Accession #: D196022540

Document #: SD-WM-SARR-004

Title/Desc:

SAFETY BASIS FOR ACTIVITIES IN SST WITH FLAMMABLE GAS CONCERNS

Pages: 149

COMPLETE

ENGINEERING CHANGE NOTICE

Page 1 of 2

1. ECN 193899

Proj. ECN N/A

2. ECN Category (mark one)	3. Originator's Name, Organization, MSIN, and Telephone No.	3a. USQ Required?	4. Date
Supplemental [] Direct Revision [X] Change ECN [] Temporary [] Standby [] Supersedure [] Cancel/Void []	R. L. Schlosser, SA&NE, A3-37, 376-7725	[] Yes [X] No	2/6/96
	5. Project Title/No./Work Order No. Tank Farms Flammable Gas Safety Issue	6. Bldg./Sys./Fac. No. Tank Farms	7. Approval Designator SQ
	8. Document Numbers Changed by this ECN (includes sheet no. and rev.) WHC-SD-WM-SARR-004, REV. 0	9. Related ECN No(s). N/A	10. Related PO No. N/A

11a. Modification Work	11b. Work Package No.	11c. Modification Work Complete	11d. Restored to Original Condition (Temp. or Standby ECN only)
[] Yes (fill out Blk. 11b) [X] No (NA Blks. 11b, 11c, 11d)	N/A	N/A Cog. Engineer Signature & Date	N/A Cog. Engineer Signature & Date

12. Description of Change

This is full revision to Revision 0 of this report. The purpose of this report is to provide a summary of analyses done to support activities performed for single-shell tanks. These activities are encompassed by the flammable gas Unreviewed Safety Question (USQ). A number of safety analyses were conducted for specific activities at tank 241-SY-101. These same activities have been, or will be, done for the other single-shell tanks covered by the USQ. The basic controls required to perform these activities involve the identification, elimination and/or control of ignition sources and monitoring for flammable gases. Controls are implemented through the Interim Safety Basis (ISB), IOSRs, and OSDs.

Since this report only provides a historical compendium of issues and activities, it is not to be used as a basis to perform USQ screenings and evaluations. Furthermore, these analyses and others in process will be used as the basis for developing the Flammable Gas Topical Report for the ISB Upgrade.

13a. Justification (mark one)

Criteria Change	[X]	Design Improvement	[]	Environmental	[]	Facility Deactivation	[]
As-Found	[]	Facilitate Const	[]	Const. Error/Omission	[]	Design Error/Omission	[]

13b. Justification Details

See Block 12 for discussion.

14. Distribution (include name, MSIN, and no. of copies)

See attached distribution sheet.

RELEASE STAMP

DATE: FEB 05 1996 HANFORD RELEASE ID:

STA: 34

A-7900-013-2 (11/94) GEF095

ENGINEERING CHANGE NOTICE

1. ECN (use no. from pg. 1)
193899

15. Design Verification Required	16. Cost Impact						17. Schedule Impact (days)	
	ENGINEERING			CONSTRUCTION				
[] Yes	Additional	[]	$	Additional	[]	$	Improvement	[]
[X] No	Savings	[]	$	Savings	[]	$	Delay	[]

18. Change Impact Review: Indicate the related documents (other than the engineering documents identified on Side 1) that will be affected by the change described in Block 12. Enter the affected document number in Block 19.

SDD/DD	[]	Seismic/Stress Analysis	[]	Tank Calibration Manual	[]
Functional Design Criteria	[]	Stress/Design Report	[]	Health Physics Procedure	[]
Operating Specification	[]	Interface Control Drawing	[]	Spares Multiple Unit Listing	[]
Criticality Specification	[]	Calibration Procedure	[]	Test Procedures/Specification	[]
Conceptual Design Report	[]	Installation Procedure	[]	Component Index	[]
Equipment Spec.	[]	Maintenance Procedure	[]	ASME Coded Item	[]
Const. Spec.	[]	Engineering Procedure	[]	Human Factor Consideration	[]
Procurement Spec.	[]	Operating Instruction	[]	Computer Software	[]
Vendor Information	[]	Operating Procedure	[]	Electric Circuit Schedule	[]
OM Manual	[]	Operational Safety Requirement	[]	ICRS Procedure	[]
FSAR/SAR	[]	IEFD Drawing	[]	Process Control Manual/Plan	[]
Safety Equipment List	[]	Cell Arrangement Drawing	[]	Process Flow Chart	[]
Radiation Work Permit	[]	Essential Material Specification	[]	Purchase Requisition	[]
Environmental Impact Statement	[]	Fac. Proc. Samp. Schedule	[]	Tickler File	[]
Environmental Report	[]	Inspection Plan	[]		[]
Environmental Permit	[]	Inventory Adjustment Request	[]		[]

19. Other Affected Documents: (NOTE: Documents listed below will not be revised by this ECN.) Signatures below indicate that the signing organization has been notified of other affected documents listed below.

Document Number/Revision	Document Number/Revision	Document Number Revision
N/A		

20. Approvals

Signature	Date	Signature	Date
OPERATIONS AND ENGINEERING		ARCHITECT-ENGINEER	
Cog. Eng. R. L. Schlosser *R L Schlosser*	2/5/96	PE	
Cog. Mgr. E. P. DiVincenzo *(signature)*	2/5/96	QA	
QA J. Weber *Jack Weber*	2/5/96	Safety	
Safety M. N. Islam *(signature)*	2/5/96	Design	
Environ. N/A		Environ.	
Other Safety Basis G. D. Johnson *(signature)*	2-5-96	Other	
Authorization Basis Manager J. J. Klos *(signature)*	2-5-96		
Tank Farm Transition Projects J. E. Truax *(signature) for*	2-5-96		
SEAC J. L. Deichman *RMMorusick for JLD*	2/5/96	DEPARTMENT OF ENERGY	
		Signature or a Control Number that tracks the Approval Signature	
		ADDITIONAL	

15. Design Verification Required	16. Cost Impact		17. Schedule Impact (days)
	ENGINEERING	CONSTRUCTION	
[] Yes	Additional [] $	Additional [] $	Improvement []
[X] No	Savings [] $	Savings [] $	Delay []

18. Change Impact Review: Indicate the related documents (other than the engineering documents identified on Side 1) that will be affected by the change described in Block 12. Enter the affected document number in Block 19.

SDD/DD	[]	Seismic/Stress Analysis	[]	Tank Calibration Manual	[]
Functional Design Criteria	[]	Stress/Design Report	[]	Health Physics Procedure	[]
Operating Specification	[]	Interface Control Drawing	[]	Spares Multiple Unit Listing	[]
Criticality Specification	[]	Calibration Procedure	[]	Test Procedures/Specification	[]
Conceptual Design Report	[]	Installation Procedure	[]	Component Index	[]
Equipment Spec.	[]	Maintenance Procedure	[]	ASME Coded Item	[]
Const. Spec.	[]	Engineering Procedure	[]	Human Factor Consideration	[]
Procurement Spec.	[]	Operating Instruction	[]	Computer Software	[]
Vendor Information	[]	Operating Procedure	[]	Electric Circuit Schedule	[]
OM Manual	[]	Operational Safety Requirement	[]	ICRS Procedure	[]
FSAR/SAR	[]	IEFD Drawing	[]	Process Control Manual/Plan	[]
Safety Equipment List	[]	Cell Arrangement Drawing	[]	Process Flow Chart	[]
Radiation Work Permit	[]	Essential Material Specification	[]	Purchase Requisition	[]
Environmental Impact Statement	[]	Fac. Proc. Samp. Schedule	[]	Tickler File	[]
Environmental Report	[]	Inspection Plan	[]		[]
Environmental Permit	[]	Inventory Adjustment Request	[]		[]

19. Other Affected Documents: (NOTE: Documents listed below will not be revised by this ECN.) Signatures below indicate that the signing organization has been notified of other affected documents listed below.

Document Number/Revision	Document Number/Revision	Document Number Revision
N/A		

20. Approvals

Signature	Date	Signature	Date
OPERATIONS AND ENGINEERING		ARCHITECT-ENGINEER	
Cog. Eng. R. L. Schlosser *R L Schlosser*	2/5/96	PE	
Cog. Mgr. E. P. DiVincenzo *[signature]*	2/5/96	QA	
QA J. Weber *[signature]*	2/5/96	Safety	
Safety M. N. Islam *[signature]*	2/5/96	Design	
Environ. N/A		Environ.	
Other Safety Basis G. D. Johnson *G D Johnson*	2-5-96	Other	
Authorization Basis Manager J. J. Klos			
Tank Farm Transition Projects J. E. Truax			
SEAC J. L. Deichman *RMMoren ch for JLD*	2/5/96	DEPARTMENT OF ENERGY	
		Signature or a Control Number that tracks the Approval Signature	
		ADDITIONAL	

Safety Basis For Activities in Single-Shell Tanks With Flammable Gas Concerns

R. L. Schlosser
Westinghouse Hanford Company, Richland, WA 99352
U.S. Department of Energy Contract DE-AC06-87RL10930

EDT/ECN: 193899 UC: 510
Org Code: 8M100 Charge Code: N2158
B&R Code: EW3120072 Total Pages: 143

Key Words: single-shell tanks, flammable gas, hydrogen, safety basis, tank farms

Abstract: This is full revision to Revision 0 of this report. The purpose of this report is to provide a summary of analyses done to support activities performed for single-shell tanks. These activities are encompassed by the flammable gas Unreviewed Safety Question (USQ). The basic controls required to perform these activities involve the identification, elimination and/or control of ignition sources and monitoring for flammable gases. Controls are implemented through the Interim Safety Basis (ISB), IOSRs, and OSDs.

Since this report only provides a historical compendium of issues and activities, it is **not** to be used as a basis to perform USQ screenings and evaluations. Furthermore, these analyses and others in process will be used as the basis for developing the Flammable Gas Topical Report for the ISB Upgrade.

2/5/96

Release Approval Date

FEB 05 1996
34

Release Stamp

Approved for Public Release

RECORD OF REVISION

(1) Document Number: WHC-SD-WM-SARR-004

Page 1

(2) Title

Safety Basis for Activities in Single-Shell Tanks With Flammable Gas Concerns

CHANGE CONTROL RECORD			
		Authorized for Release	
(3) Revision	(4) Description of Change - Replace, Add, and Delete Pages	(5) Cog. Engr.	(6) Cog. Mgr. Date
RS 1	(7) ECN #193899 Full Revision - Please recycle Revision 0	R. L. Schlosser 2/5/96	E. P. Divicenzo 2/5/96

A-7320-005 (08/91) WEF168

SAFETY BASIS FOR SELECTED ACTIVITIES IN SINGLE-SHELL TANKS WITH FLAMMABLE GAS CONCERNS

WHC-SD-WM-SARR-004

Rev. 1

February 1996

This page intentionally left blank.

CONTENTS

CONTENTS (Continued)

CONTENTS (Continued)

LIST OF FIGURES

LIST OF TABLES

This page intentionally left blank.

SAFETY BASIS FOR SELECTED ACTIVITIES IN SINGLE-SHELL FLAMMABLE GAS TANKS

1.0 INTRODUCTION

1.1 BACKGROUND

Past reactor fuel reprocessing operations conducted at the U.S. Department of Energy's Hanford Site have generated radioactive liquid and solid wastes. The wastes are stored in underground storage tanks that were built in clusters and designated "tank farms." There are 18 tank farms; each farm contains from 2 to 18 tanks of similar design. All of the tank farms are located in the 200 East and 200 West Areas of the Hanford Site.

Between 1943 and 1964, 149 single-shell tanks were built. Sixty-six of the single-shell tanks are grouped into six tank farms in the 200 East Area (241-A, 241-AX, 241-B, 241-BX, 241-BY, and 241-C). The remaining 83 single-shell tanks are grouped into 6 tank farms in the 200 West Area (241-S, 241-SX, 241-T, 241-TX, 241-TY, and 241-U).

In the original tank design, waste confinement was achieved by a reinforced concrete shell with a liner of mild carbon steel covering the bottom and the sidewalls. The 100-series tanks are 22.86 m (75 ft)* in diameter and were constructed to hold 2,006.3 m^3 (530,000 gal). Later other 100-series tanks of the same diameter were built. They hold 2,869.3 m^3 (758,000 gal) and 3,785.4 m^3 (1,000,000 gal) of waste. There are also 16 smaller 200-series tanks, called receiver tanks, with a diameter of 6.1 m (20 ft) and a capacity of 208.2 m^3 (55,000 gal). Figure 1-1 illustrates these different designs.

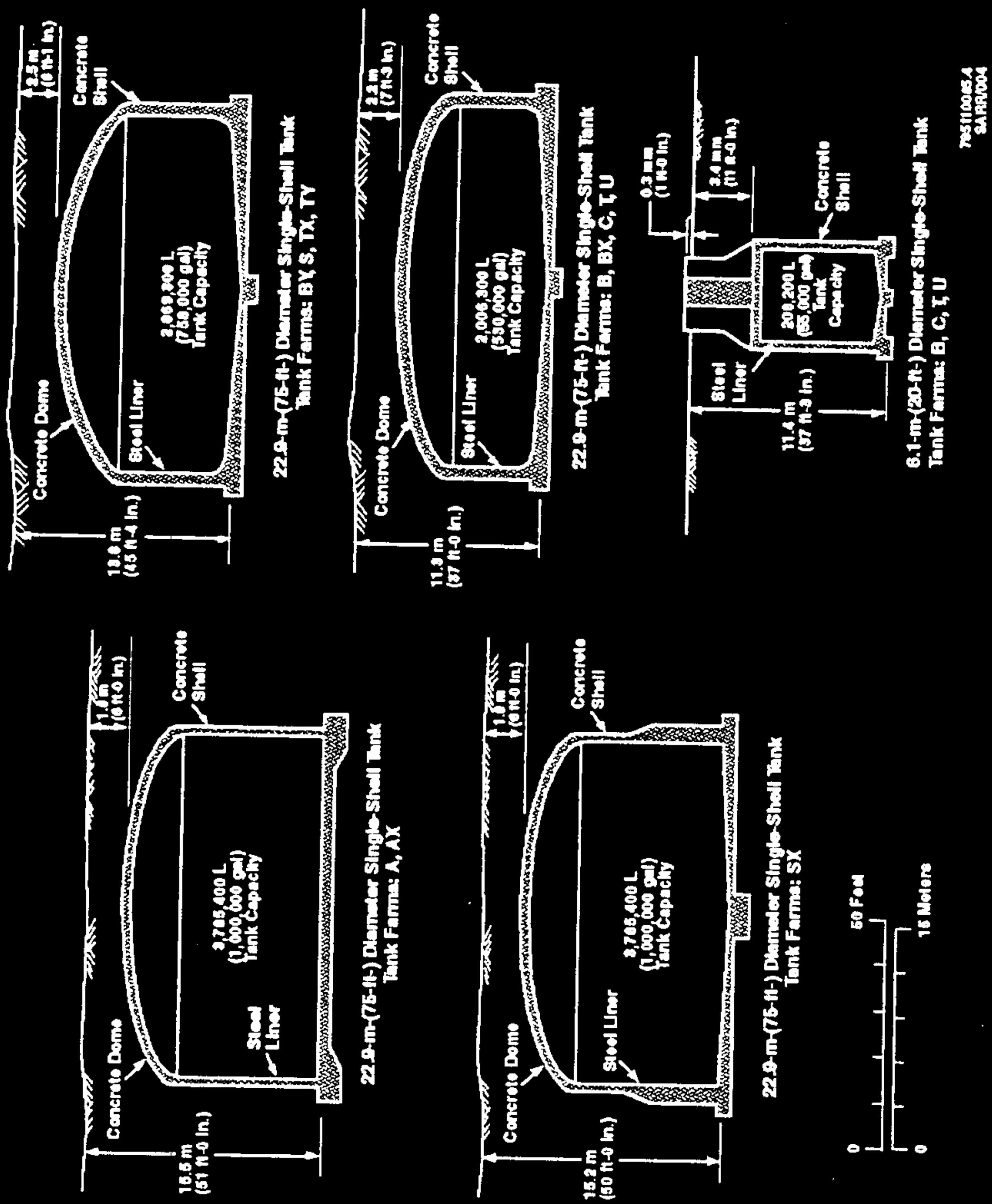
In the first part of 1990, a flammable gas unreviewed safety question was declared to exist (Daugherty 1990, Lawrence 1990) and it included both single-shell and double-shell tanks. The original statement of the unreviewed safety question was a potential release of flammable gas with its own oxidizer. This mixture would be flammable even if the tank were inerted with another gas, such as nitrogen. The original unreviewed safety question involved 22 of the 23 original tanks on the flammable gas watch list. Tank 241-SX-109 was the exception because, although it does not retain or release flammable gases, six flammable gas watch list tanks vent through it.

As of November 1, 1995, the flammable gas unreviewed safety question affects 25 tanks; tanks 241-AW-101 and 241-U-107 were added since the original list was compiled. Six of the twenty-five tanks are double shell:

---

*The tanks were built using English units. Most conversions in this document take the English measurement and convert it to the exact metric value.

Figure 1-1. Nominal Single-Shell Tank Configurations.



241-AN-103, 241-AN-104, 241-AN-105, 241-AW-101, 241-SY-101 and 241-SY-103. These double-shell tanks all exhibit episodic releases*, i.e., a period of growth where the surface levels rise because gases are retained, then a relatively quick release (several minutes to several days). Nineteen single-shell tanks round out the flammable gas watch list. They are tanks 241-A-101, 241-AX-101, 241-AX-103, 241-S-102, 241-S-111, 241-S-112, 241-SX-101, 241-SX-102, 241-SX-103, 241-SX-104, 241-SX-105, 241-SX-106, 241-SX-109, 241-T-110, 241-U-103, 241-U-105, 241-U-107, 241-U-108, and 241-U-109. Tank 241-SX-109 is on this list only because the other six flammable gas tanks in the SX tank farm vent through it. Generally, these single-shell tanks do not exhibit episodic rollover release behavior similar to tank 241-SY-101 (see also Section 4.4). They were placed under the flammable gas unreviewed safety question because their waste types are similar to those in the tanks that exhibit episodic behavior and/or unexplained growth of the waste-level height over time.

1.2 SCOPE

The purpose of this document is to study performing selected activities in single-shell tanks with flammable gas concerns. These activities are the same or very similar to activities that already have been performed in or on tank 241-SY-101. Tank 241-SY-101 was the first flammable gas tank that activities were conducted in. The basic tenets for the safe conduct of these activities will be the same as those used for tank 241-SY-101, i.e., to control ignition sources and to limit the activities to a period of time when the concentration of flammable gases is not expected to reach concentrations of concern.** Van Vleet (1994) discusses the double-shell tanks with flammable gas concerns and Graves (1994) discusses the steady-state flammable gas generation in all tanks. Other tanks may fall under the flammable gas unreviewed safety question as continued characterization and evaluation goes on. NOTE: This document is not procedurally part of the authorization basis until a change is made to the *Hanford Site Tank Farm Facilities Interim Safety Basis*, (Leach and Stahl 1995).

---

*'Episodic releases' are commonly included in the term 'gas release events' in this document. The term 'gas release event' may be more general because it includes natural and activity-based releases. The term 'rollover event' is a gas release event involving the exchange of fluids (bottom to top) in a tank.

**If flammable gases are produced, retained, and released, they may cause the entire vapor space of a tank to reach the lower flammability limit. These single-shell tanks contain mostly solids instead of liquids as in the double-shell flammable gas watch list tanks. Complete tank rollover events are not likely to occur. However, gas releases of different forms may be possible, particularly local releases caused by activities in the tank may occur. The flammable gas will be combustible at the release point and outward from this region until sufficient dilution with the air in the vapor space has lowered the concentration to below the lower flammability limit.

The following sections describe selected activities to be conducted in the single-shell tanks with flammable gas concerns. Hazards are identified and analyzed, consequences are calculated, and controls are developed. The intention is to perform these activities in a safe and environmentally sound manner. The U.S. Department of Energy has issued the *Environmental Assessment (EA) and Finding of No Significant Impact (FONSI) for the Waste Tank Safety Program at the Hanford Site (DOE/EA-0915)* (DOE 1994).

1.3 GAS RETENTION AND RELEASE MECHANISMS IN SINGLE-SHELL TANKS

All 177 waste tanks produce flammable gases at the molecular level (for example, hydrogen, ammonia, and methane) because of radiolysis, organic degradation, and corrosion. This does not create a problem when the gases are constantly released from the waste and are subsequently removed from the tank through the ventilation systems (either passive or active). In some tanks, properties of the waste lead to retention of significant amounts of gas. Preliminary work (Allemann et al. 1995) postulates up to 283 m^3 (10,000 ft^3). These stored gases may spontaneously release (for example, a natural episodic gas release) or may be triggered into a release by activities performed in or on the tank. The following are primary factors in determining gas retention/accumulation: radiolytic and chemical generation rate, gas composition, waste retention properties, and vapor space removal rate. The potential for producing flammable gas suggests that all tanks warrant general precautions. Certain tanks (e.g., those demonstrating an episodic history) warrant additional precautions. The basis of these additional precautions is presented in this document. At this time, all single-shell tanks have the potential for flammable gas concerns, since a volume of 16 m^3 (570 ft^3) of gas, if sufficiently concentrated and ignited, will cause an overpressure of 103,422 Pa (15 psi) (Fox and Stepnewski 1994) which is more than enough to collapse the dome (Julyk 1994).

Recently, studies (Gauglitz et al. 1994, Gauglitz et al. 1995) have been conducted by the Pacific Northwest Laboratory on the mechanisms of gas bubble retention in sludges and slurries (studies are not complete for salt cake). Depending on the physical properties of the waste material and the depth at which the gas is being retained, bubbles have been observed to displace the waste material (spherical bubbles) or to branch between the waste particles (dendritic bubbles). It is believed that spherical bubbles are retained in the waste because of the yield strength of the waste material, whereas the dendritic bubbles are retained by capillary forces. Figure 1-2 is a schematic of these spherical and dendritic bubbles. Other bubble retention mechanisms also have been postulated. Figure 1-3 is a schematic of other bubble retention mechanisms.

The bubble retention in noncohesive particles (settled silica) was investigated via laboratory experiment. The experiment was to simulate sludge behavior. Three distinct regimes of bubble retention were observed. In the upper regions, spherical bubbles were observed to displace the sludge particles. In the middle region, the sludge fractured and gas collected in

Figure 1-2. Schematic of Spherical and Dendritic Bubbles.

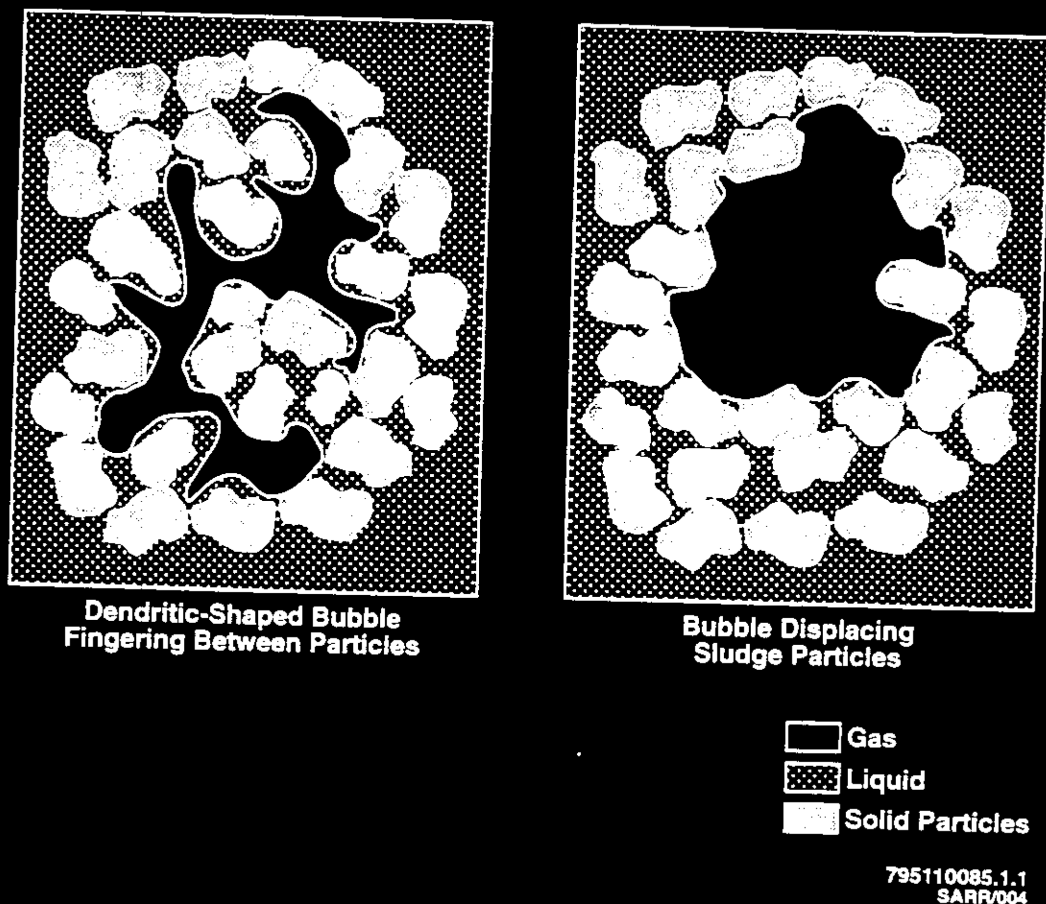
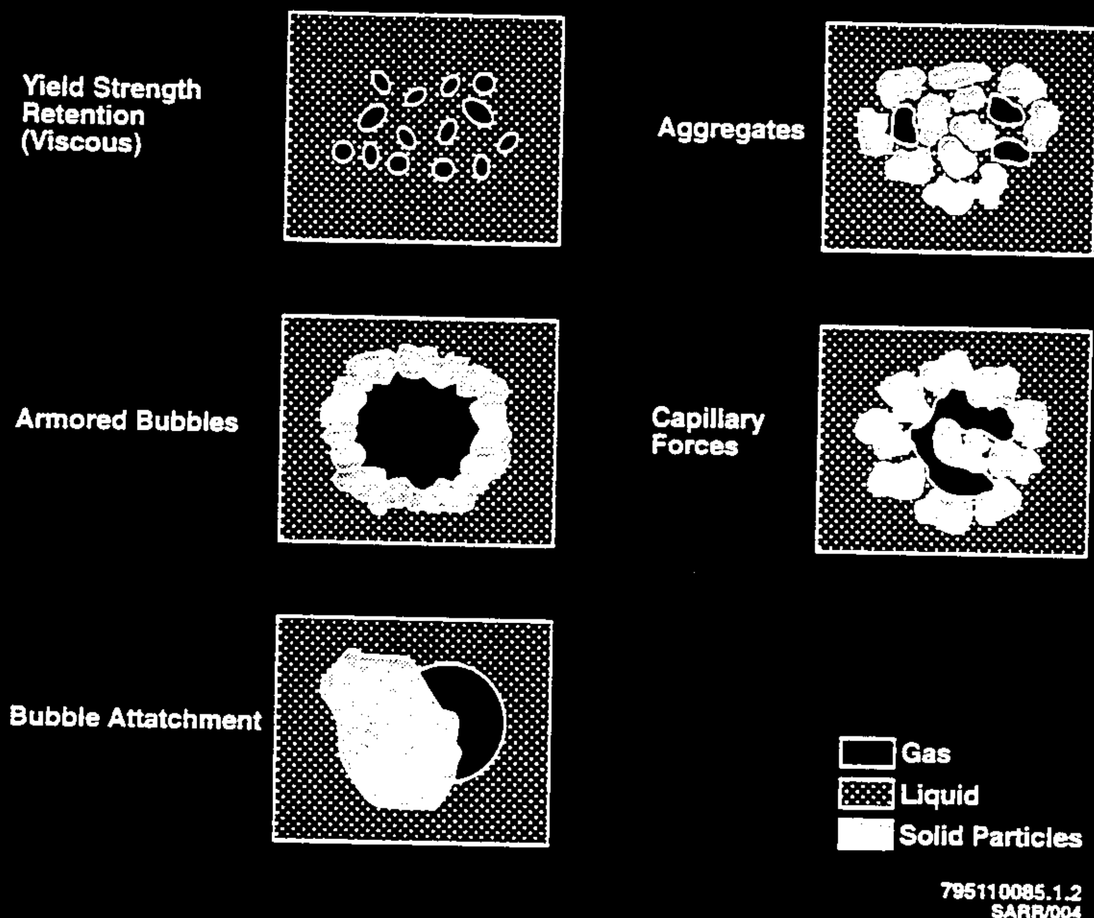


Figure 1-3. Other Bubble Retention Mechanisms.



large bubbles. In the lower region, dendritic bubbles that branch between the individual sludge particles were observed. Figure 1-4 is a schematic of the bubble retention in settled silica.

The bubble retention in cohesive particles (kaolin clay) also was investigated. The clay-based simulated sludges are ductile pastes. In this experiment, bubbles were essentially spherical and therefore were retained by viscous (yield stress) retention. As the spherical bubbles grew in size, they formed interconnected tunnels. These were larger in size than those formed in the settled silica. A few core samples have been x-rayed after they have been removed from the drill string. The x-rays show structures in the waste similar to, but larger in scale than, those observed in the laboratory studies. In addition, recent push-mode sampling campaigns have been monitoring the flammable gas concentration in the drill string. In three instances to date, it was well over the lower flammability limit after the drill string was idle for an extended period. This provides further evidence, albeit circumstantial, that gas pockets do exist in the tanks.

The nature of plausible mechanisms for large gas release events from the waste in single-shell flammable gas tanks is the subject of much speculation. Some of the mechanisms that might cause a large, rapid release of retained flammable gas are the following (Allemann et al. 1995):

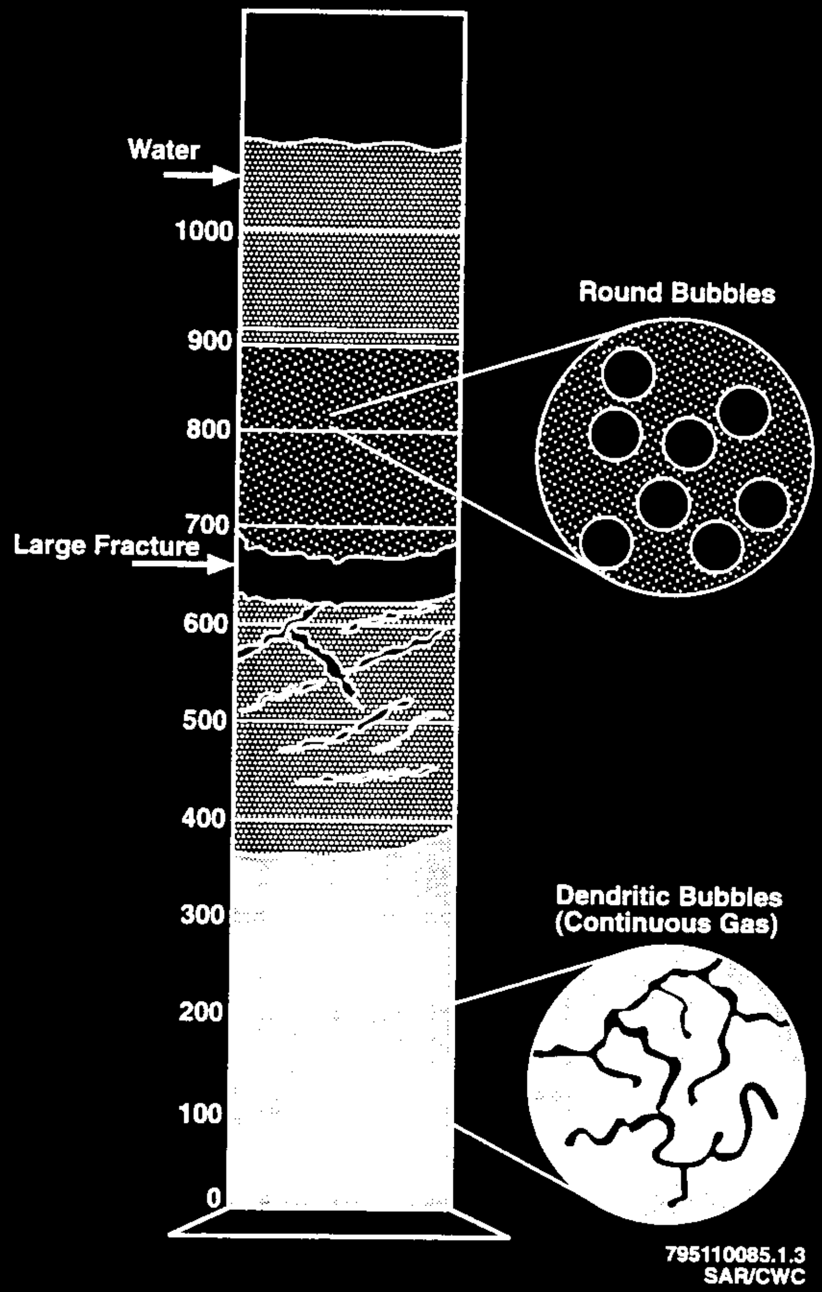
- Release of local bubble(s)
- Mud pot or fumarole
- Fracture of "dry" sludge
- Dryout of salt cake.

These mechanisms are explained in more detail in the following paragraphs.

In sludge that has a yield strength similar to that in the waste in tank 241-SY-101, the largest bubble that could be retained has an estimated diameter of 1 m (3.28 ft) (Allemann et al. 1995). Multiple bubbles might be released if a bubble at depth begins to rise, because it will collect other bubbles that are above it. The affected area will be conical in shape, with its apex at the original location of the bubble. This could be viewed as a vertical cascade of bubbles. A similar cascade might occur if a local pressure sink penetrated one bubble. The resulting collapse would draw in surrounding bubbles which also might collapse.

Gas stored as dendritic bubbles forms a finely distributed, connected phase some distance under the sludge surface. At some point, a crack, channel, or chimney is opened to the surface, and the pressurized gas suddenly is provided with a path to the surface. The path may be either naturally occurring or be made by an intrusive activity. This type of event could result in a relatively large release. Preliminary calculations (Allemann et al. 1995) indicate that the opening of a chimney (also called mudpot or fumarole) to an interconnected dendritic bubble region could produce a significant flow rate of gas over several hours. As the release continued, lateral forces in the waste would tend to close the chimney and the release would stop. Allemann (1995) postulates a flow rate of 28 m^3/hr (1,000 ft^3/hr) for 10 hours.

Figure 1-4. Schematic of Bubble Retention in Settled Silica.



In the fracture of "dry" sludge mechanism, the gas has migrated to form a pressurized layer between the sludge and a wet salt cake cap. The sudden breaking of this cap could release the gas to the dome space in a large quantity. This mechanism does not appear likely because the cap must be impervious or highly resistant to flow for gas to collect there (Allemann et al. 1995).

Gas could be retained between sludge and salt cake layers because excess pressure is required to move gas into wet salt cake in the laboratory. This would result in a layer of retained gas at a pressure dependent on the weight of the salt cake layers above it. A "gasket" made up of wet solids seals the gas. As the wet seal is eliminated, gas might transpire through the dry salt cake at a relatively high rate until the gas pressure is relieved. This mechanism does not appear likely because the cap must be impervious or highly resistant to flow for gas to collect there (Allemann et al. 1995).

This page intentionally left blank.

2.0 DESCRIPTION OF ACTIVITIES

This section addresses selected activities in and around single-shell tanks with flammable gas concerns, as defined in Section 1. Activities associated with monitoring systems, vapor-space sampling, still and video photography, instrument trees, the installation of liquid observation wells, salt well screens, and jet pumps, grab, auger, and push-mode waste sampling techniques, and routine maintenance and surveillance are discussed in the following sections.

2.1 MONITORING SYSTEMS

All single or double-shell tanks, may be equipped with thermocouple trees (temperature measuring device in waste and dome space), level-indicating devices, an observation port through which a camera can be inserted to take photographs of the inside of the tank, and a dome elevation bench mark (dome deflection monitoring device). All single-shell tanks (except tank 241-A-105) are equipped with a radiation monitoring capability. Some tanks have leak detection laterals (horizontal dry wells underneath the tank). Some single-shell tanks are equipped with liquid observation wells to provide monitoring of the liquid level (Figure 2-1).

