AR TARGET SHEET

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DOCUMENT #:	HNF-MR-0541, Draft B
TITLE:	Preliminary Safety Assessment Transfer of 100-K Basin Sludge Into DST 241-AW-105

8.0 PRELIMINARY CLASSIFICATION OF SYSTEMS, COMPONENTS, AND STRUCTURES

A preliminary Safety Class Evaluation (SCE) was performed to identify safety (safety class and safety significant) Systems, Structures, and Components (SSCs). The safety classifications were designated in accordance with the requirements and criteria of WHC-CM-4-46, *Safety Analysis Manual*. The safety classifications of individual components of the K Basin sludge offload process, including Sludge Transportation System and Sludge Transfer Station, are presented in this chapter. The safety classifications of tank SSCs are addressed in tank farm safety documentation.

Safety classifications are defined as follows (taken from WHC-CM-4-46):

- **Safety Class (SC) SSCs** prevent or mitigate releases to the public that would otherwise exceed the offsite radiological risk guidelines, or prevent an accidental nuclear criticality.

- **Safety Significant (SS) SSCs** prevent or mitigate releases of radiological materials to onsite workers and toxic chemicals to the offsite public and onsite workers. SS also describes worker safety SSCs that protect the facility worker from serious injury due to other industrial hazards.

- **Defense-in-Depth** is the strategy in which successive barriers are provided to prevent and mitigate uncontrolled releases of radioactive or hazardous chemical materials; defense-in-depth SSCs are those qualitatively deemed to contribute substantially to the reduction of risk or which support a safety SC or SS function.

The safety classifications for the individual components were established based on the design basis accident analyses presented in Chapter 7. The accident frequencies calculated in Chapter 7 were used to characterize the frequencies of accidents during K Basin sludge offload operations. Consequences were also estimated in Chapter 7 using unit dose values (radiological and toxicological) that were calculated using sludge inventory data derived from Makenas et al. (1996) and Lodwick (1997). These unit doses were used to calculate the consequences of releases resulting from the occurrence of the accident scenarios.

Table 8.1, the summary of the safety class evaluation, is divided into two sections. The first section addresses the safety SSCs for the Sludge Receiving Station to be constructed adjacent to AW-105 and the second addresses the offload features of the Sludge Transportation System. For the sludge offload process, the primary lines were designated as **safety class**. This includes the primary (or inner) pipe for the aboveground transfer line at the tank farm and the primary line of the flexible hose that connects the Sludge Transportation System to the Sludge Receiving Station. The safety function of these systems is to provide liquid confinement during offload operations. This system was designated as **safety class** because undetected failure of the primary pipe (spray leak and pipe rupture/pool release) with failure of the secondary pipe will exceed onsite and offsite risk guidelines.

The secondary (outer) piping subsystems on the Sludge Receiving Station and flexible hose were designated as **defense in depth**. The safety function provided by these subsystems is to confine

Table 8.1. Safety Classification of Individual Components

System/ Component	Safety Function	SSC Designation	Failure Consequences
Sludge Receiving Station			
Primary aboveground piping	Contain liquid waste	Safety class	Leak/rupture, spray leak -- waste to secondary pipe. No consequence unless secondary failure. Failure of both could exceed onsite and offsite guidelines.
Secondary aboveground piping	Containment of waste leakage from primary pipe should a release occur	Defense in depth	Failure -- no consequences unless primary pipe failure; secondary confinement provided by pump pit covers, fixed and portable shielding, and glove bags.
Shielding over aboveground portions of fixed piping	Radiation shielding; suppression of aerosol from spray leak	Safety class	Failure exceeds onsite and offsite exposure guidelines, assuming an event that leads to simultaneous failures of shielding and spray leak.
Pump pit cover block (in place)	Containment for spray release should a release occur	Safety class	Failure (spray leak) exceeds onsite and offsite exposure guidelines with pit cover off.
Pipe connectors in pump pit	Contain liquid waste	Defense in depth	Credit was taken in the mitigated accident analysis for the pump pit cover block as barrier to a spray leak in the pump pit.
Flexible hose connector at receiving station	Contain liquid waste	Safety class	Failure - spray leak consequences could exceed onsite and offsite exposure guidelines; no cover to reduce airborne release.[a]
Leak detection system	Indicate primary pipe leak	Defense in depth	Failure prevents monitoring of primary pipe leak; no release unless the pipe encasement fails.

System/ Component	Safety Function	SSC Designation	Failure Consequences
Spill retention basin	Confine spilled liquid waste	Safety class	Credit taken in accident analysis (pipe rupture) for confinement of liquid spills and suppression of aerosols from pool releases.
Portable shielding (in place)	Radiation protection, ALARA	Safety class	Failure -- no release unless flexible hose and pipe fail; excessive worker exposures may occur unless shielding in place; also suppresses spray release (secondary confinement).
AC Power	Provides motive force for transfer pump, control power, and leak detection system.	Defense in depth	Failure -- no release; consequences related to inability to empty shipping container; the system is required to support the safety function of the leak detection system, which was designated defense in depth.
Spill stabilization procedures and equipment	Suppress aerosol from liquid spill	Safety significant	Pipe rupture and transportation accident consequences exceed guidelines (liquid spill to soil) if release duration is not limited.
Water supply	Flush shipping container and transfer lines	Non-safety	Failure -- no release; consequences related to inability to flush residual material from shipping container and transfer lines.
Sludge Transportation System			
Pressure vessel	Sludge containment	Safety class	Spray leak consequences exceed onsite and offsite exposure guidelines.
Transfer pump	Contain liquid waste	Safety class	Spray leak consequences exceed onsite and offsite exposure guidelines.[b]

System/ Component	Safety Function	SSC Designation	Failure Consequences
Flexible hose (primary)	Contain liquid waste	Safety class	Leak/rupture, spray leak -- waste to secondary pipe. No consequence unless secondary failure. Failure of both could exceed onsite and offsite guidelines.
Flexible hose (secondary)	Containment of waste leakage from primary pipe should a release occur	Safety class	Failure -- no consequences unless primary line failure. Failure of both could lead to exposures that onsite and offsite guidelines.
Flexible hose connector on transportation system	Contain liquid waste	Safety class	Failure - spray leak consequences could exceed onsite and offsite exposure guidelines; no cover to reduce airborne release.[a]
Sludge agitator	Suspend solids in shipping container	Non-safety	Failure -- no release; consequences related to inability to empty shipping container.
HEPA filtered vents	Allows venting of accumulated hydrogen gas in shipping container	Safety class	Failure -- no release unless initiator present to ignite flammable gas; consequences could exceed onsite guidelines.
Backup AC power (portable generator on truck trailer)	Provides backup power for transfer pump, control power, and leak detection system	Non-safety	Failure -- no release; backup power source only; consequences related to inability to empty shipping container if both primary and secondary power sources fail.

(a) If a glove bag or other leak confinement system over the connectors is to be provided, the connectors may be designated as **safety significant** and placement of the leak confinement system may be designated as **safety class**, similar to the pump pit covers.

(b) If the transfer pump was to be placed in an enclosure, the transfer pump could be designated as a **defense-in-depth SSC** and the enclosure (including spill retention capabilities) would be designated as **safety class**.

liquid releases from the primary pipe system. This designation is because the secondary confinement systems credited in the spray leak and pipe rupture analyses were the pump pit cover blocks, fixed and portable shielding placed over the piping and flexible hose systems, and glove bags placed over the pipe connectors, and not the secondary piping subsystems. The secondary piping subsystems were designated as defense in depth because their failure, with the covers and shielding in place,

could lead to worker exposures during decontamination and cleanup after a leak. This would not be consistent with ALARA principles.

The unmitigated consequences of a spray leak from failed or malfunctioning connectors on either end of the flexible hose and the valve connectors (jumpers) in the pump pit were found to be above onsite and offsite exposure guidelines. The safety function provided by the flexible hose connectors is to contain liquid waste materials during offload operations. Failure of one of these components could lead to a spray release that exceeds offsite and onsite exposure guidelines. This is somewhat different than the connectors in the pump pit discussed below because the flexible hose and connectors would be located above ground; there is no pump pit and cover block to mitigate a spray release from the connectors. Therefore, the hose connectors were designated as **safety class SSCs**. If a glove bag or other leak confinement system over the connectors is to be provided, the connectors may be designated as **safety significant** and placement of the leak confinement system over the connectors before a transfer takes place may be designated as **safety class**, similar to the placement of the AW-105 pump pit cover. This is the most likely configuration for the offload system and was the configuration assumed in the mitigated spray leak accident analysis.

The safety function of the AW-105 pump pit cover block is to provide confinement of airborne particulate should a release occur in the pump pit. The pump pit cover block was found to be an important barrier to a potential spray leak caused by failed or malfunctioning connectors in the pit. Onsite and offsite exposure guidelines would be exceeded if the cover block is not in place. Therefore, placement of the cover block during the transfers is **safety class**. This does not affect the design of the cover block, but the confinement must be in place during transfers. If the cover block is in place, the consequences are below both onsite and offsite exposure guidelines. The jumpers in the pump pit were designated as **defense in depth** because their failure, with the cover block in place, could lead to worker exposures during decontamination and cleanup of the pump pit. This would not be consistent with ALARA principals.

The safety function of the shielding material (earthen berm or concrete half-shells) placed over the aboveground portions of the receiving station piping is to reduce the radiation dose rate emitted from the transfer lines to allowable levels and to suppress spray leaks from the transfer pipes and connectors. Failure of this component would not lead to a radiological release but could result in excessive radiation exposures to tank farm operators involved in the transfers. Since certain classes of events (e.g., seismic events) could lead to simultaneous failure of both inner and outer lines, such failures result in doses that exceed onsite but not offsite guidelines. However, certain classes of events could lead to simultaneous failure of the shielding structures and transfer lines. Such failures (spray leak) were shown previously to result in doses that exceed onsite and offsite guidelines. Consequently, the shielding material was designated as **safety class**. This designation would also apply to temporary shielding placed over the flexible hose during transfers; i.e., credit was taken in the accident analysis for suppression of spray leaks by the portable shielding.

Failure of the spill retention basin would not result in a release of material unless both the primary and secondary containment systems also fail. The safety function of the spill retention basin is to provide confinement of potential radioactive spills from the flexible transfer line, transportation system, and connectors. Failure of the spill retention basin in combination with a leak or rupture of

the flexible hose, packaging, or connectors could lead to a release of material to the soil. Such a release was shown in Section 7.2.2 to result in exposures above onsite and offsite guidelines. Exposures were below guidelines when the spill retention basin functions to confine and mitigate this release. Therefore, the spill retention basin was designated as a **safety class SSC**.

Failure of the primary pipe leak detection system could lead to a prolonged release of material from its containment boundary; however, failure of the leak detection system would not result in a release of radioactive material nor was credit taken for a leak detection or suppression function in the accident analysis. As a result of failure of leak detection, sludge could accumulate in the secondary piping system, pump pit, or spill retention basin. Decontamination and repairs would require substantial radiation work, and thus would adversely affect ALARA principles. Consequently, the primary pipe leak detection system, including leak detection capability for the flexible hose as well as the permanent piping of the sludge receiving station, was designated as safety-significant.

A spill stabilization capability was credited in the pipe rupture and shipping container failure accident analyses with suppressing resuspension releases from spilled pools. Failure to suppress these releases within 2 hr leads to exposures that exceed guidelines. Consequently, an emergency spill suppression capability, including planning, equipment, and training, was designated **safety-significant**.

With regard to the sludge transportation system, four components were found to be safety SSCs, including the pressure vessel, transfer pump, hose connectors, and HEPA-filtered vents. The pressure vessel, transfer pump, and connectors were determined to be **safety class**,[1] as the consequences of a spray leak from these components were estimated to exceed onsite and offsite exposure guidelines. The HEPA-filtered vents on the pressure vessel were found to be **safety class**, as a flammable gas detonation or fire within the shipping container could lead to onsite and offsite exposures that exceed guidelines based on the consequences of shipping container failures addressed in Sections 7.2.3 and 7.2.4. The vents were assumed to be closed during transport. Since the sludge generates significant quantities of hydrogen gas, the vents must be opened as soon as possible after arrival at the tank farm. Tank farm operating procedures should include a step to open these vents after arrival. Opening the vents would be safety class.

The final items to be considered are the tank farm's flammable gas controls applied to prevent accumulation of flammable concentration of gases in the tank farm and prevent ignition sources from contacting flammable atmospheres. This include minimum performance requirements placed on the ventilation system as well as controls placed on work performed and equipment used (e.g., non-sparking tools, bonding, etc.) in the tank farm. The flammable gas control strategy, described more fully in Grigsby and Leach (1996) and the TWRS BIO (LMHC 1997), was assumed to be in place during K Basin sludge offloading and storage operations and was credited in the mitigated flammable gas deflagration and pyrophoric reaction accident analyses.

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1 If the transfer pump was to be placed in an enclosure, the transfer pump could be designated as a **defense-in-depth SSC** and the enclosure (including spill retention capabilities) would be designated as **safety class.**

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9.0 SAFETY MANAGEMENT SYSTEM

This chapter presents the information on the safety management system that supports the safe operation of Tank Waste Remediation System (TWRS) facilities and the activities associated with the transfer of K Basin sludge from a shipping container to a storage tank in the Hanford Site's tank farms. This chapter also identifies the requirements for developing safety management programs and the documents that implement those programs.

TWRS is committed to safety management programs that ensure the following:

- Safe storage and transfer of radioactive and hazardous materials,
- Protection of facility workers from exposure to radioactive and hazardous materials and industrial hazards,
- Protection of the public and environment from releases of radioactive and hazardous material.

The safety management programs comprise a broad range of safety-related activities from radiation and hazardous material protection to disciplined conduct of operations. Developing and maintaining the authorization basis documents and associated safety basis documents are essential to safety management. TWRS has recently implemented improvements in the authorization basis process that includes both organizational changes and configuration control changes (see Section 9.13).

Another important part of the TWRS safety management is provided in WHC-SD-WE-HAP-002, *Tank Farm Health and Safety Plan*, which addresses routine operations performed at the tank farms, establishes procedures, and provides general guidelines to minimize health and safety risks to the facility workers and other onsite workers. Measures to protection of some of the safety controls identified during the safety analysis process is also identified in WHC-SD-WE-HAP-002.

A sludge transportation system is being designed at this time. A Safety Analysis Report for Packaging (SARP) will be prepared in the future to discuss the safety aspects of the transportation system in accordance with DOE Order 5480.3, *Safety Requirements for the Packaging and Transportation of Hazardous Materials, Hazardous Substances, and Hazardous Wastes*.

A brief description of each safety management program, applicable requirements, and implementing documents is provided in this chapter. These programs are not independent of each other. In many cases, implementation of one program is through the application of the other programs (e.g., conduct of operations is implemented through work control, procedures, and training). Implementation of all of these programs ensures the protection of the workers, the public, and the environment.

9.1 STANDARDS/REQUIREMENTS IDENTIFICATION DOCUMENT

The standards and requirements applicable to the K Basin sludge transfer facilities and operations are the same as those governing the facilities and activities at the Tank Farms.

WHC-SD-MP-SRID-001, *High Level Waste Storage Tank Farms/242-A Evaporator Standards/Requirements Identification Document*, approved by the U.S. Department of Energy, is a concise compilation of facility-specific federal, state, and local laws; regulations; permit conditions; industry consensus codes, standards, and good business practices. The applicable environment, safety and health, and safeguards and security functional areas are identified in this document.

WHC-SD-MP-SRID-001 is currently being implemented, and during implementation any required changes to the safety management programs described in the following sections will be identified. The implementation of WHC-SD-MP-SRID-001 will be verified through reviews (assessments, audits, and surveillance) conducted by internal oversight organizations.

9.2 CRITICALITY PROTECTION

The purpose of criticality protection is to ensure that sufficient controls are in place to reduce the likelihood of inadvertent nuclear criticality excursions.

The Hanford Site Criticality Protection Program follows DOE 5480.24, *Nuclear Criticality Safety;* industry standards; company safety policy; and accepted safety practice. The criticality safety program discussed in detail in the TWRS FSAR (WHC-WM-067, Draft) addresses the following general aspects of criticality safety:

- Nuclear criticality safety administration
- Nuclear criticality safety control principles
- Criticality safety training
- Nuclear criticality safety control documents
- Criticality safety plans and procedures
- Criticality emergencies and limit violations.

The following specific measures supplement the criticality protection control program. These measures will be implemented during the K Basin sludge transfer and 241-AW-105 tank addition operations.

- Parameter controls are established for waste transfer into the tank farms to meet double contingency requirements for the prevention of a criticality accident

- Parameter controls are documented and independently verified.

Criticality protection at TWRS is implemented through WHC-CM-4-29, *Nuclear Criticality Safety Manual*, and WHC-IP-0842, *TWRS Administration*.

9.3 RADIOLOGICAL PROTECTION

Radiological protection activities at the Hanford Site implement the requirements of 10 CFR 835, *Occupational Radiation Protection*, as directed by the HSRCM-1, *Hanford Site Radiological Control Manual*. The program provides for the protection of the workers during normal operations and implements specific safety controls to achieve radiological protection. The worker protection program comprises the following elements:

- As Low as Reasonable Achievable (ALARA) goals
- Radiation worker training
- Radiation exposure control
- Radiological monitoring
- General employee radiation training.

TWRS radiation protection is implemented through sitewide programs identified in the following documents:

- HSRCM-1, *Hanford Site Radiological Control Manual* (1995)
- WHC-CM-4-14, *Applied Radiological Controls* (1996)
- WHC-IP-0718, *Health Physics Procedures* (1993)
- WHC-IP-0842, *TWRS Administration* (1996)
- WHC-IP-1043, *WHC Occupational ALARA Program* (1995)
- WHC-SD-WE-HAP-002, *Tank Farm Health and Safety Plan* (1995)
- WHC-SP-1145, *WHC Radiation Protection Program Implementation of Title 10 Code of Federal Regulations Part 835* (1995).

The Tank Farms Transition Project administers the Radiological Protection and Contamination Control Program for TWRS. The Tank Farm Transition Project administration is also responsible for establishing radiological protection standards and procedures; providing independent review and evaluation of the program. Further, the project administration conducts radiological and dosimetry support; develops and implements training; and coordinates the ALARA program.

9.4 HAZARDOUS MATERIAL PROTECTION

The Hanford Site Industrial Hygiene Program is designed to protect all workers from hazardous exposures to physical, chemical, and biological agents. The program provides the basis for an effective industrial hygiene program that preserves worker health and well being following DOE 5480.4, *Environmental Protection, Safety, and Health Protection Standards*, and DOE 5480.10, *Contractor Industrial Hygiene Program*. These DOE orders implement 29 CFR 1910, "Occupational Safety and Health Standards," and 29 CFR 1926, "Safety and Health Regulations for Construction." Current procedures are documented in WHC-CM-1-11 and WHC-CM-4-40, the industrial hygiene manuals. The Industrial Hygiene Program is administered by Tank Farms Transition Project.

Contractor procedures provide for the identification and evaluation of existing and potential health hazards; the implementation of control measures; the periodic monitoring to ensure the maintenance of satisfactory conditions; and the conduct of employee training.

9.5 RADIOACTIVE AND HAZARDOUS MATERIAL WASTE MANAGEMENT

The transfer and storage of K Basin sludge should be performed in a manner that releases of radioactive and hazardous materials to the environment are maintained within regulatory limits and exposure of workers and the public to radioactive and hazardous materials is minimized.

Criteria for confinement, safe handling, and disposal of solid, liquid, and gaseous waste are provided in WHC-CM-7-5, *Environmental Compliance*, which identifies the requirements of the DOE 5400 series orders, with emphasis on DOE 5400.5, *Radiation Protection of the Public and the Environment*.

Contractor procedures, which meet the requirements of DOE 5820.2A, *Radioactive Waste Management*, establish requirements for TWRS facility waste acceptance programs. These waste acceptance requirements ensure that all waste has been properly identified and characterized before being shipped. Each hazardous and radioactive waste generator that delivers waste to TWRS facilities is required to comply with TWRS waste acceptance program requirements.

TWRS radioactive and hazardous waste management is implemented through the following:

- *Dangerous Waste Portion of the Resource Conservation and Recovery Act Permit for the Treatment, Storage, and Disposal of Dangerous Waste* (Ecology 1995a)
- *Hanford Federal Facility Agreement and Consent Order* (Ecology et al. 1994)
- WHC-CM-7-5, *Environmental Compliance* (1996)
- WHC-EP-0063, *Hanford Site Solid Waste Acceptance Criteria* (1993)
- WHC-EP-0479, *Facility Effluent Monitoring Plan for the Tank Farm Facility* (1995)
- WHC-EP-0496, *Westinghouse Hanford Company Waste Minimization and Pollution Prevention and Awareness Program* (1994)
- WHC-EP-0846, *Waste Specification System* (1995)
- WHC-SD-WM-EV-081, *Tank Farms Low-Level and Mixed Solid Waste Certification Plan* (1994)
- WHC-SD-WM-EV-090, *Tank Farms Transition Projects Waste Minimization/Pollution Prevention Plan* (1996)
- WHC-SD-WM-PLN-119, *Tank Farms Containerized Solid Waste Hazardous Chemical Characterization/Sampling and Analysis Plan Program* (1996).

9.6 TESTING, SURVEILLANCE, AND MAINTENANCE

Initial testing, in-service surveillance, and maintenance programs associated with the transfer and storage of K Basin sludge ensure the integrity and operability of safety SSCs.

The initial testing program includes program for all safety SSCs. The program requires development of testing procedures and the review, evaluation, and approval of testing results. Testing programs within the initial testing program are specified as quality assurance requirements in WHC-CM-4-2, *Quality Assurance Manual*.

In-service surveillance and inspections at TWRS are based on DOE 4330.4B, *Maintenance Management Program*. Program requirements include periodic inspections to ensure that proper conditions, cleanliness, and housekeeping are maintained to support safe and reliable facility operations.

Surveillance requirements have been established for safety-class and safety-significant SSCs. These requirements provide assurance that the necessary quality of SSCs is maintained and that the limiting conditions for operation are being met. Some of the monitoring systems that have surveillance requirements are temperature, waste-level, tank vapor space pressure, and leak detection.

The TWRS maintenance program meets the requirements of DOE 4330.4B. Compliance with this order is documented in WHC-SP-850, *Maintenance Implementation Plan for Waste Tank Maintenance and Production Management*. Major maintenance programs include the following:

- Preventive maintenance
- Spare parts control
- Maintenance history
- Corrective maintenance
- Maintenance training
- Measuring and test equipment.

Requirements for the maintenance program reflect the relative importance of facility SSCs for protection of workers, the public, and the environment.

9.7 OPERATIONAL SAFETY

Operational safety addresses a variety of programs, including conduct of operations, fire protection, occurrence reporting, unreviewed safety questions (USQs), and operational readiness review programs.

The requirements for the operational safety are contained in the following documents:

- DOE 5480.19, *Conduct of Operations Requirements for DOE Facilities*, 7/9/90 (change 1: 5/18/92)

- DOE 5480.7A, *Fire Protection* (1993)

- DOE 5480.21, *Unreviewed Safety Questions*
- DOE-STD-3006-93, *Planning and Conduct of Operational Readiness Reviews (ORR)*(1993)
- DOE 5000.3B, *Occurrence Reporting and Processing of Operations Information*
- DOE 5480.31, *Startup and Restart of Facilities Operational Readiness Review and Readiness Assessments*, 9/15/93.

The implementation guidance of these requirements is provided in WHC-IP-0842. Volume I, *Administration*, of WHC-IP-0842, *TWRS Administration*, provides implementation guidance for Operational Readiness Review and the TWRS Fire Protection Program.

Volume II, *Operations*, of WHC-IP-0842, *TWRS Administration*, provides additional implementation guidance for operations at TWRS facilities for such topics as: Management of respiratory protection controls and excavation permits, Access Control, and the Conduct of Operations.

WHC-CM-1-5, *Standard Operating Practices*, establishes requirements for WHC conduct of operations and is supplemented by the Westinghouse Electric Corporation's GOBU "Conduct of Operations" manual. The manual covers all WHC projects, programs, activities, and facilities, unless exceptions are indicted in the individual procedures.

WHC-CM-4-41, *Fire Protection Program Manual*, provide employees who are not fire protection professionals with the information on fulfilling fire protection requirements.

9.8 TRAINING AND PROCEDURES

The purpose of the training program is to provide training that supports workers in accomplishing assignments in a safe and effective manner. TWRS' commitment to safe operation of the facility is demonstrated by procedures and training that satisfy the following U.S. Department of Energy (DOE) requirements:

- DOE 4330.4B, *Maintenance Management Program* (1994)
- DOE 5480.19, *Conduct of Operations Requirements for DOE Facilities*, Change 1 (1992)
- DOE 5480.20A, *Personnel Selection, Qualification, Training, and Staffing Requirements at DOE Reactor and Non-Reactor Facilities* (1994).

Procedure development and control processes are based on WHC-CM-3-5, *Document Control and Records Management Manual*, Section 12.5, *Technical Procedure Standard*. This standard provides the minimum requirements for identification of need, preparation, review, approval, change, revision, use, and periodic review of Hanford Site procedures.

Administrative procedures have been developed to comply with WHC-CM-3-5, Section 12.5 which defines minimum technical procedure development and use requirements. These practices

ensure safe operations by requiring strict adherence to operating procedures, Technical Safety Requirements, and sound operating practices. Company policy and administrative procedures further require compliance with operating, maintenance, emergency, and alarm response procedures.

The TWRS training organization has developed training programs that are consistent with the requirements contained in DOE 5480.20A and WHC-CM-2-15, *Training Standards*.

The contractor's training program described in WHC-IP-0842, *TWRS Administration*, provides detailed information implementation guidance for operations and maintenance/production control of the facilities and the training of the personnel.

9.9 HUMAN FACTORS

The consideration of the ability of the operator to reliably and safely operate TWRS facilities is integrated into the processes that guide the engineering and operating functions at TWRS. The TWRS Engineering and Tank Farm Transition Projects organizations are responsible for the implementation of human factors.

TWRS Engineering utilizes the Safety Management System (SMS) to ensure that human factors is considered in the design or modification of TWRS facilities and equipment. The SMS requires that the TWRS Design Authority include human factors considerations in the development of the functional requirements and technical criteria that guide the design activities. The SMS also evaluates the human factor aspects of the operator in the prevention and mitigation of accidents. The Safety and Licensing organization considers the effect of human performance on the safety and reliability of operations. These considerations are reflected in the development of safety documents such as the ISB, the FSAR, the IOSRs, and the TSRs.

The consideration of human factors in the operation of the facility is the responsibility of line management in the Tank Farms Transition Project. The managers are assisted in this task by organizations that address operations safety. These organizations include units responsible for industrial hygiene, maintenance, procedures, and training. Each of these organizations has established processes that consider human factors through the analysis of operator tasks, the use of lessons learned, and the involvement of the operator in developing instruction material used in the operation of the facility.

9.10 QUALITY ASSURANCE

Requirements for systematically implementing a quality assurance program, specified in 10 CFR 830.120, "Quality Assurance" and DOE 5700.6C, *Quality Assurance*, are established in WHC-CM-4-2.

Activities affecting quality, safety, or reliability of TWRS operations, products, and services are performed following documented and approved procedures appropriate for the task. The TWRS procedure manuals are used to ensure that quality assurance requirements are systematically implemented. Procedures are provided in the contractor's quality assurance program for the following functions and processes:

- Design control
- Procurement control
- Control of instructions, procedures, and drawings
- Document control
- Control of purchased items and services
- Identification and control of items
- Control of processes
- Inspection and test control
- Control of measuring and test equipment
- Packaging, handling, shipping, and storage control
- Inspection, test, and operating status control
- Control of nonconforming items and activities
- Software control
- Control of stop-work and corrective actions
- Control of personnel training and certification
- Control of records
- Control of audits.

9.11 EMERGENCY PREPAREDNESS

The TWRS Emergency Preparedness program establishes planning, procedures, and training programs to effectively prepare, manage, and respond to emergencies and incidents affecting the health and safety of the worker and the public. The contractor's emergency management program implements the DOE 5500 series orders.

The requirements for the TWRS emergency preparedness program are listed as follows:

- 40 CFR 302, *Designation Reportable Quantities, and Notification; EPA/Superfund, Emergency Planning, and Community Right-to-Know Programs*, 07/01/93 Edition

- 40 CFR 355, *Emergency Planning and Notification; EPA/Superfund, Emergency Planning, and Community Right-to-Know Programs*, 07/01/93 Edition

- DOE 5500.1B, *Emergency Management System*, 04/30/91 (change 1: 02/27/92)

- DOE 5500.2B, *Emergency Categories, Classes, and Notification and Reporting Requirements*, 04/30/91 (change 1: 02/27/92)

- DOE 5500.3A, *Planning and Preparedness for Operational Emergencies*, 04/30/91 (change 1: 02/27/92)

- DOE 5500.7B, *Emergency Operating Records Protection Program*, 10/23/91.

- DOE 5500.10, *Emergency Readiness Assurance Program*, 4/3/0/91 (change 1: 2/27/92)

- DOE/RL-94-02, *Hanford Emergency Response Plan*, 1994

The TWRS emergency preparedness program is implemented through the following procedures.

- WHC-IP-0263-T, *Tank Farms Building Emergency Plan* (1990)

- WHC-IP-0971, *Tank Waste Remediation System (TWRS) Emergency Preparedness Program Plan* (1994).

9.12 DECONTAMINATION AND DECOMMISSIONING

A formal Decontamination and Decommissioning (D&D) plan has not been prepared for the TWRS. However, the TWRS final safety analysis report will contain limited discussions of D&D considerations. Detailed plans will be prepared as required to support final D&D of TWRS.

Cleanup methods will be assigned to TWRS facilities on the basis of the disposition method deemed appropriate for the waste in those facilities. Facilities that are identified as treatment, storage, and disposal units will be closed according to the requirements of the *Regulations for Implementing Procedural Provisions of the National Environmental Policy Act* (Ecology 1995).

The design of the original TWRS facilities contained no specific criteria to facilitate D&D. The TWRS facilities were, however, engineered with features to contain leaked waste products and minimize the spread of contamination (e.g., nonporous tank walls, double-walled pipes for waste transfer, and coatings in pits and buildings that can be decontaminated). The representative design features that benefit D&D are as follows:

- Double-shell tank
- Encased piping
- Valve pits
- High-efficiency particulate air filters
- Sludge Transportation System design, including vehicle and shipping container
- Sludge Receiving Station design, including spill retention basin
- Piping system design

Operational considerations necessary for compliance with HSRCM-1 and WHC-CM-7-5 help maintain the spread of contamination to ALARA. The representative operational features that benefit D&D are as follows:

- Leakage monitoring
- Interim stabilization.

9.13 MANAGEMENT, ORGANIZATION, AND SAFETY PROVISIONS

This chapter identifies the organizational structure, responsibilities, and interfaces that support safe operation of the TWRS. Detailed descriptions may be found in WHC-IP-0842, *TWRS Administration*.

The following federal regulations and U.S. Department of Energy (DOE) orders are required for establishing the management, organizational, and institutional aspects of the safety basis for TWRS:

- 10 CFR 830, *Nuclear Safety Management* (1994)
- G-830.120-Rev. 0, *Implementation Guide for Use with 10 CFR Part 830.120, Quality Assurance* (1994)
- RLID 232.1, *Occurrence Reporting and Processing of Operations Information* (1996)
- DOE 5480.19, *Conduct of Operations Requirements for DOE Facilities*, Change 1 (1992)
- DOE 5480.21, *Unreviewed Safety Questions* (1991)
- DOE 5480.22, *Technical Safety Requirements*, Change 2 (1996)
- DOE 5480.23, *Nuclear Safety Analysis Reports*, Change 1 (1994)
- DOE 5480.26, *Trending and Analysis of Operations Information Using Performance Indicators* (1993).

REFERENCES

10 CFR 830, 1994, "Nuclear Safety Management", *Code of Federal Regulations*.

10 CFR 830.120, 1996, "Quality Assurance", *Code of Federal Regulations*.

10 CFR 835, 1993, "Occupational Radiation Protection", *Code of Federal Regulations*.

29 CFR 1910, 1995, "Occupational Safety and Health Standards", *Code of Federal Regulations*.

29 CFR 1926, 1995, "Safety and Health Regulations for Construction", *Code of Federal Regulations*.

40 CFR 260 , 1995, "Hazardous Waste Management System: General", *Code of Federal Regulations*.

40 CFR 261, 1995, "Identification and Listing of Hazardous Waste", *Code of Federal Regulations*.

40 CFR 262, 1995, "Standards Applicable to Generators of Hazardous Waste", *Code of Federal Regulations*.

40 CFR 263, 1995, "Standards Applicable to Transporters of Hazardous Waste", *Code of Federal Regulations*.

40 CFR 264, 1995, "Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities", *Code of Federal Regulations*.

40 CFR 265, 1995, "Interim Status Standards of Owners and Operators of Hazardous Waste, Treatment Storage, and Disposal Facilities", *Code of Federal Regulations*.

40 CFR 266, 1995, "Standards for the Management of Specific Hazardous Wastes and specific Types of Hazardous Waste Management Facilities", *Code of Federal Regulations*.

40 CFR 268, 1995, "Land Disposal Restrictions", *Code of Federal Regulations*.

40 CFR 279 1995, "Standards for the Management of Used Oil", *Code of Federal Regulations*.

40 CFR 302, 1993, "Designation Reportable Quantities, and Notification: EPA Superfund, Emergency Planning, and Community Right-to-Know Programs", *Code of Federal Regulations*.

40 CFR 355, 1993, "Emergency Planning and Notification: EPA/Superfund, Emergency Planning, and Community Right-to-Know Programs", *Code of Federal Regulations*.

DOE 1540.2, 1988, *Hazardous Material Packaging for Transport-Administration Procedures*, U.S. Department of Energy, Washington, D.C.

DOE 4330.4B, 1994, *Maintenance Management Program*, U.S. Department of Energy, Washington, D.C.

DOE 5400.5, 1993, *Radiation Protection of the Public and the Environment,* Change 2, U.S. Department of Energy, Washington, D.C.

DOE 5480.3, *Safety Requirements for the Packaging and Transportation of Hazardous Materials, Hazardous Substances, and Hazardous Wastes*, U.S. Department of Energy, Washington, D.C.

DOE 5480.4, 1993, *Environmental Protection, Safety, and Health Protection Standards*, Change 4, U.S. Department of Energy, Washington, D.C.

DOE 5480.7A, 1993, *Fire Protection*, U.S. Department of Energy, Washington, D.C.

DOE 5480.10, 1985, *Contractor Industrial Hygiene Program*, U.S. Department of Energy, Washington, D.C.

DOE 5480.18B, 1994, *Nuclear Facility Training Accreditation Program*, U.S. Department of Energy, Washington, D.C.

DOE 5480.19, 1992, *Conduct of Operations Requirements for DOE Facilities*, Change 1, U.S. Department of Energy, Washington, D.C.

DOE 5480.20A, 1994, *Personnel Selection, Qualification, and Training Requirements at DOE Nuclear Facilities,* U.S. Department of Energy, Washington, D.C.

DOE 5480.21, 1991, *Unreviewed Safety Questions,* U.S. Department of Energy, Washington, D.C.

DOE 5480.22, 1996, *Technical Safety Requirements*, Change 2, U.S. Department of Energy, Washington, D.C.

DOE 5480.23, 1994, *Nuclear Safety Analysis Reports,* Change 1, U.S. Department of Energy, Washington, D.C.

DOE 5480.24, 1992, *Nuclear Criticality Safety,* U.S. Department of Energy, Washington, D.C.

DOE 5480.26, 1993, *Trending and Analysis of Operations Information Using Performance Indicators,* U.S. Department of Energy, Washington, D.C.

DOE 5480.31, 1993, *Startup and Restart of Facilities Operational Readiness Review and Readiness Assessments,* U.S. Department of Energy, Washington, D.C.

DOE 5500.1B, 1992, *Emergency Management System,* Change 1, U.S. Department of Energy, Washington, D.C.

DOE 5500.2B, 1992, *Emergency Categories, Classes, and Notification and Reporting Requirements,* Change 1, U.S. Department of Energy, Washington, D.C.

DOE 5500.3A, 1992, *Planning and Preparedness for Operational Emergencies*, Change 1, U.S. Department of Energy, Washington, D.C.

DOE 5500.7B, 1991, *Emergency Operating Records Protection Program,* U.S. Department of Energy, Washington, D.C.

DOE 5500.10, 1992, *Emergency Readiness Assurance Program*, Change 1, U.S. Department of Energy, Washington, D.C.

DOE 5700.6C, 1991, *Quality Assurance*, U.S. Department of Energy, Washington, D.C.

DOE 5820.2A, 1988, *Radioactive Waste Management,* U.S. Department of Energy, Washington, D.C.

DOE 6430.1A, 1989, *General Design Criteria*, U.S. Department of Energy, Washington, D.C.

