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Revision 4

SALTSTONE FACILITY
CONSOLIDATED HAZARD ANALYSIS (U)

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Westinghouse Savannah River Company
Aiken, SC 29808

SAFETY • RESPONSIBILITY • SECURITY
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Revision History

Revision	Affected Pages	Description of Revision
0	All	Original Issue
1	All	Revision 1 incorporates changes to source terms and hazards due to processing of low curie salt.
2	All	Revision 2 updates the low curie salt radiological inventory and associated radiological doses, provides updated justification and background for facility final hazard categorization, and corrects mis-numbering of references. All text changes are denoted with revision bars.
3	All	Revision 3 updates the hazards analysis for low curie salt facility modifications and chemical inventory and associated consequences. This revision is comprehensive, and text changes are not denoted by revision bars.
4	All	Revision 4 updates the hazard analysis for increased chemical and radiological source term. Also, this revision supports the removal of analytical portions from the CHA and the documentation of these analyses in Reference 66, S-CLC-Z-00035, Rev. 0.

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LIST OF ACRONYMS

ACs	Administrative Controls
ARF	Airborne Release Fraction
ARP	Actinide Removal Process
ARR	Airborne Release Rate
°C	Degrees Celsius
cal	Calorie
CFR	Code of Federal Regulations
CHA	Consolidated Hazards Analysis
CHAP	Consolidated Hazards Analysis Process
Ci	Curie
CSTF	Concentration, Storage, and Treatment Facility
CW	Co-Located Worker
DBA	Design Basis Accident
DID	Defense-in-Depth
DOE	Department of Energy
DR	Damage Ratio
DSA	Documented Safety Analysis
DWPF	Defense Waste Processing Facility
ERPG	Emergency Response Planning Guideline
ETP	Effluent Treatment Project
°F	Degrees Fahrenheit
FHA	Fire Hazards Analysis
FW	Facility Worker
g	Gram
Gal	Gallon
HAZOP	Hazard and Operability
HC	Hazard Category
HEPA	High Efficiency Particulate Air
HLW	High Level Waste
IC	Initial Condition
km	Kilometer
l	Liter
LCS	Low Curie Salt
LLW	Low Level Waste
LPDT	Low Point Drain Tank
LPF	Leak Path Factor
MACCS	MELCOR Accident Consequence Code System
MAR	Material at Risk
MSDS	Material Safety Data Sheet
NCSE	Nuclear Criticality Safety Evaluation
NPH	Natural Phenomena Hazard
OSHA	Occupational Safety and Health Administration
P&ID	Piping and Instrumentation Diagram
PEL	Permissible Exposure Limit
PHR	Process Hazard Review

LIST OF ACRONYMS

psf	Pounds per Square Foot
psig	Pounds per Square Inch (gauge)
PVVS	Process Vessel Vent System
RF	Respirable Fraction
SC	Safety Class
SCDHEC	South Carolina Department of Health and Environmental Control
SDD	System Description Document
SDF	Saltstone Disposal Facility
SFT	Salt Feed Tank
SHT	Saltstone Hold Tank
SPF	Saltstone Production Facility
SRS	Savannah River Site
SS	Safety Significant
SSC	Structure, System, and Component
SSHT	Salt Solution Hold Tank
ST	Source Term
TEDE	Total Effective Dose Equivalent
TNT	Trinitrotoluene
TQ	Threshold Quantity
TWA	Time Weighted Average
WAC	Waste Acceptance Criteria
WSMS	Washington Safety Management Solutions
WSRC	Westinghouse Savannah River Company

EXECUTIVE SUMMARY

This Consolidated Hazards Analysis (CHA) identifies and evaluates potential accident conditions that have the potential to cause or contribute to the uncontrolled release of hazardous material from the Saltstone Facility.

The Saltstone Facility, located in Z-Area, consists of two facility segments: the Saltstone Production Facility (SPF), which produces saltstone grout, and the Saltstone Disposal Facility (SDF) vaults used for disposal of the saltstone grout. The Saltstone Facility receives waste transfers of low activity wastewater from Tank 50H.

Based on the maximum salt solution inventory of 15,000 gal, the SPF meets the requirements for a Hazard Category (HC) 3 facility. The SDF is categorized as a HC-3 facility based on the lack of credible release mechanisms for the hardened saltstone.

The bounding event, explosion in the Salt Feed Tank (SFT), was initially qualitatively judged to result in a high unmitigated radiological consequence to the 30-meter worker. A subsequent calculation has determined that the consequence to the 30-meter worker is less than 10 rem for a 24-hour exposure period (Ref. 54). Chemical consequences for the bounding event are below the chemical evaluation criteria (Ref. 53). Control of significant assumptions leading to the HC-3 hazard categorization is through compliance with the Saltstone Facility Waste Acceptance Criteria (WAC) program and avoiding inadvertent transfers from Tank 50H by ensuring compliance with the Concentration, Storage, and Transfer Facility (CSTF) Transfer Control Program.

Although the dry materials used in the saltstone process (fly ash, slag, concrete) can cause moderate acute localized health affects, these are considered standard industrial materials and are controlled through Occupational Safety and Health Administration (OSHA) protocol, Job Hazards Analysis, and normal worker safety review, training, and monitoring.

This CHA utilized the Consolidated Hazards Analysis Process (CHAP) (Ref. 3). This process is an integrated approach that covers the full spectrum of facility hazards that previously have been addressed by multiple site processes [e.g., Process Hazards Reviews (PHRs), Process Hazards Analyses, and Hazards Analyses].

1.0 INTRODUCTION

The Saltstone Facility, part of the Waste Solidification Projects facilities, is one portion of an integrated waste management and disposal system at Savannah River Site (SRS). This integrated system is designed to convert liquid waste generated and stored at SRS into a solid waste form suitable for final disposal. The Saltstone Facility is used to safely dispose of the Low-Level Waste (LLW) that is generated during the treatment of High Level Waste (HLW) presently stored in waste tanks. This waste includes wastewater generated by the Effluent Treatment Project (ETP), filtrate from the Actinide Removal Process (ARP), and Low Curie Salt (LCS).

Radioactive startup of the Saltstone Facility was authorized by the DOE in 1990. Since startup, nearly three million gal of mixed aqueous waste has been treated to produce a non-hazardous LLW solid known as saltstone.

This report documents the CHA performed for the Saltstone Facility. The CHA team performed a systematic evaluation of the hazards associated with the Saltstone Facility using the guidance provided in

the SRS Process Safety Management Manual (U) (Ref. 1), the SRS Hazard Analysis Methodology Manual (Ref. 2) and the Consolidated Hazards Analysis Process (CHAP) Methodology Manual (Ref. 3). The CHAP includes hazard identification, facility/process segmentation, facility hazard categorization, screening of common industrial hazards, unmitigated hazard analysis, periodic PHR, mitigated hazard analysis, and identification of the Systems, Structures, and Components (SSCs) and programs credited as controls for the associated hazards and functional classification of the SSCs.

The Saltstone Facility hazards were evaluated using the Hazard and Operability (HAZOP) approach. The HAZOP analysis is a systematic method which identifies process deviations, causes of the deviation, unmitigated frequency and consequences of the deviation, and potential control strategies to reduce the frequency/consequence of the event such that the mitigated risk of the event is acceptable.

2.0 FACILITY DESCRIPTION

Saltstone Facility

The Saltstone Facility, located in Z-Area, converts salt solution containing low levels of radioactive contaminants to a grout suitable for disposal in large concrete SDF vaults, also located within Z-Area. The grout is pumped from the SPF into an SDF vault where it solidifies into a monolithic solid waste form known as saltstone. Cell A of SDF Vault 4 was used to dispose of more than 10,000 drums containing solidified waste from the Naval Fuel Material Facility operations. The saltstone production and disposal process is divided into four interrelated operations. Details on systems and processes are contained in References 4 through 11. A description of each of these operations follows:

Bulk Material Handling

Cement, slag, and fly ash (saltstone dry mix chemicals) are delivered via truck. The dry materials are conveyed pneumatically to four identical silos. The materials are blown directly to the silos using compressed air from the truck's compressor. One silo contains cement, one contains slag, one contains fly ash, and one is a spare. The dry feeds are combined in a weigh hopper and transferred to a premix air blender. From the blender, the mixture is transferred to the Premix Feed Bin located on the roof of the Process Building. Premix is fed to a screw feeder that controls the flow of the dry material to the mixer where it is combined with salt solution to form grout.

Salt Solution Transfer

Salt solution is pumped from Tank 50H through a jacketed inter-area transfer pipeline (approximately 2,776-meters) that runs through the Salt Solution Hold Tank (SSHT) dike into the SFT. The SSHT is abandoned in place and the lines are capped to prevent any flow into the tank. The SSHT is vented to the Process Vessel Ventilation System (PVVS). The SFT is located adjacent to the 210-Z Process Building in a separate dike that extends approximately 16-feet below grade and 8-feet above grade, with an access opening at grade level. Both dikes are 1-foot thick steel reinforced concrete.

The transfer line consists of a primary transfer pipe within a larger containment pipe. The annular space between the pipes allows pressure testing of the pipes, leak detection, and leakage collection. If solution leaks through the primary pipe, the secondary pipe drains it to the Low Point Drain Tank (LPDT).

The boundary between H-Area and Z-Area is the inlet flange of the manual inter-area transfer isolation valve Z-201-SSHT-V-0040, located in the SSHT dike. Components and piping used to pump salt solution upstream of V-0040 (i.e., LPDT, Tank 50H transfer pump) were not considered in this analysis,

though H-Area events were analyzed to the extent that they could affect the Saltstone Facility (i.e., high radiological material from Tank 50H pumped to the SFT).

Saltstone Mixing and Transfer

Premix from the Premix Feed Bin and salt solution from the SFT are mixed in the Saltstone Facility Mixer to produce saltstone grout. Grout discharges from the mixer into the Saltstone Hold Tank (SHT), which gravity feeds the grout to the pump system.

Saltstone Disposal

Grout is pumped from the process area to concrete vaults via a pipeline. Each filled cell is layered with clean concrete. A pig launching system is utilized for cleaning the grout transfer line during transfer shutdown. An online launcher uses 285- psig air to launch a round rubber ball ("pig"). The pig wipes the inside of the pipeline and forces any grout into the vault. The air is then expelled in the vault.

3.0 INPUTS AND ASSUMPTIONS

3.1 Input

Input data to the CHA was obtained from the following:

- System Description Documents (SDD) for Saltstone Process (Refs. 4-11).
- Saltstone process flow diagrams and piping and instrument diagrams (P&IDs). Diagrams used were the latest revision at the time of the review (Refs. 13-21, 24-28).
- PHR reports previously conducted for the Saltstone Facility (Ref. 29, 30).
- Bounding chemical inventory (Ref. 32).
- Bounding radiological inventory (Ref. 32).
- Nuclear Criticality Safety Evaluation (NCSE) for Z-Area (Ref. 33).
- Frequency data (Ref. 59).
- Facility personnel.

3.2 Assumptions

Assumptions used during the course of the CHA and control strategy development include:

- The total radionuclide and chemical inventories used as the basis for source terms for the consequence determinations are presented in Tables A-1 and A-2 (Ref. 32).
- The total salt solution inventory is assumed to be 15,000 gal for all bounding spill events. This volume is more than twice the total Saltstone Facility volume (less than 7,500 gal). The CSTF Documented Safety Analysis (DSA) (Ref. 48) assumes an unmitigated maximum missing waste of 15,000 gal based on leak detection time, leak mitigation time, and the pump flow rates. The leak detection and mitigation times in the Saltstone Facility are equal to or shorter than in CSTF due to the higher resolution of liquid level provided by the smaller tanks in the Saltstone Facility. Flow rates of Saltstone Facility pumps are less than the bounding tank farm pump flow rates. Therefore, this volume is judged to be appropriately conservative for use in Saltstone Facility analyses.
- The saltstone process is a continuous process and vapors cannot accumulate in the transfer lines, the mixer, or the SHT.

- The SFT has a volume of 6504 gal at overflow and is located in a dike that extends approximately 16-feet below grade and approximately 8-feet above grade. The dike has an access opening at grade level.
- The process room processing equipment volume is 284 gal, based on facility input.
- Salt solution, due to its high pH, is considered a contact hazard to the Facility Worker (FW), and as such, is considered a standard industrial hazard.
- Workers have the ability to react to obvious hazardous conditions and to evacuate. This invokes the assumptions that the workers are made aware of the conditions, are physically able to evacuate, and that an evacuation route is available while the hazardous condition exists, or immediately after the hazardous condition occurs.
- No reactive chemicals are added during the saltstone process other than the premix feed, which undergoes a hydration reaction when combined with the waste.
- No mechanism exists for changing the pH of the salt solution in the Saltstone process.
- The maximum process rate for the SPF is 180 gal/min of saltstone grout, corresponding to 110 gal/minute of salt solution.
- The risk to Saltstone facilities and workers resulting from accidents at the Defense Waste Processing Facility (DWPF) and other co-located facilities are addressed in the releasing facility's safety basis. No accidents in adjacent facilities will cause a release from Saltstone.

4.0 METHODOLOGY

The CHAP was used to identify potential hazardous events applicable to the Saltstone Facility and to select potential control strategies that reduce the likelihood of occurrence of the event or mitigate the consequences of the event. The CHAP includes the following steps:

- Hazard Baseline Determination
- Unmitigated Hazards Analysis
- Mitigated Hazards Analysis/Control Strategy Development

4.1 Hazard Baseline Determination

The primary purpose of the Hazard Baseline Determination activity is to identify hazardous material inventories and to establish the facility hazard category per DOE-STD-1027-92 (Ref. 34).

4.2 Unmitigated Hazard Analysis

The primary purpose of the unmitigated hazard analysis is to ensure a comprehensive assessment of facility hazards and focus attention on those events that pose the greatest risk to the public, Co-Located Worker (CW) and the FW.

During this activity, facility initial conditions and assumptions were compiled, a hazard analysis method was selected, hazards were documented, common/standard industrial hazards were identified, unmitigated scenarios were identified and grouped, and hazardous events were binned according to risk.

4.2.1 Identification of Initial Conditions

Prior to beginning the analysis, the Initial Conditions (ICs) for the facility were determined and are documented in Section 3.2 of this report. ICs are specific conditions that are a part of facility operations. ICs may include assumptions, inventory information and specific passive features (i.e., no mechanical or electrical change of state or human involvement) such as the facility construction.

4.2.2 Hazard Analysis Method

The HAZOP analysis methodology was used to conduct the unmitigated hazard analysis. The HAZOP analysis approach, which is fully described in Reference 3, focuses on specific points of the process or operation called "nodes," process sections, or operating steps. The HAZOP team examines each node or step for potentially hazardous process deviations that are derived from a set of established guide-words.

Each guide-word is combined with relevant process parameters and applied to each point (node, process section, or operating step) in the process being examined.

HAZOP guide-words were used to ensure all relevant deviations of process parameters were evaluated, to provide structure to the hazard analysis and stimulate the identification of hazards and hazardous situations. The team examined the major steps or nodes of the Saltstone facility and analyzed each to postulate hazardous situations or events.

The scope of the HAZOP included all major aspects of process operation and external and NPH events. In accordance with DOE-STD-3009-94 (Ref. 35), facility activities or systems that pose only common/standard industrial hazards routinely encountered in general industry and construction and addressed by consensus codes and/or standards were examined only if a loss of control of the activity or system could result in a release. The scope of the HAZOP did not include analysis of hazards screened as common hazards and willful acts, such as sabotage or terrorist attack.

4.2.3 Unmitigated Hazard Analysis

The HAZOP documents the hazards of the facility, identifies and documents (but does not analyze) common/standard industrial hazards, identifies and groups unmitigated scenarios, and bins these hazardous events according to risk.

The HAZOP was performed without regard for preventive or mitigative features other than the specified ICs to avoid taking credit for any types of active or passive barriers or controls. Selected controls are designated as Safety Class (SC) or Safety Significant (SS) depending upon which receptor (Offsite or Onsite) consequence or frequency was reduced. During the unmitigated hazard analysis, the maximum Material at Risk (MAR) for a spill was assumed to be 15,000 gal as described in Section 3.2 of this report.

The results of the unmitigated hazard analysis are documented in unmitigated hazard analysis tables (Appendix B). Information contained in these tables include the following:

Node

The HAZOP study focused on specific points of the process or operation called "nodes."

Deviation

Deviations are departures from the design intention.

Causes

Based on the node and deviation, causes, or reasons why the deviation might occur, were identified. Causes may be hardware failures, human errors, unanticipated process states (e.g., change of composition), external disruptions (e.g., loss of chill water), etc. By identifying the cause(s) of the postulated event, the team is able to better determine the initiating frequency and achieves a better understanding of preventive and mitigative features.

Results

Based on the node, deviation, and cause, event results were determined. Results could include a release of hazardous energy and/or material, personnel injuries, loss of equipment or facilities, loss of production, or none. If a result was determined to be a common hazard or standard industrial hazard, the event was documented as such. Results for each event are listed in the Result column of the unmitigated hazard analysis tables (Appendix B). Included in the Results column of Appendix B, where appropriate, are the type and amount of hazardous material, or MAR, assumed for the event.

Unmitigated Frequency

The unmitigated event frequency was determined through a qualitative and/or semi-quantitative process that involved assigning a frequency level to each event identified that could result in a release of hazardous energy and/or material, personnel injuries, loss of equipment or facilities, or loss of production. Frequency levels and descriptions, as specified in the SRS Hazard Analysis Methodology Manual, are outlined in Table A-3 (Ref. 2).

Sources of frequency information included: generic initiator frequency data, existing safety documentation, engineering calculations, generic failure rate data, and facility expert opinion. The frequency level was recorded in the unmitigated hazard analysis tables in the Unmitigated Frequency column according to the Table A-3 lettering scheme. Equipment failure rates and operator error rates were determined using the guidance of the Savannah River Site Hazard Analysis Generic Initiator Data Base (Ref. 59). When evaluating event frequency, credit may be taken for items identified as ICs.

Unmitigated Consequences

Event consequences are documented by specifying the impact on the receptors at specified receptor locations that have been determined without taking credit for barriers or controls, which could reduce the consequences. When evaluating event consequences, credit may be taken for items identified as ICs. Consequences are a function of the type and characteristics of the hazard, the quantity released, the release mechanism, relative location of the release, and any relevant transport characteristics. Consequences can be determined from: (1) simple source term calculations, (2) existing safety documentation, and/or (3) qualitative assessment supported by simple calculations.

Consequence evaluation is conservative, especially for those events with consequences at the high end of a given level.