2.1.1 Gas Monitoring System

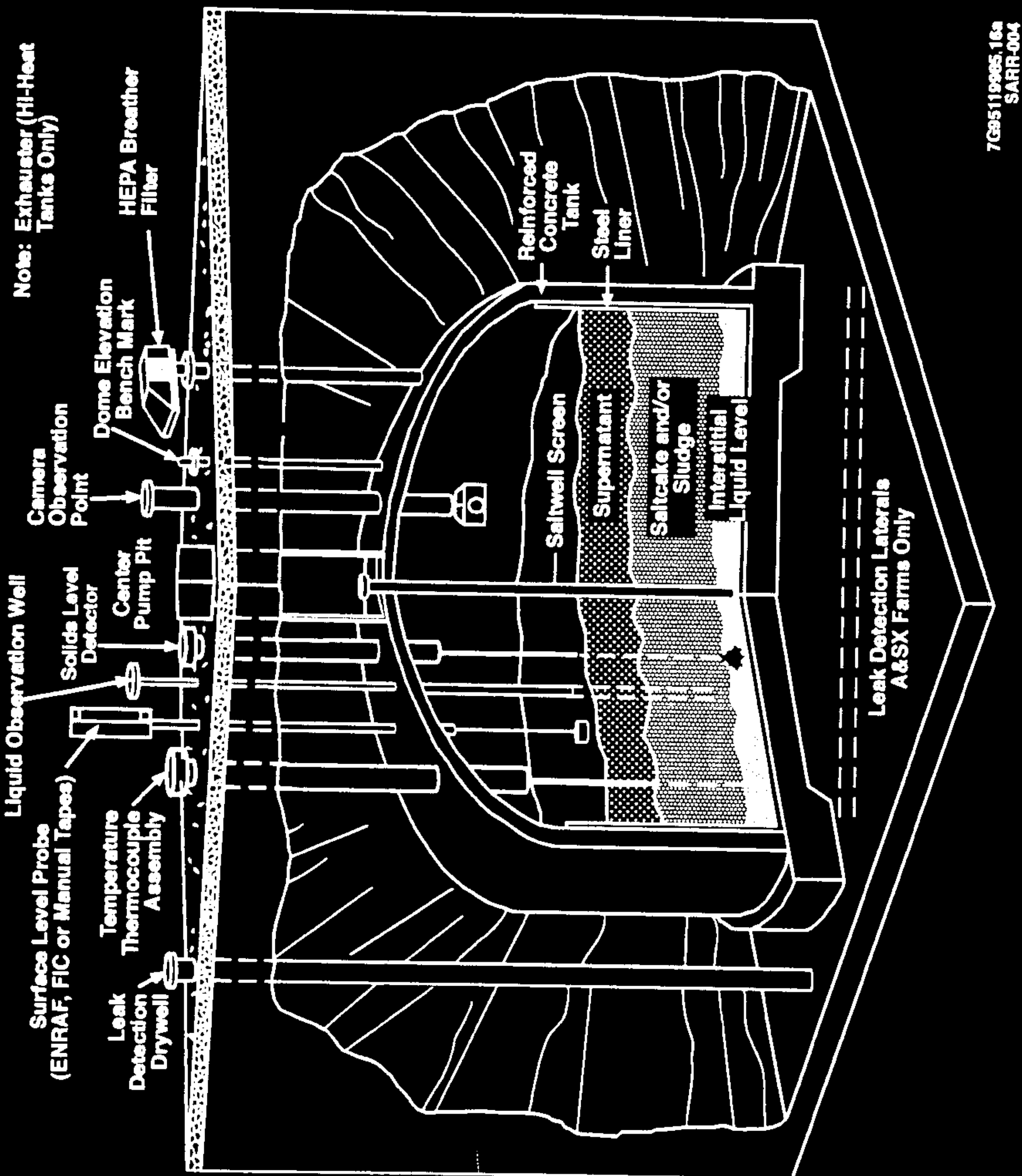
The standard hydrogen monitoring system is an installed system used to measure the hydrogen concentration in the tanks with greatest concern. The standard hydrogen monitoring system was developed to sample Class 1, Division 1, Group B (hydrogen) atmosphere. All of its components meet the National Fire Protection Association's National Electrical Code (NFPA 1994) requirements for operating in a hydrogen environment.

The standard hydrogen monitoring system provides online continuous measurements of gas samples for hydrogen content and to allow for more detailed laboratory analyses of grab samples. Details are provided in the design documentation (Atencio 1992). The hydrogen sensors used are electrochemical cells that provides an electrical signal proportional to the hydrogen partial pressure in the gas sample. The low-range sensor is calibrated for a hydrogen concentration range of 0 to 1 percent, while the high-range sensor is calibrated for 0 to 10 percent hydrogen*.

---

*NOTE: Appendix B develops a lower flammability limit for the flammable gas tanks. It accounts for hydrogen, ammonia, methane, and carbon monoxide in addition to the oxidizers of oxygen and nitrous oxide. Using this approach and setting monitoring requirements for hydrogen only (this is all the electrochemical cell detects) gives 2.5 percent hydrogen as the lower flammability limit and 0.625 percent (6,250 ppm) as 1/4 the lower flammability limit.

Figure 2-1. Single-Shell Tank Cutaway.



The main component of the sampling system, auxiliary flow loop provides a redundant hydrogen monitoring system. This system is a duplicate of the main flow loop. A flow indicator and controller is provided to measure and control low-volume flows.

An alarm provides audible and visual indications that the system needs to be maintained, or that the hydrogen level in the tank is above a preset percentage of the lower flammability limit.

2.1.2 Installation Of Gas Monitoring System and Gas Probe Assembly

The standard hydrogen monitoring system has been designed to be installed in four different configurations: (1) on the exhaust header, (2) on a gas probe assembly, (3) on a multifunction instrument tree assembly, or (4) on a modified riser flange. For single-shell tanks, the standard hydrogen monitoring system may be installed on gas probe assemblies. The gas probe assembly may be sharing the riser with the high-efficiency particulate air filter (breather filter). To accomplish this, the existing filter may be removed and a new Y-shaped spool piece may be installed. The probe assembly may be installed and the breather filter may be attached to the V-shaped spool piece.

The probe assembly shown in Figure 2-2, consists of a supply line and return line for use with the standard hydrogen monitoring system, a water-jacketed supply line and a return line for use with the vapor monitoring system, and a temperature probe to measure the temperature of the vapor space. The standard hydrogen monitoring system may be in use continuously.

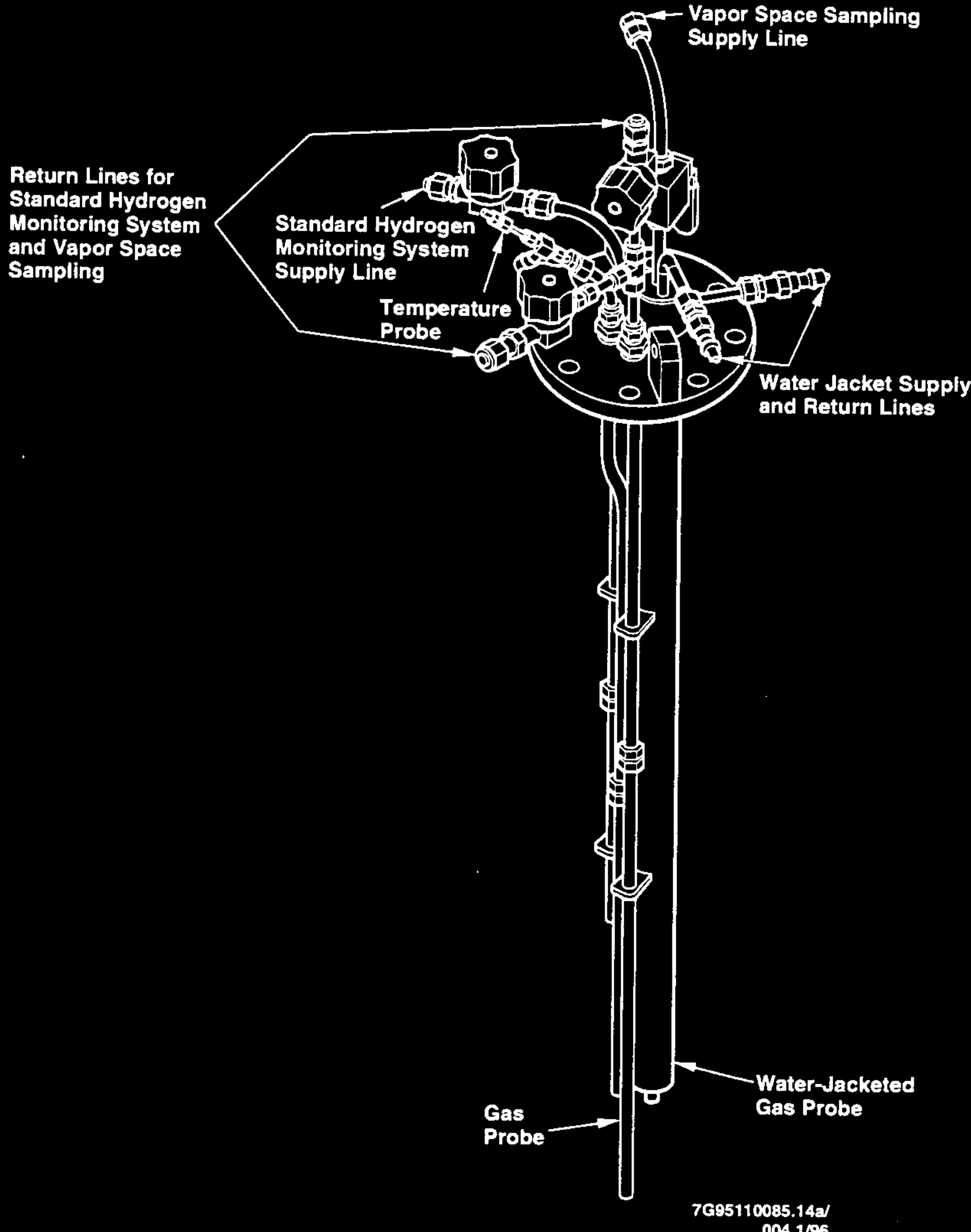
Installation on the gas probe assembly is a simple operation of connecting tubing from the assembly to the environmentally controlled system enclosure, and connecting return tubing from the enclosure to the return line on the gas probe assembly. After the tubing is connected to the fitting, a protective cover is placed over the fitting to prevent damage. Valving that is already installed on the gas probe assembly may be used to isolate the standard hydrogen monitoring system from the tank environment until after the standard startup procedure has occurred. After the system has been leak tested and calibrated, the valving is opened to allow sampling of the tank vapor space.

2.1.3 Operation

The operation of the gas monitoring system permits the continuous sampling and monitoring of the tank gases for hydrogen. In addition, gas samples can be obtained for complete gas species analysis at a laboratory.

Routine maintenance is required to support continuous monitoring. These activities include calibration of the sensors, readout and recorder, pressure indicators, and strip chart recorder and replacement of filters and strip chart paper.

Figure 2-2. Gas Probe Assembly for Single-Shell Flammable Gas Tanks.



Failure of a gas monitoring system may result in failure to monitor the concentration of hydrogen level in the tank. Increase in hydrogen concentration and the presence of a spark source may cause an ignition and result in the accidental release of radioactive and/or toxic material to the environment. The monitor's output initiates Emergency Response Plan actions or operator actions to place the operating process in a safe condition per WHC-CM-4-46.

2.2 VAPOR-SPACE SAMPLING

Vapor space sampling is performed to determine the toxic and organic components in addition to any flammable gases in the tank. The main purpose of this sampling is for worker protection.

A typical sample probe assembly is shown in Figure 7. This type of assembly may be temporarily installed in tanks that do not have the gas probe assembly shown in Figure 6. The assembly has three main components: the sample tubes of Tygon or Tygon-equivalent tubing with a helically wound stainless steel wire encircling the outside; a sampling riser cover that is a carbon steel plate predrilled for bolt holes to match the riser flange and holes for the sample ports; and sample ports that are stainless steel tubes extending through the riser cover.

The sample port tubes (a short stainless steel tube that extends on both sides of the riser cover) are connected to the Tygon or Tygon-equivalent sampling tubes on one side; on the other side the tubes are equipped with valves and connections for the sample analysis instrumentation. The wire coil on the sample tubes aids in grounding the probe, i.e., providing a pathway for electrostatic energy to be removed.

One type of sampling instrument used is the combustible- or flammable-gas meter. Two models are generally used. Both models draw the gas sample over a hot wire and measure the change in resistance of the wire to determine the concentrations of flammable gas and oxygen. When oxygen is low or when another oxidizer is present, the meter readout is affected. The gas is burned catalytically around the wire. The burning chamber is protected from the potential of a flame flashback by a sintered filter at the chamber inlet. Each meter has an integral vacuum pump that pulls the sample stream across the hot wire. Both models are listed by Underwriters Laboratories as Classified for use in Class 1, Division 1, Groups A, B (i.e., hydrogen), C, and D (see Appendix D for National Fire Protection Association definitions) applications, in accordance with the National Electrical Code (NFPA 1993).

The organic vapor monitor is used for tank space vapor sampling at the Hanford Site. The meter uses photo-ionization to detect organic molecules and ammonia. The meter has an integral vacuum pump that pulls the sample stream through the meter. The organic vapor monitor is listed by Underwriters Laboratory for use in Class 1, Division 2, Groups A, B, C, and D applications (NFPA 1993).

The hydrogen sampling cart assembly, and a similar unit called the hydrogen cyanide sampling cart, are modified hand trucks that have a vacuum pump, tubing manifolds with valves for hook up to sample probes, rotometers for measuring gas flows, and sample canisters for grab samples. The vacuum pump assemblies consist of a metal bellows pump and an electric motor that powers the pump.

Metal bellows pumps have been used with the standard hydrogen monitoring systems for monitoring and sampling tank 241-SY-101. The compliance of the pump with the requirements of National Fire Protection Association, Inc., Article 70 for use in hazardous locations is documented in Schneider (1992). The pump was assessed for use on tank 241-SY-101 in Deichman (1992). The electric motor is rated Class 1, Group D (i.e., ammonia, butane, ethane), which is not rated for Group B (hydrogen). Because the motor is in the open air and not in contact with the gas stream, the pump is considered safe in the system.

To install the vapor-space sampling equipment, it may be necessary to remove existing equipment, such as a manual tape, or a Food Instrument Corporation level-indicating device and replace it after the sampling is complete. An alternative is to remove the breather filter and install a Y-shaped spool piece. Both the breather filter and the vapor-space sampling equipment would use the same riser. Tanks that have standard hydrogen monitoring cabinets installed on probe assemblies also provide probes for use by the vapor sampling program (see Figure 2-2). The requirements for toxic gas measurements which serve a dual purpose of worker protection and detection of other flammable gases (such as ammonia) are found in Section 6.1.4.

2.3 STILL AND VIDEO PHOTOGRAPHY

In-tank still and video photography in single-shell tanks that have a flammable gas concern may be needed for one or more of the following purposes:

- Inspect the tank interior to ascertain the condition of the tank.
- Monitor the condition of the waste in the tank.
- Evaluate the condition of other instrumentation.
- Assist in installation and/or removal of other instrumentation.

Approved still-photography equipment for operation in single-shell tanks with a flammable gas concern is not currently available.

Video photography equipment for operation in single-shell tanks with a flammable gas concern is presently being developed, and is described in USQE TF-95-0103 (Farley 1995).

2.3.1 Safety Criteria

For photography to be allowed in single-shell tanks with flammable gas concern, the equipment used must conform to the following criteria, as specified in Section 30.2.A.4 of OSD-T-151-00030 (or latest revision) (WHC 1996):

- Lighting to be Underwriters' Laboratories listed for use in Class 1, Division 1, Group B; a flammable hydrogen atmosphere.

- All other electrical components located inside the tank that are not Class 1, Division 1, Group B will be purged and pressurized with instrument air or inert gas in accordance with the National Fire Protection Association, Inc., Article 496, Type X purging, to conform with the requirements of the National Electrical Code, Article 501 for use in the flammable hydrogen atmospheres.

- Purge gas system to have redundant safety instruments to alarm and automatically shut off electrical power to the electrical components served by the purge gas system due to loss of gas pressure. If required by the safety classification of the equipment of the National Fire Protection Association classification for the location where the equipment is installed, whichever is more stringent.

- In tank 241-SY-101 radiation shielding of the replacement plug to be equal to original 42-in. shield plug.

- In-Tank inspection using a still photo camera requires approval by WTO and WTPE.

In-tank photographic hardware exposed to the tank vapor space is made of materials (e.g., stainless steel, semi-conductive plastic) that are resistent to mechanical and electrostatic sparks, per requirements in Section 30.2.A of OSD-T-151-00030 (WHC 1996).

Video power and signal wires in the tank are sheathed in spark resistent materials, as above, and the sheathe tube (metal or plastic) purged. The support cable or shaft has a depth limiting device to prevent the video or light system from contacting the waste.

A temporary riser cover or glove bag is provide to maintain confinement of vapor space gases during operations. Contamination control for the camera and/or light system is implemented by lining the riser with cleanable or disposable metal and/or plastic sleeves.

2.3.2 Installation and Removal

To install the camera system, it may be necessary to remove existing equipment, such as a manual tape or a liquid-level indicating device (e.g., Food Instrument Corporation or Enraf), and replace it after the photographs have been taken.

An alternative is to remove the high-efficiency particulate air filter breather filter and install a Y-shaped spool piece on the riser. In that case, both the breather filter and the camera system can use the same riser.

Installation involves grounding/bonding of the riser flange and instrumentation, removal of the riser flange, sniffing for flammable gas in the riser immediately after riser opening, and camera deployment. Deployment may be manual or with a light winch. Where required by standard tank farm procedures, a glovebag or containment structure with high-efficiency particulate air filter (e.g., greenhouse) is incorporate around the open riser during installation, operations, or removal.

To maintain ALARA principles for personnel safety, a Health Physics Technician monitors radiation over the open riser before manual camera deployment, and monitors the camera for contamination during removal. Toxic gas in the worker space during camera installation and removal is monitored per requirements in the Tank Farm Health and Safety Plan WHC-SD-HSP-002 (Carls 1995).

The integrity of the purge system is verified with a calibrated differential pressure gauge prior to each camera installation. The camera is normally turned on after full deployment, but may occasionally be turned on in the riser or tank during deployment to check for obstructions. Whatever choice is made, at lease 10 volumes of purge gas will be passed through the system prior to turning on energy sources. All purge air is vented into the tank.

In preparation for deployment, the power-signal-support cable is taken off the storage reel prior to deployment, coiled inside the glovebag or greenhouse, and the top end connected to the air and electrical connections on the reel. This is necessary, as the reel has no slip rings. The camera is then manually installed (hand-over-hand) through a friction brake on the flange adapter. The brake ensures that the camera/light cannot be dropped onto the waste surface. The camera system is manually removed from the tank in the reverse order.

2.3.3 Operation

Power-on, pan and tilt operations, 8 to 1 zoom, and video recording is controlled by manual manipulation of switches on the Camera Control Unit. The field control unit is located at least 15 feet away from the deployment riser, so as to be away from any combustible gas plumes coming from the riser.

Average vapor space temperature in the waste tanks is about 30 °C (86 °F) and maximum temperature 89 °C (193 °F). Although the camera's maximum operating temperature is 50 °C (122 °F), thermodynamic calculations of the cooling effects of the purge system indicate that the camera will be capable of operating in all of the site underground storage tanks.

2.4 INSTALLATION OF INSTRUMENT TREES

The purpose of the instrument tree is to provide a physical support to a variety of in-tank instrumentation. Typically it is a fabrication of a central pipe with weldments or other pipes within the main pipe. This pipe is attached to a riser cap which is designed to maintain tank containment.

The instrument tree usually contains up to 12 thermoucouples. Some of the models have vapor-space sampling tubes. Installation is made using either standard water jets or ultra-high-pressure nozzles. The nozzles or jets are for penetration through any salt cake that may be present. These are only used during the installation of the instrument tree.

2.4.1 Instrument Tree Background

The following discussion deals with the installation of instrument trees. In some cases, existing equipment, such as a manual tape may have to be removed before the instrument tree can be installed. NOTE: The manual tape may not be permanently removed unless some alternate level sensing device is installed in the tank.

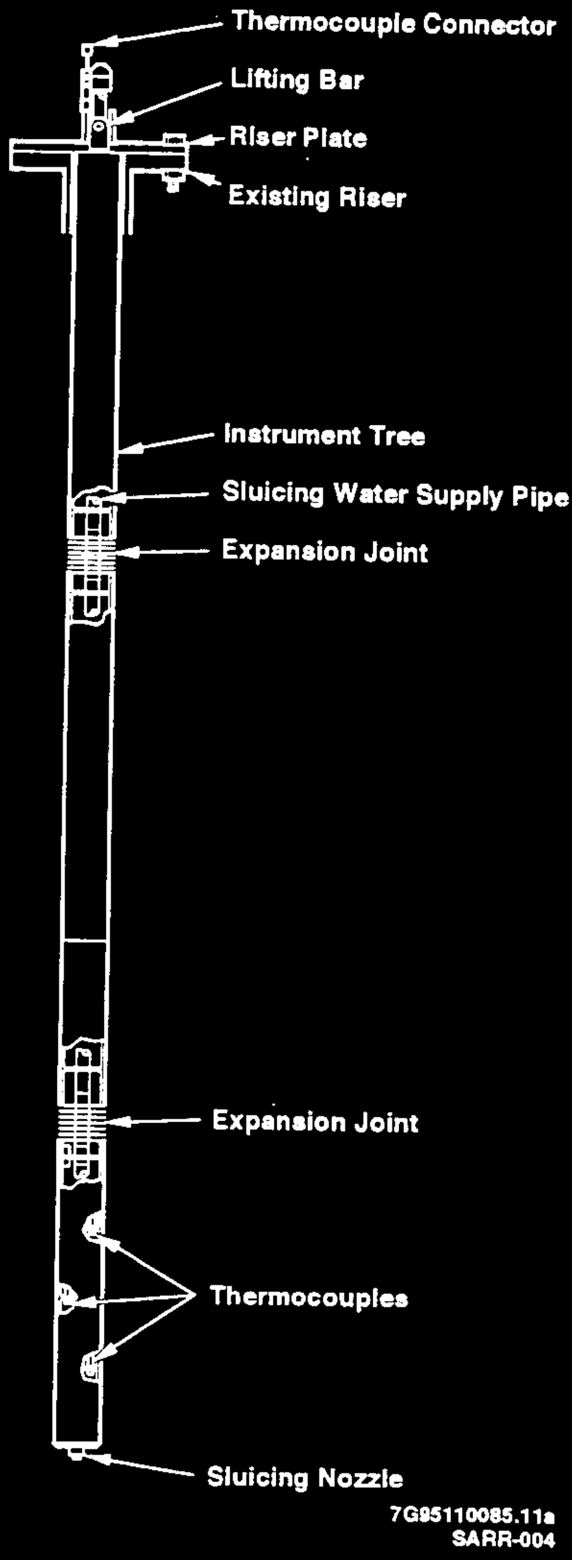
Some risers are known to be nonvertical (bent) or are known to have weld protrusions at welded joints. Some risers also contain unknown obstructions. Such factors may preclude the use of these risers for installing instrument trees. These issues are addressed as they are encountered, and will affect the selection of the riser to be used in the monitoring activities.

After checking a tank for flammable and toxic gases and before inserting an instrument tree in a riser, the riser is inspected for obstructions. The inspection may occur at any time before the instrument tree is installed. To minimize radionuclide release to the environment while the riser is open, the riser inspection is performed inside a passively ventilated confinement structure (tent, greenhouse, etc.) that has a high-efficiency particulate air filter. Direct shine radiation levels from the riser is measured by a health physics technician to determine if it is safe for the inspector to peer directly into the open riser. If required to limit radiation exposure to safe levels, the inspector uses leaded glass over the riser for direct viewing, or a mirror for indirect viewing. The 10.2-cm (4-in.) risers may also be examined using a riser gauge plug. The riser gauge plug may be inserted and removed manually with the aid of lifting crossbars that extend through the plug.

Two types of standard instrument trees are presently used. The first type is 7.62-cm- (3-in.-) inner-diameter, 8.89-cm- (3.5-in.-) outer-diameter schedule-40 pipe that is smooth outside, with 6 to 12 thermocouples or resistance temperature detectors. The assembly is constructed by inserting 0.95-cm- (0.375-in.-) outer-diameter tubes into holes around the edges of several disc spacers. The tubes are welded to the spacers and the thermocouples or resistance temperature detectors are inserted in the tube. The entire assembly is placed inside the instrument tree pipe. This type has only one thermocouple in the vapor space. A schematic diagram of this type of instrument tree is shown in Figure 2-3. The new instrument trees are variations of this basic design. One variation has the vapor-space sampling tubes and the other has an ultra-high-pressure nozzle for installation and vapor-space sampling tubes.

The second type of instrument tree presently used has 10 thermocouples or resistance temperature detectors. It is a schedule-40 pipe 6.35 cm (2.5 in.) in diameter with five angular annuli welded to the outside. The annuli are open at the bottom, and are used to hold the five thermocouples or resistance temperature detectors in the vapor space. NOTE: the annuli do not penetrate into the waste; they terminate at least 122 cm (48 in.) above the waste. The projected image of the tree with annuli is star shaped, with

Figure 2-3. Schematic Diagram of Typical Instrument Tree.



cross-sectional outside dimensions of 9.5 cm (3.75 in.). Five tubes within the pipe hold the remaining thermocouples or resistance temperature detectors. The five interior tubes terminate on the inside surface of the pipe at various waste levels.

Newer instrument trees use stainless-steel sheathed Type K thermocouples or platinum resistance temperature detectors. Older, already installed instrument trees use unsheathed K, J and E thermocouples. The trees with standard jetting nozzles have either 2.54-cm (1-in.) or 1.91-cm (0.75-in.) schedule-40 water pipe located in the center of the trees. The water pipe is connected to a water supply system and provides the nozzles with water. Both ends of the water pipe are welded to the ends of the tree. Each standard instrument tree uses a hydraulic jetting nozzle with a central opening of approximately 0.95 cm (0.375 in.). As installed, the nozzle projects approximately 2.54 cm (1 in.) beyond the end of the tree. The complete assembly weighs about 252 kg (555 lb). Instrument trees incorporating vapor sampling tubes may also be installed.

2.4.2 Electrical System

The enclosure box for electrical or electronic components external to the tank may be constructed of aluminum or steel (or materials compatible with environmental conditions). The thermocouple or resistance temperature detector wire ends terminate inside the enclosure box for protection from the weather. Instrument tree operations and potential safety issues are described in *Functional Requirements for Ferrocyanide Tank Temperature Monitoring*, WHC-SD-WM-RD-013 (Scaief 1992) and are summarized below.

A potential safety concern was sparking or resistive heating of thermocouples in the waste during operations. A thermocouple produces a voltage proportional to the difference in temperature between the thermocouple junction and the reference junction (voltmeter location). Because the thermocouples are grounded, the only credible mechanism for an electrical arc is to have one of the thermocouple wires break, causing a high voltage to be accidently applied to the thermocouple leads. There is little chance of this happening, because the signal conditioner hooked up to the thermocouples operates on 12 or 15 volts DC. Significant resistive heating of a thermocouple would require high current flow through the thermocouple, which in turn would require high voltage applied to low impedance. This also has little chance of happening, because thermocouples have an impedance of 10 to 100 ohms distributed over the entire length of the thermocouple wire. If 15 volts DC were accidently connected to a thermocouple, the potential exists for 0.15 to 1.5 A of current to flow through the thermocouple and heat the wiring a few degrees. This heating would be distributed over the entire length of the thermocouple wire and would present no safety hazard. Also, any spark or resistive heating would be confined by the thermocouple sheath in the exterior thermocouples, or by the thermocouple sheath, tubing, and pipe in the interior thermocouples. NOTE: Older already installed trees do not have sheathed thermocouples.

A platinum resistance temperature detector produces a change in resistance proportional to the temperature of the extension wire and the measuring termination point. The typical resistance of a resistance temperature detector is about 100 ohms. Assuming a typical excitation current of 0.5 A, the resistance temperature detector at 50 °C would have a resistance of 120 ohms and would produce about 0.03 mW of heat energy (Scaief 1991a). This heat would be dissipated by the surrounding sheath and would be inconsequential. The resistance temperature detectors in the protective sheath are qualified for use in a National Fire Protection Association, Inc., Class 1, Division 1, Group B hazardous location (Scaief 1991b).

2.4.3 Data Acquisition System

Data acquisition system electronics are located external to the vapor space of the tank. While various methodologies in gathering data are employed, there is no impact to the safe operation and configuration of the single-shell waste storage tank.

2.4.4 Crane

The crane used to lift the instrument trees may be a hydraulic mobile unit, or an engineering-approved equivalent. Hydraulic cranes are safe from free-wheeling load-drop accidents because they cannot be put into a free-wheeling mode unless a catastrophic failure of the hydraulic line occurs. Loads are powered down as well as up. If the crane engine or hydraulic pump should fail, the load is automatically locked in place by reserve hydraulic pressure. The crane does have frictional brakes, but they are only used for locking the drums during road transportation. Maximum lift or drop speed with the crane on a single wire rope is 2.27 m/s (446 ft/min) on the main drum and 2.31 m/s (455 ft/min) on the secondary drum, too fast to safely insert instrument trees. A safe maximum speed, based on advice from experienced crane operators and on minimizing the potential for frictional heating, would be about 0.3 m/s (1 ft/s). To prevent operator error, maximum load speed is limited to a nominal 0.3 m/s (1 ft/s) by adding block and tackle or by using other standard practices or crane features. An engineered lifting bail is used to meet the Hanford Site hoisting and rigging requirements specified in *Hanford Hoisting and Rigging Manual* (DOE-RL 1992). The lift of the instrument tree is a critical lift.

Even at slow speeds, there is the potential for generating a spark either by mechanical contact or through static charge buildup. Prior to the installation of a instrument tree, the vapor space should be verified to be below 25% of the lower flammability limit. Continuous flammable gas monitoring of the vapor space needs to be performed to insure that the vapor space remains nonflammable during the installation. Grounding and bonding of the instrument needs to be maintained during the installation process to dissipate any electrical charge.

2.4.5 Instrument Tree Installation

The standard-pressure water-injection nozzle of the standard instrument tree is designed to inject treated (not raw) water at 59 L/min (15.6 gal/min), at a pressure of 414 kPa (60 psi). To facilitate installation of the tree through solid waste, the water is injected from the nozzle at the bottom of the tree. A high-pressure rubber hose connected from the top of the instrument tree to a water truck supplies hydraulic sluicing water to the tree. The amount of water carried in the truck is specific to each tank. The standard-pressure installation method is the most common type used onsite.

The ultra-high-pressure water sluicing system (Figure 2-4) consists of a water truck; a high-pressure intensifier operated by a 37.3-kW (50-horsepower) diesel engine; 183 m (600 ft) of high-pressure hose carried on a reel mounted on a trailer; a modified crane (as described above in 2.5.3) to limit how fast the tree is lowered; and a special sluicing nozzle. This method uses pressure up to 255 MPa (37,000 psi) to inject treated (not raw) water through an instrument tree ultra-high-pressure tube rated up to 414 MPa (60,000 psi), and a special nozzle with 8 to 16 sapphire orifices with 0.015-cm- (0.006-in.-) diameter holes. With the ultra-high-pressure nozzle, low flow rates are used because the water cuts through the solid waste rather than dissolving it. Laboratory tests on salt cake simulant, using a 8.89-cm- (3.5-in.-) outer-diameter sluicing nozzle and 241 MPa (35,000 psi), resulted in an average bore rate of 360 cm/min (1.17 ft/min) and water use of 32.9 L/m (2.65 gal/ft) (Hertelendy 1993a).

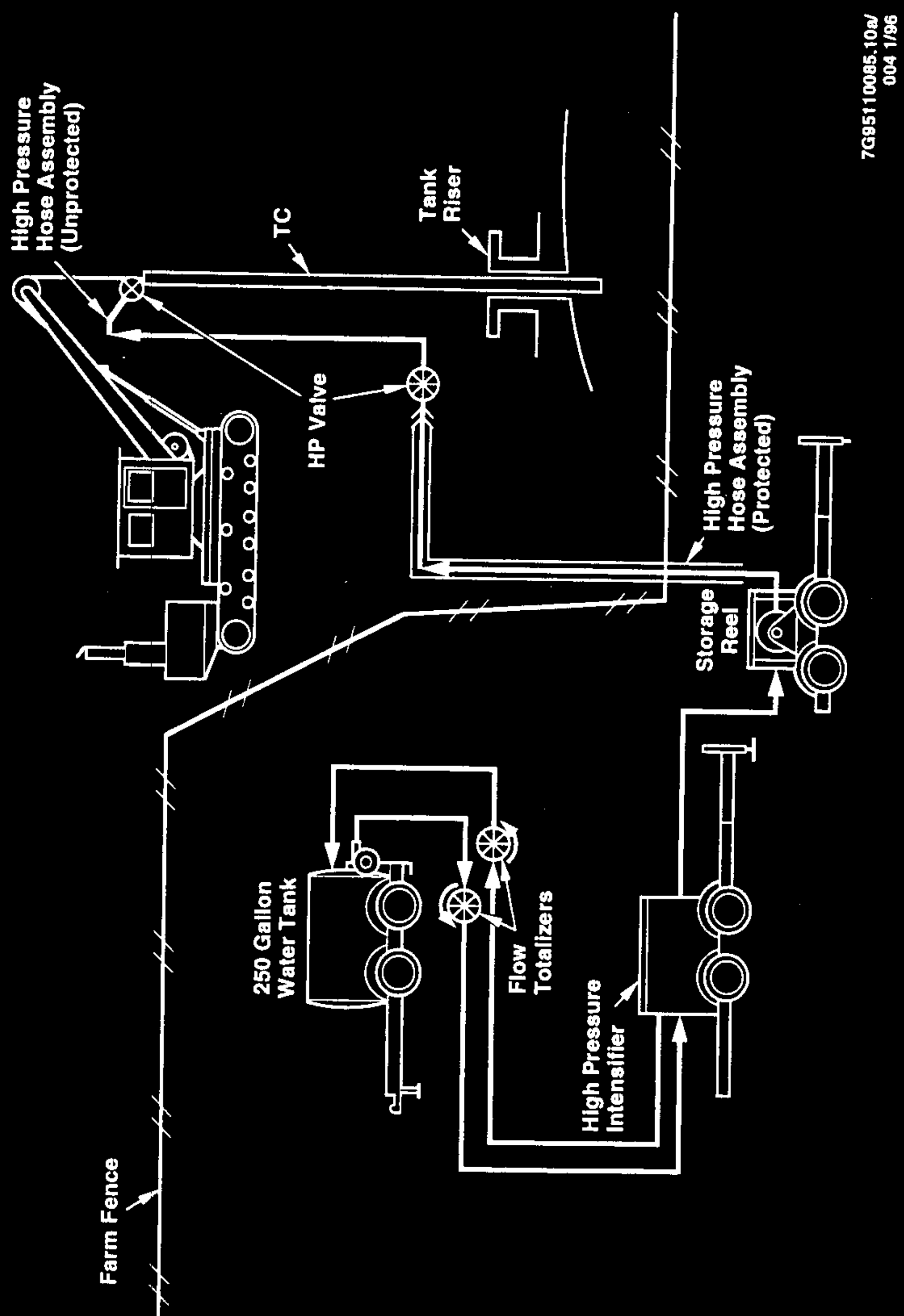
2.4.5.1 Standard Sluicing. After the 414-kPa (60-psi) water pump is hooked up to the instrument tree and tank truck, the tree is lifted to a vertical position by a single crane using a pump lift stand (strongback) or by one or two cranes using a two-point pickup to prevent bending the pipe. If the initial tree lift to vertical is successful (no support-link failures), the crane slowly swings the instrument tree over the open riser and slowly lower the tree into the tank. When the instrument tree nozzle is a short distance above the waste, sluicing water is turned on and the tree is be lowered to the waste surface. The water is turned on before the tree touches the waste so that the orifice in the nozzle may not get plugged. Sluicing through the waste may then proceed by displacing and/or dissolving the waste. Waste penetration by sluicing is expected to take from 30 to 90 minutes in tanks containing salt cake, and 15 to 30 minutes in tanks containing only sludge.

