal activities:

\[
\text{Eq. #86 } \quad \text{H}_2\text{Total} = \text{H}_2\text{Initial} + \text{TG}
\]

Where:

- \( \text{H}_2\text{Total} \) = Total hydrogen concentration in the waste tank vapor space due to sludge agitation, bulk saltcake dissolution or interstitial liquid removal, vol. frac.
- \( \text{H}_2\text{Initial} \) = Initial hydrogen concentration, vol. frac. (see Variable H2Initial Calculation)
- \( \text{TG} \) = Hydrogen concentration due to trapped gas release (see Variable TG Calculation), vol. frac.

Variable H2Initial Calculation – Initial GRM Evaluation

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 agitation, bulk saltcake dissolution, or saltcake interstitial liquid removal activities listed in Section 4.3.2 or when the steady state hydrogen equilibrium concentration is used as the initial hydrogen 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.

Flammability evaluations shall use the maximum of 2.5% of the LFL25C for hydrogen or a value based on the steady state hydrogen equilibrium concentration accounting for ventilation operation (H_{eq(Rapid/Slow)}) as the initial condition for Rapid and Slow Generation Tanks. A value greater than 2.5% of the LFL25C may be used as the initial condition; however, this value may not be less than 2.5% of the LFL25C. The steady state hydrogen equilibrium concentration is calculated using Equation 87, substituting the atmospheric breathing term, Q_{ATM}, 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 the LFL25C and the greater of the two is used as H_{2Initial} in Equation 86. If H_{eq(Rapid/Slow)} 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 Very Slow Generation Tanks, the greater of 2.5% of the LFL25C or H_{eq}, accounting for atmospheric breathing only (see Equation 88), can be used as the initial hydrogen concentration if the calculated trapped gas release does not cause the tank vapor space to exceed the LFLOC. No vapor space turnovers are required for the initial trapped gas release activity if the greater of 2.5% of the LFL25C or H_{eq} 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 the initial hydrogen concentration assumed in the hydrogen release engineering evaluation. If H_{eq} is greater than 2.5% of the LFL25C and using H_{eq} as the initial hydrogen concentration causes the waste tank vapor space to exceed 100% of the LFLOC upon releasing the trapped hydrogen, 2.5% of the LFL25C may be used as the initial hydrogen concentration; however, vapor space turnovers or hydrogen monitoring shall be required prior to each trapped gas release activity to ensure the waste tank bulk vapor space hydrogen concentration is less than or equal to 2.5% of the LFL25C.

The required number of vapor space turnovers for each tank will be documented in the ERD [Ref. 2]. The methodology specified in Reference 15 with a mixing efficiency of 0.2 shall be employed to determine the adequate number of vapor space turnovers. The mixing efficiency of 0.2 is based on the recommended value from NFPA 69 Annex D for the ventilation system arrangement (single exhaust opening, non-positive supply ventilation system) [Ref. 13]. However, vapor space turnovers and/or comparing the tank LFL reading to a reading obtained using a known LFL concentration can be employed to 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. 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 will be performed in Tank 50, when classified as a Rapid or Slow tank, to reduce the initial hydrogen concentration from 3.8% of the LFL_T to the higher of 2.5% of the LFL_25C or H_{eq}(Rapid/Slow). As a Very Slow waste tank, vapor space turnovers can be used in Tank 50 to reduce the equilibrium concentration to 2.5% of the LFL_25C 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 H_{eq} CALCULATION – INITIAL GRM EVALUATION**

For Rapid and Slow Generation Tanks, steady state hydrogen equilibrium accounting for ventilation (minimum required purge flow for the applicable flammability classification) may be used as the assumed initial hydrogen concentration prior to initiation of sludge agitation, bulk saltcake dissolution or saltcake interstitial liquid removal activities. The steady state hydrogen equilibrium (H_{eq}(Rapid/Slow)) is calculated using the following equation:

Eq. #87 \[ H_{eq}(\text{Rapid/Slow}) = \frac{Q_{H2}}{Q_{H2} + 60 \cdot Q_{\text{purge}}} \]

Where:

- \( H_{eq}(\text{Rapid/Slow}) \) = Hydrogen concentration at equilibrium accounting for minimum ventilation flow rate, vol. frac.
- \( Q_{H2} \) = Total hydrogen volumetric evolution rate, ft³/hr (see Variable \( Q_{H2} \) in Section 4.1.2.2.1)
- \( Q_{\text{purge}} \) = Minimum purge flow rate, ft³/min
  - 72 ft³/min for Rapid tanks; 45 ft³/min for Slow tanks
- 60 = Conversion factor from hours to mins

For Very Slow Generation Tanks, steady state hydrogen equilibrium accounting for atmospheric breathing may be used as the assumed initial hydrogen concentration prior to initiation of sludge agitation, bulk saltcake dissolution, or saltcake interstitial liquid removal activities based on the requirements in the Variable H_{2}Initial Calculation Section and is calculated using the expression below:

Eq. #88 \[ H_{eq} = \frac{Q_{H2}}{Q_{H2} + Q_{\text{ATM}}} \]

Where:

- \( H_{eq} \) = Hydrogen concentration at equilibrium, vol. frac.
- \( Q_{H2} \) = Total volumetric hydrogen generation rate, ft³/hr (see Variable \( Q_{H2} \) Calculation in Section 5.1.2.2.1)
**VARIABLE Q\textsubscript{ATM} CALCULATION – INITIAL GRM EVALUATION**

The atmospheric breathing assumptions and methodology are established in Reference 1 Section 3.4.1.5.5. The atmospheric breathing rate is determined as follows:

\[
\text{Q}_{\text{ATM}} = \frac{\text{mean atm. fluctuation}}{1013} \times \frac{\text{V}_V}{24}
\]

Where:

- \( \text{Q}_{\text{ATM}} \) = Atmospheric breathing rate, \( \text{ft}^3/\text{hr} \)
- \( \text{Mean atm. fluctuation} \) = Mean pressure fluctuation, 5 mbar/day [Ref. 41]
- \( \text{V}_V \) = Vapor space volume, based on the HLLCP setpoint, \( \text{ft}^3 \) (see Variable \( V_V \) Calculation)
- 24 = Conversion factor from days to hours
- 1013 = Standard atmospheric pressure, mbar

**VARIABLE V\textsubscript{V} CALCULATION – INITIAL GRM EVALUATION**

The HLLCP shall be used to protect the vapor space volume in the initial evaluation for sludge agitation, bulk saltcake dissolution, or saltcake interstitial liquid removal activities to determine if entry into Gas Release Mode will be required. For saltcake interstitial liquid removal activities, the vapor space volume may also be based on the actual waste contents/inventory. The following equation is the vapor space volume calculation in units of \( \text{ft}^3 \).

\[
\text{V}_V = 0.13368 \left[ \text{V}_T - (\text{L}_{\text{HLLCP}} + \text{IU}) \times \text{Ff} - \text{MMW} \right]
\]

Where:

- \( \text{V}_V \) = Vapor space volume, \( \text{ft}^3 \), based on the HLLCP setpoint. For saltcake interstitial liquid removal, the vapor space volume may also be based on the actual/projected waste tank level.
- \( \text{V}_T \) = Total tank vapor space volume (empty tank), gallons
- \( \text{L}_{\text{HLLCP}} \) = Level of HLLCP setpoint, inches. For saltcake interstitial liquid removal, actual/projected waste level may be used.
- \( \text{Ff} \) = Nominal waste tank fill factor, gal/in (see Section 3.0)
- \( \text{MMW} \) = Maximum volume associated with a Transfer Error event, equal to 15,000 gallons for sludge agitation and bulk saltcake dissolution. For saltcake interstitial liquid removal, MMW is considered to be zero.
IU = Uncertainty attributed to HLLCP, inches [see Ref. 12]. For saltcake interstitial liquid removal using actual/projected waste level, this value is zero.

0.13368 = Conversion factor from gallons to ft$^3$

Actual/projected waste level may be used to credit the vapor space volume when calculating trapped gas release during saltcake interstitial liquid removal. The waste level could be the tank level prior to free supernate removal activity (actual level) or the level of the bulk saltcake plus some margin (projected level) to account for uneven saltcake layer or a layer of supernate on top of the saltcake. However, it must be adjusted to account for any salt peaks/mounds with height and base in feet not inches. The hydrostatic head pressure of the waste layers between the actual/projected waste level and the bulk saltcake level must be included in the total head pressure calculations (see Variable C Calculation – Initial GRM Evaluation).