Consequence evaluation is the process of determining which of the consequence levels in Table A-4 are relevant to the three receptors for a particular release event. Table A-4 gives the radiological and chemical consequence levels for the specified receptor locations. Receptors are as follows:

Facility Worker	Facility Workers are workers immediately adjacent or in the occupied area of the hazard. The occupied area of the hazard is the area within the last possible means of physically controlling the hazard or controlling access to the hazard (i.e., building, fence, permanent chain with multiple warning signs, etc.). Note: a physical barrier credited to protect workers outside the area or prevent entrance of workers into the area is to be identified as an IC. FWs equate to the Functional Classification Receptors 1 and 2.
Co-Located Worker	Co-Located Workers are workers outside the occupied area of the hazard. If there is no defined physical means of controlling the hazard or controlling access

to the hazard, the location is assumed to be at the worst possible location, but no closer than 100 meters to the hazard. CWs equate to the Functional Classification Receptor 3. For this analysis, CW consequences were qualitatively determined from the dose at 100 meters.

Public — Public receptors are the public or everyone outside the site boundary at the time of the event. For this analysis, Public receptor consequences were qualitatively determined from the dose at 10 kilometers.

The unmitigated hazard analysis is concerned with the maximally exposed individual at each of the receptor locations.

The unmitigated hazard analysis tables (Appendix B) provide the impact (in Table A-4 terms: High, Medium, Low, Negligible) of the event on the three receptors for each of the postulated release events in the Unmitigated Consequence column. Information on consequences other than chemical or radiological exposure to individuals are presented in this column. This information may include (1) the physical consequences to the FW (e.g., an explosion that has low radiological and chemical consequences, but could result in a worker fatality), (2) safety impacts in other areas of the facility (e.g., a lightning strike knocks out facility power which in turn disables a process support system), (3) production loss, or (4) equipment or facility damage.

Risk Rank

Using event frequency and consequence levels, events are "binned" with respect to frequency and consequence to assess relative risk. The objective of risk binning is to focus attention on those events that pose the greatest risk to the Public, CW, and the FW. Higher risk events might be candidates for additional analysis and/or functional classification evaluation.

Once the unmitigated event frequency and consequence level were estimated, events were located on the appropriate Risk Criteria Matrix for the Public, CW, or FW, as shown in Table A-5 for the Public and Table A-6 for the FW and CW. The Risk Rank column of the unmitigated hazard analysis tables (Appendix B) provides the risk rank for each of the receptor locations.

Table A-5 is the Risk Criteria Matrix for the Public.

- Region A. Unmitigated events falling in Region A due to radiological release require SC controls to reduce the risk below Region A, SS controls to reduce the risk below Region A1 (if the SC controls do not do so), additional Levels of Control, and Non-SC/SS Defense-in-Depth (DID) controls as specified in WSRC Procedure Manual E7, Procedure 2.25 (Ref. 36). Unmitigated events falling in Region A due to chemical release require SS controls and additional Levels of Control as specified in E7 Manual, Procedure 2.25 (Ref. 36).
- Region A1. Unmitigated events falling in Region A1 due to radiological release require SS controls as well as additional Levels of Control as specified in WSRC Procedure Manual E7, Procedure 2.25 (Ref. 36). Unmitigated events falling in Region A1 due to chemical release require process controls.
- Region B. Unmitigated events originating in Region B require process controls.
- Region C. Unmitigated events originating in Region C generally have negligible risk.

Table A-6 is the Risk Criteria Matrix for the CW and FW.

- Region A. Region A represents risk that challenges the worker risk criteria. Unmitigated events falling in Region A require SS controls and additional Levels of Controls as specified in Reference 36.
- Region B. Unmitigated events originating in Region B require process controls.
- Region C. Unmitigated events originating in Region C generally have negligible risk.

For events with a production loss or facility/equipment loss consequence, a risk rank of B was assigned for those events with a frequency of "Anticipated" that could result in a loss of production of greater than six months or facility/equipment damages in excess of one million dollars (1981 dollars) including cleanup, equipment damage, product value, etc. (Ref. 36). If an event could result in a loss of production of greater than six months or facility/equipment damages in excess of one million dollars, but the frequency of the event was less than or equal to "Unlikely" (i.e., less than 1E-2 per year), then a risk rank of C was assigned.

A risk rank of C was assigned for events that result in a production loss of less than six months or facility/equipment damages less than one million dollars.

Principal Controls

Following the identification of hazardous events, controls are identified for events requiring SC or SS controls (i.e., events whose unmitigated frequency/consequence are in Region A or A1 of the Risk Criteria; see Table A-5 and Table A-6). For Region B events, controls designated as facility/process controls were identified. Region C events have negligible consequences; however, each Region C event was evaluated by the team to determine if process controls should be identified because the frequency of the event is higher than desired, the occurrence of the uncontrolled event is unacceptable to management in any event, or the uncontrolled event is unacceptable for programmatic or political reasons. Controls were also listed in the Controls column of the tables (Appendix B).

Preventive controls are features expected to reduce the frequency of a hazardous event. Mitigative controls are any features expected to reduce the consequences of a hazardous event. The identification of such features was made without regard to any possible pedigree of the feature such as procurement level or current classification. These might include engineered features (e.g., SSCs, etc.), administrative controls (ACs) (e.g., procedures, policies, programs, etc.), natural phenomena (e.g., ambient conditions, buoyancy, gravity, etc.), or inherent features (e.g., physical or chemical properties, location, elevation, etc.) operating individually or in combination. Mitigative features constitute a significant portion of DID and Worker Safety.

4.3 Mitigated Hazard Analysis/Control Strategy Development

The mitigated hazard analysis/control strategy development activity begins with the treatment of Region A or A1 events. Controls to be credited are selected from the list of controls initially identified and documented in the unmitigated hazard analysis tables (Appendix B). Control strategies were chosen using the following preferred selection strategy: prevention over mitigation, passive over active, and engineered controls over ACs. Factors such as cost, reliability, durability, life cycle cost, and facility operating life, etc. were also considered during control selection.

Target frequency and consequence reductions are first established. Rules of thumb are then applied to estimate the frequency/consequence reductions, and results compared against targets (i.e., do the controls move the mitigated frequency/consequence well into Regions B and C of the Risk Criteria). Controls are then selected from among those potentially available and credited against the event. This leads to the specification of SC, SS, and DID controls consistent with the E7 Manual, Procedure 2.25 (Ref. 36),

followed by the identification of applicable engineering standards. Additional scenarios are then postulated by examining control failures, or by identifying new hazards introduced by the controls, with the result that controls may be modified or additional controls added. This step continues to the subsystem and component level as necessary. The list of SC, SS and DID controls are re-examined and changes made as necessary.

At this point, the overall system and subsystems are examined along with interfaces to other potentially interfacing systems, and additional controls added as required. Finally, controls are optimized (e.g., have two or more controls been specified for various scenarios when one control may effectively address all scenarios in the group). Results are compiled and documented in the mitigated hazard analysis tables (Appendix C). Events affecting the Public and those screened as potentially having High consequences to the CW or FW are forwarded to accident analysts along with a list of candidate design basis accidents (DBA). In all cases, the evaluation must select controls to ensure that the risk is "well below" the applicable risk criteria before the event is placed into the lower region.

The mitigated hazard analysis/control strategy development activity continues by evaluating the Region B events. The first step is to determine if a control identified during the evaluation of a Region A event covers a Region B event as well. Otherwise, the steps for evaluating Region B events are very similar to the evaluation of Region A/A1 events. Results are compiled and documented in the mitigated hazard analysis tables (Appendix C).

Since Region C events generally have negligible consequences and are well below the risk criteria, mitigated hazard analysis/control strategy development activities were not conducted.

The Accident Analysis activity, which is not covered as part of CHAP, determines if SC controls are over- or under-specified and serves as a validation of the controls selected during the mitigated hazard analysis/control strategy development activity. The Accident Analysis activity also verifies DBA selection. If SC controls are not verified by the Accident Analysis activity, they are returned to the mitigated hazard analysis/control strategy development activity for revision.

Mitigated Hazard Analysis

The mitigated hazard analysis documents the results of the mitigated hazard analysis/control strategy development process for those events with a risk rank of A or B.

The results of the mitigated hazard analysis are documented in mitigated hazard analysis tables (Appendix C). The Causes, Results, Unmitigated Frequency, Unmitigated Consequences, and Unmitigated Risk Rank presented in the mitigated hazard analysis tables are carried forward from the unmitigated hazard analysis tables. Information contained in these tables include the following:

Event Number

The event number identifies the event based on the node, deviation, and cause number from the unmitigated hazard analysis table (Appendix B).

Frequency Level - Prevented

The initiating frequency level of the event (from the unmitigated hazard analysis tables) is modified with the reductions due to credited preventive features. The amount of frequency reduction is dependent on

the control(s) and is documented in the Remarks column of the mitigated hazard analysis tables (Appendix C).

Mitigated Consequence Level

The unmitigated consequence level of the event (from the unmitigated hazard analysis tables) is modified with the reductions due to credited mitigative features. The amount of consequence reduction is dependent on the control(s) and is documented in the Remarks column of the mitigated hazard analysis tables (Appendix C). Mitigated consequence levels are assigned per Table A-4.

Mitigated Risk Rank

Based on the Prevented Frequency Levels and the Mitigated Consequence Levels, the events are binned in the same manner as during the unmitigated analysis. The final risk bin determined in this manner is used to demonstrate that the prevention and mitigation features selected reduce the event risk to well below the established risk criteria.

Principal Controls

SC, SS, DID, or facility/process controls credited during the mitigated hazard analysis are annotated in the Principal Controls column of the mitigated hazard analysis tables (Appendix C).

5.0 RESULTS

This section provides a discussion of the results from the performance of Hazard Baseline Determination, Unmitigated Hazards Analysis, and Mitigated Hazards Analysis/Control Strategy Development for the Saltstone Facility.

5.1 Hazard Baseline Determination

Saltstone Facility hazardous material inventories, SDDs, process flow diagrams, and P&IDs were reviewed and initial conditions and assumptions (Section3.0), hazardous material inventories, and the Saltstone Facility HC were determined.

Hazardous Material Inventories

Saltstone Production Facility

Based on a review of input documents, facility walkdowns, and discussions with facility personnel, the CHAP team determined that radioactive salt solution is the only hazardous material that could be present in a significant quantity in the SPF. The bounding inventory of salt solution that could be present in the SPF is assumed to be 15,000 gal. This volume, consistent with the maximum missing waste credited in the CSTF DSA (Ref. 48), bounds the capacity of the SFT (6,500 gal), the mixer (30 gal), the SHT (181 gal), related piping, and other peripheral interconnecting piping external to the Process Room. Salt solution bounding radionuclide and chemical concentrations are shown in Tables A-1 and A-2 (Ref. 32).

Material properties of the bulk dry materials used to process the salt solution into grout (fly ash, concrete, and slag) were reviewed. The review of Material Safety Data Sheets (MSDS) (Ref. 37, 38, 39) for the material determined that these materials present no fire or explosion hazards. Acute hazards resulting from the release of these materials include hazards associated primarily with nuisance dusts. There are acute potential physiological burning hazards (skin, eyes, and mucous membranes) associated with some

types of concrete. Chronic long-term inhalation exposure to dry material constituents may cause fibrosis (silicosis) or chronic bronchitis. The MSDS for fly ash and also for slag states there is sufficient evidence for carcinogenicity of crystalline silica in humans. Although there are chronic health affects that could be considered moderate or high for these materials, they are recognized as common industrial hazards and are controlled through normal OSHA protocol, Job Hazards Analysis, worker safety reviews, training, pre-job briefings, and expert on-the-job industrial safety and hygiene monitoring.

Laboratory quantities of chemicals and samples are maintained in the Saltstone Product Test Laboratory. Hazards associated with these chemicals were determined to be common hazards covered by OSHA laboratory standards.

Saltstone Disposal Facility

Although a significant quantity of radionuclides contained by the saltstone will eventually be present in the SDF disposal vaults, solid saltstone is a stable, non-hazardous waste form that contains low concentrations of radionuclides. Because of the physical stability of solid saltstone, the inventory in the SDF is not readily dispersible in the extremely unlikely event of catastrophic failure of the vaults. No credible event can be postulated that would result in a direct instantaneous release of a significant quantity of radionuclides from the solid saltstone waste form (Refs. 22, 64). Based on regulatory testing, both unset saltstone grout and solid saltstone are legally considered to be non-hazardous waste by the South Carolina Department of Health and Environmental Control (SCDHEC), the state authority that regulates waste disposal in the SDF vaults (Ref. 12).

The SDF is permitted by the SCDHEC as an industrial waste landfill that is used only for the disposal of non-hazardous solid waste (saltstone and failed process equipment from the SPF). Saltstone provides primary containment for radionuclides and chemicals in the waste, and the vaults provide secondary containment. After final closure activities at the SDF are completed, the proposed overlying backfill and closure caps will provide tertiary containment, consistent with applicable regulations (Ref. 23). Neither the saltstone grout produced in the SPF nor the solidified saltstone contained in the SDF vaults pose any undue hazard to the public or to site employees (Refs. 22, 64). Therefore, events resulting in a release of both unset saltstone grout and solid saltstone were considered to have negligible health effects to FWs, CWs, and the Public.

Facility Hazard Category

The objective of facility hazard categorization is to evaluate the potential radiological hazards associated with SPF and SDF to determine their proper hazard categorization. The focus of hazard categorization is to determine the safety and health documents required for the Saltstone facility. Hazard categorization was developed in accordance with the guidance provided in Code of Federal Regulations (CFR) 10 CFR 830 (Ref. 40), DOE-STD-1027-92 (Ref. 34), and the WSRC 11Q Manual (Ref. 42).

The potential for radiological material releases and nuclear criticality was investigated. The radiological inventory was compared against the criteria for a nuclear facility identified in DOE-STD-1027-92 (Ref. 34) to determine the radiological hazard categorization of the facility. Based on the inventory of radionuclides available for release (Table A-1), the SPF and SDF are categorized as Nonreactor Hazard Category 3 Nuclear Facilities (Table A-7).

Because the Saltstone Facility is a HC-3 facility based on its radiological criteria, it was not necessary to perform chemical hazard classification.

5.2 Unmitigated Hazards Analysis

As discussed in Section 4.0, the Unmitigated Hazards Analysis consists of the following activities.

5.2.1 Initial Conditions and Assumptions

Initial conditions and assumptions used for the unmitigated hazard analysis are documented in Section 3.0.

5.2.2 Unmitigated Hazard Analysis

Based on the saltstone process and facility layout, the following process nodes were identified and analyzed during the HAZOP process:

Node #	*Process/System*
1	Bulk Material Handling System
2	SSHT & Transfer Line through Dike
3	SFT
4	Line from SFT to Saltstone Mixer
5	Saltstone Mixer and Discharge Line
6	Saltstone Hold Tank and Transfer Line to Vaults
7	Saltstone Vault
8	Pig Launcher
9	Process Vessel Vent (PVV) System
10	High Pressure Flush Tank
11	External and NPH events

5.2.3 Radiological Consequences

Reference 66 provides the confirmatory basis of radiological consequences for this CHA. The consequences calculated in Reference 66 are summarized in Table A-8.

5.2.4 Chemical Release Consequences

Salt solution, due to its high pH, is considered a contact hazard to Facility Workers, and as such, is considered a standard industrial hazard.

Consequences were analyzed for the bounding chemical inventory. Reference 53 determined the number of gallons that would have to be released to exceed the onsite or offsite evaluation criteria. Reference 53 determined that the chemical inventory is not sufficient to exceed the guidelines. The most limiting

chemical, aluminate, was less than 85% of the guidelines. All other chemicals were much less than the guidelines.

5.2.5 Results of Unmitigated Hazard Analysis

Accident consequences are based on the Saltstone Facility receiving salt solution that does not exceed the radiological and chemical inventories outlined in Table A-1 and Table A-2, including Waste Acceptance Criteria deviations, and total salt solution inventories greater than 15,000 gallons (see Section 3.2, Assumptions). To protect these assumptions, the following SS ACs were identified:

- Saltstone Facility Waste Acceptance Criteria WAC program
- Inadvertent Transfers from Tank 50H

Public Risk

No unmitigated events exceed the risk criteria for the Public receptor. All events postulated resulted in negligible consequences to the Public receptor and were classified as Region C events.

Co-Located Worker Risk

No unmitigated events exceed the risk criteria for the CW receptor. All events postulated resulted in negligible consequences to the CW receptor and were classified as Region C events. Explosion in SFT initially fell in Region B of Table A-6; however, subsequent evaluation determined the event to be in Region C.

Facility Worker Risk

For the FW, one event involving radiological material initially fell in Region A of Table A-6 and twelve events fell in Region B of Table A-6. These events require control strategies to minimize the risk of the events. The Region A event was subsequently re-evaluated and found to be in Region B (Ref. 54).

Facility Worker Region A Event:

- Event 3.1.2 Explosion in SFT

Facility Worker Region B Events:

- Event 2.3.1 Exposure to worker remaining near transfer line
- Event 2.3.2 Exposure during maintenance in SSHT dike
- Event 3.2.1 Release due to tank vent pluggage
- Event 3.2.2 Release due to bubbler air regulator failure
- Event 3.2.3 Release due to over-pressurization from pig launch air
- Event 3.7.1 Exposure due to WAC limits exceeded
- Event 3.10.1 Worker in vicinity of SFT or transfer line during operations
- Event 3.10.2 Exposure during maintenance on SFT
- Event 5.6.1 Worker enters process room during operations
- Event 5.6.2 Exposure & contamination during maintenance in process room
- Event 7.5.1 Exposure to worker remaining on top of vault
- Event 9.4.3 High radiation in PVV system HEPA filter

Facility/Equipment Damage

Four events of an unmitigated "Anticipated" frequency were identified that could result in facility or equipment damages of greater than one million dollars (Region B event), thus requiring a control strategy to minimize the risk of the event.

Facility/Equipment Damage Region B events:

Event 1.5.1 High pressure in silo (dust collector air regulator failure)
Event 1.5.2 High pressure in silo (plugged silo vents)
Event 1.5.3 High pressure in silo (blend tank air regulator failure)
Event 1.6.1 Vacuum in silo

5.3 Control Strategy Development

Control strategies are required for the hazardous events that were determined to challenge the Risk Criteria (Region A, A1 or B events). SSCs and ACs that function to maintain the facility within a safe configuration and to protect the public, workers, and the environment were identified. The CHAP team examined each event that challenged risk criteria for the FW, CW, or Public to identify those safety functions that are required to prevent (preferred) or mitigate a release of hazardous material or energy. Discussed below are the control strategies and the rationale for selecting the controls for the Region A or Region A1 events for the Public, CW, or FW.