2.4.5.2 Ultra-High-Pressure System. Communication is maintained between the person in charge, the crane operator, the worker rotating the tree, and the worker maintaining the ultra-high-pressure pump. The person in charge observes the tree insertion and could instruct the ultra-high-pressure pump operator to cut pressure if the need occurred.

The instrument tree is first positioned on a horizontal rack near the appropriate riser. After being hooked up to the water supply tank and the instrument tree, the intensifier is turned on, and the intensifier and ultra-high-pressure connecting hoses tested for leaks at 255 MPa (37,000 psi). During this test, the instrument tree piping and ultra-high-pressure nozzle is also checked for normal operation. A safety shroud or barrier is positioned around the nozzle to prevent workers from contacting the ultra-high-pressure stream during the test. The observer stands away from the ultra-high-pressure nozzle during testing.

The ultra-high-pressure system may be run for several minutes to ensure that the system is operating normally, then the ultra-high-pressure water is turned off. The instrument tree may then be raised to a vertical position over the open riser and lowered into the tank at a maximum speed of 30.5 cm/s

Figure 2-4. Schematic for the Ultra-High-Pressure Sluicing System.



(1 ft/s) until the nozzle touches the solid waste, sludge, or salt cake. The lowering speed for solid waste penetration is then reduced to a maximum of 1.5 m/min (5 ft/min). If the solid waste is soft and can be penetrated using only the weight of the instrument tree, the sluicing water is not turned on. If hard waste is encountered, the ultra-high-pressure water may be turned on. This procedure of not starting the ultra-high pressure water until the nozzle touches the solid waste may prevent aerosol generation of waste as the nozzle approaches the waste surface and minimize the amount of water used. There is no danger of plugging the orifices; they are extremely small and the ultra-high-pressure water would eject any fine material.

Water temperature does not affect the cutting rate; thus, water at ambient temperature may be used. The manufacturer of the ultra-high-pressure system states that ambient water used for ultra-high-pressure sluicing may be heated to about 71 °C (160 °F) as a result of compression. Laboratory tests on salt cake simulant, using ambient temperature water, resulted in average penetration rates of 0.36 m/min (1.17 ft/min). Average water use was 8.7 L/min (2.3 gal/min) (Hertelendy 1993a). Optimum cutting during penetration occurred when the nozzle was rotated back and forth about ±45 degrees at about 10 cycles per minute. The rotation of the tree is translated to a slight bending of the hose as it hangs in a loop, and poses no threat from fatigue failure. The hoses are rated for 5,000,000 flexes into a 0.91-m- (3-ft-) diameter loop. The maximum flexing expected from instrument tree insertion is about 600 bends into a 3.05-m- (10-ft-) diameter loop.

The system has been tested in its proposed function in numerous laboratory mockups without any problems. The lines are never in contact with the riser, so they will not rub against it. In the laboratory, the nozzle was rotated by workers manually twisting the feed pipe with their hands. In the tanks, the rotations are also done manually, but with clamp-on turning arms to prevent radiation shine on the workers hands. Controls are also implemented during instrument tree insertion to lessen the likelihood of the ultra-high-pressure water jets damaging the tank bottom steel liner. A laboratory test of 1 to 5 minutes with a nonrotating nozzle at various distances showed that maximum damage occurred to the steel plate when the nozzle was 2.54 to 5.08 cm (1 to 2 in.) from the plate and at full pressure of 255 MPa (37,000 psi) (Hertelendy 1993b). When a rotating nozzle was held in contact with the steel plate for 5 minutes, no damage occurred. When a nonrotating nozzle was held in contact with the steel liner for 5 minutes at a reduced nozzle pressure of 34.5 MPa (5,000 psi), no damage occurred (Hertelendy 1993b).

The trees are designed so that, when they are fully inserted in the tanks, the nozzle is approximately 5.08 cm (2 in.) from the bottom steel liner. This allows for thermal expansion of the tree without having it buckle. Distortion of the tank bottom, or human measurement errors, could result in the ultra-high-pressure nozzle making contact with the bottom steel liner during instrument tree insertion. As shown, steel liner damage could occur under certain conditions. Procedural controls prevent or lessen the likelihood of those adverse sluicing conditions occurring.

When the tree's top flange is 30.5 cm (12 in.) above the riser flange, the ultra-high-pressure nozzle should be 35.6 cm (14 in.) from the tank bottom steel liner. To lessen the likelihood of damage to the steel liner from the ultra-high-pressure jets, at this point the sluicing water pressure is reduced to 34.5 MPa (5,000 psi). This reduced pressure should be sufficient to penetrate the last 30.5 cm (12 in.) of sludge waste present in most tanks with no reduction in penetration rate. If penetration does not occur in any 2-minute period when using full sluicing pressure or for 5 minutes when using reduced pressure, it is assumed that the nozzle is in contact with the bottom steel liner, and the water is turned off. Rotation of the nozzle continues until the ultra-high or reduced water pressure is turned off. If the instrument tree should contact the bottom liner, the tree is adjusted so that the bottom of the tree is at least 5.08 cm (2 in.) from the tank bottom liner.

2.4.6 Instrument Tree Length Adjustments

The instrument tree length is based on configuration drawings that will attempt to keep the instrument tree bottom off the tank bottom. The only force applied to the sluicing nozzle during insertion, with either the standard-pressure system or the ultra-high-pressure system, is the weight of the instrument tree itself. Sluicing continues until one of the following takes place.

- The instrument tree flange rests on the riser flange.
- The bottom of the instrument tree rests on the bottom of the tank.
- An obstruction is encountered.
- Control limits on sluicing water are reached.

If sluicing continues until the instrument tree flange rests on the riser flange, it is assumed that the bottom of the instrument tree is approximately 5 cm (2 in.) off the bottom. The instrument tree flange may then be secured to the riser flange using appropriate bolts, and the crane and water injection system is disconnected. If the bottom of the tank is encountered before the instrument tree flange rests on the riser flange, 15- to 61-cm- (6- to 24-in.-) long permanent split riser extenders may be added to the instrument tree to raise it off the tank bottom.

If an obstruction in the waste is encountered before complete insertion through the waste, the instrument tree may be left at that position and the instrument tree secured as follows: (1) If 1.22 m (4 ft) or less of the instrument tree extends above the riser, split riser extenders may be added to the tank riser to seal and secure the system; (2) if more than 1.22 m (4 ft) of the instrument tree extends above the riser, the instrument tree-riser interface may be sealed with a special gasket and a split flange, and the extra instrument tree length may be cut off.

2.5 INSTALLATION OF LIQUID OBSERVATION WELL, SALT WELL SCREEN, AND/OR JET PUMP

The liquid observation well provides a means for measuring the waste level in the tank nonintrusively. The salt well screen provided a mechanical barrier to screen out waste salts and debris during waste transfer. The jet pump is one of the methods for transferring waste out of the tank. The jet pump is located inside a salt well screen.

2.5.1 Background for Liquid Observation Well, Salt Well Screen, and/or Jet Pump

All of the single-shell tanks have been inactive since 1980. Therefore, no waste transfers into the tanks have been made since that time, and none are planned for the future. The equipment and installations required for emergency pumping a flammable gas tank, as for any other tank, are a pump pit, a salt well screen, a pump assembly, flushing assembly, flex-hose jumpers, and associated controls. NOTE: This document only covers the installation of the salt well screen and installation or removal the jet pump and associated equipment such as dip tubes, not the use of the jet pump.

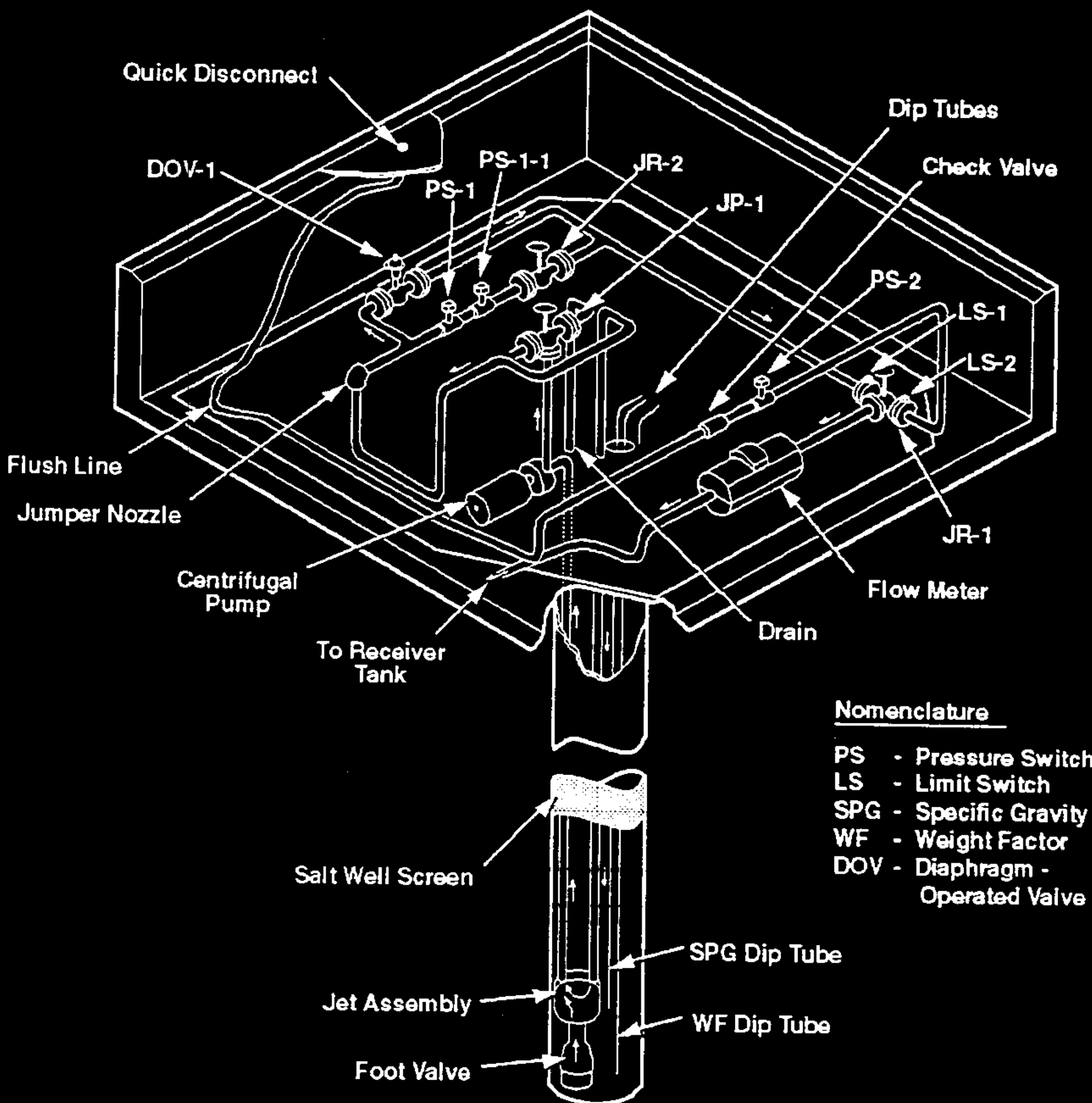
The dome of the single-shell tank is built with several risers of different diameters, one or more of which protrudes into the pump pit. A pump pit is a concrete structure located above the tank dome near the center of the tank. The pumping system is housed within the pump pit with portions of it extending into the riser and into the waste. Figure 2-5 shows a typical salt well screen and jet pump assembly.

The function of the salt well screen is to minimize the size and amount of solids pumped. The salt well system is a 25.4-cm- (10-in.-) diameter salt well casing consisting of a stainless steel slotted screen welded to a schedule-40 carbon steel pipe. The salt well system is to be inserted into the 30.48-cm (12-in.) tank riser located in the pump pit although installation also occurs on larger diameter risers. The stainless steel slotted screen portion of the system extends through the tank waste to near the bottom of the tank. The salt well screen portion of the casing varies in length but is typically a 3.05-m (10-ft) length of 300-series, 25.4-cm- (10-in.-) diameter, stainless steel pipe with screen openings (slots) of 1.27 mm (0.050 in.). A jet assembly with a foot valve is mounted to the base of two pipes that extend from the top of the well to near the bottom of the well casing inside the salt well screen. The salt well screen also holds dip tubes for measuring specific gravity and weight factor of the liquid. In some cases, the salt well screen extends above the tank waste and in those cases, the salt well is open to the tank atmosphere.

Two operations may be required for single-shell flammable gas tanks. Installation of a salt well system for emergency pumping or water lancing an existing salt well to dissolve crystallized salt in the screen openings. Both these operations involve using a water lance in the tank. The lance is made of 5.1-cm (2-in.) schedule-40 stainless steel. The lance is 20.3 m (60 ft) long and has a total mass when filled with water of 159 kg (350 lbm). Recently, the salt well screen has been fitted with high-pressure sluicing nozzles that are described in Section 2.5. This reduces the amount of water that is added to the tank and provides for easier installation.

A tanker truck supplies treated water at temperatures of less than 100 °C (212 °F) for lancing. A flow totalizer may be used to determine how much water is added to the tanks. To install a salt well screen, the lance may be lowered into the tank and used to prepare a clear channel where the salt well screen system can be lowered. That is, the solid tank waste may be slurried and dissolved by the hot water to form a hole for the salt well screen system. The salt well screen is then installed by a crane. The installation of a liquid observation well would be conducted in a similar

Figure 2-5. Typical Salt Well Jet Pump.



Typical Salt Well Jet Pump

7G95110085.15
SARR-004

fashion. To clean the screen of an existing salt well, the lance moved up and down the screen. Again, the hot water dissolves any waste that has solidified in the screen opening. During lancing, there is a possibility that trapped gases may be released from the waste. In addition, the hot water may cause an updraft from the waste that may carry the released gases and aerosolized tank waste to the open riser. Workers wear the appropriate respiratory protection, as determined by the field representative from Industrial Health and Hygiene.

The components of the jet pump system located within the pump pit include a centrifugal pump to supply power fluid to the down-hole jet assembly, flexible or rigid jumpers, a flush line, and a flowmeter. The jumpers contain piping, valves, and pressure and limit switches. Instrumentation and control devices are also located in the pump pit. A drain in the bottom of the pump pit empties into the tank and is normally open.

The jet pump, jet pump foot valve, diaphragm-operated valve, salt well screen, and dip tubes are susceptible to plugging. A specific flushing procedure is used for each of them. Typically each flush requires approximately 38 L (10 gal) of water. Water usage is controlled by existing tank farm procedures.

The centrifugal pump and jet assembly are needed to raise the interstitial liquid from the salt well screen into the pump pit, nominally a 12.19-m (40-ft) rise in elevation. The centrifugal pump, rated at approximately 1.89×10^{-3} m^3/s (30 gal/minute) at 206.8 kPa (30 psig), pressurizes power fluid to the jet assembly located in the salt well screen. The power fluid passes through a nozzle in the jet assembly and converts fluid pressure head to velocity head, thereby reducing the pressure in the jet assembly chamber. The reduction in pressure allows the interstitial liquid to enter the jet assembly chamber and mix with the power fluid. Velocity head is converted to pressure head above the nozzle, lifting power fluid and interstitial liquid to the pump pit. Pumping rates vary from 3.15×10^{-6} to $\sim 2.52 \times 10^{-4}$ m^3/s (0.05 to ~4 gal/minute).

Raw water is used to fill the salt well jet pump system loop and prime the pump for operation. A recirculation loop permits the prime on the pump to be maintained at very low pumping rates. The energy produced by the pump's operation can heat the recirculated liquid about 16.67 °C (30 °F) above tank temperatures.

Important instrument and control systems at the tank associated with salt well pumping include the following: waste material leak detection; jet pump system controls, including limit switches and safety interlocks; and weight factor and specific gravity measurement.

Waste material leak detection, via a conductivity probe, is provided in each pump pit in the salt well system. The pump pit has a drain line connected back into the tank. Up to four salt well pumps are connected by manifold to a common waste transfer line. Leak detection in a single pit is interlocked to the pump in that pit, as well as all pumps on the same manifold to provide safe and orderly shutdown of the group in case any leak detector is activated. A flashing light and an audible alarm, located on top of the pump control station outside the pump pit area, alert tank farm operators to the shutdown condition. The interlocks that shut down the pumps respond to conditions that include the following: loss of pump outlet pressure, excess pressure in the flush leg, high pressure in the circulation loop, leak detection in the pump pit, limit switches, leak detection in a double-contained receiver tank, and double-contained receiver tank at maximum operating level.

Dip tubes that extend into the liquid waste through the salt well casing are used to measure the weight factor and specific gravity. These measurements are used to determine the liquid level in the salt well screen. Controllers are set to control the liquid level within the salt well screen a fixed amount above the jet intake.

Liquid observation wells may be installed by water lancing or by use of high-pressure sluicing nozzles (as described in Section 2.5 above). Liquid observation wells are sealed hollow tubes that penetrate to approximately the bottom of the tank. Essentially, they resemble an instrument tree with no internal measuring devices. A gamma or neutron probe is lowered through the liquid observation well. The probe interrogates the waste and can accurately determine the liquid level in the tank. In some cases, existing equipment such as a manual tape, may have to be removed before the liquid observation well can be installed. NOTE: The manual tape may not be permanently removed unless some alternate level device is installed at some other location in the tank.

2.6 GRAB SAMPLING

Grab sampling of tank waste is a standard tank farm activity when a sample of tank liquid or sludge is needed. Samples are taken from various depths in the liquid using a specially designed bottle.

A 100 mL glass sampling bottle with a rubber stopper is placed in a 5.1-cm (2-in.) steel pipe sleeve and manually lowered on a stainless steel wire into the waste. The grab sample may be taken in the salt well at the dip tube or any open riser. The weight of the pipe sleeve submerges the bottle. The wire is looped through the top of the rubber stopper and tied to the neck of the bottle. After lowering the bottle to the proper level, a quick jerk removes the rubber stopper and the bottle fills with liquid supernate. For sludges, a wide-mouthed bottle is used. After a bottle is filled, the bottle is manually pulled to the surface by a worker wearing protective gloves.

The sampling bottle is placed in an onsite transport cask and transported, in accordance with the approved procedures, to a laboratory for analysis.

2.7 AUGER SAMPLING

Auger sampling is employed primarily to investigate waste for potential energetic behavior. Auger samples are taken using a hand-operated device similar to a wood boring tool. Limited solid samples of the surface of the waste can be obtained by this method of sampling.

The auger sampler uses a guide tube that extends from the top of the riser to the waste surface. A detailed description of the guide tube assembly components, their assembly, and their removal can be found in Van Vleet (1991). Figures 2-6 and 2-7 show schematics of the complete assembly, which may weigh up to 114 kg (250 lbm). In some cases, existing equipment (e.g., the manual tape, the Food Instrument Corporation level-indicating device, or the breather filter) may have to be temporarily removed for the sampling activity. After the sampling is complete, the equipment would be replaced.

2.7.1 Installation or Removal

The auger sampler can be installed manually by adding one segment at a time or by crane. At least one lifting bar must be in place at all times during manual installation. Crane installation is performed according to established guidelines. Before installation (either manually or by crane), the adjustable flange is positioned so that the guide-tube tip is above the waste surface when the flange is bolted to the riser. Then the assembly is rotated so that the guide-tube tip touches the waste surface. The guide-tube assembly is disassembled by reversing the installation procedure. All equipment used in this sampling effort has been designed for decontamination and reuse or ease of disposal.

When the guide tube assembly is ready to receive the auger sampler, the retrieval cask (Figure 2-7) is raised manually and attached to the bushing on the guide tube via a connector.

To provide assurance during crane installation that the assembly could not be inadvertently dropped into the tank, the lift is a critical lift. This minimizes the likelihood of frictional heating, mechanical sparks, or impact heating from dropped objects. The assembly then is lowered until the rate-limiting nut is resting on the retrieval container. The assembly is detached from the crane; sampling then is performed. When sampling is complete, the auger assembly is removed using the reverse of the installation process. Segments are placed in plastic bags and packed into 0.21-m^3 (55-gal) drums for decontamination and reuse or disposal.

2.7.2 Description and Operation

The auger bit is 33.7 cm (13.25 in.) long with a diameter, not including the flights, of 2.54 cm (1 in.) with a bit on one end and a connector on the other end. The entire auger bit has been machined out of a solid, round, 400-series stainless steel bar. The diameter of the auger bit, including the flights, is 5.33 cm (2.1 in.). Figure 2-8 provides a schematic of the auger bit.

A floating sleeve covers the auger bit at all times except during sampling. The inner diameter of the floating sleeve is sized to just allow the auger flights to fit. The outer diameter is sized to allow the sleeve to travel freely in the guide tube assembly. The floating sleeve is designed to help ensure sample integrity during retrieval, i.e., crust material cannot fall off the flights while the auger sampler is being removed.

Figure 2-6. Guide Tube Assembly.

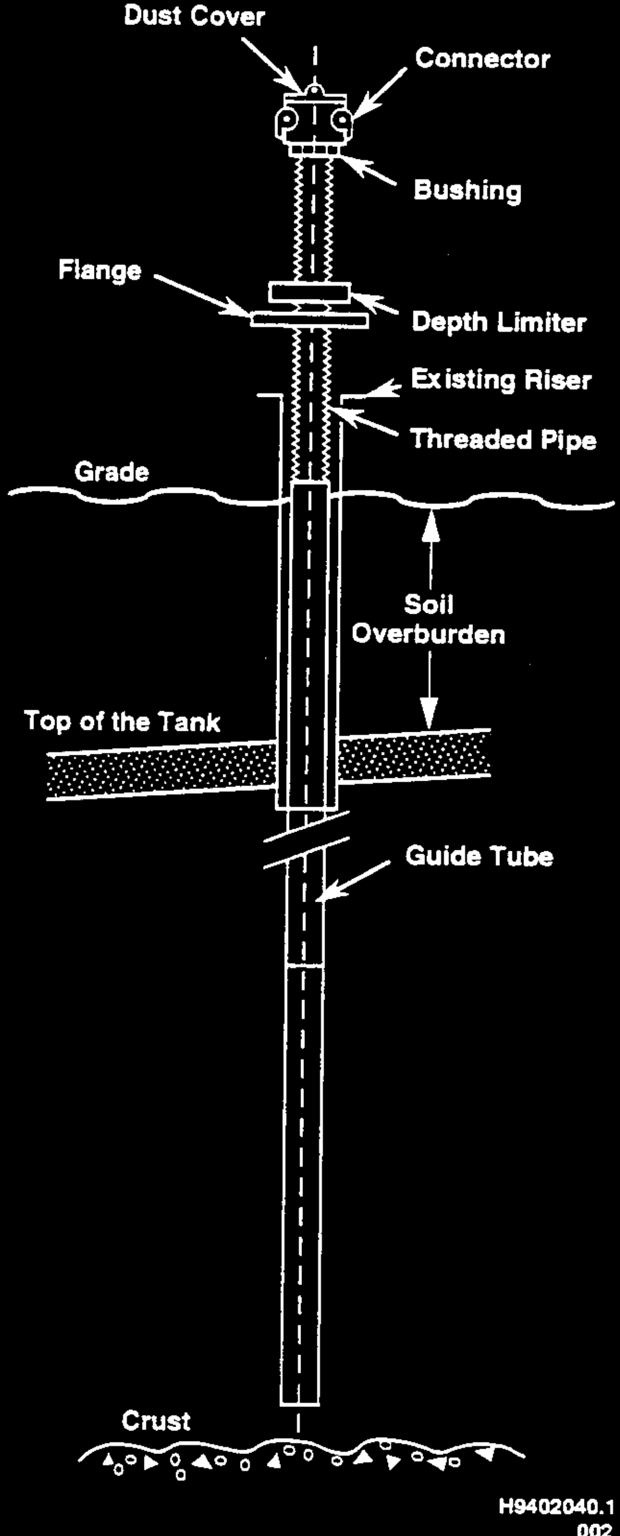


Figure 2-7. Auger Sampler Assembly.

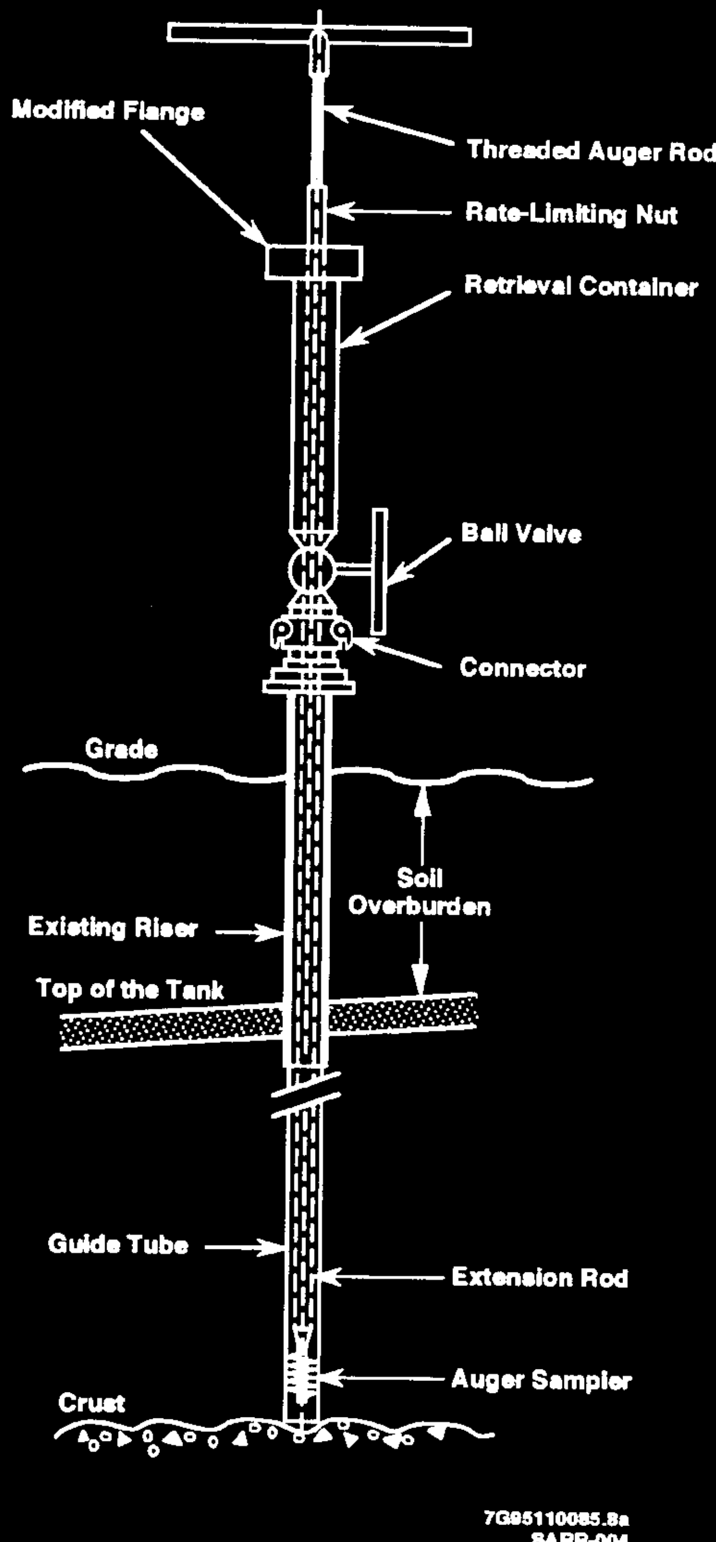
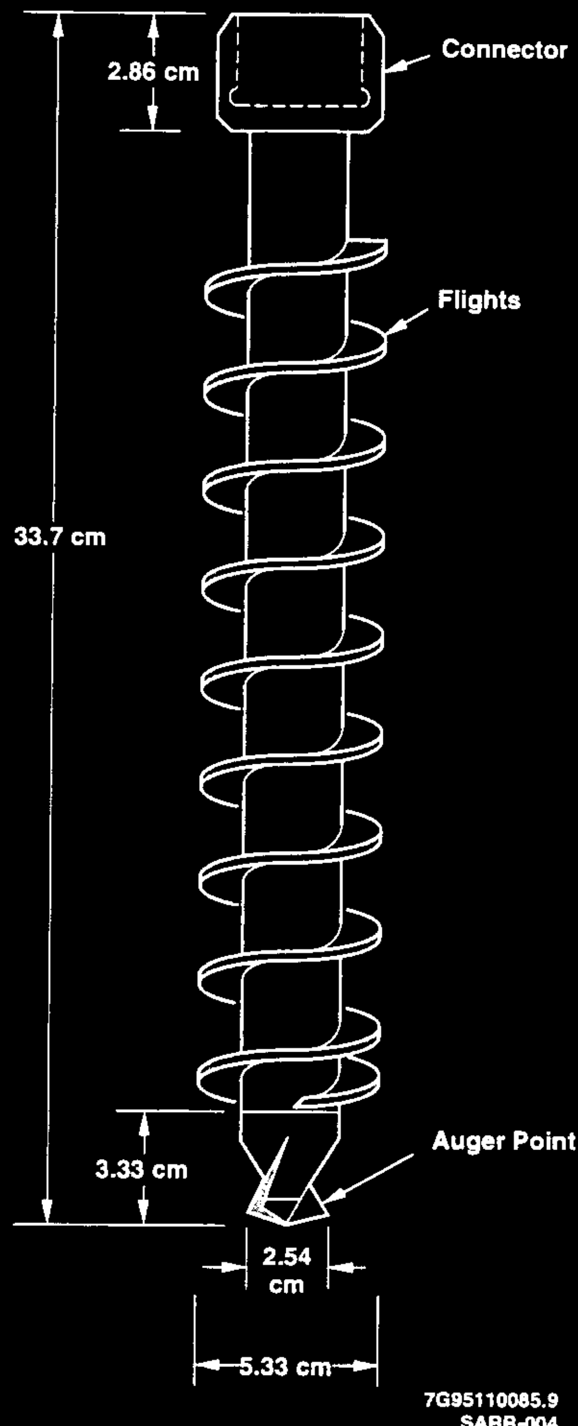


Figure 2-8. Schematic of the Auger Bit.



The auger is turned by hand using slow and deliberate motions. The last segment of the auger assembly consists of a threaded rod with a rate-limiting nut and two knurled nuts. The knurled nuts are used as a depth limiter. The rate-limiting nut is designed to fit into the modified flange plate. The threads limit how fast the auger can penetrate the crust. The two knurled nuts are adjusted so that they are up to 25.4 cm (10 in.) above the rate-limiting nut. Once the required sample depth of up 25.4 cm (10 in.) is reached, the auger assembly is manually raised using the "T" handle until the next segment of the extension rod is visible. The auger assembly then is withdrawn from the tank. The last segment is raised so that the auger bit is above the ball valve. The ball valve is closed and the auger bit lowered until it rests on the closed valve. The last segment of the auger extension rod is removed. The retrieval container is removed from the connector on the guide tube. The retrieval container is placed in an onsite transport cask and transported, in accordance with the approved procedures, to a laboratory for analysis.

2.8 PUSH-MODE CORE SAMPLING

While auger sampling allows a surface sample to be taken, push-mode core sampling is effective in retrieving sludge, cohesive solids, and liquids from a full-depth sample.

A core sampling truck provides the means to take a full-depth sample. A truck can operate in two modes: push mode and rotary mode. In push mode, the core sample is taken using hydraulic pressure to push the samplers through the waste. This works well for soft waste materials. For hard waste materials, other means of sampling may be required.

A rotary platform is mounted on the rear of the core sampling truck. Two sets of equipment are mounted on the rotary platform. One set is the shielded sample receiver unit that is used to place empty samplers into and remove full samplers from the drill string. The other set is the drill unit that is used to push the drill string and sampler into the material being sampled. A control console and electric hoist are also mounted on the rotary platform. Figure 2-9 shows a schematic of the core drill truck. Figures 2-10 and 2-11 show additional details. The following paragraphs briefly summarize the sampling procedure. A more detailed description can be found in Marusich (1991a) and Milliken (1995).

In some cases, existing equipment, e.g., the manual tape, the Food Instrument Corporation level-indicating device, or the breather filter, may have to be temporarily removed for the sampling activity. After the sampling is complete, the equipment would be replaced.

2.8.1 Installation

The first step of the installation process is to set up the equipment. The core drill truck is positioned over the chosen riser. The truck is leveled and the riser adapter, spray washer assembly, and pneumatic foot clamp are installed (see Figure 2-10b). The pneumatic foot clamp provides one of

Figure 2-9. Schematic of the Core Drill Truck.

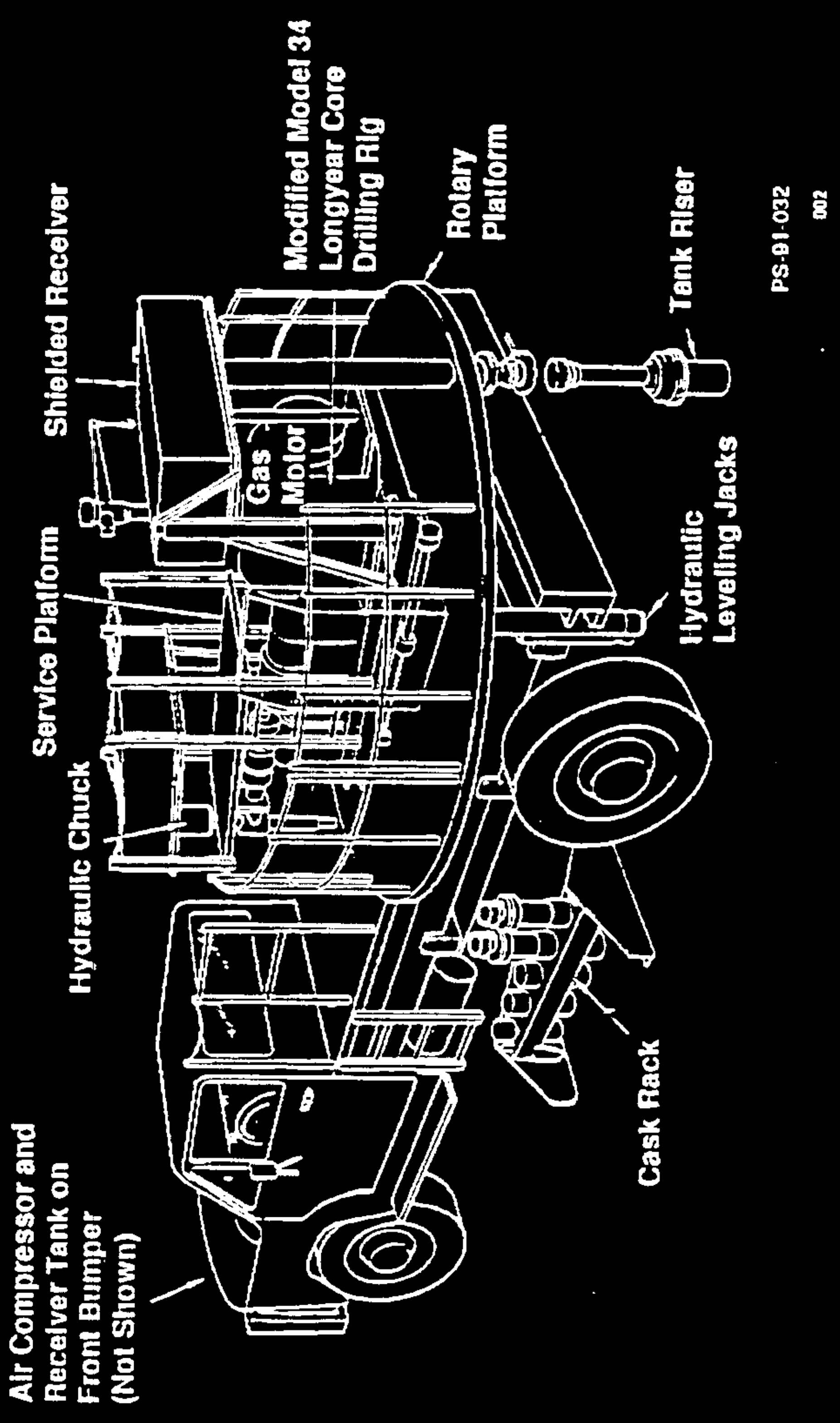


Figure 2-10. Shielded Receiver and Associated Equipment.