**VARIABLE TG CALCULATION – INITIAL GRM EVALUATION**

The methodology for determining the vapor space hydrogen concentration due to trapped gas release from sludge agitation or bulk saltcake dissolution is provided below. Each contributing phase (i.e., trapped gas release from saltcake, trapped gas release from settled sludge, and trapped gas release from slurried sludge) shall have a separate value of trapped hydrogen gas released (TG) and these values are added together to determine the total trapped gas release.

\[
TG = \frac{V_{\text{solids}} \cdot H_{\text{mix}} \cdot G_s \cdot F_R}{V_v} 
\]

Where:

- **TG** = Trapped hydrogen released due to sludge agitation and/or bulk saltcake dissolution activities, vol. frac.
- **$V_{\text{solids}}$** = Volume of solids layer that is available to liberate hydrogen, ft$^3$ (see Variable $V_{\text{solids}}$ Calculation)
- **$G_s$** = Fraction of trapped bubble gas in solids layers that is available to liberate hydrogen, vol. frac. (see Variable $G_s$ Calculation)
- **$H_{\text{mix}}$** = Hydrogen fraction in trapped gas, vol. frac. (see Variable $H_{\text{mix}}$ Calculation)
- **$C$** = Pressure correction factor (see Variable C Calculation)
- **$F_R$** = Fraction of trapped gas release, vol. frac. (see Variable $F_R$ Calculation)
- **$V_v$** = Vapor space volume protected by HLLCP, ft$^3$ (see Variable $V_v$ Calculation)
For waste tanks containing an overlying settled sludge/slurried sludge layer above a saltcake layer and/or a slurried sludge layer beneath the saltcake layer, operating a transfer pump in recirculation may have the potential to release the hydrogen gas trapped in the sludge layers. When sludge layers exist above the saltcake, bulk saltcake dissolution from recirculation of the transfer pump is considered to have the potential to disturb any overlying sludge layers as the supporting saltcake beneath is dissolved. Additionally, dissolving saltcake is conservatively assumed to have the potential to disturb the slurried sludge below the saltcake layer by initiating a spontaneous release. The release of the hydrogen gas trapped in the sludge layers is assumed to be an instantaneous release of 100% of the trapped gas from the sludge. Therefore, the volume of trapped hydrogen gas in the overlying settled sludge/slurried sludge above the saltcake layer and/or the slurried sludge layer beneath the saltcake layer shall be included in the total trapped hydrogen gas released during operation of transfer pump in recirculation in a waste tank containing saltcake [Ref. 43].

For saltcake interstitial liquid removal, removing saltcake interstitial liquid will not only release trapped hydrogen gas from saltcake where the interstitial liquid is removed but also release trapped hydrogen gas from the solids layers below the pump/jet suction due to reduction of hydrostatic head over the trapped hydrogen gas within these solids layers. The volume of trapped hydrogen gas release per inch of interstitial liquid removal for each applicable solids layer beneath the pump suction is calculated in the same manner as the volume of trapped hydrogen gas release per inch of free supernate removal (see Equation 84). Combining Equation 84 into Equation 91 and accounting for the volume of interstitial liquid removed, the total volume of trapped gas released due to saltcake interstitial liquid removal is simplified as follows:

\[
TG = \frac{H_{mix}}{V_v} \left[ V_{salt} \cdot C \cdot G_s \cdot F_R + \frac{(0.0254) \cdot (0.13368) \cdot \rho \cdot g \cdot L_{liquid}}{1.01325E+05 \cdot P_{atm}} \sum_{n=1}^{n} \left( V_{solids} \cdot P_{salt} \right) \right]
\]

Where:

- \( TG \) = Trapped hydrogen released due to saltcake interstitial liquid removal, vol. frac.
- \( V_{salt} \) = Volume of saltcake layer above the pump/jet suction, ft\(^3\) (see Variable \( V_{solids} \) Calculation)
- \( G_s \) = Fraction of trapped bubble gas in applicable solids layers, vol. frac. (see Variable \( G_s \) Calculation)
- \( H_{mix} \) = Hydrogen fraction in trapped gas, vol. frac. (see Variable \( H_{mix} \) Calculation)
- \( C \) = Pressure correction factor (see Variable \( C \) Calculation)
- \( F_R \) = Fraction of trapped gas release, vol. frac. (see Variable \( F_R \) Calculation)
- \( V_v \) = Vapor space volume protected by HLLCP, ft\(^3\) (see Variable \( V_v \) Calculation)
- 0.0254 = Conversion factor from inches to meters
- 1.01325E+05 = Conversion factor from atms to Pas (N/m\(^2\))
\[ 0.13368 \text{ = Conversion factor from gallons to ft}^3 \]
\[ \rho \text{ = Density of interstitial liquid, kg/m}^3 \]
\[ g \text{ = Standard acceleration of gravity (9.81 m/s}^2 \]
\[ P_{\text{atm}} \text{ = Ambient pressure, atm} \]
\[ L_{\text{liquid}} \text{ = Height of interstitial liquid removed, inches} \]
\[ V_{\text{solids, pump}} \text{ = Volume of solids layers below the pump/jet suction, gallons} \]
\[ n \text{ = Number of solids layers below the pump/jet suction} \]

**VARIABLE [\text{\textit{V}}_{\text{solids}}] \text{ CALCULATION – INITIAL GRM EVALUATION}**

All insoluble solids are considered to retain trapped gas for the purposes of trapped gas retention. The DSA, Section 3.4.1.5.3 and References 32, 41 and 49 establish the inputs for determining the volume of solids affected due to sludge agitation, bulk saltcake dissolution or saltcake interstitial liquid removal activities.

- **Sludge Agitation**
  - **Settled sludge:**
    - If the agitation source is a single SMP, multiple slurry pumps, multiple quad-volutes, multiple SBPs, or multiple CSMPs, the volume of sludge affected is 100% of the tank cross sectional area (accounting for sludge disturbance depth).
    - If the agitation source is a single slurry pump, single quad-volute slurry pump, single SBP, or single CSMP, the volume of sludge affected is 50% of the tank cross sectional area (accounting for sludge disturbance depth).
    - The settled 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.
  - **Slurried sludge:** The volume of sludge affected is 100% of the slurried sludge inventory, even if the agitation source is a single waste tank mixing device.

- **Saltcake removal activities**
  The trapped hydrogen gas released due to bulk saltcake dissolution is equivalent to the hydrogen gas trapped in the volume of saltcake dissolved. Reference 54 demonstrates that at a temperature less than or equal to 70\(^\circ\)C, the ratio of dissolution by volume between liquid and salt is bounded by 1:1.

For bulk saltcake dissolution, the amount of saltcake dissolved in the affected tank is equal to the smaller of the total volume of saltcake in the waste tank or the volume of the liquid which will be used for bulk saltcake dissolution. If a liquid source tank is to be used for bulk saltcake dissolution and the volume of the tank is used to estimate the volume of saltcake
dissolved, the liquid 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). For example, a dissolution water skid (DWS) is commonly used as a method for introducing water into a waste tank for saltcake dissolution. The liquid source system for the DWS contains solenoid actuated valves, controlled by a Programmable Logic Controller (PLC), that mechanically isolate the system from the continuous water source. The solenoid actuated valves and PLC controller have been shown to be extremely robust in flow isolation capabilities. A failure of the PLC causing continuous makeup flow is considered not to exist [Ref. 1, Section 3.4.1.5.2.6].

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

For saltcake dissolution with mixing devices, trapped gas release is encompassed by dissolution of saltcake rather than by mechanical agitation of the salt, and therefore volume disturbed by a mixing device (as defined by cross-sectional area and disturbance depth) is not applicable for determining trapped hydrogen release.

The volume of saltcake dissolved varies depending on the liquid addition methods and the layer of liquid above the bulk saltcake and is discussed below. Dissolution ratios are valid for supernate temperatures less than or equal to 70°C unless otherwise noted.

- **Saltcake With No Supernate Coverage:** For saltcake dissolution due to liquid addition to saltcake with no supernate coverage, the trapped hydrogen released is equivalent to the gas trapped in the volume of saltcake dissolved, where:
  - 1 gallon of water added dissolves 1 gallon of saltcake.
  - 1 gallon of dilute supernate added dissolves 1 gallon of saltcake.
  - Addition of concentrated supernate results in insignificant salt dissolution.