For Region B events, the mitigated hazard analysis tables of Appendix C outline the controls selected for these events. The level of detail in the tables of Appendix C was considered appropriate for these events for control strategy development.

Explosion in SFT

An explosion in the SFT can be caused by the ignition of benzene vapor that accumulates in the tank vapor space (Event 3.2.1). As determined in Section 5.2, a vapor space explosion in the SFT that contains material at or below the inventory limits listed in Table A-1 and Table A-2 will result in Negligible consequences to the CW and Public receptor. The consequences to the FW due to the radiological release were quantitatively determined to be Low. However, serious physical injury to the FW could result from the explosion due to the worker being in proximity to the tank when the explosion occurs. As a result of these possible High physical injury consequences, the following controls were identified:

- Operation of the PVVS sweeps flammable vapors from the SFT, thereby preventing the event. Ventilation flow through the SFT is not secured for extended periods without an Engineering evaluation.
- Limited ignition sources are available to initiate the explosion event.
- The SFT is vented through a 4-inch over flow line that will minimize the pressure in the SFT, thereby reducing the force of an explosion. Also, the SFT overflow line discharges to the SFT dike, which provides passive confinement.
- The SFT is located in a dike that extends 16 feet below grade and 8 foot above grade. The SFT also has a shield plate above the tank in the dike and a platform above the shield plate. The dike, shield plate, and platform would act to shield the FW from flying debris.

6.0 CONCLUSIONS

Facility/process control strategies were developed for the hazardous events that were determined to challenge the Risk Criteria (Region A, A1, or B events). With the application of these control strategies, the risk of each event was reduced to acceptable criteria (Region C). SS controls were identified to protect the radionuclide and chemical inventories and to limit the MAR to 15,000 gallons. These controls, which are identified in the TSRs, include the Saltstone Facility WAC program and Inadvertent Transfers from Tank 50H ACs. Other identified controls (facility/process controls) are not credited as SC/SS/DID controls in the DSA.

7.0 REFERENCES

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APPENDIX A

TABLES

Table A-1 - Bounding Accident Radionuclide Inventor

Isotope	Note	Bounding Conc. (pCi/mL) (1)	Bounding Conc. (Ci/L) (2)	Bounding Conc. (Ci/gal) (3)	Total Inventory (Ci) (4)
H-3 (oxide)		6.26E+05	6.26E-04	2.37E-03	1.54E+01
C-14		1.25E+05	1.25E-04	4.73E-04	3.08E+00
Al-26		3.20E+03	3.20E-06	1.21E-05	7.88E-02
Ni-59		1.25E+05	1.25E-04	4.73E-04	3.08E+00
Ni-63		1.25E+05	1.25E-04	4.73E-04	3.08E+00
Co-60		1.25E+06	1.25E-03	4.73E-03	3.08E+01
Se-79		1.25E+05	1.25E-04	4.73E-04	3.08E+00
Sr-90		2.50E+07	2.50E-02	9.46E-02	6.15E+02
Y-90		2.50E+07	2.50E-02	9.46E-02	6.15E+02
Nb-94		1.70E+04	1.70E-05	6.43E-05	4.18E-01
Tc-99		4.69E+06	4.69E-03	1.78E-02	1.15E+02
Ru-106		1.25E+06	1.25E-03	4.73E-03	3.08E+01
Rh-106	Note (5)	-	-	-	-
Sb-125		2.50E+06	2.50E-03	9.46E-03	6.15E+01
Te-125m		2.50E+06	2.50E-03	9.46E-03	6.15E+01
Sn-126		2.00E+04	2.00E-05	7.57E-05	4.92E-01
Sb-126		2.00E+04	2.00E-05	7.57E-05	4.92E-01
Sb-126m		2.00E+04	2.00E-05	7.57E-05	4.92E-01
I-129		1.25E+05	1.25E-04	4.73E-04	3.08E+00
Cs-134		1.25E+06	1.25E-03	4.73E-03	3.08E+01
Cs-135		1.25E+06	1.25E-03	4.73E-03	3.08E+01
Cs-137		1.32E+08	1.32E-01	5.00E-01	3.25E+03
Ba-137m	Note (5)	-	-	-	-
Ce-144		1.25E+05	1.25E-04	4.73E-04	3.08E+00
Pr-144		1.25E+05	1.25E-04	4.73E-04	3.08E+00
Pm-147		6.25E+06	6.25E-03	2.37E-02	1.54E+02
Sm-151		2.50E+04	2.50E-05	9.46E-05	6.15E-01
Eu-154		2.50E+06	2.50E-03	9.46E-03	6.15E+01
Eu-155		1.25E+04	1.25E-05	4.73E-05	3.08E-01
Th-232		3.20E+03	3.20E-06	1.21E-05	7.88E-02
U-233		1.25E+04	1.25E-05	4.73E-05	3.08E-01
U-234		1.25E+04	1.25E-05	4.73E-05	3.08E-01
U-235		1.25E+02	1.25E-07	4.73E-07	3.08E-03
U-236		1.25E+04	1.25E-05	4.73E-05	3.08E-01
U-238		1.25E+04	1.25E-05	4.73E-05	3.08E-01

Table A-1 - Bounding Accident Radionuclide Inventor (Continued)

Isotope	Note	Bounding Conc. (pCi/mL) (1)	Bounding Conc. (Ci/L) (2)	Bounding Conc. (Ci/gal) (3)	Total Inventory (Ci) (4)
Np-237	Note (6)	-	-	-	-
Pu-238	Note (6)	-	-	-	-
Pu-239		2.66E+05	2.66E-04	1.01E-03	6.55E+00
Pu-240	Note (6)	-	-	-	-
Pu-241		9.31E+05	9.31E-04	3.52E-03	2.29E+01
Pu-242	Note (6)	-	-	-	-
Am-241	Note (6)	-	-	-	-
Am-243	Note (6)	-	-	-	-
Cm-242		1.25E+04	1.25E-05	4.73E-05	3.08E-01
Cm-244	Note (6)	-	-	-	-

(1) Value in third column was obtained from WSP-SSF-2004-00015 Rev. 1.
(2) Value in fourth column equals value in third column multiplied by (1 Ci/1E+12 pCi) and (1000 mL/1 L).
(3) Value in fifth column equals value in fourth column multiplied by (3.785 L/1 gal).
(4) Value in sixth column equals value in fifth column multiplied by (6,504 gal).
(5) Dose accounted for by parent nuclide.
(6) Bounded by Pu-239.

Table A-2 – Salt Solution Chemical Inventory

Chemical Name [Formula]	Bounding Conc. (mg/L) (1)	Bounding Conc. (lb/gal) (2)	Total Inventory (lb) (3)
Aluminate [$Al(OH)_4^-$]	6.62E+05	5.52E+00	3.59E+04
Ammonium [NH_4^+]	9.50E+03	7.93E-02	5.16E+02
Carbonate [CO_3^{2-}]	1.93E+05	1.61E+00	1.05E+04
Chloride [Cl^-]	1.29E+04	1.08E-01	7.00E+02
Formate [$HCOO^-$]	1.00E+04	8.34E-02	5.43E+02
Fluoride [F^-]	6.58E+03	5.49E-02	3.57E+02
Hydroxide [OH^-]	2.55E+05	2.13E+00	1.38E+04
Nitrate [NO_3^-]	7.05E+05	5.88E+00	3.83E+04
Nitrite [NO_2^-]	3.45E+05	2.88E+00	1.87E+04
Oxalate [$C_2O_4^{2-}$]	4.40E+04	3.67E-01	2.39E+03
Phosphate [PO_4^{3-}]	4.75E+04	3.96E-01	2.58E+03
Sulfate [SO_4^{2-}]	9.19E+04	7.67E-01	4.99E+03
Arsenic [As]	1.00E+03	8.34E-03	5.43E+01
Barium [Ba]	1.00E+03	8.34E-03	5.43E+01
Cadmium [Cd]	5.00E+02	4.17E-03	2.71E+01
Chromium [Cr]	2.00E+03	1.67E-02	1.09E+02
Lead [Pb]	1.00E+03	8.34E-03	5.43E+01
Mercury [Hg]	5.00E+02	4.17E-03	2.71E+01
Selenium [Se]	1.00E+03	8.34E-03	5.43E+01
Silver [Ag]	1.00E+03	8.34E-03	5.43E+01
Aluminum [Al]	1.88E+05	1.57E+00	1.02E+04
Boron [B]	1.20E+03	1.00E-02	6.51E+01
Calcium [Ca]	3.68E+03	3.07E-02	2.00E+02
Cerium [Ce]	1.20E+03	1.00E-02	6.51E+01
Cesium [Cs]	1.20E+03	1.00E-02	6.51E+01
Cobalt [Co]	1.20E+03	1.00E-02	6.51E+01
Copper [Cu]	1.20E+03	1.00E-02	6.51E+01
Iron [Fe]	8.00E+03	6.68E-02	4.34E+02
Lithium [Li]	1.20E+03	1.00E-02	6.51E+01
Magnesium [Mg]	1.20E+03	1.00E-02	6.51E+01
Manganese [Mn]	1.20E+03	1.00E-02	6.51E+01
Molybdenum [Mo]	1.20E+03	1.00E-02	6.51E+01
Neodymium [Nd]	1.20E+03	1.00E-02	6.51E+01
Nickel [Ni]	1.20E+03	1.00E-02	6.51E+01
Potassium [K]	4.89E+04	4.08E-01	2.65E+03

Table A-2 -Salt Solution Chemical Inventory (cont'd)

Ruthenium [Ru]	1.20E+03	1.00E-02	6.51E+01
Silicon [Si]	1.72E+04	1.44E-01	9.33E+02
Sodium [Na]	4.56E+05	3.81E+00	2.47E+04
Strontium [Sr]	1.20E+03	1.00E-02	6.51E+01
Titanium [Ti]	1.20E+03	1.00E-02	6.51E+01
Zinc [Zn]	1.30E+03	1.08E-02	7.06E+01
Zirconium [Zr]	1.20E+03	1.00E-02	6.51E+01
Aluminum hydroxide [$Al(OH)_3$]	1.93E+04	1.61E-01	1.05E+03
Barium sulfate [$BaSO_4$]	1.59E+02	1.33E-03	8.63E+00
Chromium (III) hydroxide [$Cr(OH)_3$]	1.59E+02	1.33E-03	8.63E+00
Iron (III) hydroxide [$Fe(OH)_3$]	2.06E+04	1.72E-01	1.12E+03
Lead carbonate [$PbCO_3$]	1.59E+02	1.33E-03	8.63E+00
Lead sulfate [$PbSO_4$]	3.19E+02	2.66E-03	1.73E+01
Manganese dioxide [MnO_2]	1.08E+04	9.01E-02	5.86E+02
Mercuric oxide [HgO]	2.07E+03	1.73E-02	1.12E+02
Nickel hydroxide [$Ni(OH)_2$]	5.26E+03	4.39E-02	2.85E+02
Silicon dioxide [SiO_2]	3.19E+03	2.66E-02	1.73E+02
Silver (I) hydroxide [AgOH]	1.59E+02	1.33E-03	8.63E+00
Uranyl hydroxide [$UO_2(OH)_2$]	3.19E+02	2.66E-03	1.73E+01
Benzene [C_6H_6]	5.00E+02	4.17E-03	2.71E+01
Butanol & Isobutanol [C_4H_9OH]	3.00E+03	2.50E-02	1.63E+02
Isopropanol [C_3H_7OH]	3.00E+03	2.50E-02	1.63E+02
Methanol [CH_3OH]	3.00E+02	2.50E-03	1.63E+01
Phenol [C_6H_5OH]	1.00E+03	8.34E-03	5.43E+01
Tetraphenylborate [$B(C_6H_5)_4^-$]	1.00E+03	8.34E-03	5.43E+01
Toluene [$C_6H_5CH_3$]	5.00E+02	4.17E-03	2.71E+01
Tributylphosphate [$(C_4H_9)_3PO$]	4.00E+02	3.34E-03	2.17E+01
EDTA	5.00E+02	4.17E-03	2.71E+01

(1) Value in second column was obtained from WSP-SSF-2004-00015 Rev. 1.
(2) Value in third column equals value in second column multiplied by (1 g/1000 mg), (1 lb/453.59 g), and (3.785 L/1 gal).
(3) Value in fourth column equals value in third column multiplied by (6,504 gal).

Table A-3 - Frequency Evaluation Levels

Acronym	Description	Frequency Level (f) ($year^{-1}$)
A	Anticipated, Expected	$f \geq 10^{-2}$/yr
U	Unlikely	$10^{-4} \leq f < 10^{-2}$/yr
EU	Extremely Unlikely	$10^{-6} \leq f < 10^{-4}$/yr
BEU	Beyond Extremely Unlikely	$f < 10^{-6}$/yr

Table A-4 - Consequence Evaluation Levels for Hazard Receptors

Consequence Level (Abbreviation)		Offsite Public	Facility Worker	Co-Located Worker
High (H)			Prompt worker fatality, acute injury that is immediately life threatening or permanently disabling	Prompt worker fatality, acute injury that is immediately life threatening or permanently disabling
	Radiological	C ≥ 25.0 rem	C ≥ 100 rem Or Radiological material quantity exceeds Hazard Category 3 threshold quantity (TQ) (per DOE-STD-1027)	C ≥ 100 rem
	Chemical	C ≥* ERPG-2	Uniform distribution of total release C ≥ ERPG-3	C ≥ ERPG-3 or ≥ 29 CFR 1910.119 TQ released
Moderate (M)			Serious injury, no immediate loss of life, no permanent disabilities, hospitalization required	Serious injury, no immediate loss of life, no permanent disabilities, hospitalization required
	Radiological	5.0 ≤ C < 25 rem	25 ≤ C < 100 rem	25 ≤ C < 100 rem
	Chemical	ERPG-1 ≤ C < ERPG-2	Uniform distribution of total release ERPG-2 ≤ C < ERPG-3	ERPG-2 ≤ C < ERPG-3
Low (L)			Minor injuries, no hospitalization	Minor injuries, no hospitalization
	Radiological	0.5 ≤ C < 5.0 rem	5.0 ≤ C < 25 rem	5.0 ≤ C < 25 rem
	Chemical	**PEL-TWA ≤ C < ERPG-1	Uniform distribution of total release ERPG-1 ≤ C < ERPG-2	ERPG-1 ≤ C < ERPG-2
Negligible (N)			< Low	< Low
	Radiological	C < 0.5 rem	< 5.0 rem	< 5.0 rem
	Chemical	C < PEL-TWA	C < ERPG-1	C < ERPG-1

*Emergency Response Planning Guideline
**Permissible Exposure Limit-Time Weighted Average

Table A-5 - Risk Criteria Matrix – Public

Frequency (see Table A-3) / Consequence (see Table A-4)	Beyond Extremely Unlikely	Extremely Unlikely	Unlikely	Anticipated
High	C	A	A	A
Moderate	C	B	A1	A1
Low	C	B	B	A1
Negligible	C	C	C	C

Key:

A

Region A
Region A. Unmitigated events falling in Region A due to radiological release require SC controls to get below Region A, SS controls to get below Region A1 (if the SC controls do not do so), additional Levels of Control, and Non-SC/SS Defense-In-Depth (DID) controls as specified in Ref. 36. Unmitigated events falling in Region A due to chemical release require SS controls and additional Levels of Control as specified in Ref. 36. The desired result is that the mitigated combination of consequence and frequency is moved well into the B region, and possibly the C region.

A1

Region A1
Unmitigated events falling in Region A1 due to radiological release require SS controls as well as additional Levels of Control as specified in Ref. 36. Unmitigated events falling in Region A1 due to chemical release require process controls. The desired result is that the mitigated combination of consequence and frequency is moved well into the B region, and possibly the C region.

B

Region B
Unmitigated events falling in Region B require process controls. The desired result is that the mitigated combination of consequence and frequency is moved toward, and possibly into, the C region.

C

Region C
Unmitigated events falling in Region C generally have negligible risk. However, there may be events in this region that require the addition of process controls because the frequency is higher than desired, or the occurrence of the uncontrolled event is unacceptable to management in any event, or the uncontrolled event is unacceptable for programmatic or political reasons.

Table A-6 - Risk Criteria Matrix – Co-Located and Facility Worker

Frequency (see Table A-3) Consequence (see Table A-4)	Beyond Extremely Unlikely	Extremely Unlikely	Unlikely	Anticipated
High	**C**	**A**	**A**	**A**
Moderate	**C**	**B**	**B**	**B**
Low	**C**	**B**	**B**	**B**
Negligible	**C**	**C**	**C**	**C**

Key:

A

Region A
Unmitigated events falling in Region A require SS controls an additional Levels of Control as specified in Reference 36. The desired result is that the mitigated combination of consequence and frequency is moved well into the B region, and possibly the C region.

B

Region B
Unmitigated events falling in Region B require process controls. The desired result is that the mitigated combination of consequence and frequency is moved toward, and possibly into, the C region.

C

Region C
Unmitigated events falling in Region C generally have negligible risk. However, there may be events in this region that require the addition of process controls because the frequency is higher than desired, or the occurrence of the uncontrolled event is unacceptable to management in any event, or the uncontrolled event is unacceptable for programmatic or political reasons.