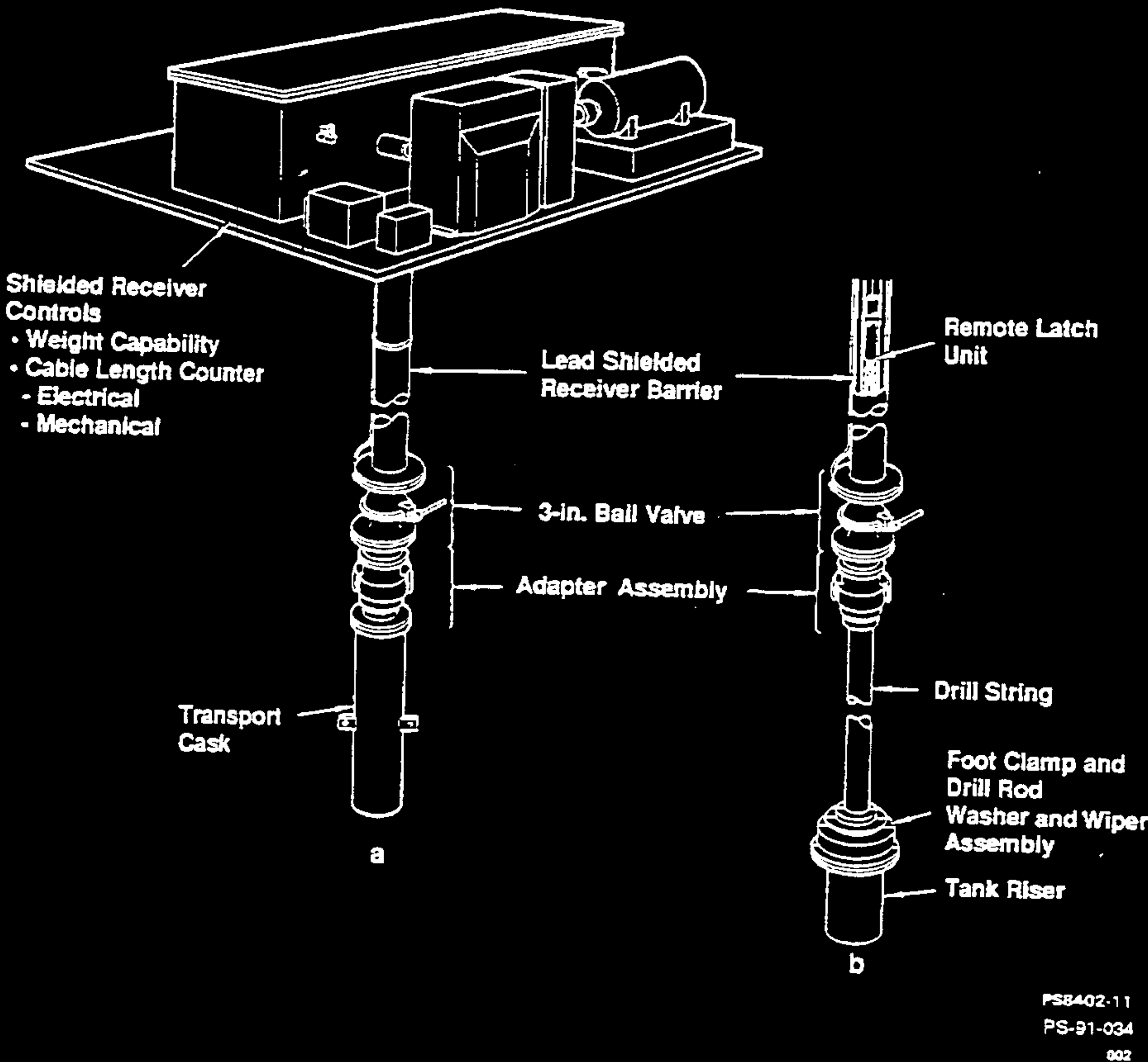
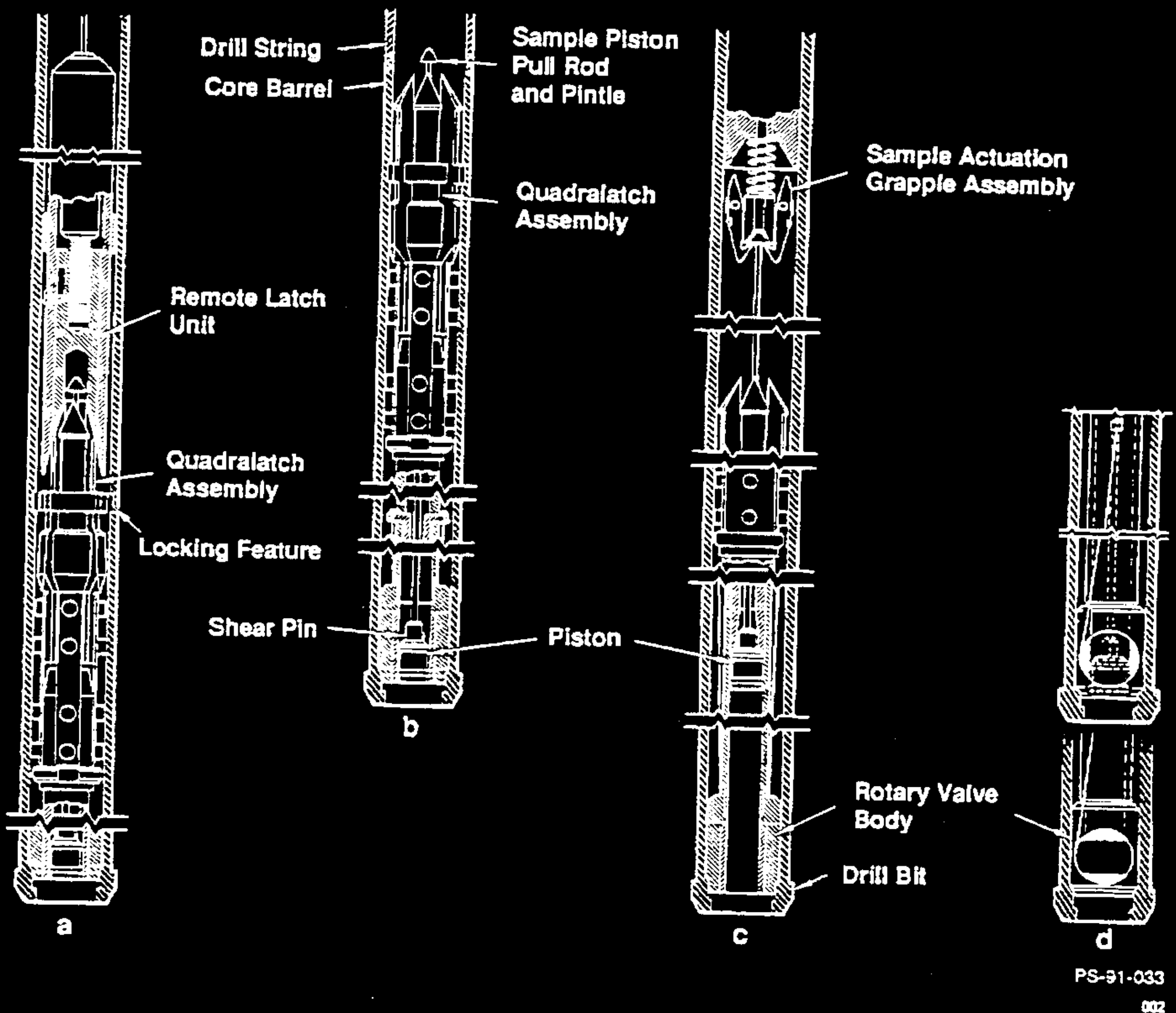


Figure 2-11. Core Sampler Assembly in the Drill String.



the physical restraints to prevent the drill string from being dropped into the tank during installation and removal. At that time, the truck is ready to perform core sampling.

2.8.2 Operation

To perform the sampling, the first core sampler is inserted into the drill string core barrel. The drill string is attached to the core barrel and then extended a section at a time. An electronic hoist and the pneumatic foot clamp are used to insert or remove the drill string. The drill string is lowered into the tank using the hoist, the pneumatic foot clamp is activated to physically restrain the drill string, and the hoist is disengaged. Then a new section of drill string is threaded onto the existing drill string, the hoist is reattached (providing a physical restraint to dropping the drill string), and the foot clamp is disengaged. This continues until the sampler is just above the surface of the waste. The distance to the surface of the waste is determined by using a manual tape and the drill string length work sheets specified in the work plan. The drill unit is attached to the drill string; the drill is not be rotated. Rotation is prevented by placing the drill speed control lever in neutral and installing a multilock device to prevent movement of the drill speed control lever. The device requires that both locks be removed before the drill speed control lever is accessed. The drill unit then pushes the drill string 48 cm (19 in.) into the waste (See Figures 2-11b and 2-11c). A rotary valve is closed at the bottom of the sampler (See Figure 2-11d), hydrostatic fluid is added inside the drill string to prevent waste from filling the drill string while the sampler is removed and a new sampler is installed, and the drill string is detached from the drill unit.

The platform is rotated so that the shielded receiver (see Figure 2-10a) is over the drill string. The sampler is raised into the shielded receiver. A ball valve is closed at the bottom of the shielded receiver. A cap with an absorbent sponge is attached to the bottom of the shielded receiver. The platform is rotated to position the shielded receiver over the empty transfer cask. The cap is removed and the sampler is lowered into the transfer cask. A new sampler is placed in the core barrel (See Figure 2-11a). The total process is repeated until a full core sample is obtained.

2.9 ROUTINE MAINTENANCE AND SURVEILLANCE

Activities with no direct communication with the tank vapor space or primary tank ventilation system (e.g., measurements for dome subsidence, and taking instrument readings) have different controls than the controls for flammable gas tanks. For example, if the equipment is isolated from the vapor space or the ventilation system by an isolation valve, bonding generally is not required.

The following are preventive maintenance activities. They are necessary to maintain the tank ventilation system and monitoring equipment in their optimal configurations. This ensures that the tank remains operable and helps maintain the safety basis.

2.9.1 Ventilation and Balance Activities for Actively Ventilated Tanks

One required activity on tanks containing active ventilation is testing the high-efficiency particulate air filters to measure the filtration efficiency of either a single filter or a bank of filters. This involves removing the aerosol test plugs located both upstream and downstream of the filter or filter bank. A nonflammable aerosol is then injected into the ventilation duct through the upstream aerosol port. A penetrometer photometer is placed in the downstream aerosol port; it measures the amount of aerosol exiting the filter. On completion of the measurements, the penetrometer probe is removed and both the upstream and downstream aerosol test plugs are replaced. If the aerosol testing indicates that the filter is breached or plugged, the high-efficiency particulate air filter is changed.

Air flow is measured to determine the rate and distribution of exhaust flow within the ventilation ducting. Typically, flow rate and distribution measurements are made within the ventilation system exhaust stacks and in each tank exhaust header. The measurement is made by removing an access port plug, inserting a pitot tube, and traversing the ventilation duct cross section with the pitot tube. At prescribed intervals, the pressure reading from the pitot tube is recorded. The pressure reading is used to calculate equivalent flow velocities. These calculated velocities are then integrated to determine the total volumetric flow rate of the gas passing through the ventilation duct. On completion of the required measurements, the pitot tube is removed and the access port plug is replaced.

Psychrometric readings, i.e., the temperature and humidity of the exhaust vapors leaving the tank, are also measured as the need arises. An access port plug is removed and ambient wet and dry bulb temperatures are measured within the ventilation duct and recorded. On completion, the access port plug is replaced.

2.9.2 Ventilation Activities for Passively Ventilated Tanks

Passively ventilated tanks also must undergo aerosol testing of the high-efficiency particulate air filter (sometimes referred to as the breather filter). This testing measures the filtration efficiency of the single high-efficiency particulate air filter. Because the tank is passively ventilated, i.e., atmospheric pressure changes force air into and out of the tank, a few additional steps are required to test the high-efficiency particulate air filter. This involves isolating the filter assembly from the tank with an isolation valve. A nonflammable aerosol is injected into the ventilation duct through the upstream aerosol port that is typically located in the flexible tubing connecting the portable exhauster to the filter assembly. A penetrometer photometer is placed in the downstream aerosol port or at the filter assembly exhaust port; it measures the amount of aerosol exiting the high-efficiency particulate air filter. Certain types of filters are also equipped with differential-pressure monitoring devices. These are also tested during this operation. When the measurements are complete, the penetrometer probe is removed and any aerosol test plugs are replaced. If aerosol testing indicates that the high-efficiency particulate air filter is breached or plugged, the filter is changed. The high-efficiency particulate air filter also is changed if it had reached the limit for radioactive loading.

2.9.3 Instrument Testing, Calibration, and Repair or Replacement

Repair or calibration of instruments in the active ventilation system requires disconnecting the instrument lines from the tank to the instrument cabinets. After the instrument lines are disconnected, the instruments are tested, calibrated, and repaired or replaced. Instrument lines are generally 0.64 cm (0.125 in.) in diameter. While the instruments are disconnected there is a direct opening into the tank. Sampling lines may range up to 2.54 cm (1 in.) in diameter. Sampling equipment is then tested, calibrated, and repaired or replaced. Again, while the sampling equipment is disconnected, there is a direct opening into the tank. However, when the ventilation system is operating, all airflow is into the tank or the ventilation duct because the ventilation system operates at negative pressure. After testing, the instruments and sampling equipment are reconnected to the tank and/or ventilation system. NOTE: If the equipment is isolated from the vapor space or the ventilation system (either passive or active) by an isolation valve, bonding generally is not required.

2.9.4 Level-Indicating Device Flushing, Repair, or Replacement

Accumulation of an icicle or lollipop shaped salt crystal deposit on the plummet of the level-indicating devices is a common occurrence. Most Food Instrument Corporation devices are equipped with a water flushing ring assembly to remove the deposit as the measuring tape is reeled into the housing. Flushing water is supplied from the tank farm water supply or a tank truck.

Most manual-tape level-indicating devices and a few Food Instrument Corporation devices do not have a flushing ring assembly. These are flushed by opening a port on the housing and inserting a water hose. Water is supplied from the tank farm water supply or a tank truck.

Up to 758 L (200 gal) of water are used each time to flush the salt crystals off the plummet of level-indicating devices. Adding water to the tank because of routine maintenance is an allowed operation, but is to be minimized.

Some repair activities on the level-indicating devices involve opening the device housing, which is mounted on a tank riser. This is required for removing or replacing electrical boards on Food Instrument Corporation devices; and for removing or replacing metal tapes, tape reels, or plummets on Food Instrument Corporation devices or manual-tapes.

Other activities can include replacing the entire level-indicating device (housing and contents) with a similar system, or a new type device (e.g., Enraf displacement gauge). In addition, new or old type level-indicating device may be installed on risers not presently containing a device.

The Enraf gauge works by measuring the tension in a wire supporting a displacer (a cone-shaped plummet), which rests on the waste surface. Changes in the surface level are detected by changes in the tension in the wire. The Enraf assembly is installed on a riser spool piece containing an isolation valve, a flushing ring assembly, and a sight glass. The Enraf system may also be equipped with a pressure sensor to monitor the pressure in the tank.

After the Enraf displacer is reeled into the Enraf housing and the isolation valve closed, the Enraf housing is isolated from the tank vapor space, and repair or replacement of items in the housing may be performed without vapor space flammable gas controls.

2.9.5 Liquid Observation Well Measurements

In some tanks, the liquid level is below the solids level in the tank. A measurement with a Food Instrument Corporation level-indicating device or a manual tape would only detect the solid surface. Therefore, the only way to measure the liquid level in the tank is to use the liquid observation well. The liquid observation well penetrates the waste to approximately the bottom of the tank. It is a sealed unit; and, under normal conditions, the inside has no contact with the contents of the tank. To measure the liquid level, a gamma/neutron probe is lowered into the liquid observation well. The probe interrogates the waste by emitting neutrons and recording their effects on the waste or by detecting natural gamma radiation levels. The level of the liquid waste within the solids can be determined using this method.

3.0 IDENTIFICATION OF HAZARDS

Potential hazards, equipment failures, and ignition sources associated with the activities in single-shell tanks with flammable gas concerns are identified in Table 3-1. Table 3-1 also lists the potential results and conditions necessary safety controls, and cites reference information. An evaluation of each hazard is covered in Chapter 4.0.

Waste intrusive activities may trigger a gas release event (see Section 1.3 for retention mechanisms). This release may be significant in volume and have high hydrogen concentrations along with ammonia, methane, carbon monoxide, and oxidizers of oxygen (from the air in the tank) and nitrous oxide (produced in the waste) (see Appendix B). The activity also is likely to produce a spark source. The amount of flammable gas that, if ignited, would generate a pressure pulse large enough to collapse the dome is small (around 16 m^3 or 570 ft^3). Table 3-1 identifies these and other potential results and conditions. Consequences are calculated and reported in Chapter 5.0.

Table 3-1. Evaluation Of Hazards For Single-Shell Tanks Flammable Gas Concerns. (4 sheets)

Items addressed	Potential results/conditions	Safety controls	Reference information
Electrostatic spark	Ignites flammable gases if present in sufficient concentrations to support combustion.	(1) Electrostatic grounding and bonding. (2) Ventilation system operable. (3) Riser purged before activity. (4) Continuous monitoring of flammable gases by two separate independent monitors is required.	See Section 4.1 and WHC-SD-WM-SAD-003 (Marusich et al. 1991)
Electric spark from in-tank equipment	Ignites flammable gases if present in sufficient concentrations to support combustion.	Existing equipment in the tanks has been evaluated and shown to be able to operate in a flammable atmosphere or it has been deenergized. New equipment must be designed for flammable atmospheres.	See Appendix A.
Mechanical spark or frictional heat during installation or removal	Ignites flammable gases if present in sufficient concentrations to support combustion.	Installation or removal occurs when flammable gas concentrations capable of supporting combustion are not present initially and conditions are continuously monitored during activity.	See Sections 4.2 and 4.4.
Failure (1) Standard hydrogen monitoring system	(1) Loss of hydrogen monitoring.	(1) Continuous monitoring of flammable gases by two separate independent monitors is required for work to continue.	(1) See Sections 4.3.1 and 6.1.3.
(2) Tank vapor space sampling	(2) Loss of vapor space characterization.	(2) None needed. Workers protected by work space monitoring.	(2) See Sections 4.3.2 and 6.1.4.
(3) Camera	(3) No photographs of inside of tank.	(3) None needed. Inspection of the waste is not required.	(3) See Section 4.3.3.
(4) Video Camera	(4) No video surveillance of the inside of tank.	(4) None needed. Inspection of the waste is not required.	(4) See Section 4.3.3.
(5) Instrument tree	(5) Loss of temperature and possibly gas measurements.	(5) Temperature measurements are required from at least one thermocouple in the waste.	(5) Single-shell tank Interim Operational Safety Requirements.
(6) Salt well screen	(6) No way to emergency pump tank.	(6) None needed. Salt-well can be replaced.	(6) See Sections 4.3.5 and 6.2.5.
(7) Auger sampling	(7) No sample to analyze.	(7) None needed due to design and operation. Grab sampling may be used if auger sampling fails.	(7) See Sections 4.3.6, 6.2.6 and 6.2.7.
(8) Push-mode sampling	(8) No sample to analyze.	(8) None needed. Broken components can be replaced and sample retaken.	(8) See Sections 4.3.7 and 6.2.8.

Table 3-1. Evaluation Of Hazards For Single-Shell Tanks Flammable Gas Concerns. (4 sheets)

Items addressed	Potential results/conditions	Safety controls	Reference information
Normal gas release event or activity-induced gas release event	Gas release event produces flammable gas concentrations capable of supporting combustion during activity.	The standard hydrogen monitoring systems on 19 single-shell watch list tanks have logged an equivalent of several years worth of data. Thus far, no gas release events have been recorded. However, releases where the concentration is at or above the lower flammable limit may occur. Therefore: (1) Ignition prevention measures are required for in-tank activities and equipment. (2) Continuous monitoring of the flammable gas concentration in the tank by two, separate, independent monitoring systems is required during any in-tank activity. (3) The number of in-tank activities is minimized.	See Sections 1.3 and 4.4; LA-UR-94-1323 (LANL 1994) (1) See Sections 6.1.1, 6.1.2, 6.1.3, 6.1.5 and 6.2. (2) See Section 6.1.3.
Toxic gas release event during activity	Exposure to occupational worker during activity, e.g., sluicing operations during installation of instrument tree, liquid observation well, or salt well screen and during core sampling.	Entry and monitoring as required by the Tank Farm Health and Safety Plan	WHC-SD-WM-HSP-002 (Carls 1995)
Toxic gas release during a deflagration	Exposure to occupational worker and/or the onsite receptor at 100 m due to toxic chemicals produced and released during a deflagration.	Occupational workers wear personal protective equipment as required by the Tank Farm Health and Safety Plan. Onsite receptors are protected through emergency preparedness. Additionally, the frequency of a deflagration is reduced by: (1) Ignition prevention measures are required for in-tank activities and equipment. (2) Continuous monitoring of the flammable gas concentration in the tank by two, separate, independent monitoring systems is required during any in-tank activity. (3) The number of in-tank activities is minimized.	WHC-SD-WM-HSP-002 (Carls 1995) (1) See Sections 6.1.1, 6.1.2, 6.1.3, 6.1.5, and 6.2. (2) See Section 6.1.3.

Table 3-1. Evaluation Of Hazards For Single-Shell Tanks Flammable Gas Concerns. (4 sheets)

Items addressed	Potential results/conditions	Safety controls	Reference information
Flammable gas buildup in equipment	Flammable gas buildup has been detected in liquid observation wells and the core drill string. Buildup in the drill string has been detected only when the truck was not in the sampling mode (i.e., no purge gas or hydrostatic fluid was flowing and a sampler was not installed in the drill string). Buildup in the liquid observation well was observed only in one that was known to have failed and potentially had waste material in the lower portion. A spark source could cause a deflagration in the equipment. The potential for a detonation is currently under evaluation.	Monitoring of the flammable gas in the liquid observation well or drill string shall occur before work starts or resumes. If concentrations above 25% of the lower flammability limit are found, the equipment should be purged. Work shall not restart until the concentration is below 25% of the lower flammability limit by two consecutive readings.	See Sections 6.2.8 and 6.2.9.
Damage to tank (1) Riser	(1) Drop of equipment damages riser.	(1) Riser damage temporarily can be fixed by using a thick flexible gasket or by placing a plastic glove bag around the damaged riser. Additionally, all crane lifts are critical lifts.	(1) See Section 4.7.
(2) Tank liner	(2) (a) Impacts on tank liner may cause breach of liner. (b) Ultra-high-pressure nozzle may cause erosion of tank liner	(2) (a) All crane lifts are critical lifts. (b) Pressure is reduced when the instrument tree flange is 30.5 cm (1 ft) above the riser flange, i.e., this means that the bottom of the equipment being installed is at least 30.5 cm above the tank liner.	(2) See Sections 6.2.1, 6.2.2, 6.2.3, 6.2.4, 6.2.5, 6.2.7, and 6.2.8.
(3) Pump pit	(3) Drop of cover plates or equipment damages the pump pit.	(3) All crane lifts are critical lifts.	(3) See Sections 6.2.1, 6.2.2, 6.2.3, 6.2.4, 6.2.5, 6.2.7, and 6.2.8.
(4) Tank dome	(4) (a) Dome is overloaded and fails. (b) Impact of dropped equipment causes dome collapse. (c) Deflagration in the tank causes dome collapse.	(4) (a) Dome loading is controlled. (b) All crane lifts are critical lifts. (c) Ignition prevention measures are required for in-tank activities and equipment. Continuous monitoring of the flammable gas concentration in the tank by two, separate, independent monitoring systems is required during any in-tank activity. The number of activities is restricted.	(4) (a) See Sections 4.8 and 6.1.6. (b) See Sections 6.2.1, 6.2.2, 6.2.3, 6.2.4, 6.2.5, 6.2.7, and 6.2.8. (c) See Sections 6.1.1, 6.1.2, 6.1.3, 6.1.5, 6.2, and Appendix A.

Table 3-1. Evaluation Of Hazards For Single-Shell Tanks Flammable Gas Concerns. (4 sheets)

Items addressed	Potential results/conditions	Safety controls	Reference information
Impact from waste berg inside tank	Ignites flammable gases if present in sufficient concentrations to support combustion and impact generates spark.	Cannot be prevented, although considered unlikely; new, permanently installed equipment is made of spark resistant material and is designed to withstand impact.	See Section 4.8; LA-UR-92-3196 (LANL 1995)
Stratification	Hydrogen becomes stratified in the tank because of thermal stratification, i.e., the temperature of the outside air is the same, greater or less than the temperature of the waste. This potentially provides a layer of gas that is at a concentration capable or supporting combustion.	(1) Electrostatic grounding and bonding. (2) Ventilation system operable. (3) Riser purged before activity. (4) Continuous monitoring of the flammable gas concentration in the tank by two, separate, independent monitoring systems is required during the activity is required.	See Sections 4.9, 6.1.1, 6.1.2, 6.1.3 and 6.1.5; Marusich (1991b); and LA-UR-92-3196 (LANL 1995)
Lightning during an activity	Lightning strikes tall equipment as it is inserted into or removed from a tank. This potentially provides an ignition source for flammable gases if they exist in concentrations capable of supporting combustion.	Annual frequency was calculated to be incredible ($<10^{-6}$); however, two controls are imposed. (1) lightning watch (2) grounding equipment for lightning strikes	See Sections 4.10 and 6.2; Powers (1992)
Spill of sample material	As the sample is transferred from the riser to the onsite transport cask, the inadvertent partial or full spill of the sample on the ground could occur.	None needed because ground contamination is covered by standard operating procedures.	See Section 4.11.
Seismic	Dynamic or impact loads from permanent equipment.	None needed because there is a standard operating procedure to cease all activities in tank farms if there is an earthquake.	See Section 4.12

This page intentionally left blank.

4.0 HAZARD ANALYSIS

Potential hazards, equipment failures and ignition sources associated with activities in the single-shell flammable gas tanks are identified in Table 3-1. Table 3-1 also lists the potential accidents, failure consequences, necessary safety controls, and the existing supporting analysis. An evaluation of activities associated with tanks having a flammable gas concern is covered in the following sections.

4.1 ELECTRICAL AND ELECTRO SPARKS

Earlier analysis (Marusich et al. 1991) showed that grounding and bonding and using conductive plastic to prevent electrostatic buildup reduced the possibility of ignition sources in the tank. The analysis was nonspecific; that is, even though the document was for a double-shell tank, it is entirely applicable to a single-shell tank.

Grounding and bonding procedures, as described in the appropriate National Fire Protection Association code sections for electric bonding requirements in classified environments, will prevent the discharge of electrical sparks. Therefore, if these procedures are followed, ignition of flammable gases by electrical or electrostatic sparks is considered to be an incredible event.

For example, during vapor space sampling the Tygon*, or Tygon-equivalent, non-conductive to dissipate tube is wire wrapped electrostatic buildup and the wire bonded and grounded. The question of electric sparks relating to existing equipment has been reviewed (Scaief 1994). Certain equipment has been determined to represent spark sources and has been deenergized or removed. Other equipment has been analyzed to show it can safely operate in flammable gas atmospheres.

However, electrostatic sparks can never be eliminated totally or discounted. Therefore, a deflagration may occur and consequences are calculated in Section 5.3.

4.2 MECHANICAL SPARKS AND FRICTIONAL HEATING

A mechanical spark potentially could be created by dropping the equipment onto the riser or by swinging equipment in the riser while it is being installed or removed. The likelihood of dropping a crane load was judged by Farley (1992) to be 2.7×10^{-5} per lift (see discussion in Section 4.8). Sparks produced by swinging are minimized by requiring equipment to be made out of spark-resistant material and by requiring installation to proceed slowly and deliberately (see Sections 6.2.1, 6.2.2, 6.2.3, 6.2.4, 6.2.5, 6.2.6, and 6.2.7).

---

*Tygon is a trademark of Norton Company.

Calculations in Sontag (1991) show that 2.55 x 10^6 joules (1.88 x 10^6 ft-lb) of frictional energy would be required to heat the edge of the riser to 800 °C (1472 °F), the autoignition temperature of a hydrogen-air mixture from small spheres or bars. Because the contact area is small, the velocity of the object must be very fast to obtain this much frictional energy.

Laboratory testing was done to qualify the auger (Griffin 1991). The temperature of the auger bit was measured during testing that was more severe than the field conditions. This testing indicated that there would be no possibility of an ignition caused by frictional heating during auger sampling because the temperature increase was only 8 °C (15 °F).

During push-mode sampling, localized heating of the waste may be a result of the friction of pushing the sampler through the waste. Extensive tests were run to determine the effect of frictional heating on the drill face surface and the waste simulant. The testing was conducted in three simulants: a sludge, a soft salt cake, and a hard salt cake. The results (Milliken 1995) indicated that there is no temperature increase from push-mode sampling the sludge simulant, there is a 6-°C (11-°F) temperature increase in the soft salt cake simulant, and there is a 22-°C (40-°F) temperature increase in the hard salt cake. These temperature increases correspond to the maximum temperature increases seen during sampling of simulants. They are considered upper bounds because the sampling was done at penetration rates that are higher than those allowed in the field. Thus, these tests indicate that push-mode sampling of the single-shell flammable gas tanks would be expected to generate little or no frictional heating. The possibility of an ignition caused by frictional heating during push-mode core sampling is an incredible event.

Activities will not occur in the tank if the measured flammable gas concentration is at or above 25 percent of the lower flammability limit (see Section 6.1.3 and Appendix B).

However, the controls for insertion speed and critical lifts are administrative controls. Therefore, a mechanical spark is credible and consequences from a deflagration are calculated in Section 5.3.

4.3 EQUIPMENT FAILURE

Each system described in the following subsections could fail or be installed improperly and generate ignition sources. Therefore, consequences from a deflagration are calculated in Section 5.3.

4.3.1 Failure of the Standard Hydrogen Monitoring System

Earlier analysis of a similar temporary gas monitoring system identified two hazards (Deere 1991). These hazards were the release of radioactive material and the potential ignition of flammable gases in the sample lines. Deere (1991) calculated that the consequence of a release of radioactive material from the sample lines was negligible (i.e., much less than dose consequences caused by normal background radiation levels). In addition, the frequency calculated for ignition was found to be incredible ($<10^{-6}$) (Deere 1991); therefore, the ignition of flammable gases in the sample line needs no further consideration.

Failure of the system to perform its intended function caused by failure of one of the system components also must be considered. One of the controls (see Section 6.1.3) for performing activities in the single-shell flammable gas tanks is to continuously monitor the concentration of flammable gases in the vapor space of the tank with two separate, independent monitors during any activity. For example, if monitoring is being done with a standard hydrogen monitoring system and a hand-held combustible-gas meter, and if the standard hydrogen monitoring system has failed, the control can be satisfied by using a second hand-held combustible-gas meter positioned so that the sample is being drawn from the tank at approximately the same location as the standard hydrogen monitoring system would draw its sample. The standard hydrogen monitoring system would be repaired or replaced.

4.3.2 Failure of Vapor-Space Sampling System

The vapor-space sampling activity provides characterization data on the vapor space of the tank. The instruments used for this activity include a combustible-gas meter, an organic vapor monitor, a vacuum pump, colorimetric tubes, the Tygon or Tygon-equivalent tubing and other miscellaneous devices. Failure of any of these devices is detectable and will not have any significant consequences for the work being performed because these measurements are not used for safety controls. In addition, while the workers are collecting data, the work site will be monitored for toxicological and radiological constituents in accordance with the Tank Farm Health and Safety Plan (Carls 1995) and the *Hanford Site Radiation Control Manual* (HSRCM 1994).

4.3.3 Failure of Photographic Equipment

The photographic equipment to be used in the flammable gas tanks must meet the requirements of National Fire Protection Association's National Electric Code, Article 501 for use in Class I, Division 2, Group B (flammable hydrogen environment), therefore an ignition in the vapor space from camera operations is judged to be an incredible event. In addition, electrical power will be off during installation and removal of this equipment.

4.3.4 Failure of the Instrument Tree

The failure of individual thermocouples or resistance temperature detectors in the instrument tree would not create a problem. Currently the single-shell tank Interim Operational Safety Requirements are met as long as at least one thermocouple or resistance temperature detector is functioning below the waste surface. If thermocouples or resistance temperature detectors fail, the instrument tree would likely be replaced. A failed instrument tree is not a hazard. NOTE: removal of the failed instrument tree would need to have separate safety documentation because this document only covers installation of instrument trees.

4.3.5 Failure of the Liquid Observation Well, Salt Well Screen, and/or Jet Pump

Liquid observation wells have failed in the past. A failed liquid observation well could contain flammable gases. Measurements of the two failed liquid observation wells in tank 241-SX-104 have confined the presence of flammable gases. In addition, if the liquid observation well is in contact with subsurface gas storage structures, the gas will diffuse through the wall of the liquid observation well. Thus, there is a credible case where nonrated equipment will be inserted into a potentially flammable atmosphere. A control to measure for flammable gases before entering the liquid observation wells has been imposed (see Section 6.2.9). The failure of liquid observation wells causes a loss of liquid-level monitoring. Previously, the failed well has been left in the tank and a new liquid observation well has been installed. At some time, failed liquid observation wells may be removed. At that time, safety documentation will be prepared for the removal activity.

If a salt well screen assembly failed, it would affect the ability to emergency-pump the tank. If this were the case, documentation would need to be developed to discuss how the failed salt well screen assembly would be removed. The tank would only be emergency-pumped if convincing evidence were presented to show that the tank was leaking waste. There appear to be unique hazards and questions about the long-term behavior of the tank waste after the interim stabilization that need to be answered. NOTE: This document only addresses the installation of salt well screen assemblies.

Failure of the jet pump assembly would also affect the ability to emergency-pump the tank. However, most of the jet pump components are in the central pump pit (see Figure 13). These components are easily replaced. Failure of the components intruding into the waste (foot valve, jet assembly, weight factor tube, and specific gravity tube) could also occur. A removal procedure following the controls in Chapter 6.0 would allow safe removal and replacement of these components as well.

4.3.6 Failure of the Auger Sampler

The auger can fail to perform functionally; i.e., the auger does not deliver a sample because the waste surface is similar to a liquid and no sample stays attached to the auger flights. If no sample is retrieved, the course of action would be to resample using the auger sampler. If the additional tries also failed, the guide tube assembly and auger assembly would be removed and an alternative method of sampling may be chosen (such as waste grab sampling as described in Section 2.7).

4.3.7 Failure of the Push-Mode Core System

The drill string in the push-mode core system could buckle and fail at 16 kN (3,600 lbf) if it is not constrained by waste (Milliken 1995). However, actual damage to the drill string is not a concern for this assessment because it does not result in a propagating exothermic waste surface reaction, an ignition of flammable concentrations of gases, a toxic gas release, or a spill of radioactive material. In addition, the tank confinement can be restored by using a split spool piece to seal around the drill string until the bent drill string can be removed from the tank.

Flammable gas buildup has been observed in the drill string; however, drill string flammable-gas measurements have only recently been required. The occurrence of flammable gas above the lower flammability limit has happened three times in the recent past. Additionally, there are components such as the remote latching unit that are not rated for flammable gas environments. However, the buildup of gas has occurred only while the drill string was inactive. While sampling is ongoing, purge gas or hydrostatic fluid floor will keep flammable gases from building up. It is only when the drill string is inactive and a sampler is not installed in the drill string (O-ring seals keep gas from entering the drill string) that this is a problem. Therefore, to prevent an accident if the drill string has been inactive, a measurement of the concentration in the drill string will be made. If the reading is above 25 percent of the lower flammability limit (as defined in Appendix B) the drill string will be vented. Purge intervals are defined in Appendix C. Purging will continue until two consecutive measurements are less than 25 percent of the lower flammability limit (as defined in Appendix B). Work then can continue.

