LA-UR-95- 78

TITLE: Retained Gas Sampler
Interim Safety Assessment

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SUBMITTED TO: Report for informal distribution related to the Hanford Waste Tank Safety Assessment Project.

Los Alamos

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DISCLAIMER

RETAINED GAS SAMPLER INTERIM SAFETY ASSESSMENT

Revision 0

by

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prepared for
Westinghouse Hanford Company

January 13, 1995

DISCLAIMER

The current revision (denoted as Rev. 0) of this document shall not be used as the safety basis for installation, operation, or removal of the retained gas sampler. Because of recent changes in the design and implementation schedule, this revision of the document is being published before completion of the equipment design and supporting documentation. Thus, many unresolved issues could not be addressed appropriately in this revision. The appropriate portions of this document may be referenced in the applicable safety basis documents after proper screening against the final design information is performed.

ACKNOWLEDGMENTS

This document was prepared by the Engineering and Safety Analysis Group (TSA-6) at Los Alamos National Laboratory for Westinghouse Hanford Company. The following individuals provided direct contributions to the preparation of this document.

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ACRONYMS

ADVENT	ADVENT Engineering Services, Inc.
ALARA	as low as reasonably achievable
DACS	data acquisition control system
DOE	Department of Energy
DOE/RL	DOE/Richland (Field Office)
DST	double-shell tank
EDE	effective dose equivalent
FDC	functional design criteria
FEA	finite-element analysis
FEM	finite element model
FIC	Food Instrument Corporation
GASFLOW	a computer code
GRE	gas release event
HazOp	hazards and operability
HazOpS	hazards and operability study
HASP	Health and Safety Plan
HMS/TRAC	hydrogen mixing study/transient reactor analysis code
IDLH	imminently (or immediately) dangerous to life or health
LFL	lower flammability limit
MAB	maximum allowable burp
MEB	maximum expected burp
MPF	multiport flange
MPR	multiport riser
NC	nonconvective
NEC	National Electrical Code
NEMA	National Electrical Manufacturers Association
NFPA	National Fire Protection Association
OSD	operational safety document
OSR	operational safety requirement
P&ID	piping and instrument diagrams
PIC	person in charge
RGS	retained gas sampler
SA	safety assessment
SCO	safety condition for operation
SS	stainless steel
SY Tank Farm	241-SY Tank Farm
Tank 101-SY	Tank 241-SY-101
TBD	to be determined
TRG	test review group
WHC	Westinghouse Hanford Company

1.0. SCOPE

1.1. General Introductory Information

This safety assessment addresses the proposed action to install, operate, and remove an RGS in Tank 101-SY located within the Hanford Site, Richland, Washington. The primary function of the RGS is to obtain experimental data to characterize the gas species retained in the tank waste. The information will be used to refine models that predict the gas-producing behavior of the waste tank.

Knowledge of these species is crucial for evaluating the success of many of the mitigation or remediation schemes and for safety analyses necessary to support them. In addition to improving modeling capabilities, knowledge in this area contributes to a better understanding of the amounts and distribution of the trapped gases in Tank 101-SY. The more these data are understood, the better we will be able to assess the merits of various possible mitigation techniques, including the current and future mixer pumps.

The RGS will allow us to take samples of the tank from top to bottom. These waste specimens will be captured in a sample chamber and then transported to an analytical chemistry laboratory for determination of the gas constituents. The information from this process will be very helpful in characterizing the reactions and reaction products of the tank. The laboratory analysis of the samples will quantify the amount of gas in Tank 101-SY that exists in the form of (1) discrete bubbles, (2) soluble gas, and (3) absorbed gas.

The proposed action is required as part of an ongoing evaluation of various mitigation concepts developed to eliminate episodic gas releases that result in hydrogen concentrations in the tank dome space that exceed 25% of the LFL. The objective of this SA is to (1) systematically identify each of the potential hazards associated with the proposed action, (2) analyze each of the resultant accident sequences using a prescribed methodology, (3) assess the consequences of the credible accident sequences, and (4) identify the controls and procedures necessary to eliminate or reduce the potential hazards. Specifically, this SA (1) identifies potential hazards associated with the proposed action, (2) analyzes each of the hazards relative to their potential severity, (3) calculates the anticipated consequences related to each potential hazard, (4) assesses the consequences, and (5) describes the controls that will be implemented to minimize the probability of any significant accidents.

We intend to install an instrument that will provide key physical characterization of the waste in Tank 101-SY to aid in the evaluation of postulated accidents, as well as provide mitigation and remediation concepts for gas release behavior. This interim SA provides sufficient evidence that the operation can be conducted safely upon completion of the items listed in Sec. 7.

1.1.1. No-Action Alternative

In addition to the proposed action, a no-action alternative was considered. For this alternative, the gas inventory in the Tank 101-SY waste will continue to be estimated in calculations predicting the response of the waste under postulated accident conditions. The no-action alternative will not provide the information needed to evaluate the effectiveness of the various proposed waste-mixing schemes in promoting the gradual release of gas from the nonconvecting bottom layer or in reducing the concentration of gas released during an episodic event. This alternative would add uncertainty to the process of the development of a mitigation approach designed to reduce the concerns of a Priority 1 waste tank safety issue. This option does not satisfy the specific need for the proposed action and will not lead to an effective evaluation of a possible mitigation and remediation approaches.

1.1.2. Safety Assessment Approach

The approach implemented in the development of this SA incorporates a systematic evaluation of the potential hazards related to the activities required for the installation, operation, and removal of the RGS. For the potential hazards identified, evaluations were completed to establish their potential severity and the resultant consequences of accidents that may occur in response to these hazards. These evaluations consisted of detailed analyses and evaluations using analytical and numerical techniques, routine engineering calculations, and/or a review of existing information to establish the consequences, if any, of these hazards. Finally, this SA identifies the procedures and controls implemented to prevent or mitigate the consequences of these hazards.

Section 2 of this SA provides detailed descriptions of the processes and systems associated with the operation of the RGS. Section 3 presents the results of a hazard identification conducted to identify the hazards associated with the hydrogen mitigation pump test. It also presents the identification of postulated accident scenarios that are used to demonstrate adequate management of the identified hazards. Section 4 presents an evaluation of the identified hazards and the postulated accidents associated with the proposed action, as well as the identification of safety-class equipment and systems. Section 5.0 presents the consequences associated with each postulated accident scenario. Section 6.0 contains the safety controls derived from the results of this SA. These controls ensure an additional level of safety beyond that provided in the design of the RGS.

1.1.3. Summary and Conclusions

Accident sequences that could result in radiological or toxicological consequences or challenges to Class I safety systems have been considered and include:

- the effect of open-tank (riser) conditions given a prompt release with or without burn conditions,
- the existence or accidental creation of sources that could ignite a flammable mixture,
- operations and operational accidents involving the RGS that could induce prompt release with or without burn conditions,
- physical challenges to the confinement or containment provided by the waste tank, and
- hazardous materials spills associated with operation of the RGS.

Design features and safety systems have been evaluated and incorporated to provide an enhanced level of safety for site workers, the environment, and the public. Key safety features include:

- electrical spark prevention measures (intrinsic barriers, physical separation from gas sources, and static electricity management features);
- a decontamination system to limit the buildup of hazardous wastes on the RGS;
- frangible drill bit material to prevent damage to the tank bottom in the event of contact;
- force-limiting feature to preclude damage to the tank bottom from push-mode operation;
- no sparking material for the sampler shear pin material, which must be sheared in the sample retrieval process; and
- choice of diesel fuel over gasoline to reduce the flammability and explosion hazards of the surface operations.

The analysis presented in this SA demonstrates that the systems and controls established for this function will provide an acceptable level of safety for the workers, public, and environment within the limits established by the DOE orders and WHC administrative procedures.

2.0. DESCRIPTION OF ACTION

This section presents a detailed description of the proposed action necessary to install, operate, and remove an instrument designed to determine retained gas species in various waste storage tanks at Westinghouse Hanford Company, Richland, Washington. To proceed with an SA for this proposed action that will eventually encompass flammable tanks generically, we chose one tank, 101-SY, for a baseline reference. This tank is ideally suited because of known hazards and waste characteristics. The extensive background material on SAs made for equipment intended for Tank 101-SY encourages this choice; we drew heavily upon this material. We will reference detailed descriptions of the tank system, conditions, and characteristics throughout this SA. However, some information contained in Ref. 1 is repeated here for clarity.

Several mitigation and/or remediation concepts are being considered to reduce the frequency and concentration of large gas releases from the nonconvecting bottom layer in Tank 101-SY. As part of this program, information about the retained gas in the waste is required to develop and validate predictive models of the flammable and toxic gas production and to support analyses of the behavior of the waste under accident conditions.

Knowledge of the retained gas species is crucial for evaluating the success of many of the mitigation, retrieval, and remediation schemes and for safety analyses necessary to support them. In addition to improving modeling capabilities, there is a general interest in better understanding the amounts and distributions of the trapped gases in Tank 101-SY. The more these data are understood, the easier it will be to assess the merits of various possible mitigation techniques, including the current mixer pump. Also important is the quantification of the gas inventory in the form of (1) discrete bubbles, (2) soluble gases, and (3) absorbed gases.

The measurement method is based on extracting a waste sample and quantitatively transferring the sampler device (with sample) to an analytical measuring laboratory. This SA is limited to examining the hazards associated with the sample extraction equipment operation and the installation/removal phases.

The RGS consists of three main components: the sampler itself, the retained gas extruder, and the retained gas extractor. This SA addresses the installation, operation, and removal of the RGS in Tank 101-SY only. Procedures for safely transporting the sample to the hot cells and extruding and extracting the waste sample from the sampler, then analyzing these samples, are not addressed in this SA. This SA will cover handling aspects relating to the sampler, as well as operations relating to the truck/drill rig combination and the drill string (which contains the sampler unit). For our purposes, the term RGS will comprise this designated equipment.

A rotary platform and stationary work platform are mounted on the rear of the truck, as shown in Fig. 2-1. Samples can be extracted using a rotary coring operation, a push-mode method, or a combination of both, depending on waste conditions. In Tank 101-SY, only the push-mode method of coring will be performed. The rotary option will be locked out and tagged out, and administrative controls will be in place to preclude this option.

There are two sets of equipment mounted on opposite sides of the rotary platform. One set is the shielded sample receiver unit, which places empty samplers into and removes full samplers from the drill string. The other set is the drill unit, which pushes the drill string and sampler into the waste material (hereafter referred to as the push-mode method). The internal combustion engine that provides power to the drill unit is mounted on the rotary platform between the drill unit and the shielded sample receiver unit. A control console and electric hoist also are mounted on the rotary platform on opposite sides from each other.

2.1. Tank Farm Design and Contents

The tank farm design and the contents of the tanks are discussed in Sec. 2.1 of Ref. 1.

2.2. Tank 101-SY

A detailed description of Tank 101-SY is contained in Sec. 2.2 of Ref. 1. Key features directly applicable to the RGS proposal are repeated here for clarity and ease of use with this SA.

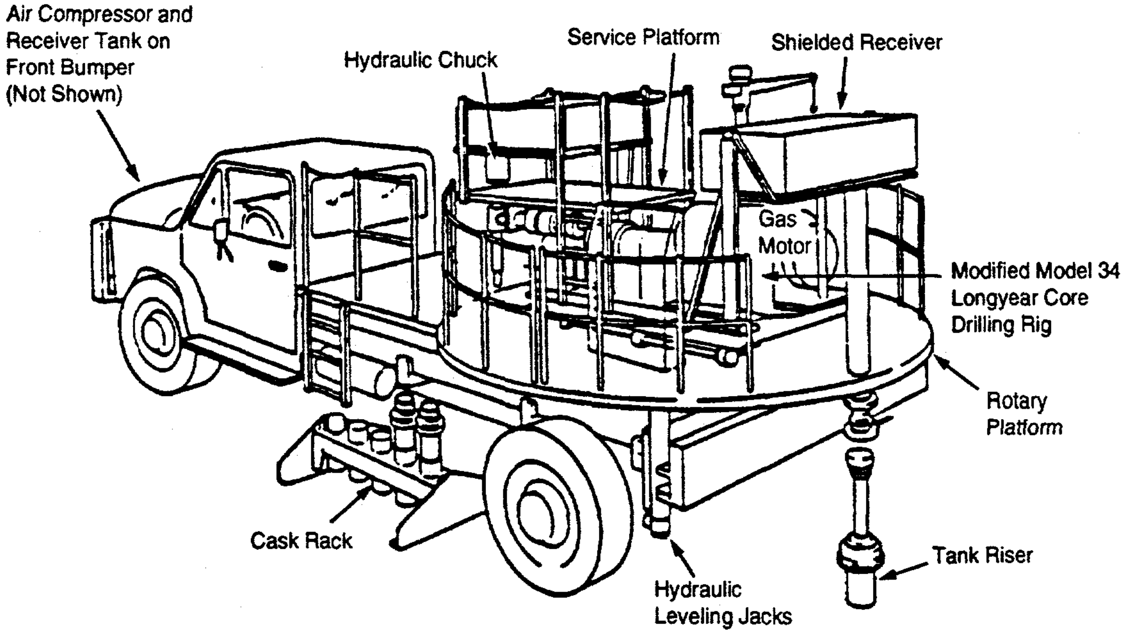

Fig. 2-1. Truck and mounted core sampling equipment.

Tank 101-SY contains waste that is both radioactive and chemically active. The chemical activity results in a release of gases that contains a variety of constituents, including potentially flammable concentrations of hydrogen, ammonia, methane, and nitrous oxide. The waste is highly caustic (pH of ~13). The radioactive constituents are characterized in Ref. 1; the major constituents are strontium and cesium. Detailed lists of the tank contents and quantities are included in Sec. 2 of Ref. 1.

The tank is instrumented to monitor tank characteristics important to safety. The total instrumentation suite, with the exception of specific instrumentation on the RGS, is discussed in Sec. 2 of the Mixer Pump SA.[1] Instrumentation requirements supporting the safe operation of the RGS are described in the subsection on RGS operation.

A cross-sectional view of a generalized DST is shown in Fig. 2-2. Tank 101-SY contains numerous risers in various sizes. The mixer pump is installed in the central pump pit. The RGS will be installed on a typical 4-in. riser (Riser 22A). The location of the specific 4-in. risers in relation to other key equipment items on the tank is shown in Fig. 2-3. Removal of existing instrumentation or equipment in the riser is not covered by this SA.

Based on the results of an NEC-Classified Locations for a Hydrogen Atmosphere study, Tank 101-SY is divided into several NEC-classified locations.

- The tank dome space above the liquid level is a hydrogen environment approaching hazardous conditions at somewhat unpredictable intervals and accordingly is classified as a Class I, Div. 1, Group B space. It is the policy of this SA that all equipment in this area must meet applicable requirements and be rated for use under these hazardous, albeit temporary, conditions. If a prompt release could occur that would result in a peak-averaged dome space hydrogen concentration ≥60% of the LFL (2.15%), all electrical equipment in the dome space, or directly communicating with the dome space, that does not meet Class I, Div. 1 must be deenergized.
- The tank space below the liquid is a nonhazardous location. Equipment located in this area is not required to be intrinsically safe. Although this area is considered nonhazardous according to NEC-classified location divisions, confined voids within the liquid space potentially are hazardous.

2.3. RGS Design and Description

This section provides a brief introductory description of the components that comprise the RGS concept and core sampling operations. Only the push-mode core sampling method is presented. The drill rig can be used without any physical rearrangement to accomplish both push-mode and rotary-core sampling. To ensure that rotary-core sampling is not being used in Tank-101-SY, a lock-out/tag-out procedure is implemented. This administrative control is consistent with the push mode being the only method of sampling planned for Tank 101-SY and other flammable tanks. A definition of terms will include aspects of the rotary-core sampling method solely for completeness and are not to be construed as an endorsement of using this method in Tank 101-SY.

2.3.1. RGS Component Description

Shielded Receiver. The samples are retrieved from the drill string with a shielded receiver. Retrieval is accomplished by a power winch, cable, and reel internal to the receiver. This unit shields personnel from the sample and deposits samplers into the transfer casks [Fig. 2-4 (a and b)]; it also removes clean sample containers from the transfer cask and transfers them to the drill string for the next sampling operation. The receiver design is independent of the core sampling mode used and has built-in limit switches.

Ball Valve. A ball valve is provided at the bottom of the shielded receiver to isolate the receiver from the surrounding environment.

Transfer Casks. The transfer casks are held at the sample site in a five-cask holder stand. Each cask is held in an upright, vertical position. The transfer casks are lead-lined chambers that provide shielding and containment for the core samples during shipment to the analytical laboratory.

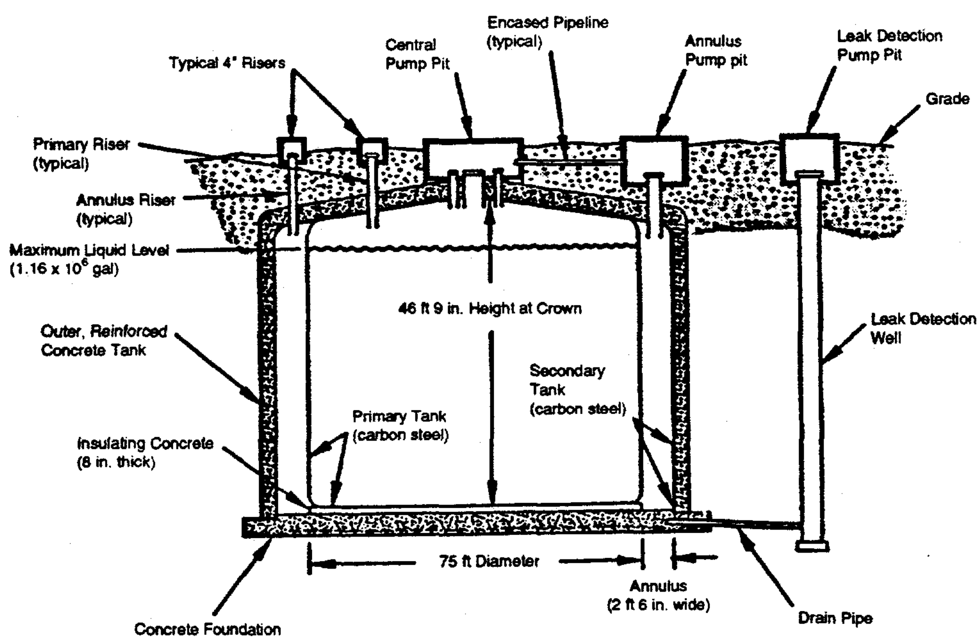

Fig. 2-2. Generalized cross section of a DST showing approximate configuration and dimensions.