Table A-7 - Saltstone Facility Hazard Categorization

Isotope	Note	Concen-tration (1)	Inventory (2)	Cat 3 Threshold	Exceeds Cat 3 Threshold?	Cat 3 Ratio (3)	Cat 2 Threshold	Exceeds Cat 2 Threshold?	Cat 2 Ratio (4)
		(Ci/gal)	(Ci)	(Ci)	(YES/NO)	(fraction)	(Ci)	(YES/NO)	(fraction)
H-3 (oxide)		2.37E-03	3.55E+01	1.60E+04	NO	2.22E-03	3.00E+05	NO	1.18E-04
C-14		4.73E-04	7.10E+00	4.20E+02	NO	1.69E-02	1.40E+06	NO	5.07E-06
Al-26	Note (7)	1.21E-05	1.82E-01	2.40E+02	NO	7.57E-04	2.40E+02	NO	7.57E-04
Ni-59		4.73E-04	7.10E+00	1.18E+04	NO	6.01E-04	1.06E+07	NO	6.70E-07
Ni-63		4.73E-04	7.10E+00	5.40E+03	NO	1.31E-03	4.50E+06	NO	1.58E-06
Co-60		4.73E-03	7.10E+01	2.80E+02	NO	2.53E-01	1.90E+05	NO	3.74E-04
Se-79		4.73E-04	7.10E+00	3.60E+02	NO	1.97E-02	3.21E+05	NO	2.21E-05
Sr-90		9.46E-02	1.42E+03	1.60E+01	YES	8.87E+01	2.20E+04	NO	6.45E-02
Y-90		9.46E-02	1.42E+03	1.42E+03	NO	1.00E+00	3.48E+06	NO	4.08E-04
Nb-94		6.43E-05	9.65E-01	2.00E+02	NO	4.83E-03	8.60E+04	NO	1.12E-05
Tc-99		1.78E-02	2.66E+02	1.70E+03	NO	1.57E-01	3.80E+06	NO	7.01E-05
Ru-106		4.73E-03	7.10E+01	1.00E+02	NO	7.10E-01	6.50E+03	NO	1.09E-02
Rh-106	Note (5)	-	-	-	-	-	-	-	-
Sb-125		9.46E-03	1.42E+02	1.20E+03	NO	1.18E-01	2.86E+06	NO	4.96E-05
Te-125m		9.46E-03	1.42E+02	7.20E+02	NO	1.97E-01	4.26E+05	NO	3.33E-04
Sn-126		7.57E-05	1.14E+00	1.70E+02	NO	6.68E-03	3.30E+05	NO	3.44E-06
Sb-126		7.57E-05	1.14E+00	2.80E+02	NO	4.06E-03	2.50E+06	NO	4.54E-07
Sb-126m	Note (7)	7.57E-05	1.14E+00	2.40E+04	NO	4.73E-05	2.40E+04	NO	4.73E-05
I-129		4.73E-04	7.10E+00	6.00E-02	YES	1.18E+02	3.17E+02	NO	2.24E-02
Cs-134		4.73E-03	7.10E+01	4.20E+01	YES	1.69E+00	6.00E+04	NO	1.18E-03
Cs-135		4.73E-03	7.10E+01	4.20E+02	NO	1.69E-01	6.35E+05	NO	1.12E-04
Cs-137		5.00E-01	7.49E+03	6.00E+01	YES	1.25E+02	8.90E+04	NO	8.42E-02
Ba-137m	Note (5)	-	-	-	-	-	-	-	-
Ce-144		4.73E-04	7.10E+00	1.00E+02	NO	7.10E-02	8.20E+04	NO	8.65E-05
Pr-144		4.73E-04	7.10E+00	1.04E+06	NO	6.82E-06	4.91E+08	NO	1.45E-08
Pm-147		2.37E-02	3.55E+02	1.00E+03	NO	3.55E-01	8.40E+05	NO	4.22E-04
Sm-151		9.46E-05	1.42E+00	1.00E+03	NO	1.42E-03	9.90E+05	NO	1.43E-06
Eu-154		9.46E-03	1.42E+02	2.00E+02	NO	7.10E-01	1.10E+05	NO	1.29E-03
Eu-155		4.73E-05	7.10E-01	9.40E+02	NO	7.55E-04	7.30E+05	NO	9.72E-07
Th-232		1.21E-05	1.82E-01	1.00E-01	YES	1.82E+00	1.80E+01	NO	1.01E-02
U-233		4.73E-05	7.10E-01	4.20E+00	NO	1.69E-01	2.20E+02	NO	3.23E-03
U-234		4.73E-05	7.10E-01	4.20E+00	NO	1.69E-01	2.20E+02	NO	3.23E-03
U-235		4.73E-07	7.10E-03	4.20E+00	NO	1.69E-03	2.40E+02	NO	2.96E-05

Table A-7 - Saltstone Facility Hazard Categorization (Continued)

U-236		4.73E-05	7.10E-01	4.20E+00	NO	1.69E-01	2.38E+02	NO	2.98E-03
U-238		4.73E-05	7.10E-01	4.20E+00	NO	1.69E-01	2.40E+02	NO	2.96E-03
Np-237	Note (6)	-	-	-	-	-	-	-	-
Pu-238	Note (6)	-	-	-	-	-	-	-	-
Pu-239		1.01E-03	1.51E+01	5.20E-01	YES	2.90E+01	5.60E+01	NO	2.70E-01
Pu-240	Note (6)	-	-	-	-	-	-	-	-
Pu-241		3.52E-03	5.29E+01	3.20E+01	YES	1.65E+00	2.90E+03	NO	1.82E-02
Pu-242	Note (6)	-	-	-	-	-	-	-	-
Am-241	Note (6)	-	-	-	-	-	-	-	-
Am-243	Note (6)	-	-	-	-	-	-	-	-
Cm-242		4.73E-05	7.10E-01	3.20E+01	NO	2.22E-02	1.70E+03	NO	4.17E-04
Cm-244	Note (6)	-	-	-	-	-	-	-	-
					Sum of Fractions	3.71E+02		Sum of Fractions	4.98E-01

(1) Value in third column was obtained from Table A-1.
(2) Value in fourth column equals value in third column multiplied by (15,000 gal).
(3) Value in seventh column equals value in fourth column divided by value in fifth column.
(4) Value in tenth column equals value in fourth column divided by value in eighth column.
(5) Dose accounted for by parent nuclide.
(6) Bounded by Pu-239.
(7) In the absence of a Cat 2 threshold, the Cat 3 threshold was conservatively used as the Cat 2 threshold.

Table A-8 - Consequences for Radiological Events

Release Mechanism	MAR (gal)	ARF*RF	ST (gal)	Consequences (rem) Consequence Level (Table A-4)		
				30 m	CW (100 m)	Public (10 km)
SSHT Fire-						
Boiling	7.01E+02	2.0E-03	1.40E+00	7.74E-01	7.72E-02	1.69E-04
Heated Liquid	1.5E+04	3.0E-05	4.50E-01	Negligible	Negligible	Negligible
Resuspension	1.5E+04	3.0E-05	4.80E-01			
SFT Fire-						
Boiling	2.96E+02	2.0E-03	5.92E-01	3.29E-01	3.29E-02	7.21E-05
Heated Liquid	6.50E+03	3.0E-05	1.95E-01	Negligible	Negligible	Negligible
Resuspension	6.50E+03	3.2E-05	2.08E-01			
210-Z Process Building						
Boiling Fire	2.84+02	2.00E-03	5.68E-01	2.16E-01	2.16E-02	4.76E-05
Resuspension	2.84+02	3.20E-05	9.09E-01	Negligible	Negligible	Negligible
Other Fire Events-PVVS						
HEPA Fire	6.5E+02	1.00E-04	6.50E-02	2.87E-02	2.77E-03	6.07E-06
Resuspension	6.5E+02	3.20E-05	2.08E-02	Negligible	Negligible	Negligible
Explosion in SFT[1]	See discussion in Section 5.2			8.0E+00 Low	8.0E-01 Negligible	1.8E-03 Negligible
Loss of Containment/Confinement						
SFT Spill	1.50E+04	2.00E-05	3.00E-01	2.32E-01	2.30E-02	5.14E-05
Resuspension	1.50E+04	3.20E-05	4.80E-01	Negligible	Negligible	Negligible
Direct Exposure to the FW-SFT[2]	NA	NA	NA	4.0E+00 Low	NA	NA
Direct Exposure to the FW- 210-Z Process Building	NA	NA	NA	9.6E+00 Low	NA	NA
Direct Exposure to the FW-Vault	NA	NA	NA	1.76E+01 Low	NA	NA
External Events-Vehicle						
Boiling	9.89E+02	2.00E-03	1.98E+00	9.92E-01	9.90E-02	2.17E-04
Heated Liquid	1.50E+03	3.00E-05	4.50E-01	Negligible	Negligible	Negligible
Resuspension	1.50E+03	3.20E-05	4.80E-01			

Note 1: The SFT Explosion was initially screened as High unmitigated consequence/risk rank but was subsequently shown to be Low.

Note 2: Because the dose approached the 5-rem limit, the risk was conservatively set to be Low.

APPENDIX B

UNMITIGATED HAZARD ANALYSIS TABLES

Appendix B Unmitigated Hazards Analysis

Node: 1. Bulk Material Handling System

Dev	Causes	Results	Unmitigated Freq	Unmitigated Consequence/Risk Rank	Controls	Remarks
1.1. High Flow						
	1. Unloading multiple dry material trucks at one time causes high flow of material into silo	Overwhelm dust collector. Release of dry material to environment (dust release). MAR: Fly ash, slag, concrete	A	Public: Neg/C CW: Neg/C FW: Neg/C	Operators monitor dust collector discharge Dust collector high differential pressure indication and alarm Automatic backflow pulsations of silo dust collectors	Region C event for chemical hazards. No control strategy required.
	2. Operator error causes loading of dry material too fast	Overflow silo. Spill of dry material to environment. MAR: Fly ash, slag, concrete	A	Public: Neg/C CW: Neg/C FW: Neg/C	Silo level indicator and alarm	Region C event for chemical hazards. No control strategy required.
	3. Air regulator failure on delivery truck causes loading of dry material too fast	Overflow silo. Release of dry material to environment. MAR: Fly ash, slag, concrete	A	Public: Neg/C CW: Neg/C FW: Neg/C	Silo level indicator and alarm	Region C event for chemical hazards. No control strategy required.
1.2. No/Low Flow						
	1. Rain enters silo causing pluggage of dry material. Maintenance fails to restore silo properly following entry.	Loss of production	A	Prod: <6 months/C	Work Control process	Region C event. No control strategy required.
	2. Loss of air causes silo discharge valve failure	Loss of production	A	Prod: <6 months/C	None required	Region C event. No control strategy required.
	3. Silo discharge valve fails shut	Loss of production	A	Prod: <6 months/C	None required	Region C event. No control strategy required.

Unmitigated Hazards Analysis cont'd

Node: 1. Bulk Material Handling System (cont'd)

Dev	Causes	Results	Unmit Freq	Unmit Consequence/Risk Rank	Controls	Remarks
1.2. No/Low Flow (cont'd)						
	4. Silo discharge valve vent clogged (insects) causing valve to remain shut	Loss of production	A	Prod: <6 months/C	None required	Region C event. No control strategy required.
	5. Bridging of material in silo due to material sitting too long	Loss of production	A	Prod: <6 months/C	None required	Region C event. No control strategy required.
	6. Operator or delivery personnel disconnect fill hose too early	Spill of dry material to environment. MAR: Fly ash, slag, concrete	A	Public: Neg/C CW: Neg/C FW: Neg/C	Operator/delivery personnel training and experience.	Region C event for chemical hazards. No control strategy required.
	7. Transfer hose from delivery truck to silo breaks or uncouples	Spill of dry material to environment. MAR: Fly ash, slag, concrete	A	Public: Neg/C CW: Neg/C FW: Neg/C	Operators monitor filling of silo	Region C event for chemical hazards. No control strategy required.
	8. Plugging tendency in line	Loss of production	A	Prod: <6 months/C	None required	Region C event. No control strategy required.
1.3. High Temperature						
	1. Spark in silo during unloading causes explosion. Dust ignites from spark/heat generated by dust collectors, maintenance, or lightning.	None		N/A		Dust explosion of fly ash, concrete, or slag considered impossible due to non-flammable nature of material.

Unmitigated Hazards Analysis cont'd

Node: 1. Bulk Material Handling System (cont'd)

Dev	Causes	Results	Unmit Freq	Unmit Consequence/Risk Rank	Controls	Remarks
1.3. High Temperature (cont'd)						
	2. Vendor delivers slag too hot (above specification)	Product quality	A	Prod: <6 months/C	None required	Region C event. No control strategy required.
	3. High ambient temperatures	None		N/A		Ambient temperatures not hot enough to affect quality of product.
	4. Fire in vicinity of bulk material handling structure. Ignition of combustible material from spark/heat from electrical equipment, vehicles, lightning, or maintenance.	Personal injury (fire related)	A	Public: Neg/C	Fire extinguishers located and maintained per NFPA standards	Region C event for chemical hazard. No control strategy required. Region A event for fire related injuries. Compliance with OSHA and NFPA life safety and fire protection codes and standards adequately protect facility worker from fire related injuries (considered standard industrial hazard).
				CW: Neg/C	Fire hydrants located and maintained per NFPA standards	
				FW: High/A High fire related injuries (serious injury) considered possible. Radiological and chemical hazards for Facility Worker estimated as Negligible.	Operator training on fire extinguisher use and fighting incipient fires Site Fire Department notification and response	
1.4. High Contaminants						
	1. Operator error loads dry material to wrong silo	Product quality	A	Prod: <6 months/C	None required	Region C event. No control strategy required.
	2. Vendor delivers wrong/out of spec raw material	Product quality	A	Prod: <6 months/C	None required	Region C event. No control strategy required.

Unmitigated Hazards Analysis cont'd

Node: 1. Bulk Material Handling System (cont'd)

Dev	Causes	Results	Unmit Freq	Unmit Consequence/Risk Rank	Controls	Remarks
1.4. High Contaminants (cont'd)						
	3. Foreign material loaded into silo due to poor vendor QC, or maintenance	Equipment damage Product quality	A	Damage: <$1M/C Prod: <6 months/C	None required	Region C event. No control strategy required.
	4. Corrosion products from silo	Product quality	A	Prod: <6 months/C	None required	Region C event. No control strategy required.
1.5. High Pressure						
	1. Dust collector plant air regulator valve fails causes high air flow into silo	Equipment damage to silo. Spill of dry material to environment. MAR: Fly ash, slag, concrete	A	Public: Neg/C CW: Neg/C	Silo conservation vents. Vents sized and maintained per Site Pressure Protection Program.	Region B event for equipment damage. Control strategy required. Event carried forward to mitigated hazard analysis.
				FW: Neg/C	Dust collector bags will blow out before silo fails. Silo design internal pressure of 4 psig.	
				Damage: >$1M/B	Truck unloading line provides alternate silo vent path. Unloading line valve removed per DCF.	

Unmitigated Hazards Analysis cont'd

Node: 1. Bulk Material Handling System (cont'd)

Dev	Causes	Results	Unmit Freq	Unmit Consequence/Risk Rank	Controls	Remarks
1.5. High Pressure (cont'd)						
	2. Plugged vent in dust collectors cause high pressure in silo	Equipment damage to silo. Spill of dry material to environment. MAR: Fly ash, slag, concrete	A	Public: Neg/C	Silo conservation vents. Vents sized and maintained per Site Pressure Protection Program	Region B event for equipment damage. Control strategy required. Event carried forward to mitigated hazard analysis.
				CW: Neg/C		
				FW: Neg/C	Dust collector bags will blow out before silo fails. Silo design internal pressure of 4 psig.	
				Damage: >$1M/B	Truck unloading line provides alternate silo vent path. Unloading line valve removed per DCF.	
					Periodic backflow pulsations of silo dust collectors.	
	3. Air regulator for blend tank fails open causing high pressure in silo	Equipment damage to silo. Spill of dry material to environment. MAR: Fly ash, slag, concrete	A	Public: Neg/C	Silo conservation vents. Vents sized and maintained per Site Pressure Protection Program	Region B event for equipment damage. Control strategy required. Event carried forward to mitigated hazard analysis.
				CW: Neg/C	Dust collector bags will blow out before silo fails. Silo design internal pressure of 4 psig.	
				FW: Neg/C	Truck unloading line provides alternate silo vent path. Unloading line valve removed per DCF.	
				Damage: >$1M/B	Process air system relief valves	

Unmitigated Hazards Analysis cont'd

Node: 1. Bulk Material Handling System (cont'd)

Dev	Causes	Results	Unmit Freq	Unmit Consequence/Risk Rank	Controls	Remarks
1.6. Low Pressure						
	1. No vent of silo while blower running causes vacuum in silo	Equipment damage. Spill of dry material to environment. MAR: Fly ash, slag, concrete	A	Public: Neg/C	Silo conservation vents. Vents sized and maintained per Site Pressure Protection Program	Region B event for equipment damage. Control strategy required. Event carried forward to mitigated hazard analysis.
				CW: Neg/C		
				FW: Neg/C	Truck unloading line provides alternate silo vent path. Unloading line valve removed per DCF.	
				Damage: >$1M/B	Blower capacity and silo construction	
1.7. High Level						
	1. Operator/delivery error: loads too much material into silo	Overflow silo. Spill of dry material to environment MAR: Fly ash, slag, concrete	A	Public: Neg/C	Silo level indicator and alarm	Region C event for chemical hazards. No control strategy required.
				CW: Neg/C		
				FW: Neg/C		
	2. Level indicator fails during loading causing too much material to be loaded	Overflow silo. Spill of dry material to environment MAR: Fly ash, slag, concrete	A	Public: Neg/C	Silo level indicator and alarm	Region C event for chemical hazards. No control strategy required.
				CW: Neg/C		
				FW: Neg/C		

Unmitigated Hazards Analysis cont'd

Node: 1. Bulk Material Handling System (cont'd)

Dev	Causes	Results	Unmit Freq	Unmit Consequence/Risk Rank	Controls	Remarks
1.8. Low Level						
	1. Level indicator fails causing silo to run dry during mixing	Product quality	A	Prod: <6 months/C	Silo level indicator and alarm Weigh hopper load cell indicates if not enough material received	Region C event. No control strategy required.
1.9. Leak						
	1. Corrosion of silo causes leak	Spill of dry material to environment. MAR: Fly ash, slag, concrete	A	Public: Neg/C CW: Neg/C FW: Neg/C	None required	Region C event for chemical hazards. No control strategy required.
	2. Maintenance related leaks (i.e., manholes not properly installed after maintenance)	Spill of dry material to environment. MAR: Fly ash, slag, concrete	U	Public: Neg/C CW: Neg/C FW: Neg/C	Work Control process	Maintenance error estimated at 1E-4/op Assume 1 maintenance activity per month on line (12 per year) 1E-4/op * 12 op/yr = 1.2E-3/yr Region C event for chemical hazards. No control strategy required.
	3. Faulty welding or joint attachment	Spill of dry material to environment. MAR: Fly ash, slag, concrete	U	Public: Neg/C CW: Neg/C FW: Neg/C	NDE and post maintenance testing	Failure rate of unions and junctions, 4E-7/hr (8760 hrs/yr 4E-7/hr * 8760 hr/yr = 3.5E-3/yr Region C event for chemical hazards. No control strategy required.