4.4 GAS RELEASE EVENT DURING ACTIVITY

Section 1.3 described some mechanisms for gas retention and release. The mechanisms of most concern is a 'chimney' being introduced by an activity allowing gas trapped in a dendritic bubble structure to be released. Los Alamos National Laboratory has provided estimates of releasable gas volumes for single-shell tanks. In particular, Los Alamos National Laboratory evaluated the 19 single-shell flammable gas watch list tanks (LANL 1995). The tanks have been separated into four categories. The first category contains tanks that do not appear to experience episodic behavior nor do they exhibit long-term growth in the waste level. The second category contains tanks for which the data are available to evaluate the behavior of the waste, but provide no firm conclusions. There are 5 tanks in category 2. Tank 241-AX-101 has a liquid level below the solids level. The liquid observation well data indicate that the liquid level has been constant. Tanks 241-SX-101 and 241-SX-104 also have liquid levels below the solids levels. There are no liquid observation well data available for either of these tanks. Tanks 241-SX-102 and 241-SX-105 have decreasing surface level trends. The third category contains tanks that are potentially exhibiting episodic gas-release behavior. The last category contains tanks that exhibit long-term waste growth but do not appear to exhibit episodic gas-release behavior. Table 4-1 presents this information.

Postulated gas release amounts are shown for only those tanks with enough information to calculate how much could be released, i.e., the tanks in categories 3 and 4 (LANL 1995). In these tanks, the level growth was attributed to stored gas. This gas would be stored under greater hydrostatic pressure than the tank waste provides. NOTE: The percent hydrogen was calculated very conservatively by assuming that the release was instantaneous and that the entire amount of gas released was hydrogen.

Table 4-1. Single-Shell Flammable Gas Watch List Tank Parameters. (2 sheets)

Tank	Los Alamos National Laboratory category[d]	Vapor space volume (m^3)	Gas release volume (m^3)	Gas release event		Calculated steady-state hydrogen concentration (%)[c]	Measured steady-state hydrogen concentration (%)
				Hydrogen concentration (%)[a]	Hydrogen concentration (%)[b]		
101-A	3	1,454	79	5.43	1.54	7.80	0.113
101-AX	2	2,481	--	--	--	2.12	0.006
103-AX	1	4,892	--	--	--	0.21	0.003
102-S	4	1,955	214	10.94	3.11	1.12	0.059
111-S	1	916	--	--	--	1.47	0.006
112-S	1	760	--	--	--	1.27	0.003
101-SX	2	3,283	--	--	--	0.63	0.001
102-SX	2	2,953	--	--	--	1.62	0.002
103-SX	1	2,540	--	--	--	6.06	0.003
104-SX	2	2,684	--	--	--	1.13	0.001
105-SX	2	2,422	--	--	--	3.37	0.001
106-SX	1	2,972	--	--	--	0.46	0.003
109-SX	1	4,064	--	--	--	0.93	0.001

Table 4-1. Single-Shell Flammable Gas Watch List Tank Parameters. (2 sheets)

Tank	Los Alamos National Laboratory category[d]	Vapor space volume (m^3)	Gas release volume (m^3)	Gas release event: Hydrogen concentration (%)[a]	Gas release event: Hydrogen concentration (%)[b]	Calculated steady-state hydrogen concentration (%)[c]	Measured steady-state hydrogen concentration (%)
110-T	4	1,738	22	1.28	0.36	0.56	0.001
103-U	4	1,401	83	5.94	1.69	0.92	0.071
105-U	4	1,590	117	7.35	2.09	0.89	0.063
107-U	4	1,636	137	8.39	2.38	0.42	0.032
108-U	4	1,401	44	3.11	0.89	0.65	0.046
109-U	4	1,420	28	1.94	0.55	0.60	0.042

[a] Slurry gas composition is assumed to be 100 percent hydrogen.

[b] Slurry gas is assumed to have the conservative gas mixture composition (LANL 1995). In this mixture, the hydrogen constitutes 28.42 percent of the released volume.

[c] Steady state concentrations based on passive breathing caused by atmospheric pressure changes (0.45 percent of vapor space removed per day) and calculated heat load in the tank. No credit is taken for other ventilation mechanisms, such as level-indicating device purge flow, chimney effect (hot air rises), venturi effects (wind blowing by the end of the filter assembly creates a vacuum), and any connections between tanks (such as cascade lines). The values are considered bounding and are not expected to actually be seen in the tank.

[d] Category 1: Tanks that do not exhibit episodic gas-release behavior or growth in the waste level.
Category 2: Tanks for which not enough data are available to decide whether they exhibit episodic gas-release behavior or growth in waste levels.
Category 3: Tanks that appear to exhibit episodic gas-release behavior.
Category 4: Tanks that exhibit growth in waste level but do not exhibit episodic gas-release behavior (LANL 1994).

The second column under the heading gas release event in the table presents a calculation of the hydrogen concentration by adjusting the release gas composition to a mixture identical to that used in the analysis in the 241-SY-101 mixer pump safety document (LANL 1995).

The last column contains a calculation of the steady-state hydrogen concentration in the tank. It is based on a calculated heat load for the tank (Kummerer 1994) and is evaluated using the derivations of Graves (1994). Graves (1994) accounts for both radiolytic and thermal production of hydrogen. In addition, the only mechanism considered for ventilation is the passive breathing of the tank caused by atmospheric pressure changes. No credit is taken for other ventilation mechanisms, such as level-indicating device purge flow, chimney effect (hot air rises), venturi effects (wind blowing by the end of the filter assembly creates a vacuum), and any connections between tanks (such as cascade lines). To determine the final hydrogen concentration in the tank, the episodic value should be added to the steady-state value.

The values reported in the last two columns are steady-state values. Three tanks (241-A-101, 241-SX-103, and 241-SX-105) are calculated to have steady-state concentrations above the lower flammable limit (see Appendix B). The time required to come to this steady-state value (this assumes that no risers are opened during this period of time) is calculated as 108 days for tank 241-A-101 and 148 days for tank 241-SX-103. Again, the steady-state value given here only takes into consideration one ventilation mechanism, i.e., passive breathing resulting from atmospheric pressure variations. NOTE: In these 19 tanks, the measured steady-state values (Brown 1995) for the hydrogen concentrations have been much smaller than the calculated values (see Table 4-1). Controls (see Chapter 6.0) are in place to monitor the hydrogen concentration in the tank before any in-tank activity begins. In addition, the hydrogen concentration will be monitored continuously with two separate, independent monitors during the activity. If at any time the hydrogen concentration is above 25 percent of the lower flammability limit (see Appendix B), the activity will cease and the tank will be placed in a safe shutdown mode.

The existence of gas release events like the rollover-type events in tank 241-SY-101 for the single-shell flammable gas tanks has not yet been established. Other mechanisms (see Section 1.3) may exist. From a review of the level history for each single-shell flammable gas watch list tank (Brager 1994), it is postulated that one tank (241-A-101) may be experiencing episodic gas releases (LANL 1994). This conclusion was reached solely based on surface-level anomalies. Abrupt, unexplained, variations in surface level can indicate that stored gas is being released periodically. However, there are other possible causes for the variations in surface level changes of tank 241-A-101. The "events" in tank 241-A-101 occur irregularly, often with multiple events occurring in short periods (approximately one month) then longer periods between events. It is not known at this time whether these represent errors in the level-indicating-device measurements, barometric pressure variations of the surface level, or "bouncing" of the level-indicating device as it could if one time it measures on a hump on the waste surface and the next time it measures in a valley on the waste surface. One way to determine if true gas-release events are occurring is to do long-term monitoring for flammable gases. Existing monitoring for flammable gases does not show gas release event.

The surface level variations of the waste in tank 241-A-101 are on the order of 5.08 to 7.62 cm (2 to 3 in.)* and it has a vapor space volume of 1,454 m^3 (51,348 ft^3). Assuming that these are tank 241-SY-101 rollover-type episodic gas releases, the variations correlate well with the size of the surface level variations of the double-shell flammable gas tanks 241-AN-103, 241-AN-105, 241-AW-101, and 241-SY-103. The surface level variations of these tanks are, respectively, 7.62 cm, 8.64 cm, 4.83 cm, and 5.84 cm, while the vapor space volumes of these tanks are, respectively, 1,722 m^3, 1,047 m^3, 1,011 m^3, and 2,481 m^3. Tank 241-AN-104 has larger level drops (up to 14.73 cm [5.8 in.]) with a vapor space volume of 1,285 m^3. It has been calculated that the vapor spaces of all double-shell flammable gas tanks (except tank 241-SY-101) would not reach flammable concentrations (Reynolds 1994, Wilkins 1994, Fox et al. 1993). However, this was done using a slurry gas mixture with 30 volume percent hydrogen. Measurements in these tanks indicate that the slurry gases in these tanks have 70 to 90 volume percent hydrogen. The conclusions of the earlier reports are potentially wrong. Because there has been no gas release event in tank 241-A-101 since the standard hydrogen monitoring system was installed, the amount of hydrogen in the slurry gas is unknown. Therefore, one can conclude that the entire vapor-space volume of tank 241-A-101 also may not reach flammable concentrations. However, it is likely that local areas of the tank may be flammable if the surface-level variations actually are caused by gas release events.

The tanks with waste levels that appear to have increased with time (Category 4) have been assumed to be retaining flammable gases (LANL 1994). This phenomenon may be explained by other mechanisms (e.g, growth of an "icicle" on the level-indicating device or a physical change in the waste matrix similar to the expansion of water when it freezes). Examinations of the tank photos provides some evidence that the waste material in the center of the tanks has collapsed from previous pumping campaigns. This may mean that there is not as much force acting to retain the gas and that an escape path may exist for any gas that is generated in the waste matrix.

The waste matrices in many single-shell tanks do not appear to be conducive to rollover-type episodic gas releases similar to those in tank 241-SY-101. The tanks contain three different waste matrices: salt cake (with or without interstitial liquid), salt cake (with or without interstitial liquid) and sludge, and sludge. These materials do not necessarily exist as discrete layers, but may be intermingled to different degrees. Of the Category 3 and 4 tanks, the sludge in the single-shell tanks 241-A-101, 241-S-102, 241-U-103, 241-U-105, and 241-U-108 constitutes less than 10 percent of the total waste volume. Tanks 241-U-109 and 241-U-107 contain sludge equivalent to 11 percent and 3.7 percent, respectively, of their total waste volume. Tank 241-T-110 is nearly 100 percent sludge; however, the growth experience over 12.5 years is only 3.81 cm (1.5 in.) out of a waste height of 3.69 m (12.11 ft). This indicates that the tanks in Categories 3

---

*NOTE: Changes in level are measured with instruments that can read to tenths of an inch. These measurements have been converted into metric equivalents. Thus, for example, 2.3 in. is 5.84 cm.

and 4 (excluding 241-T-110) are mostly salt cake and interstitial liquid. If the salt cake matrix has mechanical strength, rollover-type episodic gas releases would not be possible.

Large local gas releases could be caused by waste-intrusive activities (instrument tree installation, liquid observation well installation, salt well screen installation, and push-mode sampling). Other activities are considered unlikely to cause gas releases (routine maintenance and surveillance, installation of gas probe assembly and standard hydrogen monitoring systems, vapor-space sampling, and auger sampling). Local gas releases will be detected by the continuous hydrogen monitoring during the activity (see Section 6.1.3). In addition, ignition sources are controlled during the activity. Consequences calculated in Section 5.3 assume that an episodic gas release occurs naturally or is induced by the activity and is ignited by a spark produced by the activity or installed equipment in the tank.

The consequences from an ignition of a flammable gas mixture caused by a gas release event are presented in Section 5.3. The pressure necessary to fail a single-shell tank (Julyk 1994) varies from 76 to 96.5 kPa (11 to 14 psi) for the 3,800,000- to 1,900,000-L (1,000,000- to 500,000-gal) tanks, respectively. Fox and Stepnewski (1994) indicate that a plume of flammable gas (16 m^3 [570 ft^3] of hydrogen in a dome volume of 991 m^3 [35,000 ft^3] ranging to 40 m^3 [1,410 ft^3] of hydrogen in a dome volume of 2,407 m^3 [85,000 ft^3]), which if ignited will generate a pressure of 138 kPa (20 psi). It is further stated that more realistic calculations (e.g., taking credit for venting and heat transfer) would reduce these pressures by as much as 25 to 30 percent. However, the resulting pressure of 103 kPa (15 psi) would still be large enough to cause dome collapse.

4.5 FLAMMABLE GAS CONCERNS IN ORGANIC WATCH LIST TANKS

The criterion to place a tank on the Organic Watch List is that if any place in the tank exceeds 3 weight percent (dry basis) organic material, the tank is added to the list. In 1994, it was recommended that 10 single-shell tanks be added to the Organic Watch List (Turner 1994). Of these 10 tanks, 5 are currently on the Flammable Gas Watch List (241-A-101, 241-S-111, 241-SX-103, 241-U-103, and 241-U-105). Tanks 241-S-102, 241-SX-106, and 241-U-107 already were on both the flammable gas and organic watch lists. Thus, as of November 1995, there are 8 of the 25 flammable gas watch list tanks also on the organic watch list. Currently, three types of organic watch list tanks exist. The first is tanks containing soluble organics; the second is tanks containing a separable phase organic layer (only tank 241-C-103); and the third is tanks that formerly had separable phase organics (only three are historically known). All of the tanks that are on both the flammable gas watch list and the organic watch list are tanks that contain soluble organics. Thus, it is necessary to consider the possibility that an ignition of the flammable gases could lead to a propagating exothermic reaction in the waste material at the surface. The following paragraphs discuss why this is not a significant hazard.

All the historical samples that measured for total organic carbon were looked at and the highest value from each analysis was chosen (Toth et al. 1994). The report states:

> "One of the problems with the old data is that it did not include any quality control information such as blanks, spikes, standards, or duplicates to determine if the instrument was operating "properly." The high sensitivity and large dilutions required by this method (infrared measurement) can magnify the effect of TOC (total organic carbon) contamination...Sometimes TOC is determined by the difference between total carbon (TC) and total inorganic carbon (TIC): TOC=TC-TIC. This can result in additional errors caused by the difference of two large numbers.
>
> Measurement method was investigated as an additional source of variance to see if a relationship between measurement method and reported TOC concentration unit exists. This is summarized in Table 4.7. A disproportionate number of high observations were reported in units of moles/L. Although it does not seem to be coincidence, an explanation of this association was not found."

For example, tank 241-A-101 is the tank with the highest organic content. Table 4-3, condensed from Table 4.7 of Toth et al. (1994), provides information from the report specifically for tank 241-A-101.

From Table 4-3, excluding the two high values obtained from the reported values of mole/L, total organic carbon normally is around 2 weight percent total organic carbon (dry basis) or 26 g/L (dry basis). Computer modeling by LANL (1995) and Fox et al. (1992) showed that no exothermic propagating reactions would occur in tank 241-SY-101 (total organic carbon of 32 g/L dry basis) even with zero percent moisture in the waste material. Fox et al. (1993) modeled 64 g/L dry basis for tank 241-SY-103 and found that even with no moisture, the waste material would not undergo an exothermic propagating reaction (i.e., a crust burn). In the Fox studies (Fox et al. 1992 and Fox et al., 1993), computer modeling demonstrated that if the waste material had any water content, exothermic propagating reactions were not possible because of ignition and burns of flammable gases in the tank vapor spaces.

Total organic carbon is a poor measure of the reactivity of tank material. In the detailed analysis done for tank 241-SY-101, the total organic carbon was found to contain significant degradation products (oxalic and citric acid), which show up as total organic carbon but have very low reactivities. The organic carbon in the single-shell tanks has been aging even longer than that in the double-shell tanks, e.g., tank 241-SY-101, so that to the extent that other parameters are similar, they would contain an even higher percentage of degradation products. Differential scanning calorimetry and similar tests for determining the energetics of materials have been conducted on waste samples from tanks 241-SY-101 and 241-SY-103. The results have shown that the material is nonreactive.

The waste in the single-shell tanks is composed of mostly salt cake (moisture content ranging from ~ 50 to 40 weight percent water) and sludge (moisture content ranging from ~ 60 to 70 weight percent water). Propagating reactions would not be possible with these materials until the water was

Table 4-3. Laboratory Data for Tank 241-A-101.

Sample date	Sample type	Laboratory value (wet basis)	Laboratory units	% Total organic carbon (wet basis)	% Total organic carbon* (dry basis)
10/22/80	Filtrate	19.1	g/L	1.32	2.20
11/10/80	Filtrate	7.51	g/L	0.51	0.85
11/11/80	Filtrate	9.94	g/L	0.69	1.15
11/02/79	Filtrate	20	g/L	1.45	2.42
09/22/80	Sludge	11.025	g/L	0.76	1.27
11/10/80	Slurry	9.51	g/L	0.58	0.97
11/11/80	Slurry	15.61	g/L	0.84	1.40
10/10/83	Slurry	7.02	moles/L	6.20	10.35
10/11/83	Slurry	9.78	moles/L	7.16	11.96
09/22/80	Supernate	16.24	g/L	1.21	2.02
09/22/80	Supernate	10.14	g/L	0.89	1.49
10/13/80	Supernate	10.71	g/L	0.82	1.37
10/13/80	Supernate	11.52	g/L	0.90	1.50
08/22/80	Supernate	35.16	g/L	2.74	4.58
08/22/80	Supernate	43.79	g/L	3.36	5.61
10/10/83	Supernate	5.23	moles/L	0.40	0.67
10/11/83	Supernate	11	moles/L	0.84	1.40

*For 241-A-101 multiply % total organic carbon (wet basis) by 1.67 to get % total organic carbon (dry basis) (Toth 1994).

removed and the material heated to ~ 200 °C (this temperature is the melting point of sodium nitrate/nitrite, a necessary step before exothermic reactions occur). In addition, the Fox studies (Fox et al., 1992 and Fox et al., 1993) indicate that during a hypothetical burn, small portions of the waste surface (a protuberance modeled as a cone) could be heated to a temperature that could cause moisture to be lost. However, the time that the protuberance is at the temperature is very short (because of the time duration of the deflagration) and a propagating exothermic reaction does not occur.

To ensure further the improbability of getting an exothermic propagating reaction in the waste material of tanks on the organic watch list and with flammable gas concerns, all activities in these tanks will be done using the controls (see Section 6.0) developed for the flammable gas tanks. These controls were developed to prevent the introduction of ignition sources and to preclude work in tanks that were potentially flammable. The organic watch list controls are a limited subset of the flammable gas controls. That is, the flammable gas controls require measures that are more stringent than those imposed solely on the organic tanks. Consequences of an organic exothermic propagating reaction causing a deflagration (or vice versa) are thought to be bounded by the consequences in Section 5.3.

4.6 TOXIC GAS RELEASE DURING ACTIVITY

While tank confinement is breached (e.g., opening of the riser or sample port) there is a possibility for toxic gases (e.g., ammonia, organic vapors, and nitrous oxide) to be released. The personnel working near the open riser, open sample port, or any other opening in the tank and those personnel elsewhere in the tank farm, e.g., the upwind staging area, shall wear respiratory protection as determined by the field representative of TWRS Industrial Hygiene. The level of protection for those personnel will be based on the field measurements and the requirements in the *Tank Farm Health and Safety Plan* (Hewitt 1994).*

In addition, while tank confinement is breached, monitoring for toxic gases will be conducted periodically. The gas monitoring shall be performed in accordance with standard work practices contained in Erickson (1994). If a toxic gas release is detected during the work, the workers can be evacuated or other appropriate measures taken.

Toxic gas releases may occur during a gas release event. The amount of toxic gas released (e.g., ammonia) will be proportional to both the magnitude of the gas release and the time over which the release occurs. However, there is a short time delay between a gas release event and worker exposure. Also, the tank conditions shall be monitored for the entire time the activity is being performed. This monitoring will include, at a minimum, the tank-waste level and the hydrogen concentration in the tank using two separate operable monitors (measured at a location in the tank vapor space [below the riser lip]). For example, hand-held combustible-gas meter with a wire-wrapped, electrically-bonded Tygon or Tygon-equivalent tube and the standard hydrogen monitoring system and gas probe assembly could be used. An operator shall look for indications that a gas release event might occur, e.g., sudden decrease in level and/or an increase in the hydrogen concentration. These indications or precursors may enable the tank to be placed in a safe shutdown mode and/or the workers evacuated from the area.

The pH of the tank waste can cause differences in the production rates of toxic chemicals. For example, hydrogen cyanide should not exist in very basic conditions. However, if the pH is lower (near a pH 9), the production of hydrogen cyanide is possible. Also, addition of water or caustic to tanks with low pH values will cause ammonia to be produced. Thus, the monitoring while tank confinement is broken should take into consideration the types of toxic gases that could be formed.

---

*NOTE: It is procedurally required for nuclear safety, fire protection, and industrial hygiene organizations to review and approve safety analyses.

Toxic gases also may be produced during a deflagration. The types of gases produced would be highly sensitive to the several parameters. Some of these are the initial reactants, the temperature of the deflagration, the duration of the deflagration, any catalysts present, and any secondary reactions that might take place. Occupational workers wear personal protective equipment as required by the Tank Farm Health and Safety Plan (Carls 1995). Onsite individuals are protected through emergency preparedness and offsite individuals are protected by distance (dilution of concentration through dispersion). No consequences will be calculated in Chapter 5.0.

4.7 DAMAGE TO THE TANK

A potential safety issue is the contamination or dropping of the gauge plug, a replacement level-indicating device, or other equipment that is manually brought into the tank farm. The "T" handle would prevent the gauge plug from falling into the tank, if it were accidently dropped. Similarly, the replacement level-indicating device would be physically too large to fall into the tank. If the equipment were dropped onto the riser flange, damage to the riser flange would be minimal, and the riser could still be sealed with a thick "donut-type" gasket or a plastic glove bag until it could be repaired. The gauge plug may become contaminated by scraping a contaminated riser interior during insertion and/or removal. During removal, the gauge plug will be examined for radiation contamination by a health physics technician and, if necessary, wiped clean or disposed of in accordance with the *Tank Farm Health and Safety Plan*, (Carls 1995) and the *Hanford Site Radiation Control Manual* (HSRCM 1994). By using the guidelines in these manuals, it is expected that the dose rate to workers performing contamination control will be very low.

As discussed in WHC-SD-WM-SAD-014 (Farley 1994, Rev. 3), the likelihood of typical cranes dropping a load is 2.7×10^{-5} per lift. The likelihood assigned for a crane dropping a multifunction instrument tree is based on statistics from NUREG (1980). This report analyzed U.S. Navy crane lifts in the period from February 1974 to October 1977 for a variety of crane types. During the analysis period, there were, on average, $8.75 \times 10^{+5}$ crane lifts/year. Based on the number of reported load-drop accidents reported in this period, the likelihood of a dropped-load accident was determined to have a mean value of 2.7×10^{-5} per lift, which falls in the "extremely unlikely" category as defined in WHC-CM-4-46. Failure modes were analyzed to determine if Navy procedures could be improved to meet nuclear power plant standards in NUREG (1980). NUREG (1980) determined that the potential accident rate could be further reduced by more thorough operator training and operating procedures.

Tall equipment could be dropped into the tank and damage the tank liner. Preventive measures have been adopted to mitigate this aspect of equipment installation or removal. During manual installation, at least one lifting bar shall be in place for both the auger guide tube assembly and the auger sampling equipment. During crane installation of the guide tube, auger sampling equipment, salt well screen, jet pump assembly, and instrument tree, the lifts shall be critical lifts following the guidelines in the *Hanford Site Hoisting and Rigging Manual* (DOE-RL 1992) and precautions such as impact limiters should be taken. This will minimize the possibility that the tall equipment will be dropped into the tank. This also minimizes frictional heating, mechanical sparking, and impact heating from dropped objects. In addition, the dropped equipment could cause a "chimney" (as described in Section 1.3 for gas to be released and provide an ignition source (frictional heating, mechanical sparks, or impact heating).

The ultra-high-pressure nozzle can cause damage to the tank liner if it is within 2.54 to 5.08 cm (1 to 2 in.) from the liner, at full pressure, and stationary. To prevent liner erosion by the ultra-high-pressure water, a control has been developed. This control requires that the pressure be reduced from full pressure (255 MPa) to a reduced pressure of 34.5 MPa when the instrument tree flange is 30.5 cm (12 in.) above the riser flange (this means that the equipment being installed is at least 30.5 cm [12 in.] above the tank liner). In addition, the tree must be rotated by an operator during the entire time water is supplied to the sluicing nozzles. Other characteristics of the high-pressure system are discussed in Section 2.5.4.2.

The core drill truck has redundant features to prevent the possibility of pushing through the liner of the tank (Milliken 1995). They are as follows: the drill string is equipped with a hydraulic safety interlock that disables the hydraulic system if a resistance greater than that resulting from sampling occurs, conservative calculations show that the maximum downward force the core drill truck can exert cannot penetrate the liner of the tank even if the hydraulic interlock failed, and strict administrative and quality assurance controls on the calculation of the drill string length are relative to the tank depth.

The instrument tree has a flange welded on the top to allow it to be bolted to the riser. If the instrument tree were dropped, the flange would stop it from penetrating the tank liner.

Consequences for damage to the tank are presented in Section 5.2. Consequences from a deflagration are reported in Section 5.3.

4.8 IMPACTS FROM WASTE BERGS

Waste bergs (large, solid, floating masses of waste material) were first identified in tank 241-SY-101. Their movements were observed through the closed-circuit television camera during gas release events. For waste berg movement, the velocity, and thus the force imparted during impact, increases with the severity of the gas release events in the tank. Based on records to date, the gas release events that occurred in tank 241-SY-101 released (before the mixer pump was installed) the largest gas volume in the shortest period of time.

With one exception, all of the single-shell flammable gas tanks have salt cake and/or sludge with little supernate (mostly found as interstitial liquid or waters of hydration). Tank 241-A-101 has the most liquid in it of all the single-shell tanks. Hanlon (1995) indicates that 1,563,400 L (413,000 gal) of liquid is in the 3,607,500 L (953,000 gal) of tank waste. This represents approximately 43 percent of the waste volume. Only one single-shell tank has a higher volume percent of liquids. This is tank 241-C-103 with 503,500 L (133,000 gal) of liquid in a total waste volume of 738,200 L (195,000 gal).

Historical data for the single-shell tanks are limited to level and temperature data. Newer instrumentation on some tanks is providing hydrogen monitoring and is capable of monitoring pressure. Based on this information, the velocity of the waste bergs in tank 241-SY-101 (before the mixer pump was installed) is thought to bound the movement (energy) of waste bergs that may be found in any of the other tanks. Some of the original equipment in tank 241-SY-101, e.g., the air lances and the thermocouple tree, had been hit by waste bergs during past gas release events. These impacts were evidenced by bends in the equipment. This bent equipment has since been removed from the tank.

The movement or even the presence of waste bergs in single-shell flammable gas tanks cannot be fully dismissed at this time, although there is no evidence that the single-shell flammable gas tanks undergo rollover events similar to what occurred in 241-SY-101. See the discussion in Section 1.3 on postulated gas retention and release mechanisms for single-shell tanks.

Movement of a waste berg happens during a gas release event. The movement might produce an ignition source (impact with equipment or the walls of the tank). The consequences of a deflagration are reported in Section 5.3.

4.9 STRATIFICATION

Stratification was addressed in Marusich (1991a, Appendices D.1 and D.2) where it was shown that hydrogen does not stratify in a passively ventilated tank (used to represent a tank that has lost active ventilation). However, Los Alamos National Laboratory, the group that wrote the safety evaluation report for the activity thought that stratification could occur. As a result, a temperature-difference-based control was imposed. Further studies at Los Alamos National Laboratory (LANL 1995) were conducted and concluded that stratification would not occur in actively ventilated tanks, thus eliminating the temperature-difference-based control for these tanks. Furthermore, Wood (1994) has stated that the vapor spaces of these tanks are well mixed, or will become well mixed in a short period of time, because of the thermal differences between the waste and the ambient air temperatures. Wood (1994) has calculated ventilation rates of about 2.1 x 10^{-2} m^3 (45 cfm) in the single-shell tanks he analyzed. Modeling of a waste tank with a low ventilation rate during a gas release has been completed (Antoniak and Recknagle 1995). This modeling looked at small releases of gas with volumes ranging from 11.3 to 28.3 m^3/s (400 to 1,000 ft^3) with release durations ranging from 1 minute to 2 hours with a ventilation rate of 2.4 x 10^{-2} m^3/s (50 cfm) at two temperatures, 48.9 °C (120 °F) and -6.7 °C (20 °F). These analyses showed that a significant concentration (8 percent by volume) could accumulate at the apex of the tank and this would be reduced to 3 percent by volume within 2 hours. As described in Section 4.4, a volume of hydrogen of 16 m^3 (570 ft^3) if burned will create an overpressure sufficient to collapse the dome. These combined results will apply to the actively and passively ventilated single-shell flammable gas tanks.

To ascertain whether stratification is a valid concern, the hydrogen concentration in the tank (measured at a location in the tank vapor space [below the riser lip]) using two separate, operable monitors (see Section 6.1.3) will be monitored continuously during an activity. In addition, when a riser flange is first removed during an activity, a purge period (see Appendix C) will be observed to allow any trapped gases to escape.

Other flammable gases are generated and have been measured in tanks. For example, in tank 241-SY-101, ammonia and methane have been measured. The background concentration for ammonia has been measured at approximately 40 ppm. The lower flammable limit for ammonia is 15 volume percent (150,000 ppm)* in air. Currently methane data have only been measured in the Window I gas release event on tank 241-SY-101. The peak-measured value was approximately 370 ppm. The lower flammable limit for methane is 5 volume percent (50,000 ppm)* in air. These gases also will be measured for when using the hand-held combustible gas meter. The presence of ammonia and methane also was taken into account when developing the conservative slurry gas composition as discussed in Appendix B. The potential stratification after a gas release event is high. Because the tanks have known spark sources, therefore the consequences of a deflagration are presented in Section 5.3.

4.10 LIGHTNING

4.10.1 Lightning During an Activity

During installation or removal of tall equipment (i.e., 3 m [10 ft]), a lightning strike could occur. This is an unlikely event given the low thunderstorm/lightning frequency in the Hanford area. In fact, using the information on local lightning strikes obtained from the U.S. Geological Survey, Cowley (1994) has estimated an annual frequency of 4.5 x 10^{-4}/yr per tank.

For any activity, this would lead to a frequency of

$$\left[\frac{1}{8,766\ \frac{\text{hours}}{\text{year}}}\right]\left[4.5 \times 10^{-4}\ \frac{\text{strikes}}{\text{year}}\right] = 5.133 \times 10^{-8}\ \frac{\text{strikes}}{\text{tank}} \text{ per hour of activity}$$

Although not credited in this analysis, during installation of tall equipment into single-shell flammable gas tanks, the crane and the tall equipment will be electrically bonded to protect against lightning strikes, as indicated in Weadon (1992a). A control for bonding and grounding for lightning is included in Section 6.0.

Also not credited in this analysis is the standard practice while installing new or modified large equipment that prohibits working in the tank farm unless a storm warning report from the Pacific Northwest Laboratory states that a storm is not occurring within a 80.5-km (50-mi) radius of the

---

*Other values for the lower flammability limits in air and nitrous oxide are discussed in Appendix B of this document.

Hanford Site, and is not likely to occur within some specified time period. This would further reduce the risk from a storm. On days having higher thunderstorm potential (May through August), the prediction of no lightning within a 80.5-km (50-mi) radius may be good for only 1 hour. During the winter months, predictions may be good for several days. A control for a weather watch is included in Chapter 6.0.

The chance of lightning causing an explosion would also have to consider the likelihood that a tank contained a flammable gas mixture concurrent with the lightning strike and the installation activity. The likelihood would thus decrease even more.

4.11 SPILL OF SAMPLE MATERIAL

For either the auger sampling system or the push-mode sampling system, the inadvertent partial or full spill of the sample on the ground could occur while the sample is being transferred from the riser to the onsite transport cask. The volume of waste in the sample from the auger sampling system is 475 cm^3 (745 g). The volume of waste in the sample from the push-mode sampling system is 310 cm^3 (500 g). Two events (both human failures) must occur for a spill to happen and if a probability of 10^{-2} is assigned to each of these events, a total of 10^{-4} per sampler results. The fullest single-shell tank is 241-A-101 with 3,607,500 L (953,000 gal) of waste. This corresponds to 8.8 m (357 in.). To core sample this tank, a total of 18 to 19 samples would be used to obtain a full core sample. If it is assumed that there is a maximum of 20 samplers per core sampling, the frequency is 2×10^{-3}. Therefore, consequences from this accident will be analyzed in Section 5.1.

4.12 SEISMIC

The dynamic or impact loads on permanent equipment in the single-shell flammable gas tanks caused by seismic events will be evaluated and documented before the equipment is installed in the tank.

The annual frequency of a concurrent design basis earthquake causing a gas release event while an activity is taking place in a single-shell flammable gas tank is given as

$$\left[\frac{1}{8{,}766\ \frac{\text{hours}}{\text{year}}}\right]\left[1 \times 10^{-4}\ \frac{0.2\text{g earthquakes}}{\text{year}}\right] = 1.1 \times 10^{-8}\ \frac{0.2\text{g earthquakes}}{\text{hour}}.$$

5.0 CONSEQUENCES OF ACCIDENTS

Consequences will be calculated for two receptor locations: maximum onsite and offsite individuals. The definitions of these receptor locations (WHC-CM-4-46) are:

> "The hypothetical onsite receptor located at the distance and direction from the point of release at which the maximum dose occurs. This distance shall be at least 100 m. Line management may, with Health and Safety Assurance concurrence, redefine the maximum onsite individual for a specific facility to be located at the facility boundary, in the direction of the maximum dose."

For this analysis, the onsite receptor evaluation location is 100 m.

> The hypothetical receptor at or beyond the site boundary location, with the maximum atmospheric dilution factor, for which offsite consequences are calculated."

For this analysis, the offsite receptor evaluation location is 11.1 km to the west of the 200 Areas. The maximum atmosphere dilution factor is the largest numerical value which directly corresponds to the maximum dose consequence.

The following sections provide the consequences at these two receptor locations.

5.1 CONSEQUENCES FOR DROP OF SAMPLE MATERIAL

The consequences for dropping a sample retrieved by auger sampling or push-mode core sampling are similar. Milliken (1995) calculated that the universal sampler (used with the core drill truck) could contain a volume of 310 cm^3 (500 g) (assuming a density of 1.6 g/cm^3 for the waste material). It was further assumed that it was a dry, respirable powder with a resuspension value of 0.1 percent. This leads to a release amount of 0.31 cm^3 (3.1×10^{-4} L). Similar calculations for the auger sampler yield a volume of 465 cm^3 (745 g). Van Vleet (1991) indicates that after the auger with the floating sleeve covering the sample is in the retrieval cask, no more than half of this material could leave the sampler. Again the same assumption that the material is a dry, respirable powder with a resuspension of 0.1 percent yields a release amount of 0.23 cm^3 (2.3×10^{-4} L). The sample spilled from the universal sampler is larger and thus has bounding consequences.

Radionuclide composite inventories were developed by using characterization data for the waste tanks (Savino 1995). Radionuclide composites were generated for 12 tank groupings (for example, single-shell tank liquids and single-shell tank solids). Details on the composites can be found in Savino (1995). For this analysis, the composite selected is single-shell tank solids. The unit liter dose for this composite is 2.4×10^5 Sv/L.

The dose consequences in sieverts can be calculated using

$$D = Q \times \frac{\chi}{Q'} \times R \times ULD$$

where

Q = liters respirable tank waste released
χ/Q' = integrated atmospheric dispersion coefficient
R = breathing rate
ULD = committed effective dose equivalent per unit liter inhaled.

The atmospheric dispersion coefficients are 3.44×10^{-2} s/m^3 for the onsite receptor and 1.88×10^{-5} s/m^3 for the offsite receptor. The breathing rate is 3.3×10^{-4} m^3/s which is for a person doing light activity. The radiological consequences from a drop of sample material are presented in Table 5-1.