- **Saltcake With Supernate Coverage:** For saltcake dissolution due to liquid addition to saltcake with supernate coverage, the trapped hydrogen released is equivalent to the gas trapped in the volume of saltcake dissolved, where:
  - If supernate coverage over the **bulk** saltcake **layer is dilute supernate and** has been present for less than or equal to 4 days or if concurrent additions are made at more than one location (e.g., riser, downcomer), then adding 1 gallon of water or dilute supernate dissolves 1 gallon of saltcake. Addition of concentrated supernate (under the same conditions) results in insignificant saltcake dissolution.
  - If supernate coverage over the **bulk** saltcake **layer is concentrated supernate or** has been present for greater than 4 days, any addition of water, dilute supernate, or concentrated supernate, regardless of the location of the point of entry of the incoming liquid (e.g., in the vapor space, in the supernate or in the saltcake), results
in insignificant saltcake dissolution. This allowance does not apply for concurrent additions at more than one location (e.g., riser, downcomer). This input is not dependent on temperature.

- Saltcake Dissolution With Waste Tank Mixing Devices: For saltcake dissolution due to waste tank mixing devices, the trapped hydrogen released is equivalent to the gas trapped in the volume of saltcake dissolved, where:
  - 1 gallon of liquid in the tank above the bulk saltcake layer, whether the tank contains dilute supernate or concentrated supernate, dissolves 1 gallon of saltcake.
  - 1 gallon of any liquid being introduced (e.g., dissolution water) dissolves 1 gallon of saltcake.

- Saltcake Dissolution With Mixing Eductors: Mixing eductors are designed to promote saltcake dissolution via convective mixing. This is accomplished by discharging the water added through a nozzle, entraining the liquid above the waste tank bulk saltcake layer through an eductor assembly at a ratio of 4 gallons of the waste tank liquid to 1 gallons of water added. At the start of a dissolution campaign and after a mixing eductor is lowered to improve convective mixing, the volume of liquid present in the tank above the bulk saltcake layer may dissolve saltcake. Therefore, the volume of liquid present above the bulk saltcake layer, in addition to the volume of water being added, must be accounted for in the 1:1 salt dissolution ratio assumed in the calculation for hydrogen release until the entire volume of that material is entrained through a mixing eductor at the design entrainment ratio between tank liquid and additional water of 4:1 (i.e., 4 volumes of tank liquid plus 1 volume of water added dissolves 5 volumes of bulk saltcake). For subsequent water additions to the waste tank at the same eductors elevation or if the mixing eductors are raised, the volume of liquid above the bulk saltcake layer does not need to be accounted for since the liquid has already acted as a saltcake dissolution media. Only the liquid added via the mixing eductors will dissolve saltcake at a 1:1 ratio.

In summary, for salt dissolution associated with mixing eductors, the trapped hydrogen released is equivalent to the gas trapped in the volume of saltcake dissolved, and is dependent upon the following:

- Water added through a mixing eductor at the start of a dissolution campaign and after a mixing eductor is lowered dissolves saltcake at the following ratio, until the total volume of water added through the mixing eductor(s) equals ¼ of the liquid volume initially above the Bulk Saltcake Layer:
  - 1 gallon of water added dissolves 5 gallons of saltcake (1 gallon of saltcake dissolved for each gallon added, plus 4 gallons of saltcake dissolved due to the mixing of the liquid in the tank, whether the tank contains Dilute Supernate or Concentrated Supernate).

- After the total volume of water added through the mixing eductor(s) equals ¼ of the liquid volume initially above the Bulk Saltcake Layer, subsequent water additions through a mixing eductor at the same eductor(s) elevation or if the mixing eductor(s) are raised dissolve saltcake at the following ratio:
  - 1 gallon of water added dissolves 1 gallon of saltcake
Saltcake Dissolution With Transfer Pump Operated for the Purpose of Recirculation: Recirculation with a transfer pump is defined as the planned movement of waste tank contents through a flow path (which may or may not be exclusively internal to the waste tank) that concludes with the bulk of the material being returned to the same waste tank. Flow that returns to the waste tank through an engineering feature (such as a siphon break in the transfer line) or minor leakage from valves, fittings, etc. is not considered recirculation, as long as the bulk of the material is being removed from the waste tank. Operation of a waste tank pump in recirculation (i.e., discharging existing waste tank liquid back into the same waste tank) of dilute supernate is conservatively assumed to dissolve saltcake. Therefore, for saltcake dissolution due to transfer pump operation for the purpose of waste tank recirculation, the trapped hydrogen released is equivalent to the gas trapped in the volume of saltcake dissolved, where:

- 1 gallon of dilute supernate in the tank above the bulk saltcake layer dissolves 1 gallon of saltcake.
- Waste tank recirculation of concentrated supernate results in insignificant saltcake dissolution.

**Variable Gs Calculation – Initial GRM Evaluation**

As documented in the DSA, Section 3.4.1.5.3, the maximum percentage of trapped bubble gas in saltcake, settled sludge and slurried sludge is as follows:

- 11% by volume in saltcake
- 10% by volume in settled sludge
- 20% by volume in slurried sludge

**Variable Hmix Calculation – Initial GRM Evaluation**

In waste tanks with known chemistry and heat loads, \( H_{mix} \) may be determined using equations documented in Section 4.1.2.2.2, limited to a maximum of 75%. Otherwise, the hydrogen percent in trapped gas is:

- 75% in waste tanks that contain slurried sludge
- 50% in other waste tanks

For sludge and/or 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) may be used to determine the hydrogen concentration in trapped gas for Gas Release evaluations [Ref. 16].

**Variable C Calculation – Initial GRM Evaluation**

The expansion factor is used for predicting the effect of pressure on trapped bubble gas release due to sludge agitation, bulk saltcake dissolution, or saltcake interstitial liquid removal activities.
The relationship between the expansion factor and the head pressure is linear \( C = \frac{P_{\text{avg}}}{P_{\text{atm}}} \). The expansion correction is determined from the following head pressure equation [Ref. 14]:

\[
\text{Eq. #93} \quad P_{\text{avg}} = \left( \sum_{a=2}^{n} \frac{\rho_a \cdot g \cdot h_a}{X} \right) + \frac{1}{2} \frac{\rho_1 \cdot g \cdot h_1}{X} + P_{\text{atm}}
\]

Where:

- \( P_{\text{avg}} \) = Hydrostatic head pressure, atm
- \( n \) = Number of layers in the waste tank above the evaluated layer
- \( \rho_a \) = Density of layer material, kg/m\(^3\)
- \( \rho_1 \) = Density of the evaluated layer material, kg/m\(^3\)
- \( h_a \) = Height of layer, m
- \( h_1 \) = Height of the portion of the evaluated layer from which hydrogen can be released, m
- \( g \) = Standard acceleration of gravity (9.81 m/s\(^2\))
- \( P_{\text{atm}} \) = Atmospheric pressure, atm
- \( X \) = 101325 Pa/atm, conversion factor from Pa to atm

Actual/projected waste level may be used to credit the vapor space volume when calculating trapped gas release during saltcake interstitial liquid removal. The head pressure of the waste layers between the actual/projected waste level assumed as the initial level in the GRM evaluation for interstitial liquid removal and the saltcake level must be accounted for in the total head pressure calculation. For example,

If the assumed initial level is the tank level prior to free supernate removal activity, the hydrostatic head pressure exerted by the free supernate layer must be included in the total head pressure calculation.

If the assumed initial level is the level of the bulk saltcake plus some margin to account for uneven saltcake layer or a layer of supernate on top of the saltcake, the hydrostatic head pressure exerted by the liquid layer within the margin must be accounted for in the total head pressure calculation.

**VARIABLE \( F_r \) CALCULATION – INITIAL GRM EVALUATION**

The percentage of trapped hydrogen gas release is assumed to be 100%.