Unmitigated Hazards Analysis cont'd

Node: 2 SSHT & Transfer Line through Dike

Dev	Causes	Results	Unmit Freq	Unmit Consequence/Risk Rank	Controls	Remarks
2.1. High Temperature						
	1. Fire in SSHT dike. Ignition of combustible material from spark/heat from electrical equipment, vehicles, lightning, or maintenance.	Fire assumed to involve only the transfer line through the SSHT dike. Spill of salt solution. Personal injury (toxic fumes from SSHT insulation) MAR: 15,000 gal of salt solution	A	Public: Neg/C	Dike/sump are secondary confinement	Region C event for radiological and chemical hazards. No controls required. Region A event for fire related injuries. Compliance with OSHA and NFPA life safety and fire protection codes and standards adequately protect facility worker from fire related injuries (considered standard industrial hazard).
				CW: Neg/C	Fire extinguishers located and maintained per NFPA standards	
				FW: High/A High fire related injuries (serious injury) considered possible. SSHT insulation releases toxic gases when it burns. Process radiological and chemical hazards for Facility Worker estimated as Negligible.	Fire hydrants located and maintained per NFPA standards	
					Operator training on fire extinguisher use and fighting incipient fires	
					Site Fire Department notification and response	
					Transfer line design and materials of construction	
2.2. Leak						
	1. Corrosion	Equipment damage Spill of salt solution MAR: 15,000 gal of salt solution	A	Public: Neg/C	Dike/sump are secondary confinement	Region C event for radiological and chemical hazards. No control strategy required.
				CW: Neg/C	CST chemistry control program minimizes corrosion	
				FW: Neg/C	Transfer line design and materials of construction	

Unmitigated Hazards Analysis cont'd

Node: 2 SSHT & Transfer Line through Dike (cont'd)

Dev	Causes	Results	Unmit Freq	Unmit Consequence/Risk Rank	Controls	Remarks
2.2. Leak (cont'd)						
	2. Faulty welding or joint attachment	Equipment damage Spill of salt solution MAR: 15,000 gal of salt solution	U	Public: Neg/C	NDE and post maintenance testing	Region C event for radiological and chemical hazards. No control strategy required.
				CW: Neg/C	Dike/sump are secondary confinement	
				FW: Neg/C		
2.3. Radiation						
	1. Facility worker remains near transfer line during operations (assume 8 hours)	Direct radiation to facility worker	A	Public: Neg/C	Radiation Protection Program (access control)	Region B event for FW. Control strategy required. Event carried forward to mitigated hazard analysis.
				CW: Neg/C	WAC	
				FW: Low/B		
	2. Exposure during maintenance activities in the SSHT dike	Direct radiological exposure and contamination to facility worker	A	Public: Neg/C	Radiation Protection Program (PPE, monitor)	Region B event for FW. Control strategy required. Event carried forward to mitigated hazard analysis.
				CW: Neg/C		
				FW: Low/B		

Unmitigated Hazards Analysis cont'd

Node: 3. SFT

Dev	Causes	Results	Unmit Freq	Unmit Consequence/Risk Rank	Controls	Remarks
3.1. High Temperature						
	1. Fire in SFT dike. Ignition of combustible material from spark/heat from electrical equipment, vehicles, lightning, or maintenance.	Fire assumed to involve the SFT. Equipment damage. Spill of salt solution. MAR: 6504 gal of salt solution.	A	Public: Neg/C	Site Fire Department notification and response	Combustible loading in SFT dike insufficient to boil more than 15 gal (79 Btu). Region C event for radiological and chemical hazards. Region B event for fire related injuries. Compliance with OSHA and NFPA life safety and fire protection codes and standards adequately protect facility worker from fire related injuries (considered standard industrial hazard).
				CW: Neg/C	Fire extinguishers located and maintained per NFPA standards	
				FW: Low/B Low fire related injuries (minor injury) considered possible. Dike is open. Process radiological and chemical hazards for Facility Worker estimated as Negligible.	Fire hydrants located and maintained per NFPA standards	
					Operator training on fire extinguisher use and fighting incipient fires	
					Tank design and materials of construction	
					SFT diked area provides passive confinement	
					SFT dike sump level indication and alarm	

Unmitigated Hazards Analysis cont'd

Node 3. SFT (cont'd)

Dev	Causes	Results	Unmit Freq	Unmit Consequence/Risk Rank	Controls	Remarks
3.1. High Temperature (cont'd)						
	2. Flammable vapor accumulates in tank vapor space. Ignition of vapors due to lightning, maintenance, faulty electrical equipment (i.e., agitator) results in explosion.	Explosion in SFT. Personal injury (explosion related) MAR: 6504 gal. of salt solution. Note: The SFT volume used in the accident analysis was conservatively assumed to be 7656 gallons, which includes the vapor space above the tank overflow.	A	Public: Neg/C	SFT located within concrete diked area (12" thick) with diamond plate on top of tank (minimizes injury potential)	Region B event for radiological and chemical hazards (Low consequences). Event carried forward to mitigated hazard analysis Region A event for explosion related injuries that could effect the facility worker. The controls used to prevent the radiological and chemical hazard event also prevent the standard industrial hazard event
				CW: Low/B Radiological and chemical hazards for CW initially screened as Low/B; subsequently evaluated to be Neg/C	SFT PVV system maintains sweep on tank	
				FW: High/A Serious injuries are considered possible following an explosion event, however it is considered a standard industrial hazard. Radiological and chemical hazards for Facility Worker initially screened as High/A, but subsequently evaluated to be Low/B with an exposure of 8 rem.	SFT vents to atmosphere through 4-inch overflow line	
					Limited sources able to ignite SFT vapor space	
					SFT diked area provides passive confinement	

Unmitigated Hazards Analysis cont'd

Node: 3. SFT (cont'd)

Dev	Causes	Results	Unmit Freq	Unmit Consequence/Risk Rank	Controls	Remarks
3.1. High Temperature (con'td)						
	3. Hot material transferred to tank from H-Area	Product quality	A	Prod: <6 months/C	Feed temperature monitored in SFT. If too hot, material allowed to cool.	Region C event. No control strategy required.
	4. High ambient temperatures	None			WAC limits temperature of incoming feed stream	Ambient temperatures not hot enough to affect quality of product.
3.2. High Pressure						
	1. Tank vent clogged/plugged while transferring material to SFT.	Equipment damage. Overpressurization of SFT results in release of salt solution MAR: 6504 gal of salt solution	U	Public: Neg/C	SFT overflow line (4" line minimizes clogging or plugging)	Region B event for radiological and chemical hazards. Event carried forward to mitigated hazard analysis.
				CW: Neg/C	SFT vented to PVV system	
				FW: Low/B	Air gap between overflow line and sump	
					SFT diked area provides passive confinement	
					SFT dike sump level indication and alarm	
					Tank design	

Unmitigated Hazards Analysis cont'd

Node: 3. SFT (cont'd)

Dev	Causes	Results	Unmit Freq	Unmit Consequence/Risk Rank	Controls	Remarks
3.2 High Pressure (cont'd)						
	2. Bubbler air regulator failure	Equipment damage. Overpressurization of SFT results in release of salt solution MAR: 6504 gal of salt solution	A	Public: Neg/C	Bubblers are 1/4" lines at 1.5 scfm –insufficient to cause damage to SFT	Region B event for radiological and chemical hazards. Event carried forward to mitigated hazard analysis.
					Tank design	
				CW: Neg/C	SFT diked area provides passive confinement	
				FW: Low/B	SFT dike sump level indication and alarm	
					SFT overflow line (4" line minimizes pressure buildup in tank)	
	3. Air from pig launching system	Equipment damage. Overpressurization of SFT results in release of salt solution MAR: 6504 gal of salt solution	A	Public: Neg/C	Logic checks to make sure four way valve from pig launcher in correct position prior to launch	Region B event for radiological and chemical hazards. Control strategy required. Event carried forward to mitigated hazard analysis.
				CW: Neg/C	SFT overflow line (4" line minimizes pressure buildup in tank)	
				FW: Low/B	SFT diked area provides passive confinement	
					SFT dike sump level indication and alarm	
					Tank design	

Unmitigated Hazards Analysis cont'd

Node: 3. SFT (cont'd)

Dev	Causes	Results	Unmit Freq	Unmit Consequence/Risk Rank	Controls	Remarks
3.2 High Pressure (cont'd)						
	4. Air from pig launching system	Aerosolization/ Sparging of waste MAR: 3252 gal.of salt solution (half the tank volume)	A	Public: Neg/C	Logic checks to make sure four way valve from pig launcher in correct position prior to launch	Region C event for radiological and chemical hazards. No control strategy required.
				CW: Neg/C	PVV System mist eliminator	
				FW: Neg/C	HEPA filters	
					SFT diked area provides passive confinement	
					SFT dike sump level indication and alarm	
3.3. High Level						
	1. Overfilling of tank due to operator error, valve leaks through, downstream control valve closed, or SFT discharge pump failure	No transfer. Loss of production. Spill of salt solution MAR: 15,000 gal of salt solution	A	Public: Neg/C	SFT level indication and high level alarm	Region C event. No control strategy required.
					SFT hi-level alarm and software interlock to Tank 50 pump	
					Independent SFT high-level conductivity probe and hard-wired interlock to close SFT inlet valve	
				CW: Neg/C	SFT overflow line to diked area	
					SFT diked area provides passive confinement	
				FW: Neg/C	SFT dike sump level indication and alarm	
					Area Radiation Monitor	
				Prod: <6 months/C	Operating procedures to perform material balance	

Unmitigated Hazards Analysis cont'd

Node: 3. SFT (cont'd)

Dev	Causes	Results	Unmit Freq	Unmit Consequence/Risk Rank	Controls	Remarks
3.3. High Level						
	2. Overfilling of tank due to mixer inlet valve closed, mixer discharge line plugged, or grout pump failure	No transfer. Loss of production. Spill of salt solution MAR: 15,000 gal of salt solution	A	Public: Neg/C	SFT to mixer flow indicator and low flow alarm	Region C event. No control strategy required.
				CW: Neg/C	SFT hi-level alarm and software interlock to Tank 50 pump	
					Independent SFT high-level conductivity probe and hard-wired interlock to close SFT inlet valve	
				FW: Neg/C	SFT overflow line to diked area	
					SFT diked area provides passive confinement	
				Prod: <6 months/C	SFT dike sump level indication and alarm	
					Area Radiation Monitor	
					Operating procedures to perform material balance	
	3. Overfilling of tank due to loss of level indication	No transfer. Loss of production. Spill of salt solution MAR: 15,000 gal of salt solution	A	Public: Neg/C	Independent SFT high-level conductivity probe and hard-wired interlock to close SFT inlet valve	Region C event for radiological and chemical hazards. No control strategy required.
				CW: Neg/C	SFT overflow line to diked area	
				FW: Neg/C	SFT diked area provides passive confinement	
				Prod: <6 months/C	SFT dike sump level indication and alarm	
					Area Radiation Monitor	
					Operating procedures to perform material balance	

Unmitigated Hazards Analysis cont'd

Node: 3. SFT (cont'd)

Dev	Causes	Results	Unmit Freq	Unmit Consequence/Risk Rank	Controls	Remarks
3.3. High Level (cont'd)						
	4. Siphon effects cause transfer of salt solution from H-Area to continue after pump is stopped	Spill of salt solution MAR: 15,000 gal of salt solution	A	Public: Neg/C	CST Transfer Control program.	Region C event for radiological and chemical hazards. No control strategy required.
				CW: Neg/C	SFT level indication and high level alarm	
				FW: Neg/C		
					SFT overflow line to diked area	
					SFT diked area provides passive confinement	
					SFT dike sump level indication and alarm	
					Independent SFT high-level conductivity probe and hard-wired interlock to close SFT inlet valve	
	5. Overflow of SFT occurs due to NPH/external event. Personnel fail to stop the transfer while evacuating or are injured during the event.	Spill of salt solution MAR: 15,000 gal. of salt solution	U	Public: Neg/C	SFT overflow line to diked area	Frequency based on facility operating experience and engineering judgement
				CW: Neg/C	SFT high level interlock closes transfer valve on high level in tank	
				FW: Neg/C	SFT diked area provides passive confinement	Region C event for radiological and chemical hazards. No control strategy required.
					SFT dike sump level indication and alarm	
					Area Radiation Monitor	

Unmitigated Hazards Analysis cont'd

Node: 3. SFT (cont'd)

Dev	Causes	Results	Unmit Freq	Unmit Consequence/Risk Rank	Controls	Remarks
3.4 Low Pressure						
	1. Tank vents plugged & tank being emptied or excess vacuum pulled by PVV system	Equipment damage Spill of salt solution MAR: 6504 gal of salt solution	A	Public: Neg/C	SFT overflow line (4" line minimizes clogging or plugging)	Region C event for radiological and chemical hazards. No control strategy required.
				CW: Neg/C	SFT diked area provides passive confinement	
				FW: Neg/C	SFT dike sump level indication and alarm	
3.5. Low Temperature						
	1. Low ambient temperatures	Loss of production. Precipitated salts build up in SFT.	A	Prod: <6 months	Agitator	Region C event. No control strategy required.
	2. Freezing conditions	Loss of production. Spill of salt solution. MAR: 15,000 gal. of salt solution	U	Public: Neg/C	Salt solution low freezing point	Frequency based on engineering judgement.
				CW: Neg/C	Agitator	Region C event for radiological and chemical hazards. No control strategy required.
				FW: Neg/C	SFT diked area provides passive confinement	Region C event for radiological and chemical hazards. No control strategy required.
				Prod: <6 months/C	SFT dike sump level indication and alarm	
					Area Radiation Monitor	

Unmitigated Hazards Analysis cont'd

Node: 3. SFT (cont'd)

Dev	Causes	Results	Unmit Freq	Unmit Consequence/Risk Rank	Controls	Remarks
3.6. Low Level						
	1. See Leak (Event 3.8)					
3.7. Contaminants						
	1. SFT WAC limits exceeded due to incorrect material being transferred to H-Area Tank 50 and then being transferred to Saltstone.	Personal injury (direct radiological exposure) Permit violation	A	Public: Neg/C	Saltstone Waste Acceptance Criteria Program ensures the composition of waste streams received into the facility is within analyzed limits.	Region B event for FW. Control strategy required. Event carried forward to mitigated hazard analysis.
				CW: Neg/C	Radiation Protection Program (access control)	
				FW: Low/B	Area Radiation Monitor	
	2. Process water system contaminated	Personal injury (direct radiological exposure)	U	Public: Neg/C	Seal pot prevents contamination migration	Region C event for radiological and chemical hazards. No control strategy required.
				CW: Neg/C	Air gap on process water tank segregates from site domestic water prevents release to environment	
				FW: Neg/C	Process water pressure higher than SFT pressure.	

Unmitigated Hazards Analysis cont'd

Node: 3. SFT (cont'd)

Dev	Causes	Results	Unmit Freq	Unmit Consequence/Risk Rank	Controls	Remarks
3.8. Leak						
	1. Corrosion, cracking, overstress of tank or line	Equipment damage Spill of salt solution MAR: 15,000 gal of salt solution	A	Public: Neg/C	SFT diked area provides passive confinement	Region C event for radiological and chemical hazards. No control strategy required.
				CW: Neg/C	SFT dike sump level indication and alarm	
					CST chemistry control program minimizes corrosion	
				FW: Neg/C	Area Radiation Monitor	
					Piping/Tank design and materials of construction	
	2. Faulty welding or joint attachment. Inadequate torquing of bolts or poor welds	Equipment damage Spill of salt solution. MAR: 15,000 gal of salt solution	A	Public: Neg/C	NDE and post maintenance testing	Region C event for radiological and chemical hazards. No control strategy required.
				CW: Neg/C	SFT diked area provides passive confinement	
				FW: Neg/C	SFT dike sump level indication and alarm	
					Area Radiation Monitor	
					Materials of construction	
	3. Drain or vent or sample valve leakage	Spill of salt solution MAR: 15,000 gal of salt solutions	A	Public: Neg/C	SFT diked area provides passive confinement	Region C event for radiological and chemical hazards. No control strategy required.
				CW: Neg/C	SFT dike sump level indication and alarm	
				FW: Neg/C	Valve design and materials of construction	
					Area Radiation Monitor	
	4. Gasket or packing or valve seal failure	Spill of salt solution MAR: 15,000 gal of salt solutions	A	Public: Neg/C	WAC limits (minimize gamma radiation degradation and chlorides)	Region C event for radiological and chemical hazards. No control strategy required.
				CW: Neg/C	SFT dike sump level indication and alarm	
				FW: Neg/C	Valve design and materials of construction	
					Area Radiation Monitor	

Unmitigated Hazards Analysis cont'd

Node: 3. SFT (cont'd)

Dev	Causes	Results	Unmit Freq	Unmit Consequence/Risk Rank	Controls	Remarks
3.8. Leak (cont'd)						
	5. Flooded cell floats tank and/or ruptures line	Spill of salt solution MAR: 15,000 gal of salt solutions	U	Public: Neg/C	Raincover	Region C event for radiological and chemical hazards. No control strategy required.
				CW: Neg/C	SFT diked area provides passive confinement	
				FW: Neg/C	SFT dike sump level indication and alarm	
					Area Radiation Monitor	
3.9. No Agitation						
	1. Mechanical/electrical failure of agitator	Mechanical/electrical failure of agitator	A	Prod: <6 months/C	High through-put of low salt solution waste (i.e., rapid turnover) prevents salt buildup	Region C event for radiological and chemical hazards. No control strategy required.
	2. Mechanical/electrical failure of agitator	Loss of production. Precipitated salts build up in SFT.	A	Prod: <6 months/C	High through-put of low salt solution waste (i.e., rapid turnover) prevents salt buildup	Region C event for radiological and chemical hazards. No control strategy required.