Table 5-1. Dose Consequences for Spill of Sample Material.

Composite waste type	Committed effective equivalent dose (mSv)		Toxic chemicals sum-of-fractions	
	Onsite	Offsite	Onsite	Offsite
Single-shell tank solids	8.5×10^{-1}	4.6×10^{-4}	9.0×10^{-2}	8.4×10^{-6}

Toxic chemical source term concentrations also were developed using tank characterization data (Van Keuren 1995). Toxic composites were generated for eight tank groupings (for example, single-shell tank liquids and single-shell tank solid). For further details on the composites see Van Keuran (1995). For this analysis, the single-shell tank solid puff release sum-of-fraction of the risk guidelines for a unit liter dose were used. This is 2.9×10^{2} per liter for the onsite receptor and 2.7×10^{-2} for the offsite receptor. The dose consequences can be calculated using the following.

$$\text{Fraction of Risk Guidelines} = Q \times SOF$$

where

Q = liters of respirable tank waste released
SOF = sum-of-fractions per unit liter inhaled.

The toxicological consequences from a drop of sample material are presented in Table 5-1.

5.2 CONSEQUENCES FROM DAMAGE TO THE TANK

One postulated accident scenario would result in an adverse impact to the environment: dropping the multifunction instrument tree through the bottom of the tank. An analysis of the effect of tank leakage on the water table is discussed in Smith (1986) and covers a hypothetical 3.79 x 10^5-L (1.0 x 10^5-gal) leak from a double-shell, aging waste tank. The reference document (Smith 1986) indicates that the analyzed scenario for the double-shell, aging waste tank bounds the consequences for a single-shell tank. The analysis concluded that concentrations of radionuclides arriving at the water table would be below federal guidelines for drinking water. It was further postulated that two 1.14 x 10^5-L (3.0 x 10^4-gal) leaks of fluid waste from adjacent single-shell tanks would have a vertical penetration of only 27.4 m (90 ft), compared to 36.6 m (120 ft) for the double-shell tank leak scenario. The water table is approximately 61 m (200 ft) below the 200 West Area and 91 m (300 ft) below the 200 East Area.

Other scenarios for waste tank leakage are covered in the draft environmental impact statement, EIS-0113, Vol. 3 (DOE 1986). The environmental impact statement states that the most applicable study for potential offsite doses from single-shell tank leakage was done by Murthy et al. (1983), with the following conclusions:

> "The controlling radionuclides that contribute to these doses are technetium-99 and iodine-129, both of which are available only in small quantities. Other radionuclides of potential concern (cesium-137, strontium-90, neptunium-237) were also analyzed. Hydrological modeling indicated that although cesium-137 and strontium-90 are available in greater quantities, they will never reach the accessible environment before decay due to their relatively short half-lives and soil sorption. The trace amounts of neptunium-237 available have a very long half-life, but are not expected to reach the ground water due primarily to the lack of sufficient driving liquids and soil sorption."

Any postulated waste leak, on reaching the soil, will be driven downward by rainfall and runoff from the tank dome. This moisture recharge is concentrated around the tank perimeter because of the "umbrella effect" of the tank structure. Travel time to the aquifer is calculated to be about 60 years, provided the amount leaked is small (up to tens of cubic meters) compared to the rate of recharge. Even small leaks are expected to find their way to the groundwater. The transport model used to simulate the leak is conservative in that the travel time estimates are minimal for representative conditions and the relative concentrations in the groundwater are maximal.

Local concentrations of key waste constituents in the groundwater resulting from the most likely leak scenario are predicted to be greater than allowed by drinking water standards. These doses reflect the inherent conservatism in the transport model. The actual dose received will depend on the water well location, the extent of mixing in the aquifer, and any lateral spreading that occurs. Significant dilution is possible between the source of leak and the dose receptor, such that the resulting dose may approximate or even be less than allowed by drinking water standards. This study assumed a well located 25 m from the tank. However, all these consequences are long-term and there are no short-term consequences to the onsite or offsite receptor.

Considering the extremely low likelihood of this event, it is concluded that a leak caused by a tall piece of equipment (i.e., an instrument tree) penetrating a tank would pose no significant short-term risk to offsite or onsite workers, but might add to future cleanup efforts. Long-term risks are discussed in Smith (1986), Murthy et al. (1983), and EIS-0113, Vol. 3 (DOE 1986). Work has been ongoing in the areas of recharge and transport of the radionuclides, but the basic conclusion that there is no short-term risk still is valid.

5.3 CONSEQUENCES FROM IGNITION OF A GAS RELEASE

The consequences from an ignition of a flammable gas mixture caused by a gas release event are presented in Table 5-2. The pressure necessary to fail a single-shell tank (Julyk 1994) varies from 76 to 96.5 kPa (11 to 14 psi) for the 3,800,000- to 1,900,000-L (1,000,000- to 500,000-gal) tanks, respectively. Fox and Stepnewski (1994) indicate that a plume of flammable gas (16 m^3 [570 ft^3] of hydrogen in a dome volume of 991 m^3 [35,000 ft^3] ranging to 40 m^3 [1,410 ft^3] of hydrogen in a dome volume of 2,407 m^3 [85,000 ft^3]), which if ignited will generate a pressure of 138 kPa (20 psi). It is further stated that more realistic calculations (e.g., taking credit for venting and heat transfer) would reduce these pressures by as much as 25 to 30 percent. However, the resulting pressure of 103 kPa (15 psi) would still be large enough to cause dome collapse. These consequences in Table 5-2 are derived from the detailed calculations presented in Johansen (1994). The analysis in Johansen (1994) uses single-shell tank solids* for calculating consequences (see discussion in Section 5.1 of this document).

Table 5-2. Ignition Dose Consequences.

Composite waste type	Committed effective dose equivalent (mSv)		Toxic chemicals sum-of-fractions	
	Onsite	Offsite	Onsite	Offsite
Single-shell tank solids	1.9×10^4	1.0×10^1	2.8×10^3	2.1×10^{-1}

*The single-shell tank solids composite resulted in more conservative consequences than the single-shell tank liquids composite. Release of unburned gases from the tank is not accounted for in the reported consequences. This is because the toxic consequences (radiological consequences not affected) do not change considerably. The offsite consequence remains acceptable under the risk guidelines and the onsite consequence still exceeds the risk guidelines.

5.4 CONCLUSIONS

The Westinghouse Hanford Company Risk Acceptance Guidelines, extracted from the *Nonreactor Facility Safety Analysis Manual* (WHC-CM-4-46), are used to determine acceptability of the consequences (see Tables 5-3 and 5-4).

Table 5-3. Radiological Risk Guidelines.

Frequency category	Frequency range (yr^{-1})	Effective dose equivalent (mSv)	
		Onsite	Offsite
Anticipated	10^0 to 10^{-2}	50	5
Unlikely	10^{-2} to 10^{-4}	250	50
Extremely unlikely	10^{-4} to 10^{-6}	1,000	250
Incredible	$<10^{-6}$	>1,000	>250

Table 5-4. Toxic Chemical Risk Guidelines.

Frequency category	Frequency range (yr^{-1})	Primary concentration guidelines	
		Onsite	Offsite
Anticipated	10^0 to 10^{-2}	≤ERPG-1	≤PEL-TWA
Unlikely	10^{-2} to 10^{-4}	≤ERPG-2	≤ERPG-1
Extremely unlikely	10^{-4} to 10^{-6}	≤ERPG-3	≤ERPG-2
Incredible	$<10^{-6}$	>ERPG-3	>ERPG-2

The frequency for dropping sample material outside the tank was 2×10^{-3} per core sampling. Both the maximum onsite committed effective dose equivalent of 8.5×10^{-1} mSv (85 mrem) and the maximum offsite committed effective dose equivalent of 4.6×10^{-4} mSv (0.046 mrem) are well below the corresponding radiological risk guidelines (see Table 5-4). Additionally, the maximum onsite and the maximum offsite toxic chemical sum-of-fractions of 9.0×10^{-2} and 8.4×10^{-6} are also well below the corresponding risk acceptance guidelines. NOTE: A sum-of-fractions is calculated when there are a number of toxic chemicals involved. The method involves taking the concentration of each toxic chemical and dividing it by the risk guideline value to obtain a fraction. The fractions then are summed. If the sum-of-fractions is less than or equal to 1 the risk guidelines are met and if the sum-of-fractions is greater than 1, the guidelines are exceeded. NOTE: The sum-of-fraction methodology does not account for synergisms between interacting chemical species.

The frequency of dropping an instrument tree with a subsequent puncture of the tank liner is 2.7 x 10^{-5} per lift. As stated in Section 5.2, there are no immediate onsite or offsite dose consequences.

The annual frequency for ignition of flammable concentrations of gas is below 1 x 10^{-6} per year (see Appendix A). At this frequency, the radiological consequences of 19,000 mSv (1,900 rem) to the maximum onsite individual and 10 mSv (1 rem) to the maximum offsite individual for a dome collapse are acceptable. Likewise, the toxicological sum-of-fractions of 2,800 for the maximum onsite individual and 0.21 for the maximum offsite individual for a dome collapse also are acceptable. However, if the administrative controls in Chapter 6.0 are not followed, the consequences would exceed the radiological and toxic chemical risk guidelines.

6.0 CONTROLS

6.1 GENERIC CONTROLS

The following standard controls apply to all activities performed in single-shell tanks or ventilation systems with flammable gas concerns. Sections 6.1.1, 6.1.2, 6.1.3 and 6.1.7 are considered candidates for operational safety requirements. All other controls are considered candidates for operational specification document requirements except Section 6.1.4 which are part of the *Tank Farm Health and Safety Plan* (Carls 1995) and Section 6.2 which are at a operating procedure level.

6.1.1 Ventilation Controls

The single-shell flammable gas tanks intended to be on active ventilation are those in the SX tank farm. However, there is no requirement that the active ventilation system on single-shell flammable gas tanks be functional. Therefore, this section will treat all of the single-shell flammable gas tanks as being passively ventilated.

- The tank ventilation system shall be operating before and during the activity, i.e, the breather filter must be functional. Exceptions to these requirements may occur occasionally for short periods while maintenance activities to the high-efficiency particulate air filters are being conducted.

- On breaking tank confinement in a particular riser for the first time during the activity, a pause shall be observed. This allows any accumulated gases to be swept out of the riser. Appendix C provides a method for calculating the time required for the purge.

6.1.2 Electrical Grounding and Bonding Controls

NOTE: The electrical grounding and bonding controls apply to all single-shell tanks with flammable gas concerns and to tank ventilation systems which are not isolated from the tanks.

- Breaking confinement shall be performed in such a way as to prevent possible ignition of flammable gas by static charges or mechanical sparks. Electrical bonding to the tank in accordance with the appropriate National Fire Protection Association code requirements for the tank vapor space and ventilation system shall be performed. NOTE: Because the single-shell tanks do not have a metal liner in the dome to provide electrical continuity, different risers can be at different electric potentials. The risers are not necessarily welded to the rebar in the concrete dome.

- To prevent mechanical sparks, only spark-resistant tools shall be used, except for the initial loosening (one full turn) and the final tightening (final torquing) of the bolts.

- All equipment inserted into the tank vapor space or ventilation system shall be electrically grounded and bonded in accordance with the appropriate National Fire Protection Association section code requirements for the classified regions of the tank vapor space and in the SX tank farm ventilation system.

6.1.3 Hydrogen Concentration Control

NOTE: The hydrogen concentration control applies to all single-shell tanks with flammable gas concerns. Because no specific time of intrusion control (similar to the "window" for 241-SY-101) is imposed, it is important to provide continuous measurements of the hydrogen concentration in the tank vapor space while activities are being performed. This control can be satisfied by monitoring the tank using an installed flammable gas monitoring system, such as the standard hydrogen monitoring system and a hand-held combustible-gas meter. The wire-wrapped tubing connected to the hand-held combustible-gas meter would be positioned so that the sample is drawn from the tank vapor space below the riser lip. In tanks without an installed flammable gas monitoring system, the control can be met using two hand-held combustible-gas meters.

- Monitoring systems shall be as close as practicable to the riser in which the activity is occurring.

- If the installed flammable gas monitoring system is not installed or is not functioning, the flammable gas concentration shall be taken at the following locations before starting an in-tank activity.

  (1) After the riser bolts sealing the riser flange are loosened enough to take a gas sample from the riser, the concentration of flammable gases shall be taken at the riser opening.

  (2) After complete riser cover removal and before the activity proceeds in the tank, a flammability test shall be conducted in the tank vapor space.

  At each of these sampling locations, the following instructions should be followed. If any meter* reading exceeds 25 percent of the lower flammability limit as developed in Appendix B and the activity warrants, a flow-through bulb sample shall be taken for specific gas species analysis in the laboratory, the activity shall cease, and the tank shall be placed in a safe condition. The activity shall not resume until results of a sample analysis are known, and the appropriate Safety and Tank Farm Project Management approvals are received.

---

*An acceptable way of doing this is if the combustible-gas meter reading (calibrated on methane or pentane as appropriate to the specific meter) at the location in question is less than or equal to 25 percent of the lower flammability limit as indicated on the instrument display, the activity may proceed.

- The flammable gas concentration shall be measured continuously during the in-tank activities with two independent, operable monitors (either with two installed flammable gas monitoring systems; installed flammable gas monitoring system and the hand-held combustible-gas meter; with two hand-held combustible-gas meters; or with some other comparable systems). For the standard hydrogen monitoring system, this is accomplished by viewing the strip chart recorder or the digital display. For the hand-held combustible-gas meter, the instrument shall be monitored continuously and readings shall be recorded every 15 minutes.

- Installation or removal activities in the tank shall cease and the tank placed in a safe condition when the flammable gas concentration exceeds a value equal to 25 percent of the lower flammability limit (as developed in Appendix B) as read from any of the in-tank hydrogen monitoring probes, the hand-held combustible-gas meter(s) or other comparable instrumentation. Equipment designed to operate in flammable gas atmospheres can continue to function.

- Operations should ensure that any flammable-gas monitors used for in-tank continuous monitoring during the intrusive activity shall be functioning properly.

- If the hydrogen concentration increases 500 ppm above the baseline (preactivity background level), the activity shall be placed on hold to see if the hydrogen concentration rise continues. If the hydrogen concentration continues to rise and there is a possibility that 25 percent of the lower flammability limit (as developed in Appendix B) may be surpassed, the tank shall be placed in a safe condition. If the hydrogen concentration remains stable or decreases, work can resume.

6.1.4 Respiratory Protection Controls

NOTE: The respiratory and protection controls apply to all single-shell tanks with flammable gas concerns. The toxic gas monitoring will detect ammonia which the standard hydrogen monitoring system would not. Some single-shell tanks have very high ammonia levels.

- The personnel working near the open riser, open sample port, or any other opening in the tank or ventilation system, and those personnel elsewhere in the tank farm (i.e., the upwind staging area) shall wear respiratory protection as determined by the field representative of Industrial Health, Safety, and Fire Protection. The level of protection for those personnel will be based on the field measurements and the requirements in the *Tank Farm Health and Safety Plan* (Carls 1994).

- The toxic gas monitoring for respiratory protection shall be performed in accordance with standard work practices contained in the *Tank Farm Health and Safety Plan* (Carls 1994).

6.1.5 Time of Intrusion

- Work shall be done only after a review group has looked at recent tank behavior and decided that the tank is behaving in a manner consistent with its historical norm and there is no evidence that a gas release is expected during the time activity is to be conducted. This review group may have members from independent safety, operations (200 East or 200 West Area, as appropriate), process engineering, process control, safety analysis, plant engineering (200 East or 200 West Area, as appropriate), and safety programs. The minimum necessary for a decision are independent safety, operations, safety analysis and safety programs. This review will look at the past average behavior including any extremes (maximum or minimum) and compare it to recent behavior. If conditions exist outside of the normal behavior of the tank, a formal presentation will be made to the Plant Review Committee. This review group is not required for activities that are isolated from the tank vapor space.

6.1.6 Dome Loading

Applicable Operational Specification Requirements for dome loading (both uniform and point loads) shall be satisfied for the tank on which the activity is occurring. An analysis will need to account for loads placed on the tank: new equipment, new concrete pads, new soil cover, etc., along with equipment needed to perform the activity such as cranes and trucks.

6.1.7 Ignition Source Controls

A program shall be in place to identify, evaluate, and eliminate, as appropriate, ignition sources in flammable gas tanks.

- Spark sources shall be identified and removed, replaced with rated equipment (see Appendix D), or deenergized if necessary.

- All tools and equipment used around the open rises that are small enough to fall through the riser shall be equipped with lanyards or other fall prevention devices.

- During insertion or removal of tall objects greater than 3 m (10 ft), the objects shall be grounded to protect against lightning strikes. Grounding of a tall object provides a more favorable path for the lightning and may prevent electrical discharges within the tank.

- During insertion or removal of tall objects greater than 3 m (10 ft), a weather watch shall be maintained. If lightning is present in an 80.5-km (50-mi) radius around the tank farm where the activity is being performed, the tank will be placed in a safe shutdown condition.

- During installation and removal of equipment requiring crane or winch hoisting, the lift shall be considered a critical lift.

- During installation and removal of equipment evaluated to be a potential ignition source if dropped, a means to prevent a drop of the equipment shall be installed.

- During installation and removal of electrical equipment, the equipment shall be de-energized unless specific evaluation determines that the energized state reduces risks of ignition sources.

- Equipment installation and removal shall be performed in a slow and deliberate manner, if resistance to movement is found, installation/removal shall be halted and the source of resistance identified and corrected.

6.2 ACTIVITY-SPECIFIC CONTROLS

The following controls are activity specific, i.e., the nature of the activity invokes their inclusion into the control section. The controls listed below have been previously approved in specific applications in conjunction with the controls identified in Section 6.1. Controls identified below will be imposed in operating procedures as important to safety.

6.2.1 Standard Hydrogen Monitoring System and Gas Probe Assembly

- All components in the standard hydrogen monitoring system shall be inspected to ensure that they are installed properly and according to design requirements before operation of the system.

- The system shall be leak tested before initial startup and when components of the system that contain or contact sample gases are replaced.

- All standard hydrogen monitoring system drawings shall identify intrinsic safety features that must be maintained. No modifications will be made to any of these drawings without appropriate approvals.

- If the high-efficiency particulate air filter (breather filter) is removed to install a spool piece, the high-efficiency particulate air filter (breather filter) shall be operational again within 16 days. This is the shortest time period for any of the single-shell tanks to reach 25 percent of the lower flammability limit.

6.2.2 Vapor-Space Sampling

- Before the sample tubes are inserted into the riser, the waste level shall be determined and the sample tube lengths adjusted to reduce the possibility of removing samples from the waste surface (liquid or solids).

6.2.3 Photography or Video Surveillance

- Contamination control shall be provided around the open pump pit or open riser. The means of contamination control shall be specified in the applicable work package.

- Photographic equipment used, to include lighting and/or flash, shall conform to either the National Electric Code, Article 501 for use in Class I, Division 2, Group B, shall be purged with inerting gas in accordance with National Fire Protection Association, Inc., Article 496, or be designed so as to deenergize the camera system at a preset concentration limit such that the camera will not be operable when the tank is above 25 percent of the lower flammability limit at the camera. If the latter is chosen, analysis must show that the deenergized system can not cause ignition through residual heat, capacitor discharge, or other electrical discharge. The purge gas system, if used, shall have safety instrumentation to alarm and automatically shut off all electrical power to the electrical components served by the purge gas system if a loss of gas pressure occurs.

- Photographic hardware shall be of spark-resistant materials, such as stainless steel.

- A stainless steel insert with a static resistant plastic liner shall be used to protect the tank riser and to keep the photographic equipment from becoming contaminated.

- The photographic equipment shall provide for tank confinement at the open riser (e.g., glovebag, greenhouse, special riser cover).

6.2.4 Instrument Tree

- The riser shall be inspected for obstructions before installation of the instrument tree. Methods that could cause sparks or provide an ignition source in the tank or riser shall not be used. Excessive radiation exposure to workers should be avoided.

- If the installation of the instrument tree is done using the ultra-high-pressure nozzle, the water pressure shall be reduced to 34.5 MPa (5,000 psi) when the instrument tree flange is 30.5 cm (1 ft) above the riser flange. In addition, the instrument tree shall be rotated during the entire time water is supplied to the sluicing nozzle.

- A maximum of 950 L (250 gal) of treated water can be used for insertion of the instrument tree. If it is necessary to exceed this amount, permission must be obtained from Tank Farm Operations and Nuclear Safety.

6.2.5 Installation of Liquid Observation Well, Salt Well Screen, and/or Jet Pump Assembly

- The riser shall be inspected for obstructions before installation of the liquid observation well, salt well screen, and/or jet pump. Methods that could cause sparks or provide an ignition source in the tank or riser shall not be used. Excessive radiation exposure to workers should be avoided.

- To minimize changes in tank waste characterization, no more than 1,892 L (500 gal) of treated water shall be added to the tank for the pit decontamination and lancing operation. Tank Farms Operations and Industrial Safety will be required to authorize the use of additional water, if needed. The temperature of the water shall be less than 100 °C (212 °F). In addition, a flow totalizer shall be used to measure the amount of water added to the tank.

6.2.6 Grab Sampling

- The riser shall be inspected for obstructions before installation of the grab sampling assembly. Methods that could cause sparks or provide an ignition source in the tank or riser shall not be used. Excessive radiation exposure to workers should be avoided.

6.2.7 Auger Sampling

- During manual installation, one lifting bar shall be in place at all times.

- The riser shall be inspected for obstructions before installation of the auger assembly. Methods that could cause sparks or provide an ignition source in the tank or riser shall not be used. Excessive radiation exposure to workers should be avoided.

6.2.8 Push-Mode Sampling

- A maximum of 950 L (250 gal) of treated water with a lithium bromide tracer can be used during push-mode sampling for each complete core. If it is necessary to exceed this amount, permission must be obtained from Tank Farm Operations and Nuclear Safety.

- The hydraulic safety interlock that prevents penetration through the bottom of the tank shall be tested to ensure that it is functioning before the tank waste is sampled. The hydraulic safety interlock shall be engaged immediately before the last (determined by calculations) core segment is taken.

- The core drill truck shall not be modified to allow more pressure, i.e., 1.7 MPa (250 lbf/in^2), or more downward force than the currently allowed 23.7 kN (5,300 lbf) for push-mode core sampling.

- The old push-mode core sampling truck shall disengage rotary-mode capability using established lock and tagout procedures.
- The drill string shall be sampled for flammable gases after each inactive period of time while the drill string is open at the bottom (i.e., there is no sampler). If the concentration is greater than 25 percent of the lower flammability limit, the drill string is to be vented and/or purged.

6.2.9 Routine Maintenance and Surveillance

- Before the removal of pump pit cover blocks or before any intrusive work into the pump pit, the pump pit shall be sampled for flammable gases since the pit has open drains to the tank. If the concentration in the pump pit is greater than 25 percent of the lower flammable limit, the activity shall cease and the pump pit shall be vented by opening any access ports or removing any sealing material around the pump pit cover blocks. The activity shall not resume until the reading is below 25 percent of the lower flammability limit.
- Before performing neutron or gamma logging in a liquid observation well, the flammable gas concentration in the liquid observation well shall be sampled. The sample location shall be inside the liquid observation well. If the concentration is greater than 25 percent of the lower flammability limit, the liquid observation well shall be vented by leaving the riser cover off. Work shall not resume until the reading is below 25 percent of the lower flammability limit.

7.0 OPEN ITEMS

Photography and video surveillance will be allowed once the appropriate equipment is bought.

Rotary-mode sampling is not allowed until an approved safety basis is in place.

Interim-stabilization is not allowed until an approved safety basis is in place.

Subsurface ignition events are being analyzed to determine if they can happen and the consequences if they do.

Detonations in equipment is being analyzed to determine if it is credible and what the consequences are.

Detonations in the headspace are being evaluated for credibility. If credible, consequences will be calculated.

Lightning protection is being discussed for the tanks, at this time no tank has installed lightning protection.

This page intentionally left blank.

8.0 REFERENCES

Allemann, R. T., M. E. Brewster, P. A. Gauglitz, J. D. Hopkins, J. D. Hudson, Y. Onishi, C. S. Simmons, and C. W. Stewart, 1995, *A Discussion of Some Mechanisms for Sudden Gas Release from Single-Shell Waste Tanks at Hanford*, PNL-WTS-101095, Pacific Northwest Laboratory, Richland, Washington.

Antoniak, Z. I., and K. P. Recknagle, 1995, *Modeling of Post-GRE Spacial and Temporal Hydrogen Concentrations in Waste 241-AW-101 Dome*, WTSFG95.27, Pacific Northwest Laboratory, Richland, Washington.

Atencio, J. K., 1992, *System Description Standard Hydrogen Monitoring Systems*, WHC-SD-WM-SDD-001, Westinghouse Hanford Company, Richland, Washington.

Braun, D. J., L. D. Muhlestein, T. B. Powers, and M. D. Zentner, 1994, *High-Level Waste Tank Subcriticality Safety Assessment*, WHC-SD-WM-SARR-003, Westinghouse Hanford Company, Richland, Washington.

Brager, H. R., 1994, *Summary of Information on Flammable Gas Watch List Tanks*, WHC-EP-0711, Westinghouse Hanford Company, Richland, Washington.

Carls, D. R., 1994, *Tank Farm Health and Safety Plan*, WHC-SD-WM-HSP-002, Rev. 2D, Westinghouse Hanford Company, Richland, Washington.

Cowley, W. L., 1994, *Evaluation of Hazards to Tank Farm Facilities from Lightning Strikes*, WHC-SD-WM-SARR-007, Westinghouse Hanford Company, Richland, Washington.

Daugherty, H. F., 1990, *Initial Unusual Occurrence Report WHC-UO-90-013-TF-02*, (external letter 9052557 to R. E. Gerton, April 5), Westinghouse Hanford Company, Richland, Washington.

Davis, J. S., 1994, *Toxic Chemical Considerations for Tank Farm Releases*, WHC-SD-WM-SARR-011, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Deere, D. C., 1991, *Safety Assessment for Operation of the Temporary Gas Monitoring System in Tank 101-SY*, WHC-SD-WM-SAD-007, Westinghouse Hanford Company, Richland, Washington.

Deichman, J. L., 1992, *Letter of Applicability--Installation of Hydrogen Monitors*, Letter 9250858 to R. E. Gerton, U.S. Department of Energy, Richland Operations Office, dated March 3, 1992, Westinghouse Hanford Company, Richland, Washington.

DOE, 1986, *Disposal of Hanford Defense High-Level, Transuranic and Tank Wastes*, EIS-0113 (Vol. 3), Draft Environmental Impact Statement, U.S. Department of Energy, Washington, D.C.

DOE, 1994, *Environmental Assessment (EA) and Finding of No Significant Impact (FONSI) for the Waste Tank Safety Program at the Hanford Site (DOE/EA-0915)*, (DOE Letter from T. O'Toole, Assistant Secretary for Environment, Safety and Health, to T. P. Grumbly, Assistant Secretary for Environmental Restoration and Waste Management, dated February 25), U.S. Department of Energy, Washington, D.C.

DOE-RL, 1992, *Hanford Hoisting and Rigging Manual*, DOE/RL-92-36, U.S. Department of Energy, Richland Field Office, Richland, Washington.

Farley, W. G., 1994, *Safety Assessment for Installation and Operation of Thermocouple Trees in Ferrocyanide Tanks*, WHC-SD-WM-SAD-014, Rev. 3, Westinghouse Hanford Company, Richland, Washington.

Farley, W. G., 1996, *Video in Hanford Waste Tanks Using the Mobile Color Camera System*, USQE TF-94-0103, Westinghouse Hanford Company, Richland, Washington.

Fox, G. L., Jr., T. R. Beaver, O. B. Bechtold, and A. K. Postma, 1992, *Tank 241-SY-101 Crust Burn Analysis*, WHC-SD-WM-SAR-046, Rev. 1, Westinghouse Hanford Company, Richland, Washington.

Fox, G. L., Jr., D. D. Stepnewski, and R. P. Anantatmula, 1993, *Tank 241-SY-103 Hazard Assessment*, WHC-SD-WM-SAR-061, Westinghouse Hanford Company, Richland, Washington.

Fox, G. L., Jr., and D. D. Stepnewski, 1994, *Hazard Assessments of Double-Shell Flammable Gas Tanks*, WHC-SD-WM-SAR-064, Westinghouse Hanford Company, Richland, Washington.

Gauglitz, P. A., L. A. Mahooney, D. P. Mendoza, and M. C. Miller, 1994, *Mechanisms of Gas Bubble Retention*, PNL-10120, Pacific Northwest Laboratory, Richland, Washington.

Gauglitz, P. A., S. D. Rassat, M. R. Powell, R. R. Shah, and L. A. Mahooney, 1995, *Gas Bubble Retention and Its Effects on Waste Properties: Retention Mechanisms, Viscosity, and Tensile and Shear Strengths*, PNL-10740, Pacific Northwest Laboratory, Richland, Washington.

Graves, R.D., 1994, *Topical Report on Flammable Gas in Non-Burping Waste Tanks*, WHC-SD-WM-SARR-015, Westinghouse Hanford Company, Richland, Washington.

Griffin, T.E., 1991, *Test Results-Surface Auger Sampler*, WHC-SD-WM-TD-002, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Hanlon, B. M., 1995, *Waste Tank Summary Report for Month Ending August 31, 1995*, WHC-EP-0182-91, Westinghouse Hanford Company, Richland, Washington.

Hertelendy, N. A., 1993a, *Performance Test Report Optimized High-Efficiency Installation System Bore Head*, draft, WHC-SD-WM-TRP-137, Westinghouse Hanford Company, Richland, Washington.

Hertelendy, N. A., 1993b, *Project HEIS Final Test Results*, draft, WHC-SD-WM-TRP-132, Westinghouse Hanford Company, Richland, Washington.

Hertelendy, N. A., 1993c, *Safety Analysis of Sudden Shearing of the 37000 PSIG Flexible Water Hose by a Falling Heavy and Sharp Object (Guillotine)*, Internal Memo FSE93-003 to W. G. Farley, Westinghouse Hanford Company, Richland, Washington.

HSRCM, 1994, *Hanford Site Radiation Control Manual*, HSRCM-1, Westinghouse Hanford Company, Richland, Washington.

Jansen, D. B., 1992, *Water Additions to Ferrocyanide Tanks During Installation of Thermocouple Trees*, Washington State Department of Ecology letter 9208294 to S. H. Wisness, RL, December 2, 1992, Olympia, Washington.

Johansen, S., 1995, *Accelerated Safety Analysis and Topical Report Tank Dome Collapse*, WHC-SD-WM-SASRR-013, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Julyk, L. J., 1994, *Static Internal Pressure Capacity of Hanford Single-Shell Waste Tanks*, WHC-SD-WM-TI-623, Rev 0, Westinghouse Hanford Company, Richland, Washington.

Kummerer, M., 1994, *Topical Report on Heat Removal Characteristics of Waste Storage Tanks*, WHC-SD-WM-SARR-010, Westinghouse Hanford Company, Richland, Washington.

LANL, 1994, *Bounding Gas Release Calculations of Flammable Gas Watch List Single-Shell Tanks*, LA-UR-94-1323, Rev. 0, Los Alamos National Laboratory, Los Alamos, New Mexico.

LANL, 1995, *A Safety Assessment for Proposed Pump Mixing to Mitigate Episodic Gas Releases in Tank 241-SY-101: Hanford Site, Richland, Washington*, LA-UR-92-3196, Rev. 14, Los Alamos National Laboratory, Los Alamos, New Mexico.

Lawrence, M. J., 1990, *Unreviewed Safety Question - Waste Storage Tanks*, (external letter to L. P. Duffy, May 14), U.S. Department of Energy, Richland Operations, Richland, Washington.

Marusich, R. M., 1991a, *Push Mode Core Sampling Safety Assessment*, WHC-SD-WM-SAD-008, Rev. 0-A, Westinghouse Hanford Company, Richland, Washington.

Marusich, R. M., 1991b, *Safety Assessment for the 101-SY Ventilation Upgrades*, WHC-SD-WM-SAD-012, Rev. 2, Westinghouse Hanford Company, Richland, Washington.

Marusich, R. M., D. C. Deere, and R. J. Van Vleet, 1991, *Safety Assessment for Window B Activities in Tank 101-SY*, WHC-SD-WM-SAD-003, Westinghouse Hanford Company, Richland, Washington.

Milliken, N. J., 1995, *Safety Analysis for Push-Mode and Rotary-Mode Core Sampling*, WHC-SD-WM-SARR-031, Rev. 1, Westinghouse Hanford Company, Richland, Washington.

Murthy, K. S., L. A. Stout, B. A. Napier, A. E. Reisenauer, and D. K. Landstrom, 1983, *Assessment of Single-Shell Tank Residual Liquid Issues at Hanford Site, Washington*, PNL-4688, Pacific Northwest Laboratory, Richland, Washington.

NFPA, 1993, *NFPA 70, National Electrical Code*, National Fire Protection Association, Inc., Quincy, Massachusetts.

NFPA, 1993, *NFPA 496, Standard for Purged and Pressurized Enclosures for Electrical Equipment*, National Fire Protection Association, Inc., Quincy, Massachusetts.

NUREG, 1980, *Control of Heavy Loads at Nuclear Power Plants*, NUREG-0612, U.S. Nuclear Regulatory Commission, Washington, D.C.

Powers, T. B., 1992, *Calculation of the Probability of Ignition of a Flammable Hydrogen Mixture During Window G Activities Caused by a Lightning Strike on the SY Tank Farm*, Internal Memo 29220-92-TBP-030 to J. M. Grigsby, et al., Westinghouse Hanford Company, Richland, Washington.

Reynolds, D. A., W. Kubic, R. D. Crowe, and R. J. Van Vleet, 1993, *Technical Basis for Selection of Tank 101-SY Intrusion Window*, WHC-SD-WM-TI-458, Rev. 6, Westinghouse Hanford Company, Richland, Washington.

Reynolds, D. A., 1994, *Evaluation of 241-AN Tank Farm Flammable Gas Behavior*, WHC-EP-0717, Westinghouse Hanford Company, Richland, Washington.

Rogers, C. A., 1994 *CSER 94-001: Criticality Safety of Single-Shell Tanks*, WHC-SD-SQA-CSQ-20363, Westinghouse Hanford Company, Richland, Washington.

"Safety Measures for Waste Tanks at Hanford Nuclear Reservation," Section 3137 of *National Defense Authorization Act for Fiscal Year 1991*, Public Law 101-510, November 5, 1990.

Savino, A. V., 1994, *Tank Farm HLW Compositions and Atmospheric Dispersion Coefficients for Use in ASA Consequence Assessments*, WHC-SD-WM-SARR-016, Westinghouse Hanford Company, Richland, Washington.

Scaief, C. C., 1991a, *Temperature Measurement Error Analysis*, WHC-SD-WM-TI-483 Westinghouse Hanford Company, Richland, Washington.

Scaief, C. C., 1991b, *Engineering Study of Temperature Sensors for Use in Waste Tank Surveillance*, WHC-SD-WM-ES-183, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Scaief, C. C., 1991c, *Engineering Work Plan for Ferrocyanide Tank Temperature Monitoring*, WHC-SD-WM-WP-075 Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Scaief, C. C., 1992, *Functional Requirements for Ferrocyanide Tank Temperature Monitoring*, WHC-SD-WM-RD-013, Westinghouse Hanford Company, Richland, Washington.

Scaief, C. C., 1994, *Ignition Analysis*, Internal memo to D. D. Stepnewski, dated May 24, Westinghouse Hanford Company, Richland, Washington.

Scaief, C. C., 1995, *Tank Farm Potential Ignition Sources*, WHC-SD-WM-ES-362, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Schneider, T. C., 1992, *Technical Assessment of 200 Area Waste Tank Hydrogen Monitoring System Components*, WHC-SD-WM-TA-034, Rev. 2, Westinghouse Hanford Company, Richland, Washington.

Smith, D. A., 1986, *Single-Shell Tank Isolation Safety Analysis Report*, SD-WM-SAR-006, Rev. 2, Rockwell Hanford Operations, Richland, Washington.