DOE-STD-3006-93, 1993, *Startup and restart of Facilities Operational Readiness Review and Readiness Assessments*, U.S. Department of Energy, Washington, D.C.

DOE/RL-94-02, 1994, *Hanford Emergency Response Plan,* U.S. Department of Energy, Washington, D.C.

Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement), Rev. 4, March 1, 1994.

Hanford Facility RCRA Permit, Dangerous Waste Portion.

Ecology, 1995, *Regulations for Implementing Procedural Provisions of the National Environmental Policy Act,* Permit WA7890009067, Rev. 2, Washington State Department of Ecology, Olympia, Washington.

Ecology, EPA, and DOE, 1994, *Hanford Federal Facility and Consent Order,* as amended, Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, Olympia, Washington.

G-830.120, 1994, *Implementation Guide for Use with 10 CFR Part 830.120, Quality Assurance.*

HSRCM-1, 1995, *Hanford Site Radiological Control Manual,* Westinghouse Hanford Company, Richland, Washington.

RLID232.1, 1996, *Occurrence Reporting and Processing of Operations Information.*

WAC 173-303, 1995, *Dangerous Waste Regulations, Washington Administration Code.*

WAC 296-65, effective 01/01/92, *Asbestos Removal and Encapsulation, Washington Administration Code.*

WHC-CM-1-5, 1996, *Standard Operating Practices*, Westinghouse Hanford Company, Richland, Washington.

WHC-CM-1-8, 1996, *Work Management*, Westinghouse Hanford Company, Richland, Washington.

WHC-CM-1-11, 1996, *Industrial Hygiene Manual*, Westinghouse Hanford Company, Richland, Washington.

WHC-CM-2-14, 1988, *Hazardous Material Packaging and Shipping*, Westinghouse Hanford Company, Richland, Washington.

WHC-CM-2-15, 1996, *Training Standards*, Westinghouse Hanford Company, Richland, Washington.

WHC-CM-3-5, 1996, *Document Control and Records Management Manual*, Westinghouse Hanford Company, Richland, Washington.

WHC-CM-4-2, 1996, *Quality Assurance Manual*, Westinghouse Hanford Company, Richland, Washington.

WHC-CM-4-14, 1996, *Applied Radiological Controls*, Westinghouse Hanford Company, Richland, Washington.

WHC-CM-4-29, 1996, *Nuclear Criticality Safety Manual*, Westinghouse Hanford Company, Richland, Washington.

WHC-CM-4-40, 1996, *Industrial Hygiene Manual*, Westinghouse Hanford Company, Richland, Washington.

WHC-CM-4-41, 1996, *Fire Protection Program Manual*, Westinghouse Hanford Company, Richland, Washington.

WHC-CM-6-34, TWRS Quality Management Plan, Westinghouse Hanford Company, Richland, Washington.

WHC-CM-6-50, 1996, *TWRS Quality Assurance*, Westinghouse Hanford Company, Richland, Washington.

WHC-CM-7-5, 1996, *Environmental Compliance*, Westinghouse Hanford Company, Richland, Washington.

WHC-EP-0063, 1993, *Hanford Site Solid Waste Acceptance Criteria*, Westinghouse Hanford Company, Richland, Washington.

WHC-EP-0479, 1995, *Facility Effluent Monitoring Plan for the Tank Farm Facility*, Westinghouse Hanford Company, Richland, Washington.

WHC-EP-0496, 1994, *Westinghouse Hanford Company Waste Minimization and Pollution Prevention and Awareness Program*, Westinghouse Hanford Company, Richland, Washington.

WHC-EP-0846, 1994, *Waste Specification System*, Westinghouse Hanford Company, Richland,

Washington.

WHC-IP-0263-T, 1990, *Tank Farms Building Emergency Plan,* Westinghouse Hanford Company, Richland, Washington.

WHC-IP-0718, 1993, *Health Physics Procedures,* Westinghouse Hanford Company, Richland, Washington.

WHC-IP-0842, 1996, *TWRS Administration,* Westinghouse Hanford Company, Richland, Washington.

WHC-IP-0971, 1994, *Tank Waste Remediation System (TWRS) Emergency Preparedness Program Plan,* Westinghouse Hanford Company, Richland, Washington.

WHC-IP-1043, 1995, *WHC Occupational ALARA Program*, Westinghouse Hanford Company, Richland, Washington.

WHC-SD-SAID-001, 1996, *High Level Waste Storage Tank Farms/242-A Evaporator Standards/Requirements Identification Document*, Westinghouse Hanford Company, Richland, Washington.

WHC-SD-WE-CM-013, 1996, *TWRS Configuration Management Program Plan,* Westinghouse Hanford Company, Richland, Washington.

WHC-SD-WE-EV-081, 1994, *Tank Farms Low-Level and Mixed Solid Waste Certification Plan*, Westinghouse Hanford Company, Richland, Washington.

WHC-SD-WE-EV-090, 1996, *Tank Farms Transition Projects Waste Minimization/Pollution Prevention Plan*, Westinghouse Hanford Company, Richland, Washington.

WHC-SD-WE-HAP-002, 1995, *Tank Farm Health and Safety Plan,* Westinghouse Hanford Company, Richland, Washington.

WHC-SD-WE-PLN-119, 1996, *Tank Farms Containerized Solid Waste Hazardous Chemical Characterization/Sampling and Analysis Plan Program,* Westinghouse Hanford Company, Richland, Washington.

WHC-SD-WE-QAPP-025, 1996, *Characterization Quality Policies*, Rev.2, Westinghouse Hanford Company, Richland, Washington.

WHC-SP-850, 1992, *Maintenance Implementation Plan for Waste Tank Maintenance and Production Management*, Westinghouse Hanford Company, Richland, Washington.

WHC-SP-1145, 1995, *WHC Radiation Protection Program Implementation of Title 10 Code of Federal Regulations Part 835,* Westinghouse Hanford Company, Richland, Washington.

ANSI/ANS 8.1, 1983, *Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors*.

ANSI/ANS 8.3, 1986, *Criticality Accident Alarm System.*

ANSI/ANS 8.19, 1984, *Administrative* Practices *for Nuclear Criticality Safety*.

10.0 ITEMS REQUIRING FURTHER RESOLUTION

There are a number of technical issues involving the offloading and storage of K Basin sludge in DST AW-105, ranging from the preconceptual nature of the design of the Sludge Transportation System to the uncertainties in the chemical and physical properties of the various sludge materials. These "unknowns" tend to result in large uncertainties in the safety analyses. Many of these uncertainties are addressed in the preliminary safety assessment through the use of "bounding" assumptions that were intended to result in conservative risk estimates. Use of bounding assumptions where large uncertainties exist leads to assurance that the risks would not be greater than the risks estimated in this document; however, it also tends to lead to implementation of strict controls on K Basin sludge offloading and storage activities which may or may not be needed. Therefore, resolution of the items listed below would most likely reduce uncertainties about the sludge offloading and storage activities and may lead to less-restrictive, and less-costly control strategies.

10.1 SLUDGE CHEMICAL AND PHYSICAL PROPERTIES

There are a number of uncertainties about the chemical and physical properties of K Basin sludge materials that require resolution before approval to ship and store the material in the tank farms can be obtained. An ongoing sludge characterization program is attempting to resolve these issues. In addition, tank farm waste compatibility issues, dealing with the chemical compatibility and stability of commingled K Basin sludge and AW-105 tank wastes, must also be addressed.

The original key assumption regarding the sludge was that no treatment, other than chemical adjustments such as adjusting the pH and addition of nitrate and nitrite to meet tank farm corrosion specifications, would be performed at K Basins to specifically address pyrophoric chemical reactions or hydrogen gas generation and accumulation. This implies that the chemical compatibility of K Basin sludge and AW-105 wastes can be favorably demonstrated without requiring treatment of the sludge materials.

More specific assumptions that require resolution, further analysis, and/or experimental studies are listed below:

- Mixing studies with actual AW-105 wastes and K Basin sludge materials are required to verify waste compatibility.
- Waste compatibility assessments of KE canister and fuel wash sludges and all KW Basin sludges are required to confirm the asssumption that these sludges are compatible with AW-105 waste.
- An independent technical review is needed to verify assumptions made about the chemical forms of toxic analytes and gaseous combustion products.
- Characterization of the radionuclide and toxic chemical composition of K East canister and fuel wash sludges and all KW Basin sludges is needed to reduce uncertainties about the consequence results.

- Additional studies are needed on the chemical phenomena that could lead to generation of relatively large quantities of hydrogen gas. Similarly, sludge-specific information is needed to verify assumptions made in this preliminary safety assessment on pyrophoric chemical reaction phenomena, such as corrosion studies in aqueous and caustic environments. These data are needed for a variety of reasons, including development and implementation of operating controls and restrictions at K Basin and tank farms, design of the Sludge Transportation System, and waste compatibility studies.

- The viscosity of the sludge assumed in the spray leak accident analysis was based on K East Basin floor and pit sludge. Characterization data is required for K East Basin canister and fuel was sludge and all K West Basin sludges to determine if the assumed viscosity is bounding.

10.2 SLUDGE TRANSPORTATION SYSTEM

The design of the Sludge Transportation System is preconceptual so many of the features of the system that were incorporated into the safety assessment are subject to change or revision. A number of key assumptions about the Sludge Transportation System were made in the hazards and accident analyses (e.g., shipping container capacity, pump rating, cover gas, etc.) . These assumptions will have to be validated or the analysis revised as the design of the system proceeds. The most important characteristic of the Sludge Transportation System in terms of its performance in accident conditions was the assumption that the system would be capable of withstanding Type B hypothetical accident conditions, or the Hanford equivalent used for onsite transportation packaging systems. This includes the systems capability to retain containment integrity following a series of tests applied to the system, including a free drop, puncture, and fire tests. If the Sludge Transportation System is not Type B, or the Hanford equivalent, the safety assessment would have to be revised using a less accident-resistant transportation system. However, it is believed the assumption that the Sludge Transportation System will be designed as a Type B or equivalent packaging system is firm, given that K Basin sludge shipments, as currently envisioned, will have relatively-high radionuclide inventories.

10.3 SLUDGE RECEIVING SYSTEM

Although further advanced that the design of the Sludge Transportation System, the design of the Sludge Receiving Station to be constructed in the AW tank farm is still subject to change. Any future changes in the design of this system would need to be compared to the design parameters used in this safety assessment and adjustments or modifications would be made.

10.4 RESOLUTION OF CRITICALITY SAFETY ISSUE

A known hazard associated with certain types of K Basin sludge is it;s relatively high concentration of fissile materials. A *Criticality Feasibility Study* is being conducted to identify the criticality safety requirements for several different stoirage configuration alternatives for the sludge. Preliminary indications are that chemical pretreatment of the sludge may be required to allow storage in AW-105. This pretreatment may alleviate some of the "unique" hazards associated with K Basin

sludge, including flammable gas generation and retention and pyrophoric chemical reactions. Final resolution of the criticality safety requirements for storage of K Basin sludge will have to be considered in future revisions to this safety assessment.

APPENDIX A

GENERAL DESIGN REQUIREMENTS

CONTENTS OF APPENDIX A

GENERAL DESIGN REQUIREMENTS 1
A.1 SITE CHARACTERISTICS REQUIREMENTS 1
A.2 DESIGN REQUIREMENTS 2
A.3 SAFETY ANALYSIS REQUIREMENTS 2
A.4 SAFETY SYSTEM, STRUCTURE, AND COMPONENT REQUIREMENTS . . . 3
A.5 TECHNICAL SAFETY REQUIREMENTS 3
A.6 CRITICALITY REQUIREMENTS 3
A.7 RADIATION PROTECTION REQUIREMENTS 4
A.8 HAZARDOUS MATERIAL PROTECTION REQUIREMENTS 5
A.9 RADIOACTIVE/HAZARDOUS WASTE MANAGEMENT REQUIREMENTS . . 6
A.10 INITIAL TESTING, IN-SERVICE SURVEILLANCE, AND MAINTENANCE . . 8
A.11 OPERATIONAL SAFETY REQUIREMENTS 9
A.12 PROCEDURES AND TRAINING REQUIREMENTS 9
A.13 HUMAN FACTORS REQUIREMENTS 10
A.14 QUALITY ASSURANCE REQUIREMENTS 10
A.15 EMERGENCY PREPAREDNESS REQUIREMENTS 11
A.16 DECONTAMINATION AND DECOMMISSIONING REQUIREMENTS 12
A.17 MANAGEMENT, ORGANIZATIONAL, AND INSTITUTIONAL SAFETY PROGRAM REQUIREMENTS 12
REFERENCES 14

APPENDIX A

GENERAL DESIGN REQUIREMENTS

This appendix presents a listing of regulations, DOE Orders, and requirements applicable to the design and safety analysis of the K Basin sludge transfer systems. A concise compilation of TWRS-specific federal, state, and local laws, regulations, permit conditions, industry consensus codes, standards, and good business practices is provided in WHC-SD-MP-SRID-001, Rev 1, *High Level Waste Storage Tank Farms/242-A Evaporator Standards/Requirements Identification Document*. This document is currently being implemented and any required changes to TWRS programs, particularly environment, safety, and health and safeguards and security functional areas, are being identified. Changes required to incorporate K Basin sludge offload and storage activities will be incorporated at a later date. Note that this appendix focuses on TWRS-related requirements because the Sludge Receiving Station and DST AW-105 are, or will be, TWRS facilities. The Sludge Transportation System will be designed, fabricated, and operated under similar sets of requirements, which have been incorporated into this appendix where applicable.

The following sections present the requirements that are applicable to each major section of the safety assessment, as defined in DOE Order 5480.23 and DOE-STD-3009-94. Separate sections are provided for each major chapter in the outline provided in the DOE Standard.

A.1 SITE CHARACTERISTICS REQUIREMENTS

The following are current standards, regulations, and DOE orders that establish the requirements for Hanford Site characterization in support of safety analysis and design. Additional requirements may be imposed on new facilities and facility modifications to meet DOE safety requirements:

- DOE 5480.28, *Natural Phenomena Hazards Mitigation* (1993)[1]
- DOE 6430.1A, *General Design Criteria* (1989)[1]
- DOE-STD-1020-94, *Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities* (1994)
- DOE-STD-1021-93, *Natural Phenomena Hazards Performance Categorization Guidelines for Structures, Systems, and Components* (1993)
- DOE-STD-1022-94, *Natural Phenomena Hazards Site Characterization Criteria* (1994)
- DOE-STD-1023-95, *Natural Phenomena Hazards Assessment Criteria* (1995)

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1 Although DOE 5480.28 and DOE 6430.1A have been rescinded recently, the contractor is obligated by the existing contract to meet the requirements in these orders.

- DOE-STD-1024-92, *Guidelines for Use of Probabilistic Seismic Hazard Curves at DOE Sites* (1992)

- UCRL-15910, *Design and Evaluation Guidelines for DOE Facilities Subjected to Natural Phenomena Hazards* (1990).

A.2 DESIGN REQUIREMENTS

The design codes, standards, regulations, and DOE orders relevant to this chapter and required for establishing the authorization basis for TWRS facilities are as follows:

- DOE 5820.2A, *Radioactive Waste Management* (1988)

- DOE 5480.7A, *Fire Protection* (1993)

- DOE 5480.28, *Natural Phenomena Hazard Mitigation* (1994)[2]

- DOE 6430.1A, *General Design Criteria* (1989)[1]

- DOE-STD-1020-93, *Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities* (Change 1)

- DOE-STD-1021-94, *Natural Phenomena Hazards Performance Categorization Guidelines for Structures, Systems, and Components* (Change 1)

- DOE-STD-1022-94, *Natural Phenomena Hazards Characterization Criteria* (Change 1)

- DOE-STD-1023-95, *Natural Phenomena Hazards Assessment Criteria* (Change 1).

Before the current design requirements were issued, facilities were designed and constructed in accordance with the functional and safety requirements documented in project functional design criteria, specifications, and drawings (see WHC-SD-TWR-RPT-002, *Structural Integrity and Potential Failure Modes of the Hanford High-Level Waste Tanks*).

A.3 SAFETY ANALYSIS REQUIREMENTS

The primary requirements for the performance and documentation of facility safety analyses are provided in the following documents:

- DOE 5480.23, *Nuclear Safety Analysis Reports* (1992).

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[2] Although DOE 5480.28 and DOE 6430.1A have been rescinded recently, the contractor is obligated by the existing contract to meet the requirements stated in these orders.

- DOE-STD-1027-92, *Hazard Categorization and Accident Analysis Techniques for Compliance With DOE Order 5480.23, Nuclear Safety Analysis Reports* (1992).

- DOE-STD-3009-94, *Preparation Guide for U.S. DOE Nonreactor Nuclear Facility Safety Analysis Reports* (1994).

A.4 SAFETY SYSTEM, STRUCTURE, AND COMPONENT REQUIREMENTS

The following documents present the primary criteria for the design, analysis, and designation of safety systems, structures, and components (SSCs):

- DOE 5480.23, *Nuclear Safety Analysis Reports* (1992).

- DOE 6430.1A, *General Design Criteria* (1989)[1]

- DOE-STD-1021-94, *Natural Phenomena Hazards Performance Categorization Guidelines for Structures, Systems, and Components* (Change 1)

A.5 TECHNICAL SAFETY REQUIREMENTS

The primary requirements for preparation of the hazard and accident analyses and the TSR document are included in the following documents:

- DOE 5480.22, *Technical Safety Requirements* (1992).

- DOE 5480.23, *Nuclear Safety Analysis Reports* (1992).

A.6 CRITICALITY REQUIREMENTS

The following design codes, federal regulations, DOE orders, and standards were used to establish the foundation for criticality safety of TWRS facilities and the Sludg Transportation System:

- 10 CFR 71, "Packaging of Radioactive Material for Transport" (1995)

- 49 CFR 171-179, "Transportation" (1995)

- DOE 5480.24, *Nuclear Criticality Safety* (1992)

- DOE 5480.23, *Nuclear Safety Analysis Reports* (1994).

- As cited and modified by DOE 5480.24, 1992, *Nuclear Criticality Safety*, U.S. Department of Energy, Washington, D.C. Note: Canceled by DOE O 420.1. Compliance with DOE 5480.24 is required until the Contracting Officer directs compliance with DOE O 420.1 or provides other direction to terminate compliance with DOE 5480.24:

- ANSI/ANS-8.1-1983, *Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors* (1983)

- ANSI/ANS-8.3-1986, *Criticality Accident Alarm System* (1986)

- ANSI/ANS-8.7-1975, *Guide for Nuclear Criticality Safety in the Storage of Fissile Materials* (1975)

- ANSI/ANS-8.19-1984, *Administrative Practices for Nuclear Criticality Safety* (1984).

A.7 RADIATION PROTECTION REQUIREMENTS

The following documents form the philosophical and legal bases for the radiation protection program at Hanford facilities, including TWRS, Spent Nuclear Fuel, and transportation and packaging.

- 10 CFR 835, "Occupational Radiation Protection," (1993).

- DOE/EH-0256T, *Radiological Control Manual,* (1994).

- HSRCM-1, *Hanford Site Radiological Control Manual*, Rev. 2, (1994).

- DOE 5400.1, *General Environmental Protection Program*, (1990).

- DOE 5400.5, *Radiation Protection of the Public and the Environment*, (1990).

In addition to these principal documents, the following documents affect parts of the radiation protection program:

- DOE 5480.18B, *Accreditation of Performance-Based Training for Category A Reactors and Nuclear Facilities*, (1991)

- DOE 5480.20, *Personnel Selection, Qualification, Training, and Staffing Requirements at DOE Reactor and Non-Reactor Nuclear Facilities*, (1994)

- DOE 5480.4, *Environmental Protection, Safety, and Health Protection Standards*, (1993)[3]

- 20 CFR 1910, "Occupational Safety and Health Standards," (1996)

- 40 CFR 61, "National Emission Standards for Hazardous Air Pollutants," (1996)

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[3] This order has been canceled and replaced by DOE 0 440.1. Compliance with DOE 5480.4 is required by the WHC contract and is, therefore, the applicable requirement for the TWRS safety basis.

The radiological training program at Hanford complies with the requirements stated in 10 CFR 835 and its implementation guide G-10 CFR 835/J1-Rev. 1, DOE 5480.18B, and DOE 5480.20. The training program also meets the requirements of the DOE training program management manuals (DOE/EH-0258T-1, *General Employee Radiological Training and Radiological Worker Training*; DOE 1992b, *Radiological Control Technician Training*) and the DOE training accreditation program manual (DOE 1991, *Training and Accreditation Program Manual*). The training program is structured so that every employee receives the training necessary to safely perform their work but not extraneous training. The quality of the radiological protection training program is assured by the guidance of the radiological control organization through their oversight function. Worker qualification records are maintained by the contractor's training records organization. This section provides an overview of the radiological training program while section A.12 "Procedures and Training" of this apendix describes the management aspects of the training program.

The site-wide Hanford Training Program consists of courses in general safety awareness, nuclear safety, and hazardous materials and waste. The radiological protection training program includes information on general and specific aspects of radiation safety including: minimization of radiation exposures through the use of time, distance and shielding; radiation health effects; and radiation dose limits. The Safety Training Program includes a multitiered radiation protection training program which provides a level of training commensurate with the individual's radiological worker status and specific work assignment. Training requirements and the methods used to develop training programs are discussed in the TWRS FSAR, Chapter 12.

A.8 HAZARDOUS MATERIAL PROTECTION REQUIREMENTS

Applicable design codes, standards, regulations, and DOE orders relevant to this chapter and required for establishing the safety basis of TWRS facilities are listed in this section. These DOE orders implement 29 CFR 1910, "Occupational Safety and Health Standards," and 29 CFR 1926, "Safety and Health Regulations for Construction."

- DOE 3790.1B, *Federal Employee Occupational Safety and Health Program* (1993)
- DOE 5480.1B, *Environmental, Safety, and Health Program for DOE Operations*, Change 5 (1993)[4]
- DOE 5480.4, *Environmental Protection, Safety, and Health Protection Standards*, Change 4 (1993)[5]

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[4] Paragraph 5o canceled by DOE 5480.21 of December 24, 1991; entire order canceled by DOE N 251.4. Compliance with DOE 5480.1B required until directed by Contracting Officer to terminate compliance.

[5] Attachment 2 Paragraphs 2c, 2d(2)-(3), 2e(1)-(8) canceled by DOE O 440.1; Attachment 3 Paragraphs 2c, 2d(2)-(3), 2e(1)-(7) canceled by DOE O 440.1. Compliance with DOE 5480.4 required until the Contracting Officer directs compliance with DOE O 440.1 or provides other direction to terminate compliance

- DOE 5480.8A, *Contractor Occupational Medical Program*, Change 3 (1992)[6]
- DOE 5480.9A, *Construction Project Safety and Health Management* (1994)[7]
- DOE 5480.10, *Contractor Industrial Hygiene Program* (1985).[8]
- DOE 5483.1A, *Occupational Safety and Health Program for DOE Contractor Employees at Government-Owned Contractor-Operated Facilities* (1993)[9]
- DOE 5484.1, *Environmental Protection, Safety, and Health Protection Information Reporting Requirements* (1990)

Workers whose work may potentially expose them to hazardous materials on the job must have sufficient training to know the physical and chemical hazards presented by the materials in their environment and how to protect themselves from the deleterious effects of exposure. In addition to General Employee Training, workers who potentially may be exposed to hazardous materials during their work receive 24- or 40-hour hazardous waste operations training per 29 CFR 1910.120, "Hazardous Waste Operations and Emergency Response." A list of major training requirements and topics that are pursued is provided in the TWRS FSAR. Facility-specific training is provided to personnel regarding hazardous materials that may be encountered during work in each location.

A.9 RADIOACTIVE/HAZARDOUS WASTE MANAGEMENT REQUIREMENTS

TWRS controls wastes pursuant to the requirements of applicable federal and state regulations and DOE orders in a manner that protects the public and the environment. The following list provides the basis for the operational and safety procedures for sludge offloading and storage activities at TWRS facilities:

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with DOE 5480.4.

6 Canceled by DOE N 251.4 and DOE O 440.1. Compliance with DOE 5480.8A is required until the Contracting Officer directs compliance with DOE O 440.1 or provides other direction to terminate compliance with DOE 5480.8A.

7 Canceled by DOE N 251.4 and DOE O 440.1. Compliance with DOE 5480.9A is required until the Contracting Officer directs compliance with DOE O 440.1 or provides other direction to terminate compliance with DOE 5480.9A.

8 Canceled by DOE N 251.4 and DOE O 440.1. Compliance with DOE 5480.10 is required until the Contracting Officer directs compliance with DOE O 440.1 or provides other direction to terminate compliance with DOE 5480.10.

9 Chapter II canceled by DOE 5480.29; Chapter III Paragraphs 2a, 2b, and 2c canceled by DOE O 231.1; entire order canceled by DOE N 251.4 and DOE O 440.1. Compliance with DOE 5483.1A is required until directed by DOE-RL to comply with DOE O 440.1.

- **Solid wastes**:

  40 CFR 260, "Hazardous Waste Management System: General" (1995)

  40 CFR 261, "Identification and Listing of Hazardous Waste" (1995)

  40 CFR 262, "Standards Applicable to Generators of Hazardous Waste" (1995)

  40 CFR 263, "Standards Applicable to Transporters of Hazardous Waste" (1995)

  40 CFR 264, "Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities" (1995)

  40 CFR 265, "Interim Status Standards of Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities" (1995)

  40 CFR 266, "Standards for the Management of Specific Hazardous Wastes and Specific Types of Hazardous Waste Management Facilities" (1995)

  40 CFR 268, "Land Disposal Restrictions" (1995)

  40 CFR 279, "Standards for the Management of Used Oil" (1995)

  DOE 5820.2A, *Radioactive Waste Management* (1988)

  Hanford Federal Facility Agreement and Consent Order (Ecology et al. 1994)

  WAC 173-303, "Dangerous Waste Regulations" (1995)

- **Hazardous materials**:

  40 CFR 370, "Hazardous Chemical Reporting: Community Right-To-Know" (1995)

  40 CFR 372, "Toxic Chemical Release Reporting: Community Right-To-Know" (1995)

  40 CFR 761, "Polychlorinated Biphenyls (PCBs) Manufacturing, Processing, Distribution in Commerce, and Use Prohibitions" (1995)

  40 CFR 763, "Asbestos" (1995)

- **Water quality**:

  Consent Order DE-91NM-177 (see WHC-CM-7-5, Appendix E [1996])

DOE 5400.1, *General Environmental Protection Program*, Change 1 (1990)[10]

DOE 5400.5, *Radiation Protection of the Public and the Environment*, Change 2 (1993)

WAC 173-200, "Water Quality Standards for Ground Waters of the State of Washington" (1995)

WAC 173-216, "State Waste Discharge Permit Program" (1995)

WAC 173-218, "Underground Injection Control Program" (1995)

- **Air quality**:

40 CFR 60, "Protection of Environment" (1995)

40 CFR 61, "National Emissions Standards for Hazardous Air Pollutants" (1995)

WAC 173-400, "General Regulations for Air Pollution Sources" (1995)

WAC 173-460, "Controls for New Sources of Toxic Air Pollutants" (1995)

WAC 173-480, "Ambient Air Quality Standards and Emission Limits for Radionuclides" (1995)

WAC 246, "Department of Health" (1995)

- **Spill reporting**:

40 CFR 302, "Designation, Reportable Quantities, and Notification" (1995)

WAC 173-303, "Dangerous Waste Regulations" (1995)

- **Transportation**:

49 CFR 171, Subchapter C — Hazardous Materials Regulations, "General Information, Regulations, and Definitions" (1995)

49 CFR 172, "Hazardous Material Table, Special Provisions, Hazardous Materials Communications, Emergency Response Information, and Training Requirements" (1995)

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10 Chapter II, Paragraphs 2b, 4b, and 4c and Chapter III, Paragraphs 2d and 3b, canceled by DOE O 231.1. Compliance required until directed by Contracting Officer to terminate compliance.

49 CFR 173, "Shippers — General Requirements for Shipments and Packagings" (1995)

DOE 1540.2, *Hazardous Material Packaging for Transport - Administrative Procedures*, Change 1 (1988)[11]

DOE 5480.3, *Safety Requirements for the Packaging and Transportation of Hazardous Materials, Hazardous Substances, and Hazardous Wastes* (1985)[12]

Hanford Facility RCRA Permit, Dangerous Waste Portion.

A.10 INITIAL TESTING, IN-SERVICE SURVEILLANCE, AND MAINTENANCE

Initial testing, in-service surveillance, and maintenance policies and programs addressed in this safety assessment are regulated by the following DOE orders:

- DOE 4330.4B, *Maintenance Management Program* (1994)[13]
- DOE 4700.1, *Project Management System*, Change 1 (1992)[1]
- DOE 5480.19, *Conduct of Operations Requirements for DOE Facilities*, Change 1 (1992)
- DOE 5480.23, *Nuclear Safety Analysis Reports*, Change 1 (1994)
- DOE 5480.31, *Startup and Restart of Nuclear Facilities* (1993)[14]
- DOE-76-45/1, *Occupancy/Use Readiness Manual* (1992).

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11 Canceled by DOE O 460.1 and DOE O 460.2. Compliance required until DOE O 460.1 or DOE O 460.2 is for compliance or other Contracting Officer directing to cancel.

12 Paragraph 2e canceled by DOE O 231.1; entire order canceled by DOE O 460.1 and DOE N 251.4. Compliance required until DOE O 460.1 is for compliance or other Contracting Officer direction to cancel.

13 DOE 4330.4B and DOE 4700.1 will be phased out/canceled upon meeting implementation conditions of DOE O 430.1, *Life-Cycle Asset Management* (1995).

14 DOE 5480.31 canceled by DOE N 251.4, *Cancellation of Directives*. Compliance with DOE 5480.31 is required until the Contracting Officer provides direction to terminate compliance.

The requirements of initial testing, in-service surveillance, and maintenance programs reflect the safety-class assignments of SSCs for protection of the public, personnel, and the environment as discussed in Chapter 4.0, "Safety Systems, Structures, and Components."

A.11 OPERATIONAL SAFETY REQUIREMENTS

Adherence to the following design codes, standards, regulations, and DOE orders is required for establishing the safety basis for offloading and storing K Basin sludge in DST AW-105. This list includes only those requirements specific to the safety analysis of K Basin sludge transport, offloading, and storage activities described in this report, which will ultimately be required to be incorporated into the TWRS authorization basis.

- DOE 5480.31, *Startup and Restart of Nuclear Facilities* (1993)
- DOE 5480.7A, *Fire Protection* (1993)
- DOE 5480.19, *Conduct of Operations Requirements for DOE Facilities*, Change 1 (1992)
- DOE-STD-3006-93, *Planning and Conduct of Operational Readiness Reviews (ORR)* (1993)
- RLID 5480.7, *Fire Protection* (1994).

A.12 PROCEDURES AND TRAINING REQUIREMENTS

TWRS commitment to safe operation of the tank farm, including the sludge transportation, offloading, and storage activities, is demonstrated by procedures and training that satisfy the following DOE requirements:

- DOE 4330.4B, *Maintenance Management Program* (1994)
- DOE 5480.18B, 1994, Nuclear Facility Training Accreditation Program, U. S. Department of Energy, Washington, D. C.
- DOE 5480.19, *Conduct of Operations Requirements for DOE Facilities*, Change 1 (1992)
- DOE 5480.20A, *Personnel Selection, Qualification, Training, and Staffing Requirements at DOE Reactor and Non-Reactor Facilities* (1994).

A.13 HUMAN FACTORS REQUIREMENTS

The regulations and DOE orders relevant to human factors and required for establishing the authorization basis for TWRS facilities are as follows:

- 10 CFR 830, "Nuclear Safety Management" (1994)
- DOE 5000.3B, *Occurrence Reporting and Processing of Operations Information* (1993)[15]
- DOE 5480.19, *Conduct of Operations Requirements for DOE Facilities*, Change 1 (1990)
- DOE 5480.20A, *Personnel Selection, Qualifications, Training, and Staffing Requirements at DOE Reactors and Nonreactor Nuclear Facilities* (1991)
- DOE 5480.23, *Nuclear Safety Analysis Reports*, Change 1 (1994)
- DOE 6430.1A, *General Design Criteria*, Section 1300-12, "Human Factors Engineering" (1989)[16]
- HSRCM-1, *Hanford Site Radiological Control Manual* (1994).

A.14 QUALITY ASSURANCE REQUIREMENTS

10 CFR 830.120 is the source document for the contractor Quality Assurance Program (QAP). WHC-SP-1131, *Westinghouse Hanford Company Quality Assurance Program and Implementation Plan, Implementation of Title 10 Code of Federal Regulations Part 830.120,* details the contractor QAP and the measures taken to comply with 10 CFR 830.120. WHC-SP-1131 has been issued by the contractor and approved by the DOE. Appendix A of WHC-SP-1131 contains details of unique, TWRS-specific features and implementation shortcomings that are part of the implementation plan. A standards/requirements identification document (S/RID) produced for each TWRS facility lists specific codes, standards, and requirements used to implement the contractor QAP. These TWRS S/RIDs are subsets of the company-level S/RIDs set.

A.15 EMERGENCY PREPAREDNESS REQUIREMENTS

The following DOE orders, regulations, standards, and codes contain specific emergency preparedness requirements that establish the safety basis for the tank farm facilities, including the DST AW-105 and Sludge Receiving Station, as well as the Sludge Transportation System.

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15 DOE 5000.3B, *Occurrence Reporting and Processing of Operations Information*, Change 1 (1993) was canceled May 10, 1996. Subsequent references will be to DOE O 231.1.

16 Non-safety-related portions of DOE 6430.1A will be phased out or canceled when implementation conditions of DOE O 430.1 are met; portions related to nuclear safety for nonreactor nuclear facilities will be canceled by DOE O 420.1. Compliance with DOE 6430.1A is required until directed by U.S. Department of Energy, Richland Operations Office, to comply with DOE O 430.1 and DOE O 420.1. Contract modification is required when DOE 6430.1A is canceled.

- 10 CFR 835, "Radiation Protection" (1993)
- 29 CFR 1910, "Occupational Safety and Health Standards" (1995)
- 40 CFR 265, "Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities for EPA Solid Wastes" (1995)
- 40 CFR 302, "Designation Reportable Quantities, and Notification; EPA/Superfund, Emergency Planning, and Community Right-To-Know Programs" (1995)
- 40 CFR 355, "Emergency Planning and Notification; EPA/Superfund, Emergency Planning, and Community Right-To-Know Programs" (1995)
- WAC 173-303, "Dangerous Waste Regulations" (1995)
- WAC 296-62, "Occupational Health Standards—Safety Standards for Carcinogens" (1995)
- DOE O 232.1, *Environment, Safety, and Health Reporting* (1995)[17]
- DOE 5480.10, *Contractor Industrial Hygiene Program*, Change 3 (1985)
- DOE 5480.11, *Radiation Protection for Occupational Workers*, Change 3 (1992)[18]
- DOE 5482.1B, *Environment, Safety, and Health Appraisal Program*, Change 1 (1991)
- DOE 5500.1B, *Emergency Management System*, Change 1 (1992)[19]
- DOE 5500.2B, *Emergency Categories, Classes, and Notification and Reporting Requirements*, Change 1 (1992)[20]
- DOE O 151.1, *Comprehensive Emergency Management System* (1995).

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17 DOE 5000.3B, *Occurrence Reporting and Processing of Operations Information*, Change 1 (1993) was canceled May 10, 1996. Subsequent references will be to DOE O 231.1.

18 Canceled by DOE N 441.1 and DOE N 251.4. Compliance with DOE 5480.11 is required until the Contracting Officer directs compliance with DOE N 441.1 and DOE N 251.4 or provides other direction to terminate compliance with DOE 5480.11.

19 Entire order canceled by DOE O 151.1, Change 1. Compliance with DOE 5500.1B is required until directed by DOE-RL to comply with DOE O 151.1.

20 Entire order canceled by DOE O 151.1, Change 1. Compliance with DOE 5500.1B is required until directed by DOE-RL to comply with DOE O 151.1.

- HSRCM-1, *Hanford Site Radiological Control Manual* (1994).

A.16 DECONTAMINATION AND DECOMMISSIONING REQUIREMENTS

The current regulatory basis for Decontamination and Decommissioning (D&D) activities is being developed. DOE plans to address D&D requirements for existing facilities in greater technical detail in the future. The following requirements are representative of those currently in place for D&D activities.

- DOE 5400.5, *Radiation Protection of the Public and the Environment* (1993)
- DOE 5820.2A, *Radioactive Waste Management*, Chapter V, "Decommissioning of Radioactively Contaminated Facilities" (1988)
- *National Environmental Policy Act of 1969*
- *Resource Conservation and Recovery Act of 1976*
- WAC 173-303, "Dangerous Waste Regulations," *Washington Administrative Code* (1995).