Unmitigated Hazards Analysis cont'd

Node: 3. SFT (cont'd)

Dev	Causes	Results	Unmit Freq	Unmit Consequence/Risk Rank	Controls	Remarks
3.10 Radiation						
	1. Facility worker remains near SFT and/or transfer line during operations (assume 8 hours)	Direct radiation to facility worker	A	Public: Neg/C	Radiation Protection Program (access control)	Region B event for FW. Control strategy required. Event carried forward to mitigated hazard analysis.
				CW: Neg/C	Shielding plate	
				FW: Low/B	Area Radiation Monitor	
	2. Exposure during maintenance activities in the SFT or related equipment	Direct radiological contamination exposure to facility worker	A	Public: Neg/C	Radiation Protection Program (PPE, monitor)	Region B event for FW. Control strategy required. Event carried forward to mitigated hazard analysis.
				CW: Neg/C	Area Radiation Monitor	
				FW: Low/B	Shielding plate	

Unmitigated Hazards Analysis cont'd

Node: 4. Line from SFT to Saltstone Mixer

Dev	Causes	Results	Unmit Freq	Unmit Consequence/Risk Rank	Controls	Remarks
4.1. High Temperature						
	1. Overheating due to heat tracing	Product quality	A	Prod: <6 months/C	Annual check of heat trace	Region C event for radiological and chemical hazards. No control strategy required.
	2. Fire in Process Room. Ignition of combustible material from spark/heat from electrical equipment, vehicles, lightning, or maintenance. Fire in administration building spreads to Process Room.	Fire assumed to involve holdup in the transfer lines, Mixer, SHT, and pump. Equipment damage Spill of salt solution. Personal injury fire related) MAR: 284 gal of salt solution	A	Public: Neg/C	Fire extinguishers located and maintained per NFPA standards	MAR based on: a) Salt solution - 35 feet of 3 inch pipe - +10% = 14 gal b) Mixer - 30 gal Saltstone grout - SHT - 180 gal Pumps- 20 gal Pipe - 55 feet of 4" pipe +10% = 40 gal Total = 284 gal holdup in Process Room
				CW: Neg/C	Fire hydrants located and maintained per NFPA standards	
				FW: High/A High fire related injuries (serious injury) considered possible. Radiological and chemical hazards for Facility Worker estimated as Negligible.	Operator training on fire extinguisher use and fighting incipient fires	
					Piping design and materials of construction	Region C event for radiological and chemical hazards. No control strategy required. Region A event for fire related injuries. Compliance with OSHA and NFPA life safety and fire protection codes and standards adequately protect facility worker from fire related injuries considered standard industrial hazard).
					Process room fire detection system	
					Site Fire Department notification and response	
					SFT provides passive confinement	
					SFT level indication and high level alarm	
					Process Room floor drain to SFT provides passive confinement	
					Area Radiation Monitor	
					Administration building fire walls installed and maintained per NFPA standards	
					Fire separation distances between administration building and process areas per NFPA standards	
					Administration building fire detection and suppression systems installed and maintained per NFPA standards	

Unmitigated Hazards Analysis cont'd

Node: 4. Line from SFT to Saltstone Mixer (cont'd)

Dev	Causes	Results	Unmit Freq	Unmit Consequence/Risk Rank	Controls	Remarks
4.2. High Flow						
	1. Overfilling of mixer	Spill of salt solution MAR: 15,000 gal of salt solution	A	Public: Neg/C	SFT pump rate designed to not overflow mixer	Region C event for radiological and chemical hazards. No control strategy required.
				CW: Neg/C	Redundant conductivity probes and hard-wired interlock in premix feed chute to shut off feed	
				FW: Neg/C	Area Radiation Monitor	
					SFT dike provides passive confinement	
					SFT level indication and high level alarm	
					Process Room floor drain to SFT provides passive confinement	
4.3. Low Pressure						
	1. Upstream pump failure	Loss of production	A	Prod: <6 months/C	None required	Region C event for radiological and chemical hazards. No control strategy required.
4.4. Low Temperature						
	1. Line freeze-up	Transfer line/component leaks. Spill of salt solution MAR: 15,000 gal of salt solution	U	Public: Neg/C	Line heat traced	Frequency based on engineering judgement.
				CW: Neg/C	Salt solution low freezing point	Region C event for radiological and chemical hazards. No control strategy required.
				FW: Neg/C	SFT dike provides passive confinement	
					SFT level indication and high level alarm	
					Process Room floor drain to SFT provides passive confinement	
					Area Radiation Monitor	

Unmitigated Hazards Analysis cont'd

Node: 4. Line from SFT to Saltstone Mixer (cont'd)

Dev	Causes	Results	Unmit Freq	Unmit Consequence/Risk Rank	Controls	Remarks
4.5. Leak						
	1. Corrosion, cracking, overstress of line.	Transfer line/component leaks. Spill of salt solution MAR: 15,000 gal of salt solution	U	Public: Neg/C	SFT dike provides passive confinement	Region C event for radiological and chemical hazards. No control strategy required.
				CW: Neg/C	SFT level indication and high level alarm	
				FW: Neg/C	Process Room floor drain to SFT provides passive confinement	
					WAC provides chemistry control to minimize corrosion	
					Area Radiation Monitor	
					Piping design and materials of construction	
	2. Faulty welding or joint attachment. Inadequate torquing of bolts or poor welds.	Transfer line/component leaks. Spill of salt solution. Potential spill of contaminated flush water. MAR: 15,000 gal of salt solution	A	Public: Neg/C	NDE and post maintenance testing	Region C event for radiological and chemical hazards. No control strategy required.
				CW: Neg/C	SFT dike provides passive confinement	
				FW: Neg/C	SFT level indication and high level alarm	
					Process Room floor drain to SFT provides passive confinement	
					Area Radiation Monitor	
					Materials of construction	
	3. Gasket or packing or valve seal failure	Transfer line/component leaks. Spill of salt solution. MAR: 15,000 gal of salt solution	A	Public: Neg/C	WAC limits (minimize gamma radiation degradation and chlorides)	Region C event for radiological and chemical hazards. No control strategy required.
				CW: Neg/C	SFT dike provides passive confinement	
				FW: Neg/C	SFT level indication and high level alarm	
					Process Room floor drain to SFT provides passive confinement	
					Area Radiation Monitor	

Unmitigated Hazards Analysis cont'd

Node: 4. Line from SFT to Saltstone Mixer (cont'd)

Dev	Causes	Results	Unmit Freq	Unmit Consequence/Risk Rank	Controls	Remarks
4.6. Radiation						
	1. Facility worker remains near SFT transfer line during operations (assume 8 hours). Can be located in the SFT dike or Process Room.	See Events 3.10.1 and 5.6.1	--	--	--	--
	2. Exposure during maintenance activities. Can be located in the SFT dike or Process Room.	See Events 3.10.2 and 5.6.2	--	--	--	--

Unmitigated Hazards Analysis cont'd

Node: 5. Saltstone Mixer and Discharge Line

Dev	Causes	Results	Unmit Freq	Unmit Consequence/Risk Rank	Controls	Remarks
5.1. High Temperature						
	1. Fire in Process Room impacts mixer and discharge line. Ignition of Combustible material from spark/heat from electrical equipment, lightning, or maintenance.	See Event 4.1.2	--	--	--	--
5.2 High Level						
	1. Too much dry material added to mixer	Loss of production Material backs up into screw feeder	A	Prod: <6 months/C	Mixer speed indication and alarms	Region C event for radiological and chemical hazards. No control strategy required.
	2. Too much liquid added to mixer	Product quality	A	Prod: <6 months/C	Grout density indication Grout flow indication	Region C event for radiological and chemical hazards. No control strategy required.
5.3. Contaminants						
	1. Foreign material in dry material due to poor vendor QC or maintenance causes mixer to rock up	Equipment damage.	A	Prod: <6 months/C Damage: <$1M/C	None required	Region C event for radiological and chemical hazards. No control strategy required.

Unmitigated Hazards Analysis cont'd

Node: 5. Saltstone Mixer and Discharge Line (cont'd)

Dev	Causes	Results	Unmit Freq	Unmit Consequence/Risk Rank	Controls	Remarks
5.4. Leak						
	1. Corrosion	Spill of grout/salt solution MAR: 15,000 gal of grout/salt solution	U	Public: Neg/C	Mixer leaks contained in process room	Failure rate of general pressure vessels applied 3E-6/hr 2500 hrs/year. 3E-6/hr * 2500 hr/yr = 7.5E-3/yr
				CW: Neg/C	Mixer design and materials of construction	
				FW: Neg/C	SFT provides passive confinement	Region C event for radiological and chemical hazards. No control strategy required.
					SFT level indication and high level alarm	
					Process Room floor drain to SFT provides passive confinement	
					Control Room visual inspection	
					Area Radiation Monitor	
5.5. Reverse/Misdirected Flow						
	1. Mixer discharge outlet plugged causing salt solution to back up into dry material line	Loss of production. Spill of grout/salt solution. MAR: 15,000 gal of grout/salt solution	A	Public: Neg/C	Mixer speed indication and alarms	Region C event for radiological and chemical hazards. No control strategy required.
				CW: Neg/C	Inspection port on dry material chute provides leak path	
				FW: Neg/C	Redundant conductivity probes and hard-wired interlock in premix feed chute to shut off feed	
				Prod: <6 months/C	Area Radiation Monitor	
5.6. Radiation						
	1. Facility worker enters process room during operations (assume 8 hours)	Direct radiation to facility worker	U	Public: Neg/C	Radiation Protection Program (access control)	Region B event for FW. Control strategy required. Event carried forward to mitigated hazard analysis.
				CW: Neg/C	Shielding	
				FW: Low/B	Area Radiation Monitor	
	2. Exposure during maintenance activities in the process room	Direct radiological exposure and contamination to facility worker	A	Public: Neg/C	Radiation Protection Program (PPE, monitor)	Region B event for FW. Control strategy required. Event carried forward to mitigated hazard analysis.
				CW: Neg/C	Area Radiation Monitor	
				FW: Low/B		

Unmitigated Hazards Analysis cont'd

Node: 6. Saltstone Hold Tank and Transfer Line to Vaults

Dev	Causes	Results	Unmit Freq	Unmit Consequence/Risk Rank	Controls	Remarks
6.1. High Temperature						
	1. High feed stream temperature from SHT to vault. High temperature results from out of spec feed material from vendor/H-Area, or chemical reaction in mixer.	Product quality	A	Prod: <6 months/C	Grout temperature monitored at SHT outlet	Region C event for radiological and chemical hazards. No control strategy required.
	2. Deadheaded transfer pump adds heat to line (valve lineup error, valve failure)	Negligible heat contribution. Equipment damage. Loss of production.	A	Prod: <6 months/C	Saltstone transfer pump discharge pressure and speed indication	Region C event for radiological and chemical hazards. No control strategy required.
				Damage: <$1M/C	Grout flow indication	
					Piping design and materials of construction	
	3. Fire in Process Room impacts transfer lines. Ignition of combustible material from spark/heat from electrical equipment, vehicles, lightning, or maintenance.	See Event 4.1.2	--	--	--	--

Unmitigated Hazards Analysis cont'd

Node: 6. Saltstone Hold Tank and Transfer Line to Vaults (cont'd)

Dev	Causes	Results	Unmit Freq	Unmit Consequence/Risk Rank	Controls	Remarks
6.2. High Flow						
	1. SHT level controller failure sends signal to increase pump speed	Equipment damage	A	Damage: <$1M/C	SHT level indication and alarms	Region C event for radiological and chemical hazards. No control strategy required.
	2. SHT level indicator fails high	Equipment damage	A	Damage: <$1M/C	Redundant SHT level indication	Region C event for radiological and chemical hazards. No control strategy required.
	3. Mechanical or electrical failure of transfer pump causes pump to overspeed	Equipment damage	A	Damage: <$1M/C	SHT level indication and alarms	Region C event for radiological and chemical hazards. No control strategy required.
	4. Overfilling of SHT with waste (due to density transmitter fails or indicates improper density indicating incorrect level, etc.)	Overflow vent scrubber. Spill of grout to environment. MAR: 15,000 gal of grout	A	Public: Neg/C	Mixer vent scrubber level indication and alarms	Region C event for radiological and chemical hazards. No control strategy required.
				CW: Neg/C	Mixer vent scrubber high-high alarm initiates system set back	
				FW: Neg/C	Redundant SHT level interlock and alarms	
					Area Radiation Monitor	
	5. Valve to control flow to SHT spray nozzle fails open (normally timed to open every 20 minutes during operations) and overflows SHT	Overflow vent scrubber. Spill of grout to environment. MAR: 15,000 gal of grout	A	Public: Neg/C	Mixer vent scrubber level indication and alarms	Region C event for radiological and chemical hazards. No control strategy required.
				CW: Neg/C	Mixer vent scrubber high-high alarm initiates system set back	
				FW: Neg/C	Area Radiation Monitor	
					Redundant SHT level interlock and alarm	
	6. Overfilling of vent scrubber with water	Spill of contaminated process water to environment. MAR: Contaminated process water	A	Public: Neg/C	Mixer vent scrubber level indication and alarms	Region C event for radiological and chemical hazards. No control strategy required.
				CW: Neg/C	Mixer vent scrubber high-high alarm initiates system set back	
				FW: Neg/C	Area Radiation Monitor	

Unmitigated Hazards Analysis cont'd

Node: 6. Saltstone Hold Tank and Transfer Line to Vaults (cont'd)

Dev	Causes	Results	Unmit Freq	Unmit Consequence/Risk Rank	Controls	Remarks
6.3. High Pressure						
	1. Plugged line due to grout too thick	Transfer line/component leaks. Spill of grout. MAR: 15,000 gal of grout	A	Public: Neg/C	Grout density indication	Region C event for radiological and chemical hazards. No control strategy required.
				CW: Neg/C	Transfer line design	
				FW: Neg/C	SFT provides passive confinement	
					SFT level indication and high level alarm	
					Process Room floor drain to SFT provides passive confinement	
					Control Room visual inspection	
					Area Radiation Monitor	
					High Pressure Flush System	
	2. Transfer line pressure transmitter fails/indicates low	Loss of flow indication-no impact				

Unmitigated Hazards Analysis cont'd

Node: 6. Saltstone Hold Tank and Transfer Line to Vaults (cont'd)

Dev	Causes	Results	Unmit Freq	Unmit Consequence/Risk Rank	Controls	Remarks
6.3. High Pressure (cont'd)						
	3. Air from pig launching system lined up to grout transfer line during operations (4 way valve misaligned)	Loss of production	A	Prod: <6 months/C	Four way valve design Pig launching interlocks	Region C event. No control strategy required.
	4. Transfer pump buffer fluid reservoir over pressurized	Excess water into transfer line. Product quality.	A	Prod: <6 months/C	Reservoir pressure indication	Region C event. No control strategy required.
6.4. Low Pressure						
	1. Transfer line pressure transmitter fails/indicates high	Loss of flow indication-no impact				
	2. Transfer pump buffer fluid reservoir not pressurized or filled (can be due to a leak in reservoir)	Pump seal leakage. Spill of grout. MAR: 15,000 gal of grout	A	Public: Neg/C CW: Neg/C FW: Neg/C	Reservoir pressure indication Reservoir low level alarm SFT provides passive confinement SFT level indication and high level alarm Process Room floor drain to SFT provides passive confinement Control Room visual inspection Area Radiation Monitor	Region C event for radiological and chemical hazards. No control strategy required.

Unmitigated Hazards Analysis cont'd

Node: 6. Saltstone Hold Tank and Transfer Line to Vaults (cont'd)

Dev	Causes	Results	Unmit Freq	Unmit Consequence/Risk Rank	Controls	Remarks
6.5. Low/No Flow						
	1. Transfer line valve fails closed	Transfer line/component leaks. Spill of grout. MAR: 15,000 gal of grout	A	Public: Neg/C	Grout density indication	Region C event for radiological and chemical hazards. No control strategy required.
				CW: Neg/C	Transfer line design	
				FW: Neg/C	SFT provides passive confinement	
					SFT level indication and high level alarm	
					Process Room floor drain to SFT provides passive confinement	
					Control Room visual inspection	
					Area Radiation Monitor	
	2. Operator fails to align correct lines/valves	Transfer line/component leaks Spill of grout. MAR: 15,000 gal of grout	A	Public: Neg/C	Grout density indication	Region C event for radiological and chemical hazards. No control strategy required.
				CW: Neg/C	Transfer line design	
				FW: Neg/C	SFT provides passive confinement	
					SFT level indication and high level alarm	
					Process Room floor drain to SFT provides passive confinement	
					Control Room visual inspection	
					Area Radiation Monitor	
	3. Transfer pump mechanical or electrical failure	Loss of production	A	Prod: <6 months/C	High Pressure Flush System	Region C event for radiological and chemical hazards. No control strategy required.

Unmitigated Hazards Analysis cont'd

Node: 6. Saltstone Hold Tank and Transfer Line to Vaults (cont'd)

Dev	Causes	Results	Unmit Freq	Unmit Consequence/Risk Rank	Controls	Remarks
6.5. Low/No Flow (cont'd)						
	4. Loss of feed from SHT	Equipment damage	A	Damage: <$1M/C	SHT level indication and alarms Saltstone transfer pumps shut down on low level	Region C event for radiological and chemical hazards. No control strategy required.
6.6. Reverse/Misdirected Flow						
	1. Grout sent to wrong cell due to valve misalignment	Loss of production	U	Prod: <6 months/C	Operating Procedures and Training	Operator error failure rate of 1E-5/op. Assume 400 line ups per year. 1E-5/op * 400 op/yr =4E-3/yr Region C event for radiological and chemical hazards. No control strategy required.
6.7. Contamination						
	1. Maintenance activities leave foreign material in line or SHT	Equipment damage. Loss of production	U	Damage: <$1M/C Prod: <6 months/C	Work Control process	Maintenance error estimated at 1E-4/op Assume 1 maintenance activity per month on line (12 per year) 1E-4/op * 12 op/yr = 1.2E-3 Region C event. No control strategy required.
	2. Flush of line not completed on previous batch	Equipment damage.	U	Damage: <$1M/C	DCS automatically launches pig and flushes line in shutdown mode	Operator error failure rate of 1E-5/op. Assume 400 cleanouts per year. 1E-5/op * 400 op/yr = 4E-3/yr Region C event. No control strategy required.
	3. Grout solidifies in the SHT due to poor flushes, extended down time, etc.	Equipment damage.	A	Damage: <$1M/C	SHT design with cone insert	Region C event. No control strategy required.