**4.3.2.3 GAS RELEASE MODE SLUDGE AGITATION, BULK SALTCAKE DISSOLUTION, AND SALTCAKE INTERSTITIAL LIQUID REMOVAL ACTIVITIES**

For planned sludge agitation, bulk saltcake dissolution, or saltcake interstitial liquid removal activities where the percent LFL (initial hydrogen concentration plus trapped gas release) could exceed the SAV (or 60% of the LFLT for trapped gas release from Very Slow Generation Tanks) 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, GRM shall be declared for the
waste tank prior to sludge agitation, bulk saltcake dissolution or saltcake interstitial liquid
removal activities. Once the waste tank has entered GRM, the waste tank sludge agitation, bulk
saltcake dissolution or saltcake interstitial liquid removal activities shall be controlled to
maintain the waste tank bulk vapor space hydrogen concentration less than or equal to the SAV
and the minimum time to LFL defined by the waste tank flammability classification. The
methodology used to determine the necessary controls (e.g., number of waste tank mixing
devices and mixing device speed/indexing [for sludge agitation], amount/rate of liquid addition
and recirculation pump flow rate [for bulk saltcake dissolution], amount/rate of saltcake
interstitial liquid removal transfer pump flow rate [saltcake interstitial liquid removal]) shall be
based on an individual engineering evaluation and shall consider the solids layers (saltcake,
settled sludge, and slurried sludge) that are affected by the activity. The trapped gas release
evaluation shall be based on the actual waste contents/inventory (considering incoming
transfers), minimum required ventilation flow rate for waste tanks (72 scfm for all waste tanks
except Tanks 40 and 51 [188 scfm]). The calculated time to LFL shall be based on the vapor
space volume protected by the HLLCP setpoint. Consideration should also be given to the
resulting GRM Quiescent Time for a waste tank in GRM if slurried sludge is created. The
methodology used for the GRM evaluation is similar to the methodology discussed in Section
4.3.2.2, except as follows:

- Sludge Agitation Activities
  - Trapped hydrogen gas release percentage: The evaluation may be based on controlled
    parameters (e.g., number of waste tank mixing devices, mixing device speed/indexing)
    to determine the affected tank cross sectional area and sludge disturbance depth.
  - Actual waste height: Actual/projected waste tank level may be used to credit the waste
tank vapor space volume when calculating trapped gas released. For waste tanks
receiving transfers, the actual waste level shall be adjusted to account for the planed
transfer amount and does not have to be adjusted for the maximum volume associated
with a Transfer Error event (i.e., 15,000 gallons).

- Saltcake Removal Activities
  - Volume/amount of saltcake for bulk saltcake dissolution due to liquid addition with or
    without supernate coverage, except when performed via mixing eductors: The evaluation
may be based on controlled parameters (e.g., amount/rate of liquid addition) to determine
the saltcake volume and affected dissolution rate and corresponding hydrogen release
rate for the activity using the 1:1 saltcake dissolution ratio between liquid (water/dilute
supernate) and salt. This hydrogen release rate may be then used to calculate the time
dependent hydrogen concentration accumulated in the waste tank vapor space rather than
assuming an instantaneous hydrogen release from the total volume of saltcake.
  - Volume/amount of saltcake for bulk saltcake dissolution for liquid addition via mixing
eductors with or without supernate coverage: The evaluation may be based on controlled
parameters (e.g., amount/rate of liquid addition) to determine the saltcake volume and
affected dissolution rate (and corresponding hydrogen release rate) for this activity. The
evaluation shall be performed in accordance with the methodology described in
Reference 59. The resulting hydrogen release rate may then be used to calculate the time
dependent hydrogen concentration accumulate in the waste tank vapor space rather than assuming an instantaneous hydrogen release from the total volume of saltcake.

- Volume/amount of saltcake for bulk saltcake dissolution due to transfer pump waste tank recirculation: The evaluation may be based on controlled parameters (e.g., transfer pump/recirculation flow rate) to determine the saltcake volume and affected dissolution rate and corresponding hydrogen release rate for the activity using the 1:1 dissolution ratio between liquid (water/dilute supernate) and salt. This hydrogen release rate may then be used to calculate the time dependent hydrogen concentration accumulated in the waste tank vapor space rather than assuming an instantaneous hydrogen release from the total volume of saltcake.

For waste tanks containing an overlying settled sludge/slurried sludge layer above a saltcake layer and/or a slurried sludge layer beneath the saltcake layer, operating a transfer pump in recirculation may have the potential to release the hydrogen gas trapped in the sludge layers. When sludge layers exist above the saltcake, bulk saltcake dissolution from recirculation of the transfer pump is considered to have the potential to disturb any overlying sludge layers as the supporting saltcake beneath is dissolved. Additionally, dissolving saltcake is conservatively assumed to have the potential to disturb the slurried sludge below the saltcake layer by initiating a spontaneous release. Therefore, the release of hydrogen gas trapped in the sludge layers is assumed to be an instantaneous release of 100% of the trapped gas from the sludge and will be included in the assumed initial hydrogen concentration [Ref. 43].

- Volume/amount of saltcake for bulk saltcake dissolution due to waste tank mixing device operation: The evaluation may be based on controlled parameters (e.g., number of waste tank mixing devices, mixing device speed/indexing) to determine the saltcake volume and affected dissolution rate (and corresponding hydrogen release rate) for this activity. The evaluation shall be performed in accordance with the methodology described in Reference 59. The resulting hydrogen release rate may then be used to calculate the time dependent hydrogen concentration accumulated in the waste tank vapor space rather than assuming an instantaneous hydrogen release from the total volume of saltcake.

- Volume/amount of saltcake for saltcake interstitial liquid removal: The evaluation may be based on controlled parameters (e.g., saltcake interstitial liquid removal transfer pump flow rate) to determine the saltcake volume and affected hydrogen release rate for the activity. This hydrogen release rate may be then used to calculate the time dependent hydrogen concentration accumulated in the waste tank vapor space rather than assuming an instantaneous hydrogen release from the total volume of saltcake.

- Actual waste height: Actual/projected waste tank level may be used to credit the waste tank vapor space volume when calculating trapped gas release. For waste tanks receiving transfers, the actual waste level shall be adjusted to account for the planed transfer amount and does not have to be adjusted for the maximum volume associated with a Transfer Error event (i.e., 15,000 gallons).
Using controlled parameters to modify the inputs stated above (e.g., actual waste height) is considered acceptable given the waste tank in GRM with associated level of controls (e.g., exhaust low flow/high hydrogen concentration interlocks) and continued use of conservative trapped gas release inputs (e.g., bubble gas fraction, hydrogen percent in trapped gas) in the evaluation. In lieu of using the actual waste contents/inventory, the evaluation may be based on the vapor space volume protected by the Tank Fill Limits Program.

When an activity affects multiple solids layers (e.g., waste tank mixing device operation resulting in settled sludge agitation and bulk saltcake dissolution), the engineering evaluation may utilize more than one of the modified inputs/methodologies stated above (based on controlled parameters).

4.3.2.4 IMPLEMENTATION ACTIONS

1. Prior to initiation of sludge agitation, bulk saltcake dissolution or saltcake interstitial liquid removal activities, an engineering evaluation shall be performed to determine whether entry into the Gas Release Mode will be required [TSR SAC 5.8.2.29.a]. Additionally, if an unintended saltcake interstitial liquid removal has occurred, subsequent interstitial liquid removal activities or water/dilute supernate additions to exposed saltcake shall require an engineering evaluation to determine whether entry into the Gas Release Mode will be required.

2. Operating procedures shall address the requirement to perform an adequate number of vapor space turnovers and/or verifying vapor space hydrogen concentration prior to planned trapped gas release activities to ensure the waste tank bulk vapor space hydrogen concentration is less than the initial value assumed in the hydrogen release engineering evaluation. Operating procedures shall address the requirement to have second person verification of completion of vapor space turnover time and/or comparison of the hydrogen concentration reading to the hydrogen concentration acceptance value. If verifying the vapor space hydrogen concentration (i.e., comparing the tank LFL reading to a reading obtained using a known LFL concentration) is implemented, the methodology used to determine the flammable vapor concentration shall be consistent with the requirements of Reference 7. [TSR SAC 5.8.2.29.b & TSR SAC 5.8.2.29.d]

3. For sludge agitation activities, the GRM evaluation shall account for water additions that will be used prior to or during waste tank mixing device operation (e.g., SMP flushing, slurry pump bearing water inleakage).

4. During bulk saltcake dissolution or saltcake interstitial liquid removal activities, the amount of hydrogen released from associated insignificant release activities shall be considered in the GRM evaluation for bulk saltcake dissolution or saltcake interstitial liquid removal activities.