A.17 MANAGEMENT, ORGANIZATIONAL, AND INSTITUTIONAL SAFETY PROGRAM REQUIREMENTS

This section lists the requirements specific to this chapter and pertinent to the safety analysis. The following federal regulations and DOE orders are required for establishing the management, organizational, and institutional aspects of the safety basis for TWRS facilities and operations:

- 10 CFR 830, "Nuclear Safety Management" (1994)
- G-830.120-Rev. 0, *Implementation Guide for Use with 10 CFR Part 830.120, Quality Assurance* (1994)
- RLID 232.1, *Occurrence Reporting and Processing of Operations Information* (1996)
- DOE 5480.19, *Conduct of Operations Requirements for DOE Facilities*, Change 1 (1992)
- DOE 5480.21, *Unreviewed Safety Questions* (1991)
- DOE 5480.22, *Technical Safety Requirements*, Change 2 (1996)
- DOE 5480.23, *Nuclear Safety Analysis Reports*, Change 1 (1994)
- RLP 5480.23, *Review and Approval of Nuclear Safety Analysis Reports*, (1996).

- DOE 5480.26, *Trending and Analysis of Operations Information Using Performance Indicators* (1993).

REFERENCES

10 CFR 71, 1995, "Packaging of Radioactive Material for Transport," *Code of Federal Regulations*.

10 CFR 830, 1994, "Nuclear Safety Management," *Code of Federal Regulations*.

10 CFR 830.120, 1996, "Quality Assurance Requirements," *Code of Federal Regulations*.

10 CFR 835, "Occupational Radiation Protection," *Code of Federal Regulations*, as amended.

29 CFR 1910, "Occupational Safety and Health Standards," *Code of Federal Regulations*, as amended.

40 CFR 60, 1995, "Protection of Environment," *Code of Federal Regulations*.

40 CFR 61, 1995, "National Emissions Standards for Hazardous Air Pollutants," *Code of Federal Regulations*.

40 CFR 70, 1995, "State Operating Permit Programs," *Code of Federal Regulations*.

40 CFR 260, 1995, "Hazardous Waste Management System: General," *Code of Federal Regulations*.

40 CFR 261, 1995, "Identification and Listing of Hazardous Waste," *Code of Federal Regulations*.

40 CFR 262, 1995, "Standards Applicable to Generators of Hazardous Waste," *Code of Federal Regulations*.

40 CFR 263, 1995, "Standards Applicable to Transporters of Hazardous Waste," *Code of Federal Regulations*.

40 CFR 264, 1995, "Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," *Code of Federal Regulations*.

40 CFR 265, 1995, "Interim Status Standards of Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," *Code of Federal Regulations*.

40 CFR 266, 1995, "Standards for the Management of Specific Hazardous Wastes and Specific Types of Hazardous Waste Management Facilities," *Code of Federal Regulations*.

40 CFR 268, 1995, "Land Disposal Restrictions," *Code of Federal Regulations*.

40 CFR 279, 1995, "Standards for the Management of Used Oil," *Code of Federal Regulations*.

40 CFR 302, 1995, "Designation, Reportable Quantities, and Notification," *Code of Federal Regulations*.

40 CFR 355, 1995, "Emergency Planning and Notification; EPA/Superfund, Emergency Planning, and Community Right-To-Know Programs," *Code of Federal Regulations*, as amended.

40 CFR 370, 1995, "Hazardous Chemical Reporting: Community Right-To-Know," *Code of Federal Regulations*.

40 CFR 372, 1995, "Toxic Chemical Release Reporting: Community Right-To-Know," *Code of Federal Regulations*.

40 CFR 761, 1995, "Polychlorinated Biphenyls (PCBs) Manufacturing, Processing, Distribution in Commerce, and Use Prohibitions," *Code of Federal Regulations*.

40 CFR 763, 1995, "Asbestos," *Code of Federal Regulations*.

40 CFR 1500-1508, 1986, "Council on Environmental Quality Regulations," *Code of Federal Regulations*.

49 CFR 171-179, 1995, "Transportation," *Code of Federal Regulations*.

49 CFR 171, 1995, "General Information, Regulations, and Definitions," Subchapter C — Hazardous Materials Regulations, *Code of Federal Regulations*.

49 CFR 172, 1995, "Hazardous Material Table, Special Provisions, Hazardous Materials Communications, Emergency Response Information, and Training Requirements," *Code of Federal Regulations*.

49 CFR 173, 1995, "Shippers — General Requirements for Shipments and Packagings," *Code of Federal Regulations*.

ANSI/ANS-8.1-1983, 1983, *Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors*, American National Standards Institute/American Nuclear Society, New York, New York.

ANSI/ANS-8.3-1986, 1986, *Criticality Accident Alarm System*, American National Standards Institute/American Nuclear Society, New York, New York.

ANSI/ANS-8.7-1975, 1975, *Guide for Nuclear Criticality Safety in the Storage of Fissile Materials*, American National Standards Institute/American Nuclear Society, New York, New York.

ANSI/ANS-8.19-1984, 1984, *Administrative Practices for Nuclear Criticality Safety*, American National Standards Institute/American Nuclear Society, New York, New York.

Consent Order DE-91NM-177 (see WHC-CM-7-5, Appendix E).

DOE O 151.1, 1995, *Comprehensive Emergency Management System*, U.S. Department of Energy, Washington, D.C.

DOE O 232.1, 1995, *Environment, Safety, and Health Reporting*, U.S. Department of Energy, Washington, D.C. Note: DOE 5000.3B, *Occurrence Reporting and Processing of Operations Information*, Change 1 (1993) was canceled May 10, 1996. Subsequent references will be to DOE O 231.1.

DOE 1540.2, 1988, *Hazardous Material Packaging for Transport - Administrative Procedures*, Change 1, U.S. Department of Energy, Washington, D.C.

DOE 3790.1B, 1993, *Federal Employee Occupational Safety and Health Program*, U.S. Department of Energy, Washington, D.C.

DOE 4330.4B, 1994, *Maintenance Management Program*, Change XX, U.S. Department of Energy, Washington, D.C.

DOE 4700.1, 1992, *Project Management System*, Change 1, U.S. Department of Energy, Washington, D.C.

DOE 5000.3B, 1993, *Occurrence Reporting and Processing of Operations Information*, U.S. Department of Energy, Washington, D.C.

DOE 5400.1, 1988, *General Environmental Protection Program*, U.S. Department of Energy, Washington, D.C.

DOE 5400.5, 1993, *Radiation Protection of the Public and the Environment*, Change 2, U.S. Department of Energy, Washington, D.C.

DOE 5480.1B, 1993, *Environmental, Safety, and Health Program for DOE Operations*, Change 5, U.S. Department of Energy, Washington, D.C.

DOE 5480.3, 1985, *Safety Requirements for the Packaging and Transportation of Hazardous Materials, Hazardous Substances, and Hazardous Wastes*, U.S. Department of Energy, Washington, D.C.

DOE 5480.4, *Environmental Protection, Safety, and Health Protection Standards*, U.S. Department of Energy, Washington, D.C., (Original publication 5/15/84; Change 4: 1/7/93. Has been replaced by DOE O 440.1).

DOE 5480.7A, 1993, *Fire Protection*, U.S. Department of Energy, Washington, D.C.

DOE 5480.8A, 1992, *Contractor Occupational Medical Program*, Change 3, U.S. Department of Energy, Washington, D.C.

DOE 5480.9A, 1994, *Construction Project Safety and Health Management*, U.S. Department of Energy, Washington, D.C.

DOE 5480.10, 1985, *Contractor Industrial Hygiene Program*, U.S. Department of Energy, Washington, D.C.

DOE 5480.11, 1992, *Radiation Protection for Occupational Workers*, Change 1, U.S. Department of Energy, Washington, D.C.

DOE 5480.18B, *Accreditation of Performance-Based Training for Category A Reactors and Nuclear Facilities*, U.S. Department of Energy, Washington, D.C.

DOE 5480.19, 1992, *Conduct of Operations Requirements for DOE Facilities*, Change 1, U.S. Department of Energy, Washington, D.C.

DOE 5480.20, *Personnel Selection, Qualification, Training, and Staffing Requirements at DOE Reactor and Non-Reactor Nuclear Facilities*, U.S. Department of Energy, Washington, D.C.

DOE 5480.21, 1991, *Unreviewed Safety Questions*, U.S. Department of Energy, Washington, D.C.

DOE 5480.22, 1992, *Technical Safety Requirements*, Change 1 (1992) and Change 2 (1996), U.S. Department of Energy, Washington, D.C.

DOE 5480.23, 1992, *Nuclear Safety Analysis Reports*, Change 1 (1994), U.S. Department of Energy, Washington, D.C.

DOE 5480.24, 1992, *Nuclear Criticality Safety*, U.S. Department of Energy, Washington, D.C. Note: Canceled by DOE O 420.1. Compliance with DOE 5480.24 is required until the Contracting Officer directs compliance with DOE O 420.1 or provides other direction to terminate compliance with DOE 5480.24

DOE 5480.26, 1993, *Trending and Analysis of Operations Information Using Performance Indicators*, U.S. Department of Energy, Washington, D.C.

DOE 5480.28, 1993, *Natural Phenomena Hazards Mitigation*, U.S. Department of Energy, Washington, D.C.

DOE 5480.31, 1993, *Startup and Restart of Nuclear Facilities*, Change XX, U.S. Department of Energy, Washington, D.C.

DOE 5482.1B, 1991, *Environment, Safety, and Health Appraisal Program*, Change 1, U.S. Department of Energy, Washington, D.C.

DOE 5483.1A, 1993, *Occupational Safety and Health Program for DOE Contractor Employees at Government-Owned Contractor-Operated Facilities*, U.S. Department of Energy, Washington, D.C.

DOE 5484.1, 1990, *Environmental Protection, Safety, and Health Protection Information Reporting Requirements*, U.S. Department of Energy, Washington, D.C.

DOE 5500.1B, 1992, *Emergency Management System*, Change 1, U.S. Department of Energy, Washington, D.C.

DOE 5500.2B, 1992, *Emergency Categories, Classes, and Notification and Reporting Requirements*, Change 1, U.S. Department of Energy, Washington, D.C.

DOE 5820.2A, 1988, *Radioactive Waste Management*, U.S. Department of Energy, Washington, D.C.

DOE 6430.1A, 1989, *General Design Criteria*, U.S. Department of Energy, Washington, D.C.

DOE-76-45/1, 1992, *Occupancy/Use Readiness Manual*, Rev. XX, Systems Safety Development Center, Idaho Falls, Idaho.

DOE, 1991, *Training Accreditation Program Manuals*, TAP 1 and TAP 2, U.S. Department of Energy, Washington, D.C.

DOE, 1992b, *Radiological Control Technician Training - Program Management Manual*, U.S. Department of Energy, Washington, D.C.

DOE/EH-0256T, 1994, *Radiological Control Manual*, Rev. 1, U.S. Department of Energy, Washington, D.C.

DOE/EH-0258T-1, 1992, *General Employee Radiological Training and Radiological Worker Training - Program Management Manual*, U.S. Department of Energy, Washington, D.C.

DOE/EIS-0189, 1996, *Draft Environmental Impact Statement for the Tank Waste Remediation System*, U.S. Department of Energy, Washington, D.C.

DOE-STD-1020-94, *Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities*, U.S. Department of Energy, Washington, D.C.

DOE-STD-1021-93, *Natural Phenomena Hazards Performance Categorization Guidelines for Structures, Systems, and Components*, U.S. Department of Energy, Washington, D.C.

DOE-STD-1022-94, *Natural Phenomena Hazards Site Characterization Criteria*, U.S. Department of Energy, Washington, D.C.

DOE-STD-1023-95, *Natural Phenomena Hazards Assessment Criteria*, U.S. Department of Energy, Washington, D.C.

DOE-STD-1024-92, *Guidelines for Use of Probabilistic Seismic Hazard Curves at DOE Sites*, U.S. Department of Energy, Washington, D.C.

DOE-STD-1027-92, *Hazard Categorization and Accident Analysis Techniques for Compliance With DOE Order 5480.23, Nuclear Safety Analysis Reports*, U.S. Department of Energy, Washington, D.C..

DOE-STD-3006-93, 1993, *Planning and Conduct of Operational Readiness Reviews (ORR)*, U.S. Department of Energy, Washington, D.C.

DOE-STD-3009-94, *Preparation Guide for U.S. DOE Nonreactor Nuclear Facility Safety Analysis Reports*, U.S. Department of Energy, Washington, D.C.

Ecology, 1995, *Regulations for Implementing Procedural Provisions of the National Environmental Policy Act*, Permit WA7890009067, Rev. 2, Washington State Department of Ecology, Olympia, Washington.

Ecology, EPA, and DOE, 1996, *Hanford Federal Facility Agreement and Consent Order*, Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, Olympia, Washington.

G-830.120-Rev. 0, 1994, *Implementation Guide for Use with 10 CFR Part 830.120, Quality Assurance*, U.S. Department of Energy, Washington, D.C.

HSRCM-1, 1994, *Hanford Site Radiological Control Manual*, Rev. 2, Westinghouse Hanford Company, Richland, Washington.

National Environmental Policy Act of 1969, 42 USC 4321, et seq.

Resource Conservation and Recovery Act of 1976, 42 USC 6901, et seq.

RLID 232.1, 1996, *Occurrence Reporting and Processing of Operations Information*, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

RLID 5480.7, 1994, *Fire Protection*, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

RLP 5480.23, 1996, *Review and Approval of Nuclear Safety Analysis Reports*, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

UCRL-15910, 1990, *Design and Evaluation Guidelines for DOE Facilities Subjected to Natural Phenomena Hazards*, University of California Research Laboratory, Berkeley, California.

Hanford Facility RCRA Permit, Dangerous Waste Portion.

WAC 173-200, 1995, "Water Quality Standards for Ground Waters of the State of Washington," *Washington Administrative Code*.

WAC 173-216, 1995, "State Waste Discharge Permit Program," *Washington Administrative Code*.

WAC 173-218, 1995, "Underground Injection Control Program," *Washington Administrative Code*.

WAC 173-303, 1995, "Dangerous Waste Regulations," *Washington Administrative Code*.

WAC 173-307, 1995, "Plans," *Washington Administrative Code*.

WAC 173-400, 1995, "General Regulations for Air Pollution Sources," *Washington Administrative Code*.

WAC 173-401, 1995, "Operating Permit Regulation," *Washington Administrative Code*.

WAC 173-460, 1995, "Controls for New Sources of Toxic Air Pollutants," *Washington Administrative Code*.

WAC 173-480, 1995, "Ambient Air Quality Standards and Emission Limits for Radionuclides," *Washington Administrative Code*.

WAC 246, 1995, "Department of Health," *Washington Administrative Code*.

WAC 296-62, 1995, "Occupational Health Standards—Safety Standards for Carcinogens," *Washington Administrative Code*.

WHC-CM-7-5, 1995, *Environmental Compliance*, Westinghouse Hanford Company, Richland, Washington.

WHC-SP-1131, 1996, *Westinghouse Hanford Company Quality Assurance Program and Implementation Plan, Implementation of Title 10 Code of Federal Regulations Part 830.120,* Rev. 1, Westinghouse Hanford Company, Richland, Washington.

APPENDIX B

SUMMARY OF OCCURRENCES

APPENDIX B

SUMMARY OF OCCURRENCES

LIST OF TABLES

B.1. Summary of Relevant Operational Occurrences B.1
B.2. Tank Farm Events, Off-Normal and Critiques B.2
B.3. Occurrence Report Database B.6

Table B.1. Summary of Relevant Operational Occurrences

Description of Occurrence	Number of Occurrences
AW FARM MENTIONED	42
OCCURRENCES DURING TRANSFERS	
Misroute/Mistransfer/Inadvertant Transfer	38
Overfill Receiver Tank	9
Transfer Line/Valve/Connector Leak/Failure	42
Line Plugged	8
High Pressure in Receiver Tank	3
Inadequate Procedures/Failure to Follow Procedures	7
Inadequate/Failure to Adjust Prior to Transfer	8
Level Decrease	11
Potential Excessive Radiation Exposures	7
Other	3
EXCAVATION INCIDENTS	9
NON-TRANSFER	
Inadequate Procedures/Failure to Follow Procedures	5
Instrumentation and Control	3
Hardware Failure	9
Other	3
FAILURE OF SUPPORT SERVICES	
AC Power	27
Raw Water	3
Steam	1
Compressed Air	9
VEHICULAR ACCIDENTS	9

Table B.2. Tank Farm Events, Off-Normal and Critiques. (4 sheets)

Date	Event #	Event Type	Event Description
1-8-86	86-02	ON	Tank 101-AW pressurized after transfer, reason unknown
1-9-86	86-03	ON	Tank 101-AW slurry distributor plugged during transfer.
1-16-86	86-06	ON	Valve AX-B-15 leaked, allowing AY-102 to AW-102 transfer to enter AN-101.
2-6-86	86-11	ON	204-AR 702 leak detector switch mislabeled, improperly bypassed. Transfer stopped due to bypass signal.
2-25-86	86-17	ON	Primary exhauster shutdown, backup failed. Six AW tanks pressurized.
11-18-86	86-19	ON	241-AW annulus exhauster fan failed, loose blade caused hole in housing.
1-17-87	86-20	ON	Tank 106-AW pressurized during slurry transfer.
3-26-86	86-21	ON	Tank 105-AW pressurized during PUREX E-5 transfers. (4 times)
1-17-87	86-25	ON	241-AW primary & annulus exhauster failure. AW tanks pressurized.
1-21-87	86-27	ON	241-AW portable exhauster failed during primary exhauster maintenance. AW tanks pressurized.
6-30-86	86-29	ON	102-AW pressurized due to sump jet air DOV leak-through.
7-21-86	86-31	ON	Power shut off to 241-AN tank farm. Operations notified 30 days prior, but not at the time.
7-21-86	86-32	ON	271-AN air conditioner repair tripped building power off.
7-23-86	86-33	ON	241-AW portable exhauster fail, would not restart. AW tanks pressurized.
1-17-87	86-36	ON	102-AW tank pressurized during transfer, pressure instruments valved out.
9-17-86	86-38	ON	241-AW Raw water service pit strainer leaked 850 gallons due to improper size of hold down lid.
10-3-86	86-41	ON	AY & AZ farm steam diverter valve stuck during test, flow to 216-A-08 crib.
10-7-86	86-45	ON	AN farm air compressor failed causing loss of air to farm instruments.
11-29-86	86-54	ON	Electrical outage at 200-East farm, AN, AP, and AW tanks pressure alarms activated.
12-1-86	86-55	ON	Power supply tripped to AP farm, tripped vent systems. Tanks pressurized.
12-10-88	WHC-C-88-185-TF-10	Critique	Misrouted condensate from A-417 to 101-AZ tank, instead of 102-AY receiver tank.
12-19-90	WHC-TANKFARM-1990-346	ON	AW farm backup exhaust fan failed to start as required. High pressure in tank farm.
1-11-91	WHC-TANKFARM-1991-32	ON	241-AW primary exhaust fan restarted during testing, while personnel near by. "Near-miss" injury.
1-23-91	WHC-TANKFARM-1991-72	ON	Portable air compressor failure causes loss of inst. air at 244-AR vault.
6-22-91	WHC-TANKFARM-1991-1023	ON	Portable compressor seized, high pressure alarms tripped at 241-AW farm.
6-29-91	WHC-TANKFARM-1991-1026	ON	Power lost to 200-East Area during electrical storm.
8-6-91	WHC-TANKFARM-1991-1031	ON	Momentary power loss to 200-East and West Areas.

Table B.2. Tank Farm Events, Off-Normal and Critiques. (4 sheets)

Date	Event #	Event Type	Event Description
11-26-91	WHC-TANKFARM-1991-1067	ON	Front-end loader backed into and broke a thermocouple riser at T-108 tank.
11-28-91	WHC-TANKFARM-1991-1068	ON	AY-102 level increased during transfer from 244-CR-003 to AY-101.
12-31-91	WHC-TANKFARM-1991-1085	ON	Air compressor failure leads to 241-SX exhauster shutdown.
1-1-92	WHC-TANKFARM-1992-01	ON	Truck at 241-TX farm picked up tumbleweeds on carriage, tumbleweeds ignited.
1-24-92	WHC-TANKFARM-1992-09	ON	During a transfer line hydro test in 241-S farm, water leaked and drained into valve pit.
2-25-92	WHC-TANKFARM-1992-15	ON	SX farm exhauster shutdown due to portable compressor shutdown when it ran out of fuel.
2-28-92	WHC-TANKFARM-1992-20	ON	While fueling a portable compressor at 241-BY, fuel was spilled on the ground.
3-6-92	WHC-TANKFARM-1992-25	ON	Tank C-100 inadvertently transferred to 102-AW.
3-24-92	WHC-TANKFARM-1992-29	ON	Operator backed a van into a riser and punctured the gas tank. Spilled fuel onto the ground.
4-2-92	WHC-TANKFARM-1992-31	ON	Hazardous substance in railcar not pumped at 204-AR within time limits.
4-29-92	WHC-TANKFARM-1992-36	ON	Transformer failure interrupts 241-S farm leak detection and level monitoring instruments.
5-14-92	WHC-TANKFARM-1992-40	ON	Transfer line SL-116 in 241-S farm, failed hydro test, leak sprayed out heat trace conduit.
6-10-92	WHC-TANKFARM-1992-45	ON	Attempting to hydro test transfer line SL-115, 200 gallons more than the calculated line holdup was added. Assume line failed.
6-12-92	WHC-TANKFARM-1992-46	ON	Attempted to hydro test transfer line SN-215, line did not hold pressure for 30 seconds. Assume line failed.
7-15-92	WHC-TANKFARM-1992-54	ON	Transfer made through diversion box which drains to catch tank A-302-A which level above 50%. Exceeded level limit.
9-30-92	WHC-TANKFARM-1992-72	ON	During 106-AN to 102-AP transfer, 102-AW level increased. 3,575 gallon discrepancy in tank level.
10-21-92	WHC-TANKFARM-1992-83	ON	AW-101 pressurization and level decrease. Tank placed on flammable gas watchlist.
1-15-93	WHC-TANKFARM-1993-08	ON	Transfer from 204-AR to 101-AY failed due to frozen jumpers in path.
1-26-93	WHC-TANKFARM-1993-14	ON	Transfer from 204-AR railcar to 101-SY made. Some of flow ended up in 102-AY.
2-4-93	WHC-TANKFARM-1993-20	ON	242-A circuits deenergized for modifications, control valve opened allowing raw water flow to 106-AW tank.
4-21-93	WHC-TANKFARM-1993-40	ON	102-T core sample casks uncontrolled.
8-17-93	WHC-TANKFARM-1993-76	ON	Personnel backed van into riser in 241-S farm. Ruptured fuel tank under van.
1-8-94	WHC-TANKFARM-1994-01	ON	Transfer not aborted as required when leak detector tripped.
3-10-94	WHC-TANKFARM-1994-14	ON	Missed filter differential pressure readings in 241-AW and AP tank farms.
4-27-94	WHC-TANKFARM-1994-23	ON	Spurious shutdown signal at evaporator caused 2000 gallons of waste to dump back into 102-AW.
8-5-94	WHC-TANKFARM-1994-40	ON	Electrical utilities severed power cable, lost ventilation in AN, AP, AW, and C farms, and 244-BX and 244-CR.

Table B.2. Tank Farm Events, Off-Normal and Critiques. (4 sheets)

Date	Event #	Event Type	Event Description
8-8-94	WHC-TANKFARM-1994-42	ON	Truck driver drove under steam line near 103-SY tank, striking steam line and knocking off insulating material.
8-19-94	WHC-TANKFARM-1994-45	ON	Feeder breaker to 241-AN farm opened, tripping both primary and annulus ventilation fans. Pressurized waste tanks.
10-1-94	WHC-TANKFARM-1994-55	ON	241-AW primary ventilation shutdown, could not be restarted. Loss of confinement in farm.
10-4-94	WHC-TANKFARM-1994-57	ON	101-AW tank had gas release event. Tank pressure increased, hydrogen concentration increased, and level decreased. Tank is on hydrogen watchlist.
10-26-94	WHC-TANKFARM-1994-59	ON	Transfer line SL-503 failed during transfer from 204-AR to 102-AY. Tripped leak detector in sluice pit on tank 102-AY.
11-2-94	WHC-TANKFARM-1994-62	ON	During saltwell pumping of 109-BY a high radiation dose rate existed. Saltwell pump discharge also developed a leak.
12-8-94	WHC-TANKFARM-1994-67	ON	Main control power breaker tripped at 241-AN. Primary and annulus exhausters shutdown.
12-28-94	WHC-TANKFARM-1994-74	ON	106-AW exhaust isolation valve closed to watch position indicator. Pressurization alarm tripped.
2-17-95	WHC-TANKFARM-1995-15	ON	Electrical utilities personnel tripped off electrical power to East/West Areas while installing a microwave transfer trip.
5-3-95	WHC-TANKFARM-1995-44	ON	241-AW pressurization alarm occurred during camera installation in 106-AW central pump pit.
5-30-95	WHC-TANKFARM-1995-50	ON	Energized electrical wire struck during hand excavation near 102-AZ tank.
5-15-95	WHC-TANKFARM-1995-56	ON	241-AW lockout installed without proper signature authorization.
8-7-95	WHC-TANKFARM-1995-67	ON	Diesel generator at BX/BY farm fuel leaked into soil.
10-4-95	WHC-TANKFARM-1995-81	ON	Transfer line SN-274 leaked during transfer between AX-B valve pit and 101-AN. Leak at flexible jumper connection. 2 gallons leaked.
10-5-95	WHC-TANKFARM-1995-86	ON	Implemented new criticality specifications for transfer systems without changing the Interim Safety Basis.
10-19-95	WHC-TANKFARM-1995-91	ON	Incorrect transfer line filled for pressure test. SN-245 filled rather than SN-246.
11-2-95	WHC-TANKFARM-1995-97	ON	High pressure alarm at AW-106 tank. High vacuum alarm setpoint outside LCO limit.
11-21-94	WHC-TANKFARM-1995-109	ON	Pressure test of supernate transfer line SN-246 (yard line) failed, indicating loss of integrity.
12-11-95	WHC-TANKFARM-1995-114	ON	107-AN tank pressure instrument air line froze due to tripped breaker on heat trace line.
1-8-96	WHC-TANKFARM-1996-003	ON	Personnel skin contamination due to pumping leak detection pits in 241-AW farm without wearing any Personal Protective Equipment.
1-30-96	WHC-TANKFARM-1996-012	ON	Pressure transmitter for tank 106-AW failed which disabled the alarm capabilities.
2-21-96	WHC-TANKFARM-1996-019	ON	Railcar was scheduled to have 1000 to 1500 gallons pumped into it at T-Plant. It was found to have 15,000 to 18,000 gallons in it instead of the 1000 to 1500 gallons.
3-7-96	WHC-TANKFARM-1996-023	ON	Plugged instrument air line to 101-AY pressure instruments, caused failure of remote monitoring.

Table B.2. Tank Farm Events, Off-Normal and Critiques. (4 sheets)

Date	Event #	Event Type	Event Description
3-18-96	WHC-TANKFARM-1996-026	ON	Unauthorized low flying helicopters performing aerial radiological surveys over 241-A, AW, AX, AY, AZ, and C farms.

CAM - Continuous air monitor
DACS -
DCRT - double-containment receiver tank
HEPA - high-efficiency particular air
ICF KH - ICF Kaiser Hanford Company
LCO -
LEL -
LFL -
LOW -
NFPA - National Fire Prevention Association
ON - Off-normal
OOS - Out of service
WHC - Westinghouse Hanford Company

Table B.3. Occurrence Report Database. (7 sheets)

Occurrence Number	Discovery Date	Description of Event	Event Cause
72-26	04/20/1972	WASTE TRANSFER LINE THAT FLOWS TO 241-A-152 LEAKED INTO ENCASEMENT, THEN THRU COVER BLOCK JOINTS TO GROUND.	WASTE LINE FAILED, ENCASEMENT DRAINS PLUGGED.
72-54	08/11/1972	BROKE 6-INCH SANITARY WATER LINE WITH BACKHOE.	PERSONNEL ERROR, FAILURE TO NOTE WATER LINE USING DETAILED DRAWING.
72-67	10/29/1972	MISROUTED 3,700 GALLONS OF PAS TO TANK 101-AY INSTEAD OF 003-CR.	PERSONNEL ERROR/INCORRECT SETTING FOR TRANSFER ROUTE MADE AT 151-AX DIVERTER STATION.
72-72	11/20/1972	LEAK FROM TRANSFER LINE DURING FLUSHING CAUSED SPRAY UP THROUGH VALVE OPERATOR HOLES IN VALVE PIT COVER.	GASKET FAILURE IN VALVE PIT.
73-1	01/08/1973	LIVE 13.8 KV LINE DOWN NEAR 244 UR, LINE WAS FLASHING AND BURNING.	WIRE BROKE FROM APPARENT FATIGUE ON WIRE FROM COLD WEATHER AND VIBRATION.
73-45	07/05/1973	BACKHOE RAN OVER AND BROKE A FLANGE ON A BELOW GRADE RISER ON A TRANSFER LINE AT 241-T TANK FARM. WATERY LIQUID WAS SEEN SEEPING FROM THE GROUND.	PIPE FLANGES ON TRANSFER LINES AT T-FARM WERE NOT ADEQUATELY MARKED.
73-78	11/14/1973	DURING TRANSFER FROM 107-S TO 102-S THE TRANSFER LINE PLUGGED AND WASTE BACKED UP AND FLOWED OUT THE TANK RISER ONTO THE GROUND.	APPARENT PLUGGING OF TRANSFER LINE BY CRYSTALLIZED MATERIAL.
74-32	04/18/1974	INSTRUMENT POWER OUTAGE IN 241-S TANK FARM CAUSED BY PERSONNEL AUGURING A TEST HOLE TO FIND A PIPING LEAK.	PERSONNEL FAILURE. EMPLOYEE FAILED TO HAND DIG PRIOR TO USING THE AUGER. CABLES WERE NOT IN THE LOCATION INDICATED ON THE TANK FARM DRAWING.
74-37	05/03/1974	DURING A TRANSFER THE LEVEL IN 102-BY DROPPED 10 INCHES, INCREASED 10 3/4 INCHES IN TANK 111-BX. LEVEL IN 111-BX EVENTUALLY DROPPED 3/4 INCH (CONSIDERED SIGNIFICANT LEVEL DECREASE).	LEVEL DECREASE BELIEVED TO BE CAUSED BY STABILIZATION OF THE CRUST SURFACE AFTER TRANSFER.
74-43	05/27/1974	3800 GALLONS OF PUREX ACIDIFIED SLUDGE MISTRANSFERRED FROM 244-AR VAULT TO 106-A TANK INSTEAD OF TO CR VAULT.	PERSONNEL FAILURE. DIVERTER SETTINGS INCORRECT.
74-44	05/27/1974	150 GALLONS OF NITRIC ACID ADDED TO TANK 002 AT 244-AR VAULT INSTEAD OF TANK 001. ADDED TO 10,500 GALLONS OF SLUDGE SLURRY.	PERSONNEL ERROR. OPENED WRONG VALVE OUT OF CHEMICAL MAKEUP TANK.
74-144	11/05/1974	CONTAMINATION SPREAD FROM OPEN PUMP PIT ON TANK 106-A DURING REMOVAL OF A FAILED JUMPER. THE JUMPER WAS DROPPED AND CONTAMINATION SPLASHED UP OVER THE PIT WALL.	PROCEDURE, NOT SUFFICIENT CONTAINMENT PROVIDED WHILE PUMP PIT OPEN.
74-154	12/11/1974	MISROUTING OF WASTE DURING TRANSFER FILLED 241-EW VENT STATION CATCH TANK FROM 18.75 INCHES TO 73.75 INCHES.	PERSONNEL ERROR. TFO PLANNER-SCHEDULER ERRED IN NOZZLE CONNECTION PROCEDURE INSTRUCTIONS.
74-159	12/30/1974	UNDERGROUND ELECTRICAL CABLE POWERING 244-AR VAULT COOLING WATER EFFLUENT DIVERSION VALVE BROKEN BY BACKHOE EXCAVATION.	PERSONNEL ERROR. BACKHOE OPERATOR CLEARED TRENCH WITHOUT HAND DIGGING TAKING PLACE.
75-03	01/06/1975	244-AR VAULT HAD AN ACTIVATION OF EMERGENCY VENTILATION SYSTEM, AND VESSEL VENT SYSTEM SHUTDOWN.	MECHANICAL FAILURE, OVERHEATED CIRCUIT BREAKER IN ELECTRICAL SUPPLY TO AIR COMPRESSOR.
75-15	02/13/1975	SPILL OF CONTAMINATION TO GROUND DURING OVERGROUND TRANSFER FROM TANK 105-BY.	PERSONNEL ERROR, MATERIAL FAILURE. PLASTIC WRAPPED JOINTS ON OVERGROUND LINE DID NOT HOLD THE LEAK.
75-36	04/06/1975	OVERFILLED TANK 002-CR IN 271-CR, TANK LIMIT IS 13,000 GALLONS, FILLED WITH 16,947 GALLONS.	PERSONNEL ERROR. OPERATOR PUSHED PUMP BUTTON INSTEAD OF AGITATOR BUTTON.
75-42	04/09/1975	TRANSFER OF WASTE WITH pH OF 4.2 FROM 244-AR TO TANK 107-U. pH LIMIT SHOULD BE GREATER THAN 9.	ASSUMED PERSONNEL ERROR.
75-78	07/16/1975	JUMPER CONNECTOR FAILURE DURING WASTE TRANSFER FROM 107-TX TO 103-U. JUMPER LOCATED IN 153-TXR DIVERSION BOX.	MECHANICAL FAILURE OF FLEX JUMPER, THREADS STRIPPED.

Table B.3. Occurrence Report Database. (7 sheets)

Occurrence Number	Discovery Date	Description of Event	Event Cause
75-82	07/29/1975	VEHICLE ACCIDENT IN 241-U TANK FARM, STRUCK AN 8-INCH WELL CASING THAT PROTRUDED UP 18-INCHES. PICKUP TRUCK HAD TO BE LIFTED OFF THE CASING.	PERSONNEL ERROR. CUT A TURN SHORT, NON-ESSENTIAL TANK FARM TRAFFIC NEEDS TO BE ELIMINATED.
75-97	08/22/1975	UNPLANNED WASTE TRANSFER FROM 102-A TANK TO 101-A TANK.	PERSONNEL ERROR. INADVERTENT ENERGIZING OF 102-A PUMP INSTEAD OF 101-A PUMP.
75-110	10/02/1975	RADIATION ALARM IN 101-AY "B" LEAK DETECTION PIT AFTER TRANSFER FROM 152-AX DIVERTER STATION CATCH TANK.	UNKNOWN, TRANSFER PIPELINE MAY HAVE LEAKED.
75-111	10/03/1975	2200 GALLON WASTE TRANSFER THROUGH OPEN JUMPER NOZZLE FLOWED VIA PUMP PIT DRAIN INTO INCORRECT TARGET TANK.	PERSONNEL ERROR. JUMPER NOT INSTALLED FOR TRANSFER, ROUTE NOT CHECKED.
75-115	10/11/1975	SMALL, SLOW, LEAK OCCURRED IN OVERGROUND TRANSFER LINE BETWEEN 108-C AND 103-C.	MECHANICAL FAILURE. LEAK AT CONNECTOR HEAD TO TRANSFER PUMP.
75-127	11/09/1975	MISROUTING OF TRANSFER INTO TANK 102-AY INSTEAD OF 103-A.	PERSONNEL ERROR. USED WRONG PROCEDURE FOR SECOND PHASE OF TRANSFER.
75-134	11/21/1975	MISROUTED WASTE TRANSFER FROM 104-SX TO 101-SX PIT.	PERSONNEL ERROR. OPERATOR CHANGED VALVE SETTINGS WHILE WALKING THROUGH A PROCEDURE.
75-141	12/02/1975	SIGNIFICANT MATERIAL BALANCE DISCREPANCY AFTER TRANSFER FROM TANK 102-C TO 103-C.	UNKNOWN, SUSPECT LEVEL GAUGE ANOMALIES A RESULT OF THE CHARACTER OF THE MATERIAL SURFACE IN TANK 102-C.
75-145	12/19/1975	POSSIBLE TRANSFER PIPING LEAKAGE DURING TRANSFER FROM TANK 103-B TO 110-SX.	UNKNOWN, MATERIAL BALANCE PROBLEM WAS NOT RESOLVED.
76-04	01/09/1976	SIGNIFICANT RADIATION READINGS IN AN EXCAVATION SITE WHERE PERSONNEL WERE WORKING DUE TO A WASTE TRANSFER NEARBY.	PERSONNEL ERROR. RISK TO PERSONNEL FROM WASTE TRANSFER NOT ADEQUATELY CONSIDERED.
76-15	01/27/1976	CROSS-COUNTRY TRANSFER LINE PLUGGED DURING TRANSFER FROM 107-S TO 109-B AFTER PUMP SHUTDOWN DUE TO POWER LOSS.	PLUG DUE TO CUTTING DILUTION WATER DURING TRANSFER.
76-24	02/23/1976	STEAM USED INSTEAD OF AIR AFTER TRANSFER LINE FLUSH.	PERSONNEL ERROR. FAILURE TO FOLLOW PROCEDURE.
76-48	04/12/1976	DURING JUMPER INSTALLATION IN 241-A TANK FARM, RADIATION MONITOR RECOMMENDED WORK HALT DUE TO WIND, OPERATIONS SUPERVISOR DIRECTED THAT ONE MORE CONNECTOR HEAD BE INSTALLED TO FINISH THE JOB.	PERSONNEL, POLICY CONFLICT OF ASSIGNED AUTHORITY.
76-55	04/08/1976	TRANSFER TO 244-AR MADE OF MATERIAL WITH HIGH H+ CONCENTRATION.	PERSONNEL ERROR. MISINTERPRETATION OF SPECIFICATION, FAILURE TO FOLLOW PROCEDURE.
76-61	04/25/1976	SPILLED 500 GALLONS OF WATER WHEN OVERGROUND LINE FROM 104-TX TO 108-TX PUMP PIT CONNECTION FAILED.	MECHANICAL. HOSE CONNECTION FAILED.
76-64	04/29/1976	CONTAMINATION RELEASE WHEN A PILOT HOLE WAS DRILLED IN A FLUSHED OUT TRANSFER PIPE, BEING READIED FOR REROUTING.	TRAPPED AIR IN THE HEAT TRACED LINE PUSHED OUT LIQUID WHEN THE HOLE WAS DRILLED IN THE PIPE.
76-118	08/31/1976	CROSS-COUNTRY TRANSFER LINE V361 ENCASEMENT SWAB RISERS HAD ACTIVITY INCREASE.	POSSIBLE MIGRATION OF PREVIOUS CONTAMINATION.
76-131	09/27/1976	RADIOACTIVE WASTE SPILL DURING JUMPER DISCONNECTION IN 105-U PUMP PIT.	MECHANICAL FAILURE. WASTE TRANSFER ONGOING IN ADJACENT TANK PRESSURIZED JUMPER DUE TO PARTIAL FAILURE OF A CLOSED VALVE.
76-136	10/05/1976	RADIOACTIVE LIQUID SPRAYED FROM A CHECK VALVE UNDER REPAIR ONTO THREE PERSONNEL IN BX TANK FARM.	PERSONNEL ERROR. PREPARATIONS FOR THE REPAIR WERE INADEQUATE.
76-139	10/07/1976	INCREASED ACTIVITY IN CROSS-COUNTRY TRANSFER LINE V361 SWAB RISERS.	ASSUME CONTAMINATION IS FROM PREVIOUS LEAKS.
76-143	10/04/1976	APPARENT LEAK DETECTION PIT LEVEL INCREASES FOR TANK 102-AZ.	INSTRUMENT AIR VALVED OFF SOME INSTRUMENTS AND FAULTY TRANSMITTER. TANK NOT IN SERVICE AT TIME OF ANOMALIES.