Sontag, S. P., 1991, *Safety Assessment for TV Camera and Lights Installation, Operation, and Removal in Tank 101-SY*, WHC-SD-WM-SAD-005, Rev. 2, Westinghouse Hanford Company, Richland, Washington.

Stone, W. A., J. M. Thorp, O. P. Gifford, and D. J. Hoitink, 1983, *Climatological Summary for the Hanford Area*, PNL-4622, Pacific Northwest Laboratory, Richland, Washington.

Toth, J. J., C. E. Willingham, P. G. Heasler, and P. D. Whitney, 1994, *Organic Carbon in Hanford Single-Shell Tank Waste*, PNL-9434, Pacific Northwest Laboratory, Richland, Washington.

Turner, D. A., 1994, *Revision of the Organic Watch List*, external letter 9453328 to R. E. Gerton, dated May 13, 1994, Westinghouse Hanford Company, Richland, Washington.

Van Vleet, R. J., 1991, *Safety Assessment for Penetrometer Testing and Auger Sampling in Tanks that Generate Flammable Gases*, WHC-SD-WM-SAD-004, Rev. 2, Westinghouse Hanford Company, Richland, Washington.

Van Vleet, R. J., 1996, *Safety Basis for Activities in Double-Shell Flammable Gas Watch List Tanks*, WHC-SD-WM-SARR-002, Rev. 1, Westinghouse Hanford Company, Richland, Washington.

Weadon, A. M., 1992, *Lightning Protection of Underground Storage Tank 101-SY Inquiry #W-168884 Final Report*, (external letter to G. M. Christensen, dated July 2), Electric Research & Management, Inc., State College, Pennsylvania.

WHC, 1993, *Perform Installation of New or Modified Large Equipment in Tank Farms*, Tank Farm Operating Procedure TO-020-250, Westinghouse Hanford Company, Richland, Washington.

WHC, 1996, *Operating Specification for Watch List Tanks*, OSD-T-151-00030, Rev. B-16, Westinghouse Hanford Company, Richland, Washington.

WHC-CM-4-46, *Safety Analysis Manual*, Westinghouse Hanford Company, Richland, Washington.

WHC-CM-7-5, *Environmental Compliance*, Westinghouse Hanford Company, Richland, Washington.

Wilkins, N. E., 1994, *Evaluation of Tank 241-AW-101 Flammable Gas Behavior*, WHC-SD-WM-TI-617, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Wood, S. A., 1994, *Phase 1 Analysis for Single Shell Tanks on the Flammable Gas Watch List*, WHC-SD-WM-ER-342, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

APPENDIX A

FREQUENCY OF OCCURRENCE OF IGNITION

This page intentionally left blank.

APPENDIX A

FREQUENCY OF OCCURRENCE OF IGNITION

1.0 INTRODUCTION

This appendix contains a qualitative, semiquantitative argument to determine the frequency of ignition for the flammable gas tanks. This appendix applied to both double-shell and single-shell tanks. This is done because the type of analysis done for either tank is similar, the types of flammable gases are similar, and the types of equipment used are similar.

2.0 PROBABILITY OF IGNITION SOURCES

This section will be divided into two subsections. One on external ignition sources and one on internal ignition sources. These are discussed below.

2.1 EXTERNAL EVENTS

The *Hanford Waste Vitrification Plant Preliminary Safety Analysis Report* (Herborn 1991) examined the potential for flooding the 200 Areas (both the 200 East and 200 West Areas). Probable maximum floods on streams and rivers, surge and seiche flooding, flooding from ice dams, flooding from tsunamis, and flooding from dam failures were analyzed. The worst-case flood was found to be caused by a hypothetical direct-hit detonation of a nuclear warhead on the Grand Coulee Dam. In that scenario, the floodwaters would peak at an elevation of 140.2 m (460 ft). This is well below the 213.4-m (700-ft) elevation of the 200 Area. As a result, flooding is eliminated as an external ignition initiating event.

A range fire as an external ignition initiating event can be eliminated from consideration for two reasons. First the tank farms are kept clear of vegetation and are surrounded by fences that will keep out most burning debris. Even in the event burning debris enters a tank farm, there are no combustible materials stored in the farm. Second, there are no mechanisms to propagate a fire back into a tank. For example, tank 241-SY-101 has been classified according to National Fire Protection Association provisions (NFPA 1993). The vapor space is Class 1, Division 2, Group B, whereas outside the tank on the top is considered a nonclassified region. Additionally, a flame front could not propagate back into the tank unless the concentration would support downward propagation. For hydrogen, this concentration is 9.0 percent (well above the maximum measured concentration of 5.1 percent). For the slurry gas mixture presented in Appendix B, this may not be true. Measurements of the downward, horizontal, and upward propagation limits are being conducted during fiscal year 1996. Therefore, range fires are eliminated as an external ignition initiating event.

High winds are not considered a credible external ignition initiating event. The tanks are buried in the ground and are not susceptible to wind-borne missiles. Additionally, flammable concentrations could not exist outside of the tank during the high winds, and a flame front could not propagate back into the tank because of the required hydrogen concentration for downward flame propagation (see paragraph above). Tornadoes also were evaluated by Herborn (1991). Tornadoes are rare in the Pasco Basin, and on the average, the State of Washington experiences just over one tornado per year. Additionally, as specified by the U.S. Department of Energy (DOE 1989), *Design and Evaluation Guidelines for Department of Energy Facilities Subjected to Natural Phenomena Hazards* is used for nonreactor facilities. This document says that tornadoes are not considered a viable threat or hazard at the Hanford Site. Dust devils are another wind phenomena. These occur frequently during the summer months. Dust devils have a short lifespan and are believed to have low wind speeds as compared to tornadoes. The consequences of any missiles generated are bounded by those generated by high winds. Consequently, high winds, tornadoes, and dust devils are eliminated as an external ignition initiating event.

Herborn (1991) also examined the volcanic hazards for the 200 Areas. In the report, it is stated that there is no evidence of lava flows, ash flows, or mudflows from Cascade Range volcanoes having reached the Pasco Basin during the Quaternary period. The nearest Cascade Range volcano is 96.6 km (60 mi) from the Hanford Site. Most eruption products remain within 48.3 km (30 mi) of the Cascade Range volcanoes. The only exceptions are mudflows and ashfall. The mudflows tend to follow existing drainage channels, and since there are no streams flowing directly from the Cascade Range to the Hanford Site, this volcanic hazard is not considered credible. Ashfall is considered for structural purposes; however, the ashfall is not considered as a ignition source. As a result, volcanic activity is eliminated as an external ignition initiating event.

The annual frequency for a large earthquake (0.2g) is given as 5×10^{-4} per year (Tallman 1994). Two cases will be evaluated, one during normal operations (storage of the waste) and one during an activity in the tank. For the case of normal operations, the earthquake might cause a tank to have a gas-release event. However, there is a time delay between the jolt to the tank and the gas being released into the vapor space. For example, in tank 241-SY-101, it was calculated that it took 2 minutes for the gas to move from the bottom of the tank to the headspace during a rollover type gas release event.

Some of the permanent equipment installed in the tank, such as thermocouple trees, liquid observation wells, and salt well screens are secured at the top (by being bolted to the riser flange) and at the bottom (by being inserted in the waste matrix). Generally the waste matrix is made up of solids, for example, salt cake or sludge in the single-shell tanks or settled solids or slurry in double-shell tanks. Therefore, one could expect that the tank, the equipment, and the waste would move together during the earthquake. Other equipment, such as sludge weights, manual tapes, Food Instrument Corporation level probes, and Enraf displacement probes, may be able to move during the earthquake. However, even if they did move, they would have to be able to travel some distance to impact other equipment in the tank or the tank walls. Typically, this would be a distance of 3.1 to 4.6 m (10 to 15 ft).

After earthquakes, aftershocks typically occur. These are usually smaller in magnitude. The same arguments about equipment movement holds true.

Because there are no credible ignition sources in the vapor space during normal operations (see discussion below) and because any equipment movement would have occurred when the earthquake struck, this ignition is not considered credible. For the second case, assuming that tank activities last 8 hours, the probability of an earthquake occurring during that time is given by

$$P = \left(\frac{8\ hr}{(24\ \frac{hr}{day})(365\ \frac{day}{yr})}\right)\left(\frac{5 \times 10^{-4}}{yr}\right)$$

$$= 4.6 \times 10^{-7}.$$

For example, for 2 8-hour activities in the tank (or any combination of activities totaling 14 hours), the annual frequency would still be less than 1×10^{-6} per year (i.e., it is in the incredible category). However, 18 hours of activity brings you into the highly unlikely category. No single tank has activities performed for a duration of 18 hours. Therefore, earthquakes are eliminated as external initiating events.

Lightning as an ignition source has an estimated frequency of 4.52×10^{-4} per year per tank (Cowley 1994). Cowley (1994) indicates that if protection against lightning strikes is taken (an example includes the measures found in military standard MIL-B-5087B), this frequency might be reduced. Using the method as shown above, lightning strikes during activities that last for less than a cumulative total of 20 hours are incredible (frequency of lightning during the time of activity coupled with the frequency of flammable gas being present in concentrations above 25 percent of the lower flammable limit averaged over the total vapor space is $< 1 \times 10^{-6}$). No single tank has activities performed for a duration of 20 hours. Thus, lightning is eliminated as an external initiating event during an activity (NOTE: Two controls are still imposed because a thunderstorm at the Hanford Site can develop with no warning in less than 1 hour). However, lightning during normal operation (storage of the waste) is still a credible external initiating event.

2.2 INTERNAL EVENTS

In this section, it will be assumed that known spark sources in the tanks have been removed or deenergized (See Section 6.1.7 of this document).

Powers and Morales (1994) was reviewed for internal events. The following paragraphs, which are excerpted from Van Vleet (1994), discuss how the data were manipulated and provide the technical basis for the manipulation. This section covers both normal operation (storage of the waste) and activities in the tanks (e.g., photography using equipment rated for Class I, Division 2, Group B; sampling and installation of monitoring equipment).

The first manipulation was to correct the probabilities to a per event basis. To do this, the probabilities in Powers and Morales, Appendix E (1994) were divided by 3.65, the average number of gas releases that tank 241-SY-101 had before the mitigation mixer pump was installed. This information is presented in Table A-1.

In the normal storage mode, the potential ignition sources for either single-shell or double-shell flammable gas tanks are the same. These potential sources are the ventilation system; permanent closed-circuit television cameras (double-shell tanks only); the level-indicating instrument; and the thermocouple tree. These systems are described below, and where appropriate, credit is taken for meeting the NFPA requirements for potentially flammable atmospheres (NFPA 1993). In the activity mode, credit will be taken for the use of ignition-source prevention controls and for flammable gas monitoring during all activities.

All cutsets dealing with external to the tank ignition sources (i.e., the sources in the ventilation system) were removed. This was done because propagation of a flame through the duct and into the tank would not occur unless the concentration of hydrogen was at the concentration that supported downward propagation of the flame front. This limit is 9.0 volume percent for hydrogen in air (Coward and Jones 1952). This is well above the peak hydrogen concentration ever measured in tank 241-SY-101, 5.1 volume percent. For the slurry gas mixture presented in Appendix B, this may not be true. Measurements of the downward, horizontal, and upward propagation limits are being conducted during fiscal year 1996. However, the other double-shell tanks apparently have significantly smaller gas-release events (as evidenced by the surface level drops and the absence of pressure pulses). Therefore, the hydrogen concentration in tank 241-SY-101 is used as a bound for the hydrogen concentration in the other flammable gas double-shell tanks. An earlier section of this document, Section 1.3, describes retention and release mechanisms for single-shell tanks. Hydrogen monitoring on these single-shell tanks has been in place for less than one year. To date, no episodic behavior has been observed.

The removal of external ignition sources is still justified. There are no ignition sources in the ventilation system except at the exhauster. The exhauster has basically four potential ignition sources: the heater elements, the fan blade, the fan bearings, and the radiation monitoring equipment in the stack. For these to be ignition sources, they must fail or malfunction while a flammable concentration of gas is present. Additionally, because the ventilation systems serve multiple tanks, air is pulled from the other tanks (three tanks in the SY farm, 13 tanks in the SX farm*, seven tanks in the AN farms, and six tanks in the AW farm) and the actual concentration arriving

---

*The SX farm is the only single-shell tank farm actively ventilated. Only 13 of the 15 SX farm tanks are actively ventilated. An exhauster also ventilates tanks 241-C-104, 241-C-105, and 241-C-106 in the C farm. The SY, AN, and AW are among the double-shell tank farms.

at the exhauster is less than that in the vapor space of the tank having a gas-release event. Additionally, the bounding gas-release event from 241-SY-101 is no longer deemed a credible event since a mitigation option (mixer pump) was chosen and implemented in 1993. As required by the U.S. Department of Energy, Richland Operations Office, the mixer pump must continue the mitigation by mixing pump operation (Sidpara 1995). The remaining cutsets (Powers and Morales 1994, PE-4) are represented in Table A-1.

Table A-1. Ignition Frequency for Flammable Gas Tanks.

Cutsets	Description	241-SY-101 frequency[a]	FG DST frequency[b]	FG SST frequency[b]
5	Electrical sparks from explosion-proof lights, or faults in the electrical leads to the lights.[c]	1.31×10^{-3}	0.00	NA
9	Mechanical sparks caused by metal striking metal in the tank.	3.65×10^{-4}	1.00×10^{-4}	1.00×10^{-4}
10	Mechanical sparks from sludge-level-weight cable striking gas monitoring probes.[d]	3.65×10^{-4}	0.00	0.00
11	Electrical sparks from operation of the FIC level measurement device.[c]	2.19×10^{-4}	0.00	0.00
Total	--	2.26×10^{-3}	1.00×10^{-4}	1.00×10^{-4}

[a]Assumes 3.65 gas-release events per year.
[b]Assumes one gas-release event per year.
[c]This failure, or that of any of the other level-measurement instruments, is no longer considered credible.
[d]The gas monitoring probes installed in the other tanks have grid plates to prevent the tubes from hitting one another and causing sparks.
DST = double-shell tank.
SST = single-shell tank.
FG = flammable gas.
FIC = Food Instrument Corporation.

The cutset for electrical sparks caused by the explosion-proof lights or the electrical leads to the lights has been eliminated. This is because originally certain design features were not taken into account. With these design features included in the analysis, the ignition frequency becomes $< 1 \times 10^{-6}$ (Scaief 1994).

Some of the Food Instrument Corporation level-indicating devices have been outfitted with a slack-tape switch. This is a known spark source and must be removed on flammable gas tanks. It is assumed that this has been done (see Section 6.1.7) so that the cutset for the operation of the Food Instrument Corporation level-indicating device has been eliminated also. A more thorough review of the Food Instrument Corporation level-indicating device (Scaief 1994) indicated that it could not fail in the manner that was originally assumed. Other means of in-tank level measurement (displacement gauge, manual tapes, and zip cords) have been evaluated and determined not to be spark sources (Scaief 1994).

A potential safety concern was sparking or resistive heating of thermocouples in the waste. A thermocouple produces a voltage proportional to the difference in temperature between the thermocouple junction and the reference junction (voltmeter location). Because the thermocouples are grounded, the only credible mechanism for an electrical arc is to have one of the thermocouple wires break, and at the same time a high voltage to be accidently applied to the thermocouple leads. There is little chance of this happening because the signal conditioner hooked up to the thermocouples operates on 12 or 15 volts DC. Significant resistive heating of a thermocouple would require high current flow through the thermocouple, which in turn would require high voltage applied to low impedance. This also has little chance of happening because thermocouples have an impedance of 10 to 100 ohms distributed over the entire length of the thermocouple. If 15 volts DC were accidently connected to a thermocouple, the potential exists for 0.15 to 1.5 A of current to flow through the thermocouple and heat the wiring a few degrees. Such heating would be distributed over the entire length of the thermocouple wire and would present no safety hazard. Also, any spark or resistive heating would be confined by the thermocouple sheath, tubing, and pipe in the interior thermocouples of the thermocouple tree. External thermocouples would have only the thermocouple sheath for a barrier.

A platinum resistance temperature detector produces a change in resistance proportional to the temperature of the extension wire and the measuring termination point. The typical resistance of a resistance temperature detector is about 100 ohms. Assuming a typical excitation current of 0.5 A, the resistance temperature detector at 50 °C (120 °F) would have a resistance of 120 ohms and would produce about 0.03 mW of heat energy (Scaief 1991a). This heat would be dissipated by the surrounding sheath and would be inconsequential. The resistance temperature detectors in the protective sheath will be qualified for use in a National Fire Protection Association, Class 1, Division 1, Group B hazardous location (Scaief 1991b). Therefore, there is no cutset dealing with the instrument tree being an ignition source.

As mentioned above in the External Events section, the instrument tree, liquid observation well, or the salt well screen could be one of many ignition sources (either in the vapor space or subsurface) if the tank were struck by lightning. However, as mentioned above, if protection against lightning strikes is taken (similar to the measures found in military standard MIL-B-5087B) this frequency might be reduced.

Another subsurface spark source could be the push-mode sampling apparatus if it were struck by lightning. However, lightning strikes during activities have been shown to be incredible (frequency of lightning during the time at risk coupled with frequency of flammable gas is < 1 x 10^{-6}). Furthermore, the sampling truck is grounded and bonded for lightning strikes. Spark sources during the use of the sampling equipment itself have been administratively controlled (see discussion below).

In this section of this appendix, it was shown that there is only one external spark source of concern and that the operating equipment (level-measuring equipment and the temperature-monitoring equipment if the actions described in Section 6.1.7 are taken) in the tank is not considered to be a source of sparks. For a deflagration to occur, the ignition source must exist in the same location as the flammable concentration of released gases. Thus, the internal ignition sources being dealt with are mechanical sparks caused by metal striking metal in the tank. This type of ignition source could occur in the tank during normal storage mode if tank equipment during a gas-release event was affected in such a manner as to cause it to impinge upon the tank wall. Sludge weights (obsolete equipment consisting of a small metal weight on a long cable) have been postulated to swing into the wall. In tank 241-SY-101, sludge weights were observed (via the closed circuit television camera) to move around (but not swing free of the waste) during the roll-over events. The postulated maximum gas-release events in all the double-shell flammable gas tanks are less than the gas-release volume postulated to occur during a tank 241-SY-101 activity window before the mitigation mixer pump was installed (see also the 2445 m^3 burn analysis in LA-UR-92-3196, LANL, 1995. However, the sludge weight will move away from the upwelling during a partial or local gas-release event. Thus, even if it does strike a wall, it may not have enough energy to cause a spark and even if it does, the spark would occur away from the highest concentrations of flammable gas, potentially in a region that is nonflammable. Another concern associated with the sludge weights moving during a gas-release event was frictional heating caused by the cable rubbing on the riser lip. A similar analysis for a stainless steel probe was analyzed and determined to be an incredible ignition source (Marusich et al. 1991). The sludge weights have been removed from tank 241-SY-101.

Movement of thermocouple trees also was observed in tank 241-SY-101 during gas-release events. Evidence of this behavior was postulated before actually seeing it because of the bends in the thermocouple tree. The thermocouple tree in tank 241-SY-101 was removed, and it was replaced with a sturdier multifunction instrument tree. Recent in-tank videos of tanks 241-SY-103 and 241-AW-101 do not show any bends in the thermocouple trees. The postulated maximum gas-release events in all the double-shell flammable gas tanks are less than the gas-release volume postulated to occur during a tank 241-SY-101 activity window before the mitigation mixer pump was installed. Thus, spark sources caused by movement of equipment in the double-shell tanks during a gas-release event is considered to be not credible.

The single-shell flammable gas tanks have behavior that is significantly different than that of tank 241-SY-101. These tanks have not had rollover-type gas release events (a conclusion drawn from surface-level data only because temperature data are not taken frequently enough to provide useful information, and pressure data are nonexistent). Additionally, gas-release events that cause the waste to roll over (a rapid exchange of waste in the bottom layers of the tank with the waste in the upper layers) do not appear to be credible events. Calculations on postulated gas storage and release mechanisms show that if a gas-release event occurred in a single-shell tank it would likely take a long time (Allemann et al. 1995). Other mechanisms for storage and release are discussed in Section 1.3 of this document. Additionally, the release most likely would not be a complete tank rollover (similar to 241-SY-101), simply because the waste types generally are different (solids, sludges, and salt cakes versus sludges and liquids). Thus, spark sources caused by movement of equipment in the single-shell tanks during a gas-release event are considered to be not credible.

Thus, the only internal ignition sources of concern are those generated during an activity. To minimize these ignition sources, a number of administrative controls have been imposed on operations in flammable gas tanks. These include, but are not limited to, grounding and bonding to prevent electrostatic sparks; grounding and bonding tall objects (3 m or more in length) for protection against lightning; use of spark-resistant materials, using spark-resistant tools; and minimizing frictional heating or mechanical sparking. With these controls in place, an engineering judgment is made that a probability of 1/10,000 for ignition sources being present is reasonable.

3.0 PROBABILITY OF FLAMMABLE GASES BEING PRESENT

The next subject that needs to be addressed is the probability of flammable gases in ignitable concentrations. For tank 241-SY-101, the probability that the entire vapor space contained flammable gases at concentrations that could be ignited during each gas-release event was taken as one. This has been shown to be a correct assumption for tank 241-SY-101. During the releases in the tank, monitoring was performed on the gas probe assemblies (Reynolds 1994). The first test measured the hydrogen concentration at three probe positions 45.72 cm (18 in.) from the surface. These measurements agreed well with one another and did not show any significant time lag. Another test measured the hydrogen concentrations 45.72 cm (18 in.) from the waste surface and near the tank dome. Again the measurements for this tank were virtually identical and there was no time lag. These tests proved that the release in tank 241-SY-101 was large enough and quick enough that the entire vapor space volume was uniformly mixed within seconds. However, Reynolds (1994) reports the concentration reached in the vapor space did not exceed the lower flammability limit of hydrogen in air of 4 volume percent, except for 2 of 11 releases.

For the double-shell flammable gas tanks (241-AN-103, 241-AN-104, 241-AN-105, and 241-AW-101), two analyses have been completed that indicate that the entire vapor space of these other tanks will never reach the lower flammability limit (Reynolds 1994, Wilkins 1994). Additionally, more detailed modeling of tank 241-SY-103 indicated that the release area had to be restricted (37.2 m^2 [400 ft^2] out of 410.4 m^2 [4,417.9 ft^2] [Fox et al. 1993]) and the release had to occur over a few minutes for a local region to develop where the concentration is above the lower flammability limit. This phenomenon is called a plume. Because the volume of the plume containing gas in flammable concentrations is much smaller than the volume of the entire vapor space containing gas in flammable concentrations, the consequences from a plume burn are bounded by the consequences from a global burn (Fox and Stepnewski 1994). Frequencies are discussed in Section 3.2 of this appendix.

The argument that the entire vapor space of the single-shell flammable gas tanks is unlikely to reach flammable concentrations also can be made. During the limited time monitoring data on single-shell tanks has been taken, none of the tanks has experienced episodic behavior although the tanks may have the potential to have an episodic release. The tanks of concern (LANL 1994) have been experiencing level growth for 10 to 12 years. If a gas-release event occurs, Alleman et. al. (1994) postulates it would likely take a long time. Additionally, the release would most likely not be a complete tank roll-over (similar to 241-SY-101) simply because the waste types are different (solids, sludges, and salt cakes versus sludges and liquids). Additionally, the standard hydrogen monitoring systems have been in place on the tanks for several months now. Nineteen single-shell flammable tanks have had hydrogen mounting for at least 6 months. This information will be used in the probability argument later.

Additionally, there are administrative controls for monitoring the flammable gas concentration in the tank during an activity. Before the any work begins in a flammable gas tank, the nonflammability of the vapor space will be assured. No work is allowed if the vapor space is above 25 percent of the lower flammability limit. Additionally, if work in the vapor space is in progress, work is to cease if the concentration exceeds 25 percent of the lower flammability limit. A review of existing gas release data and the response of the Whittaker cells showed that if work were being done at the time the release occurred, the 25% LFL limit would always allow shutdown of activities before the lower flammability limit was released. Given the arguments in the previous paragraphs, a probability of 1/100 (an independent human error) is considered reasonable.

3.1 DEFINITION OF ACTIVITIES

Not all tank farm activities have the potential for causing a deflagration. Activities such as dome surveillance; ventilation and balance activities; instrument testing, calibration, repair, or replacement; level-indicating device flushing or repair; and liquid observation well gamma/neutron logging are not considered intrusive activities; that is, they are isolated from the tank atmosphere or are purged. These activities are generally conducted outside of the tank environment and have only a small chance of being a problem. However, because they potentially could result in toxic gas exposures or local deflagrations (the flammable gas concentration is enough to support combustion in the area where work is being performed), prudent work controls still are required. The potential for causing a deflagration inside the tank is considered incredible.

Only activities that have the potential for introducing an ignition source into the tank vapor space and waste are considered when calculating the frequency of a deflagration. Any activity that penetrates the plane of the riser and/or is in direct communication with the tank atmosphere is considered an intrusive activity. This is further broken down into vapor space intrusive activities and waste intrusive activities. Examples of vapor space intrusive activities include, but are not limited to, installing temporary or permanent photographic equipment, installing gas monitoring probes, installing equipment in the ventilation system, replacing the level-indicating device (when no isolation valve is present), and sampling the vapor space. Examples of waste-intrusive activities include, but are not limited to, installing instrument trees or liquid observation wells; installing salt well screens; removing or installing jet pumps; and grab, or auger, or push-mode sampling of the waste. Additionally, if several waste-intrusive activities are conducted at the same time, i.e., the tank is open and continuous monitoring with an independent, operable, and functioning system is ongoing, the multiple activities count as one intrusive activity. For example, a riser is open and an auger sample is taken, a hole is lanced in the waste; and then an instrument tree is inserted. All three of these together would be considered one intrusive activity. However, at no time shall the duration of this combination of activities exceed a total of 1 days.

3.2 FREQUENCY OF FLAMMABLE GAS DEFLAGRATIONS

The basis for acceptable risk is defined in WHC-CM-4-46 the WHC Safety Analysis Manual. Section 4.1 states the risk frequency is based on the event sequence for each accident scenario, i.e., a per activity risk frequency. The frequency for ignition of flammable gases in the flammable gas tanks is

$$\text{Ignition Frequency} = (P_{FLAMMABLE})(P_{IGNITION})(P_{MONITORING})$$

where

$P_{FLAMMABLE}$ is the probability that flammable gases concentrations are present.

$P_{IGNITION}$ is the probability that an ignition source exists even when prevention measures are taken.

$P_{MONITORING}$ is the probability that monitoring is not conducted or fails.

The information from the above sections and this equation will be used to determine ignition frequencies for vapor-space intrusive activities and waste intrusive activities.

3.2.1 Vapor Space Intrusive Activities

For vapor space intrusive activities, the $P_{FLAMMABLE}$ will be 1/10 based on the measured data from the tank vapor spaces in both double-shell and single-shell tanks, $P_{IGNITION}$ will be 1/10,000 based on the Powers and Morales analysis; and $P_{MONITORING}$ will be 1/100 (an independent human failure frequency is estimated to be 1/100). Substituting these values in the equation gives

$$\text{Ignition Frequency} = (1 \times 10^{-1})(1 \times 10^{-4})(1 \times 10^{-2})$$
$$= (1 \times 10^{-7})$$

Thus, the ignition frequency is in the incredible range assuming the independent human failure frequency is estimated to be 1/100.

3.2.2 Waste Intrusive Activities

For waste intrusive activities, the $P_{FLAMMABLE}$ will be assumed to be 1 for single-shell flammable gas tanks based on the discussion in Section 1.3 of the main document; $P_{IGNITION}$ will be 1/10,000 based upon the Powers and Morales analysis; and $P_{MONITORING}$ will be 1/100 (an independent human failures frequency is estimated to be 1/100). Substituting these values in the equation gives

$$\text{Ignition Frequency} = (1)(1 \times 10^{-4})(1 \times 10^{-2})(F_{ACTIVITIES})$$
$$= (1 \times 10^{-6})(F_{ACTIVITIES})$$

Thus, the ignition frequency is in the incredible range assuming the independent human failure is estimated to be 1/100. (See discussion in Section 3.1 of this appendix on the definition of an activity).

4.0 REFERENCES

Allemann, R. T., M. E. Brewster, P. A. Gauglitz, J. D. Hopkins, J. D. Hudson, Y. Onishi, C. S. Simmons, and C. W. Stewart, 1995, *A Discussion of Some Mechanisms for Sudden Gas Release from Single-Shell Waste Tanks at Hanford*, PNL-WTS-101095, Pacific Northwest Laboratory, Richland, Washington.

Coward, H. F., and G. W. Jones, 1952, *Limits of Flammability of Gases and Vapors*, Bureau of Mines Bulletin 503.

Fox, G. L., Jr., D. D. Stepnewski, and R. P. Anantatmula, 1993, *Tank 241-SY-103 Hazard Assessment*, WHC-SD-WM-SAR-061, Westinghouse Hanford Company, Richland, Washington.

Fox, G. L., Jr., and D. D. Stepnewski, 1994, *Hazard Assessment of Double-Shell Flammable Gas Tanks*, WHC-SD-WM-SAR-064, Westinghouse Hanford Company, Richland, Washington.

Herborn, D. I., 1991, *Hanford Waste Vitrification Plant Preliminary Safety Analysis Report*, WHC-EP-0250, Westinghouse Hanford Company, Richland, Washington.

Highland, J. A., 1992, *WHC Safety Analysis Manual*, WHC-CM-4-46, Westinghouse Hanford Company, Richland, Washington.

LANL, 1994, *Bounding Gas Release Calculations of Flammable Gas Watch List Singe-Shell Tanks*, LA-UR-94-1323, Los Alamos National Laboratory, Los Alamos, New Mexico.

LANL, Los Alamos National Laboratory, 1995, *A Safety Assessment for Proposed Pump Mixing Operations to Mitigate Episodic Gas Releases in Tank 241-SY-101: Hanford Site*, Richland, Washington, LA-UR-92-3196, Rev. 14, Los Alamos, New Mexico.

Marusich, R. M., D. C. Deere, and R. J. Van Vleet, 1991, *Safety Assessment for Window B Activities in Tank 101-SY*, WHC-SD-WM-SAD-003, Westinghouse Hanford Company, Richland, Washington.

NFPA, 1993, *National Electrical Code*, NFPA 70, National Fire Protection Association, Incorporated, Quincy, Massachusetts.

Powers, T. B., and S. D. Morales, 1994, *SY Farm Ventilation Isolation Option Risk Assessment Report*, WHC-EP-0579, Westinghouse Hanford Company, Richland, Washington.

Reynolds, D. A., 1994, *Evaluation of 241-AN Tank Farm Flammable Gas Behavior*, WHC-EP-0717, Westinghouse Hanford Company, Richland, Washington.

Scaief, C. C., 1991a, *Temperature Measurement Error Analysis*, WHC-SD-WM-TI-483 Westinghouse Hanford Company, Richland, Washington.

Scaief, C. C., 1991b, *Engineering Study of Temperature Sensors for Use in Waste Tank Surveillance*, WHC-SD-WM-ES-183, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Scaief, C. C., 1994, *Ignition Analysis*, (internal memo to D. D. Stepnewski dated May 24), Westinghouse Hanford Company, Richland, Washington.

Sidpara, A. B, 1995, *Operation of the Mitigation-by-Mixing Pump in Tank 241-SX-101*, (External letter 95-TSD-107 to President, Westinghouse Hanford Company, August 21), U.S. Department of Energy, Richland, Washington.

Tallman, A. M., 1994, *Probabilistic Seismic Hazard Analysis DOE Hanford Site*, WHC-SD-W236A-TI-002, Westinghouse Hanford Company, Richland, Washington.

Van Vleet, R. J., 1994, *Probability for Ignition in Other Double-Shell Flammable Gas Watch List Tanks*, (internal memo 8D114-RJVV-94039 to K. O. Fein, dated April 21), Westinghouse Hanford Company, Richland, Washington.

WHC-CM-4-46, *Safety Analysis Manual*, Westinghouse Hanford Company, Richland, Washington.

Wilkins, N. E., 1994, *Evaluation of Tank 241-AW-101 Flammable Gas Behavior*, WHC-SD-WM-TI-617, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

This page intentionally left blank.

APPENDIX B

CONSERVATIVE ESTIMATE OF SLURRY GAS COMPOSITION AND LOWER FLAMMABILITY LIMIT IN THE FLAMMABLE GAS TANKS

This page intentionally left blank.

APPENDIX B

CONSERVATIVE ESTIMATE OF SLURRY GAS COMPOSITION AND LOWER FLAMMABILITY LIMIT IN THE FLAMMABLE GAS TANKS

1.0 INTRODUCTION

This document discusses hypothetical slurry gas mixtures. One mixture is a slurry gas totally composed of hydrogen. Such a mixture probably is not physically possible because as vapor space sampling of other tanks has shown, ammonia is present in the vapor spaces of double- and single-shell tanks. Therefore, a reasonable expectation is that some proportion of the gas mixture will be ammonia. A second hypothetical mixture is a slurry gas mixture based on measurements taken in tank 241-SY-101, this mixture was chosen because it has been well characterized. The mixture includes hydrogen, nitrous oxide, methane, carbon monoxide, and ammonia.

However, the lower flammability for this mixture has not been measured. The U.S. Bureau of Mines has done extensive testing with hydrogen/air/oxygen and hydrogen/air mixtures; this yields a lower flammability limit for hydrogen/air/nitrous oxide of 4 volume percent. Limited testing was performed by the U.S. Bureau of Mines for hydrogen/air/nitrous oxide. Again, depending on the interpretation of the data, the lower flammability limit for hydrogen/air/nitrous oxide is around 4 volume percent at room temperature. More extensive testing of gas mixtures may be performed during fiscal year 1995.

2.0 GAS COMPOSITION

The composition of the mixture is important. If the mixture is hydrogen and air, it takes a relatively small ignition source (0.01 mJ - equivalent to pieces of fabric rubbing together or to stray radio waves) to ignite the mixture. However, only when the hydrogen concentration becomes larger (~6%) is combustion rapid and complete. Mixing in other gases (such as ammonia) raises the lower flammability limit. Mixing in other gases also causes the size of the ignition source to increase. Additionally, ignition of mixtures at the lower flammability limit still will be lean burns and often are incomplete. Also, the energetics of the mixture is another issue. Of the three gases of concern in tank 241-SY-101, methane is the most energetic on a per mole basis, followed by ammonia, then hydrogen. However, the amount of oxidizer required for combustion varies. Therefore, the most energetic reaction would come from assuming the released gas was methane. However, it is unrealistic to expect 100% methane being produced based on the knowledge of gas production mechanisms in tank waste.

2.1 DERIVATION OF SLURRY GAS COMPOSITION

Only one tank, tank 241-SY-101, has had the slurry gas composition measured. The data collection from tank 241-SY-101 was started in April 1990. Instruments used to collect the data included online mass spectrometers, gas chromatographs, electrochemical cells, and Fourier transform infrared spectrometer. Also, confirmatory grab samples have been taken and analyzed to verify collection results.

This data has been used to develop a best estimate and conservative estimate for the gas composition of the slurry gas released in tank 241-SY-101 (Table B-1). The conservative estimate was obtained by maximizing the fuel and toxicological gas content of the mixture within the uncertainty bounds of the measured data (LANL 1995).

Table B-1. Estimates of Gas Composition at 325 K[a].

Gas	Best estimate (%)	Conservative estimate (%)
Hydrogen	28.77	31.41
Nitrous oxide	24.45	26.69
Ammonia	10.95	14.95
Nitrogen	32.82	23.51
Methane	0.35	0.53
Others[b]	0.25	0.50
Water vapor	2.40	2.40

[a]This temperature is the maximum temperature in the nonconvecting layer of tank 241-SY-101.
[b]Carbon monoxide is assumed to be representative of "others."

This slurry gas composition is considered conservative for tank 241-SY-101. As more data becomes available for the gas compositions from other flammable gas tanks, the analysis will be changed appropriately. Section 3.0 of this appendix will discuss the energetics of different slurry gas compositions.