5. For waste tanks undergoing sludge agitation, bulk saltcake dissolution or saltcake interstitial liquid removal activities, the GRM evaluation shall determine the number of vapor space turnovers required to reduce the waste tank bulk vapor space hydrogen concentration to less than or equal to the initial value assumed in the hydrogen release engineering evaluation.
The number of vapor space turnovers shall be documented in the ERD.

Vapor space turnovers and/or comparing the tank LFL reading to a reading obtained using a known LFL concentration are not required for the following activities:

- Insignificant sludge mixing, bulk saltcake dissolution or saltcake interstitial liquid removal activities, when performed as a stand-alone activity.
- Initial trapped gas release activities in Very Slow Generation Tanks, since the initial hydrogen concentration in the Gas Release evaluation is assumed to be equal to the maximum of 2.5% of the LFL$_{25^\circ C}$ or the equilibrium hydrogen concentration. For each subsequent trapped gas release activity (e.g., after a pump is lowered, dissolution batch is added to the tank), vapor space turnovers and/or verifying vapor space hydrogen concentration shall be required to ensure the waste tank bulk vapor space hydrogen concentration is less than or equal to the initial value assumed in the evaluation.

6. Operating procedures shall address all the parameters (e.g., mixing device speed/indexing, number of waste tank mixing devices, transfer pump/recirculation pump flow rate, HLLCP setpoint) assumed in the hydrogen release evaluation prior to initiation of sludge agitation, bulk saltcake dissolution or saltcake interstitial liquid removal activities.

7. Planned operation (e.g., waste tank to waste tank transfers) shall be pre-evaluated to ensure bulk saltcake 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 Saltcake removal activities listed in Section 4.3.2).

8. 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.

9. Liquid additions to the waste tanks shall be pre-evaluated using WCS [Ref. 11] or an engineering evaluation (excluding Insignificant Saltcake removal activities listed in Section 4.3.2 and excluding planned saltcake removal activities which require a separate engineering evaluation) to ensure bulk saltcake dissolution does not occur from dissolution of exposed bulk salt in the receipt tank.

10. Bulk saltcake dissolution and interstitial liquid removal activities in Type I/II Acidic Chemical Cleaning Waste Tanks and Non-Acidic Chemical Cleaning Waste Tanks are prohibited.

11. Prior to operation of a waste tank mixing device in a waste tank containing only slurried sludge (for a waste tank mixing device that has not been operated within 180 days), operating procedures shall address the requirements to verify that the waste tank level is less than or equal to the associated Waste Tank Level Limitations for Flammable Transient provided in Table 2 and to have second person verification of waste tank level. [TSR SAC 5.8.2.29.f]

12. Prior to operation of a waste tank mixing device in a waste tank containing saltcake, settled sludge, or any combination of saltcake, settled sludge, or slurried sludge, operating
procedures shall address the requirements to verify that the waste tank level is less than or equal to the associated Waste Tank Level Limitations for Flammable Transient provided in Table 3 and to have second person verification of waste tank level. [TSR SAC 5.8.2.29.g]

13. Operation of the following pumps, which require bearing water for operation, is prohibited in a waste tank containing saltcake [TSR SAC 5.8.2.43.ee]:
   - Slurry pump
   - Telescoping transfer pump when operated for the purpose of waste tank recirculation

This prohibited operation does not apply to waste tanks that contain a limited amount of saltcake, such that the resulting hydrogen release (assuming instant release of all trapped gas contained in the saltcake) would not exceed the Gas Release Criteria.

14. Operating procedures shall address the requirement to have second person verification of the controlled parameters identified in Section 4.3.2.3. These may include (depending on the activity and controlled parameters) the following:
   1. Waste tank mixing device or transfer pump speed setting
   2. Waste tank mixing device turntable operation (rotating or indexed)
   3. Mixing eductor turntable operation (rotating or indexed)
   4. Saltcake dissolution liquid addition rate or saltcake interstitial liquid removal rate (if pump capacity exceeds the allowable addition/removal rate)
   5. Transfer pump/waste tank recirculation flow rate (if pump capacity exceeds the allowable recirculation rate)

15. Saltcake interstitial liquid removal activities using a transfer jet that could exceed the Gas Release Criteria are prohibited. [TSR SAC 5.8.2.43.hh]

This prohibited operation does not apply to unintended transition between free supernate removal and saltcake interstitial liquid removal using a transfer jet. The controls associated with free supernate removal provide adequate protection for trapped gas release for this unintended transition.

16. Saltcake mounds located within a 20 ft radius from the center of the evaporator concentrate receipt riser in Tank 30, Tank 37, and Tank 38 are excluded from consideration as part of the bulk saltcake layer. Therefore, transfers out of an evaporator drop tank that exposes these saltcake mounds are not considered interstitial liquid removal.

17. If the facility recognizes the occurrence of an unintended saltcake interstitial liquid removal activity during a free supernate removal activity, then immediately shut down the transfer and contact engineering.

18. Actual/projected waste level may be used to credit the vapor space volume when calculating trapped gas release during saltcake interstitial liquid removal. Based on the actual/projected waste level assumed as the initial level in the GRM evaluation for interstitial liquid removal, operating procedures shall appropriately address the requirement to perform an adequate number of vapor space turnovers and/or verifying vapor space hydrogen concentration (see Section 4.3.2.4.2 for requirement of second person verification). For example,
If the assumed initial level is the tank level prior to free supernate removal activity, verification of vapor space hydrogen concentration shall be performed prior to initiation of free supernate removal activity.

If the assumed initial level is a projected level between the current tank level and the bulk saltcake with some margin to account for uneven saltcake layer or a layer of supernate on top of the saltcake, then verification of vapor space hydrogen concentration shall be performed prior to initiation of free supernate removal activity and also between the projected level and the bulk saltcake layer.

### 4.4 TANK FILL LIMITS PROGRAM

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 6.3. 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 4.6.

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. 40].

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 7-11
- 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 (i.e., 15,000 gallons) associated with a Transfer Error event (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.

**Table 4: Waste Tank Type Maximum Fill Limits**

<table>
<thead>
<tr>
<th>Waste Tank Type</th>
<th>Maximum Fill Limit (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type I</td>
<td>274</td>
</tr>
<tr>
<td>Type II</td>
<td>304</td>
</tr>
<tr>
<td>Type III/IIIA</td>
<td>372</td>
</tr>
<tr>
<td>Type IV</td>
<td>386</td>
</tr>
</tbody>
</table>

**Maximum Fill Limit to Protect Waste Tank Overflow**

This is the level at which the tank would physically overflow (typically through a sidewall penetration) [Ref. 44].

**Table 5: Waste Tank Level Limitations for Overflow**

<table>
<thead>
<tr>
<th>Tank</th>
<th>Tank Type</th>
<th>Fill Limit (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1F</td>
<td>I</td>
<td>275.9</td>
</tr>
<tr>
<td>2F</td>
<td>I</td>
<td>279.2</td>
</tr>
<tr>
<td>3F</td>
<td>I</td>
<td>280.0</td>
</tr>
<tr>
<td>4F</td>
<td>I</td>
<td>280.3</td>
</tr>
<tr>
<td>5F</td>
<td>I</td>
<td>Closed</td>
</tr>
<tr>
<td>6F</td>
<td>I</td>
<td>Closed</td>
</tr>
<tr>
<td>7F</td>
<td>I</td>
<td>278.2</td>
</tr>
<tr>
<td>8F</td>
<td>I</td>
<td>279.5</td>
</tr>
<tr>
<td>9H</td>
<td>I</td>
<td>277.2</td>
</tr>
<tr>
<td>10H</td>
<td>I</td>
<td>276.4</td>
</tr>
</tbody>
</table>
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) [Ref. 19]. 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.