Table B.3. Occurrence Report Database. (7 sheets)

Occurrence Number	Discovery Date	Description of Event	Event Cause
77-22	02/03/1977	TRANSFER PIPELINE EXPOSED AND STRUCK DURING EXCAVATION NEAR 244-AR VAULT.	PERSONNEL ERROR. PIPELINE LOCATION NOT NOTED ON EXCAVATION PERMIT.
77-31	02/28/1977	004-AR WEIGHT FACTOR REFERENCE LINE PLUGGED DURING TRANSFER, CAUSING OVERFILLING OF TANK AND AUTOMATIC SHUTDOWN OF VESSEL VENT SYSTEM.	MATERIAL. PLUGGED WEIGHT FACTOR REFERENCE LINE.
77-64	04/30/1977	MISROUTED WASTE TRANSFER INTO TANKS 101-SY, 103-SY, AND 103-SY LEAK DETECTION PIT, DURING TRANSFER FROM 111-U TO 102-SY.	PERSONNEL ERROR. TRANSFER MISROUTED.
77-68	05/10/1977	OVERFILLED TANK 103-S DURING TRANSFER FROM 242-S EVAPORATOR AND DIVERSION OF STEAM CONDENSATE.	PERSONNEL ERROR. STEAM CONDENSATE WAS INADVERTENTLY VALVE TO WASTE TANK INSTEAD OF CRIB.
77-71	05/13/1977	LIQUID LEVEL IN TANK 102-SX DECREASED 2.95 INCHES AFTER TRANSFER FROM 103-S.	ASSUME MIXING SALT CAKE AND DILUTE WASTE IN TRANSFER CAUSED LEVEL DECREASE. NO CAUSE WAS CERTAIN.
77-93	06/11/1977	LIQUID LEVEL IN TANK 103-BX DECREASED .6 INCHES.	ASSUME REDISTRIBUTION OF SLUDGE FOLLOWING TRANSFER OF 46 INCHES.
77-103	12/07/1977	MANY INSTANCES OF RADIATION ACTIVITY IN TANK 103-TX DRY WELLS.	ASSUME MANY CAUSES OF INCREASED ACTIVITY: TANK LEAK, TANK OVERFILL, TRANSFER LINE LEAKAGE, MIGRATION OF SOIL CONTAMINATION, OR CONTAMINATION CARRIED BY MATERIAL CHANNELING.
77-105	06/29/1977	TANK 111-U OVERFILLED DURING A TRANSFER FROM 107-TX AND 102-U.	PERSONNEL ERROR. FAILURE TO NOTE LEVEL LIMIT, AND FAILURE TO RESPOND TO HIGH LEVEL ALARM.
77-132	08/03/1977	OPERATION OF 002-BXR PUMP IN STRONG ACID SOLUTION.	PERSONNEL ERROR. ACID WAS TO HAVE BEEN NEUTRALIZED BEFORE PLACING PUMP IN SOLUTION.
77-137	08/08/1977	2200 GALLONS MISROUTED TO TANK 109-TX DURING 102-TY TO 105-TX TRANSFER.	VALVE IN 109-TX PIT COULD NOT BE COMPLETELY CLOSED DUE TO INTERFERENCE FROM JUMPER.
77-147	08/24/1977	LIQUID LEVEL IN TANK 101-S DECREASED .7 INCHES.	LEVEL CHANGE IS APPARENT TRANSIENT PHENOMENA ASSOCIATED WITH 242-S EVAPORATOR TRANSFER.
77-155	09/08/1977	EXCEEDED MAXIMUM LEVEL LIMIT IN 002-TXR TANK BY 4.25 INCHES.	PERSONNEL ERROR. TANK OVERFILLED WHEN FLUSHING LINE FROM 155-TX DIVERSION BOX TO 002-TXR TANK.
77-158	09/12/1977	EXCEEDED MAXIMUM LEVEL LIMIT IN 002-TXR SUMP.	FLUSH OF LINE BETWEEN TANKS 103-TX AND 102-SY OCCURRED, THE LINE BROKE IN 151-TXR DIVERSION BOX WHICH OVERFILLED THE SUMP.
77-160	09/14/1977	LIQUID LEVEL IN TANK 114-TX EXCEEDED MAXIMUM OPERATING LIMIT.	APPARENT CAUSE OF LEVEL INCREASE IS DUE TO WATER ENTERING THE TANK FROM PRESSURE TESTING A LINE INTO THE TANK.
77-163	09/19/1977	LIQUID LEVEL IN TANK 102-BY INCREASED 1.25 INCHES.	APPARENT CAUSE OF LEVEL INCREASE IS REDISTRIBUTION OF LIQUID AFTER A SALT WELL TRANSFER.
77-169	09/23/1977	LIQUID LEVEL IN TANK 115-TX DECREASED 2.25 INCHES.	ASSUME LEVEL CHANGE IS DUE TO SETTLING OF SLUDGE FOLLOWING SALT WELL PUMPING.
77-171	09/29/1977	PUREX SUMP WASTE JETTED TO TANK 104-C INSTEAD OF TANK 102-A.	PERSONNEL AND PROCEDURE ERRORS. PROCEDURE CHANGES HAD NOT BEEN COMPLETED.
77-177	10/10/1977	LIQUID LEVEL IN TANK 202-B DECREASED 1 INCH.	ASSUME LEVEL DECREASE DUE TO SLUDGE SETTLING FOLLOWING PUMPING OF THE TANK.
77-193	11/05/1977	LIQUID LEVEL IN TANK 105-U DECREASED .55 INCHES.	ASSUME DECREASE DUE TO SETTLING OF TANK MATERIAL FOLLOWING TRANSFER.
77-205	12/06/1977	SPRAY LEAK FROM 111-S PUMP PIT DURING LEAK CHECK OF SALT WELL PUMP AND JUMPER.	PROCEDURE ERROR AND MECHANICAL FAILURE. LEAK CHECK SHOULD BE DONE WITH COVER BLOCKS INSTALLED, AND FAILED GASKET AT PUMP INLET FLANGE.
77-210	12/20/1977	LIQUID LEVEL IN TANK 203-T DECREASED 2.5 INCHES.	ASSUME LEVEL DECREASE IS DUE TO SETTLING OF THE SLUDGE FOLLOWING SALT WELL PUMPING.

Table B.3. Occurrence Report Database. (7 sheets)

Occurrence Number	Discovery Date	Description of Event	Event Cause
78-2	01/02/1978	WASTE MISROUTED FROM 004-AR TO TANK 102-A RATHER THAN TANK 106-A.	PERSONNEL AND PROCEDURE ERRORS. SUPERVISOR SIGNED INCOMPLETE DATA SHEET WITHOUT PROPER REVIEW, AND PROCEDURE LACKS ADEQUATE CHECKS AND APPROVALS.
78-6	01/10/1978	BACKFLOW OF CONTAMINATION INTO RAW WATER SYSTEM IN 241-TX TANK FARM.	PERSONNEL ERROR/PROCEDURE. CHECK VALVE ON FLUSH PIPING INSTALLED IN THE INVERTED POSITION, MANUAL FLUSH VALVE LEFT PARTIALLY OPEN.
78-13	01/23/1978	UNDETECTED FILLING OF A-40 RETENTION BASIN AT 244-AR VAULT WITH 200,000 GALLONS.	MECHANICAL FAILURES. RADIATION ALARM FAILED CAUSING DIVERTER VALVE TO DIVERT. VALVE STEM WAS BINDING AND THE VALVE DID NOT CLOSE COMPLETELY, INDICATING LIGHT SHOWED VALVE CLOSED.
78-14	01/20/1978	CONTAMINATED LIQUID SPRAYED FROM HOLE DRILLED IN TOP OF TRANSFER LINE V453 WHEN PREPARING TO CUT LINE.	PROCEDURE ERROR. NO CONTAINMENT USED WHEN DRILLING INTO LINE. (SIMILAR TO 76-64)
78-24	02/23/1978	UNDERGROUND RAW WATER LINE BREAK RELEASED 60,000 GALLONS IN 241-A TANK FARM AND CAUSED CAVE-IN BETWEEN 102-A AND 105-A. HOLE READ 1R/HR DUE TO WATER FLOW THROUGH A BURIED UNUSED DE-ENTRAINER.	MECHANICAL FAILURE. RAW WATER LINE M5a RUPTURE.
78-44	04/25/1978	RAW WATER LINE LEAK OF 5000 GALLONS BETWEEN 241-S AND 241-SX TANK FARMS.	MECHANICAL FAILURE OF A BELL AND SPIGOT JOINT IN THE RAW WATER LINE.
78-64	06/21/1978	ROAD GRADER STRUCK TRANSFER LINES HSW-202-M8 AND HSW-203-M8, LINE 202 ENCASEMENT WAS BENT AND PARTIALLY CRUSHED.	PERSONNEL ERROR. RESPONSIBLE PARTY WAS NOT FOLLOWING THE ROAD GRADING WORK, TRANSFER LINES WERE WELL MARKED AND BERMED.
78-76	07/26/1978	MINOR LEAK IN 4-INCH RAW WATER LINE NEAR 241-TX TANK FARM.	MECHANICAL FAILURE OF A BELL AND SPIGOT JOINT IN LINE.
78-78	07/25/1978	RADIOGRAPHY CREW LEFT THE JOB SITE IN 241-TX FARM DUE TO AN UNDERGROUND TRANSFER IN PROGRESS.	PERSONNEL ERROR. PROBLEMS IN SCHEDULING AND MANAGING PERSONNEL.
78-80	07/27/1978	PROCESS TRANSFER LINE EXPOSED DURING HAND EXCAVATION, OVER-EXPOSURE OF PERSONNEL.	PROCEDURE ERROR. PERSONNEL NOT MADE AWARE OF THE PRESENCE OF THE UNDERGROUND LINE.
78-83	08/10/1978	MISTRANSFER OF WASTE FROM TANK 101-A TO TANK 104-BX INSTEAD OF 102-A.	PERSONNEL ERROR. VALVING CHANGED IN AA VALVE PIT INSTEAD OF AB VALVE PIT DURING TRANSFER.
78-88	08/22/1978	TRANSFER LINE BETWEEN TANK 107-S AND 105-BX PLUGGED DURING TRANSFER.	PLUGGAGE APPEARS TO BE CAUSED BY SOLIDS SETTLED IN LINE WHEN POWER WAS LOST TO 107-S TRANSFER PUMP.
78-90	08/26/1978	FRACTURED 6" SANITARY WATER LINE AND 8" RAW WATER LINE NEAR 275-EA BUILDING. AFFECTED WATER SUPPLY TO 244-AR FACILITY.	APPARENT CAUSE OF BROKEN PIPES WAS FROM HEAVY WEIGHT OF A CRANE UNLOADING PLATES FROM A RAILROAD CAR FOR USE AT 241-AW TANK FARM.
78-117	10/30/1978	UNDETECTED FAILURE OF LEAK DETECTORS IN 241-SA AND 241-SB VALVE PITS DURING CROSS-COUNTRY TRANSFER.	MECHANICAL PROBLEM. COMMON DRAIN FOR BOTH VALVE PITS BLOCKED.
79-25	02/12/1979	IMPROPER VALVE LINE-UP DURING WASTE TRANSFER OR SUBSEQUENT FLUSHING CONTAMINATED RAW WATER HOSE BIB IN 241-S FLUSH PIT.	PERSONNEL ERROR. IMPROPER VALVING IN FLUSH PIT OR VALVE PIT.
79-26	02/17/1979	MISROUTING OF TRANSFER FROM TANK 102-S TO TANK 103-SX INSTEAD OF TANK 106-SX.	PERSONNEL ERROR. IMPROPER VALVING IN 241-SX-A VALVE PIT.
79-61	05/25/1979	SLURRY LINE SL-113 LEAKED IN 241-S FARM WHEN BEING READIED FOR A PRESSURE TEST.	MECHANICAL FAILURE OF 2-INCH CARBON STEEL LINE.
79-65	06/06/1979	WASTE TANK SURVEILLANCE SIGNALS LOST WHEN LINES CUT BY BACKHOE NEAR 241-B AND BX TANK FARMS.	PERSONNEL ERROR. PROCEDURE INDICATED HAND DIGGING IN THIS AREA INSTEAD OF BACKHOE USE.
79-80	08/17/1979	MISROUTING OF 13,000 GALLONS OF CROSS-COUNTRY LINE LEAK CHECK WATER TO TANK 103-S.	PERSONNEL ERROR. FAILURE TO REALIGN VALVE IN 241-SA VALVE PIT.
79-100	10/10/1979	LIQUID LEVEL IN TANK 102-S EXCEEDED LIMIT.	PERSONNEL ERROR. FAILURE TO MAINTAIN CONTROL WHILE 242-S EVAPORATOR STEAM TURBINE PRESSURE REGULATING VALVE WAS CYCLED.

Table B.3. Occurrence Report Database. (7 sheets)

Occurrence Number	Discovery Date	Description of Event	Event Cause
79-104	10/21/1979	WASTE TRANSFER FROM TANK 106-SX TO 101-SX MISROUTED TO TANK 102-S.	PERSONNEL ERROR. VALVE ALIGNMENT IN 241-SA VALVE PIT FOR OTHER TRANSFER REROUTED THIS TRANSFER.
79-113	10/10/1979	INADVERTENT FLOW ROUTING TO INACTIVE CRIB 216-A-24.	PERSONNEL ERROR. TWO SETS OF ROUTING VALVES WERE MISALIGNED.
80-8	01/18/1980	MISROUTED 2000 GALLONS INTO TANK 102-AY FROM TANK 103-A INSTEAD OF INTO TANK 101-AY.	PERSONNEL ERROR. MISVALVING THE SLURRY DISTRIBUTOR VALVE IN TANK 102-AY 02A VALVE PIT.
80-9	01/16/1980	CROSS-COUNTRY TRANSFER LINE FROM TANK 107-S TO 105-BX PLUGGED DURING TRANSFER OF TERMINAL LIQUOR SOLUTION.	PLUG DUE TO INADEQUATE DILUTION OF WASTE, DILUTION WATER METER FAILED.
80-25	02/20/1980	UNUSUAL LIQUID LEVEL DECREASE IN TANK 103-SX FOLLOWING TRANSFER IN.	LEVEL DECREASE CAUSED BY MIXING LARGE AMOUNT OF LOW DENSITY LIQUID INTO TANK OF SOLIDS.
80-26	02/21/1980	LINE LEAK IN SLURRY LINE SL 126 BETWEEN 241-SD VALVE PIT AND TANK 107-S CROSS-SITE PUMP PIT.	ASSUME LINE LEAKS DUE TO UNANTICIPATED CORROSION.
80-50	05/16/1980	PARTIAL MISTRANSFER OF 4125 GALLONS INTO TANK 101-AY FROM TANK 103-A. TRANSFER WAS TO GO TO TANK 102-AY.	MECHANICAL FAILURE. 3-WAY SDV VALVE IN 241-AY-02A VALVE PIT SPLIT FLOW BETWEEN TWO TANKS. BALL VALVE ORIENTATION WITHIN VALVE BODY DID NOT CORRESPOND TO PAINTED FLOW DIAGRAM ON PROCESS PIT COVER BLOCK
80-51	05/31/1980	4120 GALLONS MISROUTED TO TANKS 101-AY AND 102-AY FROM 244-A CATCH TANK. INTENDED RECEIVER TANK WAS 102-A.	PERSONNEL ERROR. INSTALLED JUMPER WAS MISALIGNED IN 241-A-02C PIT.
80-73	07/10/1980	MISROUTED 2200 GALLONS TO TANK 103-TX FROM 118-TX, INTENDED RECEIVER TANK WAS 106-SX.	PERSONNEL ERROR. FAILURE TO CLOSE VALVE IN 241-152-TXR DIVERSION BOX.
80-81	08/26/1980	SPRAY LEAK IN 241-AW-05A CENTRAL PUMP PIT DURING SLURRY TRANSFER TO TANK 105-AW.	PERSONNEL AND DESIGN ERROR. WORKER UNABLE TO TIGHTEN CONNECTION BETWEEN JUMPER AND DISTRIBUTOR SUFFICIENTLY.
80-82	09/04/1980	LIQUID LEVEL IN TANK 103-A DECREASED 3.3 INCHES.	ASSUME LEVEL DECREASE IS DUE TO MIXING OF DISSIMILAR SOLIDS WITHIN THE TANK.
80-84	09/08/1980	WORKER EXCEEDED WEEKLY EXPOSURE WHILE WORKING IN A TRENCH IN 241-SY FARM DURING WASTE TRANSFER.	PROCEDURE ERROR. TRANSFER NOT COMMUNICATED TO CONSTRUCTION WORKERS.
80-87	10/02/1980	5775 GALLONS MISTRANSFERRED INTO TANK 103-AX FROM TANK 101-AX. INTENDED RECEIVER TANK WAS 103-AW.	PERSONNEL ERROR. VALVE MISPOSITIONED IN AX-A VALVE PIT.
80-88	10/17/1980	9625 GALLONS MISTRANSFERRED TO TANK 102-AY FROM 101-A. INTENDED RECEIVER TANK WAS 102-A.	PERSONNEL ERROR. CORRECT TRANSFER ROUTE NOT SET UP.
80-90	11/11/1980	SLURRY LINE SL 176 LEAKED DURING TRANSFER FROM 242-S EVAPORATOR TO TANK 103-SY.	MECHANICAL FAILURE. ASSUME CORROSION OF CARBON STEEL TRANSFER LINE.
81-24	03/02/1981	20-40 GALLONS/DAY LEAK IN 4" RAW WATER LINE FEEDING 244-UR PROCESS VAULT.	MECHANICAL FAILURE. RAW WATER LINE DEVELOPED LEAKS AND CLOSED DISCHARGE LINE VALVES LEAKED THROUGH.
81-48	07/10/1981	FIC BOX NEAR 118-TX VALVE PIT DAMAGED BY CRANE BACKING UP.	APPARENT ACCIDENT CAUSED BY ERROR IN JUDGMENT BY FLAGMAN, CONGESTION IN TANK FARM, AND EXTREMELY ROUGH TERRAIN.
81-52	08/17/1981	WASTE TRANSFER FROM 101-AY TO 104-AW MISROUTED TO 102-AY.	MECHANICAL FAILURE. MISROUTING CAUSED BY FAILURE OF 3-WAY DISCHARGE VALVE IN TK-AY-102-02D TO BE POSITIONED AGAINST MECHANICAL STOP.
81-55	09/03/1981	CONTAMINATION RELEASE IN 204-S UNLOADING STATION WHILE HOOKING UP RAILROAD CAR FOR UNLOADING.	MECHANICAL FAILURE. FAULTY SPRAY RING VALVE ON TOP OF CAR.
81-61	09/08/1981	RADIOACTIVE FLUSH WATER PUMPED TO TANK 102-SY THROUGH TRANSFER LINE THAT GOES THROUGH S-FARM WHERE WORKERS WERE EXCAVATING.	PERSONNEL ERROR. COMMUNICATION FAILURE, AND FAILURE TO FOLLOW LOCK AND TAG PROCEDURE.
82-02	01/05/1982	FAILURE OF PROCESS LINE V-402 DURING TX-FARM SALT WELL PUMPING.	MECHANICAL FAILURE. LINE FAILURE CONFIRMED BY PRESSURE TEST.

Table B.3. Occurrence Report Database. (7 sheets)

Occurrence Number	Discovery Date	Description of Event	Event Cause
82-12	03/24/1982	LOSS OF EMERGENCY POWER TO 204-AR UNLOADING STATION AND 242-A EVAPORATOR.	MECHANICAL FAILURE. APPARENT LOSS OF BACK-UP POWER DUE TO DIRT IN RELAY CONTACTS, FAILURE OF MANUAL/AUTOMATIC SWITCH, AND FAILURE IN AUTOMATIC START CONTROL CIRCUIT MODULE.
82-21	05/15/1982	FAILURE OF PROCESS LINE BETWEEN 241-TX-155 AND 241-U-151, V-398.	MECHANICAL FAILURE OF INNER PROCESS LINE.
83-1	01/22/1983	FAILURE OF PUREX 36" CHEMICAL SEWER LINE DISCOVERED BY CRANE TIRE CAUSING CAVE-IN IN 241-AP TANK FARM.	MECHANICAL FAILURE. BELLS OF VITRIFIED CLAY PIPE WERE BROKEN AND LEAKING.
83-07	04/11/1983	WASTE TRANSFER INTO AY TANK WITHOUT VENTILATION ON RECEIVER TANK. NORMAL VENTILATION SYSTEM WAS OUT-OF-SERVICE, PORTABLE EXHAUSTER STARTED, BUT OPERATOR FAILED TO OPEN THE EXHAUSTER INLET VALVE.	PERSONNEL ERROR, FAILURE TO FOLLOW PROCEDURE. OPERATOR OPENED VALVE ONE QUARTER TURN INSTEAD OF 15 1/2 TURNS.
83-31	11/16/1983	TANKS 102,101,104 AND 106-AW PRESSURIZED WHEN HOT WATER (123oF) DUMPED INTO TANK 102-AW FROM 242-A EVAPORATOR.	RAPID EXPANSION OF TANK VAPORS OVERWHELMED THE EXHAUST AIR FLOW.
83-33	11/06/1983	MULTIPLE PRESSURIZATIONS OF TANK 103-AW WHEN RECEIVING PUREX E-5 WASTE.	PRESSURIZATION DUE TO VAPORIZATION OF THE THERMALLY HOT WASTE AS IT IS DUMPED INTO A COOLER TANK.
84-19	03/21/1984	FIRE IN FUEL DELIVERY TRUCK IN 200-WEST AREA.	PINHOLE LEAK IN POWER STEERING LINE CAUSED FLUID TO SPRAY ONTO THE MANIFOLD OF THE TRUCK. FLUID FLASHPOINT IS 375oF, MANIFOLD TEMPERATURE WAS 800-900oF.
84-21	03/28/1984	2800 GALLONS OF PUREX WASTE ROUTED TO TANK 102-AZ INSTEAD OF TANK 101-AZ.	PERSONNEL ERROR. DIVERTER VALVE IN 152-AX DIVERTER STATION NOT RETURNED TO NORMAL POSITION AFTER TRANSFER TO NEARBY WASTE TANK.
84-71	11/19/1984	TRANSFER LINE BETWEEN B-PLANT AND 244-A LIFT STATION (SN-233) LEAKED TO ENCASEMENT.	MECHANICAL FAILURE OF TRANSFER LINE.
85-34	04/12/1985	UNNEUTRALIZED TANK F-18 (PUREX) TRANSFER RESULTED IN PIPE DAMAGE IN LINE BETWEEN 241-AW-A VALVE PIT AND 241-101-AW DISTRIBUTOR.	PERSONNEL ERROR.FAILURE TO NEUTRALIZE BATCH PRIOR TO TRANSFER.
85-48	05/23/1985	TRANSFER BETWEEN PUREX AND 101-AZ TANK RESULTED IN EXPOSURE TO PERSONNEL IN EXCAVATION NEAR 241-AY FARM.	PERSONNEL ERROR. FAILURE TO COMMUNICATE A DELAY IN TRANSFER TIME TO PERSONNEL IN EXCAVATION.
87-05	03/30/1987	I-129 EMISSIONS FROM 241-AW FARM PRIMARY EXHAUSTER EXCEEDED OPERATIONS ADMINISTRATIVE CONTROL VALUE	OPERATIONAL. PUREX FLUSHED A SILVER REACTOR TO THE AW FARM IN JUNE, 1986. I-129 LEVELS WENT UP TO 4 TIMES THE LIMIT. LEVELS STARTED DECREASING IN JULY, BACK TO NORMAL IN DECEMBER.
WHC-UO-89-030-SAH P-01	05/24/1989	RAILROAD WASTE TANK CAR SHIPPED FROM 340 FACILITY IN 300-AREA TO 204-AR FACILITY WITH SMEARABLE CONTAMINATION IN EXCESS OF LIMITS.	PERSONNEL ERROR. FAILURE TO COMMUNICATE THE REQUIREMENTS OF DEPT. OF TRANSPORTATION IN SAFETY ANALYSIS REPORT FOR PACKAGING (SARP) AND THE HEALTH PHYSICS PROCEDURE.
WHC-UO-89-059-TF-08	11/28/1989	AUTOMATIC TRANSFER OF ELECTRIC POWER FAILED TO TRANSFER TO DIESEL GENERATED POWER ON LOSS OF NORMAL POWER TO 242-A EVAPORATOR.	MECHANICAL. MALFUNCTION OF AUTOMATIC EMERGENCY TRANSFER SWITCH.
RL-WHC-TANKFARM-1990-0145	10/14/1990	LOSS OF POWER TO A SECTION OF HANFORD 230 KV LINE. LINE FAULT CAUSED POWER LOSS AT 100-B, 100-KE, 100-KW, AND 100-N.	MECHANICAL. CONTAMINATED INSULATOR CAUSED POWER POLE FIRE.
RL-WHC-TANKFARM-1990-0319	12/12/1990	INADVERTENT SHUTDOWN OF 241-SY PRIMARY EXHAUSTER, OPERATOR OPENED INCORRECT CIRCUIT BREAKER.	PERSONNEL ERROR. BREAKERS WAS NOT LABELED, OPERATOR DID NOT VERIFY CORRECT CIRCUIT BREAKER.
RL-WHC-TANKFARM-1991-1008	04/18/1991	DIESEL FUEL SPILL FROM THE EMERGENCY GENERATOR AT 241-SY TANK FARM.	PERSONNEL ERROR. THE FUEL TANK WAS OVERFILLED, WHEN HEATED UP DO TO WARM WEATHER, THE FUEL EXPANDED AND OVERFLOWED.

Table B.3. Occurrence Report Database. (7 sheets)

Occurrence Number	Discovery Date	Description of Event	Event Cause
RL-WHC-TANKFARM-1991-1050	10/02/1991	UNPLANNED LIQUID LEVEL INCREASE IN TANK 241-AW-102. LEVEL INCREASED ONE INCH OVER ONE SHIFT. EYEWASH UNIT WAS LEFT ON, OR LEAKED, AND DRAINED INTO TANK.	MANAGEMENT PROBLEM, IMPROPER RESOURCE ALLOCATION.
RL-WHC-TANKFARM-1991-1063	11/16/1991	LOSS OF POWER TO 200 WEST TANK FARMS. LOST VENTILATION TO 241-SY FARM AND 242-T EVAPORATOR. POWER OFF FOR ONE MINUTE.	SUSPECT THAT A SMALL ANIMAL CAUSED THE OUTAGE.
RL-WHC-TANKFARM-1992-0028	03/16/1992	200 EAST/200 WEST POWER OUTAGE. TWO BACKUP POWER SYSTEMS FAILED TO START DURING OUTAGE.	MECHANICAL. 204-AR DIESEL GENERATOR AND 241-SY TANK FARM DIESEL GENERATOR FAILED TO START WHEN REQUIRED.
RL-WHC-TANKFARM-1992-0051	06/28/1992	ELECTRICAL STORM DISRUPTS 200 WEST POWER.	WEATHER CONDITIONS.
RL-WHC-TANKFARM-1992-0074	10/01/1992	LEAKAGE FROM CONTAINMENT CASK CONTAINING AN AIR LANCE TAKEN FROM TANK 241-SY-101. SOIL CONTAMINATED.	DEFECTIVE OR INADEQUATE DESIGN. NEEDED A GASKET IN THE LOCKING ASSEMBLY.
RL-WHC-TANKFARM-1993-0028	03/05/1993	WASTE TRANSFER STOPPED DUE TO FAULTY AIR VALVE, LEAK BY ON BALL VALVE ALLOWED 700 GALLON TRANSFER TO 102-SY.	MECHANICAL. AIR VALVE FAILURE, BALL VALVE LEAK BY, LEAK DETECTORS FAILED TO ALARM.
RL-WHC-TANKFARM-1993-0072	08/11/1993	LOSS OF POWER TO AP, AW, AND AN TANK FARMS RESULTING IN LOSS OF PRIMARY EXHAUST FANS IN AP, AW, AN, AND C TANK FARMS.	POWER LOSS DUE TO LARGE BIRD LANDING ON POWER POLE AT GABLE MOUNTAIN.
RL-WHC-TANKFARM-1994-0070	12/12/1994	SPILL OF ONE GALLON OF WASTE AT C-110 SALTWELL AFTER FLUSH OF C-110 AND C-107.	PROCEDURE PROBLEM/MECHANICAL. SALTWELL FLUSH WATER BACKPRESSURE CAUSED WASTE WATER INTO RAW WATER FEED LINE WHERE IT LEAKED OUT OF DEFECTIVE QUICK DISCONNECTS.
RL-WHC-TANKFARM-1996-0007	01/16/1996	OSD VIOLATION, 244-TX DCRT HYDROXIDE LEVELS NOT SUFFICIENT. SHOULD HAVE HAD 0.1178 MOLES/LITER, ONLY HAD 0.0025 MOLES/LITER. HYDROXIDE LEVEL NOT ADJUSTED AFTER SALTWELL WASTE AND FLUSH WATER TRANSFER FROM SST T-107.	IMPROPER CHEMICAL ADJUSTMENT AFTER WASTE TRANSFER.

COB - clean out box
DCRT - double-containment receiver tank
DNFSB - Defense Nuclear Facilities Safety Board
DOE - U.S. Department of Energy
KEH - Kaiser Engineers Hanford
OSD -
OSR - Occupational safety requirements
PM - Preventive maintenance (activities)
PNL - Pacific Northwest Laboratory
SAR - Safety analysis report
USA - unreviewed safety question

APPENDIX C

PRELIMINARY HAZARDS ANALYSIS TABLES

APPENDIX C

PRELIMINARY HAZARDS ANALYSIS TABLES

This appendix presents the PHA tables developed for this assessment. The PHA forms the basis for the identification of accident scenarios and subsequent selection of evaluation-basis accident scenarios. The PHA is presented in four tables: Table C.1 presents the PHA for receipt and onsite transport of the K Basin sludge shipping container at the AW tank farm; Table C.2 is for the connection and transfer operations at tank AW-105; and the PHA for storage activities is presented in Table C.3. Note that Table C.3 is divided into four sub-sections: Table C.3a addresses hazards associated with the storage tank structures and contents; Table C.3b addresses the AW tank farm ventilation system; Table C.3c addresses the central pump pit, sluice pit, and other dome penetrations; and Table C.3d addresses piping, the annulus pump pit, and leak detection pit.

The PHA identifies a number of accident scenarios and provides preliminary estimates of their frequencies and consequences. In some cases, such as the natural phenomena and extrinsic hazard preliminary evaluation (Chapter 5), frequency and consequence data are presented that form the basis for assigning particular scenarios to their respective frequency and consequence categories. For other scenarios, engineering judgement and the analyst's experience with similar systems and components formed the basis for the qualitative assessment of scenario frequencies and consequences. Each scenaro was assigned to a frequency category shown in Table C.1 and a consequence category shown in Table C.2. Some rules of thumb were followed in making these judgements, as described below:

Frequency Assignments

1. No credit was taken for operation of active mitigation and prevention features, such as exhaust fans, pump shut-offs, etc.

2. Credit was taken for the presence of passive barriers, such as the integrity of the tank liners, shipping container containment vessel, ventilation ductwork, etc.

3. Administrative barriers, such as sludge acceptance criteria, operating procedures, training, etc., were assumed to fail.

Consequence Category Assignments

1. Scenarios resulting in pressurized releases (explosions, fires, etc.) of K Basin sludge were assigned to Category 1 as the energy of the release was judged to be sufficient to reach offsite receptors.

2. Scenarios resulting in non-pressurized releases of K Basin sludge were assigned to Category 2, as were, in general, vapor and liquid releases.

3. Occupational exposures above limits were assigned to category 3. Direct exposures to excessive radiation levels were judged to be insignificant outside the tank farm.

Table C.1. Frequency Categories Used in PHA

Accident Frequency Category	Frequency Category Description	Nominal Frequency Range (events per year)
F3 or Anticipated (A)	An off normal condition that individually may be expected to occur once or more during facility operation.	>1 E-02
F2 or Unlikely (U)	Individually, the condition is not expected to occur during facility operation, but collectively events in this category may occur several times.	1 E-04 to 1 E-02
F1 or Extremely Unlikely (EU)	Extremely low-probability conditions that are not expected during facility operation but that present extreme or limiting cases of faults identified as possible. This category includes design basis accidents.	1 E-06 to 1 E-04
F0 or Beyond Extremely Unlikely (<EU)	Accidents for which no credible scenario can be identified.	<1 E-06

Table C.2. Consequence Categories Used in the PHA

Consequence Category	Description of Consequences to the Public, Onsite Personnel, or Environment
Category S3	Based on material at risk and cause(s) postulated, there is sufficient material and release energy to impact a receptor at the Site boundary.
Category S2	Based on material at risk and cause(s) postulated, there is sufficient material and energy to impact a receptor at 100 m from the source of the material at risk.
Category S1	Based on material at risk and cause(s) postulated, the release is confined to the facility where it occurred.
Category S0	Based on material at risk and cause(s) postulated, there is insufficient material released to affect facility workers.