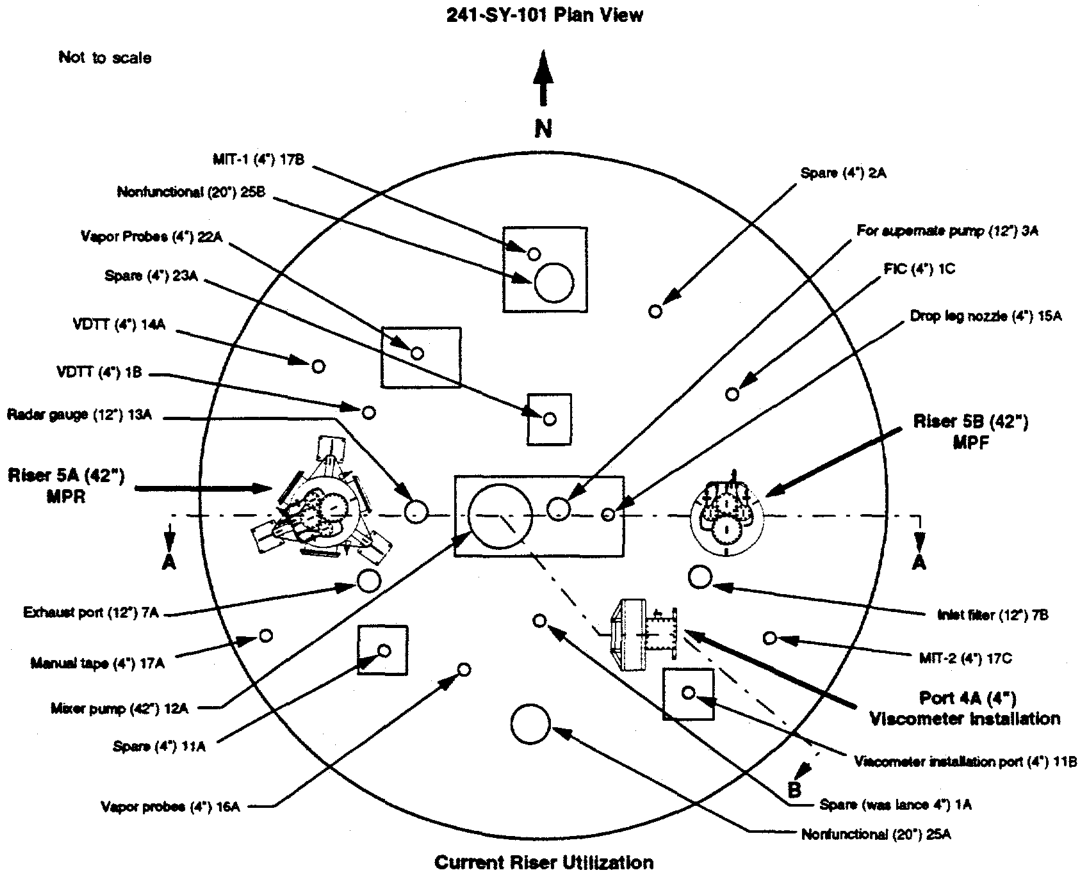

Fig. 2-3. Plan view of Tank 101-SY showing locations of various risers and sensors currently in the tank.

Core Barrel and Bit Assembly. This assembly contains the drill bit and the core sampler device. The drill bit is the first section of the drill string and is used for the drilling mode of operation.

Drill String. The drill string transmits power from the quill rod to the drill bit. The drill string is composed of numerous longitudinal drill sections, which are capable of reaching from the ground surface into the nonconvecting waste layer.

Drill Rod. Individual thin-walled drill sections are threaded at both ends and joined together to form the long drill string.

Quill Rod. The quill rod, which transfers power to the drill string, is the top-most section of the drill rod. This unit remains in the drill head and transmits power via a hydraulic chuck. The quill rod has a quick disconnect feature to allow addition of fluid to balance the hydrostatic head in the drill string.

Drill Head. The drill head, part of the drill unit, raises and lowers with the quill rod.

Drill Unit. The drilling rig applies downward force and rotary motion to the quill rod, which in turn transfers these motions to the drill string. This unit also includes the grapple unit.

Electric Hoist. An electric winch provides an onsite method to handle and transfer the cask stand, riser equipment, and the assembled drill string. This hoist lowers the drill string into the tank. The electric hoist also is used to prevent the drill string from falling into the tank whenever the pneumatic foot clamp is released completely.

Pneumatic Foot Clamp. This air-operated clamp retains the drill clamp string when the quill rod is disconnected. The foot clamp has a spring-actuated wedge clamp that must be pneumatically opened to release the drill string. If the pneumatic pressure is lost, the drill string cannot drop. The string must be raised 2 in. before the wedge action releases, freeing the drill string to move downward. The wedge clamp does not prevent upward motion of the drill string.

Hydraulic Chuck. The quill rod is clamped in place with a hydraulically operated chuck.

Hydraulic Leveling Jacks. The drill rig is leveled into place with stationary jacks.

Hydrostatic Head Liquid. In the case of Tank 101-SY, argon gas is used to prevent waste entry into the drill string when the sampler is removed from the core barrel.

Camloc™ Adapter. This device provides quick release for the adapter connector from the shielded receiver and casks to the drill string and quill rod.

Remote Latch Unit. This unit is an electrically driven mechanical latching device that provides a method to latch onto and release a core sampler assembly. The unit is raised and lowered by a winch located in the shielded receiver.

Pintle Rod. This rod attaches to the piston. A pin on the pintle rod trips the trigger mechanism to close the rotary valve. The pintle rod is removed by shearing a pin connecting the rod to the piston.

Quadralatch. This is a mechanism for ingress and egress of the sampler. The quadralatch rotates with the drill string in the rotary-core sampling mode. The remote latch locks onto the quadralatch fingers and disengages the latch mechanism from the drill string's internal bore, thus providing a method for retrieving the sampler.

Rotary Valve. This valve at the bottom of the sampler is rotated closed after completion of the sampling of one 19-in. segment of waste and seals the sample inside the sampler. The valve is rotated closed by actuating a spring-loaded trigger mechanism as the piston completes its 19-in. travel during the sampling operation.

Riser Adapters. These devices connect the riser equipment to various sizes of risers.

Decontamination. Decontamination is accomplished through a hot-water spray wash of the exterior surfaces as the drill rig is being extracted. The seal between the riser and the drill rod provides a wiping action during drill-rod recovery operations. The rubber seal that wipes the drill rod also serves to stabilize the drill string during rotation and seals around the drill string.

2.3.2. RGS Operations

The RGS sampling stages described below are subject to the assumptions listed. The overall RGS activities include setting up the truck equipment, sampling the core, and recovering the sample unit from the drill string. Also included in these activities is inserting an empty sampler unit into the drill string, transferring the sample unit to the transfer cask for shipping, cleaning up equipment, and restoring the tank, as well as performing operator maintenance activities. Activities required to set up the tank surface equipment to support the sampling operation are not covered by this SA. Only those operations relating to the installation, operation, and removal of the RGS are covered.

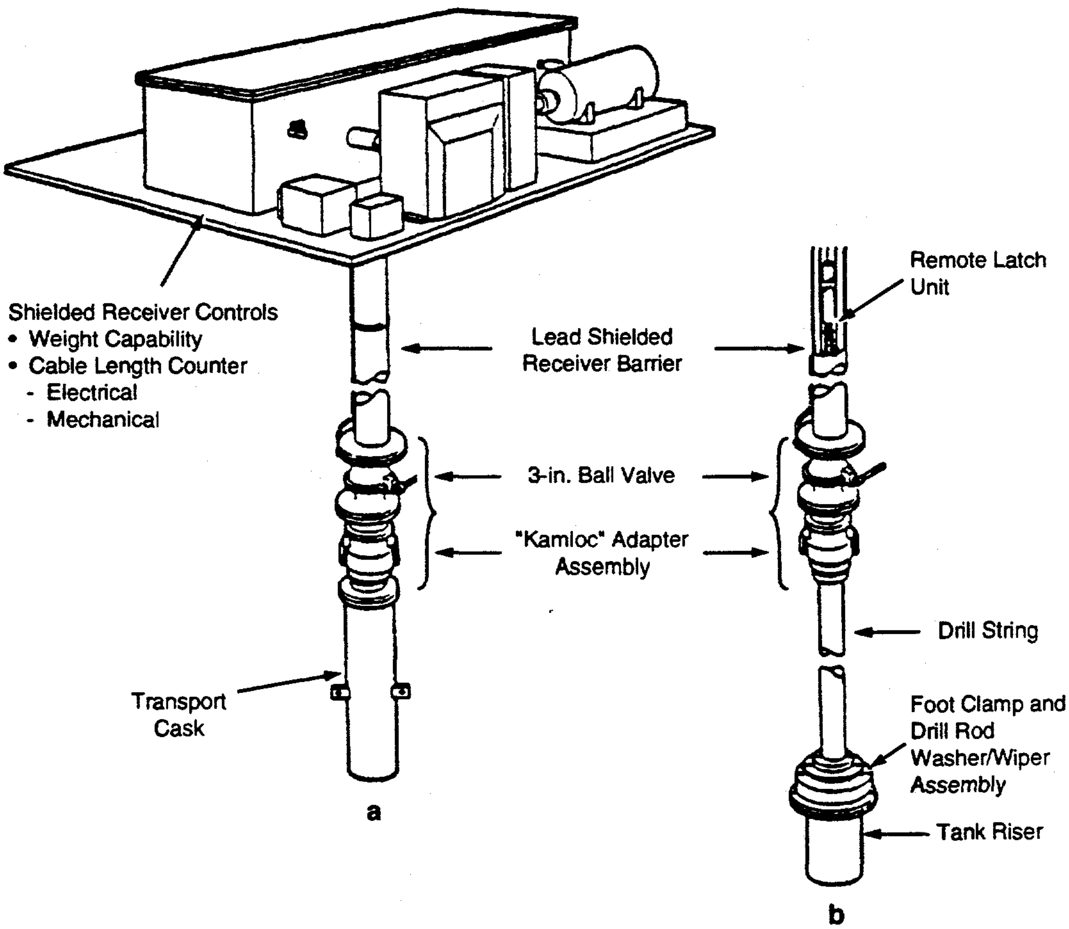

Fig. 2-4. Shielded receiver and riser adapter.

Specific measures will be taken during RGS installation to mitigate the potential for excessive personnel exposure to hazardous materials or releases to the environment of radioactive or other hazardous material. Controls required by WHC's ALARA requirements ensure that the potential for contamination spread is minimal. These measures incorporate factors related to weather conditions, monitoring requirements, lifting, rigging, and handling. These and other safety measures are discussed in greater detail in Sec. 6.

2.3.2.1. Installation. Installation includes the determination that tank conditions are suitable for intrusive open activities [work controls for intrusive operations with an open tank (Sec. 6.0)], initial preparation of the riser (such as removal of existing equipment or piping), preparation of installation equipment, and insertion of the drill string into the tank.

The core sampling truck will be positioned on the dome in the vicinity of the riser opening. The stationary leveling jacks will be used to level the RGS support truck. Energized equipment necessary to affect the positioning and leveling of the truck rotary table to the riser will be de-energized before the riser cover is removed. Procedural steps will be taken to appropriately bond and ground necessary equipment to reduce electrical discharge hazards in preparation for riser cover removal.[2] Nonsparking tools will be used to remove or tighten bolts (except for the initial loosening and final torquing).[2] Before opening the riser, actions required by WHC standard controls to access the riser area will be performed. Sequential steps guided by a work plan[3] will be followed to install the appropriate riser adapters and the decontamination spray ring. This phase ends when the preparation tasks are complete and the riser is ready for the first drill-string section to be inserted. Gasoline- or diesel-powered equipment may not be started nor electrical equipment energized until the riser is completely sealed. The accessory power unit may be gasoline or diesel powered, depending on the truck system (i.e., the push-mode or the new rotary-core sampling truck used in the sampling operation).

2.3.2.2. Drill-String Assembly during RGS Installation and RGS Sampling Phases. The core sampler is inserted into the core barrel manually. The quadralatch mechanism of this component locks into the bore serrations [Fig. 2-5 (b)]. A seal (Rainier) between the bottom of the sampler and the drill bit housing ensures that waste cannot flow around the sampler up into the interior of the drill string. This seal isolates the waste from the upper regions of the drill string, assuming that no failures occur.

The core bit/sampler assembly is inserted past a circumferential rubber seal housed in the riser adapter and beyond the decontamination spray ring region. Considerable force is required to insert the unit pass the seal, which isolates the tank vapor space from the external surroundings. Subsequent drill-string sections can be added using an electric hoist. Administrative controls preclude dropping any heavy items onto the riser, thus ensuring that potentially excessive loads will not be imposed on the tank.

Subsequent drill-string sections are added until the sampler drill bit is within 18 in. of the waste surface, as determined by (1) an FIC reading, (2) the number of string sections, and (3) the riser grade level information. The drill unit next is connected to the drill string using the cable winch. The grapple unit [Fig. 2-5 (c)] is lowered into place and connected to the sampler-piston's pull rod. With the grapple unit in place, the pull rod and sampler piston are now fixed relative to the waste. The unit now is ready for the sampling phase.

2.3.2.3. Operation. Operation includes normal sample collection operations, as well as operational checks, measurement, and calibration. Specific operations include activities of performing the core sampling, as well as operator maintenance activities. These operations will be performed in accordance with an approved WHC test plan.[4]

During operation of the RGS key system, parameters will be monitored for adherence to predetermined performance guidelines. RGS operation will be terminated when a critical parameter is exceeded. These performance criteria formed the basis for the safe shutdown definitions utilized in constructing the administrative controls section.

2.3.2.4. Sampling-Push Mode. Lowering the drill string and latched-down sampler causes the waste to be extruded into the sample chamber. A 19-in. downward motion produces a sample 1 in. in diameter and 19 in. long. As a precaution, the drill is fitted with a hydraulic tank bottom indicator that will interrupt downward travel if resistance above a preset value is encountered. This feature is activated manually once the crust has been penetrated. As an added safety feature, the drill bit is constructed of a material that is incapable of drilling into steel of the type used in the tank fabrication. This feature ensures that penetration of the tank in a drilling operation is not possible.

At this juncture, raising the grapple unit will close a rotary valve at the bottom of the sample unit, thus sealing the waste specimen in the sample chamber [Fig. 2-5 (c)]. Raising the grapple unit any further will cause a pin to shear, which separates the pull rod from the sampler piston. Now the sample is sealed by the piston at the top, the sampler chamber body, and the rotary valve at the bottom.

The sample is recovered from the drill-string assembly by lowering the remote latch mechanism onto the quadralatch mechanism. The remote latch releases the quadralatch from the serrations in the core wall. When the remote latch is retrieved, the sampler unit is withdrawn into the shielded receiver unit, which is positioned over the drill string at the platform interface. A weight transducer assures that the sampler is latched into the remote latch unit. If the transducer indicates an excessive load (>150 lb) after several attempts to withdraw the remote latch, the removal process will be terminated. No further attempts at removal will be made, and the PIC is notified of the abnormal condition. Retrieval attempts beyond procedures outlined in the approved work plan for the aforementioned condition will require TRG approval.

With the assembly withdrawn into the shielded receiver, a ball valve is closed at the lower end of the receiver to isolate the radiative sampler from the surrounding environment. The ball valve is operated manually; thus, this design facet ensures complete valve closure and isolation of the radioactive material.

Maintenance operations, such as equipment repair, also may be required. For those operations involving tank intrusion and removal of contaminated material, WHC has developed work plans[5] to ensure that radiation and other contaminants are within allowable levels.

An argon purge system[6] will be used to prevent waste from entering the long cavity formed by the outer drill-string shell. Important characteristics of the purge system, including the internal tank dome pressure and gas flow rate, will be monitored.

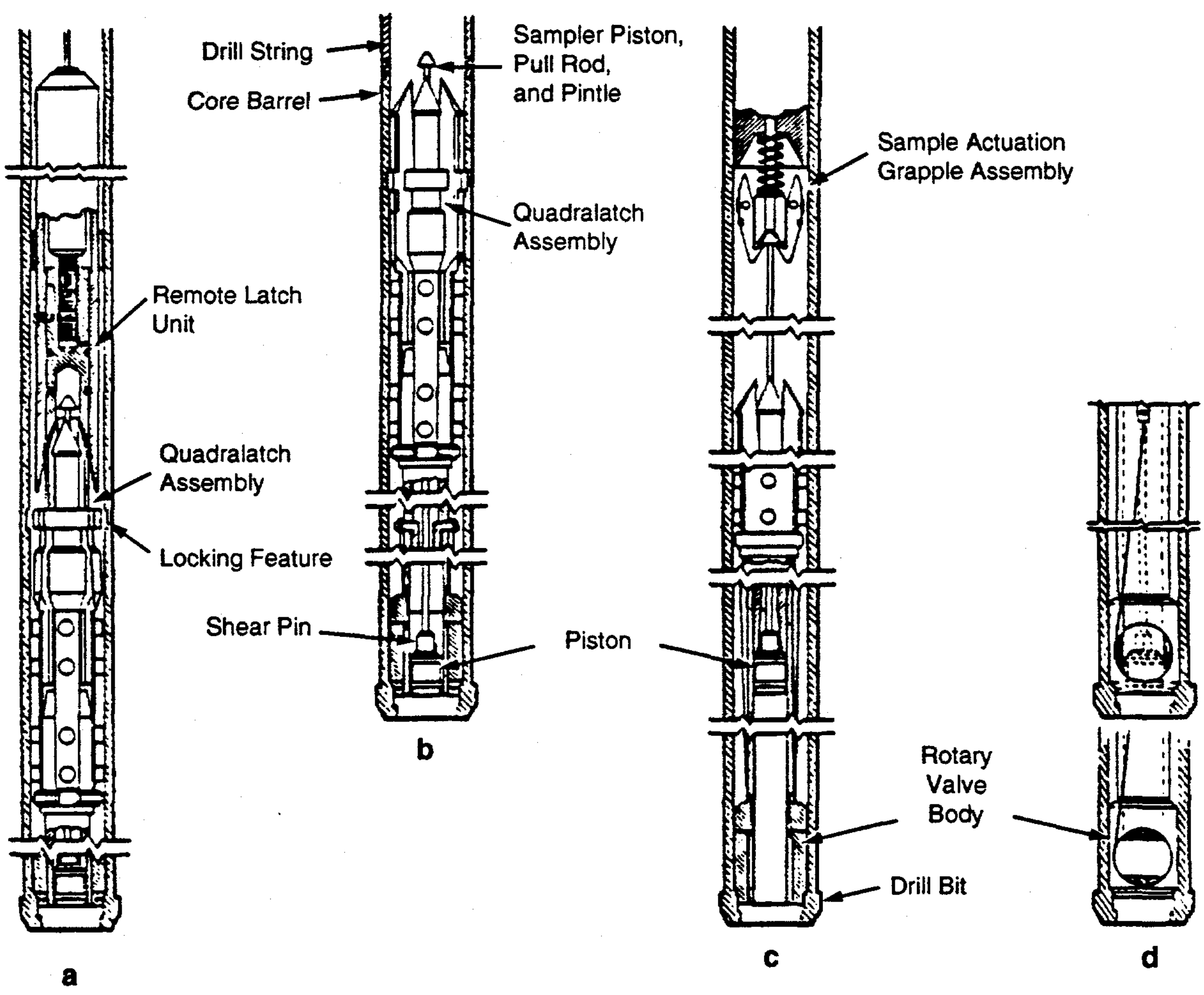

Fig. 2-5. Illustration of RGS and its components.