Table 6: Type I Waste Tank Level Limitations for Wall Stress

<table>
<thead>
<tr>
<th>Specific Gravity (SpG)</th>
<th>Fill Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unflawed Tanks with or without SMP/CSMP (inches)</td>
</tr>
<tr>
<td>[Ref. 19, Table E-1]</td>
<td>[Ref. 19, Table E-5]</td>
</tr>
<tr>
<td>1.00</td>
<td>276.0</td>
</tr>
</tbody>
</table>
Table 7: Type II Waste Tank Level Limitations for Wall Stress
[Ref. 19, Table E-6]

<table>
<thead>
<tr>
<th>Specific Gravity</th>
<th>Fill Level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Flawed Tanks without SMP/CSMP (inches)</td>
</tr>
<tr>
<td>1.00</td>
<td>306.0</td>
</tr>
<tr>
<td>1.20</td>
<td>306.0</td>
</tr>
<tr>
<td>1.40</td>
<td>302.0</td>
</tr>
<tr>
<td>1.60</td>
<td>302.0</td>
</tr>
<tr>
<td>1.80</td>
<td>268.0</td>
</tr>
<tr>
<td>2.00</td>
<td>242.0</td>
</tr>
<tr>
<td>2.20</td>
<td>232.0</td>
</tr>
</tbody>
</table>

**Maximum Fill Limit to Prevent Siphon Through Cooling Coils (Tanks 1-4 and 7-11)**

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 7-11). 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 7-11, determined in Reference 51, is presented in the table below.

Table 8: Type I Waste Tank Level Limitations for Siphon through Cooling Coils

<table>
<thead>
<tr>
<th>Tank</th>
<th>Fill Limit (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1F</td>
<td>245</td>
</tr>
<tr>
<td>2F</td>
<td>246</td>
</tr>
<tr>
<td>3F</td>
<td>243</td>
</tr>
</tbody>
</table>
MAXIMUM FILL LIMIT BASED ON FLAMMABLE TRANSIENT ASSUMPTIONS

This is the level required to protect a plume of hydrogen gas released into the waste tank vapor space as a result of trapped gas release activities in the waste tank from exceeding the LFL.

For waste tanks that do not have an operating waste tank mixing device or waste tanks that contain only slurried sludge (for the solids present in the tank) and the specific waste tank mixing device (planned for operation) has been operated less than or equal to 180 days ago, the waste tank maximum fill limits in Table 4 protect the vapor space volume to ensure flammable transients do not pose a safety concern.

For waste tanks that contain only slurried sludge and have an operating waste tank mixing device and the specific waste tank mixing device (planned for operation) has not been operated within 180 days, the waste tank level limitations for protection of flammable transients is performed by the Gas Release Program (see Section 4.3) and is not part of the criteria for HLLCP setpoint determination [Ref. 1].

For waste tanks that contain saltcake, settled sludge, or any combination of saltcake, settled sludge, or slurried sludge and have an operating waste tank mixing device (planned for operation), the waste tank level limitations for protection of flammable transients is performed by the Gas Release Program (see Section 4.3) and is not part of the criteria for HLLCP setpoint determination [Ref. 1].

MAXIMUM FILL LIMIT TO PROTECT WASTE TANK FLAMMABILITY LEVEL

This is the level to protect the time to LFL for a waste tank (excluding Type I/II waste tanks in Acidic Chemical Cleaning Mode and waste tanks in Closure Mode), which in turn protects the waste tank flammability classification, upon loss of ventilation. The time to LFL for a waste tank is determined as the lower of the radiolytic time to LFL or the spontaneous time to LFL. The waste tank vapor space used in the radiolytic time to LFL calculation is protected by the HLLCP setpoint; whereas, the one used in the spontaneous time to LFL calculation is based on the actual/projected tank level. Both the HLLCP setpoint and actual/projected tank level shall be adjusted to account for missing waste volume associated with a Transfer Error event (see Section 4.1.2). Therefore, the maximum fill limit to protect the waste tank flammability level is the lower of the HLLCP setpoint or the maximum tank level protecting the waste tank flammability classification.
**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. 40]. The locations of known leaksites are documented in Reference 42.

### 4.4.1 IMPLEMENTATION ACTIONS

1. The most limiting of the maximum fill levels for each individual waste tank shall be determined in WCS [Ref. 11].

2. The WCS 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 WCS [Ref. 11].

5. 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 WCS [Ref. 11] 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 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.
4.5 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 Tank 1) 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, 34]. 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. 26]. 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. 34].

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].

4.5.1 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 saltcake dissolution and removal of interstitial liquid from saltcake are prohibited.

4.6 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 a NO eff equal to zero [Ref. 1]. Using the Radiolytic Hydrogen Generation Model outlined in Section 4.1.2.2.1, 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. 36]. 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 4.1.2.2).

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. 37].

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., NFPA Standard 69 [Ref. 13]) 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. 38, 39] and is defined in the following paragraphs along with the implementation items of Section 4.6.1.

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 LFLOC 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 LFLOC, it is reasonable to use the
methodology described in Section 6.2 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. 39]. 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.

4.6.1 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 4.1.3.

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:

   a. Ventilate the location with forced ventilation

   OR

   b. 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%.

  o 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 greater than or equal to 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 greater than or equal to 55% LFL, perform the following:

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

  o 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.
4.7 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 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 21 lists the currently evaluated compressor lubrication oils that can be used in the facility without causing these analyzed vapor spaces to exceed their 5% CLFL requirement. The oils were evaluated at three temperatures: 1) 160°C if used in the 2H evaporator, 2) 186°C if in the 3H evaporator, 3) 100°C if in the waste tanks, pump tanks, etc. In addition, Reference 47 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.

4.7.1 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.

4.8 Interim Safety Basis Requirements

Potential Inadequacy Recognition of the Effect of Organics on Hydrogen Generation Rates in the CSTF (PISA PI-2017-0003) was declared on February 28, 2017 and the following compensatory measures listed in the Evaluation of the Safety of the Situation (ESS), U-ESS-G-00007, that impact this PDD. These compensatory measures supersede the requirements of this PDD for the affected sections [Ref. 57].

Compensatory Measure 2.2.1 - Prior to the addition of an organic compound to CSTF waste, the addition will be evaluated by engineering to confirm that either:

A. The organic compound has previously been added to CSTF waste in quantities greater than or equal to the proposed addition.

OR

B. The organic addition will not impact the conclusions of this ESS or the CSTF Organic Hydrogen Generation Report [Ref. 58].

Compensatory Measure 2.2.6 - Tank 50 will be maintained as a Very Slow Generation Tank.
Compensatory Measure 2.2.8 – For Type I, II, III, and IIIA waste storage tanks: If the waste tank supernate temperature limit established in the CSTF Emergency Response Data document [Ref. 2] is greater than 60°C, then the affected tank will be classified as a Rapid Generation Tank and will be subject to the corresponding DSA, TSR, and ESS controls.

Compensatory Measure 2.2.9 – For Type IV waste storage tanks: If the waste tank supernate temperature limit established in the CSTF Emergency Response Data document [Ref. 2] is greater than 65°C, then the affected tank will be classified as a Rapid Generation Tank and will be subject to the corresponding DSA, TSR, and ESS controls.

Compensatory Measure 2.2.18 – For waste tanks under Waste Tank Quiescent Time Program with non-infinite quiescent times: Prior to establishing a waste tank supernate temperature limit or sludge/salt temperature limit greater than 60°C in the CSTF Emergency Response Data document [Ref. 2], quiescent time calculations for the affected tank will meet the requirements established in Attachment 4 of Reference 57.

4.8.1 IMPLEMENTATION ACTIONS

1. Organic additions to CSTF waste shall be pre-evaluated by engineering to confirm that the quantity of the proposed additions is less than or equal to the evaluated quantity. Acceptability of this evaluation will be documented in the Technical Review of the associated work document (e.g., procedure, work package) [U-ESS-G-00007, 2.2.1.a].

2. If the quantity of the proposed organic additions is greater than the evaluated quantity or if the organic compound has not been evaluated, a new organic chemical evaluation will be required having an increased scope to ensure that the additions will not impact the conclusions of the ESS or the CSTF Organic Hydrogen Generation Report [Refs. 57, 58] [U-ESS-G-00007, 2.2.1.b].

3. Tank 50 will be maintained as a Very Slow Generation Tank in the ERD [U-ESS-G-00007, 2.2.6].

4. For Type I, II, III, and IIIA waste tanks with Slow/Very Slow classification, the supernate temperature limit (excluding dry salt tanks) shall be less than or equal to 60°C. This limit will be tracked in the ERD [U-ESS-G-00007, 2.2.8].

5. If the supernate temperature limit for a Type I, II, III, or IIIA waste tank (excluding dry salt tanks) classified as Slow/Very Slow Generation Tank is greater than 60°C, then the affected waste tank shall be classified as a Rapid Generation Tank [U-ESS-G-00007, 2.2.8].