4. Industrial accidents or scenarios that do not involve exposures to radioactive or hazardous chemical materials.

Table C.1. PHA for Receipt and Onsite Transport at AW Tank Farm
(See Section 2.2 for definitions)

HAZARD	PHENOMENA	CAUSES	CAUSE FREQ.	CONSE-QUENCES		PREVENTION/MITIGATION		SCENARIO FRE-QUENCY
				OCC.	SEV.	ENGINEERING	ADMINISTRATIVE	
Acceleration/ Deceleration	Sludge container dislodged and breached	A1. Truck collision	F3	Y	S3	Container tiedown, container structural integrity, crash barriers, marked roadway	Vehicle spotter, container tiedown procedure, driver qualification, speed limit	F1
		A2. Severe driving error	F3	Y	S3			F1
		A3. Liquid sloshing	F3	Y	S3			F1
	Other object(s) dislodged	A4. Truck collision	F2	Y	S0	Crash barriers, marked roadway		F2
		A5. Driving error	F3	Y	S0			F2
Contamination	Exposure from sludge container contents	A6. Externally contaminated container received	F3	N	S1	None	Health physics inspections at K Basin and tank farm	F1
		A7. Tank farm chemicals corrode container	F1	N	S1	Container material	Tank farm chemical storage requirements, routine inspection, expeditious scheduling of sludge transfer	F1
	Exposure from tank farm contents	A8. Tank farm surface contamination	F3	N	S1	None		F2

HAZARD	PHENOMENA	CAUSES	CAUSE FREQ.	CONSE-QUENCES		PREVENTION/MITIGATION		SCENARIO FRE-QUENCY
				OCC.	SEV.	ENGINEERING	ADMINISTRATIVE	
Chemical Reaction (see Explosion and Fire)	Hazardous vapor release	A9. Tank farm chemicals	F2	Y	S1	Liquid containment/ confinement	Chemical storage requirements, "good housekeeping", also see A.7	F1
Corrosion	Sludge-wall internal reaction	A10. Improperly conditioned sludge loaded at K Basin	F2	N	S2	Container material	Container inspection, neutralization procedures, sludge sampling, expeditious scheduling of sludge transfer	F1
		A11. Slightly corrosive mixture left standing too long (enhancing corrosion)	F2	N	S2	Container material	See A.10, flushing following transfer	F1
Electrical	Electrical short/ sparks	A12. Power supply lines, outlets (external to sludge container)	F3	Y	S0	Equipment design	Electrical work permits, routine maintenance/ inspection	F1
		A13. Transportation system mixer pump	F3	N	S0			F2
		A14. Air compressor on trailer	F3	Y	S0			F2
		A15. I&C	F3	Y	S0			F2
Explosion	Highly energetic release internal or external to the sludge container, possibly generating missiles	A16. Fuel or lube oil	F2	Y	S0	Container material, pressurized gas storage, tank structural integrity	Routine maintenance/ inspection, welding prohibition during loading/unloading operations	F1
		A17. Welding gases	F2	Y	S0			F1

HAZARD	PHENOMENA	CAUSES	CAUSE FREQ.	CONSE-QUENCES		PREVENTION/MITIGATION		SCENARIO FRE-QUENCY
				OCC.	SEV.	ENGINEERING	ADMINISTRATIVE	
		A18. Hydrogen or other flammable gas within or released from sludge container	F2	Y	S3	Transportation System I&C, ventilation, mixer pump, tank structural integrity	Sludge characterization analysis, pre-transport sludge sampling	F1
Fire	Exothermic release internal or external to the sludge container, possibly long duration	A19. Truck-related: fuel, lube oil, engine, hot brakes	F3	Y	S0	Container fire resistance	Combustible control, routine maintenance/ inspection	F1
		A20. Welding gases	F2	Y	S0	Pressurized gas storage	Welding prohibition during unloading operations	F1
		A21. Hydrogen or other flammable gas within or released from sludge container	F2	Y	S3	Transport system I&C, flammable gas control, container sealed during transportation	Sludge characterization analysis, pre-transport sludge sampling, container grounding	F1
		A22. Pyrophoric U metal in sludge container	F3	Y	S3	Transport system I&C, moisture, sludge mostly oxidized	Expeditious scheduling of sludge transfer	F1
Heat and High Temperature	Uniform or differential heating of sludge container from external source	A23. Solar exposure: overpressure, seal distortion	F3	N	S2	Container thermal resistance, wall thickness, container strength	Expeditious scheduling of sludge transfer	F1
		A24. Exposure to welding equipment or materials	F1	N	S2		Welding prohibition during unloading operations	F1
		A25. Lead slump in shielding from heat exposure	F1	N	S2			F1

HAZARD	PHENOMENA	CAUSES	CAUSE FREQ.	CONSE-QUENCES		PREVENTION/MITIGATION		SCENARIO FRE-QUENCY
				OCC.	SEV.	ENGINEERING	ADMINISTRATIVE	
Low Temperature	Prolonged exposure to cold (either during transport to tank farm or upon receipt)	A26. Expansion of water as it freezes	F2	N	S1	Container strength, internal heat generation in sludge container, mixer, freeze protection/heat trace, insulation	Expeditious scheduling of sludge transfer	F1
		A27. Embrittlement of gaskets	F3	Y	S1	Material selection		F2
		A28. Material brittle fracture (container wall, penetrations)	F1	Y	S3			F1
Temperature Change	Non-uniform heating and cooling of sludge container either spatially or temporally	A29. Thermal stress for diurnal temperature change: seal deformation, structural fatigue	F3	N	S1	Material selection, container strength	Expeditious scheduling of sludge transfer	F1
		A30. Differential thermal expansion of materials	F2	N	S1			F1
Impact and Shock	Rapid transfer of kinetic energy possibly beyond design limit	A31. Tank auxiliary struck by truck: pump pit, diversion box, riser, vent equipment	F2	N	S3	Barriers, marked roadway	Vehicle spotter, driver qualification	F1
		A32. Sludge container struck by missile: wind-driven/explosion-driven	F1	N	S3	Container strength	No outdoor exposure during severe winds	F1
		A33. Radiation-embrittled sludge container struck	F1	N	S3	Transportation System I&C, material selection	Routine maintenance/ inspection	F1

HAZARD	PHENOMENA	CAUSES	CAUSE FREQ.	CONSE-QUENCES		PREVENTION/MITIGATION		SCENARIO FRE-QUENCY
				OCC.	SEV.	ENGINEERING	ADMINISTRATIVE	
		A34. Mishandled truck drives atop tank dome	F2	Y	S3	Crash barriers, marked roadway, tank strength	Vehicle spotter, driver qualification	F0
Leakage/ Spills (Gas, Vapor, Liquid)	Non-energetic release of sludge container contents	A35. Improper sealing: over/under-torque, failure to install	F2	N	S2	Container double containment, leak detection/ collection system	Container loading procedures, routine maintenance/ inspection	F2
		A36. Valve failure, failure to close	F2	N	S2	Transportation System I&C		F2
		A37. Vapor leak through improperly installed HEPAs/seals	F2	N	S2			F2
High Pressure	Overpressure inside a container, causing a leak	A38. Sludge container overpressure: chemical reaction, sloshing, hot spot, gas generation	F3	Y	S3	Container strength, double containment, mixer pump	Expeditious scheduling of sludge transfer	F2
		A39. Air compressor (on trailer) overpressure	F3	Y	S0	Automatic compressor shutoff	Routine maintenance/ inspection	F2
Ionizing Radiation	External or internal exposure to excessive dose	A40. Surface contamination: sludge container or tank farm	F3	N	S1	Transportation System I&C	Health physics inspection at K Basin and tank farm	F2
		A41. Excessive surface dose rate	F2	N	S1	Transportation System I&C, shielding		F2
		A42. Inhalation of released radioactive vapors, gases	F2	N	S2	HEPA filters, tank ventilation		F2
		A43. Criticality in shipping container	F1	Y	S1	Low fissile concentration, availability of poisons	Crit. Safety evaluation required; controls not yet specified	F0

HAZARD	PHENOMENA	CAUSES	CAUSE FREQ.	CONSE-QUENCES		PREVENTION/MITIGATION		SCENARIO FRE-QUENCY
				OCC.	SEV.	ENGINEERING	ADMINISTRATIVE	
Structural Damage or Failure (see Leakage/Spills)	Sludge container damage from inherent defects or induced forces	A44. Defective sludge container fails	F2	N	S3	Material selection, container structural integrity, double containment	Routine maintenance/ inspection, manufacturer QA, acceptance tests, pre-transport inspection, K Basin loading procedures	F1
		A45. Trailer/ tiedown failure drops sludge container to ground, breaking open	F2	Y	S3			F1
Toxicity	External or internal exposure to excessive levels of hazardous chemicals	A46. Exposure to sludge waste	F3	N	S1	Container walls, seals	Routine maintenance/ inspection, worker access to respirators, safety training	F2
		A47. Exposure to chemicals in pump or compressor	F3	N	S1	Equipment seals, pipe-in-pipe		F2
Vibration	Repeated rapid movement from external sources	A48. Sludge container seal, valve, or tiedown loosening during transport (road vibration)	F3	N	S2	Container seal design, container tie-downs	Routine maintenance/ inspection, pre-transport inspection	F2
		A49. Volatization of sludge: road transport, tank farm activities	F1	N	S2	Transportation System I&C, HEPA filters, container sealed during transportation	Speed limit, driver qualification	F1
Weather and Environment	External forces of nature sufficient to breach sludge container	A50. Truck accident due to inclement weather	F2	Y	S3	Container tiedown, structural integrity	Transport limits during severe weather, driver qualification	F1
		A51. Earthquake	F2	Y	S3	Tank farm location in low seismicity area	None	F0

HAZARD	PHENOMENA	CAUSES	CAUSE FREQ.	CONSE-QUENCES		PREVENTION/MITIGATION		SCENARIO FRE-QUENCY
				OCC.	SEV.	ENGINEERING	ADMINISTRATIVE	
		A52. Flood (including dam burst), heavy rain, hail	F1	Y	S3	Tank farm elevation, surface drainage		F0
		A53. High wind	F2	Y	S3	Container tiedown, structural integrity		F2
		A54. Snowfall or ashfall (heavy loading)	F2	Y	S3			F0
		A55. Brush fire	F2	Y	S3	Tank farm location away from combustible brush, container thermal resistance	Tank farm operating procedures, fire services	F1
		A56. Aircraft impact	F2	Y	S3	None	Ban on aircraft flyovers	F0

Table C.2 PHA for Connection and Transfer
(See Section 2.2 for definitions)

HAZARD	PHENOMENA	CAUSES	CAUSE FREQ.	CONSE-QUENCES		PREVENTION/MITIGATION		SCENARIO FREQUENCY
				OCC.	SEV.	ENGINEERING	ADMINISTRATIVE	
Acceleration/ Deceleration	Sludge transfer containment/ confinement barrier breached	B1. Trailer slip (including human error) during hookup or pumping, breaking connection, rupturing valve or line	F2	Y	S3	Wheel blocks, transfer line flexibility, leak detection/ collection system	Tank farm unloading operating procedures	F1
		B2. Fluid splash (sludge or supernate) in tank	F3	N	S1		Control of pumping flow rate	F2
		B3. Sludge distributor component drops into tank waste	F2	N	S1	Distributor design	Distributor inspection/repair, Tank Farm operation procedures	F1
		See "Receipt and Onsite Transport" PHA						
	Other object(s) dislodged	See "Receipt and Onsite Transport" PHA						
Contamination	Exposure from sludge container contents	B4. Residual material in valves or lines	F3	Y	S1	Transfer line berming, double insulation, flow velocity prevents settling	Health physics inspections at K Basin and tank farm, post-transfer line and container flush, limit on solids content	F2
		See "Receipt and Onsite Transport" PHA						
	Equipment failure, possibly generating missiles	B5. Sand in pump or air compressor lubricating oil	F2	Y	S1	Pump and compressor air filters, automatic shutoffs	Routine maintenance/ inspection	F1

HAZARD	PHENOMENA	CAUSES	CAUSE FREQ.	CONSE-QUENCES		PREVENTION/MITIGATION		SCENARIO FREQUENCY
				OCC.	SEV.	ENGINEERING	ADMINISTRATIVE	
	Exposure from tank farm contents	See "Receipt and Onsite Transport" PHA						
Chemical Reaction (see Explosion and Fire)	Hazardous vapor release	B6. Residuals in lines, valves, etc.,react to produce heat and pressure	F2	Y	S1	Transfer line encased	Post-transfer line and container flush, waste compatibility analysis, K Basin pre-transport inspection, routine maintenance/ inspection, tank labeling, sludge transfer unloading station, transfer duration	F1
		B7. Air/oxygen passes through HEPA vents or opened valve, contacting sludge	F2	Y	S2	Container internal positive pressure		F1
		B8. Chemical incompatibility between sludge and tank contents, increasing tank temperature and pressure	F2	Y	S3	Tank structural integrity, ventilation system		F1
		B9. Mistransfer to wrong tank	F1	Y	S3	None	OGT is dedicated line	F1
		See "Receipt and Onsite Transport" PHA						
Corrosion	Loss of connection/ transfer component integrity	B10. External components corroded	F2	N	S2	Container material	Routine maintenance/ inspection, container electrical grounding	F1
		B11. Galvanic corrosion between dissimilar metals (transfer line to truck, transfer line to unloading station)	F1	N	S2			F1
	Sludge-wall internal reaction	See "Receipt and Onsite Transport" PHA						

HAZARD	PHENOMENA	CAUSES	CAUSE FREQ.	CONSE-QUENCES		PREVENTION/MITIGATION		SCENARIO FREQUENCY
				OCC.	SEV.	ENGINEERING	ADMINISTRATIVE	
Electrical	Electrical short/sparks	B12. Loss of lighting leads to improper connection	F3	N	S2	Secondary power source	Tank farm operating procedures, routine maintenance/ inspection	F2
		B13. Electrical fault in electric-driven pump, I&C	F3	Y	S2			F2
		See "Receipt and Onsite Transport" PHA						
Explosion	Highly energetic release internal or external to the sludge container, possibly generating missiles	B14. Chemical incompatibility between sludge and tank contents	F2	Y	S3	Tank structural integrity, ventilation system	Waste compatibility analysis, pre-transport sludge sampling	F1
		B15. Mistransfer to wrong tank, see B9	F1	Y	S3	Sludge transfer unloading station	Tank labeling	F1
		See "Receipt and Onsite Transport" PHA						
Fire	Exothermic release internal or external to the sludge container or tank, possibly long duration	B16. Pyrophoric material in container or tank	F3	Y	S3	Container and tank I&C, moisture, sludge mostly oxidized	Expeditious scheduling of sludge transfer	F1
		B17. Spark source ignites flammable gas generated in tank	F2	Y	S3	Tank I&C, ventilation system, flammable gas controls	Tank farm operating procedures	F1
		B18. Inadvertent connection made with common header between nearby flammable gas tank AW-101 and AW-105, see B9	F2	Y	S3	Tank farm I&C		F1
		B19. Mistransfer to wrong tank, see B9	F1	Y	S3	Sludge transfer unloading station	Tank labeling	F1

HAZARD	PHENOMENA	CAUSES	CAUSE FREQ.	CONSE-QUENCES		PREVENTION/MITIGATION		SCENARIO FREQUENCY
				OCC.	SEV.	ENGINEERING	ADMINISTRATIVE	
		See "Receipt and Onsite Transport" PHA						
Heat and Temperature	Uniform or differential heating of sludge container or connecting/ transfer equipment from external source	B20. Solar exposure: embrittles transfers lines, overheats sludge container	F3	N	S2	Material thermal resistance	Expeditious scheduling of sludge transfer	F1
		See "Receipt and Onsite Transport" PHA						
Low Temperature	Prolonged exposure to cold	B21. Freezing plugs lines, valves, etc.	F3	Y	S2	Material selection, automatic pump shutoff	No outdoor exposure during cold snap, no interruption during transfer	F2
		B22. Relatively cold sludge strikes warmer tank waste, increasing vaporization	F3	N	S1	None	Expeditious scheduling of sludge transfer	F2
Temperature Change	Non-uniform heating and cooling of sludge container or tank either spatially or temporally	B23. Differential thermal expansion as sludge strikes tank surfaces	F2	N	S1	Material thermal resistance, container and tank material strength, large in tank heat sink	Expeditious scheduling of sludge transfer	F1
	See "Receipt and Onsite Transport" PHA							
Impact and Shock	Rapid transfer of kinetic energy possibly beyond design limit	B24. Trailer struck by moving vehicle, breaking connection	F2	Y	S2	Transfer line flexibility, automatic pump shutoff, leak detection/ collection system, barricades	Vehicle spotter, driver qualification	F2

HAZARD	PHENOMENA	CAUSES	CAUSE FREQ.	CONSE-QUENCES		PREVENTION/MITIGATION		SCENARIO FREQUENCY
				OCC.	SEV.	ENGINEERING	ADMINISTRATIVE	
		B25. Fatigue failure of transfer lines, connections	F2	N	S2	Material design and strength	Routine maintenance/ inspection	F1
		B26. Foreign object in sludge strikes tank wall or internal equipment	F2	N	S1	K Basin loading system picks up only small particles, slurry distributor, tank secondary liner, automatic pump shutoff	Routine maintenance/ inspection, tank farm waste acceptance specifications	F1
		See "Receipt and Onsite Transport" PHA						
Leakage/Spills (Gas, Vapor Liquid)	Non-energetic release of sludge container or tank contents	B27. Transfer line rupture	F2	Y	S2	Transfer line double containment	Routine maintenance/ inspection	F2
		See "Receipt and Onsite Transport" PHA						
Power Source Failure	Loss of essential equipment leads to operator error or loss of process control	B28. Instrument failure (loss of pneumatic or electrical power): sludge container or tank level indicator, pump flowmeter, etc.	F3	N	S1	Secondary power source	Tank farm operating procedures, routine maintenance/ inspection, provision to cease pumping	F2
		B29. Loss of tank farm lighting	F3	Y	S1			F2
		B30. Loss of sludge mixer in container	F3	N	S1	Secondary power source, gravity drain		F2
		B31. Failure of sludge distribution system in tank	F2	N	S1	None		F1

HAZARD	PHENOMENA	CAUSES	CAUSE FREQ.	CONSE-QUENCES		PREVENTION/MITIGATION		SCENARIO FREQUENCY
				OCC.	SEV.	ENGINEERING	ADMINISTRATIVE	
High Pressure	Overpressure inside a container, causing a leak	B32. Pressure buildup from normal pumping	F2	Y	S2	Automatic pump shutoff, leak detection/ collection system, structural integrity	Provision to cease pumping, post-transfer line and container flush	F2
		B33. Pump dead-heads against closed/plugged valve, transfer line	F2	Y	S1			F2
		B34. Chemical incompatibility of sludge and tank contents pressurizes tank	F2	Y	S2	Pressure sensors, ventilation system, double containment	Waste compatibility analysis	F1
		B35. Steam flash when sludge contacts tank contents	F2	N	S2	Tank ventilation system, structural integrity		F1
		B36. Gas or air pockets in sludge or tank waste released	F3	N	S1	Tank ventilation system, structural integrity, distribution system, sludge mixer pump		F1
		See "Receipt and Onsite Transport" PHA						
Low Pressure	Under-pressure inside a container, causing an implosion or vapor inleakage	B37. Rapid overcooling of tank vapor	F1	Y	S2	Tank structural integrity, ventilation system	Tank farm operating procedures	F1
Ionizing Radiation	External or internal exposure to excessive dose	B38. Exposure to leakage through connectors, ruptured lines, valves, failed HEPAs	F2	N	S2	Bermed transfer line	Pre-transport sludge sampling, worker distance during transfer	F2
		B39. Fuel "fleas" in transfer line	F3	N	S2	Bermed transfer line	Worker distance during transfer	F2
		See "Receipt and Onsite Transport" PHA						

HAZARD	PHENOMENA	CAUSES	CAUSE FREQ.	CONSE-QUENCES		PREVENTION/MITIGATION		SCENARIO FREQUENCY
				OCC.	SEV.	ENGINEERING	ADMINISTRATIVE	
Structural Damage or Failure (see Leakage/Spills)	See "Receipt and Onsite Transport" PHA							
Toxicity	See "Receipt and Onsite Transport" PHA							
Vibration	See "Receipt and Onsite Transport" PHA							
Weather and Environment	External forces of nature sufficient to breach sludge transfer containment/ confinement barrier	B40. Breach in connection or transfer line	F2	Y	S2	Transfer line shielding, auto-matic pump shutoff	Operator stay-time limited by procedures	F2
		See "Receipt and Onsite Transport" PHA and Chapter 6, "Natural Phenomena and Extrinsic Hazards"						

Table C.3a. PHA for Storage Operations - Tank Structure And Contents

HAZARD	PHENOMENA	CAUSES	CAUSE FREQ.	CONSEQ.		PREVENTION/MITIGATION		SCEN. FRE.
				OCCU.	SEV.	ENGINEERING	ADMINISTRATIVE	
Chemical Reaction	Breach of tank integrity, exothermic energy release	C.1 Exothermic reactions involving incompatible waste, pyrophoric reaction	F3	Y	S3	Double-barrier	Waste compatability program, maximum discharge pressure into tank	F1
		C.2 Paraffinic, organic materials in sludge	F2	Y	S3	Double-barrier		F1
		C.3 Mistransfer (wrong receiver tank)	F1	Y	S3	Marked roadway; tank indicator; off loading station		F1
Corrosion	Breach of tank integrity, internal equipment failure	C.4 Tank corrosion accelerated by sludge	F1	N	S2	Double-barrier; leak detection		F1
		C.5 Equipment (i.e. sludge distributor, piping, HVAC, etc.) corrosion accelerated by sludge	F1	N	S2			F1
Electrical and Power Source Failure	Loss of power to essential equipment, loss of control	Loss of HVAC (see "HVAC system" PHA)						
		C.6 Loss of instrumentation, controls, alarms	F2	N	S1	Electrical design; emergency diesel generator; double-barrier	Routine inspection and maintenance	F2
		C.7 Loss of sludge distributor	F2	N	S1			F2
		C.8 Electrical fault in electric-driven equipment	F2	N	S1			F2
Explosion	Breach of tank integrity (i.e., tank linear, tank dome, etc.) highly energetic release	C.9 Exothermic reactions involving pyrophoric materials in sludge	F1	Y	S3	Double-barrier; tank ventilation system		F0

HAZARD	PHENOMENA	CAUSES	CAUSE FREQ.	CONSEQ.		PREVENTION/MITIGATION		SCEN. FRE.
				OCCU.	SEV.	ENGINEERING	ADMINISTRATIVE	
		C.10 Exothermic reactions involving incompatible between sludge and tank contents	F2	Y	S3			F1
		C.11 Exothermic reactions involving hydrogen/flammable gas exhausted from tank	F1	Y	S3			F0
Fire	Breach of tank integrity, exothermic release	C.12 Sparks from electrical instrument in tank ignite flammable vapors	F2	Y	S3	Electrical bonding; use of spark resistant equipment; double-barrier; ventilation system; fire fighting equipment	Waste compatability program.	F1
		C.13 Exothermic reaction involving organic material contained in tank waste material	F2	Y	S3	Use of compatible materials; double-barrier; ventilation system; fire fighting equipment		F1
		C.14 Exothermic reaction involving ammonium nitrate contained in tank waste material	F2	Y	S3			F1
		C.15 Exothermic reaction involving other nitrates contained in tank waste material	F2	Y	S3			F1
		C.16 Exothermic reaction involving flammable gases formed by tank waste material that accumulate in the tank headspace	See C11					

HAZARD	PHENOMENA	CAUSES	CAUSE FREQ.	CONSEQ.		PREVENTION/MITIGATION		SCEN. FRE.
				OCCU.	SEV.	ENGINEERING	ADMINISTRATIVE	
		C.17 Vehicle operations within or near the tank create fire which propagates to tank	F2	Y	S3	Fire fighting equipment	Operations standing order requiring a spotter for vehicles	F1
		C.18 Fuel storage near the tank farm (e.g., propane, oil drums, gasoline) creates fire which propagates to tank	F1	Y	S3	Fire fighting equipment	WHC-SD-WM-HSP-002, Tank Farm Health and Safety Plan	F1
		C.19 HVAC fire propagates to tank	F2	Y	S3	Fire fighting equipment		F0
		C.20 Riser, pump pit, or other penetration equipment fire which propagate to tank	F1	Y	S3	Minimal combustible loading, fire fighting equipment	Combustible loading	F0
Heat and Temperature	Tank burp or bump	C.21 Equipment movement in tank creates heat	F1	N	S2	Ventilation system; double-barrier	Safety/design evaluation	F0
		C.22 Temperature increase due to incompatible sludge	F2	N	S2		Waste compatibility control	F0
		C.23 Hot spots in sludge	F1	N	S2	Sludge distributor	Pre-transport sludge sampling; sludge characterization analysis	F0
Temperature Change	Tank buckling	C.24 Tank thermal cycling caused by repeated transfers	F1	N	S2	Ventilation system		F0
Leakage (Gas, Vapor, Liquid)	Release of tank contents	C.25 Tank damage causes leakage to soil	F1	Y	S2	Secondary-barrier; leak detection; drywells around tank monitored on periodic basis	Leak detection control; thermal stress analysis	F0
		HVAC failure leads to release of airborne (see "HVAC system" PHA)						
		Riser, Pump pit, or other penetration equipment open leads to release of airborne (see "Riser, Pump Pit, Equipment" PHA)						

HAZARD	PHENOMENA	CAUSES	CAUSE FREQ.	CONSEQ.		PREVENTION/MITIGATION		SCEN. FRE.
				OCCU.	SEV.	ENGINEERING	ADMINISTRATIVE	
Moisture - High Humidity	Increase tank pressure, cause equipment failure	C.26 Increasing water content of tank affects vaporization rate, tank pressure.	F1	N	S1	Ventilation system	Waste compatiblity program; K Basin sludge sampling	F0
		HVAC failure (see "HVAC system" PHA)						
Pressure - High	Tank pressurization, integrity impact	C.27 Transfer pump discharges pressure into tank	F2	Y	S2	Dome pressure monitor; double-barrier	Waste compatiblity program; K Basin sludge sampling and maximum discharge pressure into tank	F0
		C.28 Chemical reaction leads to tank overpressure	F2	Y	S2			F0
Pressure - Low	Under-pressure inside the tank leads to dome failures	C.29 HVAC inlets to tank plug, exhaust fans continue running	F2	Y	S2	Dome pressure monitor; air pressure monitor; HVAC system	Routine inspection and maintenance	F1
Radiation - Ionizing	Internal or external exposure to excessive dose	C.30 Sludge in tank.	F2	Y	S1	Soil barrier/shielding, coverblocks	ALARA program	F1
		C.31 Exhaust in HVAC system	F2	Y	S1			F1
Structural Damage/Failure	Breach of tank integrity (tank wall, tank dome, or tank liner damage)	Ventilation system failure (see "HVAC system" PHA)						
		C.32 Tank internal hydrostatic load	F1	Y	S2	Double-barrier	IOSR for maximum waste level.	F0
		C.33 Tank internal buckling due to dynamic stress	F1	Y	S2		IOSRs for maximum waste level and ventilation system control.	F0
		C.34 Tank wall penetration by installed equipment after structural failure of mounting	F0	Y	S2			F0
		C.35 Tank wall failure through internally generated missiles	F2	Y	S2			F0

HAZARD	PHENOMENA	CAUSES	CAUSE FREQ.	CONSEQ.		PREVENTION/MITIGATION		SCEN. FRE.
				OCCU.	SEV.	ENGINEERING	ADMINISTRATIVE	
		C.36 External pressure from ground creep and movement (e.g., truck, crane, other equipment)	F1	Y	S2			F0
		C.37 Tank dome overburden	F0	Y	S2		Dome loading surveys by TFSE.	F0
		C.38 External dropped equipment	F1	Y	S2		Tank farm heavy loading restrictions	F0
Toxicity	External or internal exposure to excessive levels of hazardous chemicals	C.39 Toxic materials in sludge, vapors (e.g. ammonia)	F3	N	S1	Double-barrier; ventilation system	Tank farm Health and Safety Plan	F3
Vibration and Noise	Repeated rapid movement from external sources	C.40 Tank wall failure through equipment vibration	F1	N	S2	Double-barrier	Routine inspection and maintenance	F1
		C.41 Nearby workers operating heavy equipment, machinery	F2	N	S2			F1
Criticality	Breach of tank resulting from tank pressurization, thermal shock to the tank wall or tank dome, physical stress to the tank wall or tank dome. Personnel exposure to high dose rates	C.42 Chemical reactions (e.g., Precipitation, extraction, or dissolution of materials within the tank)	F1	Y	S2	Tank is subcritical and over moderated	WHC-IP-0842. Administrative control of fissile material inventory; WHC-SD-WM-SARR-001, Braun 1994; WHC-SD-CSQ-20363, Rogers 1994, criticality safety program (controls not yet determined)	F0
		C.43 Evaporation or condensation of materials within the tank, sludge distribution in unfavorable geometry, incorrect K Basin sludge analysis.	F1	Y	S2			F0

HAZARD	PHENOMENA	CAUSES	CAUSE FREQ.	CONSEQ.		PREVENTION/MITIGATION		SCEN. FRE.
				OCCU.	SEV.	ENGINEERING	ADMINISTRATIVE	
Overfill	Tank contents release	C.44 Tank overfill	F0	Y	S3	Tank level instrumentation and control, pit leak detection	IOSR for maximum waste level; mass balance control	F0

Table C.3b. PHA For Storage Operations - Ventilation System
(See Section 2.2 for Definitions)

HAZARD	PHENOMENA	CAUSES	CAUSE FREQ.	CONSEQ.		PREVENTION/MITIGATION		SCENA. FREQ.
				OCCU.	SEV.	ENGINEERING	ADMINISTRATIVE	
Chemical Reaction	Breach of ventilation system integrity	D.1 Pressurization due to exothermic reaction, pyrophoric reaction	F3	Y	S3	Tank dome pressure monitor; HVAC control system	Waste compatibility program	F0
Corrosion	Breach of system integrity; equipment failure	D.2 Ventilation system corrosion accelerated by vapor produced by sludge	F2	N	S2	Redundant/backup heater and filter; material specification, condensate return line		F2
Electrical and Power Source Failure (Contribute to other scenarios)	Loss of power to equipment; loss of control	D.3 Loss of heater	See "Moister-High Humidity" hazard					
		D.4 Loss of moisture separator	See "Moister-High Humidity" hazard					
		D.5 Loss of exhaust fan	See "High Pressure" hazard					
		D.6 Loss of instrumentation and control due to power source failure	F2	N	S1	Emergency diesel generator		F2
Explosion	Breach of system integrity	D.7 Exothermic reaction involving nitrated organic materials that form in ventilation system or are accumulated in ventilation system components	F1	Y	S2	Air pressure monitor; Air flow monitor; redundant system	Administrative/programmatic controls for exothermic reactions	F1
		D.8 Exothermic reaction involving ammonium nitrate or other inorganic nitrates that accumulate in the ventilation filters	F1	Y	S2	Air pressure monitor; Air flow monitor; redundant system	Administrative/programmatic controls for exothermic reactions	F1

HAZARD	PHENOMENA	CAUSES	CAUSE FREQ.	CONSEQ.		PREVENTION/MITIGATION		SCENA. FREQ.
				OCCU.	SEV.	ENGINEERING	ADMINISTRATIVE	
		D.9 Pressurized gas bottles use or storage within or near the tank farm	F2	Y	S2	Container integrity	WHC-SD-WM-HSP-002, Tank Farm Health and Safety Plan	F1
Fire	Exothermic release internal or external to ventilation system, possibly long duration	D.10 Exothermic reaction involving flammable vapor (hydrogen, NPH fog, etc.) that accumulated in the ventilation system	F2	Y	S2	HVAC operability		F1
		D.11 Accumulation of combustible material within the ventilation system (e.g., rags, paper, solvents) due to poor housekeeping	F0	Y	S2	HVAC operability	WHC-IP-0842, Waste Tanks Administration	F0
		D.12 Exothermic reaction involving pyrophoric uranium	F0	Y	S2	HVAC operability	WHC-IP-0842, Waste Tanks Administration	F0
		D.13 Vehicle operations within or near the tank farm create fire which propagates to HVAC system	F2	Y	S2	Fire fighting equipment	Operations standing order requiring a spotter for vehicle.	F1
		D.14 Fuel storage accidents near the tank farm create fire which propagates to HVAC system	F2	Y	S2	Removed from tank farm	WHC-SD-WM-HSP-002, Tank Farm Health and Safety Plan	F1
		D.15 Non-intrinsically safe electrical equipment including blower motors, electrical power distribution equipment, electrical instrumentation create fire which propagates to HVAC system	F2	Y	S2	Electrical bonding	WHC-IP-0842, Waste Tanks Administration; WHC-SD-WM-HSP-002, Tank Farm Health and Safety Plan; herbicide program in farm; gravel cover	F1

HAZARD	PHENOMENA	CAUSES	CAUSE FREQ.	CONSEQ.		PREVENTION/MITIGATION		SCENA. FREQ.
				OCCU.	SEV.	ENGINEERING	ADMINISTRATIVE	
		D.16 Use of sparking tools or equipment during maintenance/construction creates fire which propagates to HVAC system	F1	Y	S2	Use of spark resistant equipment	WHC-SD-WM-HSP-002, Tank Farm Health and Safety Plan	F1
		D.17 Tank fire or explosion that propagates to the HVAC system	See other PHA for Tank Structures and Contents					
Heat and Temperature	Uniform or differential heating of ventilation system from external source	D.18 Solar exposure (overpressure, seal distortion)	F1	N	S2	Radiation protection alarm; temperature monitoring; overburden; material selection		F1
Low Temperature	Prolonged exposure to cold	D.19 Freezing and subsequent thawing of ventilation system component that contain liquids	F1	N	S2	Overburden; material selection		F1
Temperature Change	Non-uniform heating and cooling of ventilation system	D.20 Thermal stress for diurnal temperature change (seal deformation, structural fatigue)	F1	N	S1	Overburden; material selection		F1
Leakage	Release of contaminated vapor	D.21 Internal flooding of ventilation system due to moisture separator failure or over flow	F1	Y	S2	Redundant system; drain line,	Routine inspection and maintenance	F1
		D.22 HEPA filter loading leads to off gas	F3	Y	S2	Radiation monitor in stack; pressure monitor	Active ventilation systems; OSD for pressure drop across HEPA filters	F2

HAZARD	PHENOMENA	CAUSES	CAUSE FREQ.	CONSEQ.		PREVENTION/MITIGATION		SCENA. FREQ.
				OCCU.	SEV.	ENGINEERING	ADMINISTRATIVE	
		D.23 Excessive off-gas system moisture carryover	F3	Y	S1	Air monitor; heater; moisture separator; drain lines; pressure difference	OSD for air inlet temperature to HEPA filter, filter efficiency, and temperature change across air heater	F2
		D.24 Excessive off-gas temperatures	F3	Y	S1	Temperature monitor	OSD for air inlet temperature to HEPA filter, filter efficiency, and temperature change across air heater	F2
		D.25 Off-gas system incompatible chemical carryover resulting in HEPA filter degradation (loss of filtration efficiency)	F3	Y	S2	Redundant or backup filter; material selection	OSD for air inlet temperature to HEPA filter, filter efficiency, and temperature change across air heater, waste compatibility program	F2
		D.26 HEPA filter rupture	F3	Y	S2	Redundant or backup filter; radiation monitor; pressure difference	OSD for air inlet temperature to HEPA filter, filter efficiency, and temperature change across air heater	F2
		D.27 Structural damage (e.g., pipe, valve, etc.)	F2	Y	S2	Radiation monitor; pressure monitor	Routine inspection and maintenance	F1
Moisture - High humidity	Reduction of HEPA filter efficiency	D.28 Extended duration from fan failure increases evaporation	F2	Y	S1	Redundant HVAC train	Filter efficiency, and temperature change across air heater, vent system OSR	F1
		D.29 Heater failure leads to wet HEPA filters	F2	Y	S1	Redundant HVAC train; moister separator; heater function indicator; drain line	Drain lines	F1
		D.30 Moisture separator failure	F2	Y	S1	Redundant HVAC train	Vent system OSR	F1

HAZARD	PHENOMENA	CAUSES	CAUSE FREQ.	CONSEQ.		PREVENTION/MITIGATION		SCENA. FREQ.
				OCCU.	SEV.	ENGINEERING	ADMINISTRATIVE	
Pressure - High	Pressure exceeds HVAC system containment boundary stress limit	D.31 External pressure from ground creep and movement	F2	Y	S1	Redundant system, material selection	Routine inspection and maintenance; OSD for pressure change	F1
		D.32 Pipe plugged	F2	Y	S2	Redundant system; pressure change monitor		F1
		D.33 Dampers fail closed	F2	Y	S2			F1
		D.34 Loss of exhaust fan	F2	Y	S2			F1
		D.35 Moisture separator failure	F2	Y	S2	Redundant system; exhaust fan monitor	Routine inspection and maintenance; OSD for pressure change across moisture separator	F1
Pressure - Low	Excessive vacuum causes HVAC filter failure.	D.36 Loss of intake or reduction in intake (excessive vacuum)	F2	N	S1	Pressure, air monitor; tank vapor, pressure, function indicator; redundant HVAC system	Active ventilation systems; OSD for pressure drop across HEPA filters.	F1
		D.37 Valve failure	F2	N	S1	Function indicator; redundant HVAC system	OSD for pressure drop and/or change	F1
Radiation - Ionizing	Internal or external exposure to excessive dose	D.38 Handling of decontamination and spill clean up waste materials (including waste personal protective equipment)	F3	Y	S1	Overburden provides shielding	Radiation protection program HSRCM-1; WHC-CM-2-24 Hazardous Material Packaging and Shipping; Operating procedure	F1
		D.39 Handling of waste materials generated during ventilation system testing, maintenance, surveillance, and sampling (Including waste personal protective equipment)	F3	Y	S1	Designed for contact maintenance	WHC-CM-2-24 Hazardous Material Packaging and Shipping; Operating procedure; Radiation protection program HSRCM-1	F1