2.2 CONSERVATISMS ASSOCIATED WITH THE SLURRY GAS COMPOSITION

The ammonia fraction in the release gases is assumed to be a constant. It is considered conservative to use a constant ammonia fraction. The use of a constant ammonia fraction also adds conservatism by maximizing the fuel and toxicological gas content within the uncertainty bounds of the measure data. Additional information on the use of a constant ammonia fraction can be found in Appendix B of the tank 241-SY-101 mixer pump safety assessment (LANL 1995).

The amount of minor gases is reported, from the measured data, as being 0.5 percent of the noncondensible gases. In this analysis, it will be used as 0.5 percent of the total released gas (both condensible and noncondensible gases). Also, methane will be treated as separate gas. Finally, the gases assumed to be in the minor gas category are assumed to be flammable and are represented as carbon monoxide.

The methane used in this analysis was measured in the gas composition of the tank 241-SY-101 gas release event called Event I, June 1993. The Fourier transform infrared spectrometer is not calibrated extensively for methane and the methane data must be analyzed by hand at 20 percent. Because of the limited number of data points and because the Fourier transform infrared spectrometer methane calibration is not as good as the ammonia calibration, a more conservative uncertainty of 35 percent is applied. Thus, the ratio of methane/nitrous oxide is obtained as 0.02. For this analysis, this ratio yields a conservative estimate of 0.48 percent methane in the released gas.

3.0 ENERGETICS

As mentioned earlier, the fuel in the slurry gas composition has been maximized within the uncertainty of the measured data. This section will develop a model for calculating the equivalent fuel content for different slurry gas compositions. This is done by calculating the equivalent internal energy of the combustion for the mixture and uses the following assumptions:

- The combustion process is approximated as a constant volume process.
- The only combustion products are water, nitrogen, and carbon dioxide (i.e., combustion is complete).
- The available nitrous oxide is consumed first, the remainder of the burn uses oxygen (or air) as an oxidizer.
- The reactants and products behave as an ideal gas mixture.

The Table B-2 provides the combustion reactions of interest and the associated energies of combustion. The internal energy, u_{RP}, for an ideal gas mixture is calculated as

$$u_{RP} = h_{RP} - RT(n_P - n_R)$$

where h_{RP} is the enthalpy of combustion, R is the ideal gas constant, T is the temperature of the vapor space after mixing (307 K), n_P is the number of moles of products, and n_R is the number of moles of reactants. It is assumed that water is in the vapor state.

Table B-2. Combustion Reactions and Associated Internal Energies.

Reaction	u_{RP} (kJ/mole of fuel)
$H_2 + 0.5\ O_2 \rightarrow H_2O$	-240.55
$H_2 + N_2O \rightarrow H_2O + N_2$	-323.80
$NH_3 + 0.75\ O_2 \rightarrow 1.5\ H_2O + 0.5\ N_2$	-317.44
$NH_3 + 1.5\ N_2O \rightarrow 1.5\ H_2O + 2\ N_2$	-442.45
$CH_4 + 2\ O_2 \rightarrow 2\ H_2O + CO_2$	-798.31
$CH_4 + 4\ N_2O \rightarrow 2\ H_2O + CO_2 + 4\ N_2$	-1,132.10
$CO + 0.5\ O_2 \rightarrow CO_2$	-281.72
$CO + N_2O \rightarrow CO_2 + N_2$	-365.04

Using these energies, the equivalent fuel in terms of volume of hydrogen burning in air can be calculated. First, the fraction of the fuel that is oxidized by nitrous oxide is given by

$$\theta = \frac{F(N_2O)}{F(H_2) + 1.5F(NH_3) + 4F(CH_4) + F(CO)}.$$

Then, using the internal energies from Table B-2, the equivalent fuel can be calculated using the following equation.

$$\begin{aligned} Fuel_{EQUIV} &= F(H_2)[R_1\theta + (1-\theta)] + F(NH_3)[R_2\theta + R_3(1-\theta)] + \\ &\quad F(CH_4)[R_4\theta + R_5(1-\theta)] + F(CO)[R_6\theta + R_7(1-\theta)] \end{aligned}$$

where

$$R_1 = \frac{-323.80}{-240.55} = 1.35$$

$$R_2 = \frac{-442.45}{-240.55} = 1.84$$

$$R_3 = \frac{-317.44}{-240.55} = 1.32$$

$$R_4 = \frac{-1,132.10}{-240.55} = 4.71$$

$$R_5 = \frac{-798.31}{-240.55} = 3.32$$

$$R_6 = \frac{-365.04}{-240.55} = 1.52$$

$$R_7 = \frac{-281.72}{-240.55} = 1.17.$$

The use of equivalent fuel allows comparison of varying slurry gas compositions. Figure B-1 shows curves for various slurry gas mixtures. One curve shows hydrogen with air; a second curve of hydrogen with nitrous oxide; a third curve with hydrogen, nitrous oxide, and 10 percent ammonia; a fourth curve with hydrogen, nitrous oxide, and 20 percent ammonia; and a fifth curve representing the conservative mixture from Table B-1 (with the exception that the hydrogen is allowed to vary from 0 to 84 percent and nitrous oxide is used account for the remainder of the slurry gas). NOTE: 84 percent is the maximum the hydrogen value can be if the ammonia is at 14.95 percent, the methane is at 0.53 percent, and the carbon monoxide is at 0.5 percent).

For example, if the slurry gas were composed of 30 percent hydrogen (the rest of the slurry gas mixture was inert gases) and there was another oxidizer (no nitrous oxide), the bottom curve would show that 30 % hydrogen translates into 30 percent hydrogen burning in air.. The conservative estimate curve on Figure B-1 uses nitrous oxide as the remainder of the slurry gas, i.e., after the hydrogen, ammonia, methane and carbon monoxide are accounted for, the remainder is taken as nitrous oxide.

This makes the conservative estimate curve in Figure B-2 slightly more energetic than what was calculated for tank 241-SY-101 (LANL 1995). For example, if the conservative slurry gas concentrations from Table B-1 were used (hydrogen at 31.41 percent, ammonia at 14.95 percent, methane at 0.53 percent, carbon monoxide at 0.5 percent), the remainder (52.61 percent) will be nitrous oxide. This mixture would be equivalent to 71.7 percent hydrogen in air (see Figure B-1) (compared with 68.2 percent hydrogen in air [LANL 1995]). Another way of interpreting the chart is that it gives the energy liberated by burning one mole of the mixture (with whatever oxidizer is

Figure B-1. Equivalent Energetics in Terms of Hydrogen in Air for Different Slurry Gas Mixtures.

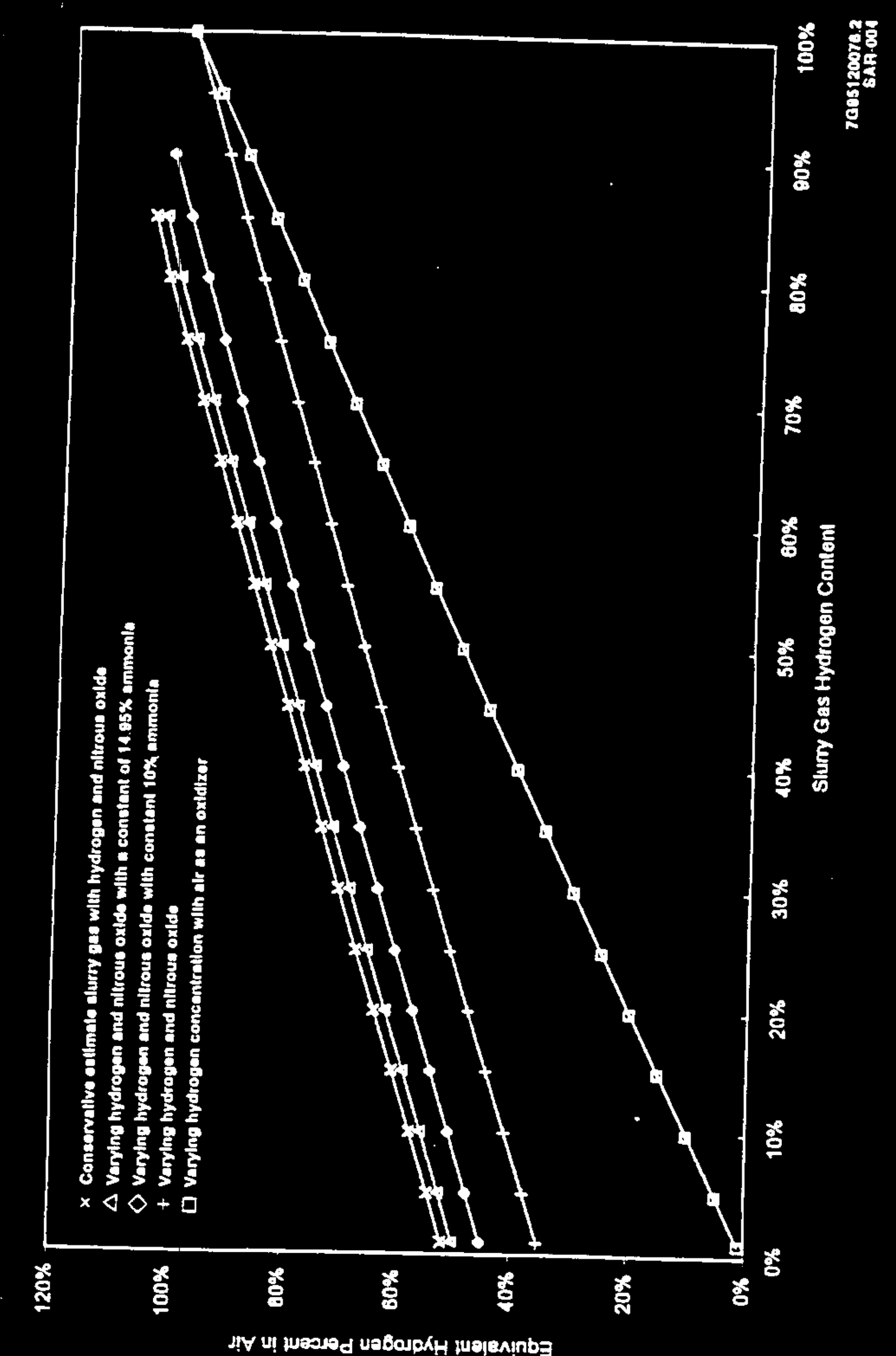
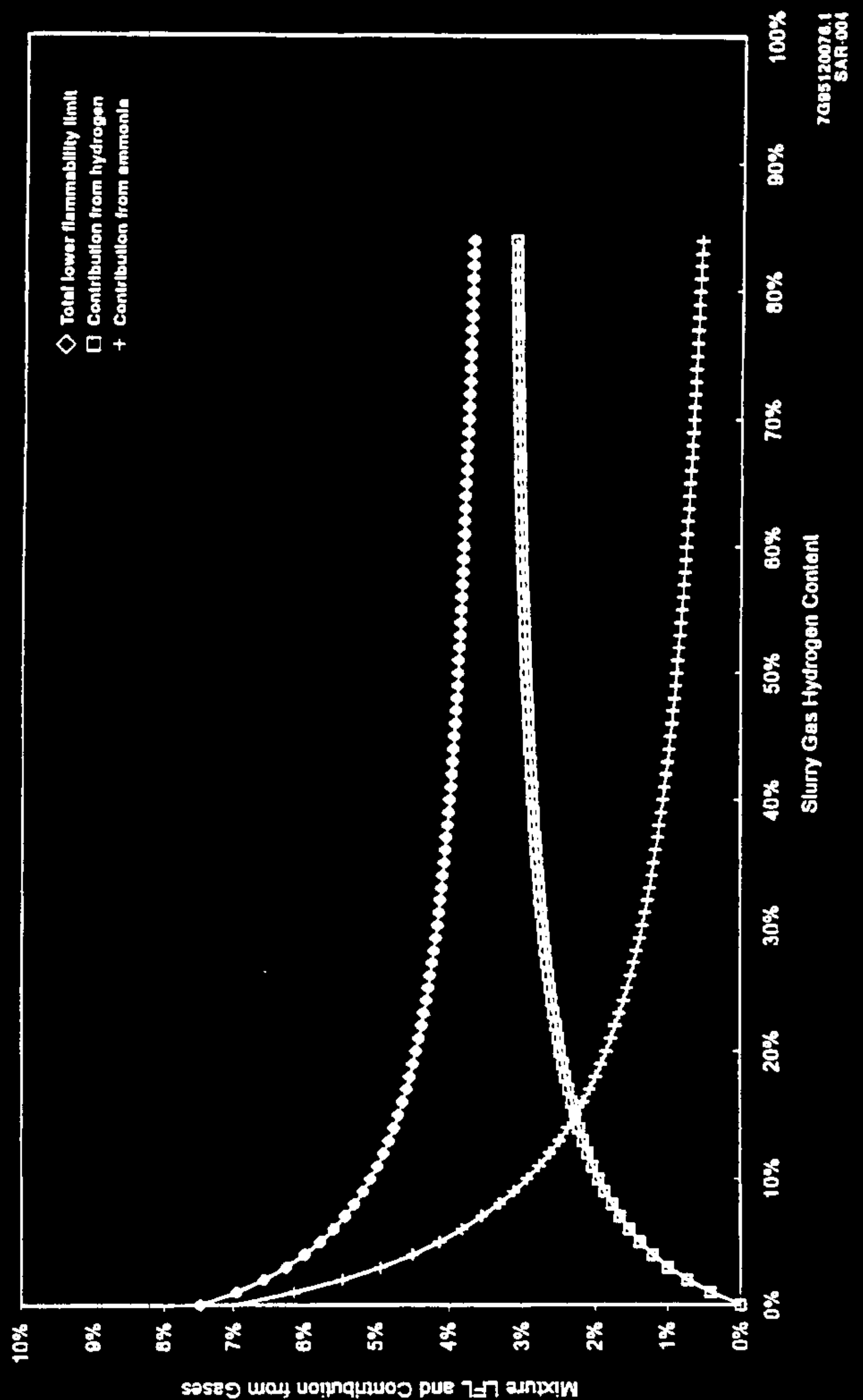


Figure B-2. Lower Flammability Limit as a Function of the Best Estimate (Slurry Gas Composition and Two Oxidizers).



present). That is, for the first example, the energy liberated is (0.3)(240.55) kJ/mole or 72.2 kJ/mole and for the second example is (0.717)(240.55) kJ/mole or 172.5 kJ/mole.

Figure B-2 shows that the conservative estimate (i.e., based on tank 241-SY-101) is more energetic than any of the other compositions shown on the graph. Until better data from other flammable gas tanks are available, the conservative estimate will be used for determining consequences.

4.0 LOWER FLAMMABILITY LIMIT

4.1 BACKGROUND

The lower flammability limit of a mixture depends on a number of parameters. These include the number and types of gases, the number and types of oxidizers, the geometry of the situation, and the energetics of the ignition source. For this estimate, the following assumptions were made.

- LeChatelier's law applies.
- Measured lower flammability limits are the same in the tank environment as they are in the laboratory.
- The mixture of gases does not change the ignition temperature or the energy required to ignite the mixture (as compared to hydrogen).

LeChatelier's law allows a lower flammability limit to be calculated if one knows the fraction of each flammable gas present in the mixture (i.e., the flammable gases are normalized and any other gases are ignored) and the lower flammability limit for each of those constituents. For example, the conservative mixture reported in Table B-1 contains at least seven constituents. However, only four are flammable. These are hydrogen (31.41 percent), ammonia (14.95 percent), methane (0.53 percent) and others (modeled as carbon monoxide @ 0.5 percent). The fraction of hydrogen is 31.41/(31.41 + 14.95 + 0.53 + 0.5) or 0.663. Likewise the fractions for ammonia, methane, and carbon monoxide are 0.315, 0.011, and 0.011, respectively.

Table B-3 gives the lower flammability limit for the flammable gases in air/oxygen (Coward and Jones 1952) and nitrous oxide (Hertzberg and Zlochower 1993).

Table B-3. Lower Flammability Limits in Various Oxidizers.

Gas	Lower flammability limit	
	Air/oxygen	Nitrous oxide
Hydrogen	3.5[a]	1.8
Ammonia	8.0[b]	2.0
Methane	5.0	0.8
Carbon monoxide	12.5	--

[a]This is the lower flammability limit for hydrogen at 400 K and the others were measured at 293 K.
[b]This value was used to represent the upward propagation limit. Further research did not find support for this number. The value commonly used is 15 percent.

LeChatelier's law (Coward and Jones) is

$$LFL_{mixture} = \frac{1}{\frac{f_1}{LFL_1} + \frac{f_2}{LFL_2} + \dots + \frac{f_n}{LFL_n}}$$

where LFL is the lower flammability limit of the particular gas and f is the normalized fraction of the particular flammable gas. Thus, for the slurry gas conservative estimate (see Table B-1), the lower flammability limit in air is 4.68 percent while in nitrous oxide it is 1.86 percent. However, this is for one particular mixture of slurry gases.

4.2 OPERATING LIMITS FOR IN-TANK ACTIVITIES

Because the standard hydrogen monitoring system measures for only one gas, e.g., hydrogen, appropriate limits must be set for in-tank activities. To set limits, some assumptions must be made on potential slurry gas compositions and on oxidizers. The following assumptions will be used:

- The slurry gas will contain four flammable gases. Ammonia will be a constant at 14.95 percent, methane a constant at 0.53 percent, and carbon monoxide a constant at 0.5 percent. Hydrogen will be allowed to vary from 0 to 84 percent.

- The maximum amount of nitrous oxide available for combustion is bounded by tank 241-SY-101. It is assumed that the volume available for the released gas to mix is only the hemispherical portion (no credit is taken for the cylindrical volume above the waste). This volume is 950 m^3. The maximum expected gas release event from tank 241-SY-101 is 263 m^3 of slurry gas. Of this, 26.69 percent is nitrous oxide. Thus, the amount of oxidizer that will be nitrous oxide is given by (0.2669)(263/950) or 7.4 percent.

The limited literature available on burns in air/oxygen with nitrous oxide indicates that the lower flammability limit is linear function depending only on the amount of nitrous oxide versus air/oxygen (i.e., a simple weighted average). Figure B-2 presents the lower flammability limit of slurry gas compositions with 92.6 percent air and 7.4 percent nitrous oxide.

Current operating experience with tank 241-SY-101 and tank 241-AW-101 indicates that the percent hydrogen in the slurry gas mixture can range from approximately 30 percent to 70 percent. Over this range, the lower flammability limit ranges from approximately 4.5 to 3.9 percent. Of this, the hydrogen contribution to the lower flammability limit would yield concentrations in the tank ranging from approximately 2.5 to 3.0 percent (see Figure B-2). Hydrogen is the only flammable gas measured . To conduct activities safely in a tank, a limit must be chosen that will cause activities to cease before there is any problem with flammability. The National Fire Protection Association, Inc., indicates that 25 percent of the lower flammability limit is the cut off for stopping activities. For the currently known situation, the safety limit should be (0.25) times (2.5 percent) or 0.625 percent (6,250 ppm) for hydrogen. If additional monitoring is added for ammonia, a limit for ammonia would be (0.25) times (0.86 percent) or 0.215 percent (2,150 ppm). NOTE: If the value used for the lower flammability limit of ammonia is changed from 8 percent to 15 percent as noted in Table B-3, the monitoring levels would change to 7,375 ppm for hydrogen and 1,700 ppm for ammonia.

5.0 CONCLUSIONS

To operate safely, an analysis was performed to determine a conservative estimate of slurry gas composition. This slurry gas composition was shown to be more energetic than a few other mixtures. The lower flammability limit was developed over a range of hydrogen concentrations using the conservative slurry gas composition. An operating limit of 6,250 ppm hydrogen is set for in-tank activities. Additionally, for future contingencies, an operating limit of 2,150 ppm of ammonia was developed. As more data are obtained from the tanks, the information on slurry gas compositions, lower flammability limits, and operating limits may change.

6.0 REFERENCES

Coward, H. F., and G. W. Jones, 1952, *Limits of Flammability of Gases and Vapors*, Bulletin 503, Bureau of Mines, Pittsburgh, Pennsylvania.

Hertzberg, M., and I. A. Zlochower, 1993, *Explosibility of Nitrous Oxide Gas: The Effect of H-Atom-Bearing Impurities*, 25th International Symposium on Combustion, University of California, Irvine, California.

LANL, Los Alamos National Laboratory, 1995, *A Safety Assessment for Proposed Pump Mixing Operations to Mitigate Episodic Gas Releases in Tank 241-SY-101: Hanford Site, Richland, Washington*, LA-UR-92-3196, Rev. 14, Los Alamos, New Mexico.

This page intentionally left blank.

APPENDIX C

DEVELOPMENT OF THE RISER PURGE TIME REQUIREMENTS

This page intentionally left blank.

APPENDIX C

DEVELOPMENT OF THE RISER PURGE TIME REQUIREMENTS

When an initially capped riser on a passively ventilated waste tank is opened, gases within it will be purged by density-driven flows and in actively ventilated tanks by the pressure gradient between the tank and ambient. Epstein (Epstein et al. 1994) systematically surveyed the possible mechanisms for gas exchange between single-shell tanks and the ambient. A letter (Plys 1994) suggested an equation that can be used to predict the purge rate and therefore the characteristic time for purging the riser. Because no tank is perfectly isolated (i.e., there are always leak paths), a limiting flow rate is given when the flow resistance is dominated by a filter. The volumetric purge rate is given by:

$$Q = \frac{c\, \Delta\rho\, g\, L}{R}$$

where

- c = Geometric coefficient
  - = 0.5 (for a single filter)
  - = 1.0 (for two filters)
- $\Delta\rho$ = Density difference, kg/m^3
- g = Acceleration of gravity
  - = 9.81 m/s^2
- L = Riser length, m
- R = Filter resistance
  - = 2,340 Pa·

NOTE: The density difference in the equation may be related to molecular weight differences or temperature differences. The latter is chosen because the temperature differences are a factor of 3 to 10 more important (Plys 1994). Thus,

$$\Delta\rho = \frac{\rho\, \Delta T}{T}.$$

Assuming ρ = 1.1 kg/m^3, ΔT = 6 K, T = 300 K, and L = 3 m, yields Q = 2.8 x 10^{-4} m^3/s. Because the volume of a riser with a diameter of 10.2 cm (4 in.) and a length of 3 m is about 0.024 m^3, the time to flush the riser would be given by

$$V/Q = \frac{0.024\ m^3}{0.00024\ m^3/s}$$
$$= 86\ s$$
$$\approx 1.5\ min.$$

NOTE: If the concentration of hydrogen in the riser was 1 percent, the flow rate would be 50 percent higher and the purge time would be about 1 minute.

The above volumetric purge rate equation can be used to provide the basis for the purge times associated with opening a riser on a single-shell tank flammable gas tank.

Table C-1. Required Riser Purge Times.

ΔT Range	Purge time[a] (min)	Required time[b] (min)
$\Delta T \geq 6$ K ($\Delta T \geq 10.8$ °F) or tank is on active ventilation	1.5	5.0
$3 \leq \Delta T < 6$ K ($5.4 \leq \Delta T < 10.8$ °F)	3.0	10.0
$1 \leq \Delta T < 3$ K ($1.8 \leq \Delta T < 5.4$ °F)	9.0	30.0
$\Delta T < 1$ K ($\Delta T < 1.8$ °F)	Wait until ΔT will fall into one of the defined categories above	

[a]Time required to purge one volume.
[b]Time required to purge three volumes.

REFERENCES

Epstein, M., et al., 1994, *Ferrocyanide Safety Program: An Assessment of the Possibility of Ferrocyanide Sludge Dryout*, WHC-EP-0816, Westinghouse Hanford Company, Richland, Washington.

Plys, M. G., 1994, *Riser Purge Transient*, (external letter to R. J. Van Vleet, November 28), Fauske & Associates, Inc., Burr Ridge, Illinois.

APPENDIX D

DEFINITION OF NATIONAL FIRE PROTECTION ASSOCIATION TERMS

This page intentionally left blank.

APPENDIX D

DEFINITION OF NATIONAL FIRE PROTECTION ASSOCIATION TERMS

This appendix contains the definitions for the various terms used by the National Fire Protection Association. The following two definitions are direct quotes from NFPA 496, *Standard for Purged and Pressurized Enclosures for Electrical Equipment*.

Class I, Division 1. A Class I, Division 1 location is a location: (1) in which ignitable concentrations of flammable gases or vapors can exist under normal operating conditions; or (2) in which ignitable concentrations of such gases or vapors may exist frequently because of repair or maintenance operations or because of leakage; or (3) in which breakdown or faulty operation of equipment or processes might release ignitable concentrations of flammable gases or vapors and might also cause simultaneous failure of electric equipment. (See Article 500-5[a] of NFPA 70, *National Electrical Code.*)

Class I, Division 2. A Class I, Division 2 location is a location: (1) in which volatile flammable liquids or flammable gases are handled, processed, or used, but in which the liquids, vapors, or gases will normally be confined within closed containers or closed systems from which they can escape only in case of accidental rupture or breakdown of such containers or systems, or in case of abnormal operation of equipment; or (2) in which ignitable concentrations of gases or vapors that are normally prevented by positive mechanical ventilation and that might become hazardous through failure or abnormal operation of the ventilating equipment; or (3) that is adjacent to a Class I, Division 1 location and to which ignitable concentrations of gases or vapors might occasionally be communicated unless such communication is prevented by adequate positive-pressure ventilation from a source of clean air, and effective safeguards against ventilation failure are provided. (See Article 500-5[b] of NFPA 70, *National Electrical Code.*)

The following definitions of Class I Groups are direct quotes from Article 500-3 of NFPA 70, *National Electrical Code*.

Group A. Atmospheres containing acetylene.

Group B. Atmospheres containing hydrogen, fuel and combustible process gases containing more than 30 % hydrogen by volume, or gases or vapors of equivalent hazard such as butadiene, ethylene oxide, propylene osice, and acrolein.

Group C. Atmospheres such as ethyl ether, ethylene, or gases or vapors of equivalent hazard.

Group D. Atmospheres such as acetone, ammonia, benzene, butane, cyclopropane, ethanol, gasoline, hexane, methanol, methane, natural gas, naptha, propane, or gases or vapors of equivalent hazard.

REFERENCES

NFPA, 1993, *National Electrical Code*, NFPA 70, Article 500-3, National Fire Protection Association, Quincy, Massachusetts.

NFPA, 1993, *Purged and Pressurized Enclosures for Electrical Equipment*, NFPA 496, National Fire Protection Association, Quincy, Massachusetts.

APPENDIX E

PEER REVIEW CHECKLISTS

This page intentionally left blank.

PEER REVIEW CHECKLIST

Document Reviewed: Appendix A, titled "FREQUENCY OF OCCURRENCE OF IGNITION", for WHC-SD-WM-SARR-004 REV. 1 DRAFT (This review will also apply to WHC-SD-WM-SARR-002 REV. 1, Appendix A)
Author: Dr. Rick J. Van Vleet
Date: Peer review performed on January 18, 1996
Scope of Review: Text of Appendix A including checking calculations

Yes	No	NA	
[X]	[ ]	[ ]	Problem completely defined.
[X]	[ ]	[ ]	Accident scenarios developed in a clear and logical manner.
[X]	[ ]	[ ]	Necessary assumptions explicitly stated and supported.
[ ]	[ ]	[X]	Computer codes and data files documented.
[X]	[ ]	[ ]	Data used in calculations explicitly stated in document.
[X]	[ ]	[ ]	Data checked for consistency with original source information as applicable.
[X]	[ ]	[ ]	Mathematical derivations checked including dimensional consistency of results.
[ ]	[ ]	[X]	Models appropriate and used within range of validity or use outside range of established validity justified.
[X]	[ ]	[ ]	Hand calculations checked for errors. Spreadsheet results should be treated exactly the same as hand calculations.
[ ]	[ ]	[X]	Software input correct and consistent with document reviewed.
[ ]	[ ]	[X]	Software output consistent with input and with results reported in document reviewed.
[ ]	[ ]	[X]	Limits/criteria/guidelines applied to analysis results are appropriate and referenced. Limits/criteria/guidelines checked against references.
[X]	[ ]	[ ]	Safety margins consistent with good engineering practices.
[X]	[ ]	[ ]	Conclusions consistent with analytical results and applicable limits.
[X]	[ ]	[ ]	Results and conclusions address all points required in the problem statement.
[ ]	[ ]	[X]	Review calculations, comments, and/or notes are attached.
[X]	[ ]	[ ]	Document approved.

COMMENTS:

Thomas B. Powers [signature] 1/18/96
Reviewer (Printed Name and Signature) Date

PEER REVIEW CHECKLIST

Document Reviewed: SARR-004, Safety Basis for Selected Activities in Single-Shell Flammable Gas Tanks, and SARR-002, Safety Basis for Selected Activities in Double-Shell Flammable Gas Tanks

Author: R. J. Van Vleet, Ph.D.

Date: January 16, 1995

Scope of Review: This review and the informal comments provided considered readabiltiy and consistenancy only.

Yes	No	NA	
[ ]	[ ]	[x]	Previous reviews complete and cover analysis, up to scope of this review, with no gaps.
[x]	[ ]	[ ]	Problem completely defined.
[x]	[ ]	[ ]	Accident scenarios developed in a clear and logical manner.
[x]	[ ]	[ ]	Necessary assumptions explicitly stated and supported.
[ ]	[ ]	[x]	Computer codes and data files documented.
[ ]	[x]	[ ]	Data used in calculations explicitly stated in document.
[ ]	[x]	[ ]	Data checked for consistency with original source information as applicable.
[ ]	[x]	[ ]	Mathematical derivations checked including dimensional consistency of results.
[ ]	[ ]	[x]	Models appropriate and used within range of validity or use outside range of established validity justified.
[ ]	[x]	[ ]	Hand calculations checked for errors. Spreadsheet results should be treated exactly the same as hand calculations.
[ ]	[ ]	[x]	Software input correct and consistent with document reviewed.
[ ]	[ ]	[x]	Software output consistent with input and with results reported in document reviewed.
[ ]	[ ]	[x]	Limits/criteria/guidelines applied to analysis results are appropriate and referenced. Limits/criteria/guidelines checked against references.
[ ]	[ ]	[x]	Safety margins consistent with good engineering practices.
[ ]	[x]	[ ]	Conclusions consistent with analytical results and applicable limits.
[ ]	[x]	[ ]	Results and conclusions address all points required in the problem statement.
[ ]	[x]	[ ]	Format consistent with appropriate NRC Regulatory Guide or other standards
[ ]		[x]	Review calculations, comments, and/or notes are attached.
[ ]	**[ ]**	**[x]**	**Document approved.**

G. R. Sawtelle ______ January 19, 1996

Reviewer (Printed Name and Signature) Date

The checklist further identifies what the scope of the review does or does not cover. "No" and "NA" marks only indicate the applicability to this review.

PEER REVIEW CHECKLIST

Document Reviewed: WHC-SD-SARR-002 REV 1
Author: R. J. Van Vleet
Date: January 18, 1996
Scope of Review: Radiological and toxic release calculations in Chapter 5

Yes	No	NA	
[X]	[ ]	[ ]	Previous reviews complete and cover analysis, up to scope of this review, with no gaps.
[X]	[ ]	[ ]	Problem completely defined.
[X]	[ ]	[ ]	Accident scenarios developed in a clear and logical manner.
[X]	[ ]	[ ]	Necessary assumptions explicitly stated and supported.
[ ]	[ ]	[X]	Computer codes and data files documented.
[X]	[ ]	[ ]	Data used in calculations explicitly stated in document.
[X]	[ ]	[ ]*	Data checked for consistency with original source information as applicable.
[ ]	[ ]	[X]	Mathematical derivations checked including dimensional consistency of results.
[X]	[ ]	[ ]	Models appropriate and used within range of validity or use outside range of established validity justified.
[X]	[ ]	[ ]	Hand calculations checked for errors. Spreadsheet results should be treated exactly the same as hand calculations.
[ ]	[ ]	[X]	Software input correct and consistent with document reviewed.
[ ]	[ ]	[X]	Software output consistent with input and with results reported in document reviewed.
[X]	[ ]	[ ]	Limits/criteria/guidelines applied to analysis results are appropriate and referenced. Limits/criteria/guidelines checked against references.
[ ]	[ ]	[X]	Safety margins consistent with good engineering practices.
[X]	[ ]	[ ]	Conclusions consistent with analytical results and applicable limits.
[X]	[ ]	[ ]	Results and conclusions address all points required in the problem statement.
[ ]	[ ]	[X]	Format consistent with appropriate NRC Regulatory Guide or other standards
[ ]	[ ]	[X]	Review calculations, comments, and/or notes are attached.
[X]	[ ]	[ ]	**Calculation approved.**

J. C. Van Keuren [signature] 1/18/96
Reviewer (Printed Name and Signature) Date

* Calculation is consistent with ASA approach and values.

PEER REVIEW CHECKLIST

Document Reviewed: WHC-SD-SARR-004 REV 1
Author: R. J. Van Vleet
Date: December 20, 1995
Scope of Review: Radiological and toxic release calculations in Tables 4 and 5

Yes	No	NA	
[X]	[ ]	[ ]	Previous reviews complete and cover analysis, up to scope of this review, with no gaps.
[X]	[ ]	[ ]	Problem completely defined.
[X]	[ ]	[ ]*	Accident scenarios developed in a clear and logical manner.
[X]	[ ]	[ ]	Necessary assumptions explicitly stated and supported.
[ ]	[ ]	[X]	Computer codes and data files documented.
[X]	[ ]	[ ]	Data used in calculations explicitly stated in document.
[X]	[ ]	[ ]	Data checked for consistency with original source information as applicable.
[ ]	[ ]	[X]	Mathematical derivations checked including dimensional consistency of results.
[ ]	[ ]	[X]*	Models appropriate and used within range of validity or use outside range of established validity justified.
[X]	[ ]	[ ]	Hand calculations checked for errors. Spreadsheet results should be treated exactly the same as hand calculations.
[ ]	[ ]	[X]	Software input correct and consistent with document reviewed.
[ ]	[ ]	[X]	Software output consistent with input and with results reported in document reviewed.
[X]	[ ]	[ ]**	Limits/criteria/guidelines applied to analysis results are appropriate and referenced. Limits/criteria/guidelines checked against references.
[ ]	[ ]	[X]	Safety margins consistent with good engineering practices.
[X]	[ ]	[ ]	Conclusions consistent with analytical results and applicable limits.
[X]	[ ]	[ ]	Results and conclusions address all points required in the problem statement.
[ ]	[ ]	[X]	Format consistent with appropriate NRC Regulatory Guide or other standards
[ ]	[ ]	[X]	Review calculations, comments, and/or notes are attached.
[X]	[ ]	[ ]	**Calculation approved.**

J. C. Van Keuren (signature) 12/20/95
Reviewer (Printed Name and Signature) Date

* Calculation is consistent with ASA approach and values.

** Calculation for ignition is based on limits for extremely unlikely event. The event is classified as incredible. There are no toxicological acceptance criteria for incredible events. Calculations show that both rad and toxic exposures would result in a fatality for the onsite receptor. This is acceptable only because the event is judged incredible.

This page is intentionally left blank.

This page intentionally left blank.

DISTRIBUTION SHEET

To	From	Page 1 of 1
Distribution	R. L. Schlosser	Date 2/5//96
Project Title/Work Order		EDT No. 193899
Safety Basis For Activities in Single-Shell Tanks With Flammable Gas Concerns		ECN No. N/A

Name	MSIN	Text With All Attach.	Text Only	Attach./ Appendix Only	EDT/ECN Only
J. L. Deichman	T6-03	X			
E. P. DiVincenzo	A3-37	X			
M. N. Islam	R3-08	X			
G. D. Johnson	S7-14	X			
J. J. Klos	R2-54	X			
C. E. Leach	A2-34	X			
D. S. Leach	A3-34	X			
E. J. Lipke	S7-14	X			
A. L. Ramble	A3-38	X			
R. L. Schlosser	A3-37	X			
J. E. Truax	R2-50	X			
J. Weber	S1-57	X			
Central Files (Orginal+2)	A3-88	X			
~~OSTI (2)~~	~~A3-36~~	~~X~~ JM 2/6/95			

A-6000-135 (01/93) WEF067