6. For Type IV waste tanks with Slow/Very Slow classification, the supernate temperature limit (excluding dry salt tanks) shall be less than or equal to 65°C. This limit will be tracked in the ERD [U-ESS-G-00007, 2.2.9].
7. If the supernate temperature limit for a Type IV waste tank (excluding dry salt tanks) classified as Slow/Very Slow Generation Tank is greater than 65°C, then the affected waste tank shall be classified as a Rapid Generation Tank [U-ESS-G-00007, 2.2.9].

8. Operating procedures (e.g., roundsheets) shall include the notification to engineering if the waste tank supernate temperature reaches 55°C for Type I, II, III, or IIIA waste tanks or 60°C for Type IV waste tanks that are classified as Slow/Very Slow Generation Tanks for consideration of changing the waste tank classification to Rapid Generation Tank [U-ESS-G-00007, 2.2.8 & 2.2.9].

9. For waste tanks under the Quiescent Time Program with non-infinite DSA defined Quiescent Times (i.e., Seismic Quiescent Time and/or Spontaneous Quiescent Time), prior to establishing a waste tank supernate temperature limit or sludge/salt temperature limit greater than 60°C in the ERD, an engineering evaluation shall be performed to establish new hydrogen generation rates [U-ESS-G-00007, 2.2.18]. The evaluation shall incorporate experimental evidence from real waste testing of representative waste samples under conditions that bound those that are anticipated for the affected waste tank. These conditions include (but are not limited to) [Ref. 57]:

   a. Temperature of the waste.
   b. Aluminum concentration in the waste.
   c. Total organic carbon (TOC) concentration in the waste.

The conservative direction for all conditions listed is maximum.

The evaluation shall incorporate experimental evidence to calculate new hydrogen generation rates as follows [Ref. 57]:

\[
\begin{align*}
\text{Eq. \#94} & \quad x_{\text{RAD, ESS}} = x_{\text{EXP}} + \left[ \frac{R_{\beta/\gamma} H_{\beta/\gamma}}{10^6} \right] \\
\text{Eq. \#95} & \quad x_{\text{H}_2, \text{ESS}} = x_{\text{RAD, ESS}} + x_{\text{CORR}} \\
\text{Eq. \#96} & \quad Q_{\text{H}_2, \text{ESS}} = \frac{x_{\text{H}_2, \text{ESS}} (T+273)}{(T_i+273)}
\end{align*}
\]

Where:

\[
\begin{align*}
x_{\text{RAD, ESS}} & = \text{New radiolytic hydrogen generation rate (HGR) at 25°C, ft}^3/\text{hr} \\
x_{\text{EXP}} & = \text{Bounding experimental HGR at 25°C basis, ft}^3/\text{hr} \\
R_{\beta/\gamma} & = \text{Volume (ft}^3\text{) of hydrogen generated per MBTU of heat added from beta or gamma decay (for calculation, see Equation 8 in Section 4.1.2.2.1)} \\
H_{\beta/\gamma} & = \text{Heat generated by beta and gamma decay, BTU/hr (for calculation, see Equation 10 in Section 4.1.2.2.1)} \\
x_{\text{H}_2, \text{ESS}} & = \text{New total HGR at 25°C, ft}^3/\text{hr}
\end{align*}
\]

\[\uparrow\] The newly derived radiolytic HGR \((x_{\text{RAD, ESS}})\) includes an empirical HGR term \((x_{\text{EXP}})\). This empirical term may comprise hydrogen generated via non-radiolytic mechanisms (e.g., thermolysis). However, to maintain congruence with the methodology described in other sections, the new HGR is still termed “radiolytic.”
\(x_{\text{CORR}}\) = Corrosion induced hydrogen generation rate at 25°C, ft\(^3\)/hr. This HGR has been shown to be insignificant except during Acidic Chemical Cleaning which is prohibited under Compensatory Measure 2.2.2 of Reference 57.

\(Q_{H2,\text{ESS}}\) = New temperature corrected HGR, ft\(^3\)/hr

\(T\) = Temperature at which \(Q_{H2,\text{ESS}}\) is to be evaluated, °C

\(T_i\) = Initial temperature at standard pressure of 1 atm (e.g., 25°C)

The newly derived temperature corrected HGR (\(Q_{H2,\text{ESS}}\)) shall be used in place of all instances of the original temperature corrected HGR (\(Q_{H2}\)) for calculations in Sections 4.2 and 4.3 (e.g., GRM Quiescent Time, Seismic Quiescent Time, Spontaneous Quiescent Time, NFPA Spontaneous Quiescent Time).

10. For waste tanks under the Quiescent Time Program with non-infinite DSA defined quiescent times, prior to establishing a waste tank supernate temperature limit or sludge/salt temperature limit greater than 60°C in the ERD, an engineering evaluation shall be performed to verify the contributions of organic compounds to flammability [U-ESS-G-00007, 2.2.18]. The evaluation shall incorporate experimental evidence from real waste testing of representative waste samples. Evaluated experimental data shall include [Ref. 57]:

a. Comprehensive volatile organic analysis (VOA) and semi-volatile organic analysis (SVOA) of the representative waste samples. If specific volatile organics are not analyzed, n-butanol may be considered as a representative organic for the VOA because it is the primary volatile organic product of the thermal degradation of most of the organic compounds seen in the Tank Farm waste. If specific semi-volatile organics are not analyzed, diisopropylnaphthalenes may be used as a representative organic for the SVOA due to the fact that the organic compound has a high Henry’s Law constant and a relatively low LFL.

b. Vapor space methane sampling conducted under conditions that bound those that are anticipated for the affected waste tank (e.g., temperature, aluminum concentration, TOC concentration).

The engineering evaluation shall show that the combined flammability contributions from organics in items a and b are less than or equal to a total 5% organic contribution to the hydrogen LFL at 100°C according to Equation 97.

\[
\%\text{LFL} = \sum_{N}^{[N]} \frac{LFL_{N}}{LFL_{N}} \times 100\% 
\]

Where:

\(\%\text{LFL}\) = Total organic contribution to the hydrogen LFL, % by volume

\([N]\) = Vapor space concentration of flammable organic compound N, vol. frac.

\(LFL_{N}\) = LFL for flammable organic compound N at 100°C, vol. frac.

11. Liquid additions [excluding small quantity of water additions (e.g., bearing water in-leakage, reel tape flushing) or chemical additions (e.g., caustic/nitrite solutions to comply with the Corrosion Control Program)] to the waste tank from which the representative
waste samples have been collected will invalidate the results of the real waste testing that supports Implementation Actions 9 and 10.

12. Waste tanks affected by U-ESS-G-00007 Compensatory Measure 2.2.18 may exit the compensatory measure via the following sequence [Ref. 57]:

   a. Verify that waste tank temperatures (i.e., supernate and sludge/salt) are less than or equal to 60°C.
   b. Complete mixing device operations in accordance with calculated quiescent times that meet the requirements established in Implementation Action 9 listed above. Waste tank mixing device operations shall meet the requirements of Section 4.2.1.1 for a 100% hydrogen depletion operation.
   c. Issue a new ERD document revision that: (1) establishes a waste tank supernate temperature limit and a sludge/salt temperature limit less than or equal to 60°C and (2) establishes quiescent times calculated using the methodology described in Section 4.2.

13. Waste tanks that have infinite DSA defined quiescent times but non-infinite non-DSA defined quiescent times (i.e., GRM Quiescent Time, NFPA Spontaneous Quiescent Time) must maintain the supernate temperature limits and sludge/salt temperature limits less than or equal to 60°C.

14. Waste tanks that undergo bulk saltcake dissolution and interstitial liquid removal activities must maintain the supernate temperature limits less than or equal to 50°C (to comply with Corrosion Control Program [Ref. 8]) and the sludge/salt temperature limits less than or equal to 60°C.

15. Waste tanks that are currently not under the Quiescent Time Program and undergo sludge agitation must maintain the supernate temperature limits and sludge/salt temperature limits less than or equal to 60°C.

5.0 OUTPUT DOCUMENTATION

The output documents generated in compliance with 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.
6.0 BEST MANAGEMENT PRACTICE

6.1 GAS RELEASE MODE

Best management practice will be to limit releases such that the vapor space remains below the TSR hydrogen concentration LFL limit (i.e., as documented in the ERD), which accounts for potential organics and instrument uncertainty according to the designated SAV, by controlling number of waste tank mixing devices, mixing device speed/indexing, transfer pump/recirculation pump flow rate, etc. The best management practice, which includes the use of calculations, is to ensure that the TSR hydrogen concentration interlocks (second level of control) are not activated. The TSR hydrogen concentration LFL 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 in the facility. References 3, 4, and 31 provide instrument uncertainty values for a range of various SAVs, which are employed to determine the TSR hydrogen concentration LFL limit (i.e., indicated hydrogen reading).