Details of the drill-string assembly, RGS operation, and operational limits are outlined in the Push Mode Core Sampling Safety Assessment.[2] This information was used in preparing the RGS SA and is summarized in Table 2-1.

2.3.2.5. Removal. Removal includes the entire set of operations required from the time the final RGS unit completes operation until it is transported from the tank farm facility. Specifically, it includes removing the sample unit from the drill string, inserting a new empty sample chamber for additional sampling (if appropriate) or preparing the sample unit for shipping, cleaning up equipment, and restoring the tank, as well as performing operator maintenance activities. In some cases, the individual RGS samplers may remain at the site for short periods in shielded receivers. Removal operations begin with physical removal of the sample unit. Open-tank conditions exist from the time that the interface of the RGS to the tank is broken until a blind flange is attached to the riser.

A decontamination system cleans tank waste from the exposed surfaces of the RGS.[7] The effectiveness of the decontamination system is evaluated by radiation monitoring of the drill string as it is removed. If contamination is higher than acceptable levels, the offending section is inserted below the decontamination system and the decontamination process is repeated. This process continues until the RGS is completely withdrawn from the tank.

TABLE 2-1
OPERATIONAL PARAMETERS FOR PUSH-MODE SAMPLING METHOD

Parameter	Low Value	High Value	Normal Range
Purge Gas Pressure (psi)	0	90	0–20
Purge Gas Temperature (°F)	40[a]	100[a]	60–80
Enclosure Temperature (°F)	50[a]	90[a]	75
Purge Gas Flow (scfm)	0	10	0
Shielded Receiver Flow (scfm)	0.1	10	0.3–4.0
Drill-String Flow (scfm)	0.1	10	0.3–0.5
Drill-String Speed (rpm)	0.0	0[b]	0
Shielded Receiver Pressure (psi)	0.1	35	0.5–30
Drill-String Pressure (psi)	0.1[a]	35	0.5–30
Penetration Rate (in./min)	0	10	3–7
Downward Force (lb)	0	5370[a]	0–1000
Lower Ram Pressure (psi)	0	250	100–200

[a]Alarm value.
[b]Shutdown interlock value.

Once the drill-string sections are withdrawn from the tank, they are prepared either for temporary storage or removal from the tank farm. The process for temporary storage or removal is not addressed in this SA but is governed by existing safety controls and procedures for handling contaminated equipment.

2.3.3. RGS Safety Design Features

Table 2-2 summarizes aspects of the RGS design concerned with safety issues associated with RGS operations. The list comprises four categories: the drill string, drill truck, purge gas system, and those aspects relating to the system interfaces. It was impractical to make this particular list of safety-related design features all-inclusive. However, we attempted to cover those safety issues likely to have a bearing on operations in Tank 101-SY.

2.3.4. RGS System Weight

RGS operations for Tank 101-SY will impose an increase in the dead weight over the tank dome. Table 2-3 lists the weights of the various components[7] that possibly will be imposed simultaneously on the dome surface. This additional tank dome loading is considered to be a live load in the WHC evaluation of the tank structural integrity (Sec. 4.3.4.1).

A potential hazard to the tank structural integrity exists if the RGS drill string were to fall and impact the tank bottom. For this reason, the total weight of the components suspended over the tank bottom is an important factor. However, the weight of the drill string projecting from the top of the riser into the waste region varies according to the installed number of drill sections and the equipment placed within the drill-string cavity. The outer drill-string section weighs nominally 4 lb/ft, and the 19-in. sample chamber weighs 6.3 lb.[8] The quadralatch assembly with sample piston pull rod and pintle also is part of the weight suspended during the core drill-string insertion [Fig. 2-5 (b)]. This component adds another 25 lb to the assembled weight. The combined suspended weight for a core sample operation would peak as sample operations approach the tank bottom (e.g., a 50-ft drill-string length effectively would be 231.3 lb. However, the impact energy peaks at an intermediate sampling depth because it is a product of the suspended weight and drop height. This is considered in the drill-string drop analysis (Sec. 4.3.4).

2.4. Data Acquisition and Control System

Currently, this section is written based on preliminary design information. The contents must be verified/revised when the design information is complete.

The RGS pressurization and sampler systems will be operated using a specially designed control system.

TABLE 2-2
RGS DESIGN SAFETY FEATURES

Drill-String Safety Features	Description
Drill Bit Material	An earlier design used a sintered carbide matrix drill bit material that was chosen so that the drill would not cut through the tank bottom in the event of contact. We understand that the design later was changed to use 300 SS. At the time of this report, the final design information was not available.
Tank Bottom Detector	The bottom detector is a hydraulic interlock system that detects the increase in resistance above that resulting from sampling. When that increase is sensed, the hydraulic system is disabled to prevent further pushing.
Material Compatibility	The materials used in the RGS and drill string were chosen to be compatible with the contents of the tank so that neither chemical action nor materials failure is expected as a result of expected or accidental contact with the waste. For example, aluminum, bronze, and Teflon are known to be incompatible with the waste in Tank 101-SY. These materials therefore are avoided in the design.
Push Force Limitation	In the push and rotary mode of operations, a force-limiting feature provides an upper bound on the amount of downward force that can be applied. This ensures against breaching tank integrity and drill-string buckling damage.
Grounding and Bonding	The drill string, argon trailer, and exhauster will be grounded to the tank by means of a riser ground.
Hydraulic Drill-String Ram	The drill-string hydraulic ram for the push mode is supplied with hydraulic pressure. The hydraulic system has a pressure relief valve to control overpressure and check valves to prevent flow reversal.
Hoist Cable Tension	Tension is monitored during removal of the sample unit. Tension >150 lb may indicate that waste is accumulating in the core barrel.
Pneumatic Foot Clamp	This clamp prevents the drill string from falling into the tank when a drill section is being added. A design feature of the drill-string support requires that the drill string be lifted 2 in. before it can be lowered. This feature precludes a drop if the foot clamp fails.
Sampler Shear Pin	The shear pin material was chosen in part so that the spring action and shear would not result in a spark that could ignite any flammable gas.
Drill Truck Safety Features	**Description**
Exhaust System Protection	Heat/spark production areas of the exhaust system are located away from flammables. The exhaust outlet is screened to stop or dissipate any sparks.
Grounding	The truck is grounded and bonded to help eliminate sparking from electrical equipment and static electricity buildup.
Stabilizer	The vehicle hydraulic stabilizer assures a level surface before operations begin. The stabilizer arms lock so that the surface remains level in case of hydraulic failure.
Fuel	In the final design application, diesel fuel was chosen over gasoline for use in the rotary-core sampling truck to minimize fire and combustion hazards (originally, the push-mode drilling truck used gasoline).

TABLE 2-2 (CONT)
RGS DESIGN SAFETY FEATURES

Drill Truck Safety Features	**Description**
Hydraulic System	The hydraulic system for truck rotary platform and truck level stabilizers is also used for the hydraulics for the drill-string ram and drill stream chuck. Redundant hydraulic pressure relief valves protect against overpressure.
Audible Alarms	If drill platform movement or out-of-safety envelope condition occurs, distinctive audible alarms will sound.
Decontamination System	The RGS is decontaminated as the drill string and hoist cable are withdrawn from the tank. Decontamination is accomplished by using a hot-water spray applied to the hoist cable and sampler. Decontamination also includes the hot-water spray wash of the drill string.
Radiological Controls	The area around the riser is monitored to assure that personnel are not exposed to hazardous radiological conditions. Limits are set by WHC ALARA conditions.
Personnel Protective Equipment	Personnel protective equipment includes breathing protection, clothing, dosimetry, etc., for protection against site hazards.
Argon System Safety Features	**Description**
Argon Purge Supply	The continuous flow of argon gas, used in maintaining the hydrostatic equilibrium in the drill column, is controlled by a regulator to ensure that excessive amounts of argon will not be injected into the waste.
Pressure Relief	TBD pending review of the final work plan or equivalent documentation.
Manual Regulators/Flow Control Valves	TBD pending review of the final work plan or equivalent documentation.
Grounding/Bonding	The argon support trailer is grounded and bonded to help eliminate sparking from electrical equipment and static electricity buildup.
Safety Limits	The amount of argon gas and/or water introduced into the tank is controlled to within acceptable limits to ensure that the possibility of a GRE is eliminated.
System Interface Safety Features	**Description**
Truck System Interlocks	TBD pending review of the final work plan or equivalent documentation.
Safety Alarms	A computer-controlled alarm system was implemented that monitors system parameters (purge gas flow and temperature, drill string and shielded receiver flow, etc.) and automatically places the operation in a shutdown mode if critical parameters fail to stay within specifications.
Data Collection and Recording System	The data collection and recording system for the tanks and the test equipment provides a real-time sensing of tank and other conditions so that unusual or unexpected conditions are displayed to permit corrective action.

TABLE 2-3
RGS COMPONENT WEIGHT BREAKDOWN

Component	Weight (lb)
Core Sample Truck	24,425
Cask Trailer	6000
Support Trailer	4000
Cask Stand	500
Casks (5 total)	1925
People (10 total)	2000
Total	38,850

Some system setpoints are made within the RGS pressurization system housing, such as adjustments of the pressure regulators and replacement of the argon source cylinder. Controls for the decontamination system are operated manually and are located outside the radiation control area, near the RGS control console. All other controls on the RGS are actuated electronically.

As discussed in Secs. 4 and 5, continuous monitoring of radiation near the RGS will be required. The radiation detector will be mounted to a fixed location near the RGS and will have an alarm setpoint. This measurement is not controlled by the control unit.

If a visual inspection in the dome is necessary, a video camera also may be used to examine the RGS when the lower assembly is in the dome. Visual inspection is necessary before removal if there is an indication of apparent damage to the string from a wasteberg impact.

The depth of the sampler and the pressure of the argon connecting lines will be measured to gain RGS information.

- The depth of the RGS will be measured by maintaining length measurements of added drill-string sections.
- The pressure of the argon pressurization system will be measured by electronic pressure transducers [as shown on the piping and instrument diagram (P&ID) in Fig. 2-6].
- The position of the various valves will be determined by the position-indicating systems built into the valve housing and indicated on the control screen.

Decontamination system operation will be controlled manually by operators at the direction of the PIC, in accordance with operating procedures.

(The necessary information to generate this figure was not available at the time of this report.)

Fig. 2-6. RGS P&ID.

2.5. Riser Preparation

The initial installation of the RGS on any new riser will require riser preparation, which includes the removal of equipment installed on the riser and verification that the riser is suitable for installation of the RGS. This portion of the operation is not covered in this SA. For the purposes of this SA, suitable riser preparation is defined as an empty riser covered with a blind flange.

2.6. Principal Safety Criteria

Assessment of all safety aspects associated with implementation of the RGS in Tank 101-SY has been predicated on the same relevant and applicable principal safety requirements established by DOE Orders for controlling mixer pump operations. The results of this evaluation indicate that the design, operation, and removal processes meet the content of the requirements established in the DOE Orders.

REFERENCES

1. L. H. Sullivan, "A Safety Assessment for Proposed Pump Mixing Operations to Mitigate Episodic Gas Releases in Tank 241-SY-101: Hanford Site, Richland, Washington, " Los Alamos National Laboratory report LA-UR-92-3196, Rev. 13 (November 4, 1994).

2. R. M. Marusich, "Push Mode Core Sampling Safety Assessment," Westinghouse Hanford Company report WHC-SD-WM-SAD-008, Rev. O-A (May 10, 1991).

3. Westinghouse Hanford Company, "Instructions for Installation and Removal of RGS in Tank 241-SY-101," Westinghouse Hanford Company report (in progress).

4. Westinghouse Hanford Company, "RGS Test Plan," Westinghouse Hanford Company report (in progress).

5. Westinghouse Hanford Company, "RGS Operations and Maintenance Manual, " Westinghouse Hanford Company report (in progress).

6. B. J. Webb, "RGS Functional Design Criteria," Westinghouse Hanford Company report (in progress).

7. Frank J. Reitz, Westinghouse Hanford Company, "Perform Push Mode Core Sampling on Tank 103-SY," Westinghouse Hanford Company report TFPE-YP-0231, Rev. A/Mod O (August 9, 1994).

8. Informal communication with B. Webb/R. Bolden of Westinghouse Hanford Company (September 1994).

3.0. IDENTIFICATION OF HAZARDS

The procedure used in the Mixer Pump SA[1] hazards identification study was applied here to identify the hazards of concern for the installation/removal and operation of the RGS. This appraisal process identified hazards based on the specific features and characteristics of the RGS. This RGS SA focused on hazards and the mitigation of hazards that may result in the release of radioactive or toxic materials from the push-mode sampling method. In addition, specific analyses were identified to quantify the potential for structural damage to the tank dome that may lead to a breach in containment.

The results of this hazards identification, like the Mixer Pump SA, indicate that the potential contributors to the release of radioactive and toxic materials and structural damage to the tank can be combined as follows:

- hydrogen or toxic gas release through the open 4-in. riser or RGS assembly;
- hydrogen release with burn, resulting in challenges to RGS components that form the boundary between the tank and the atmosphere;
- releases from the ventilation system, tank penetrations, and tank structural failures caused by RGS activities;
- external events (e.g., flooding, fires, earthquakes, and winds) potentially interacting adversely with the RGS and RGS support systems;
- exposure of personnel to radiation or hazardous materials during RGS operations;
- damage to Tank 101-SY, an SC-I structure; and
- damage to other in-tank structures or instruments.

3.1. Methodology

The methodology chosen for identifying hazards for the proposed RGS operation are predicated on an in-depth HazOpS presented in Ref. 1. The HazOpS included operations very similar to those expected for the RGS and also characterized intrinsic tank hazards that provide energy for potential materials release. As with the mixer pump, using the RGS requires opening the tank for installation and removal. Unlike the mixer pump, RGS operations are simple, with only a minor disruption of tank contents during the operational phases. Hazards unique to the RGS and its operation are considered through the investigation of the proposed system and its operation. The consequences of these hazards were evaluated systematically; results are presented in Sec. 5.

The Mixer Pump SA[1] considered burns in the Tank 101 SY crust, beneath the crust, and in the liquid and determined that these burns are not possible. Observations indicate that the crust is porous and thus incapable of trapping gas in or immediately beneath the crust. The results of this study show that the crust will not sustain combustion. Further studies also have revealed that a gas burn of any substantial magnitude in the C or NC layer is not credible. A substantial burn requires a coalescence of the combustible gas. Reference 1 states that the gas is approximately uniform throughout the tank. The mixer pump operation has enhanced this equilibrium and has minimized the potential for significant GREs by promoting gas release. These aspects of the tank behavior were considered in assessing the hazards associated with in-tank operations of the RGS.

As with previous SAs, this hazard identification is qualitative and deliberately does not attempt to quantify the likelihood of a contributing cause, nor does it express the potential consequences in quantitative terms. The hazard identification does not provide a detailed breakdown of the contributing causes at the root cause level unless the root cause is important in differentiating potential consequences.

3.2. Results of the RGS Hazards Identification

The hazard identification conducted for the proposed action in Tank 101-SY examined three RGS processes: (1) installation, (2) operation, and (3) removal. The hazards associated with transportation of contaminated RGS equipment from the tank farm or the ultimate decontamination and disposal of this equipment are not considered. These activities are included in the safety analysis reports for site transportation, and waste storage and handling are subject to the applicable controls therein.

The results of the hazards identification process are summarized as hazard assessments in Table 3-1. The first column of the table identifies the hazard of concern. The second column identifies the cause(s) of the hazard. The third column summarizes the hazards analysis and assessment of the RGS design characteristics performed to ensure that the hazardous condition has been mitigated by design action or through administrative controls. References in Table 3-1 refer to appropriate SA sections and WHC documentation.