HAZARD	PHENOMENA	CAUSES	CAUSE FREQ.	CONSEQ.		PREVENTION/MITIGATION		SCENA. FREQ.
				OCCU.	SEV.	ENGINEERING	ADMINISTRATIVE	
		D.40 Filter, HEPA failure during operation	F2	Y	S1	Redundant filter, radiation monitor	OSD for pressure change; radiation monitor	F1
Structural Damage/ Failure	Breach of ventilation system integrity (vapor releases)	D.41 Ventilation system integrity failure resulting from internally generated missiles	F1	Y	S2	Minimal active components	Routine inspection and maintenance	F1
		D.42 Ventilation system overburden (duct damage)	F1	Y	S1	Design specification	OSD on negative air pressure balance; air monitor pressure balance	F1
		D.43 External dropped equipment	F2	Y	S2	Overburden	Tank farm heavy loading restrictions	F1
		D.44 Raw water or fire main flooding resulting in subsidence of ventilation system component support structures	F1	Y	S2	Surface draining system; vent system on pad.	Control of raw water addition to tank farm; routine tank farm surveillance	F1
		D.45 Vehicular collision with above grade ventilation system/component	F2	Y	S2	Marked roadway	Operations standing order requiring a spotter for vehicles.	F1
		D.46 System/component structure damage (heater, moisture separator, fan, etc.)	F3	Y	S2	Redundant system	Routine inspection and maintenance; Installation procedures	F2
Toxicity	External or internal exposure to excessive levels of hazardous vapors	D.47 Hazardous chemicals, vapors	F3	Y	S1	Exhaust fans	Tank Farm Health and Safety Plan	F1
		D.48 Exhaust of operating heavy equipment nearby	F2	Y	S1	Design specifications; exhaust filters	Tank Farm Health and Safety Plan; vehicle maintenance	F1
		D.49 Incompatible chemicals during chemical additions generate toxic vapors	F2	Y	S1		Tank Farm Health and Safety Plan; waste compatibility program	F2

HAZARD	PHENOMENA	CAUSES	CAUSE FREQ.	CONSEQ.		PREVENTION/MITIGATION		SCENA. FREQ.
				OCCU.	SEV.	ENGINEERING	ADMINISTRATIVE	
Vibration and Noise	Repeated rapid movement from internal or external sources	D.50 Fatigue failure of ventilation equipment resulting from excessive vibration, etc.	F1	Y	S2	Redundant system; design specifications	Routine inspection and maintenance	F1
		D.51 System failure through transfer equipment vibration	F1	Y	S2	Design specification; transfer equipment isolated from HVAC equipment	Routine inspection and maintenance	F1
Impact and Shock	Structural impact	D.52 Vehicular collision with above grade ventilation system/component	See "Structural Damage or Failure" hazards					

Table C.3c. PHA For Tank Storage Operations - Risers, Central Pump Pit, Sluice Pit, And Other Dome Penetrations or Equipment
(See Section 2.2 for definitions)

HAZARD	PHENOMENA	CAUSES	CAUSE FREQ.	CONSEQ.		PREVENTION/MITIGATION		SCENA. FREQ.
				OCCU.	SEV.	ENGINEERING	ADMINISTRATIVE	
Corrosion	Breach through the risers, pits, and other penetrations	E.1 Riser failure from vapor space corrosion	F1	N	S1	Tank design; material selection	K Basin sludge property and material property controls	F1
		E.2 Risers to dome corrosion accelerated by sludge	F1	N	S1	Leak detection in pump pit; tank design; pit coverblocks; material selection		F1
		E.3 Blanked risers; seals corrosion accelerated by sludge	F1	N	S1			F1
		E.4 Equipments corrosion accelerated by sludge	F1	N	S1			F1
Explosion	Breach of structure integrity	E.5 Hydrogen gas exhausted from tank	F1	Y	S2	Ventilation system	Waste compatibility program	F0
Fire	Breach of structure integrity, exothermic release	E.6 Spark sources from electrical instrument or pump motor ignite flammable vapor	F1	Y	S2	Electrical bonding; use of spark resistant equipment; ventilation system	Tank farm safety practices	F0
		E.7 Pyrophoric or organic materials	F1	Y	S2	Ventilation system	Exothermic reaction control	F0
		E.8 Vicinity welding creates fire and ignites flammable gas/vapors	F1	Y	S2	Non-combustible materials	Welding procedures; herbicide; gravel overburden; combustible materials control program	F0
		E.9 External fire ignites flammable gas	F1	Y	S2	Riser, pit, other penetration or equipment isolation	Flammable gas control, routine maintenance and inspection, herbicide, gravel overburden	F0

HAZARD	PHENOMENA	CAUSES	CAUSE FREQ.	CONSEQ.		PREVENTION/MITIGATION		SCENA. FREQ.
				OCCU.	SEV.	ENGINEERING	ADMINISTRATIVE	
Leakage (vapor)	Release of hazardous airborne or gaseous material	E.10 Riser gasket degradation	F1	Y	S1	Radiation monitoring; tank vapor head space maintains negative pressure; Ventilation system.	WHC-IP-0842, Waste tanks administration, Health Physics Technician survey procedures and radiation work permit for opening	F1
		E.11 Riser or pump pit opening for equipment installation or removal	F3	Y	S1			F3
		E.12 Riser left open due to human error	F3	Y	S1			F2
		E.13 Infiltration through pump pit drain lines	F1	N	S1			F1
		E.14 Infiltration through leak detection pit drains	F2	N	S1			F2
		E.15 Infiltration through instrument opening	F3	Y	S1			F3
		E.16 Infiltration through the central pump pit to annulus pump pit cross-connection line	F3	N	S1			F3
Leakage (liquid)	Release of liquid	E.17 Sludge leakage to pit	F2	Y	S1	Leak detection; draining system	Tank farm operating procedures	F1
		E.18 Cover block left open	F3	Y	S2		Cover block operating procedures	F2
Pressure - High	Integrity impact	E.19 Riser failure from tank pressurization (vapor or liquid)	F1	Y	S2	Ventilation system	Air balance control	F0
		E.20 Pit failure from tank pressurization	F1	Y	S2			F1

HAZARD	PHENOMENA	CAUSES	CAUSE FREQ.	CONSEQ.		PREVENTION/MITIGATION		SCENA. FREQ.
				OCCU.	SEV.	ENGINEERING	ADMINISTRATIVE	
Radiation - Ionizing	Internal or external exposure to excessive dose	E.21 Vapors in riser, pump pit or other penetrations	F2	Y	S1	Radiation monitor; vent system	Radiation control	F0
Structural Damage/ Failure	Breach of structure integrity	E.22 Vehicle collision with riser	F2	Y	S1	Marked roadway, vent system	Operations standing order requiring a spotter for vehicles.	F2
		E.23 External dropped equipment or objects	F2	Y	S1	Design specifications; tank and pits vent system	Tank farm heavy loading restrictions	F1
		E.24 Riser failure from dome/riser overburden	F1	Y	S1		Dome loading surveys by TFSE in accordance with WHC-SD-WM-MA-012, Waste Tank Dome Loading Survey Program, review WHC-IP-0842	F0
		E.25 Loss of integrity through pit openings	F2	Y	S1	Design specifications; tank and pits vent system	WHC-IP-0842, Waste tanks administration, Health Physics Technician survey procedures and radiation work permit for opening	F0
Vibration and Noise	Repeated rapid movement from external sources	E.26 Riser failure from equipment vibration or torque	F2	N	S1	Tank design; vent system; material selection		F1

Tale C.3d. PHA for Storage Operations - Piping, Annulus Pump Pit, And Leak Detection Pit
(See Section 2.2 for definitions)

HAZARD	PHENOMENA	CAUSES	CAUSE FREQ.	CONSEQ.		PREVENTION/MITIGATION		SCENA. FREQ.
				OCCU.	SEV.	ENGINEERING	ADMINISTRATIVE	
Corrosion	Breach of structure integrity; loss of instrumentation and control	F.1 Equipment/piping within pit corrosion accelerated by sludge	F1	N	S1	Leak detection	K Basin sludge property and material property controls	F0
		F.2 Piping corrosion accelerated by sludge	F1	N	S1	Piping isolation; cathodic protection; design; material selection		F0
Electrical	Electrical short/sparks	F.3 Loss of leak detection pit motor	Conditional failure, contributes to other hazards					
		F.4 Loss of annulus pump pit motor	Conditional failure, contributes to other hazards					
		F.5 Loss of instrumentation and control	Conditional failure, contributes to other hazards					
		F.6 Electrical fault in electric-driven equipment	Conditional failure, contributes to other hazards					
Explosion	Breach of structure integrity	F.7 Concentration of pyrophoric, hydrogen, or flammable gas within pit	F1	Y	S2	Leak detection; Ventilation system	Waste compatibility program; sampling; characterization	F0
		F.8 Concentration of pyrophoric, hydrogen, or flammable gas within a pipe	F1	Y	S2	Line flush		F0
Fire	Breach of structure integrity, exothermic release	F.9 Pyrophoric material in pit	F1	Y	S2	Tank level monitor; leak detection	Tank farm safety practices	F0
		F.10 Accumulated pyrophoric material in pipe.	F1	Y	S2	Line flush; leak detector		F0

HAZARD	PHENOMENA	CAUSES	CAUSE FREQ.	CONSEQ.		PREVENTION/MITIGATION		SCENA. FREQ.
				OCCU.	SEV.	ENGINEERING	ADMINISTRATIVE	
		F.11 Spark sources ignite hydrogen gas concentrated in pit	F1	Y	S2	Ventilation system; leak detection	Tank farm safety practices	F0
		F.12 Inadvertent connection made with other flammable gas tanks	F1	Y	S3	Tank level (Receiving tank)	Waste compatibility program; routine material balance	F0
Leakage (Gas, Vapor, Liquid)	Release of gas and/or liquid	F.13 Pipe rupture	F2	Y	S2	Primary containment; encased lines	Routine maintenance and inspection	F1
		F.14 Pit rupture	F2	Y	S1	Lined pits		F1
Radiation - Ionizing	Internal or external exposure to excessive dose	F.15 Exposure to leakage through pipe or pit	F1	Y	S1	Primary containment, encased piping	WHC-SD-WM-HSP-002, Tank Farm Health and Safety Plan; Rad Protection Program	F1
		F.16 Fuel fleas	F3	Y	S1			F2
Structural damage/Failure	Breach of structure integrity	F.17 Transfer piping overburden	F2	Y	S1	Primary containment; Design specification for stress due to overburden	Routine maintenance and inspection	F1
		F.18 Pit or equipment overburden	F2	Y	S1			F1
		F.19 External dropped equipment or objects	F2	Y	S1	Primary containment; annular tank; tank structural design; encased piping; coverblocks	Crane operation training	F1
		F.20 External pressure from ground creep and movement	F2	Y	S1		Routine maintenance and inspection	F1
		F.21 Vehicular collision with above grade transfer system component	F2	Y	S1		Operations standing order requiring a spotter for vehicles; driver qualification	F1
		F.22 Vehicular collision with pit structure or component	F2	Y	S1			F1

HAZARD	PHENOMENA	CAUSES	CAUSE FREQ.	CONSEQ.		PREVENTION/MITIGATION		SCENA. FREQ.
				OCCU.	SEV.	ENGINEERING	ADMINISTRATIVE	
Vibration and Noise	Repeated rapid movement from external sources	F.23 Pipes and pit failure through transfer vibration	F1	N	S1	Primary containment	Routine maintenance and inspection	F1

APPENDIX D

HAZARDOUS CHEMICAL CONSEQUENCE ASSESSMENT SPREADSHEET

ONSITE RECEPTOR

Unit Release		Type	Duration	X/Q
Onsite Receptor	Onsite	Steady state	> 3.5 s	3.41E-02 s/m3
All Frequencies	Onsite	Puff	< 3.5 s	9.85E-03 per m3

	Fraction of Risk Guideline, Steady-state release			Fraction of Risk Guideline, Puff release		
	Anticipated	Unlikely	EU	Anticipated	Unlikely	EU
Corrosives, Irritants						
Ammonia (NH3)	2.61E-01	1.31E-02	5.22E-03	7.54E-02	3.77E-03	1.51E-03
Barium (Ba metal)	8.54E-01	4.21E-02	1.69E-02	2.47E-01	1.22E-02	4.88E-03
Chromium (Cr+3 metal)	7.52E+00	3.80E-01	1.52E-01	2.17E+00	1.10E-01	4.38E-02
Sodium hydroxide (NaOH)	7.62E+01	3.81E+00	1.52E+00	2.20E+01	1.10E+00	4.40E-01
TOC	4.57E-03	9.14E-04	2.74E-04	1.32E-03	2.64E-04	7.92E-05
Sum of Fractions	8.48E+01	4.25E+00	1.70E+00	2.45E+01	1.23E+00	4.90E-01
Allowable release	1.2E-02	2.4E-01	5.9E-01	4.1E-02	8.2E-01	2.0E+00
Units		Liters per second			Liters	
Toxics						
Berylium (Be metal)	4.54E+01	1.09E+01	2.72E+00	1.31E+01	3.15E+00	7.87E-01
Cadmium (Cd metal)	3.94E+00	7.88E-01	7.88E-02	1.14E+00	2.28E-01	2.28E-02
Copper (Cu metal)	3.23E+00	1.94E+00	3.87E-01	9.32E-01	5.59E-01	1.12E-01
Selenium (Se metal)	1.93E+01	9.64E+00	1.93E+00	5.57E+00	2.78E+00	5.57E-01
Thallium (Tl metal)	2.60E+01	3.90E+00	3.90E-01	7.52E+00	1.13E+00	1.13E-01
Uranium (U metal)	4.37E+03	4.37E+02	2.18E+02	1.26E+03	1.26E+02	6.31E+01
Polychlorinated Biphenyls	2.03E-02	1.22E-02	6.10E-03	5.87E-03	3.52E-03	1.76E-03
Sum of Fractions	4.42E+03	4.52E+02	2.21E+02	1.28E+03	1.31E+02	6.39E+01
Allowable release	2.3E-04	2.2E-03	4.5E-03	7.8E-04	7.7E-03	1.6E-02
Units		Liters per second			Liters	

OFFSITE RECEPTOR

Unit Release		Type	Duration	X/Q
Offsite receptor	Offsite	Steady state	> 420 s	2.83E-05 s/m3
All Frequencies	Offsite	Puff	< 420 s	1.14E-07 per m3

	Fraction of Risk Guideline, Steady-state release			Fraction of Risk Guideline, Puff release		
	Anticipated	Unlikely	EU	Anticipated	Unlikely	EU
Corrosives, Irritants						
Ammonia (NH3)	2.17E-04	2.17E-04	1.08E-05	8.73E-07	8.73E-07	4.36E-08
Barium (Ba metal)	9.64E-03	7.09E-04	3.49E-05	3.88E-05	2.86E-06	1.41E-07
Chromium (Cr+3 metal)	3.25E-02	6.24E-03	3.15E-04	1.31E-04	2.52E-05	1.27E-06
Sodium hydroxide (NaOH)	6.32E-02	6.32E-02	3.16E-03	2.55E-04	2.55E-04	1.27E-05
TOC	4.55E-06	3.79E-06	7.58E-07	1.83E-08	1.53E-08	3.06E-09
Sum of Fractions	1.06E-01	7.04E-02	3.52E-03	4.25E-04	2.84E-04	1.42E-05
Allowable release	9.5E+00	1.4E+01	2.8E+02	2.4E+03	3.5E+03	7.0E+04
Units		Liters per second			Liters	
Toxics						
Berylium (Be metal)	1.13E-01	3.77E-02	9.04E-03	4.55E-04	1.52E-04	3.64E-05
Cadmium (Cd metal)	1.31E-01	3.27E-03	6.54E-04	5.27E-04	1.32E-05	2.63E-06
Copper (Cu metal)	8.04E-03	2.68E-03	1.61E-03	3.24E-05	1.08E-05	6.47E-06
Selenium (Se metal)	1.60E-02	1.60E-02	8.00E-03	6.45E-05	6.45E-05	3.22E-05
Thallium (Tl metal)	6.48E-02	2.16E-02	3.24E-03	2.61E-04	8.70E-05	1.31E-05
Uranium (U metal)	1.81E+01	3.62E+00	3.62E-01	7.30E-02	1.46E-02	1.46E-03
Polychlorinated Biphenyls	5.06E-05	1.69E-05	1.01E-05	2.04E-07	6.79E-08	4.08E-08
Sum of Fractions	1.82E+01	3.67E+00	3.75E-01	7.34E-02	1.48E-02	1.51E-03
Allowable release	5.5E-02	2.7E-01	2.7E+00	1.4E+01	6.8E+01	6.6E+02
Units		Liters per second			Liters	

APPENDIX E

HVAC SYSTEM FAULT TREE ANALYSIS

APPENDIX E

HVAC SYSTEM FAULT TREE ANALYSIS

This appendix provides and documents the results of an assessment of the reliability of the active ventilation system installed at tank AW-105. Fault tree analysis was used to estimate the reliability of the HVAC system.

Figures E.1 and E.2 illustrate the 241-AW HVAC system. These drawings were derived from informaiton in Section 3.3 and formed the basis for estimating the probability of failure of the HVAC system.

The level of detail included in the fault tree was limited by the availability of detailed up-to-date system design and operating information. The system models were developed using the following sources of information:

1. Existing Westinghouse Hanford Company safety studies,
2. System schematics and operating procedures provided by WHC,
3. Verbal information from WHC cognizant engineers and technicians,
4. Published sources of data for component reliabilities, and
5. Engineering judgment.

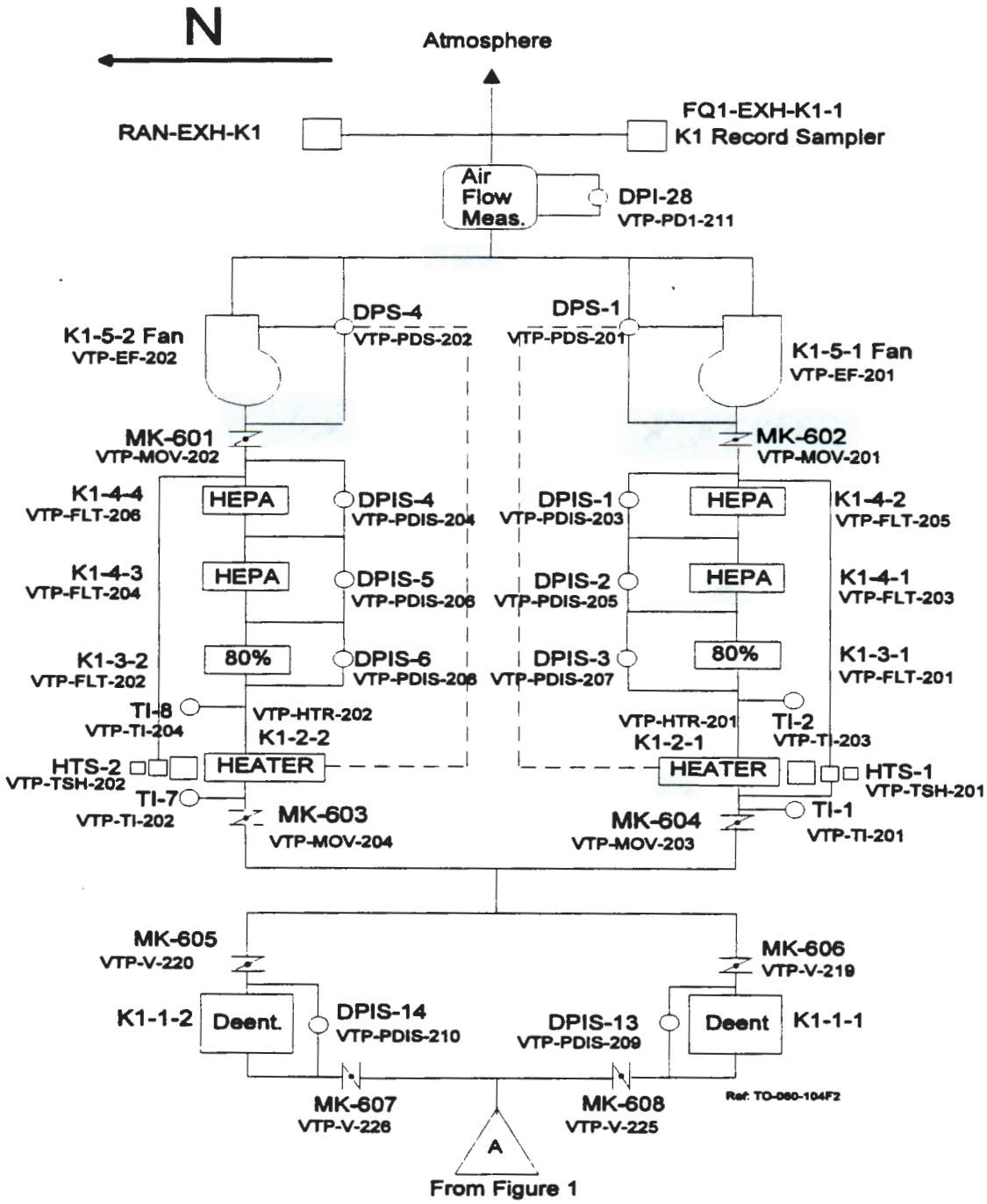
Figure E.3, sheets 1 to 4, shows the fault tree developed to model the 241-AW ventilation system. Failure of the ventilation system to maintain the tank pressure below established limits is modeled as an AND gate, named "VEN", with inputs from: 1) monitor/control systems failure and 2) ventilation system failure. Failure of the monitor/control systems (modeled as an OR gate, named VEN7) may result from equipment failure, alarm systems failure, loss of power or operator fails to respond.

Ventilation system failure is modeled as an OR gate, named "VEN1" with inputs from air inlet system failure and exhauster system failure. Failure of the air inlet system (modeled as an OR gate, named "VEN11") may result from filters failure/plugged, valves failure/plugged, vacuum breaker failure, air flow controller failure, and/or human errors. Failure of the exhauster system is modeled as an OR gate "VEN12" with 2 inputs, moisture separator paths failure and exhauster path failure. As mentioned in the system description section, there are 2 moisture separator paths in parallel, one named "K1-1-1" and the other named "K1-1-2". Hence failure of the moisture separator paths is modeled as an AND gate, named "VEN22". Failure of these paths may result from valves failure, moisture separator failure, exhauster failure and/or unavailable due to maintenance. There are 2 trains of the exhauter, K1-1 and K1-2, designed to perform in parallel. Exhauter subsystem failure is modeled as an AND gate, named "VEN23" with input from K1-1 and K1-2 subsystems failure. These systems may be failed by valves failure, heater failure, HEPA filters failure, and/or fan failure.

The fault tree and system quantification were modeled and performed using SAPHIRE 5.50. Table E.1 provides the basic event failure rates, probabilities, and the basis/rationale behind these values.

The fault tree cut set quantifcation report, developed by SAPPHIRE, is presented in Table E.2. The table shows the minimal cut sets generated by SAPPHIRE, that were generated from the HVAC system fault tree. Based on the basic event values shown in Table E.1., the ventilation system unavailability was calculated to be 9.28E-02. As shown, over 50% of the failure probability is due to a 2-element cut set involving loss of AC power to the HVAC system and failure to recover/restore AC power. The next-highest cut set, contributing over 10% of the total HVAC system unavailability, was a 3-element cut set involving failure of both exhaust fans and failure of an alarm to alert operators to the fan failures.

Birnbaum importance ranking was performed (see Table E.3) to identify the most important conponents of the HVAC system in terms of their contribution to system failure. Based on the results, failure to recover power was concluded to be the most important contributor to system failure. Isolation butterfly valve inadvertent closure and HEPA filters 205A and 205B failure were also identified as important contributors.



Deent. = De-entrainer

Figure E.1. 241-AW HVAC System Flow Diagram

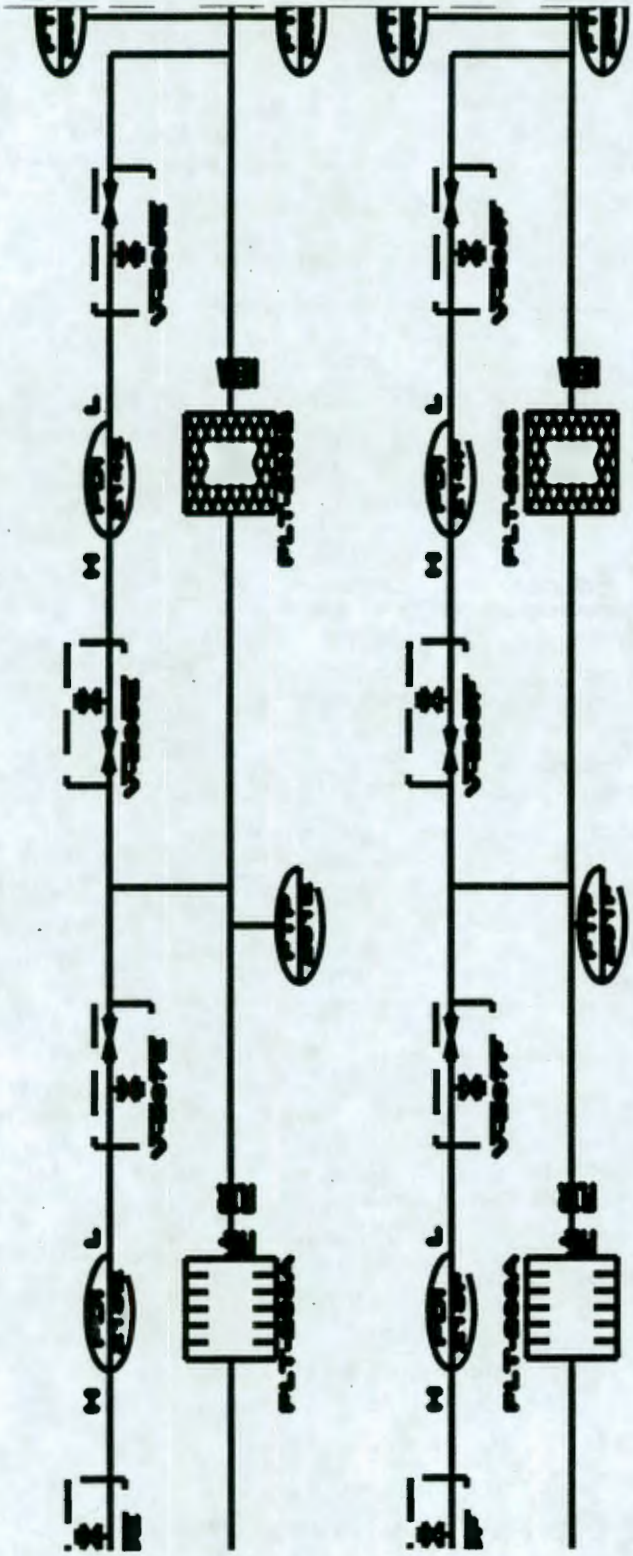


Figure E.2. Tanks 105-AW and 106-AW Air Inlet Station

Table E.1. Basic Event Failure Probability Data

BASIC EVENT	DESCRIPTION	PROBA-BILITY	BASIS/RATIONALE
VEN-AFC-FA-1	Air flow controller failure/plugged	7.71E-02	λ = 9.16E-6/hr (a)
VEN-AFC-HE-1	Human error	3.00E-03	λ = 3.0E-3/act (b)
VEN-ALA-FA-ALL	Alarm systems failure	1.97E-01	λ = 2.5E-5/hr (a)
VEN-DE-FA-K111	Moisture separator. K1-1-1 failure/plugged	1.23E-01	λ = 1.5E-5/hr (c)
VEN-DE-FA-K112	Moisture separator. K1-1-2 failure/plugged	1.23E-01	λ = 1.5E-5/hr (c)
VEN-FAN-FA-K151	Fan K1-5-1 failure/plugged	2.31E-01	λ = 3.0E-5/hr (d)
VEN-FAN-FA-K152	Fan K1-5-2 failure/plugged	2.31E-01	λ = 3.0E-5/hr (d)
VEN-FLT-FA-205A	Pre-filter failure/plugged	3.00E-03	(probability) 3.0E-3 (b)
VEN-FLT-FA-205B	HEPA Filter failure/plugged	3.00E-03	(probability) 3.0E-3 (b)
VEN-HEA-FA-HTS1	Heater HTS-1 failure/plugged	8.37E-02	λ = 1.5E-5/hr (c)
VEN-HEA-FA-HTS2	Heater HTS-2 failure/plugged	8.37E-02	λ = 1.5E-5/hr (c)
VEN-HEP-FA-K141	HEPA filter K1-4-1 failure/plugged	3.00E-03	(probability) 3.0E-3 (b)
VEN-HEP-FA-K142	HEPA filter K1-4-2 failure/plugged	3.00E-03	(probability) 3.0E-3 (b)
VEN-HEP-FA-K143	HEPA Filter K1-4-3 failure/plugged	3.00E-03	(probability) 3.0E-3 (b)
VEN-HEP-FA-K144	HEPA filter K1-4-4 failure/plugged	3.00E-03	(probability) 3.0E-3 (b)
VEN-MON-FA-ALL	Monitor/control equipment failure	3.95E-02	λ = 4.6E-6/hr (a)
VEN-MOV-FA-MK601	Valve MK-601 failure/plugged	3.06E-03	λ = 3.5E-7/hr (a)

BASIC EVENT	DESCRIPTION	PROBA-BILITY	BASIS/RATIONALE
VEN-MOV-FA-MK602	Valve MK-602 failure/plugged	3.06E-03	λ = 3.5E-7/hr (a)
VEN-MOV-FA-MK603	Valve MK-03 failure/plugged	3.06E-03	λ = 3.5E-7/hr (a)
VEN-MOV-FA-MK604	Valve MK-604 failure/plugged	3.06E-03	λ = 3.5E-7/hr (a)
VEN-MOV-FO-MK603	Valve MK-603 fails to open	3.00E-03	(Fails to open on demand) 3.0E-3/denabd (f)
VEN-OPE-DIAGNOSE	Operator fails to diagnose and open valve MK-603	5.00E-02	λ = 5.0E-2/act. (b)
VEN-PAT-UA-K111	Path K1-1-1 unavailable due to maintenance	3.84E-02	Assumed 2 weeks per year ventilation system is down for service 336 hr per yr / 8760 hr per yr = 3.84E-02
VEN-PAT-UA-K112	Path K1-1-2 unavailable due to maintenance	3.84E-02	Assumed 2 weeks per year ventilation system is down for service 336 hr per yr / 8760 hr per yr = 3.84E-02
VEN-POW-LOSS	Loss of power	1.00E-02	1.0E-2/yr (e)
VEN-RES-HUMERR	Operator fails to response	5.00E-02	5.0E-2/act (b)
VEN-VAL-FA-254E	Isolation butterfly valve failure/plugged	4.37E-03	λ = 3.5E-7/hr (a)
VEN-VAL-FA-MK605	Butterfly valve MK-605 failure/plugged	3.06E-03	λ = 3.5E-7/hr (a)
VEN-VAL-FA-MK606	Butterfly valve MK-606 failure/plugged	3.06E-03	λ = 3.5E-7/hr (a)
VEN-VAL-FA-MK607	Butterfly valve MK-607 failure/plugged	3.06E-03	λ = 3.5E-7/hr (a)
VEN-VAL-FA-MK608	Butterfly valve MK-608 failure/plugged	3.06E-03	λ = 3.5E-7/hr (a)
VEN-VBR-AU-1	Vacuum breaker fails to automatically actuate	1.00E-02	λ = 1.0E-2/d (a)

BASIC EVENT	DESCRIPTION	PROBA-BILITY	BASIS/RATIONALE
VEN-VBR-MA-1	Vacuum breaker fails to manually actuate	6.00E-02	Assumed operator error = 5.0E-2 and vacuum breaker λ = 1.0E-2/demand

λ = Component failure rate (failures per unit time).