The methodology described in Sections 4.3.2.3 must be followed during all gas release activities in sludge and salt.

6.2 TIME TO LFL METHODOLOGY

The primary flammable vapor contribution to the radiolytic time to LFL is the release of hydrogen gas generated from waste due to water decomposition. The hydrogen generation rate equations used in the time to LFL calculations 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. 25]. 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. 27]:

- 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 waste tank with the time to LFL is found to meet the above criteria during periodic reviews (e.g., Rapid Generation Tanks with less than 10 days time to LFL, Slow Generation Tanks with less than 36 days time to LFL) [Ref. 27], 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

‡ 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).
predicted hydrogen generation rate, and measured hydrogen generation rates based on measurements in waste tanks [Ref. 28]. 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 Reference 28) 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.

The primary flammable vapor contribution to the spontaneous time to LFL is the release of the trapped hydrogen gas from slurried sludge. To determine the amount of trapped hydrogen released from the slurried sludge, the spontaneous time to LFL methodology assumes that the trapped hydrogen release from the slurried sludge is 100% instantaneous release. This is a very conservative assumption because the actual trapped gas release is known to be a time-dependent phenomenon and is not a full release. The data sheets in Reference 56 provide the portable LFL monitor sampling results for Tank 40 from 5/26/15 thru 8/3/15. As can be seen from the data sheets, at no time except during and after completion of slurry pump operations was a value above 0% of the LFL observed in Tank 40 LFL monitor sampling results. The information indicates that the release of hydrogen trapped in the waste tank slurried sludge is not an instantaneous or full release. Even when the tank undergoes trapped gas release activities (e.g., sludge agitation), the percent hydrogen seen in the waste tank vapor space is insignificant (the highest recorded from Tank 40 during and after completion of slurry pump operations was 5% of the LFL). Without waste tank mixing device operation, the release of the hydrogen bubbles would be much slower. Therefore, no additional uncertainty allowances due to trapped gas release need to be applied to the spontaneous time to LFL calculation.

Best management practice will be to limit the Very Slow Generation designation to tanks that reach equilibrium at less than 95% of the LFLLOC. For a Very Slow Generation Tank that is found to reach equilibrium at or above 60% of the LFLLOC, the tank shall undergo quarterly ventilation operation using an installed or portable ventilation system (i.e., for a duration of 12 vapor space turnovers). 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.

6.3 **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. 34]. 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.

6.4 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 storage vessel, pretreatment facility or treatment facility [Ref. 46]. 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.

6.5 QUIESCENT TIME PROGRAM

For waste tanks where the Seismic Quiescent Time or Spontaneous Quiescent Time is calculated using Equation 53, 54, or 64 (i.e. where the equilibrium hydrogen concentration is less than LFLoc and the initial hydrogen concentration plus trapped gas release is greater than or equal to LFLoc), Best Management Practice will be to round the calculated Q-Time down to the next lower day (e.g., 52.9 days will be rounded to 52 days). This, along with the additional conservatism already included in the Seismic and Spontaneous Quiescent Time methodology (See Section 7.2) is considered to provide sufficient margin to prevent reaching a flammable condition. Additionally, for waste tanks in the condition described above, the tank flammability classification is designated Rapid or Slow, which requires continuous ventilation operation.

7.0 UNCERTAINTIES AND CONSERVATISMS

7.1 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. 28].

- The equations used to determine the radiolytic hydrogen generation rate are based on experimental data that has margin added [Ref. 50].

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

### 7.2 Quiescent Times Methodology

There are several conservatisms that exist in the calculation of quiescent times including:

- All trapped gas that is released upon operation of waste tank mixing devices, or following a seismic event, is assumed to be released instantaneously. This is conservative because actual gas release is known to be a time-dependent phenomenon.

- Gas is retained in a step-wise fashion: 25% retention for an inventory of less than 40 inches of sludge; 50% retention for an inventory of greater than or equal to 40 inches and less than 90 inches of sludge; 75% retention for an inventory of greater than or equal to 90 inches and less than 110 inches of sludge; and 100% retention for an inventory of greater than or equal to 110 inches [Ref. 1]. Actual data shows retention to be a 2nd order polynomial function of sludge depth [Ref. 20].

- Ventilation system operation during waste tank mixing device operation serves to limit the vapor space flammable gas concentration significantly below 25% of the LFL for hydrogen. Routine waste tank mixing device runs with ventilation operating cause the vapor space to reach only 5-10% of the LFLOC [Refs. 25, 46].

- 100% of the hydrogen generated after the waste tank mixing device 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. 50].

Additional conservatism is included in waste 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 WCS [Ref. 11].

### 8.0 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.

### 9.0 References

1. WSRC-SA-2002-00007, Concentration, Storage And Transfer Facilities Documented Safety Analysis.
27. X-ESR-G-00056, Quarterly Flammability Report for F and H Tank Farm Waste Tanks.
38. F-FHA-F-00018, Rev. 5, Fire Hazard Analysis for the F-Area Tank Farm (U), January 29, 2016.
   CST-I-PR-0001, Waste Tank Area Releasing Trapped Gas During Agitation of Settled Sludge
   CST-I-TA-0009, Barometric Pressure Variation
   CST-I-TA-0011, Type I Waste Tank and Annulus Volumes and Heights
CST-I-TA-0012, Type II Waste Tank and Annulus Volumes and Heights
CST-I-TA-0013, Type III/IIIA Waste Tank Volumes and Heights
CST-I-TA-0014, Type IV Waste Tank Volumes and Heights
CST-I-PR-0010, Liquid to Saltcake Dissolution Ratio

42. Waltz, R. S., C-ESR-G-00003, Rev. 17, SRS High Level Waste Tank Crack and Leak Information (Rev. 13), February 12, 2019.
51. Burgin, J. E., M-ESR-F-00271, Rev. 0, Siphon Fill Limits for Tanks 1-4 and 7-11 Due to Tank to Tank Siphon Potential Via CRW Headers, February 23, 2016.
55. SW11.6-SVP-ERD, Tank Farm ERD Linking Surveillance Manual.
The following checklist is required to be completed and attached to the document under review in compliance with Manual E7 and S4 procedures. This list should not be considered all inclusive. Add any additional notes or comments to the end of the checklist.

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**RESULTS / CONCLUSIONS**

| 40      | Are the results of the document consistent with the input and assumptions? | N/A |
| 41      | Do the results of the document affect any other technical documents? | N/A |
| 42      | Do the results substantiate the conclusion? | N/A |

**APPROVALS**

| 43      | Does the document identify the method of verification, if applicable, and does it have a signature block for the verifier/checker? | Yes |

Checker: K.M. Welsh
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Date: 11/7/19
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<td>49</td>
<td>Have engineering actions required to support risk handling strategies been verified?</td>
<td>Yes</td>
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<td>50</td>
<td>Is the design output reasonable compared to the design or analytical inputs?</td>
<td>N/A</td>
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<td>51</td>
<td>Are the necessary design inputs for interfacing organizations specified in the design documents or in supporting procedures or instructions?</td>
<td>N/A</td>
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<td>52</td>
<td>Have suitable materials, parts, processes, and inspection and testing criteria been specified?</td>
<td>N/A</td>
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<tr>
<td>53</td>
<td>Have existing and potential workplace hazards been identified, evaluated, and controls incorporated for the risk to worker injury or illness?</td>
<td>N/A</td>
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<tr>
<td>54</td>
<td>Was a review conducted to confirm that there are no interferences with other ongoing or planned modifications?</td>
<td>N/A</td>
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<tr>
<td>55</td>
<td>Have engineering judgments been identified, technically justified, and supported?</td>
<td>Yes</td>
<td></td>
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<tr>
<td>56</td>
<td>Have design optimization strategies been considered / met (e.g., appropriate tailoring of requirements, design attributes, and operating strategies)?</td>
<td>Yes</td>
<td></td>
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Verifier: K. M. Welsh  
Print:  
Signature:  
Date: 11/7/19
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<th>Comment Continuation</th>
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