TABLE 3-1
HAZARDS IDENTIFICATION FOR INSTALLATION/REMOVAL AND OPERATION OF THE RGS

HAZARD	CAUSE	SAFETY ANALYSIS
Hydrogen or Toxic Gas Release	Loss of tank vapor containment combined with unexpected GRE	
	•Riser open during RGS installation or removal	•Toxicological and radiological issue mitigated by virtually no pressure difference (Sec. 4.3.1). Installation/removal controls in Sec. 6.0 on waste level to lower the probability of unexpected GRE
	•Radiation or chemically damaged seals	•Seal materials selected to withstand stringent environmental conditions; material specification contained in WHC documentation (Ref. 2)
Hydrogen or Toxic Gas Release with Burn	Hydrogen accumulation and ignition source caused by RGS equipment installation, removal, and/or operation:	All hazards associated with various ignition sources have been mitigated. Spark sources are mitigated by imposing administrative restrictions on the permissible tank waste level during intrusive operations. Action precludes burn event that endangers tank structural integrity. Other considerations are:
	•Surface ignition source (spark) stemming from RGS operations, and mechanical impact from tools, equipment, etc.	•Grounding and bonding of truck, drill string, and spark production areas[3–5]
	•Internal spark generated from mechanical action or operation of RGS •Dropping sampler in drill string, etc.	•Sampler shear pin selected on basis of nonsparking material[6]
	•Chemical reaction combined with exothermic release, incompatible materials with waste environment	•Materials selection based on compatibility with waste[2]
	•GRE precipitated by RGS operation, or GRE from admitting excessive argon gas in waste, leading to ignitable gas mix	•Sec. 6.0 (Controls)
	•Lightning strike, ungrounded equipment	•Electrically grounded equipment, Sec. 6.0 (Controls). All electrical equipment in dome space must meet Class 1, Div. 1, Group B
Filter System Release from Ducts or HEPA Filter (Not Associated with Burn)	Damaged HEPA filters and ducts	
	•Drop of equipment on HEPA filters or truck encroachment onto ventilation system	•Work plan control for all RGS surface operations (Sec. 2.0). See Secs. 4.3.3, and 6.0 (Controls)

TABLE 3-1 (CONT)
HAZARDS IDENTIFICATION FOR INSTALLATION/REMOVAL AND OPERATION OF THE RGS

HAZARD	CAUSE	SAFETY ANALYSIS
Loss of Containment	Breaches of the tank enclosure or boundary caused by:	
	•Objects falling against tank wall or mixer pump	•Drill string retained by pneumatic clamp. (Sec. 4.3.4). (Impact analysis of damage to wall is not complete).
	•Drill string falling inside tank and rupturing tank bottom	•Drill string retained by pneumatic clamp (Sec. 4.3.4). Impact analysis shows no damage to tank bottom
	•Drill string forced into tank bottom by push mode	•Hydraulic safety interlock, force sensor limits on push force (Sec. 4.4.2)
	•Drill bit coring the tank bottom	•Drill bit composed of frangible material, which protects tank liner integrity (Sec. 4.4.2)
	•Internal forces other than those associated with burn (e.g., wasteberg)	•WHC structural analysis shows that hazard to tank from wasteberg is mitigated by design (WHC report in progress)
	•External forces on tank (earthquake, dome loads, heavy equipment, etc.)	•WHC structural analysis shows tank surface load limit not exceeded by transit of RGS truck and related equipment[7]
Flooding of Tank	Uncontrolled fluid source	
	•Excessive operation of, or failure of, decontamination spray system	•Sec. 4.3.5, administrative controls [Sec. 6.0 (Controls)]
Radiation Exposure	Personnel exposure from open-riser operations	
	•Inadequate shielding (shine)	•Sec.4.3.6; WHC work plan (in progress); Sec. 6.0 (administrative controls)
	•Handling contaminated components associated with RGS operations	•Decontamination of external and internal components provided; hydrostatic balance of waste prevents ingress to drill string (Sec. 4.3.6.2)
Ejection of RGS from Tank	Drill string, sample container, and contaminated associated equipment ejected from unexpected GRE/burn event	
	•Drill-string pneumatic clamp failure	•Analysis confirms that assembly cannot be ejected (Sec. 4.3.7)
Uncontrolled Toxic Gas and Radioactive Stack Emissions	Failure of RGS gas supply for hydrostatic fluid balance of drill-string column	
	• Loss of argon gas flow control, resulting in GRE	•Loss of negative pressure terminates operation [Sec. 6.0 (administrative controls)]
Release of Tank Waste Sample	Breach of waste sample container during extraction from tank riser	
	•Dropping of sample container	•Sample chamber confined within enclosure, either in drill string or shielded receiver; drop of equipment does not create unacceptable exposure problem (Sec. 5.3.1)

REFERENCES

1. L. H. Sullivan, "A Safety Assessment for Proposed Pump Mixing Operations to Mitigate Episodic Gas Releases in Tank 241-SY-101: Hanford Site, Richland,

Washington, " Los Alamos National Laboratory report LA-UR-92-3196, Rev. 13 (November 4, 1994).

2. B. J. Webb, "RGS Functional Design Criteria," Westinghouse Hanford Company draft report, no date available.

3. Frank J. Reitz, "Perform Push Mode Core Sampling on Tank SY103 7 B," Westinghouse Hanford Company Engineering work plan WHC-TFPE-Y-0231 (August 9, 1994).

4. R. J. Van Vleet, "Safety Basis for Activities in Double-Shell Flammable Gas Watch List Tanks," Westinghouse Hanford Company report WHC-SD-WM-SARR-002, Rev. 0 (May 9, 1994).

5. N. J. Milliken, "Safety Assessment for Push-and Rotary-Mode Core Sampling in Ferrocyanide Tanks," Westinghouse Hanford Company report WHC-SD-WM-SAD-013, Rev. 3-A (October 29, 1993).

6. R. M. Marusich, "Push Mode Core Sampling Safety Assessment," Westinghouse Hanford Company report WHC-SD-WM-SAD-008 (August 15, 1991).

7. L. J. Julyk, "Analysis of Underground Waste Storage Tanks 241-SY at Hanford, Washington," ARH-R-172 Rev. 0-A(ECN191846) (June 24, 1994).

4.0. HAZARDS AND ACCIDENT ANALYSIS

This section develops the accident sequences for hazards identified in Sec. 3; the methodology is presented in Sec. 4.2. The sequences developed here are predicated on similar sequences presented in Sec. 4 of the Mixer Pump SA.[1]

4.1. Accident Sequence Development

Accident sequences are developed based on the hazards analysis presented in Table 3-1 of Sec. 3. These sequences were developed based on accident analyses made previously for Tank 101-SY, where applicable, and on an understanding of the basic processes and operations to be performed in this tank using the RGS. Accidents are analyzed by considering the consequences and probabilities where appropriate. This SA demonstrates that adequate measures have been taken to prevent accidents. The appropriate measures taken to mitigate the hazards include use of design codes and appropriate design criteria, as well as adoption of administrative controls provided in the SA.

Accident sequences were developed using identified accident initiators. All accident sequences except those involving a GRE are single-initiator, single-consequence sequences. There are multiple consequences for the GRE-initiated accident sequences; therefore, a generic event tree, as shown in Fig. 4-1, was used to develop the accident sequences. The outcomes of these sequences depend on whether an ignition source is present and whether the ventilation system is operating. The generic event tree is applicable to the GRE cases for all phases of the action.

We will show that all RGS accident consequences are bounded by the Mixer Pump SA[1] for Tank 101-SY. Thus, the frequencies, accident scenarios, and/or probabilities for RGS-specific accidents are outlined in Table 4-1. In all cases, the risks associated with RGS activities, defined as the probability of occurrence multiplied by the consequences of the occurrence, are bounded by corresponding accidents for the mixer pump. Tables of detailed mixer pump accident frequencies are located in the Mixer Pump SA.[1]

The consequences of the identified accident sequences are discussed in Sec. 5.

4.2. Accident Analysis Methodology

The methodology used to evaluate identified accident conditions is similar to that discussed in Sec. 4 of Ref. 1. In this process, some hazard causes were grouped and considered as a single initiators. The ignition sources from Table 3-1 were considered conditional events and are required for all accident sequences involving burns. There is a one-to-one correspondence between the accident sequences listed in Table 4-1 and the Hazard columns in Table 3-1.

Computer-based models used to predict the tank gas releases and their magnitude and composition, the structural model for the tank, and release consequence models are the same used extensively in preparing the Mixer Pump SA.[1]

In preparing the RGS assessment, specific efforts were made to credit contributions of safety systems and administrative controls that serve to reduce overall risk in mitigating the hazard under consideration.

Reference 1 contains a detailed description of the methodology used in updating the accident frequencies associated with Tank 101-SY. In this SA, the procedures outlined in Ref. 1 were utilized for estimating accident frequencies for events similar to those defined for the mixer pump. In particular instances, the pump accident frequency incorporates an exposure factor of 1/8, i.e., for accidents involving insertion and pump removal, where pump replacement is anticipated to occur once every 8 yr. This exposure factor was set to 1 for the RGS, effectively increasing the accident frequencies involving GREs in conjunction with burn events. The frequencies listed in Table 4-1 reflect these adjustments. In several instances, the rationale for accident frequencies somewhat unique to the RGS cases are detailed in the section that discusses the particular accident.

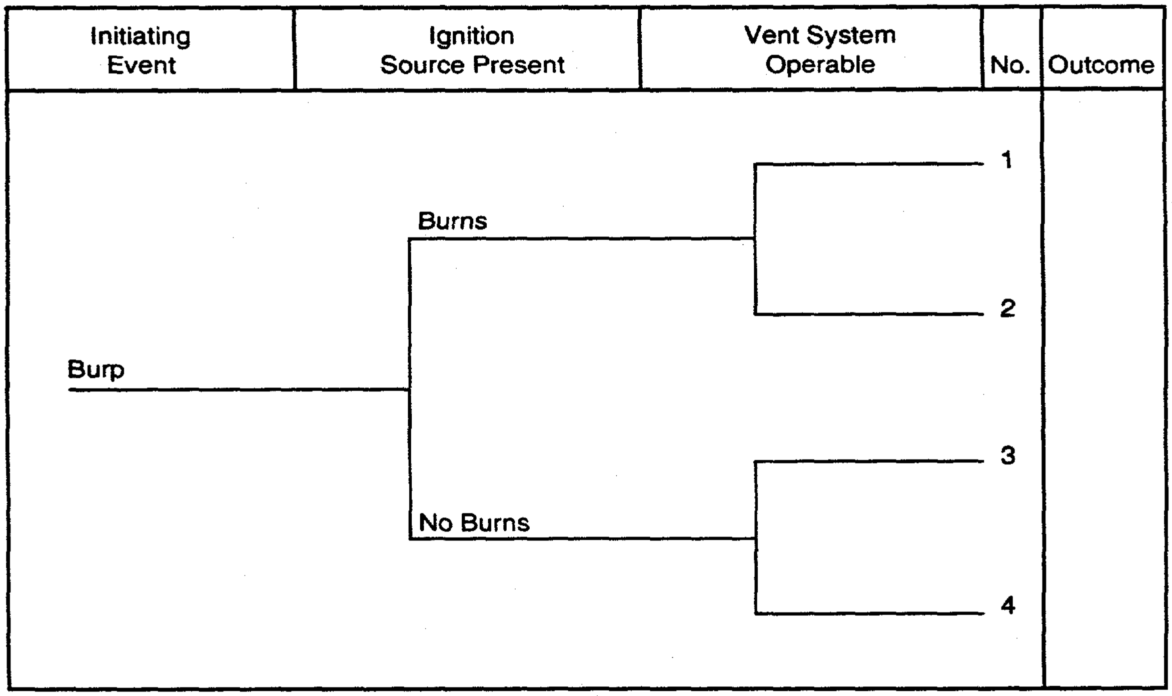

Fig. 4-1. Generic event tree for hydrogen release.

TABLE 4-1
ACCIDENT SEQUENCES DURING RGS INSTALLATION/OPERATION/REMOVAL

Accident Outcome	Accident Initiators	Event Tree	Mean Frequency	Reference Section
Hydrogen or toxic gas release, L (level) ≤404[a] in.	Window GRE	Fig. 4.1, branch 3 -no burn -ventilation operable	1.2E-2/yr	5.2.1
Hydrogen or toxic gas release L ≤404 in.	Window GRE	Fig. 4.1, branch 4 -no burn -ventilation not operable	1.2E-6/yr	5.2.1
Hydrogen release with burn, L ≤404 in.	Window GRE and ignition source	Fig. 4.1, branch 1 -burn -ventilation operable	1.2E-5/yr	5.2.1
Hydrogen release with burn, L ≤404 in.	Window GRE and ignition source	Fig. 4.1, branch 2 -burn -ventilation not operable	1.2E-9/yr	5.2.1
Filter system release	Filter train failure caused by hydrogen release with burn		1/burn	4.4.2
Filter system release from ducts or HEPA filter (not associated with a burn)	Drop of equipment on HEPA filters		3.E-4	4.3.3
Loss of tank containment	Dropped drill-string assembly, internal or external -Small parts drop -surface fire		1.2E-9 1.2E-7	4.3.4.2 4.3.2.2
Spill during removal	-Core sampler drop with 500-g release		4.8E-3/yr	5.3.1
	-Ejection of waste during addition of string section		1.2E-5/yr	5.3.2
Flooding of tank	-External event -Inadvertent water addition to tank			4.3.5
Unfiltered release through open riser	-Loss of negative tank pressure -External events		1.2E-5/yr	5.2.2
Radiation exposure	-Inadequate shielding -Handling contaminated components		1E-3	4.3.6

[a]Accident frequency based on probability of exceeding 25% of LFL (Ref. 1, App. F). See Sec. 5.0 for restrictions on this tank waste level limit.

TABLE 4-1 (CONT)
ACCIDENT SEQUENCES DURING RGS
INSTALLATION/OPERATION/REMOVAL

Accident Outcome	Accident Initiators	Event Tree	Mean Frequency	Reference Section
Ejection of RGS	-Drill-string pneumatic clamp failure		1.2E-8	4.4.8

The RGS SA intentionally addresses a tank waste level limit of 404 in. as the criteria to judge the consequences of hazards associated with the RGS installation/removal and operation activities. Section 5.0 details specific unacceptable consequences that result from using this criteria. Thus, Sec. 6.0 administrative controls set the intrusive activities at 402 in. For the sake of consistency, the accident frequencies contained in Table 4-1 reflect the intrusive tank waste limit of 404 in. This situation ultimately will be corrected.

4.3. Accident Assessment—RGS Installation and Removal Accidents

This section examines accidents that may occur during open-tank (riser) conditions and then considers the likelihood of a GRE when the open-tank conditions exist. Intrusive operation criteria that limit the waste level for open-tank and waste-intrusive operations for Tank 101-SY is discussed in Ref. 1. The current waste limit for the RGS has been set as <404 in. for intrusive operations. Radiological, toxicological, and structural consequences of a conservative GRE-and-burn accident have been analyzed for RGS installation, operation, and removal. The results of our study show that setting the waste level limit at 404 in. for these activities will not maintain all radiological and toxicological releases from the accident cases considered to be within WHC guidelines. The consequences will be discussed in Sec. 5.0 of this SA.

Given an open riser, a GRE of sufficient magnitude to cause the normal negative pressure inside the tank to exceed that of the atmosphere must occur for there to be a release. Controls are in place to reduce the likelihood of a GRE during planned open-tank conditions associated with installation and removal operations. These controls, enumerated in the Mixer Pump SA,[1] are designed to ensure that (1) the flammable conditions in the tank are minimal (by monitoring the concentration of hydrogen), (2) tank pressures are within prescribed limits (so that gases do not escape without a GRE occurring), and (3) a GRE condition is minimized (by restricting operations to a given period after operation of the mixer pump). Other sources of potential gas releases, such as operation of another intrusive instrument (which would cause a gas release), are minimized by restricting such activity. GREs from neighboring tanks could be released through the open riser because the tanks are interconnected by a common ventilation system. The latter system was examined in the Mixer Pump SA[1] and was demonstrated to be an event that does not lead to a hazardous release condition.

GREs occurring from pump or other equipment operation are observed events. Controls (see Sec. 6 of this SA) prohibit opening the tank to install or remove the RGS for at least 4 h after such an operation (much longer than the observed period for an operation-induced GRE to occur). Additionally, controls prohibit the operation of other potential GRE-producing equipment during RGS installation.

Many of the hazards associated with RGS installation, removal, and operation are similar, if not identical, to hazards associated with installation and removal of the mixer pump. In this SA, we address only those hazards specific to RGS activities.

Before installing the RGS on Riser 22A, any equipment located on this riser will be removed. A riser adapter will be installed that accepts the drill-string sections. This adapter provides a positive seal around the drill string and restores the system to a closed-tank condition. The accident analysis reviews both open- and closed-riser conditions.

4.3.1. Hydrogen or Toxic Gas Release (Unexpected GRE—Open Riser)

A toxic gas release could occur at various stages of installing or removing the RGS drill-string sections, either from natural convective action of the dome gas or from a GRE condition with the tank riser open. An analysis of unfiltered release through the RGS riser (22A) with an inoperable ventilation system is discussed in Sec. 5.2.2. This condition results in a gas release through free-convection effects of the dome gas driven by a thermal source of the hotter bulk waste. However, as stated in Sec. 5.2.2, the occurrence of this gas release without a burn through a 4-in.-diam riser does not result in a serious radiological consequence. Section 5.2.2 states that the projected exposure will remain within acceptable bounds. To mitigate this issue during the RGS installation and/or removal, standard WHC procedures will be implemented through administrative controls to ensure that an unexpected GRE will be a highly improbable event. Mitigation of a GRE event during installation and/or removal is provided through imposition of tank intrusion criteria. These control limits, as well as anticipated environmental conditions that must be avoided, are contained in Sec. 6.0. A GRE or a GRE with burn may occur during RGS installation and removal phases. An assessment of these accident cases is discussed in later sections.

The release terms determined in this assessment are bounded by Sec. 5.1.1 of the Mixer Pump SA,[1] which contains an evaluation of situations with and without the ventilation system operable, combined with a maximum window GRE condition.

The controls in Sec. 6.0 will be followed to mitigate the hazards associated with sparks or with personnel exposure to radiological or toxicological substances. These controls are developed from the WHC standard controls for open-riser conditions, except that additional controls have been imposed to deal with the hazards of dropped equipment, which are discussed in detail in subsequent subsections.

We believe that the occurrence of a GRE with an open riser does not present any new hazards that are not presently addressed with standard WHC administrative controls.

4.3.2. Hydrogen or Toxic Gas Release with Burn (Open Riser)

During installation and removal operations of any equipment associated with Tank 101-SY, a spark source may ignite a gas pocket where hydrogen has accumulated. This situation specifically was addressed in Sec. 4.3.1 of Ref. 1. Numerous spark sources have been identified and enumerated in Table 3-1 of Sec. 3.0. In this section (Sec. 4), we presume that a tank burn condition has been initiated from one of the potential sources.