(a) IEEE-500
(b) RCS-SA
(c) Oconee PRA
(d) NUCLARR
(e) Trojan Database
(f) NUREG/CR-4550

Table E.2. System Cut Sets (Quantification) Report

Family : KBASIN Analysis : RANDOM
System : VEN Case : ALTERNATE
Mincut Upper Bound : 9.282E-002

Cut No.	% Total	% Cut Set	Prob/ Freq.	CUT SETS
1	53.8	53.8	5.0E-002	VEN-POW-LOSS, VEN-POW-RECOVERY
2	65.1	11.3	1.0E-002	VEN-ALA-FA-ALL, VEN-FAN-FA-K151, VEN-FAN-FA-K152
3	69.2	4.1	3.8E-003	VEN-ALA-FA-ALL, VEN-FAN-FA-K151, VEN-HEA-FA-HTS2
4	73.3	4.1	3.8E-003	VEN-ALA-FA-ALL, VEN-FAN-FA-K152, VEN-HEA-FA-HTS1
5	76.6	3.2	2.9E-003	VEN-ALA-FA-ALL, VEN-DE-FA-K111, VEN-DE-FA-K112
6	79.4	2.8	2.6E-003	VEN-FAN-FA-K151, VEN-FAN-FA-K152, VEN-RES-HUMERR
7	81.9	2.4	2.2E-003	VEN-ALA-FA-ALL, VEN-FAN-FA-K151, VEN-OPE-DIAGNOSE
8	84.1	2.2	2.1E-003	VEN-FAN-FA-K151, VEN-FAN-FA-K152, VEN-MON-FA-ALL
9	85.6	1.4	1.3E-003	VEN-ALA-FA-ALL, VEN-HEA-FA-HTS1, VEN-HEA-FA-HTS2
10	86.7	1.0	9.6E-004	VEN-FAN-FA-K151, VEN-HEA-FA-HTS2, VEN-RES-HUMERR
11	87.7	1.0	9.6E-004	VEN-FAN-FA-K152, VEN-HEA-FA-HTS1, VEN-RES-HUMERR
12	88.7	0.9	8.9E-004	VEN-ALA-FA-ALL, VEN-DE-FA-K111, /VEN-PAT-UA-K111, VEN-PAT-UA-K112
13	89.6	0.9	8.9E-004	VEN-ALA-FA-ALL, VEN-DE-FA-K112, VEN-PAT-UA-K111, /VEN-PAT-UA-K112
14	90.6	0.9	8.6E-004	VEN-ALA-FA-ALL, VEN-VAL-FA-254E
15	91.5	0.8	8.2E-004	VEN-ALA-FA-ALL, VEN-HEA-FA-HTS1, VEN-OPE-DIAGNOSE
16	92.3	0.8	7.6E-004	VEN-FAN-FA-K151, VEN-HEA-FA-HTS2, VEN-MON-FA-ALL
17	93.1	0.8	7.6E-004	VEN-FAN-FA-K152, VEN-HEA-FA-HTS1, VEN-MON-FA-ALL
18	93.9	0.8	7.5E-004	VEN-DE-FA-K111, VEN-DE-FA-K112, VEN-RES-HUMERR
19	94.6	0.6	5.9E-004	VEN-DE-FA-K111, VEN-DE-FA-K112, VEN-MON-FA-ALL
20	95.2	0.6	5.9E-004	VEN-ALA-FA-ALL, VEN-FLT-FA-205A

Cut No.	% Total	% Cut Set	Prob/ Freq.	CUT SETS
21	95.8	0.6	5.9E-004	VEN-ALA-FA-ALL, VEN-FLT-FA-205B
22	96.5	0.6	5.7E-004	VEN-FAN-FA-K151, VEN-OPE-DIAGNOSE, VEN-RES-HUMERR
23	97.0	0.4	4.5E-004	VEN-FAN-FA-K151, VEN-MON-FA-ALL, VEN-OPE-DIAGNOSE
24	97.3	0.3	3.5E-004	VEN-HEA-FA-HTS1, VEN-HEA-FA-HTS2, VEN-RES-HUMERR
25	97.6	0.3	2.7E-004	VEN-HEA-FA-HTS1, VEN-HEA-FA-HTS2, VEN-MON-FA-ALL
26	97.9	0.2	2.2E-004	VEN-DE-FA-K111, /VEN-PAT-UA-K111, VEN-PAT-UA-K112, VEN-RES-HUMERR
27	98.1	0.2	2.2E-004	VEN-DE-FA-K112, VEN-PAT-UA-K111, /VEN-PAT-UA-K112, VEN-RES-HUMERR
28	98.4	0.2	2.1E-004	VEN-RES-HUMERR, VEN-VAL-FA-254E
29	98.6	0.2	2.0E-004	VEN-HEA-FA-HTS1, VEN-OPE-DIAGNOSE, VEN-RES-HUMERR
30	98.8	0.1	1.8E-004	VEN-DE-FA-K111, VEN-MON-FA-ALL, /VEN-PAT-UA-K111, VEN-PAT-UA-K112
31	99.0	0.1	1.8E-004	VEN-DE-FA-K112, VEN-MON-FA-ALL, VEN-PAT-UA-K111, /VEN-PAT-UA-K112
32	99.2	0.1	1.7E-004	VEN-MON-FA-ALL, VEN-VAL-FA-254E
33	99.3	0.1	1.6E-004	VEN-HEA-FA-HTS1, VEN-MON-FA-ALL, VEN-OPE-DIAGNOSE
34	99.5	0.1	1.5E-004	VEN-FLT-FA-205A, VEN-RES-HUMERR
35	99.7	0.1	1.5E-004	VEN-FLT-FA-205B, VEN-RES-HUMERR
36	99.8	0.1	1.3E-004	VEN-ALA-FA-ALL, VEN-FAN-FA-K151, VEN-MOV-FA-MK601
37	100.0	0.1	1.3E-004	VEN-ALA-FA-ALL, VEN-FAN-FA-K151, VEN-MOV-FA-MK603
38	100.0	0.1	1.3E-004	VEN-ALA-FA-ALL, VEN-FAN-FA-K152, VEN-MOV-FA-MK602
39	100.0	0.1	1.3E-004	VEN-ALA-FA-ALL, VEN-FAN-FA-K152, VEN-MOV-FA-MK604
40	100.0	0.1	1.3E-004	VEN-ALA-FA-ALL, VEN-FAN-FA-K151, VEN-HEP-FA-K143
41	100.0	0.1	1.3E-004	VEN-ALA-FA-ALL, VEN-FAN-FA-K151, VEN-HEP-FA-K144
42	100.0	0.1	1.3E-004	VEN-ALA-FA-ALL, VEN-FAN-FA-K151, VEN-MOV-FO-MK603

Cut No.	% Total	% Cut Set	Prob/ Freq.	CUT SETS
43	100.0	0.1	1.3E-004	VEN-ALA-FA-ALL, VEN-FAN-FA-K152, VEN-HEP-FA-K141
44	100.0	0.1	1.3E-004	VEN-ALA-FA-ALL, VEN-FAN-FA-K152, VEN-HEP-FA-K142

Table E.3. System Importance Measures Report

Family : KBASIN Analysis : RANDOM
System : VEN Case : ALTERNATE

(Sorted by Birnbaum Importance Measure)

Event Name	Num. of Occ.	Prob. of Failure	Birnbaum Importance Measure	Risk Reduction Difference	Risk Increase Difference
VEN-POW-RECOVERY	1	5.000E-002	9.549E-001	4.774E-002	9.071E-001
VEN-VAL-FA-254E	3	4.370E-003	2.425E-001	1.135E-003	2.413E-001
VEN-FLT-FA-205B	3	3.000E-003	2.424E-001	7.793E-004	2.416E-001
VEN-FLT-FA-205A	3	3.000E-003	2.424E-001	7.793E-004	2.416E-001
VEN-ALA-FA-ALL	68	1.966E-001	1.408E-001	2.924E-002	1.116E-001
VEN-RES-HUMERR	68	5.000E-002	1.375E-001	7.331E-003	1.302E-001
VEN-MON-FA-ALL	68	3.949E-002	1.373E-001	5.785E-003	1.315E-001
VEN-FAN-FA-K151	24	2.311E-001	9.699E-002	2.315E-002	7.384E-002
VEN-HEA-FA-HTS1	24	8.371E-002	9.545E-002	8.303E-003	8.714E-002
VEN-MOV-FA-MK604	24	3.061E-003	9.461E-002	3.020E-004	9.431E-002
VEN-MOV-FA-MK602	24	3.061E-003	9.461E-002	3.020E-004	9.431E-002
VEN-HEP-FA-K141	24	3.000E-003	9.461E-002	2.959E-004	9.432E-002
VEN-HEP-FA-K142	24	3.000E-003	9.461E-002	2.959E-004	9.432E-002
VEN-FAN-FA-K152	18	2.311E-001	8.392E-002	1.989E-002	6.402E-002
VEN-HEA-FA-HTS2	18	8.371E-002	8.276E-002	7.141E-003	7.562E-002
VEN-OPE-DIAGNOSE	18	5.000E-002	8.250E-002	4.256E-003	7.825E-002
VEN-MOV-FA-MK601	18	3.061E-003	8.214E-002	2.598E-004	8.188E-002
VEN-MOV-FA-MK603	18	3.061E-003	8.214E-002	2.598E-004	8.188E-002
VEN-HEP-FA-K144	18	3.000E-003	8.214E-002	2.546E-004	8.189E-002
VEN-HEP-FA-K143	18	3.000E-003	8.214E-002	2.546E-004	8.189E-002
VEN-MOV-FO-MK603	18	3.000E-003	8.214E-002	2.546E-004	8.189E-002
VEN-POW-LOSS	1	1.000E+000	4.774E-002	4.774E-002	1.387E-017
VEN-DE-FA-K112	12	1.231E-001	4.269E-002	5.332E-003	3.735E-002
VEN-DE-FA-K111	12	1.231E-001	4.269E-002	5.332E-003	3.735E-002
VEN-VAL-FA-MK605	12	3.061E-003	4.244E-002	1.320E-004	4.231E-002

Event Name	Num. of Occ.	Prob. of Failure	Birnbaum Importance Measure	Risk Reduction Difference	Risk Increase Difference
VEN-VAL-FA-MK607	12	3.061E-003	4.244E-002	1.320E-004	4.231E-002
VEN-VAL-FA-MK606	12	3.061E-003	4.244E-002	1.320E-004	4.231E-002
VEN-VAL-FA-MK608	12	3.061E-003	4.244E-002	1.320E-004	4.231E-002
VEN-PAT-UA-K112	18	3.840E-002	3.076E-002	1.190E-003	2.957E-002
VEN-PAT-UA-K111	18	3.840E-002	3.076E-002	1.190E-003	2.957E-002
VEN-VBR-AU-1	6	1.000E-002	1.237E-003	1.237E-005	1.224E-003
VEN-VBR-MA-1	6	5.950E-002	2.079E-004	1.237E-005	1.955E-004
VEN-AFC-FA-1	3	7.710E-002	1.544E-004	1.191E-005	1.425E-004
VEN-AFC-HE-1	3	3.000E-003	1.544E-004	4.634E-007	1.540E-004

REFERENCES FOR APPENDIX E

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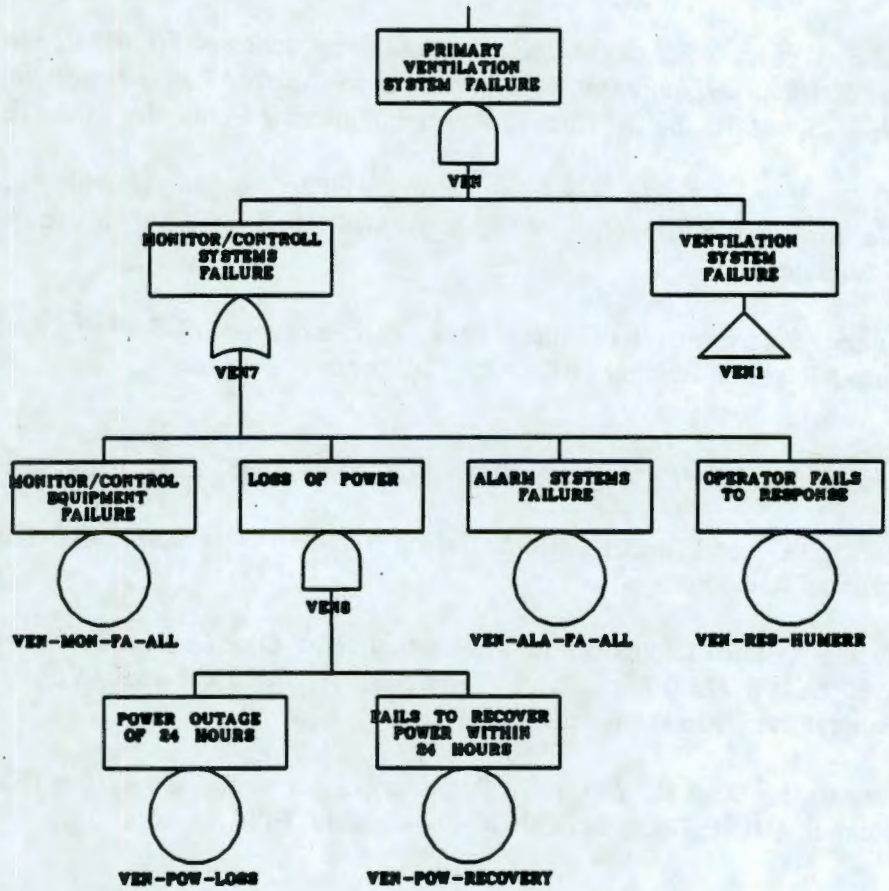

Figure E.3. Primary Ventilation System Fault Tree (Sheet 1 of 4)

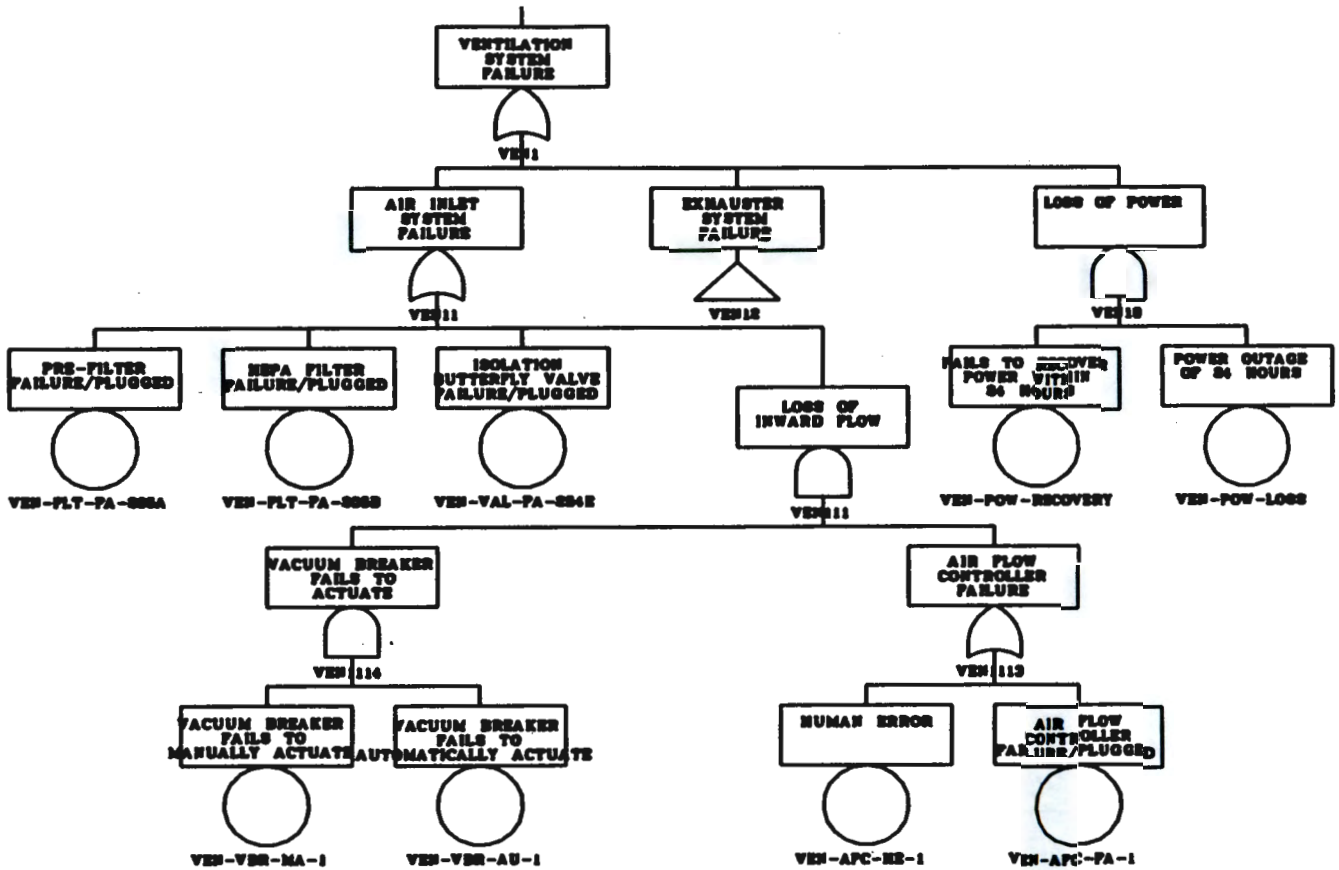

Figure E.3. Primary Ventilation System Fault Tree (Sheet 2 of 4)

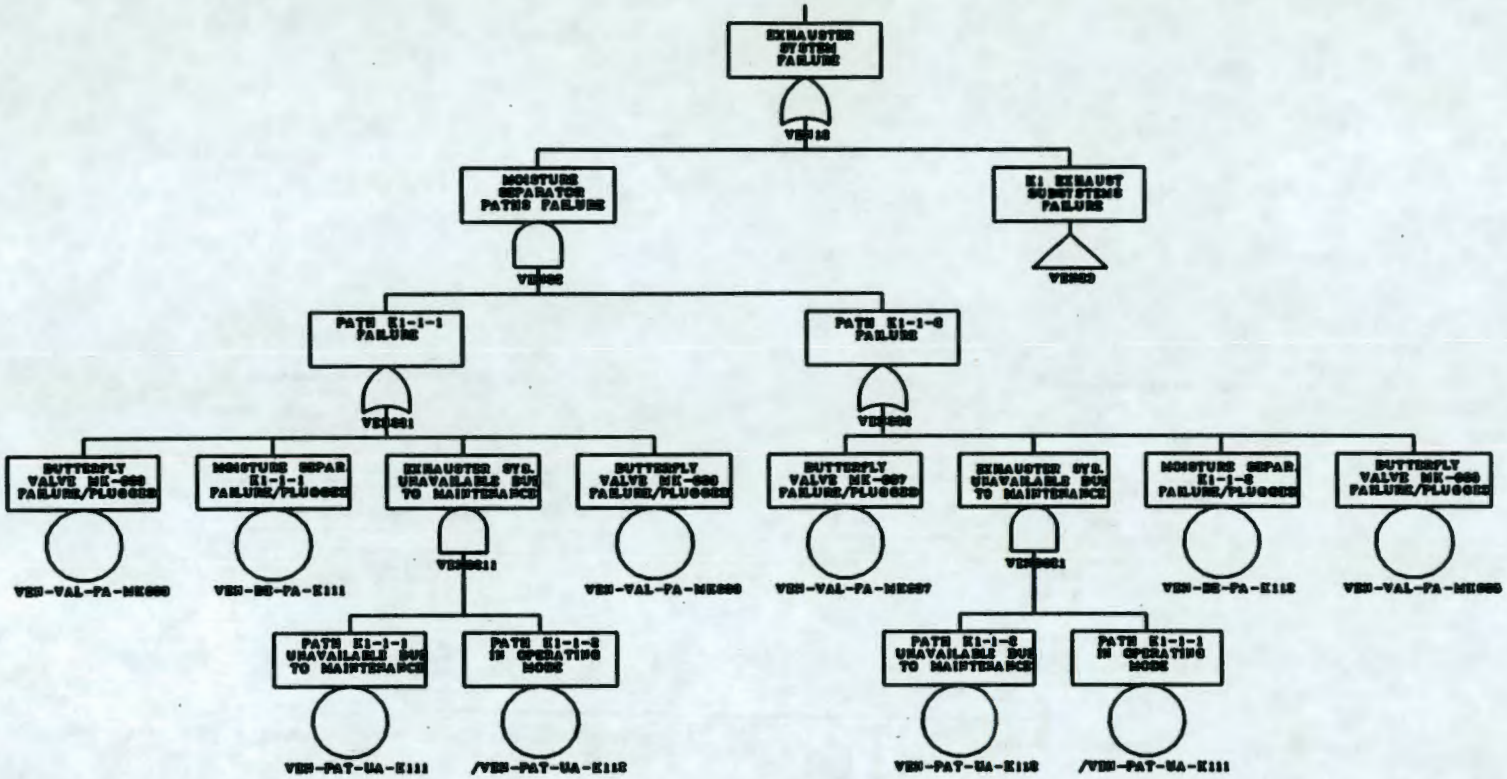

Figure E.3. Primary Ventilation System Fault Tree (Sheet 3 of 4)

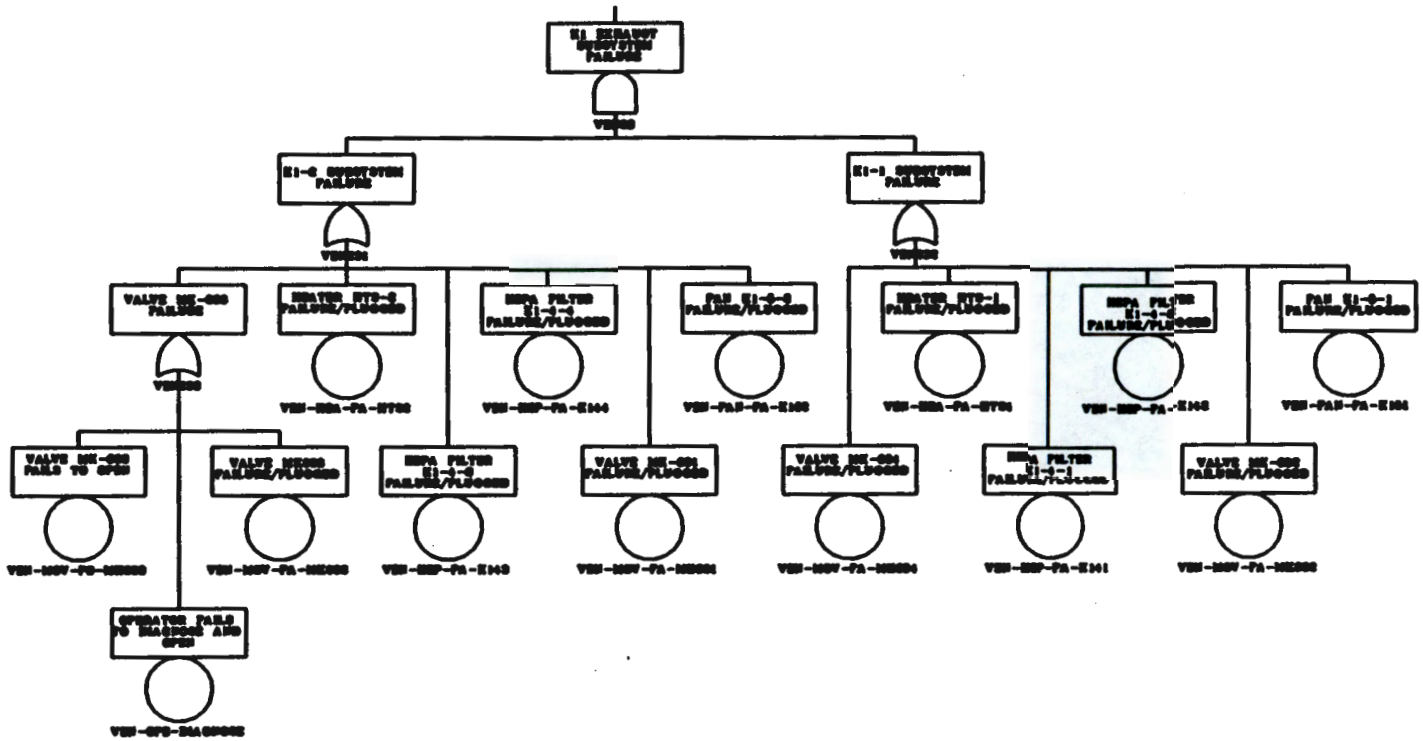

Figure E.3. Primary Ventilation System Fault Tree (Sheet 4 of 4)

APPENDIX F

THE CORROSION OF URANIUM IN A DOUBLE-SHELL TANK ENVIRONMENT

M. D. Danielson

NOTE: This appendix is reformatted and reprinted version of a literature survey performed by the author in 1995.

F.1 BACKGROUND

WHC is currently working on an accelerated schedule to remove the spent fuel from the K-basins. Work is to start by December 1997 and be completed in two years. The sludge from the bottom of the basin (containing metallic uranium from ruptured fuel) will be shipped to the TWRS facility for interim storage in tanks AW-103 or AW-105. A major issue is the acceptability of the fuel sludge by the TWRS facility since it will be added to tanks containing liquid and solid wastes. The purpose of this task is to determine the general corrosion rate of reactor grade metallic uranium in the chemical environment that will be encountered in waste tanks AW-103 or AW-105 (See Table F.1 for compositions). Reactor grade uranium at Hanford has the following approximate composition (Pearce 1995a): 0.07-.09% Al, 0.036-.074% Fe, and 0.010% Si.

F.2 RESULTS

Most of the uranium corrosion work is decades old (Weirick 1979). The work generally falls into two categories: (1) corrosion of uranium in contact with high temperature water ($T > 100°C$) which is probably driven by a concern with the failure of fuel cladding under reactor operating conditions, and (2) corrosion under moist, oxygenated, ambient temperature conditions which is driven by the use of uranium as high energy penetrators (armor piercing projectiles). Recently, uranium corrosion was reviewed in a Hanford study (Puigh 1995) that explored the technical basis for fuel removal from the K basins. This study reviewed the general aspects of uranium corrosion with a focus on hydrogen gas evolution and the corrosion kinetics in moist environments. There are no corrosion data in the literature for the specific liquid solution conditions ($T \leq 100°C$, oxygenated, caustic, nitrites, and nitrates) associated with Hanford waste tanks (see Table F.1 for waste tank compositions).

Uranium is a silvery metal that is highly reactive in an aqueous environment. Figure F.1 shows two Pourbaix diagrams (Pourbaix 1974) based on U and UH_3, respectively. The metal and hydride phases are far below the equilibrium lines for hydrogen evolution ('a') and oxygen reduction ('b') indicating that both the metal and hydride will spontaneously corrode even in the absence of oxygen with the formation of UO_2. Balanced equations for the corrosion of uranium and uranium hydride by the reaction with water and oxygen are shown below:

$$U + 2H_2O \longrightarrow UO_2 + 2\,H_2\,(g) \quad (1)$$
$$U + O_2\,(g) \longrightarrow UO_2 \quad (2)$$
$$UH_3 + 2H_2O \longrightarrow UO_2 + (7/2)\,H_2\,(g) \quad (3)$$
$$UH_3 + (7/4)\,O_2\,(g) \longrightarrow UO_2 + (3/2)\,H_2O \quad (4)$$

The Pourbaix diagram indicates that UH_3 is more stable than U. Pourbaix diagrams are useful to the extent of predicting the most stable phases because they assume equilibrium conditions, but these diagrams have limited value for estimating the rate of a corrosion process. Waber (1960) reports that UO_2 is resistant to further attack in water up to 300°C. Karraker and Hobbs (1994) have determined the solubility of uranium oxides in simulated Savannah River Site wastes (see Figure F.2), and they conclude that aged, dissolved uranium has a number of oxidation states. The solubility of uranium oxides is quite low in hydroxide solutions.

Table F.1. Tank Compositions (concentrations in g/liter)

DST	Notes	pH	OH^-	NO_3^-	NO_2^-	Cl^-	F^-	TOC
241-AW-103	yellow analysis dated 9/30/94	12.9	2.48	3.44	1.12	0.12	17.2	0.94
241-AW-105	green analysis dated 8/25/94	12.9	4.19	5.64	1.19	0.035	1.79	0.31

Since oxygen has a low solubility in aqueous solutions, the major cathodic reaction will be hydrogen evolution during uranium corrosion. UH_3 is expected to form under the UO_2 film since uranium metal readily reacts with hydrogen. Waber (1960) reports that UH_3 corrodes at about the same rate as pure uranium. He measured corrosion rates of pure uranium of about 1 mg/cm^2/h (0.46 cm/y or 180 mils/y) in both air-saturated and hydrogen-saturated DI (deionized) water at 100°C. Weirick (1979) quotes a pure uranium metal corrosion rate in DI water at 25°C as 0.57 mg/cm^2/h (0.26 cm/y or 103 mils/y). The reaction product was identified as $UO_3 \bullet 0.8H_2O$. Tyfield (1988) measured a corrosion rate activation energy of 60 kJ/mole (14 kcal/mole) over a temperature range of 75-140°C for **reactor grade** uranium. Leach and Nehru (1964a) found a similar activation energy over the temperature range of 30-60°C for pure uranium. This fairly low activation energy indicates that a diffusional process plays a role in controlling the rate of the corrosion process.

Leach and Nehru (1964b) studied the room temperature (deoxygenated) corrosion of pure uranium at pHs of 9.7, 11.6, and 13 (0.1 N NaOH), values particularly appropriate to the present study. Unfortunately, their data are in terms of a relative rate constant related to oxide thickening rather than in terms of mass/area changes. They concluded that the corrosion rate is similar for pH 9.7 and 11.6 but that the rate increases at pH 13. There is an implication that the corrosion rate in alkaline solutions is somewhat greater than in DI water (pH $\approx$5.4). However, Tyfield (1988) in his literature review quotes a modest reduction (20%) in the corrosion rate at 100°C upon raising the pH from ~6 to ~13. Tyfield's own experiments with reactor grade uranium (Magnox fuel, contains ~0.1% Al and ~0.03% Fe) show a decrease in the corrosion rate of irradiated fuel by a factor of three when going from pH of 7 to 12.5 by NaOH addition at 30°C. He measured a rate of 0.015 mg/cm^2/h for irradiated fuel at 30°C in pH 12.5 solution containing 1 g/l fluoride. The presence of Al in **reactor grade** uranium acts to reduce the corrosion rate relative to **pure** uranium, and Tyfield's rate is approximately a factor of forty smaller than that observed for pure uranium (0.57 mg/cm^2/h) by Weirick (1979). Tyfield also examined the effect of fluoride ion concentration (1 and 10 g/l) on the corrosion rate. Fluoride increases the corrosion rate at a pH < 12.5 but has no effect at pH 12.5. Tyfield made a number of other valuable observations that are summarized below:

1) Uranium corrosion has an induction period which characterizes the process. No corrosion takes places during this period, and then the rate slowly increases to the steady state values reported in the literature. At pH 12.5 ($\leq$60°C), 1 g/l fluoride results in an induction time of about ten hours. The role of fluoride is to reduce the induction period.

2) The uranium oxide corrosion product over the metal surface consists of a thin, adherent black layer of UO_2 which is overlaid by a friable scale that readily spalls. Increasing the solution pH increases the proportion of fine particles in the spalled scale. UH_3 is present as a thin

film at the uranium/oxide interface with occasional fingers of penetration into the metal. Increasing the pH appears to inhibit the formation of UH_3 with only slight hydriding noted at pH 12.5.

3) Irradiated fuel corrodes similarly to unirradiated fuel. Any differences are due to an increased surface area induced by the swelling of the fuel.

The other issues relevant to the corrosion of uranium in Hanford waste concern the effects of nitrate, nitrite, and chloride. Based on open circuit potential measurements of pure uranium (Bullock 1976, Ward and Waber 1962, Levy and Zabielski 1974) in neutral pH water (deoxygenated), nitrate (0.1 molar studied) was found to be a more potent inhibitor that nitrite (0.0005, .005, .05, and .5 molar studied) after an observation period of sixteen hours. Curiously, no corrosion rate measurements were made, the assessment of the inhibitor potency being evaluated on the anodic (positive) open circuit potential. The presence of air resulted in even more anodic potentials than that determined in the nitrate solution, leading to some suspicion as to the validity of this assessment method. At lower pHs, chloride causes uranium to pit; however, in 1.0 M NaOH + 1.0 M NaCl, the pitting is completely suppressed (Levy and Zabielski 1974).

F.3 CONCLUSIONS

Waste tanks AW-103 and 105 contain significant amounts of hydroxide (2.48 and 4.19 g/l, respectively), nitrate (3.44 and 5.64 g/l), nitrite (1.12 and 1.19 g/l), and fluoride (17.2 and 1.79 g/l) (see Table F.1). Most of the literature data are not relevant for predicting the reactor grade uranium corrosion rates expected in the Hanford waste tank environment. The most relevant paper is that of Tyfield (1988), and he clearly shows that (1) reactor grade uranium corrodes at significantly lower rates than pure uranium, (2) that there is an induction period before the corrosion rates reach a steady value, (3) that fluoride ion at 10 g/l (tank AW-103 contains 17 g/l fluoride) does not have an accelerating effect in Hanford waste pH regime (pH > 12.5), (4) UO_2 is the dominant oxide and that it readily spalls, and (5) pH 12.5 inhibits the formation of uranium hydride. Tyfield's corrosion rate data of 0.015 $mg/cm^2/h$ for irradiated fuel at 30°C in pH 12.5 solution is the best estimate at the present time for the Hanford environment. Uranium dissolution in the Hanford waste tanks will undoubtedly be at higher temperatures which would result in a higher rate constant. However, the inhibiting effects of nitrate and nitrite are presently unknown but may act to greatly decrease the rate. The effects of fluoride and chloride can probably be ignored.

Using Tyfield's data at 30°C, it is possible to estimate the time required to dissolve reactor grade uranium in a spherical form, assuming that nitrate, nitrite, and elevated temperatures have no effect on the dissolution rate. The time for complete dissolution for pellets of 0.635 cm (0.25 inches) diameter is 46 years at 30°C. The derivation for this calculation is shown in Appendix 1A. Using Tyfield's activation energy, a factor of 80 increase in the corrosion rate would be expected if the corrosion process was carried out at 100°C. Complete dissolution would then be expected in 0.57 years (assuming no induction period). It should be emphasized that much of the available experimental data are the result of tests carried out with pure uranium, which has substantially different corrosion kinetics from reactor grade uranium. There are a few additional uncertainties that are discussed in the following section.

F.4 RECOMMENDED FUTURE WORK

The uranium corrosion literature is inconsistent, and corrosion rate measurements were rarely carried out with the result that the database is quite small. The most important work for this study is that of Tyfield (1988), and his experimental conditions differ significantly from the Hanford waste conditions in terms of temperature and solution composition. Test calculations using Tyfield's data indicate excessively long times for complete dissolution in the waste tanks at ambient temperature. The role of nitrates and nitrites as inhibitors on the corrosion rate of uranium is unknown, and their presence in the Hanford waste tanks may have a significant effect on the time for complete dissolution. It is recommended that corrosion testing be carried out at PNL under conditions relevant to Hanford waste tanks AW-103 and AW-105. This testing is relatively straight forward using the test protocol set forth by Tyfield. Tyfield monitored the increase in hydrogen pressure in sealed containers which contained the uranium metal and the test solution. The corrosion rate is directly proportional to the increase in hydrogen pressure over time. A statistical (Plackett-Burman) test matrix of solution compositions and temperature would be chosen to minimize the number of tests. The test variables would be temperature, pH, nitrate concentration, nitrite concentration, and fluoride concentration.

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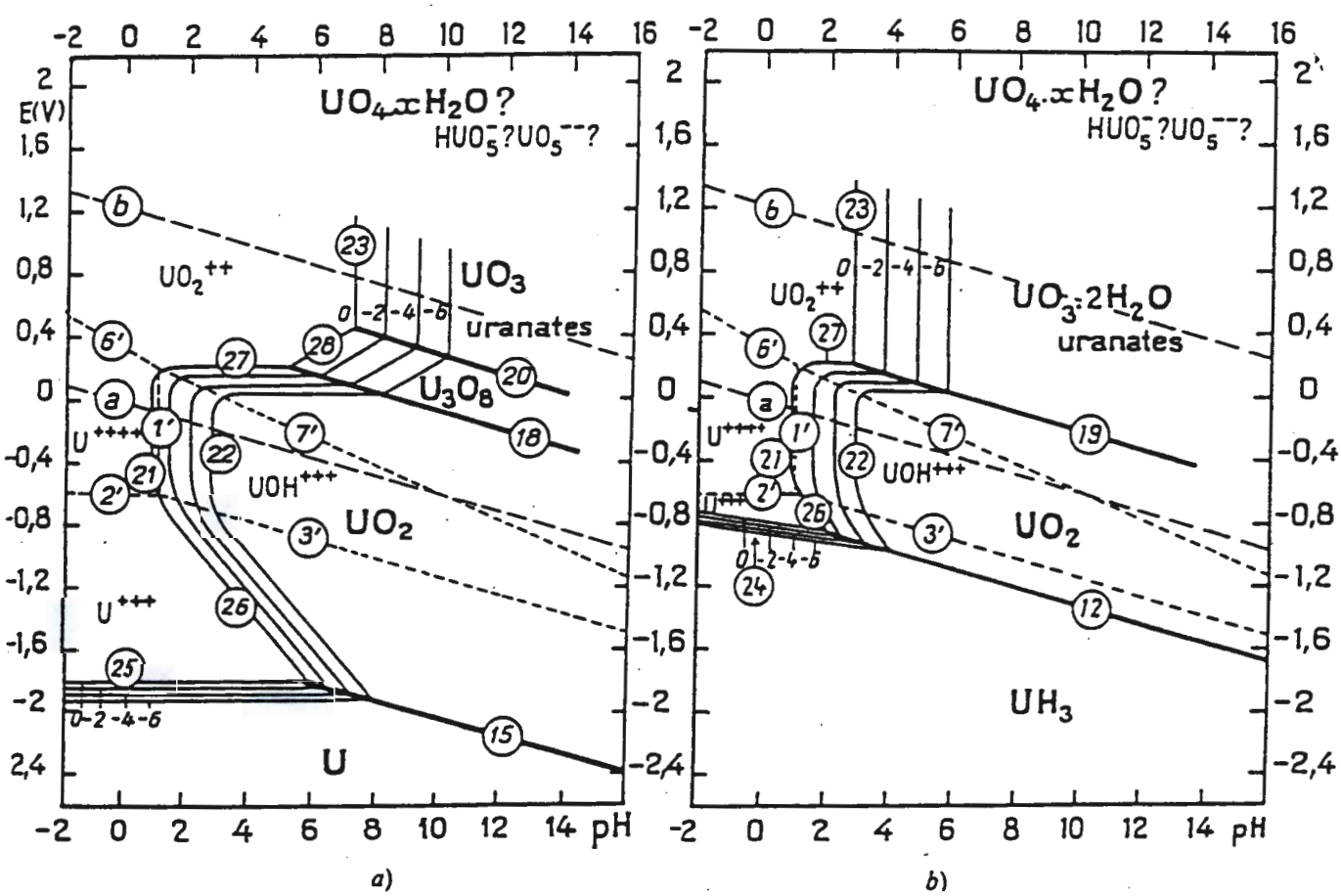

Figure F.1. Uranium-water Pourbaix Diagram (Pourbaix 1974)

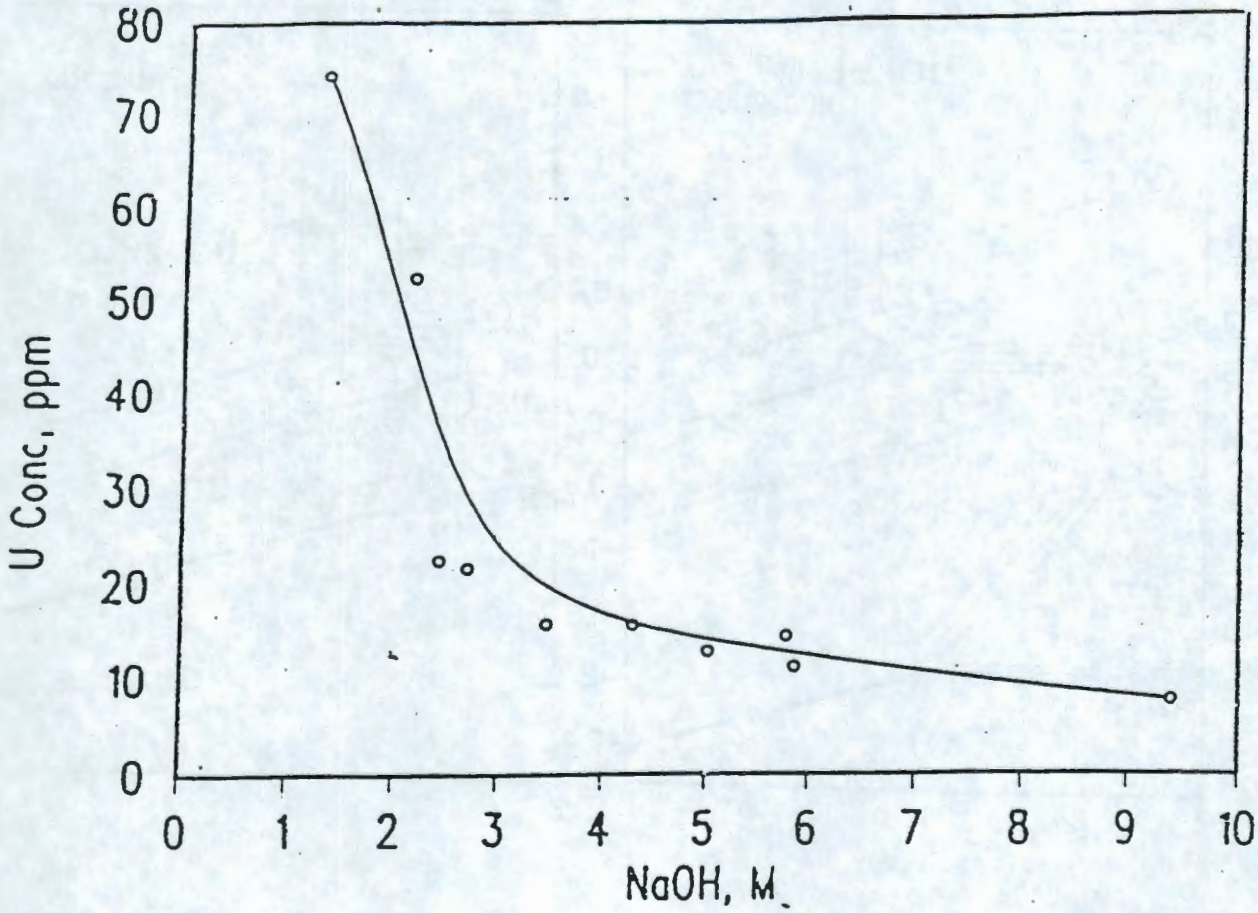

Figure F.2. U Solubility in Synthetic Waste Supernate (Karraker 1994)

ATTACHMENT TO APPENDIX F

Derivation of Equation to Calculate Dissolution Time for a Spherical Particle

The following assumptions are made for this derivation:

(a) spherical particle
(b) mass corrosion rate (R) is constant

Volume, $V = (4/3)\pi r^3$
Area, $A = 4\pi r^2$
r = radius
R = mass corrosion rate, $g/cm^2/h$
t = time, h
ρ = uranium density, 19.05 g/cm^3
$m = \text{mass} = V\rho = (4/3)\pi r^3\rho$

The following finite difference equation for the change in mass is true for all times:

$$m_{n+1} = m_n - RA\Delta t$$

$$\Delta m/\Delta t = -RA$$

Expressing the above equation in differential form and substituting for the mass and area in terms of the radius:

$$dr/dt = -R/\rho$$

Integrating with the condition that at $t = 0$, $r = r_o$

$$r = -(R/\rho)t + r_o$$

The time for complete dissolution is when $r = 0$

$$t_{dissolution} = r_o\rho/R$$

A suggested diameter for uranium particles was 0.635 cm (0.25 inches) and using Tyfield's rate of 15E-6 $g/cm^2/h$ (note units change from mg to g):

$$t_{dissolution} = (.318\ cm)(19.05\ g/cm^3)/(15E\text{-}6\ g/cm^2/h)$$

$$t_{dissolution} = 4.0E5\ h \text{ or } 46 \text{ year}$$

APPENDIX G

FLAMMABLE GAS CONCENTRATIONS IN AW-105 AFTER ADDITION OF SLUDGE

Don't Say It - Write It! LOCKHEED MARTIN

From: S. A. Barker - TWRS Process Engineering: Models and Inventory
Phone: 372-0485 R2-11
Date: March 26, 1997
Subject: EVALUATION OF AW-105 FOR LENGTH OF TIME UNTIL 25% LFL IS EXCEEDED FOLLOWING ADDITION OF K-BASIN SLUDGES

To: Y. Liu (PNNL) K8-07

cc: K. M. Hodgson R2-11 K. D. Fowler R2-11
W. B. Barton R2-12 P. M. Daling (PNNL) K8-07

This DSI documents the calculations performed to determine the length of time that it would take for tank 241-AW-105 with K-Basin sludge to reach 25% of the lower flammability limit. The calculations are based on the spreadsheet K. D. Fowler put together previously. Fowler's assumption was that tank was full to capacity. The amount of supernatant was varied to determine the relationship between tank fill and time to 25% LFL. The following table presents a selection of the results. The last data point, volume equals 1,145,700 gallons, represents Fowler's full tank case. The following 5 pages present my calculations as run in MathCAD.