Unmitigated Hazards Analysis cont'd

Node: 6. Saltstone Hold Tank and Transfer Line to Vaults (cont'd)

Dev	Causes	Results	Unmit Freq	Unmit Consequence/Risk Rank	Controls	Remarks
6.8. Leak						
	1. Corrosion, cracking, overstress, erosion of line.	Spill of grout. MAR: 15,000 gal of grout	U	Public: Neg/C	CCTV monitored at vault	Failure rate of pipes (< 3") 1E-7/hr. Assume 2500 hr/yr. 1E-7 * 2500 hr/yr = 2.5E-4/yr
				CW: Neg/C	SFT provides passive confinement	Region C event for radiological and chemical hazards. No control strategy required.
				FW: Neg/C	SFT level indication and high level alarm	
					Process Room floor drain to SFT provides passive confinement	
					Control Room visual inspection	
					Area Radiation Monitor	
	2. Drain or vent or sample valve leakage	Spill of grout. MAR: 15,000 gal of grout	A	Public: Neg/C	SFT provides passive confinement	Region C event for radiological and chemical hazards. No control strategy required.
				CW: Neg/C	SFT level indication and high level alarm	
				FW: Neg/C	Process Room floor drain to SFT provides passive confinement	
					Control Room visual inspection	
					Area Radiation Monitor	
	3. Gasket or packing or valve seal failure	Spill of grout. MAR: 15,000 gal of grout	A	Public: Neg/C	SFT provides passive confinement	Region C event for radiological and chemical hazards. No control strategy required.
				CW: Neg/C	SFT level indication and high level alarm	
				FW: Neg/C	Process Room floor drain to SFT provides passive confinement	
					Control Room visual inspection	
					Area Radiation Monitor	

Unmitigated Hazards Analysis cont'd

Node: 6. Saltstone Hold Tank and Transfer Line to Vaults (cont'd)

Dev	Causes	Results	Unmit Freq	Unmit Consequence/Risk Rank	Controls	Remarks
6.8. Leak (cont'd)						
	4. Inadequate torquing of bolts	Spill of grout. MAR: 15,000 gal of grout	U	Public: Neg/C	Post maintenance inspection & testing procedures	Maintenance error estimated at 1E-4/. Assume 1 maintenance activity per month on line (12 per year) 1E-4/op * 12 op/yr = 1.2E-3/yr
				CW: Neg/C	SFT provides passive confinement	Region C event for radiological and chemical hazards. No control strategy required.
				FW: Neg/C	SFT level indication and high level alarm	
					Process Room floor drain to SFT provides passive confinement	
					Control Room visual inspection	
					Area Radiation Monitor	
	5. Freezing of grout in line	Equipment damage. Spill of grout. MAR: 15,000 gal of grout	U	Public: Neg/C	Properties of grout prevent freezing	Frequency based on facility operating experience, properties of grout, and engineering judgement.
				CW: Neg/C	SFT provides passive confinement	
				FW: Neg/C	SFT level indication and high level alarm	Region C event for radiological and chemical hazards. No control strategy required.
					Process Room floor drain to SFT provides passive confinement	
					Control Room visual inspection	
					Area Radiation Monitor	
6.9. Radiation						
	1. Facility worker remains near transfer line (can be exposed) during operations (assume 8 hours)	Direct radiation to facility worker	A	Public: Neg/C	Radiation Protection Program (access control)	Region C event for radiological and chemical hazards. No control strategy required.
				CW: Neg/C	Shielding	
				FW: Neg/C	Area Radiation Monitor	
	2. Exposure during maintenance activities on exposed transfer line	Direct radiological exposure and contamination to facility worker	A	Public: Neg/C	Radiation Protection Program (PPE, monitor)	Region C event for radiological and chemical hazards. No control strategy required.
				CW: Neg/C	Shielding (jersey barriers)	
				FW: Neg/C	Area Radiation Monitor	

Unmitigated Hazards Analysis cont'd

Node: 7. Saltstone Vault

Dev	Causes	Results	Unmit Freq	Unmit Consequence/Risk Rank	Controls	Remarks
7.1. High Temperature						
	1. High grout temperature	Product quality	A	Prod: <6 months/C	Temperature indication	Region C event for radiological and chemical hazards. No control strategy required.
	2. Fire in vicinity of vault. Ignition of combustible material from spark/heat from electrical equipment, vehicles, lightning, or maintenance.	Equipment damage. Loss of production. Personal injury (fire related).	U	Public: Neg/C	Fire extinguishers located and maintained per NFPA standards	External fire frequency that places a particular area at risk 2E-3 fires/yr. Probability of vault damage due to fire assumed to be 1.0.
				CW: Neg/C	Fire hydrants located and maintained per NFPA standards	
				FW: High/A High fire related injuries (serious injury) considered possible. Radiological and chemical hazards for Facility Worker estimated as Negligible.	Operator training on fire extinguisher use and fighting incipient fires	Region C event for radiological and chemical hazards. No control strategy required. Region A event for fire related injuries. Compliance with OSHA and NFPA life safety and fire protection codes and standards adequately protect facility worker from fire related injuries (considered standard industrial hazard).
					Site Fire Department notification and response	
					Vault material of construction	
					CCTV allows personnel to monitor condition of vaults	
	3. Vault temperature Indicator fails/indicates incorrectly	Product quality	A	Prod: <6 months/C	Visual level indication prevents overfilling.	Region C event for radiological and chemical hazards. No control strategy required.
7.2. High Level						
	1. Overfilling due to camera failure during pumping	Spill of grout. MAR: 15,000 gal of grout	U	Public: Neg/C	Rate of level increase in cell is slow, which reduces possibility of overfilling	Failure of general instrumentation applied 1E-6/hr. Assume 2500 hr/yr. 1E-6/hr * 2500 hr/yr = 2.5E-3/yr
				CW: Neg/C		
				FW: Neg/C		Region C event for radiological and chemical hazards. No control strategy required.

Unmitigated Hazards Analysis cont'd

Node: 7. Saltstone Vault (cont'd)

Dev	Causes	Results	Unmit Freq	Unmit Consequence/Risk Rank	Controls	Remarks
7.2. High Level (cont'd)						
	2. Overfilling due to operator error	Spill of grout. MAR: 15,000 gal of grout	A	Public: Neg/C CW: Neg/C FW: Neg/C	CCTV monitored at vault Rate of level increase in cell is slow, which reduces possibility of overfilling	Region C event for radiological and chemical hazards. No control strategy required.
7.3. High Contaminants						
	1. Maintenance activities leave foreign material or chemical residues in vault	Product quality	U	Prod: <6 months/C	Work control process	Maintenance error estimated at 1E-4/op. Assume 1 maintenance activity per month on vaults (12 per year) 1E-4/op * 12 op/yr = 1.2E-3/yr Region C event for radiological and chemical hazards. No control strategy required.
	2. Rain enters vault due to roof leakage	Equipment damage	A	Damage: <$1M/B	Periodic roof/vault inspection and drain wall void spaces of accumulated water. Vault Drainage System	Region C event for equipment damage. No control strategy required.
	3. Grout dust, high in alpha activity, exits cell vent in Vault 4	High airborne activity by vaults	A	Public: Neg/C CW: Neg/C FW: Neg/C	None required	Region C event for radiological and chemical hazards. No control strategy required.

Unmitigated Hazards Analysis cont'd

Node: 7. Saltstone Vault (cont'd)

Dev	Causes	Results	Unmit Freq	Unmit Consequence/Risk Rank	Controls	Remarks
7.4. Leak						
	1. Cracks in vault walls due to hydrostatic pressure from rainwater in-leakage	Spill of grout. MAR: 15,000 gal of grout	A	Public: Neg/C CW: Neg/C FW: Neg/C	Roof over vaults Vault Drainage System	Region C event for radiological and chemical hazards. No control strategy required.
	2. Vault air space sampling valve open	Spill of grout. MAR: 15,000 gal of grout	A	Public: Neg/C CW: Neg/C FW: Neg/C	Sampling connection capped and not normally used	Region C event for radiological and chemical hazards. No control strategy required.
7.5. Radiation						
	1. Facility worker remains near vault (assume 8 hours)	Direct radiation to facility worker	A	Public: Neg/C CW: Neg/C FW: Low/B	Radiological Protection Program (access control)	Region B event for radiological and chemical hazards. Control strategy required. Event carried forward to mitigated hazard analysis.
	2. Exposure during maintenance activities near the vault	Direct radiological exposure and contamination to facility worker	A	Public: Neg/C CW: Neg/C FW: Neg/C	Radiation Protection Program (PPE, monitor)	Region C event for radiological and chemical hazards. No control strategy required.

Unmitigated Hazards Analysis cont'd

Node: 8. Pig Launcher

Dev	Causes	Results	Unmit Freq	Unmit Consequence/Risk Rank	Controls	Remarks
8.1. High Pressure						
	1. Air compressor or back-up air bottle regulator fails high causes high discharge pressure	Equipment damage	A	Damage: <$1M/C	Relief valve on discharge of compressor Relief valve on pig air accumulators Pressure indication and alarms Relief valve on back-up air manifold	Region C event. No control strategy required.
	2. Accumulator relief valve fails shut	Equipment damage	A	Damage: <$1M/C	Relief valve on discharge of compressor Pressure indication and alarms Compressor pressure regulator.	Region C event. No control strategy required.
	3. Fire in vicinity of compressors or accumulators causes high pressure. Ignition of combustible material from spark/heat from electrical equipment, vehicles, lightning, or maintenance.	Equipment damage Personal injury (fire related)	A	Public: Neg/C CW: Neg/C FW: High/A High fire related injuries (serious injury) considered possible. Radiological and chemical hazards for Facility Worker estimated as Negligible.	Fire extinguishers located and maintained per NFPA standards Fire hydrants located and maintained per NFPA standards Operator training on fire extinguisher use and fighting incipient fires Site Fire Department notification and response Fire detection and suppression system installed and maintained per NFPA standards Air piping and accumulator design and materials of construction Accumulator and compressor relief valves.	Region C event for radiological and chemical hazards. No control strategy required. Region A event for fire related injuries. Compliance with OSHA and NFPA life safety and fire protection codes and standards adequately protect facility worker from fire related injuries (considered standard industrial hazard).
	4. Cross connect between instrument air and pig accumulator left open	Equipment damage	A	Damage: <$1M/C	Air regulator on instrument air system Relief valve on instrument air system	Region C event. No control strategy required.
	5. High grout pressure in transfer line when pig launched	Equipment damage	A	Damage: <$1M/C	Piping design and materials of construction	Region C event. No control strategy required.

Unmitigated Hazards Analysis cont'd

Node: 8. Pig Launcher (cont'd)

Dev	Causes	Results	Unmit Freq	Unmit Consequence/Risk Rank	Controls	Remarks
8.1. High Pressure (cont'd)						
	6. Pig caught in pig launcher ball valve causing high pressure in launcher	Personal injury (when opening launcher)	A	FW: Low/B	Pressure gage on launcher Procedure to open launcher vent valve and bleed pressure off prior to opening cap Pig launcher pig isolation valve failure alarm Launcher cap secured to stanchion to prevent cap from becoming missile hazard	Region B event for Facility Worker injury (non-rad). Compliance with OSHA and concensus standards adequately protect facility worker from injuries (considered standard industrial hazard).
	7. Pig launcher pressure indicator fails low	Personal injury (when opening launcher)	A	FW: Low/B	Procedure to open launcher vent valve and bleed pressure off prior to opening cap Launcher cap secured to stanchion to prevent cap from becoming missile hazard	Region B event for Facility Worker injury (non-rad). Compliance with OSHA and concensus standards adequately protect facility worker from injuries (considered standard industrial hazard).
8.2. High Temperature						
	1. Loss of cooling water to air compressor after cooler and/or compressor	Equipment damage	A	Damage: <$1M/C	Compressor high temperature alarms Pig launcher air high temperature indication and alarm	Region C event. No control strategy required.

Unmitigated Hazards Analysis cont'd

Node: 8. Pig Launcher (cont'd)

Dev	Causes	Results	Unmit Freq	Unmit Consequence/Risk Rank	Controls	Remarks
8.3. High Flow						
	1. See 8.1, High Pressure					
8.4. Low Pressure						
	1. Air compressor failure causes low pressure in pig launching system	No flush of transfer line. Equipment damage.	A	Damage: <$1M/C	Two pig air accumulators (one is backup)	Region C event. No control strategy required.
					Accumulators charged prior to start-up	Region C event. No control strategy required.
					Backup pig air system	
	2. Accumulator relief valve fails open	No flush of transfer line. Equipment damage.	U	Damage: <$1M/C	Two pig air accumulators (one is backup)	Relief valve leakage 2E-6/hr. 2500 hrs/year. 2E-6/hr * 2500 hr/yr = 5E-3/yr
					Backup pig air system	Region C event. No control strategy required.

Unmitigated Hazards Analysis cont'd

Node: 8. Pig Launcher (cont'd)

Dev	Causes	Results	Unmit Freq	Unmit Consequence/Risk Rank	Controls	Remarks
8.5. Low/No Flow						
	1. Timer for primary pig launcher times out too early	Incomplete/no flush of transfer line. Equipment damage.	A	Damage: <$1M/C	Back-up air accumulator and pig launching system Backup pig air system	Region C event. No control strategy required.
	2. Transfer line plugged due to grout setting up – too long between transfer and flush	Incomplete/no flush of transfer line. Equipment damage.	A	Damage: <$1M/C	Pig launched by DCS during shut down.	Region C event. No control strategy required.
	3. Pig launcher 4- way valve in wrong position	Incomplete/no flush of transfer line. Equipment damage.	A	Damage: <$1M/C	Logic checks to make sure valve in correct position prior to launch	Region C event. No control strategy required.
8.6. Reverse/Misdirected Flow						
	1. Pig launched to SFT	Incomplete/no flush of transfer line. Equipment damage.	A	Damage: <$1M/C	Logic checks to make sure valve in correct position prior to launch	Region C event. No control strategy required.
	2. Operator fails to align lines/valves. Grout pumped to pig launching system	Loss of Production	A	Prod: <6 months/C	Four way valve design Four way valve position indication	Region C event. No control strategy required.
8.7. Contamination						
	1. Wrong sized or wrong material pig placed in pig launcher	Incomplete/no flush of transfer line. Equipment damage.	A	Damage: <$1M/C	Operator training Purchasing QA controls	Region C event. No control strategy required.

Unmitigated Hazards Analysis cont'd

Node: 8. Pig Launcher (cont'd)

Dev	Causes	Results	Unmit Freq	Unmit Consequence/Risk Rank	Controls	Remarks
8.8. Leak						
	1. Drain or vent valve leakage	Incomplete/no flush of transfer line. Equipment damage.	A	Damage: <$1M/C	Back-up air accumulator and pig launching system Backup pig air system	Region C event. No control strategy required.
	2. Gasket or packing or valve seal failure	Incomplete/no flush of transfer line. Equipment damage.	A	Damage: <$1M/C	Back-up air accumulator and pig launching system Backup pig air system	Region C event. No control strategy required.
	3. Air line failure or leak	Incomplete/no flush of transfer line. Equipment damage.	A	Damage: <$1M/C	Back-up air accumulator and pig launching system Backup pig air system	Region C event. No control strategy required.

Unmitigated Hazards Analysis cont'd

Node: 9. PVV System

Dev	Causes	Results	Unmit Freq	Unmit Consequence/Risk Rank	Controls	Remarks
9.1. High Pressure						
	1. Mist eliminator clogged or failure of DP gage	Low vent flow	U	Damage: <$1M/C	Flush of mist eliminator conducted	Frequency of filter leakage/blockage 1E-6/hr. Assume 8760 hr/yr. 1E-6/hr * 8760 hr/yr = 8.8E-3/yr
					PVV system air flow indication and low flow alarm	Region C event. No control strategy required.
	2. HEPA filter clogged or failure of DP gage	Low vent flow Rupture HEPA filter Release of particulates to environment	U	Public: Neg/C	Back-up HEPA filter	Failure frequency of HEPA 1E-2/yr.
				CW: Neg/C	PVV system air flow indication and low flow alarm	Region C event. No control strategy required
				FW: Neg/C		
9.2. High Temperature						
	1. PVV system heater controller fails	Equipment damage. Release of particulates to environment. MAR: 1 HEPA filter	A	Public: Neg/C	HEPA filter DP indication and high DP alarm	Region C event for radiological and chemical hazards. No control strategy required.
				CW: Neg/C	PVV system air temperature indication	
				FW: Neg/C		
				Damage: <$1M/C		
	2. Fire in vicinity of HEPAs causes HEPAs to ignite. Ignition of combustible material from spark/heat from electrical equipment, vehicles, lightning, or maintenance.	Equipment damage Release of particulates to environment MAR: 1 HEPA filter	A	Public: Neg/C	Fire extinguishers located and maintained per NFPA standards	Region C event for radiological and chemical hazards. No control strategy required. Region B event for fire related injuries. Compliance with OSHA and NFPA life safety and fire protection codes and standards adequately protect facility worker from fire related injuries (considered standard industrial hazard).
				CW: Neg/C	Fire hydrants located and maintained per NFPA standards	
				FW: Mod/B Moderate fire related injuries (serious injury) considered possible. Radiological and chemical hazards for Facility Worker estimated as Negligible.	Operator training on fire extinguisher use and fighting incipient fires	
					Site Fire Department notification and response	
					PVV system air temperature indication	

Unmitigated Hazards Analysis cont'd

Node: 9. PVV System (cont'd)

Dev	Causes	Results	Unmit Freq	Unmit Consequence/Risk Rank	Controls	Remarks
9.2 High Temperature (cont'd)						
	3. Blower discharge damper closed. Blowers dead headed.	No ventilation Equipment damage	A	Damage: <$1M/C	PVV system air flow indication and low flow alarm	Operator error failure rate of 1E-4/op. Assume 400 line-ups per year. 1E-4/op * 400 op/yr =4E-2/yr
					Stand-by PVV system blower energized on low flow condition	Region C event. No control strategy required.
9.3. Low Temperature						
	1. PVV system heater controller fails	Moisture in air flow Damage/degradation of HEPA filters Release of particulates to environment. MAR: 1 HEPA filter	A	Public: Neg/C CW: Neg/C FW: Neg/C	PVV system air temperature indication	Heater controller failure rate assumed to be similar to electrical relay failure rate 2E-6/hr. 8760 hr/yr. 2E-6/hr * 8760 hr/yr = 1.7E-2/yr Region C event for radiological and chemical hazards. No control strategy required.
	2. Process water line to mist eliminator frozen due to low temperatures	No back-flushing of mist eliminator. Low vent flow	A	Damage: <$1M/C	Insulated/heat traced process water line	Frequency based on facility operating experience and engineering judgement. Region C event. No control strategy required.
9.4. High Contaminants						
	1. High organic content in SFT	Organic emissions to environment Air permit violation	U	Public: Neg/C CW: Neg/C FW: Neg/C	Saltstone Waste Acceptance Criteria Program ensuring the composition of waste streams received into the facility is within analyzed limits.	Operator error failure rate of 1E-5/op. Assume 400 transfers from H-Area to Z-Area. 1E-5/op * 400 op/yr =4E-3/yr Region C event. No control strategy required.