4.3.2.1. Spark Source within Tank Interior. If a GRE and burn accident occurred when a drill section was being added to the suspended column, the lower sampler seal (Rainier) would be subjected to the burn transient pressure. In this evaluation, we assumed that the tank burn was triggered through a combustion source originating in the ventilation system. During the burn transient with the riser and string open to atmosphere, the seal will be subjected to a peak pressure of 51.92 psia. This pressure transient is within the structural limit of the tank; consequently, a breach of tank confinement is not a predicted consequence. Restrictions placed on tank-intrusive operations ensure that any gas release will be $<7673\ ft^3$ during RGS installation or removal, whereas the GRE corresponding to the structural limit is $9300\ ft^3$. However, we anticipate that waste will be forced into the drill-string column past the Rainier seal and released during the burn condition. We have computed the radiological and toxicological release terms for this postulated event. Study results of this accident are discussed in Sec. 5.3.2. The total radiological and toxicological emissions, including contributions from the open RGS drill string, did not remain within WHC guidelines. Thus, we conclude that new risks associated with a spark-induced burn accident would be introduced in the unlikely event that this accident could occur (1.2E-5 frequency). Therefore, we lowered the intrusive tank waste limit to 402 in.

4.3.2.2. Surface-Support Equipment Fire. The drill rig utilizes a gasoline engine to power a hydraulic pump, which in turn provides power to the drill head. During open-tank operations, a fire on the drill rig support truck could lead to a tank burn condition. Hydrogen gas emanating from the open riser could be ignited; if this gas combined with a flame front that propagated down the riser, it would ignite the flammable gas in the tank dome space.

Several factors make these combined events unlikely. First, the gasoline engine is not needed either during installation of the riser adapter or during initial assembly of the drill string. Once the riser adapter has been installed and the first drill-string section that carries the sampler unit is in place, the riser effectively is sealed. Once the riser is sealed, this hazard essentially is mitigated. Controls in Sec. 6.0 require that the tank ventilation system be functioning properly, producing a negative tank pressure; otherwise, opening the riser for this initial step is not allowed. This control is intended to guard against flammable and toxic gas emanating from the riser; thus, the source of ignitable gas does not exist if all steps have been enforced properly.

At each stage that a drill-string section is being added, the tank effectively is open. If the RGS sampling operations up to this point have created conditions leading to a GRE, flammable gas could come in proximity to the gasoline engine. If the gasoline engine is still hot, constituting an ignition source, a tank burn event may ensue. We have assigned a frequency of 1.2E-04 for the occurrence of this event (1.2E-2 GRE exceeding 25% LFL and an exposure factor of 1%). If we factor into this frequency the essential ingredient that the gasoline engine must be sufficiently hot (probability of 1E-3) to ignite the tank GRE gases, the prospect of this event is diminished to the point of being an incredible event (1.2E-07).

Reference 2 deals with open-riser spark sources such as metal-to-metal contact, static electricity, lightning, and tank combustion induced through a drill rig gasoline fire; we noted the similarity in their conclusions with those contained herein. This document shows that Marusich et al.[2] systematically examined RGS design features and/or administrative controls that minimized this hazard.

Based on the analysis of this potential accident case, we conclude that open-riser hazards associated with installation and/or removal of RGS drill-string sections, improper grounding, a burn initiated in the ventilation system, sparks generated by tool impacts, etc., are not new, nor do they pose additional risk. To reduce risk exposure, controls have been imposed in Sec. 6.0 that ensure operability of the ventilation system to avoid hydrogen accumulation; otherwise, these operations are immediately placed in a secure mode and terminated until normal conditions are achieved. Nonsparking materials have been invoked by WHC in the RGS design; these materials contribute to the mitigation of hazardous elements associated with any personnel error involved.

4.3.3. Filter System Release

A HEPA filter system release accident from a hydrogen release with burn is discussed in Ref. 1, and no new hazards related to this event are introduced from the installation and/or removal operations associated with the RGS. However, our hazards analysis raises the issue that during the RGS installation or removal phase, damage to the HEPA filters may result during operation. RGS installation or removal could promote inadvertent damage to the HEPA filters (e.g., from maneuvering a truck on the tank surface). In the event of filter damage, we believe that most of the radioactive material confined to the filter elements would be drawn into the ventilation system by the negative pressure existing at the time of impact. If major damage were sustained, it is unlikely that the ventilation system would be operable; this would place the tank operations under a state of emergency. Repair and waste cleanup would correct the damaged state at some risk to personnel. This accident must be avoided by implementing approved work plans and administrative controls. Under no circumstances should the RGS handling operations place critical ventilation elements at risk. The controls that mitigate this hazard are contained in Sec. 6.0.

We conclude that no new hazards will be introduced that currently are not mitigated effectively through standard WHC administrative controls.

4.3.4. Loss of Containment

A loss of confinement of the toxic and radioactive waste from a structural failure of the tank liner is an SC-I issue. Installation, removal, and/or decontamination operations potentially constitute hazards to the structural integrity of the tank. The following subsections discuss the assessment made of these situations.

4.3.4.1. Excessive Dome Loading. The RGS surface equipment, truck, and mounted core sampling equipment comprise ~39,000 lb of added weight that the tank dome must sustain without collapsing. The static load capacity of the tank dome is monitored carefully, and an overload state that could precipitate a structural failure must be avoided. The equipment required on the surface of the tank to support RGS sampling operations qualifies as a live load. The tank loads study permits a 50-ton live load on the tank dome. The weight of the RGS equipment is <20 tons; thus, this limit is not exceeded by a significant margin. The results of the loads analysis can be found in Ref. 3.

4.3.4.2. Tank Penetration from Drill-String Impact. The drill string is restrained from falling and impacting the tank bottom by the pneumatic foot clamp. After numerous sections of the drill string have been added, the suspended weight will cause the drill string to fall if the clamp is released because the force of gravity exceeds the frictional forces. Initially, the frictional force developed at the riser seal interface exceeds the string weight. The frictional force is produced by the rubber seal that girths the outside diameter of the drill-string shell. This constant force eventually is overcome by the column weight as the sections are added. The long drill string extending nominally halfway into the tank poses the largest hazard to the integrity of the tank bottom from an impact. We evaluated the impact force that would occur if the drill string were released.[4]

The critical drop accident corresponds to an initial drill-string immersion of 152 in. and a drop height of 248 in. The overall drill-string length is the sum of these two dimensions (i.e., 400 in., which corresponds to the present waste level in Tank 101-SY). In the numerical solution of the equation of motion, we made allowances for drill buoyancy and form drag. These forces oppose the gravitational force. Inclusion of these terms reduces the impact velocity from 437.8 in./s to 304 in./s by nominally 31%. Bending stresses in the tank liner are directly proportional to this reduction. The liner impact stress level is reduced from 109,900 psi (437.8 in./s) to nominally 76,330 psi (304 in./s) by inclusion of these effects. This stress level is expected to challenge the ultimate strength of liner material despite the inherent ability of the carbon steel liner to withstand higher stresses under high strain rate conditions. Because this accident can lead to a breach of the waste confinement, it is a major concern and must be avoided through the application of administrative controls. The very low expected accident frequency associated with this drop significantly ameliorates the hazards. This mitigating consideration is discussed next.

The pneumatic foot clamp provides a positive grip around the string from the applied gas pressure. Even when de-energized, the clamp will provide positive restraint to prevent the string from falling. Built-in springs maintain a force on the wedge-like gripping device. Although the fail-safe spring actuation prevents the string from falling under gravity, it does not preclude upward motion. The potential for ejection under a major GRE and burn event is discussed in Sec. 4.3.7. To release the wedge action with the clamp de-energized, the drill string must be raised ~2 in. Several events must occur for the drill string to fall and impact the tank bottom. The tacit assumption is that the wedge clamp functions as designed. The events are:

- simultaneous failure of drill-string foot-clamp pneumatic pressure, and
- GRE and burn of a 7673-ft^3 gas release, causing upward motion to release the wedge-clamp retention feature.

When an accident frequency associated with the loss of pneumatic pressure (~1E-3) is combined with the accident frequency for a GRE and burn condition (1.2E-5), the combined probability of this occurrence is extremely low (~1.2E-8). We conclude that the accident is very unlikely and that through exercising administrative controls this accident will be avoided.

4.3.5. Tank Flooding Accidents

These accidents address the possibility of excessive water additions to the tank that would cause the level to rise in excess of that allowed by safety controls. In the limit, flooding could result in the release of tank materials into the environment caused by hydrostatic failure of the tank. Three conditions are considered—two related to the operation of the RGS and one related to natural phenomena flooding.

Concerns associated with flooding may be characterized by two tank levels.

1. **422 in.:** This level has been assessed to cause hydrostatic failure.[5]

2. **404 in.:** This level, currently defined in Sec. 5.2, is an administrative level associated with more restrictive tank operating conditions. In the case of the RGS, no operations are allowed when the level exceeds this value.

This second level is tied to the amount of gases that the tank could liberate. Although it generally is thought that an increase in level caused solely by excessive water addition will not add to the gas content of the waste, no measure of the adjustment to account for water currently has been made.

The maximum quantity of water available for decontamination during operation and removal is 250 gal.,[6] which physically is controlled by the size of the water supply. Total operational water addition is limited to 1000 gal. by the controls established for the mixer pump. These numbers are predicated on the flow rate, duration of operation of the decontamination system, and maximum number of anticipated decontamination operations. Any addition of water beyond this total level must be approved by the TRG with consideration for overall effects on the tank waste. The following scenarios consider the likelihood of exceeding the levels identified in Sec. 4.4.5. Regardless of the maximum quantity allowed, the controls require that the source be limited and that the amount of water addition be closely monitored.

4.3.5.1. Flooding of Tank caused by RGS Decontamination System. For the tank level to increase above 422 in., an incredible sequence of events would have to occur. First, the tank level increase would have to go unnoticed or be grossly misinterpreted for an extended number of days. Second, numerous 1500-gal. tanks of water would have to be added in violation of the 1000-gal. total addition limit. Third, RGS operations are prohibited above 404 in.; thus, an RGS operation would be required for this water addition. A possible consideration is water addition by some other operation, but this is limited by similar water addition controls, so multiple violations would be required. Because a preponderance of errors and violations of controls would be required, this event is considered incredible, although the consequences of the event would be failure of the tank.

4.3.5.2. Flooding of Tank from External Flood. Based on site studies, external floods resulting in flooding of the tank have been determined to be incredible events.

4.3.6. Radiation Exposure Accidents

Personnel could be exposed to excessive levels of radiation in association with proposed operations for the RGS. Two accident scenarios are posed: (1) radiation exposure from the shine within the tank through the riser and (2) radiological exposure associated with waste that could be on the RGS structure.

4.3.6.1. Excessive Radiation Exposure to Personnel (Open Riser). Ionizing radiation from inside the tank caused by radioactive waste produces a nearly constant radiation field when viewed from an open riser. The maximum radiation field at the throat of an open 4-in. riser has been determined to be in excess of WHC limits for areas not considered to be high in radiation. The WHC allowable radiation dose at 30 cm from the top of the riser (for normal operations) is 100 mrem/h. Controls will be required to ensure that workers do not receive excessive exposure during installation and removal, where a direct line of sight to the tank wastes is possible. Because the RGS essentially fills the riser, there is little chance for workers to be exposed to a direct line of sight during operation. Only through failure of workers to follow procedures limiting the exposure or through improper development of work plans can workers be exposed to excessive levels of waste on the RGS if the decontamination system is not effective. This issue is discussed in the next section.

4.3.6.2. Excessive Personnel Radiation Exposure during RGS Decontamination. The RGS may be contaminated by tank waste during removal or operation phases. The amount of waste on the RGS can increase the radiation caused by tank shine. Workers are required to aid in the assessment of decontamination effectiveness during removal actions. Therefore, workers could be exposed to the combined fields of tank waste on the drill string and tank shine.

A hand-held radiation monitor is used by radiological health technicians to ensure that radiation levels are acceptable for unrestricted work. Protective equipment and other work limitations (such as work duration) are specified by tank radiological and industrial health authorities, according to established procedures. All open-riser work requires respiratory protection, as indicated in Sec. 6 of this SA.

The consequences of radiation exposure are developed in Sec. 5.5 of this SA. We found that the exposure limits potentially are far above the allowable annual exposure limits, although immediate threat to health was not a consequence.

The likelihood that workers will be exposed to this high level of radiation depends on whether the decontamination system and handling procedures are effective. WHC has experience with other similar activities,[7,8] and what can be expected for the RGS should not result in increased personnel risk. In general, the water decontamination method is successful in removing hazardous levels of waste from the exterior surfaces of exponents, particularly if the components are designed to facilitate decontamination, as in the RGS.

In summary, workers could be exposed to high levels of radiation; however, this is a very unlikely occurrence because the controls are strictly enforced and monitored, and workers are highly trained in both radiation protection techniques and the types of exposure possible at the tank farm.

4.3.7. Ejection of RGS from Riser while Not Adequately Secured

During some phase of both the installation and removal activities, the RGS will be secured to the riser solely with the pneumatic clamp; the RGS will be free to be ejected given a GRE and burn event within the tank, assuming that the pneumatic gas supply either fails or is inadvertently depressurized. The spring-actuated wedge-clamp feature embodied in the foot-clamp design does not prevent upward motion of the drill string, which presents the possibility of complete ejection. This accident is quite similar in terms of the upward motive force provided by the burn sequence described in Sec. 4.3.4. In this instance, we presume that the drill string is ejected while carrying waste that has accumulated behind the Rainier seal. A drill string that extends to the bottom of the tank, plus the sample chamber assembly, weighs ~231 lb, minus 86 lb for buoyancy at 400-in. immersion, leaving a net downward force of 145 lb. The peak gas pressure during the transient is 51.92 psia, which produces an upward force of 148 lb. The gas pressure force is not sufficient to overcome the combined weight of the drill string and the frictional force at the riser/drill-string adapter face. Thus, an installed drill string with its sampling point near the tank bottom cannot be ejected, even if an allowance were made for buoyancy. It becomes problematical whether a drill string that extends barely into the waste and weighs much less than the previous example could be ejected under the right circumstances. However, the entrained waste under this circumstance would be diminished greatly.

If a drill string became filled with waste behind the Rainier seal, then radioactive waste potentially could be released with an ejected drill string. However, for this supposition the buoyancy term must be removed from the force balance discussed above because the waste fills the drill string. The string weight then dominates over the burn pressure force, and the string cannot be ejected. The accident frequency for this postulated accident is low (<1.2E-5). Because the GRE-with-burn event frequency must be coupled with a failed pneumatic foot clamp (1E-3, taken as a typical mechanical failure rate), the combined frequency (1.2E-8) would be considered a highly unlikely event. Consequently, we conclude that this potential accident is fully mitigated and that no increase of hazards associated with Tank 101-SY is encountered.

4.4. Accident Assessment—RGS Operation

Tank 101-SY contains corrosive compounds that react to form flammable gases. The waste liquid is reactive particularly to aluminum, releasing heat and combustible gases. Considerable attention has been given to establishing the release rates for hydrogen and ammonia gases, as well as characterizing the retained gases in the waste. With the introduction of the mixer pump, release rates of trapped hydrogen gas have changed significantly for the better. In some ways, this situation has lowered the apparent risk associated with closed-tank operations in Tank 101-SY. Nonetheless, much work remains to complete the characterization of the behavior of the Tank 101-SY, particularly in terms of entrapped gas. More information is needed to enhance the probabilistic determination of major gas releases brought on by external disturbances. Operation of equipment such as the RGS in Tank 101-SY raises the prospect of stimulating increased gas releases that may result in a major burn event. In the following sections we address the hazards associated with the RGS operations and quantify the consequences of a postulated accident.

4.4.1. Hydrogen or Toxic Gas Release with Burn (Closed Riser)

4.4.1.1. Chemical Reaction with Waste. Marusich[2] has discussed extensively the prospect of chemical reactions being produced through RGS operations in Tank 101-SY. He concluded that if the drill string were rotated (e.g., using the rotary-mode sampling method), under certain conditions a chemical reaction could occur from frictional heating. To preclude rotation in the tank crust, there are interlocks on the drill-string operations that lock out the ability for the string to rotate (see Sec. 2.3.2). Further, because the rotary-mode sample method is not permitted for Tank 101-SY or for other flammable watchlist tanks, this prospect is eliminated.

The existence of an exothermic chemical reaction between aluminum material and the waste has been documented recently as a significant hazard. The reactions produce copious quantities of flammable and toxic gas and heat. This material must not be used in the RGS application in the vicinity of the waste tanks. Unfortunately, the seriousness of this issue has not been highlighted sufficiently in the past, and the material has been used without due concern for the hazards involved. Inadvertent placement of this material in the waste tank environment presents itself as one of the more logical sources of an accident initiator. For example, use of this material in the drill-string column would lead to rapid chemical reaction and possible ejection of contaminated waste as a drill section was added. An explosion could occur in the drill string during installation of the sections, endangering personnel in a life-threatening manner. All that is required for this accident to occur during the core sampling phase is for the outer insert seal (Rainier seal) to leak waste into the column. Personnel exposure to this hazard occurs when the drill-string column is opened to add a section. At this point, the pressure balance across the seal provided by the argon gas has been removed, and the string is at atmospheric pressure. This allows the waste to rise up into the column. When the waste encounters the incompatible aluminum material, an exothermic reaction occurs. This reaction proceeds in a confined space, leading to a rapid expulsion of radioactive waste and toxic gases. Reference 9 provides a probability estimate of a seal failure. The accident frequency associated with a seal damaged through external environmental factors is 1E-3, which is a concern. To mitigate this extreme personnel hazard, the RGS design approach has eliminated incompatible materials of construction with the waste. Administrative controls and work plans must be enforced to ensure that personnel exposed to an open riser are aware of the hazard and to ensure that their total exposure is brief and rigidly controlled.