Waste Volume (kgals)	Time to 25% LFL (days)	Time to 100% LFL (days)
404.6	16.9	78.2
504.6	15.2	69.0
604.6	13.5	60.2
704.6	11.7	51.8
804.6	10.0	43.7
904.6	8.3	35.8
1145.7	4.3	18

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Determination of Time Required to Reach 25 % LFL in Tank AW-105 Following Transfer of K-Basin Sludge

Assumptions

- Kenny Fowler's spreadsheet data is basis for this calculation
- Assume a range of tank supernate volumes

$Vol_{tank} := 188490 \cdot ft^3$ Volume of tank including dome ...

$Vol_{solids} := 304592 \cdot gal$

$Cap_{tank} := 2754 \cdot \frac{gal}{in}$ Volume of tank per inch of depth ...

$$Vol_{supernate} := \begin{bmatrix} 100000 \\ 150000 \\ 200000 \\ 250000 \\ 300000 \\ 350000 \\ 400000 \\ 450000 \\ 500000 \\ 550000 \\ 600000 \\ 650000 \\ 700000 \\ 750000 \\ 800000 \\ 841108 \end{bmatrix} \cdot gal$$

Range of Volume of Supernate from 100 kgal to full tank at 841 kgal. Vector is 16 members long ranging from 0 to 15 ...

$Depth_{solids} := \frac{Vol_{solids}}{Cap_{tank}}$

$Depth_{solids} = 111 \cdot in$

$Depth_{supernate} := \frac{Vol_{supernate}}{Cap_{tank}}$

$Depth_{supernate_{15}} = 305 \cdot in$ $Depth_{supernate_0} = 36 \cdot in$

$Depth_{waste} := Depth_{solids} + Depth_{supernate}$

$Depth_{waste_{15}} = 416 \cdot in$ $Depth_{waste_0} = 147 \cdot in$

A-6002-067 (10/96) GEF397

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- Hydrogen Generation Rate

$Rate_{H2_Thermolysis} := 49.59 \cdot \frac{ft^3}{day}$

Thermolysis contribution is a function of waste temperature – assumed to be 63 °F ...

$Rate_{H2_Radiolysis} := 1.03 \cdot \frac{ft^3}{day}$

Radiolysis contribution is a function of NO_3^- concentration. Dilute tanks are expected to have greater H_2 generation rates based on radiolysis ...

$Rate_{H2_Corrosion} := 1.10 \cdot \frac{ft^3}{day}$

Corrosion is a function of wetted surface area – not adjusted to compensate for varying volumes in this model ...

$Rate_{H2_total} := Rate_{H2_Thermolysis} + Rate_{H2_Radiolysis} + Rate_{H2_Corrosion}$

$Rate_{H2_total} = 52 \cdot \frac{ft^3}{day}$

$Rate_{H2_total} = 0.036 \cdot \frac{ft^3}{min}$

- Head Space

$Vol_{waste} := Vol_{solids} + Vol_{supernate}$

$Vol_{waste_{15}} = 1145700 \cdot gal$ $\quad$ $Vol_{waste_0} = 404592 \cdot gal$

$Vol_{Head_space} := Vol_{tank} - Vol_{waste}$

$Vol_{Head_space_{15}} = 35332 \cdot ft^3$ $\quad$ $Vol_{Head_space_0} = 134404 \cdot ft^3$

- Active Ventilation Rate

$Rate_{vent_flow_active} := 70 \cdot \frac{ft^3}{min}$

Ventilation rate from K. Fowler's spreadsheet ...

$Rate_{vent_flow_active} = 100800 \cdot \frac{ft^3}{day}$

- Ventilation Rate when forced ventilation is turned off

$Rate_{Breathing} := 0.45 \cdot \frac{\%}{day}$

Ventilation rate due to natural breathing only – does not include natural convection or Bernoulli affect (this value may be very conservative) ...

$Rate_{vent_flow_nb} := Vol_{Head_space} \cdot Rate_{Breathing}$

$Rate_{vent_flow_nb_{15}} = 0.11 \cdot \frac{ft^3}{min}$ $\quad$ $Rate_{vent_flow_nb_0} = 0.42 \cdot \frac{ft^3}{min}$

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- Maximum H_2 accumulation (%) with active ventilation

$$Conc_{H2_max} := \frac{Rate_{H2_total}}{\left(Rate_{H2_total} + Rate_{vent_flow_active}\right)}$$

$$Conc_{H2_max} = 0.05 \cdot \%$$

- Time (days) to reach 25% LFL with active ventilation

$$Time_{25\%LFL} := \begin{cases} \dfrac{-Vol_{Head_space}}{\left(Rate_{H2_total} + Rate_{vent_flow_active}\right)} \cdot \ln\left(\dfrac{Conc_{H2_max} - \frac{0.625}{100}}{Conc_{H2_max}}\right) & \text{if } Conc_{H2_max} \geq \dfrac{0.625}{100} \\ (100000 \cdot day) & \text{otherwise} \end{cases}$$

$$Time_{25\%LFL} = 100000 \cdot day$$

Value of 100,000 indicates that 25% LFL will not be reached at assumed conditions ...

- Time (days) to reach 100% LFL with active ventilation

$$Time_{LFL} := \begin{cases} \dfrac{-Vol_{Head_space}}{\left(Rate_{H2_total} + Rate_{vent_flow_active}\right)} \cdot \ln\left(\dfrac{Conc_{H2_max} - \frac{2.5}{100}}{Conc_{H2_max}}\right) & \text{if } Conc_{H2_max} \geq \dfrac{2.5}{100} \\ (100000 \cdot day) & \text{otherwise} \end{cases}$$

$$Time_{LFL} = 100000 \cdot day$$

Value of 100,000 indicates that 100% LFL will not be reached at assumed conditions ...

- Maximum H_2 accumulation (%) with passive ventilation

$i := 0, 1 .. 15$

$$Conc_{H2_max_nb_i} := \frac{Rate_{H2_total}}{\left(Rate_{H2_total} + Rate_{vent_flow_nb_i}\right)}$$

$$Conc_{H2_max_nb_0} = 7.88 \cdot \% \qquad Conc_{H2_max_nb_{15}} = 24.55 \cdot \%$$

- Time (days) to reach 25% LFL with passive ventilation

$$Time_{25\%LFL_nb_i} := \begin{cases} \dfrac{-Vol_{Head_space_i}}{\left(Rate_{H2_total} + Rate_{vent_flow_nb_i}\right)} \cdot \ln\left[\dfrac{Conc_{H2_max_nb_i} - \frac{0.625}{100}}{Conc_{H2_max_nb_i}}\right] & \text{if } Conc_{H2_max_nb_i} \geq \dfrac{0.62}{10} \\ (100000 \cdot day) & \text{otherwise} \end{cases}$$

$$Time_{25\%LFL_nb_0} = 16.9 \cdot day \qquad Time_{25\%LFL_nb_{15}} = 4.3 \cdot day$$

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- Time (days) to reach 100 % LFL with passive ventilation

$$Time_{LFL_nb_i} := \begin{cases} \dfrac{-Vol_{Head_space_i}}{\left(Rate_{H2_total} + Rate_{vent_flow_nb_i}\right)} \cdot \ln\left[\dfrac{Conc_{H2_max_nb_i} - \frac{2.5}{100}}{Conc_{H2_max_nb_i}}\right] & \text{if } Conc_{H2_max_nb_i} \geq \dfrac{2.5}{100} \\ (100000 \cdot day) & \text{otherwise} \end{cases}$$

$Time_{LFL_nb_0} = 78 \cdot day$ $\quad$ $Time_{LFL_nb_{15}} = 18 \cdot day$

Depending on the fill of the tank, it will take from 18 to 78 days to reach 25% LFL ...

- Minimum Required Ventilation Rate to maintain flammable gas concentration to less than 25% LFL

$$Rate_{vent_minimum_i} := \begin{cases} Rate_{H2_total} \cdot \dfrac{100 - 0.625}{0.625} - Rate_{vent_flow_nb_i} & \text{if } Conc_{H2_max_nb_i} \geq \dfrac{0.625}{100} \\ \left(0 \cdot \dfrac{ft^3}{min}\right) & \text{otherwise} \end{cases}$$

$Rate_{vent_minimum_0} = 5.29 \cdot \dfrac{ft^3}{min}$ $\quad$ $Rate_{vent_minimum_{15}} = 5.6 \cdot \dfrac{ft^3}{min}$

A ventilation rate of 5.6 cfm or greater will assure that 25% LFL will not be exceeded at assumed conditions ...

$Rate_{vent_minimum_0} = 149.82 \cdot \dfrac{liter}{min}$ $\quad$ $Rate_{vent_minimum_{15}} = 158.58 \cdot \dfrac{liter}{min}$

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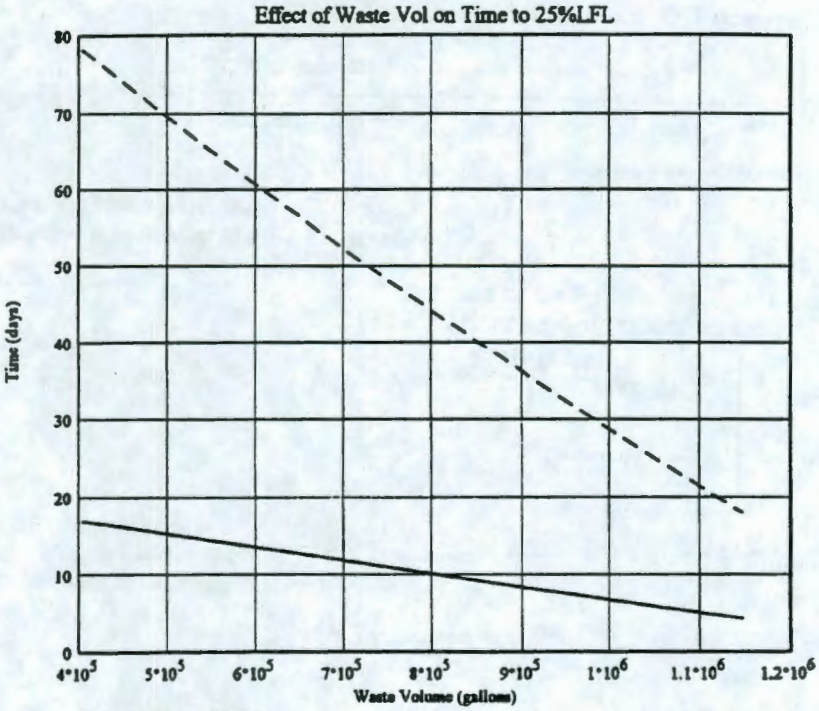

- Summary Table of Results:

Time to reach 25% LFL and 100% LFL with natural breathing only

i	Vol_{waste_i} (gal)	$Time_{25\%LFL_nb_i}$ (day)	$Time_{LFL_nb_i}$ (day)
0	404592	16.9	78.2
1	454592	16	73.5
2	504592	15.2	69
3	554592	14.3	64.6
4	604592	13.5	60.2
5	654592	12.6	56
6	704592	11.7	51.8
7	754592	10.9	47.7
8	804592	10	43.7
9	854592	9.2	39.7
10	904592	8.3	35.8
11	954592	7.5	32
12	1004592	6.7	28.3
13	1054592	5.8	24.6
14	1104592	5	21
15	1145700	4.3	18

PROJECTED SCREENING OF TANK 241-AW-105 FOR FLAMMABLE GAS AFTER ADDITION OF K BASIN SLUDGE WASTE

Two screenings were performed. The first (KSLUDG2.XLS) is a base case for tank 5-AW after K Basin sludge receipt. The following assumptions were used for this screening.

- Tank 5-AW was filled with 416 inches of waste at all times to maximize pressure on trapped gas and to minimize tank headspace volume
- Combined total of 70 m^3 of KE and KW sludge received
- Default screening spreadsheet values representative where no data available
- KE floor and pit sludge max. data from WHC-SP-1182 for centrifuged sludge bounding for Cs, Sr, TOC and Al concentrations and for solids density

For the second screening (KS21YR.XLS), the following additional assumptions were used.

- Gas generation from the K Basin sludge is 0.05 ft^3/min. for 365.25 days
- Generated gas is trapped in the waste
- As trapped gas volume increases, supernate volume was decreased to keep tank level at 416 inches (i.e., tank remains within LCO)
- Trapped gas volume was treated as a horizontal cross-section of the tank centered at a height equal to 22.5% of the solids height from the tank bottom

RESULTS

Results indicate that the ventilation in tank AW-105 would be adequate to keep the tank headspace well below 25% of the LFL under steady state conditions. However, if gas were generated and trapped in the tank, under conditions assumed for this screening, a gas release event would cause the tank headspace to exceed the LFL (actual result 278 % of the LFL or 11% H_2).

OPTIONS

1) Use more representative specific gravity data and the tank non-convective layer, empirical correlation (Estey and Guthrie) to indicate that gas would not be trapped in the waste matrix under tank conditions.

2) Bound gas generation volume for K Basin sludge so that generation rate is not .05 Ft^3/min over an indefinite period of time.

3) If sludge will be treated, use gas generation rate representative of sludge as received into tank AW-105.

Results of Calculations of Entrapped Gas Volume and % LFL Based on Surface Level Rise

	A	B	C	D	E
1	Tank No.	enter	C96/03A	AW-105*	Data Sources/Comments
2	Calculation date:	enter		02/27/97	@NOW
3	Total waste volume	enter	gal	1,145,600	Tank assumed full with 416 inches of waste
4	Total solids volume (sludge + saltcake), including gas	enter	gal	304,492	Tank database + KE&KW estimate
5	Supernate volume	enter	gal	841,108	Total waste volume - solids volume
6	Volume of drainable interstitial liquid	enter	gal	48,719	Solids vol * porosity
7	Volume of sludge	enter	gal	304,492	same as solids volume
8	Current solid surface level height (Reading SLC)	enter	in.	110.60	Calc from solids volume
9	Original solid surface level height (Reading SLH)	enter	in.	110.60	No data available to assume solids level increase
10	as of this date:	enter	date		
11	Current liquid level height (Reading LLC)	enter	in.	416.00	Assumed full tank
12	Original liquid level height (Reading LLH)	enter	in.	416.00	No data available to assume liquid level increase
13	as of this date:	enter	date		
14	Engineer selects source of solids volume (Hanlon, SLC or LLC)	enter		SLC	Use Solids Level (SLC) or Liquid Level (LLC) Reading
15	Engineer selects source of interstitial liquid volume (Hanlon, SLC or LLC)	enter		SLC	Use Solids Level (SLC) or Liquid Level (LLC) Reading
16	Engineer selects source of supernate volume (Hanlon, SLC or LLC)	enter		Hanlon	Use Solids Level (SLC) or Liquid Level (LLC) Reading
17	Supernate density. If unknown, enter 1.40.	enter	g/mL	1.291	Todd's case 4 sludge with no supernate
18	Solids density. If unknown, enter 1.80.	enter	g/mL	1.67	Max. value for KE floor & pit density
19	Porosity (liquid fraction) in solids, by assay. If unknown, enter 0.501.	enter		0.160	All sludge no salt default
20	Porosity (sludge). If unknown, enter 0.16.	enter		0.160	Default
21	Average gas location: fraction of wet solids from bottom center. If unknown, enter = 0.225.	enter		0.225	Default
22	Estimated maximum evaporation	enter	in.	0.01	No evaporation assumed
23	g TOC/L waste (wet)	enter	gTOC/L	43.6	Weighted avg
24	g Al/L waste (wet)	enter	gAl (wet)	57.200	Weighted avg
25	Average trapped gas temperature	enter	°F	63	Max temp from SACS 2/17/97
26	Average solids temperature	enter	°F	63	Max temp from SACS 2/17/97
27	Power load from published source. If not available, leave blank.	enter	kW		
28	Heat load from published source. If not available, leave blank. (Don't leave both blank.)	enter	kW	2.480	Tank DB + max K centrifuged sludge Cs and Sr
29	Tank Farm (A, AN, AP, AW, AX, AY, AZ, B, BX, BY, C, S, SX, SY, T, TX, TY, U)	enter		AW	
30	H2 generation rate, G(H2). If unknown, enter 0.1.	enter	molecules H2/100 eV	0.048	Graves' spreadsheet for 5AW
33	If sampled, actual H2 value from sampling	enter	ppm		
34	If sampled, actual NH3 value from sampling	enter	ppm		
37	% H2 in trapped gas, ft3 H2/ft3 trapped gas. If unknown, enter 97%.	enter	%	97%	Default
38	% of trapped gas releasable. If unknown, enter 25%.	enter	%	25.0%	Default
39	Mean air pressure on waste surface. If unknown, enter 14.50.	enter	psia	14.49	Default
40	Add to Current Surf Lvl: compaction	enter	in.	0.00	
41	Add to Current Surf Lvl: out leakage	enter	in.	0.00	
42	Add to Current Surf Lvl: pumped out	enter	in.	0.00	
43	Add to Current Surf Lvl: measuring error (known or possible icicle at start, kink in tape now, etc.)	enter	in.	0.00	
44	Add to Current Surf Lvl: any gas contained in original surface level	enter	in.	0.01	
45	Subt from Current Surf Lvl: measuring error (known or possible icicle now, kink in tape at start, etc.)	enter	in.	0.00	
46	Subt from Current Surf Lvl: intrusion or addition	enter	in.	0.00	
47	Subt from Current Surf Lvl: condensation from ambient air, which has dripped into tank	enter	in.	0.00	
48	Subt from Current Surf Lvl: hygroscopic absorption	enter	in.	0.00	
49	Subt from Current Surf Lvl: crust expansion by gas	enter	in.	0.00	
50	Subt from Current Surf Lvl: crystal expansion	enter	in.	0.00	
51	Tank atmospheric breathing rate - SSTwoFIC (Crippen: 0.45% natl breathing)	enter		0.45%	Crippen 1993
52	Tank FIC purge rate (nominally 50-200 cfh)	enter	cfh	0	
53	Tank Vent Rate	enter	cfm	70	AW-105 inlet nominal flow
54	Tank breathing rate: SSTxFIC, SSTwFIC, or DST	enter		DST	SST w/o FIC (SSTxFIC), SST with FIC (SSTwFIC), or DST (DST)
55	Ratio of NH3 % to H2 % (normally 4)	enter		4	Hopkins 1994
56	Ratio of CH4 vol to fraction of H2 conc. (normally 0.020)	enter		0.020	Hopkins 1994
57	Assume NH3 vol = this fraction of trapped gas released (normally 0.220)	enter		0.220	Assumed. Max = 0.29, per WHC-EP-0702.
58	Assume CH4 vol = this fraction of trapped gas released (normally 0.00)	enter		0.000	Hopkins 1994
59	Select Confidence Level for Barometric Pressure/Surface Level Correlation	enter		75%	
60	Slope at 95% confidence	enter	in./in. Hg		Whitney 1995b
61	Slope at 75% confidence	enter	in./in. Hg		Whitney 1995b
62	Slope at 50% confidence	enter	in./in. Hg		Whitney 1995b
63	QFit Mean	enter			Whitney 1995b
64	QFit Standard Deviation	enter			Whitney 1995b
65	Engineer Selects Surface Rise Method: L (Liquid) or S (Solid)	enter		L	L (Liquid) or S (Solid)
66	Engineer Identifies Level Measurement Condition: SUP, SOL, LIH	enter		SUP	SUP (Supernate), SOL (Solid Surface), LIH (Liquid in Hole)
67	Temperature of Entering Air. If unknown, enter 56.3 F (Year Avg).	enter	deg F	56.3	
68	Relative Humidity of Entering Air. If unknown, enter 50%.	enter	%	50.0%	
69	Temperature of Vapor in Dome Space (Year Avg)	enter	deg F	63.7	
70	Relative Humidity of Exiting Air. If unknown, enter 100%.	enter	%	100.0%	
71	Surface Temperature of Waste (Year Ave)	enter	deg F	63.6	
72	Enter Period of Time over which evaporation occurs	enter	years	0.01	
73	Enter Fraction of Heat Load used in calculating Vent Rate. If unknown, enter 50%.	enter	%	50.00%	
74	Enter Calculation Result to Report Vent Flow Rate on Lines 123-124	enter		INP	Based on HL (Heat Load), SAM (Vapor Sample), or INP (Input Vent Rate)

Results of Calculations of Entrapped Gas Volume LFL Based on Surface Level Rise

A	B	C	D	E
Tank No.	enter	C96/03A	AW-105*	Data Sources/Comments
Calculation date:	enter		02/27/97	@NOW
	Method		Value (ft^3)	
Volume of Tank		gal.	1,160,000	
Total Waste Volume	SLC	gal.	1,145,661	
Total Solids	SLC	gal.	304,592	
Sludge Volume	Hanlon	gal.	304,592	
Saltcake Volume	SLC	gal.	0	
Interstitial Liquid	SLC	gal.	48,735	
Supernatant Liquid	Hanlon	gal.	841,108	
	Method		Value (ft^3)	
Volume of Tank		ft3	155,490	
Total Waste Volume	SLC	ft3	153,153	
Total Solids	SLC	ft3	40,718	
Sludge Volume	Hanlon	ft3	40,718	
Saltcake Volume	SLC	ft3	0	
Interstitial Liquid	SLC	ft3	6,515	
Supernatant Liquid	Hanlon	ft3	112,440	
Waste Depth (in)	SLC	in.	416.00	
Solids Depth (in)	SLC	in.	110.60	
Supernatant Depth, (in)	Hanlon	in.	305.41	
Effective Wet Solids Depth, (in)	SLC	in.	110.60	

STEADY STATE - ASSUMES ENTRAPMENT RATE = 0

TEST VS. CRITERIA (% of LFL)			
% LFL (Calc. Vapor Sample)		%	0.00%
% LFL (Calc. Nat'l Breathing Only)		%	1278.39%
Vent Rate (CFM) (Calc. Nat'l Breathing Only)		cfm	0.11
%LFL (Calc. Based on Given Vent Rate)	INP	%	2.67%
Vent Rate (CFM) (Calc. Based on Given Vent Rate)		cfm	70.00

EPISODIC RELEASE (EGR/GRE)

EGR/GRE: QUICK SCREEN

TEST VS. CRITERIA (% of LFL)	
% LFL	471.85%

EGR/GRE: EVAL BASED ON SL RISE

TEST VS. CRITERIA (% of LFL)		
%LFL (Calc. Based on Given Vent Rate)	INP	[illegible]
Vent Rate (CFM) (Calc. Based on Given Vent Rate)		70.00
Compressed Volume of Entrapped Gas (ft3)		[illegible]
Void Fraction (%)		[illegible]

CALCULATION USING PAUL WHITNEY'S SLOPE

% LFL = ([H2]/0.04) + ([NH3]/15.0) =	[illegible]
Compressed Volume of Entrapped Gas (ft3)	[illegible]
Void Fraction (%)	[illegible]

Results of Calculations of Entrapped Gas Volume and % LFL Based on Surface Level Rise

A	B	C	D	E
Tank No.	enter	C96/03A	AW-105*	Data Sources/Comments
Calculation date:	enter		02/27/97	@NOW
Total waste volume	enter	gal	1,145,600	Tank assumed full with 416 inches of waste
Total solids volume (sludge + saltcake), including gas	enter	gal	353,725	Tank database + KE&KW estimate
Supernate volume	enter	gal	791,875	Total waste volume - solids volume
Volume of drainable interstitial liquid	enter	gal	48,719	Original Solids vol * original porosity
Volume of sludge	enter	gal	353,725	same as solids volume, no saltcake
Current solid surface level height (Reading SLC)	enter	in.	128.44	Calc from solids volume
Original solid surface level height (Reading SLH)	enter	in.	110.60	Orignial Solids volume from Ksludg2.xls
as of this date:	enter	date		
Current liquid level height (Reading LLC)	enter	in.	416.00	Assumed full tank
Original liquid level height (Reading LLH)	enter	in.	398.10	Assume 1 yr gas volume subtracted to account for increase
as of this date:	enter	date		
Engineer selects source of solids volume (Hanlon, SLC or LLC)	enter		SLC	Use Solids Level (SLC) or Liquid Level (LLC) Reading
Engineer selects source of interstitial liquid volume (Hanlon, SLC or LLC)	enter		SLC	Use Solids Level (SLC) or Liquid Level (LLC) Reading
Engineer selects source of supernate volume (Hanlon, SLC or LLC)	enter		Hanlon	Use Solids Level (SLC) or Liquid Level (LLC) Reading
Supernate density. If unknown, enter 1.40.	enter	g/mL	1.291	Todd's case 4 sludge with no supernate
Solids density. If unknown, enter 1.80.	enter	g/mL	1.67	Max. value for KE floor & pit density
Porosity (liquid fraction) in solids, by assay. If unknown, enter 0.501.	enter		0.150	All sludge no salt default
Porosity (sludge). If unknown, enter 0.16.	enter		0.160	Default
Average gas location: fraction of wet solids from bottom center. If unknown, enter = 0.225.	enter		0.225	Default
Estimated maximum evaporation	enter	in.	0.01	No evaporation assumed
g TOC/L waste (wet)	enter	gTOC/L	43.6	Weighted avg
g Al/L waste (wet)	enter	g/L (wet)	57.200	Weighted avg
Average trapped gas temperature	enter	°F	63	Max temp from SACS 2/17/97
Average solids temperature	enter	°F	63	Max temp from SACS 2/17/97
Power load from published source. If not available, leave blank.	enter	kW		
Heat load from published source. If not available, leave blank. (Don't leave both blank.)	enter	kW	2.480	Tank DB + max K centrifuged sludge Cs and Sr
Tank Farm (A, AN, AP, AW, AX, AY, AZ, B, BX, BY, C, S, SX, SY, T, TX, TY, U)	enter		AW	
H2 generation rate, G(H2). If unknown, enter 0.1.	enter	molecules H2/100 eV	0.049	Graves' spreadsheet for 5AW
If sampled, actual H2 value from sampling	enter	ppm		
If sampled, actual NH3 value from sampling	enter	ppm		
% H2 in trapped gas, ft3 H2/ft3 trapped gas. If unknown, enter 97%.	enter	%	97%	Default
% of trapped gas releasable. If unknown, enter 26%.	enter	%	26.0%	Default
Mean air pressure on waste surface. If unknown, enter 14.50.	enter	psia	14.49	Default
Add to Current Surf Lvl: compaction	enter	in.	0.00	
Add to Current Surf Lvl: out leakage	enter	in.	0.00	
Add to Current Surf Lvl: pumped out	enter	in.	0.00	
Add to Current Surf Lvl: measuring error (known or possible icicle at start, kink in tape now, etc.)	enter	in.	0.00	
Add to Current Surf Lvl: any gas contained in original surface level	enter	in.	0.01	
Subt from Current Surf Lvl: measuring error (known or possible icicle now, kink in tape at start, etc.)	enter	in.	0.00	
Subt from Current Surf Lvl: intrusion or addition	enter	in.	0.00	
Subt from Current Surf Lvl: condensation from ambient air, which has dripped into tank	enter	in.	0.00	
Subt from Current Surf Lvl: hygroscopic absorption	enter	in.	0.00	
Subt from Current Surf Lvl: crust expansion by gas	enter	in.	0.00	
Subt from Current Surf Lvl: crystal expansion	enter	in.	0.00	
Tank atmospheric breathing rate - SSTw/oFIC (Crippen: 0.45% natl breathing)	enter		0.45%	Crippen 1993
Tank FIC purge rate (nominally 50-200 cfh)	enter	cfh	0	
Tank Vent Rate	enter	cfm	70	AW-105 inlet nominal flow
Tank breathing rate: SSTxFIC, SSTwFIC, or DST	enter		DST	SST w/o FIC (SSTxFIC), SST with FIC (SSTwFIC), or DST (DST)
Ratio of NH3 % to H2 % (normally 4)	enter		4	Hopkins 1994
Ratio of CH4 vol to fraction of H2 conc. (normally 0.020)	enter		0.020	Hopkins 1994
Assume NH3 vol = this fraction of trapped gas released (normally 0.220)	enter		0.220	Assumed. Max = 0.29, per WHC-EP-0702.
Assume CH4 vol = this fraction of trapped gas released (normally 0.00)	enter		0.000	Hopkins 1994
Select Confidence Level for Barometric Pressure/Surface Level Correlation	enter		75%	
Slope at 95% confidence	enter	in./in. Hg		Whitney 1995b
Slope at 75% confidence	enter	in./in. Hg		Whitney 1995b
Slope at 50% confidence	enter	in./in. Hg		Whitney 1995b
QFit Mean	enter			Whitney 1995b
QFit Standard Deviation	enter			Whitney 1995b
Engineer Selects Surface Rise Method: L (Liquid) or S (Solid)	enter		L	L (Liquid) or S (Solid)
Engineer Identifies Level Measurement Condition: SUP, SOL, LIH	enter		SUP	SUP (Supernate), SOL (Solid Surface), LIH (Liquid in Hole)
Temperature of Entering Air. If unknown, enter 56.3 F (Year Avg).	enter	deg F	56.3	
Relative Humidity of Entering Air. If unknown, enter 50%.	enter	%	50.0%	
Temperature of Vapor in Dome Space (Year Avg)	enter	deg F	63.7	
Relative Humidity of Exiting Air. If unknown, enter 100%.	enter	%	100.0%	
Surface Temperature of Waste (Year Ave)	enter	deg F	63.6	
Enter Period of Time over which evaporation occurs	enter	years	0.01	
Enter Fraction of Heat Load used in calculating Vent Rate. If unknown, enter 50%.	enter	%	50.00%	
Enter Calculation Result to Report Vent Flow Rate on Lines 123-124	enter		INP	Based on HL (Heat Load), SAM (Vapor Sample), or INP (Input Vent Rate)

Results of Calculations of Entrapped Gas V nd % LFL Based on Surface Level Rise

	A	B	C		E
1	Tank No.	enter	C96/03A	AW-105*	Data Sources/Comments
2	Calculation date:	enter		02/27/97	@NOW
76					
78		Method		Value (ft^3)	
79	Volume of Tank		gal.	1,160,000	
80	Total Waste Volume	SLC	gal.	1,145,661	
81	Total Solids	SLC	gal.	353,723	
82	Sludge Volume	Hanlon	gal.	353,723	
83	Saltcake Volume	SLC	gal.	0	
84	Interstitial Liquid	SLC	gal.	56,596	
85	Supernatant Liquid	Hanlon	gal.	791,875	
86		Method		Value (ft^3)	
87	Volume of Tank		ft3	188,490	
88	Total Waste Volume	SLC	ft3	153,153	
89	Total Solids	SLC	ft3	47,286	
90	Sludge Volume	Hanlon	ft3	47,286	
91	Saltcake Volume	SLC	ft3	0	
92	Interstitial Liquid	SLC	ft3	7,566	
93	Supernatant Liquid	Hanlon	ft3	105,858	
94					
95					
96	Waste Depth (in)	SLC	in.	416.00	
97	Solids Depth (in)	SLC	in.	128.44	
98	Supernatant Depth, (in)	Hanlon	in.	287.54	
99	Effective Wet Solids Depth, (in)	SLC	in.	128.44	
101					
102	**STEADY STATE - ASSUMES ENTRAPMENT RATE = 0**				
103					
104	TEST VS. CRITERIA (% of LFL)				
105					
106	% LFL (Calc. Vapor Sample)		%	0.00%	
107	% LFL (Calc. Nat'l Breathing Only)		%	1234.92%	
108	Vent Rate (CFM) (Calc. Nat'l Breathing Only)		cfm	0.11	
109	%LFL (Calc. Based on Given Vent Rate)	INP	%	2.55%	
110	Vent Rate (CFM) (Calc. Based on Given Vent Rate)		cfm	70.00	
111					
112					
113	**EPISODIC RELEASE (EGR/GRE)**				
114	**EGR/GRE: QUICK SCREEN**				
116	TEST VS. CRITERIA (% of LFL)				
117	% LFL			640.35%	
118					
119					
120	**EGR/GRE: EVAL BASED ON SL RISE**				
122	TEST VS. CRITERIA (% of LFL)				
123	%LFL (Calc. Based on Given Vent Rate)	INP		[illegible]	
124	Vent Rate (CFM) (Calc. Based on Given Vent Rate)			70.00	
125	Compressed Volume of Entrapped Gas (ft3)			[illegible]	
126	Void Fraction (%)			[illegible]	
127					
128	**CALCULATION USING PAUL WHITNEY'S SLOPE**				
130	% LFL = ([H2]/0.04) + ([NH3]/15.0) =			[illegible]	
131	Compressed Volume of Entrapped Gas (ft3)			[illegible]	
132	Void Fraction (%)			[illegible]	
133					