Unmitigated Hazards Analysis cont'd

Node: 9. PVV System (cont'd)

Dev	Causes	Results	Unmit Freq	Unmit Consequence/Risk Rank	Controls	Remarks
9.4. High Contaminants (cont'd)						
	2. High rad content in SFT	Radiological emissions to environment Air permit violation See Event 3.7.1				
	3. High radionuclide concentrations on HEPA filters due to personnel failing to change out filters as required	Personal injury (direct radiological exposure)	U	Public: Neg/C	Radiation Protection Program	Operator error failure rate of 1E-4/op. Assume weekly rad surveys of HEPA filters (52 op/yr). 1E-4/op * 52 op/yr = 5.2E-3/yr
				CW: Neg/C	HEPA d/p reading and PVV system monitoring	
				FW: Low/B		Region B event for FW. Control strategy required. Event carried forward to mitigated hazard analysis.
	4. Flammable vapor builds up in the ventilation system (from failure of exhaust fan, low point, etc.)	Explosion. Equipment damage. Release of HEPA filter content to environment. MAR: 1HEPA filter	U	Public: Neg/C	Saltstone Waste Acceptance Criteria Program ensuring the composition of waste streams received into the facility is within analyzed limits.	Frequency based on facility operating experience and engineering judgement.
				CW: Neg/C	Design of ventilation system (prevents benzene accumulation)	Region C event for radiological and chemical hazards. No control strategy required.
				FW: Neg/C		
9.5. Leak						
	1. Corrosion	Release of particulates to environment. MAR: 1 HEPA filter	A	Public: Neg/C	Radiation Protection Program	Region C event for radiological and chemical hazards. No control strategy required.
				CW: Neg/C		
				FW: Neg/C		
	2. Drain or vent valve leakage	Release of particulates to environment. MAR: 1 HEPA filter	A	Public: Neg/C	Radiation Protection Program	Region C event for radiological and chemical hazards. No control strategy required.
				CW: Neg/C		
				FW: Neg/C		
	3. Gasket or valve failure	Release of particulates to environment. MAR: 1 HEPA filter	A	Public: Neg/C	Radiation Protection Program	Region C event for radiological and chemical hazards. No control strategy required.
				CW: Neg/C		
				FW: Neg/C		

Unmitigated Hazards Analysis cont'd

Node: 10. High Pressure Flush Tank						
Dev	Causes	Results	Unmit Freq	Unmit Consequence/Risk Rank	Controls	Remarks
10.1. Contaminants						
	1. Incorrect or incompatible material pumped into tank (i.e., sump, process drains)	Loss of production. Personal injury (direct radiological or chemical exposure)	A	Public: Neg/C	Tank design and materials of construction	Region C event for radiological and chemical hazards. No control strategy required.
				CW: Neg/C	3-way valve prevents waste transfer into HPFT	
				FW: Neg/C	Radiation Protection Program (monitor)	
				Prod: <6 months/C	HPFT pressure higher than process	

Unmitigated Hazards Analysis cont'd

Node: 11. External and NPH Events						
Dev	Causes	Results	Unmit Freq	Unmit Consequence/Risk Rank	Controls	Remarks
11.1. External Events						
	1. Full facility fire. Ignition of combustible material from spark/heat from electrical equipment, vehicles, lightning, or maintenance. Fire in administration building spreads to rest of facility.	Fire assumed to involve entire facility inventory. Equipment damage. Spill of dry material to environment. Spill of grout/salt solution. Personal injury fire related MAR: 7000 gal of salt solution (full facility inventory)	BEU	Public: Neg/C	Fire extinguishers located and maintained per NFPA standards	Fire in administration building is expected to only affect the process room (284 gal holdup) which is covered in Event 4.1.2. SFT is located in 12" reinforced concrete walls extending 8' above grade. Tank liquid would not be in the line of sight of facility fires. Therefore, this event is BEU.
				CW: Neg/C	Fire hydrants located and maintained per NFPA standards	
				FW: High/A High fire related injuries (serious injury) considered possible. Radiological and chemical hazards for Facility Worker estimated as Low.	Operator training on fire extinguisher use and fighting incipient fires	
					Site Fire Department notification and response	Region C event for radiological and chemical hazards. No control strategy is required. Region A event for fire related injuries. Compliance with OSHA and NFPA life safety and fire protection codes and standards adequately protect facility worker from fire related injuries (considered standard industrial hazard).
					Administration building fire walls installed and maintained per NFPA standards	
					Fire separation distances between administration building and process areas per NFPA standards	
					Administration building fire detection and suppression systems installed and maintained per NFPA standards	

Unmitigated Hazards Analysis cont'd

Node: 11. External and NPH Events (cont'd)						
Dev	Causes	Results	Unmit Freq	Unmit Consequence/Risk Rank	Controls	Remarks
11.1. External Events (cont'd)						
	2. External brush/grass fire occurs and spreads to process areas	Spill of dry material to environment. Spill of grout/salt solution. Personal injury MAR: 284 gal of salt solution in process room External fire would affect process room. SFT in 12" reinforced concrete walls extending 8' above grade. Tank liquid would not be in the line of sight of fire.	U	Public: Neg/C	Fire extinguishers located and maintained per NFPA standards	External fire frequency that places a particular area at risk 2E-3 fires/yr (Ref. 58)
				Public: Neg/C	Fire hydrants located and maintained per NFPA standards	MAR based on: a) Salt solution - 35 feet of 3 inch pipe - +10% = 14 gal b) Mixer - 30 gal Saltstone grout - SHT - 180 gal Pumps- 20 gal Pipe - 55 feet of 4" pipe +10% = 40 gal Total = 284 gal holdup in Process Room
				FW: High/A High fire related injuries (serious injury) considered possible. Radiological and chemical hazards for Facility Worker estimated as Negligible.	Site Fire Department notification and response	
					Fire buffer maintained between brush/grass area and process areas (i.e., grass cut, asphalt/concrete surrounds Saltstone process areas)	
					Concrete vaults	Region C event for radiological and chemical hazards. No control strategy is required. Region A event for fire related injuries. Compliance with OSHA and NFPA life safety and fire protection codes and standards adequately protect facility worker from fire related injuries (considered standard industrial hazard). From the Saltstone Fire Hazard Analysis (Ref.51), a wildland fire is not a significant threat to Saltstone structures

Unmitigated Hazards Analysis cont'd

Node: 11. External and NPH Events (cont'd)						
Dev	Causes	Results	Unmit Freq	Unmit Consequence/Risk Rank	Controls	Remarks
11.1. External Events(cont'd)						
	3. Transportation collision or vehicle impact into facility or transfer lines. May result in fire.	Spill of dry material to environment. Spill of grout/salt solution. Personal injury MAR: 6504 gal of salt solution (Worst case assumes resulting fire boils 6504 gal in the SFT) Worst case impact assumes vehicle hits dike around SFT.	A	Public: Neg/C	Vehicle access to roads near process areas is limited	Region C event for radiological and chemical hazards. No control strategy is required. Region A event for transportation related injuries. Compliance with OSHA and site transportation safety codes and standards adequately protect facility worker from transportation related injuries (considered standard industrial hazard).
				CW: Neg/C	1 foot thick concrete dike wall	
				FW: High/A High transportation related injuries (serious injury) considered possible. Radiological and chemical hazards for Facility Worker estimated as Negligible.	Posts installed to prevent vehicles from impacting process equipment	
					Low combustible loading in dike	
					Posted speed limit.	
	4. Aircraft/helicopter crash into facility with resulting fire	Spill of dry material to environment. Spill of grout/salt solution. Personal injury MAR: 7500 gal of salt solution (full facility inventory)	BEU	Public: Neg/C	Fire extinguishers located and maintained per NFPA standards	Frequency of aircraft/helicopter crash into facility size of process and administration buildings is 3.4E-7/yr (crash frequency of 3.8E-11 and facility footprint of 9000 square feet-Ref. 60))
				CW: Neg/C	Fire hydrants located and maintained per NFPA standards	Region C event for radiological and chemical hazards. Region A event for fire related injuries. Compliance with OSHA and NFPA life safety and fire protection codes and standards adequately protect facility worker from fire related injuries (considered standard industrial hazard).
				FW: High/A High fire related injuries (serious injury) considered possible. Radiological and chemical hazards for Facility Worker estimated as Low.	Operator training on fire extinguisher use and fighting incipient fires	
					Site Fire Department notification and response	

Unmitigated Hazards Analysis cont'd

Node: 11. External and NPH Events (cont'd)						
Dev	Causes	Results	Unmit Freq	Unmit Consequence/Risk Rank	Controls	Remarks
11.2. NPH Events						
	1. Tornado/high winds causes facility damage. Could initiate facility fire.	Spill of dry material to environment. Spill of grout/salt solution. Personal injury MAR: 15,000 gal of salt solution Worst case assumes winds cause spills and fire from SFT.	A	Public: Neg/C	Fire extinguishers located and maintained per NFPA standards	Assume PC-1 wind frequency. Frequency of PC-1 high winds 2E-2/yr (Ref. 61)
				CW: Neg/C	Fire hydrants located and maintained per NFPA standards	
				FW: High/A High fire and wind related injuries (serious injury) considered possible. Radiological and chemical hazards for Facility Worker estimated as Negligible.	Operator training on fire extinguisher use and fighting incipient fires Site Fire Department notification and response	Region C event for radiological and chemical hazards. No control strategy required. Region A event for fire and wind related injuries. Compliance with OSHA and NFPA life safety and fire protection codes and standards adequately protect facility worker (considered standard industrial hazard).
	2. Lightning strikes facility and causes fire	Lightning is regarded as an initiator for individual fire events.	A	FW: High/A Lightning strike could cause serious injury or fatality (e.g., shock)		Region A event for lightning related injuries. Compliance with OSHA and NFPA life safety and fire protection codes and standards adequately protect facility worker (considered standard industrial hazard).
	3. Lightning	Damage to DCS (electrical, mechanical). Loss of production. Loss of facility monitoring. Loss of PVV system. Equipment damage.	A	Public: Neg/C	Redundant processors.	No control strategy required.
				CW: Neg/C		
				FW: Neg/C		
				Prod: <6 months/C		

Unmitigated Hazards Analysis cont'd

Node: 11. External and NPH Events (cont'd)						
Dev	Causes	Results	Unmit Freq	Unmit Consequence/Risk Rank	Controls	Remarks
11.2. NPH Events(cont'd)						
	4. Flooding of Z-Area causes release of material due to equipment being washed away	Spill of dry material to environment Spill of grout/salt solution. Personal injury MAR: 15,000 gal of salt solution Worst case event assumes flooding breaches SFT.	BEU	Public: Neg/C CW: Neg/C FW: Neg/C	None required	Frequency based on engineering judgement. Region C event for radiological and chemical hazards. No control strategy required.
	5. Snow/rain onto facility causes collapse of structures	Spill of dry material to environment. Spill of grout/salt solution. Personal injury MAR: 15,000 gal of salt solution Worst case impact assumes snow causes breach of SFT.	BEU	Public: Neg/C CW: Neg/C FW: Neg/C	None required	Frequency based on engineering judgement. Region C event for radiological and chemical hazards. No control strategy required.
	6. Seismic event occurs causing facility damage and resulting fire	Spill of dry material to environment. Spill of grout/salt solution. Personal injury MAR: 15,000 gal of salt solution (full facility inventory) Worst case event assumes earthquake causes release from entire facility and resulting fire.	U	Public: Neg/C CW: Neg/C FW: High/A High fire and earthquake related injuries (serious injury) considered possible. Radiological and chemical hazards for Facility Worker estimated as Negligible.	Fire extinguishers located and maintained per NFPA standards Fire hydrants located and maintained per NFPA standards Operator training on fire extinguisher use and fighting incipient fires Site Fire Department notification and response	Assume PC-1 seismic event Frequency of PC-1 seismic event 2E-3/yr 15,000 gal is maximum missing waste assumed in CST seismic event Combustible loading in SFT dike sufficient to boil only 15 gal. Process building contains 284 gal. Region C event for radiological and chemical hazards. No control strategy is required. Region A event for fire and earthquake related injuries. Compliance with OSHA and FPA life safety and fire protection codes and standards adequately protect facility worker from injuries (considered standard industrial hazard).

APPENDIX C

MITIGATED HAZARD ANALYSIS TABLES

Appendix C - Mitigated Hazards Analysis

Event No.	Causes	Results	Unmit Freq	Unmit Cons	Risk Rank	Principal Controls	Mit Freq	Mit Consequences	Mit Risk Rank	Remarks
1.5.1	Dust collector plant air regulator valve fails causes high air flow into silo	Equipment damage to silo. Spill of dry material to environment. MAR: Fly ash, slag, concrete	A	Equipment damage may exceed $1M	Damage: B	Silo conservation vents. Vents sized and maintained per Site Pressure Protection Program Truck unloading line provides alternate silo vent path. Unloading line valve removed per DCF.	EU	Equipment damage may exceed $1M	Damage: C	Event defined as silo failure (equipment damage) resulting from air regulator failing. • Frequency of regulator failing (F) = 4.8E-1/yr (from unmitigated analysis) • Probability of failure of conservation vent (engineered control) is estimated at 1E-4 (Pec) • Probability of failure of leaving the truck unloading valve open (administrative control) is estimated at 1E-1 (Pac) Frequency of mitigated event (silo damage) = Fdam Fdam = F * Pec * Pac Fmit = 4.8E-1/yr * 1E-4 * 1E-1 = 4.8E-6/yr

Mitigated Hazards Analysis cont'd

Event No.	Causes	Results	Unmit Freq	Unmit Cons	Risk Rank	Principal Controls	Mit Freq	Mit Consequences	Mit Risk Rank	Remarks
1.5.2	Plugged vent in dust collectors cause high pressure in silo	Equipment damage to silo. Spill of dry material to environment MAR: Fly ash, slag, concrete	A	Equipment damage may exceed $1M	Damage: B	Truck unloading line provides alternate silo vent path. Unloading line valve removed per DCF. Periodic backflow pulsations of silo dust collectors.	U	Equipment damage may exceed $1M	Damage: C	Event defined as silo failure (equipment damage) resulting from plugged vent and dust collectors. • Frequency of vent being plugged (F) = 2E-1/yr (from unmitigated analysis) • Probability of failure of leaving the truck unloading valve open (administrative control) is estimated at 1E-1 (Pac) • Probability of failure of backflow pulsations (active engineered control) to keep dust collector from being clogged is estimated at 1E-2 (Pec) Frequency of mitigated event (silo damage) = Fdam Fdam = F * Pac * Pec Fmit = 2E-1/yr * 1E-1 * 1E-2 = 2E-4/yr

Mitigated Hazards Analysis cont'd

Event No.	Causes	Results	Unmit Freq	Unmit Cons	Risk Rank	Principal Controls	Mit Freq	Mit Consequences	Mit Risk Rank	Remarks
1.5.3	Air regulator for blend tank fails open causing high pressure in silo	*Equipment* damage to silo. Spill of dry material to environment MAR: Fly ash, slag, concrete	A	*Equipment* damage may exceed $1M	Damage: B	Silo conservation vents. Vents sized and maintained per Site Pressure Protection Program Truck unloading line provides *alternate silo vent* path. Unloading line valve removed per DCF.	EU	Equipment damage may exceed $1M	Damage: C	Event defined as silo failure (equipment damage) resulting from air regulator failing. • Frequency of regulator failing (F) = 1.4E-1/yr (from unmitigated analysis) • Probability of failure of conservation vent (engineered control) is estimated at 1E-4 (Pec) • Probability of failure of leaving the truck unloading valve open (administrative control) is estimated at 1E-1 (Pac) Frequency of mitigated event (silo damage) = Fdam Fdam = F * Pec * Pac Fmit = 1.4E-1/yr * 1E-4 * 1E-1 = 1.4E-6/yr

Mitigated Hazards Analysis cont'd

Event No.	Causes	Results	Unmit Freq	Unmit Cons	Risk Rank	Principal Controls	Mit Freq	Mit Consequences	Mit Risk Rank	Remarks
1.6.1	No vent of silo while blower running causes vacuum in silo	Equipment damage. Spill of dry material to environment. MAR: Fly ash, slag, concrete	A	Equipment damage may exceed $1M	Damage: B	Truck unloading line provides alternate silo vent path. Unloading line valve removed per DCF. Blower capacity and silo construction	U	Equipment damage may exceed $1M	Damage: C	Event defined as silo failure (equipment damage) resulting from plugged vent. • Frequency of vent being plugged (F) = 2E-1/yr (from unmitigated analysis) • Probability of failure of leaving the truck unloading valve open (administrative control) is estimated at 1E-1 (Pac) Frequency of mitigated event (silo damage) = Fdam Fdam = F * Pac Fmit = 2E-1/yr * 1E-1 = 2E-2/yr Through an operating control, the frequency of the event is reduced, though still remains an Anticipated event. The CHAP team considers the event less than unlikely when the capacity of the blower and construction of the silos are considered. Based on engineering judgement the mitigated frequency was determined to be unlikely .

Mitigated Hazards Analysis cont'd

Event No.	Causes	Results	Unmit Freq	Unmit Cons	Risk Rank	Principal Controls	Mit Freq	Mit Consequences	Mit Risk Rank	Remarks
2.3.1	Facility worker remains near transfer line during operations (assume 8 hours)	Direct radiation to facility worker	A	Public: Neg CW: Neg FW: Low	Public: C CW: C FW: B	Radiation Protection Program (access control) WAC	EU	Public: Neg CW: Neg FW: Low	Public: C CW: C FW: C	Unmitigated analysis assumed the worker remains in the SSHT dike for an 8 hour shift. The nature of the process does not require personnel to remain in the area of the SSHT and transfer line. With the Radiological Protection Program (postings, training), the frequency of this event is qualitatively considered EU. Based on this program, the event is considered adequately controlled.
2.3.2	Exposure during maintenance activities in the SSHT dike	Direct radiological exposure and contamination to facility worker	A	Public: Neg CW: Neg FW: Low	Public: C CW: C FW: B	Radiation Protection Program (PPE, monitor)	EU	Public: Neg CW: Neg FW: Low	Public: C CW: C FW: C	The nature of the process does not require frequent maintenance activities in the area of the SSHT or transfer line. With the Radiological Protection Program (PPE, training, monitoring), the frequency of this event is qualitatively considered EU. Based on this program, the event is considered adequately controlled.

Mitigated Hazards Analysis cont'd

Event No.	Causes	Results	Unmit Freq	Unmit Cons	Risk Rank	Principal Controls	Mit Freq	Mit Consequences	Mit Risk Rank	Remarks
3.1.2	Flammable vapor accumulates in tank vapor space. Ignition of the vapors due to lightning, maintenance, faulty electrical equipment (i.e., agitator) results in explosion.	Explosion in SFT. *Personal injury* (explosion related) MAR: 6504 gal of salt solution Note: The SFT volume used in the accident analysis was conservatively assumed to be 7656 gallons which includes the vapor space above the tank overflow.	A	Public: Neg CW: Low FW: High Radiological and chemical hazards for CW initially screened as Low/B; subsequently evaluated to be Neg/C Radiological and chemical hazards for FW initially screened as High/A but subsequently evaluated to be Low/B. Serious injuries are considered possible following an explosion event, however they are considered a standard industrial hazard.	Public: C CW: B FW: A	SFT PVV system maintains sweep on tank Feed and bleed process	BEU	Public: Neg CW: Neg FW: Neg	Public: C CW: C FW: C	Based on the SFT PVV system maintaining a sweep of the tank vapor space, in addition to the feed and bleed process, the frequency of this event is qualitatively considered BEU. Note: The mitigated consequences are based on radiological effects only. The consequences of the explosion are considered standard industrial hazard and not considered beyond this point.