4.4.1.2. Internal Spark Generated from Mechanical Action. RGS core sampling will require that specific mechanical actions be performed beneath the waste surface. These mechanical actions introduce the possibility of a spark occurring in gases trapped in the waste. Sparks could be produced at the waste surface, either from crust reactions or tool impactions. These conditions may lead to a burn of gases entrapped in the waste, in the sampler drill-string column, or within the tank dome space. These spark sources and associated hazards were acknowledged by Marusich[2] in his assessment. The more notable of the specific examples would be breaking the shear pin to remove the pintle rod and thus dropping a sampler unit into the drill string. Spark sources occurring within the drill-string column accidentally could be suppressed by the presence of the argon gas in the string column. The primary purpose of this gas is to equilibrate the large hydrostatic component of pressure being exerted by the surrounding waste. For gases to be ignited in the string column, the RGS must sustain a failure of the argon gas that equilibrates the hydrostatic pressure imposed by the waste. As noted earlier, the shear pin material was selected on the basis of its nonsparking properties and should not present a problem.

The risk associated with any one of these conditions has been mitigated suitably through controls imposed in Sec. 6.0. We have managed to place this hazard into an acceptable risk category by ensuring that the initial burn conditions could not produce an event that would endanger the tank's structural integrity. We have limited the RGS operations in Sec. 6.0 to coincide within a tank waste level domain that precludes initiating a major burn. We conclude that no new risks are encountered that are not bounded already by operation of the mixer pump.

4.4.1.3. Frictional Heating of the Crust Surface. Frictional forces generated by the waste substance oppose the downward action of the drill string. WHC conducted exploratory tests because of speculation that the resultant localized frictional heating may serve to ignite the flammable gas.[10] The testing with three simulants revealed that no frictional heating of a sludge-like waste occurred. Very moderate temperature rises were recorded for soft and hard salt-cake-like simulants. The temperature rise certainly was not sufficient to be of concern. We conclude from the WHC test results that push-mode sampling of double-shell flammable gas watchlist tanks can occur with little or no frictional heating that would lead to a combustion hazard.

4.4.2. Loss of Containment

Operation of the RGS hydraulic ram for sampling near the bottom of the tank introduces the possibility of impacting the tank bottom. Precautions are taken in setting up the drill string to avoid this accident simply by recording the string depth during installation. Nonetheless, in the push-mode sampling method, the drill string can produce an axial force of 5370 lb. The force produced on the drill string by hydraulic action, although significant, will neither cause the drill string to penetrate the tank liner nor threaten the tank's structural integrity in any way. The drill string is a very long, slender column when fully extended to the tank bottom. This column will buckle at a load less than the ram capacity force of 5370 lb. As an added protective feature, the RGS incorporates a bottom contact sensor that reverses the hydraulic ram pressure used in the drill-string operation. The pressure reversal causes the sampling operation to cease and pulls the drill bit away from the tank bottom.

Although the axial forces that can be produced by the RGS during sampling are significant, we judge that the impacting the tank liner does not pose an unacceptable risk to the tank's structural integrity.

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5.0. CONSEQUENCES OF ACCIDENTS

This section discusses the consequences of accidents developed in Sec. 4. HMS/TRAC calculational results are summarized for the bounding radiological and toxicological consequences used for the installation, operation, and removal of the RGS. The evaluation of the intrusive waste level requires that the radiological and toxicological consequences of burn accidents be acceptable. We first consider limiting the intrusive waste level to 404 in. for RGS operations. The bounding gas release at this level is obtained from Ref. 1 as 7673 ft^3. We will analyze the radiological and toxicological consequences if a burn with a gas release of 7673 ft^3 occurs during removal, installation, or operation of the RGS. If consequences are acceptable, the waste limit will be determined as 404 in. for RGS operations. Otherwise, the intrusive waste level will be revised, and we will present our basis for selecting a waste level limit. This process will be performed for each phase of the operation.

For the RGS installation and removal operations, we performed a burn calculation using a gas release of 7673 ft^3 with an open 4-in. riser and an inoperable ventilation system.[2] The area of the inlet leakage flow path in the HMS/TRAC model was increased to account for the area of Riser 22A, which is 4 in. in diameter and will be used for RGS activities. The waste release during installation and removal is assumed to be caused by burn only. The material release calculated from the burn analysis is used to calculate the radiological releases at several locations.

A burn analysis with a closed-riser condition is performed for the operation phase of the RGS. Waste release scenarios in addition to the release caused by burn are considered for the operation phase, such as (1) the waste release during a spill from a dropped core sampler and (2) a failure of the lower seal in the drill-string assembly during a burn event. Waste ejection also can occur during the last phase of operation, where the sampler is removed from the drill string. In this phase, our current information indicates that there is a direct waste ejection path if a burn occurs. We will compare the radiological and toxicological consequences with the WHC acceptance criteria. If the radiological and toxicological consequences of accidents considered in this SA do not meet the WHC acceptance criterion, we will propose another intrusive waste limit that can meet the guidelines.

All burn calculations presented in this SA assume that the MPR has an exhaust area of 100% after the burn is initiated.

The structural consequences of a burn with a 7673-ft^3 gas release is not of concern because structural damage can occur only if the burp size exceeds 9300 ft^3 (Mixer Pump SA).[1]

Section 5.1 presents a summary of all the accident consequences. Sections 5.2 through 5.4 present the consequences of accidents during RGS installation, normal RGS operation, and RGS removal, respectively. Section 5.5 discusses the consequences of radiation exposure.

5.1. Summary of Accident Consequences

The consequences of accidents identified in Sec. 4 of this SA are summarized in Table 5-1 for radiological effects and in Table 5-2 for toxicological effects. Consequences are presented by accident sequence and the phase of operation of the RGS. The radiological and toxicological consequences given in Tables 5-1 and 5-2 are computed for a 7673-ft^3 gas release that can occur at a waste level of 404 in. The 7673-ft^3 gas release with a 4-in. open riser is considered to occur in burn accidents for the installation and removal phases of RGS operations. For the normal RGS operation phase, a 7673-ft^3 GRE with a closed 4-in. riser calculation was selected. The burn calculation considered a bottom-up burn because these are more restrictive conditions than the top-down burn for radiological and toxicological assessments. Toxicological consequences are based on accidents that occur before a burn or during a GRE without a burn.

The accident frequencies used in Tables 5-1 and 5-2 were taken from Rev. 13 of the Mixer Pump SA[1] for similar window gas release analyses. The accident frequency (3.0×10^{-4}/yr) used for the HEPA filter release is the same as that used for contamination from a dropped pump accident in Ref. 1. Similarly, the accident frequency for the core sampler drop is the frequency used for a spill from a contaminated pump[1] (i.e., 4.8 10^{-3}/yr).

All results presented in Tables 5-1 and 5-2 are shown in Figs. 5-1 through 5-4, along with their corresponding risk acceptance limits when applicable. Figure 5-1 shows the calculated offsite dose limits for RGS installation, operation, and removal accidents. The calculated offsite doses are well below the WHC risk acceptance guidelines and therefore are acceptable. The calculated onsite doses and their acceptance limits for the SY Tank Farm are shown in Fig. 5-2 for RGS operations. This figure also shows that the calculated doses are below the guidelines and therefore are acceptable.

The Mixer Pump SA[1] describes the methodology used to calculate the organ doses. We multiplied the onsite radiological doses by a factor of 15. The calculated organ doses were compared to an onsite limit 10 times higher than the acceptance criteria shown in Fig. 5-2. The results of this comparison are given in Fig. 5-3 and indicate that all consequences are below guidelines; however, the consequence of releasing waste through the drill string does not meet the WHC acceptance criterion if the RGS is operated at a waste level ≥404 in. Therefore, we

TABLE 5-1
RADIOLOGICAL CONSEQUENCES OF ACCIDENT SEQUENCES

Radiological Dose EDE for Accident Sequences during RGS Installation							
		Radiological EDE (rem)					
Accident Sequence	**Frequency (1/yr)**	**SY Farm**	**242-S Evaporator**	**U Plant**	**Hwy. 240**	**Max. Offsite[a]**	**Max. Offsite[b]**
Open 4-in. riser—GRE and no burn	1.2E-02	3.245E-1	6.525E-2	1.339E-2	1.046E-3	1.559E-4	5.157E-3
Open 4-in. riser—GRE and burn	1.2E-05	10.42	2.100	4.223E-1	3.146E-2	4.688E-3	1.552E-1
Unfiltered release from open 4-in. riser	1.2E-2	8.80E-2	1.77E-2	3.55E-3	2.55E-4	3.81E-5	1.26E-3
Release from physical damage to tank HEPA filter system	3.0E-04	3.05	6.14E-1	1.24E-1	9.92E-3	1.48E-3	4.88E-2
Radiological Dose EDE for Accident Sequences during RGS Operation							
		Radiological EDE (rem)					
Core sampler drop with 500-g release	4.8E-03	1.38	2.77E-1	5.55E-2	3.99E-3	5.95E-4	1.97E-2
Release from drill string during sampler replacement with closed-riser burn	1.2E-05	31.62	6.37	1.29	0.101	1.50E-2	4.96E-1
Radiological Dose EDE for Accident Sequences during RGS Removal							
		Radiological EDE (rem)					
Open 4-in. riser—GRE and no burn	1.2E-02	3.245E-1	6.525E-2	1.339E-2	1.046E-3	1.559E-4	5.157E-3
Open 4-in. riser—GRE and burn	1.2E-05	10.42	2.100	4.223E-1	3.146E-2	4.688E-3	1.552E-1
Unfiltered release from open 4-in. riser	1.2E-2	8.80E-2	1.77E-2	3.55E-3	2.55E-4	3.81E-5	1.26E-3
Release from physical damage to tank HEPA filter system	3.0E-04	3.05	6.15E-1	1.24E-1	9.92E-3	1.48E-3	4.88E-2

[a]Acute dose.
[b]50-yr dose.

recommend lowering the allowable waste level to 402 in. for all phases of RGS operations. At this level, the frequency of the GRE and burn becomes 4.0E-6 (4.0E-3 x 1.0E-3), and the radiological release is much less than those reported in this SA because the gas release will be smaller. We did not repeat the burn calculation at 402 in. The lower GRE and burn frequency at a waste level of 402 in. already causes the current radiological consequences for organ doses to be less than the WHC guidelines. The current Mixer Pump SA[1] also requires that the pump be operated

TABLE 5-2
TOXICOLOGICAL CONSEQUENCES OF ACCIDENT SEQUENCES

Ammonia Exposures for Accident Sequences during RGS Installation						
		Toxicological (ppm)				
Accident Sequence	Frequency[a] (1/yr)	SY Farm	242-S Evaporator	U Plant	Hwy. 240
Open 4-in. riser—release and no burn	1.2E-02	39.13	30.61	11.94	1.26
Open 4-in. riser—release and burn	1.2E-05	39.13	30.61	11.94	1.26
Unfiltered release from open 4-in. riser	1.2E-2	—	—	—	—
Release from physical damage to tank HEPA filter system	3.0E-04	—	—	—	—
Ammonia Exposures for Accident Sequences during RGS Operation						
		Toxicological (ppm)				
Core sampler drop with 500-g release	4.8E-03	—	—	—	—
Release from drill string during sampler replacement with closed riser burn	1.2E-5	40.27	31.29	12.06	1.27
Ammonia Exposures for Accident Sequences during RGS Removal						
		Toxicological (ppm)				
Open 4-in. riser—release and no burn	1.2E-02	39.13	30.61	11.94	1.26
Open 4-in. riser—release and burn	1.2E-05	39.13	30.61	11.94	1.26
Unfiltered release from open 4-in. riser	1.2E-2	—	—	—	—
Release from physical damage to tank HEPA filter system	3.0E-04	—	—	—	—

[a]The magnitude of these estimated frequencies is unimportant because they fall below the range of the WHC guidelines.

aggressively to maintain a waste level lower than 402 in. Thus, it is very unlikely that there will be a need to operate the RGS at waste levels >402 in. as long as the pump is operational. We recommend limiting the waste level to 402. in. for RGS operations. This limit also is valid for the installation and removal phases because it is smaller than those obtained for installation and removal.

The onsite toxicological consequences are shown in Fig. 5-4. This figure illustrates that the toxicological consequences are less than the WHC risk acceptance guidelines. In this figure, we plot only the maximum ammonia release at the SY Tank Farm with various frequencies. Results shown in Fig. 5-4 will be smaller at an operating waste level of 402 in.

In summary, the radiological and toxicological consequences for postulated RGS operations accidents (Tables 5-1 and 5-2) are within WHC guidelines. In the following sections, we discuss the consequences of each accident in detail.

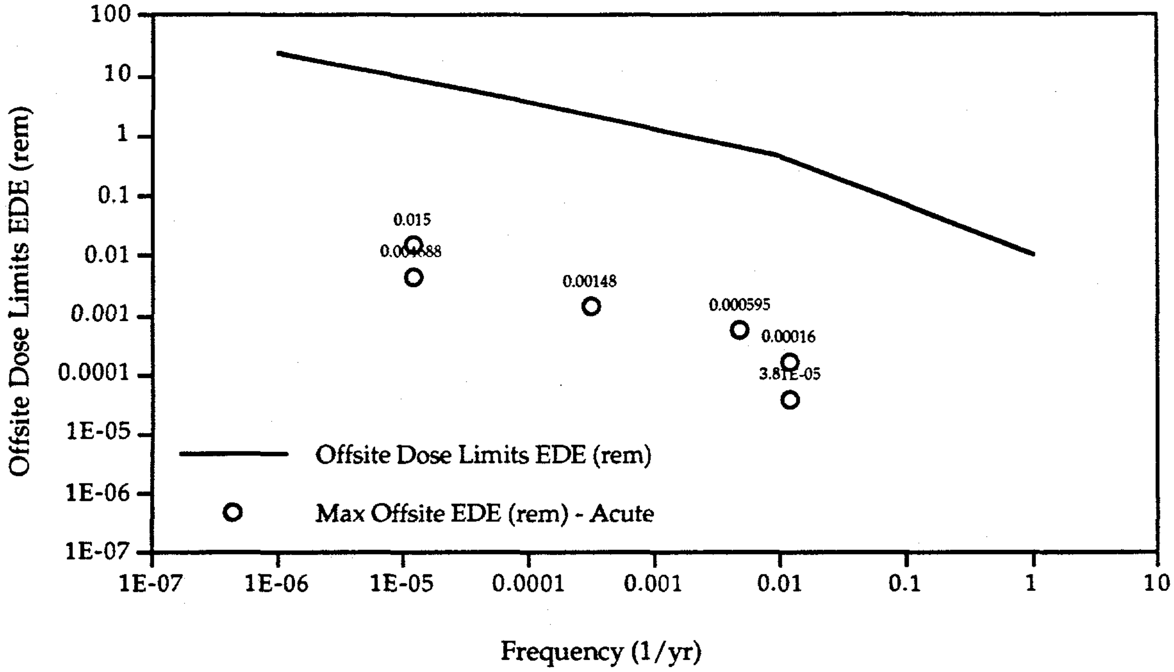

Fig. 5-1. Offsite radiological dose consequences.

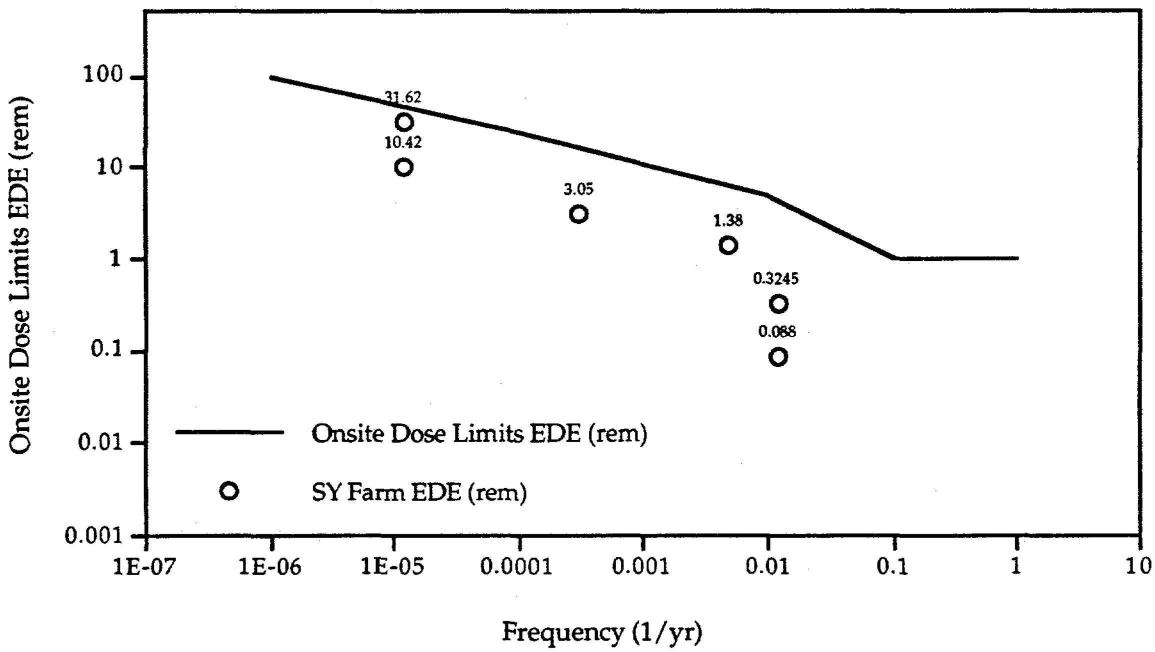

Fig. 5-2. Onsite radiological dose consequences.

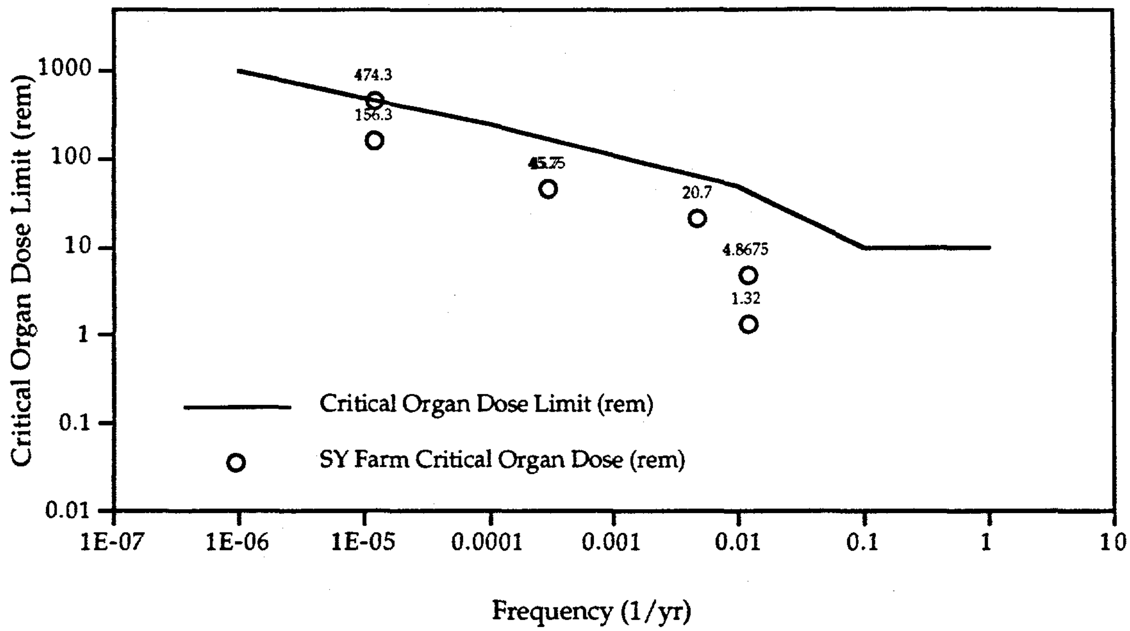

Fig. 5-3. Critical organ radiological dose consequences.

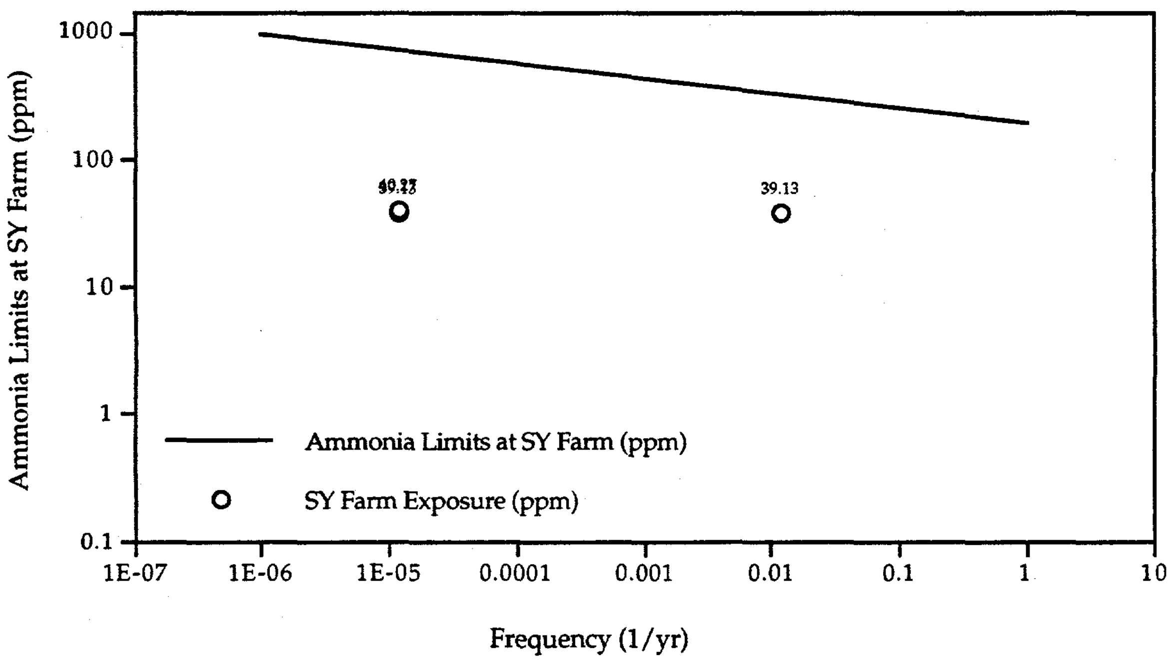

Fig. 5-4. Toxicological consequences.

5.2. Accident Sequences during Retained Gas Sampler Installation

This section presents the consequences of postulated accidents occurring during installation of the RGS. The material release conditions governing the evaluation of radiological and toxicological consequences in this assessment are presented below.

5.2.1. Hydrogen and Toxic Gas Releases—4-in. Open Riser

The intrusive waste level of the tank selected for RGS installation is 404 in., as specified in Sec. 6 of this SA. This level corresponds to a gas release of 6672 ft^3 [using the conservative gas release-waste level relation given in Ref. 1. Considering a 15% increase (a conservative estimate) of this value to account for the gas release as a result of interfacial mass transfer, we obtain a total gas release of 7673 ft^3. Below we will analyze the radiological and toxicological consequences of a burn event with a release size of 7673 ft^3.

During installation of the RGS assembly, we assume that Riser 22A, a 4-in. riser, is completely open to the atmosphere. We performed HMS/TRAC burn analyses[2] for release and burn scenarios using a limiting gas release of 7673 ft^3 with an open 4-in. riser to estimate the released material from the tank. In these calculations, we modeled the 4-in. riser by increasing the inlet vent area and also included the effects of an open 42.-in. pressure relief riser. The ventilation system was assumed not to be operable during installation. This assumption results in a conservative estimate of the waste release.

The results of these calculations are presented in Table 5-3. The radiological ground and stack releases calculated for the no-burn case are 0.035 and 0.083 kg, respectively. For the burn case, the radiological ground and stack releases are 2.561 and 0.119 kg, respectively. The ammonia releases are the same for both cases shown in Table 5-3 because they are based on peak ammonia concentrations that occur before a burn (i.e., during the gas release phase).

The radiological and toxicological consequences were computed using the methodology described in the Mixer Pump SA[1] and are summarized in Tables 5-4 and 5-5, respectively. The radiological consequences for the burn cases include the addition of a 1.11-kg ground release caused by tank filter system failure, as discussed in the SA.[1]

The ammonia exposures calculated for the RGS installation with an open 4-in. riser and no burn are less than those computed with an open 42-in. riser in the Mixer Pump SA[1] for the maximum window release case. Therefore, the toxicological consequences predicted for RGS installation accidents are bounded by the releases for the 8654-ft^3 release given in the Mixer Pump SA.[1]

TABLE 5-3
THERMAL-HYDRAULIC RESULTS FOR HYDROGEN OR TOXIC GAS RELEASES DURING RGS INSTALLATION

Accident Sequence	Peak Pressure during Injection (psia)	Peak Pressure during Burn (psia)	Peak Temp. during Burn (°F)	Ammonia Released (g/s) Ground Release	Ammonia Released (g/s) Stack Release	Radiological Release (kg) Ground Release	Radiological Release (kg) Stack Release
Open 4-in. riser, no burn	14.87	—	—	7.01	3.50	0.035	0.083
Open 4-in. riser, burn	14.87	51.92	1844	7.01	3.50	2.561	0.119

TABLE 5-4
RADIOLOGICAL DOSE EDE (rem) FOR HYDROGEN GAS RELEASES DURING RGS INSTALLATION

Accident Sequence	SY Farm	242-S Evaporator	U Plant	Hwy.240	Max. Offsite[a]	Max. Offsite[b]
Open 4-in. riser, no burn	3.245E-1	6.525E-2	1.339E-2	1.046E-3	1.559E-4	5.157E-3
Open 4-in. riser, burn	10.42	2.096	4.223E-1	3.146E-2	4.688E-3	1.552E-1

[a]Acute dose.
[b]50-yr dose.

TABLE 5-5
AMMONIA EXPOSURES (ppm) FOR TOXIC GAS RELEASES DURING RGS INSTALLATION

Accident Sequence	SY Farm	242-S Evaporator	U Plant	Hwy. 240
Open 4-in. riser, no burn	39.13	30.61	11.94	1.26
Open 4-in. riser, burn	39.13	30.61	11.94	1.26

At a waste level of 404 in., the probability of having a GRE with a hydrogen concentration exceeding 25% of the LFL is estimated as 1.2E-2 in the Mixer Pump SA.[1] The spark probability is 1.0E-3. If we assume that RGS will be installed once in a year, the release and burn frequency becomes 1.2E-5 1/yr. Our burn calculations consider no ventilation flow because this case yields more fuel in the tank dome before the initiation of burn. However, we did not take credit for the no-ventilation flow case in estimating the release and burn frequency. This is a conservative approach and yields higher frequency values.

WHC acceptance criterion for the onsite dose rates at this frequency is 91 rem, which is higher than the estimated dose rate of 10.42 rem. The calculated organ dose at onsite locations (15 times the onsite dose = 15*10.42) is 156.3 rem. This number is less than the WHC acceptance criterion for the all organ dose rates at a frequency of

1.2E-5 1/yr (917 rem). The above results show that the radiological and toxicological consequences of accidents considered for installation of the RGS are acceptable when the waste level is ≤404 in.

5.2.2. Consequences of Unfiltered Release from Loss of Negative Tank Pressure

Section 4.4.1 of this SA identified conditions under which a release through an open 4-in. riser was possible if the tank dome pressure were greater than or equal to the atmospheric pressure. If this case were to occur, tank gases would exit the tank through the 4-in. riser and impact the immediate area around the riser. The analysis in Sec. 5.2.5 of the Mixer Pump SA[1] discusses the unfiltered release through an open 42-in. riser or the MPR given a failed ventilation system with a release duration of 1 h.

To determine the release rate from the 42-in. riser or the MPR, an HMS/TRAC analysis was performed that assumed a heat-generation rate of 12 kW in the waste. The calculated release rate from natural circulation was found to be 0.093 m^3/s. If we assume that the natural circulation rates are not affected by the open-riser area (because the tank dome space is so large), we can scale the gas release from the 4-in. riser by the area fraction. However, this assumes that the frictional losses are similar in the 4- and 42-in. risers. The 4-in. riser is 11 ft long; therefore, the friction losses are expected to be much higher than in the 42-in. riser. Thus, the release rate obtained from area scaling actually will be smaller. Even when this effect is neglected, the release is expected to be three orders of magnitude smaller. However, the exit velocity from the riser will be the same in both cases because the release is scaled with the area fraction. Thus, a gas release from a 4-in. riser and the radiological and toxicological consequences from this release are bounded by the gas release from the 42-in. riser, as reported in the Mixer Pump SA.[1]

If the concentration of waste suspended in the dome space were 10^{-7} g/cm^3, then in 1 h, 32 g of suspended waste would be convected to the environment at ground level. Because of the ease of covering a 4-in. riser, the open time is expected to be less than the 1 h identified in the 42-in. riser analysis; therefore, the release consequences are reduced even further. Using the unit release factors given in the Mixer Pump SA,[1] the radiological consequences of an airborne release of 32 g of material near the riser area were calculated and are shown in Table 5-6.

5.2.3. Consequences of Release from Damaged HEPA Filter System

If the tank filter system is damaged during installation of the RGS drill-string assembly, a release of materials trapped in the filter system is possible. The radiological consequences are assumed to be those calculated for a burn accident where 1.11 kg of waste is assumed to be released to the environment. A strong case could be made for a reduction of the release fraction to 1% rather than 10% (as used

TABLE 5-6
CALCULATED RADIOLOGICAL DOSES FOR UNFILTERED RELEASE THROUGH OPEN RISER

Receptor Location	Distance (km)	Riser Release EDE (rem)
SY Farm Area	0.10	8.80E-2
242-S Evaporator	0.30 W	1.77E-2
U Plant	0.78 NE	3.55E-3
Hwy. 240	3.9 SE	2.55E-4
Max. Offsite—Acute Dose	13.8 WNW	3.81E-5
Max. Offsite—50-yr Dose	13.8 WNW	1.26E-3

in the Mixer Pump SA[1] analysis) because the damage mechanism is not as energetic as the release-and-burn condition assumed in the Mixer Pump SA.[1] The radiological consequences of this event, shown in Table 5-7, are less than WHC guidelines and therefore are acceptable.

5.3. Accident Sequences during Retained Gas Sampler Operation

Discussions related to radiological consequence assessment for RGS accidents during normal RGS operations are included. First, a discussion concerning the release of waste from a dropped core sampler is presented. Next, exposure from ejected waste contained within the RGS drill string is discussed. These two cases are assumed to represent material releases caused by operation of the RGS. In the spill case, we will estimate only the amount of waste release and assume no burn. In the second case, we will assume that there is a burn with a gas release of 7673 ft^3 (corresponding to a waste level of 404 in.) and that the waste inside the drill string is ejected. The information in these two discussions is used to compute the radiological consequences of the RGS operation accidents presented in Table 5-1 of this SA.

TABLE 5-7
CALCULATED RADIOLOGICAL DOSES FOR A FILTER SYSTEM RELEASE

Receptor Location	Distance (km)	Riser Release EDE (rem)
SY Farm Area	0.10	3.05E00
242-S Evaporator	0.30 W	6.14E-1
U Plant	0.78 NE	1.24E-1
Hwy. 240	3.9 SE	9.92E-3
Max. Offsite—Acute Dose	13.8 WNW	1.48E-3
Max. Offsite—50-yr Dose	13.8 WNW	4.88E-2

5.3.1. Consequences of Hazardous Materials Exposure during Removal of the Universal Core Sampler

The hazardous material contained inside the universal core sampler presents a release hazard if the core sampler is dropped during the core sampler removal operation. Section 5.1 of Ref. 3 states that the core sampler can accommodate up to 0.5 kg of waste material. The radiological consequences based on a 0.5-kg waste release were computed using the methodology described in the Mixer Pump SA[1] and are summarized in Table 5-8. The release fraction of the spill accident is assumed conservatively as 100%.

The frequency of this accident is estimated as 4.8E-3, as given in Table 5-1. Radiological consequences that consider the event frequency are less than the WHC acceptance guidelines.

5.3.2. Consequences of Hazardous Materials Exposure during Addition of Drill-Rod Section

During normal operation of the RGS in the push mode, the core sampler must be retrieved and replaced after each 19-in. sample segment is taken. After the first sample is taken, the waste-filled core sampler is removed using the shielded receiver assembly and placed in the appropriate transfer cask. An empty core sampler then is retrieved, lowered, and locked into the drill string. The upper drill string is disconnected from the shielded receiver barrel at the Camloc adapter assembly. A new 19-in. drill-rod section is threaded to the drill string and then connected to the shielded receiver barrel. During this procedure, the drill string is open to the environment as the new drill-rod section is being mounted to the drill string. Because the drill string is open to the atmosphere, the drill string cannot be pressurized by the argon source. Therefore, a failure of the lower drill-string seal will allow waste to flow around the core sampler into the drill string.

A release and burn event during this time period combined with a failure of the lower drill-string seal may result in waste being ejected from the drill string into the environment. When the sampler is taken from the drill string for removal of the

TABLE 5-8
CALCULATED RADIOLOGICAL DOSE CONTRIBUTION FROM THE RGS CAUSED BY DROPPED SAMPLER

Receptor Location	Distance (km)	Riser Release EDE (rem)
SY Tank Farm	0.10	1.38E00
242-S Evaporator	0.30 W	2.77E-1
U Plant	0.78 NE	5.55E-2
Hwy. 240	3.9 SE	3.99E-3
Max. Offsite—Acute Dose	13.8 WNW	5.95E-4
Max. Offsite—50-yr Dose	13.8 WNW	1.97E-2

RGS, there could be direct path from the tank waste to the atmosphere. Ejection during this condition could occur if the burn occurs. Therefore, we estimated the amount of waste during a burn event that can be ejected through a 1.9-in.-i.d. drill string.

As the burn pressure increases in the dome, some waste will penetrate into the drill string. The minimum distance between the waste surface and the end of the drill string is 248 in., which is obtained when the drill string is fully inserted into the waste. The static pressure head corresponding to this height is 77,900 Pa. The ejection of waste from the top end of the drill string will begin when the burn pressure exceeds 2.0E5 Pa. The pressure history of the burn shows that the dome pressure exceeds 2.05 Pa at 2.22 s. The peak pressure of the burn is 3.65E5 Pa. We integrated the pressure trace conservatively and obtained an average dome pressure of 2.781E5 Pa during the ejection period.

We considered the unsteady Bernoulli equation, including the friction losses, and estimated the average discharge velocity over the ejection period of 2.22 s as 6.1 m/s. This value is conservative on the following basis. If we consider a steady-state case without friction losses, the discharge velocity can be calculated as 9.8 m/s. However, with a conservative friction loss coefficient of 0.02 and a pipe length of 248 in., the friction losses decrease to a discharge velocity of 5.2 m/s. Thus, the use of a 6.1-m/s discharge velocity is reasonable. This velocity results in a 40-kg waste ejection into the atmosphere.

Estimating the airborne release fraction from this ejected amount is not straightforward. We therefore took the following approach. We assume that 20% of the ejected waste would be released to the environment as airborne particles. We believe that the release fraction of 20% is very conservative. We can calculate the total kinetic energy of the waste slug using a weight of 40 kg. This kinetic energy can be used to estimate the release fraction using Fig. 4.3 of Ref. 4, where the airborne release as a result of explosive events is given in terms of an effective energy source. Such an analysis, although not exactly scaled to this particular ejection and spill scenario, gives a release fraction of 0.4%. Therefore, the assumption of a 20% release fraction is conservative. Thus, 8 kg of waste is assumed to be released as a result of ejection. This amount will be added to the ground releases calculated from the burn analysis mentioned below.

To determine the total waste mass released to the environment, we performed an HMS/TRAC burn analysis[2] for a gas release of 7673 ft^3 with a closed 4-in. riser to estimate the released material from the tank during normal RGS operation. The ventilation system also is assumed not to be operable in this calculation. The results of these calculations are presented in Table 5-9. The radiological ground and stack releases calculated for the no-burn case are 0.038 and 0.080 kg, respectively. For the burn case, the radiological ground and stack releases are 2.283 and 0.106 kg, respectively. The burn analysis assumes that the drill string sampler seal is intact, whereas the ejection analysis assumes that the sampler is not in place. The burn analysis should have included an additional leak area equivalent to the cross-sectional area of the drill string. Tables 5-3 and 5-9 show that having a closed or open riser does not significantly influence the total ground releases. The major contribution is not from a burn but from ejection in this particular case. Thus, we did not repeat the burn calculation with a 2.25-in. open riser.

The ammonia releases are the same for both cases shown in Table 5-9 because these releases are based on peak ammonia concentrations that occur before a burn (i.e., during the gas release phase).

The radiological and toxicological consequences were computed using the methodology described in the Mixer Pump SA[1] and are summarized in Tables 5-10 and 5-11, respectively. The radiological consequences for the burn case (Table 5-10) include the addition of (1) a 1.11-kg ground release caused by failure of the tank filter system and (2) an 8-kg ground release from the drill string.

TABLE 5-9
THERMAL-HYDRAULIC RESULTS FOR THE HYDROGEN OR TOXIC GAS RELEASES DURING RGS OPERATION

Accident Sequence	Peak Pressure during Injection (psia)	Peak Pressure during Burn (psia)	Peak Temp. during Burn (°F)	Ammonia Released (g/s) Ground Release	Ammonia Released (g/s) Stack Release	Radiological Release (kg) Ground Release	Radiological Release (kg) Stack Release
Closed 4-in. riser, no burn	14.88	—	—	6.80	3.78	0.038	0.080
Closed 4-in. riser, burn	14.88	51.63	1844	6.80	3.78	2.283	0.106

TABLE 5-10
RADIOLOGICAL DOSE EDE (rem) FOR THE HYDROGEN GAS RELEASES DURING RGS OPERATION

Accident Sequence	SY Farm	242-S Evaporator	U Plant	Hwy. 240	Max. Offsite[a]	Max. Offsite[b]
Closed 4-in. riser, no burn	3.245E-1	6.525E-2	1.341E-2	1.045E-3	1.558E-4	5.154E-3
Closed 4-in. riser, burn	31.62	6.37	1.29	0.101	1.50E-2	4.96E-1

[a]Acute dose.
[b]50-yr dose.

TABLE 5-11
AMMONIA EXPOSURES (ppm) FOR THE TOXIC GAS RELEASES DURING RGS OPERATION

Accident Sequence	SY Farm	242-S Evaporator	U Plant	Hwy. 240
Closed 4-in. riser, no burn	40.27	31.29	12.06	1.27
Closed 4-in. riser, burn	40.27	31.29	12.06	1.27

The frequency of the release from the drill string during operation is the frequency of a GRE and burn event because the ejection is a result of burn. At 404 in., the probability of having a burn with a hydrogen concentration exceeding 25% of the LFL is estimated as 1.2E-2 in the Mixer Pump SA.[2]

The WHC acceptance criterion for the onsite dose rate at this frequency is 91 rem, which is higher than the estimated dose rate of 31.62 rem. The calculated organ doses at an onsite location (15 times the onsite dose = 15*31.62) is 474.3 rem and is almost identical to the WHC acceptance criterion for all organ dose rates at a frequency of 1.2E-5 1/yr, as shown in Fig. 5-3. Thus, radiological consequences of accidents considered for the operation phase of the RGS do not meet the acceptance criteria when the waste level is ≥404 in. Therefore, we recommend lowering the allowable waste level to 402 in. for RGS operation. At this level, the frequency of the GRE and burn becomes 4.0E-6 (4.0E-3 x 1.0E-3), and the radiological release is much less than that reported in this SA because the gas release will be smaller. We did not repeat the burn calculation at 402 in. The lower release and burn frequency at a waste level of 402 in. already causes the current radiological releases to be below the WHC guidelines. The current Mixer Pump SA[1] also requires that the pump be operated aggressively to keep the waste level at <402 in. Thus, our recommendation is to limit the waste level to 402 in. for RGS operation. This limit also is valid for the installation and removal phases.

5.4. Accident Sequences during Retained Gas Sampler Removal

This section presents the consequences of the accidents postulated to occur during removal of the RGS. The material release conditions governing the evaluation of radiological and toxicological consequences in this assessment are presented below.

5.4.1. Hydrogen and Toxic Gas Releases—4-in. Open Riser

This accident sequence and the consequences are identical to the gas release accidents during RGS installation discussed in Se. 5.2.1.

5.4.2. Consequences of Unfiltered Release from Loss of Negative Tank Pressure

This accident sequence is assumed to be bounded by the consequences of an unfiltered release from negative tank pressure during RGS installation, as discussed in Sec. 5.2.2.

5.4.3. Consequences of Release from a Damaged Filter System

This accident sequence is assumed to be bounded by the consequences of a release from a damaged filter system during RGS installation, as discussed in Sec. 5.2.3.

5.5. Consequences of Radiation Exposure during Decontamination

The RGS assembly may be contaminated by tank waste during removal or operation phases. The amount of waste on the RGS can increase the radiation caused by tank shine. The accident condition considered in Sec. 4.3.6.2 of this SA may be bounded by the estimated dose rates determined for the voidmeter.[2]

The basis for this is as follows. If the decontamination process is assumed to fail during removal of a 19-in. drill string, the interior and exterior surfaces of the drill string could be covered with waste. We performed laboratory experiments using waste simulant to estimate the amount of waste film that could remain on flat surfaces; our findings are discussed in Add. 2 of the Mixer Pump SA.[2] Based on that experimental study, the waste film density is expected to be 0.13 $g/in.^2$ When we consider the inner and outer surfaces of the 19-in.-long drill string, 35 g of waste could be accumulated as a film. For the worst-case scenario, we added this amount to the 0.5 kg of waste that could be in the drill string. Thus, the total waste in a 19-in. length could be 0.535 g.

The sampler is removed once a shielded receiver is attached to the adapter that is placed on the riser. Currently, we do not have radiation dose calculations for the outside of the shielded receiver. Thus, we will assume that the contact dose (the outside surface of the shielded receiver surrounding the sampler) exceeds the WHC acceptance limit of 100 mrem/h. In other words, we will assume that there are high-radiation conditions until an analysis for the radiation doses is available.

The high-radiation conditions require special work controls to limit the exposure. A control requiring the radiation survey is included in the RGS operational controls in Sec. 6 of this SA. Normal operations are not allowed when radiation levels >100 mrem/h are detected outside the shielded receiver; special radiation work plans must be implemented to limit worker exposure under any high-radiation conditions. The exposure limits must be revised when dose rate calculations performed specifically for RGS removal become available.

REFERENCES

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2. R. K. Fujita, "HMS/TRAC Burn Analysis for Revision 13 of the Mixing Pump SA," Los Alamos National Laboratory calc note TSA6-CN-WT-SA-TH-057 (October 1994).

3. R. J. Van Fleet, "Safety Basis for Activities in Double-Shell Flammable Gas Watch List Tanks," Westinghouse Hanford Company report WHC-SD-WM-SARR-002 (May 1994).

4. J. E. Ayer, A. T. Clark, P. Loysen, M. Y. Ballinger, J. Mishima, P. C. Owczarski, W. S. Gregory, and B. D. Nichols, "Nuclear Fuel Cycle Facility Accident Analysis Handbook," U.S. Nuclear Regulatory Commission Report, NUREG-1320 (May 1988).

6.0. CONTROLS

This section provides the controls to be used for the RGS system installation, operation, and removal. Administrative controls for the RGS are derived largely from the controls developed for Tank 101-SY mitigation operations.[1] This section does not reiterate the controls for functions unrelated to the RGS. This section assumes that no other activities unrelated to the RGS installation, operation, and/or removal are in process when the RGS activities are undertaken.

A set of controls has been established for each of the RGS activities for clearer and easier procedures development. These controls were developed using WHC standard controls integrated with the results, assumptions, initial conditions, and behavioral aspects of Tank 101-SY. Those WHC standard controls for Tank 101-SY[1] important to RGS activities have been repeated in this SA for clarity; however, the controls listed in this SA are intended only to supplement the WHC standard controls, not replace them. WHC standard controls are derived from a series of WHC documents that define the safety envelope for the tank farm. The primary document is the WHC Health and Safety Plan (HASP manual),[2] although other documents include the double-shell flammable gas watchlist tank safety basis document[3] and the interim safety basis document.[4] During the development of the procedures for each of the activities, the current OSRs and OSDs must be considered. The safety envelope established by the analyses shall not be changed without approval of the Secretary of the DOE. The controls provided in this section can be modified if the appropriate organization grants approval.

The RGS activity is to last for a finite time period. Therefore, the controls designated for RGS should be followed only for that period. The time period for the applicability of the specific controls appears in the related section.

Most of the controls presented in this section are based on analyses performed for the Mixer Pump SA[1] and this SA. These controls have been designed to ensure that the analysis assumptions and initial conditions are maintained throughout the RGS activities. In a few cases, controls have been developed to provide an additional safety margin. Therefore, the controls should be an integral part of the procedure development process to maintain the level of safety demonstrated in this SA.

Safe conditions for operation, surveillance monitoring, and administrative controls have been developed for each system or condition required to be controlled. Safe conditions for operation are defined as the limits within which the RGS activity will be controlled. Surveillance monitoring requirements establish how the limit shall be monitored. Administrative controls are the procedural requirements that shall be followed to ensure that the activity stays within the bounds of the SA. Safe shutdown definitions also are provided for each of the mitigation activities. These instructions provide the guidance and recommended operator actions to be taken if any of the controls are no longer met. As such, these sets of guidelines and recommendations should be used during the development of procedures for the RGS activities. These actions are intended to restore the level of safety as rapidly as possible.

Sections 6.1 and 6.2 provide the specific controls to be used for the activities covered by this SA. Changes to these controls will require TRG approval and WHC management review, and DOE/RL will be notified of the changes and their technical bases. Restart after shutdown involving a control that has no designated level will require TRG approval. The TRG comprises representatives from WHC, PNL, LANL, and DOE and is defined in the test management plan.[5]

6.1. Standard Controls for Tank 101-SY

To promote consistent work plan preparation, the set of mitigation standard controls developed for open-tank operations for the mixer pump[1] will be utilized for the RGS. Open-tank mitigation activities are intended for installation or removal of the mixer pump, water lance, water wands, and MPR, as well as the RGS. The standard mitigation controls for open-tank operations are presented in Table 6-1. Similarly, the set of mitigation standard controls developed for closed-tank operations of the mixer pump, water lance, or water wands has been adapted for the RGS. The standard mitigation controls for closed-tank operations are presented in Table 6-2. Open- and closed-tank mitigation controls apply to the RGS work during those phases of the RGS activity.

Exceptions can be taken to the standard controls by explicitly annotating the activity-specific control table (Table 6-3). Likewise, the setpoints provided in that RGS-specific table for a given control take precedence over the setpoints in the standard control tables.

These standard mitigation controls have been developed from WHC standard controls that may be found in the previous safety documentation for Tank 101-SY.[2–5] These controls from past safety documentation are not repeated in total in this SA—only those controls considered particularly important to the activities covered by this SA are included. Several of the WHC standard controls have been modified to ensure their applicability to the activities covered by this SA. These modifications were required to match the assumptions and initial conditions used in this SA.

6.2. Installation, Removal, and Operation of the RGS System

6.2.1. Description of Activity

As previously mentioned, the purpose of the RGS work is to collect and analyze mixed waste samples from Tank 101-SY. Analysis of the gas species will be performed in one of the hot cells at the Hanford Site. Equipment needed for the RGS work includes the core sampling truck, drill-string components, and associated equipment (including the core sampler). A rotary platform and a stationary platform are mounted on the rear of the truck.

The overall operation includes setting up equipment, sampling the core, recovering the sample from the drill string, inserting an empty sampler into the drill string, preparing the sample for shipping, cleaning equipment, removing the core sample equipment, and restoring the tank.

The controls for the RGS system installation, operation, and removal processes shall apply starting when the RGS system is readied at the tank and the riser is uncovered and ending when the riser is covered and the drill truck is removed.

6.2.2. Controls

The controls provided for the RGS system during installation, removal, and operation processes are based on the modified WHC standard controls and appear in Table 6-3. The analyses for these controls are presented in this SA.

6.3. Conclusions

Controls were developed for each of the Tank 101-SY RGS system activities. Modifications were made to the WHC standard controls to make them specific to each of the activities analyzed in the SA. These modified standard controls were combined with those that were based on the results of the RGS SA. The design of the RGS system, the conservative approach to the analyses, and the controls established for the RGS activity ensure that these activities can be performed within the bounds of this SA.

REFERENCES

1. L. H. Sullivan, "A Safety Assessment for Proposed Pump Mixing Operations to Mitigate Episodic Gas Releases in Tank 241-SY-101: Hanford Site, Richland, Washington," Los Alamos National Laboratory report LA-UR-92-3196, Rev 13 (November 4, 1994).

2. T. P. Rudolph, "Tank Farm Health and Safety Plan," Westinghouse Hanford Company report WHC-SD-WM-HSP-002, Rev. 0A (September 28, 1993).

3. R. J. Van Fleet, "Safety Basis for Activities in Double-Shell Flammable Gas Watch List Tanks," Westinghouse Hanford Company report WHC-SD-WM-SARR-002 (April 12, 1994).

4. C. E. Leach, "Hanford Site Tank Farm Facilities Interim Safety Basis," Westinghouse Hanford Company report WHC-SD-WM-ISB-001, Rev. 0 (August 1, 1993).

5. G. Bear, "Mitigation Test Management," Westinghouse Hanford Company report WHC-SD-WM-MA-014, Rev. 2 (October 5, 1993).

6. R. Clinton, "Safety Evaluation for Adding Water to Tank 101-SY," Westinghouse Hanford Company report WHC-SD-WM-SAD-016, Rev. 2 (August 1994).

TABLE 6-1

MITIGATION ACTIVITIES STANDARD CONTROLS FOR OPEN-TANK CONDITIONS

System or Condition	SCO	Surveillance Monitoring	Administrative Procedures	Basis for Control	Safe Shutdown Definition
Ventilation System	Both the primary and auxiliary exhausters must be available before starting this activity	DACS, data logger, or per WHC procedure	Assure both exhausters operational before starting activity	WHC modified standard controls	If activity has not started, do not start activity unless authorized by TRG
- Primary Ventilation Flow Rate	Minimum flow 0.19 m^3/s (400 ft^3/min)	DACS	Alarm at 0.20 m^3/s (425 ft^3/min) Place tank in safe shutdown mode if primary ventilation fails. Get auxiliary exhauster on line	WHC standard controls	Terminate activities and hold assembly in place while ventilation flow is < 400 ft^3/min during primary exhauster investigation. If primary exhauster flow is not available within 1 h, start auxiliary exhauster for ventilation. If assembly is in the riser, continue installation with auxiliary exhauster operating at 400 ft^3/min. If the assembly is not in the riser, move assembly to a holding area and wait for primary exhauster flow of 400 ft^3/min to be restored
	Maximum flow 0.33 m^3/s (700 ft^3/min)	DACS	Alarm at 0.319 m^3/s (675 ft^3/min)	WHC standard controls	Terminate activity and investigate reasons for ventilation flow being > 700 ft^3/min from Tank 101-SY. Do not continue activities until Tank 101-SY flow is <700 ft^3/min
- Hydrogen Concentration	Initiate operations when H_2 concentration <500 ppm	DACS	Do not initiate activity if H_2 concentration > 500 ppm H_2	Mixer Pump SA[1]	Activities can be initiated only while the hydrogen concentrations are relatively low
Gas Concentrations (All Locations)					
- Maximum Hydrogen Concentration	<0.75 vol %	DACS or locally	Alarm at 75% SCO value. Terminate activity if SCO value is exceeded	DOE 5480.4 (NFPA)	Terminate activities and remove personnel from riser area until H_2 concentration is <500 ppm
- Maximum Ammonia Concentration	<3000 ppm	DACS	Alarm if SCO is exceeded. Terminate activity if SCO value is exceeded	Mixer Pump SA[1]	Terminate all operations until ammonia concentration is ≤500 ppm

TABLE 6-1 (CONT)

MITIGATION ACTIVITIES STANDARD CONTROLS FOR OPEN-TANK CONDITIONS

System or Condition	SCO	Surveillance Monitoring	Administrative Procedures	Basis for Control	Safe Shutdown Definition
Crane and Loads	Critical lift procedures must be in place during installation and removal of equipment in risers. Administrative controls will be developed to preclude crane-to-crane interactions	Approved work plans	The readiness review shall ensure that work plans include critical lift procedures	To reduce likelihood of drop, waste spill accidents, or damage to equipment important to safety	Do not start installation or removal activities until critical lift procedures are in place
- Load Path	Loads will not be lifted over HEPA filters, risers, or other safety-related equipment	Visual	A lift path that will present the least possibility of hitting HEPA filters, risers, or other safety-related equipment if the load drops will be developed as part of the work package	To minimize probability of damaging equipment important to safety as a result of a drop accident	If load is over equipment that is important to safety, move the load to a safe location immediately
- Loading from Heavy Objects on Dome	The crane or heavy vehicles (≥10,000-lb gross vehicle weight) will remain at least 20 ft away from the edge of the dome unless specifically authorized by the TRG based on suitable analysis	Visual	A distance of 20 ft shall be clearly marked on the ground, and observers shall monitor the vehicle's position while vehicle is in motion	To prevent overloading of the dome for additional related dome-loading controls	If the crane or heavy vehicles encroach within 20 ft of the dome, remove the vehicles immediately
Intrusion Criteria	Duration of intrusion period < $(L_{max}-L_{opened})/0.1$ Following the last activity that can induce a gas release, there shall be a 4-h minimum waiting period	Intrusion day count starts when the intrusion period is declared open	All activities shall be completed within the intrusion period and within work plans and procedures	Mixer Pump SA[1]	Terminate activities and place tank in safe shutdown condition if intrusion criteria is not met

TABLE 6-1 (CONT)

MITIGATION ACTIVITIES STANDARD CONTROLS FOR OPEN-TANK CONDITIONS

System or Condition	SCO	Surveillance Monitoring	Administrative Procedures	Basis for Control	Safe Shutdown Definition
Intrusion Criteria (Cont.)					
- Tank Conditions before Opening Intrusion Window	The tank conditions before waste-intrusive operations will be evaluated and must be acceptable	Approved work plans	TRG will evaluate tank conditions before opening a waste-intrusive window	Minimize probability of a GRE	If waste intrusive operations are begun without TRG authorization, terminate activities until tank conditions can be evaluated
-No Other Tank Activities That Could Lead to a Gas Release	No operations that may lead to releases are allowed in Tanks 101-, 102- , or 103-SY while the intrusive operation is in progress without TRG approval	Communication at tank DACS	Approved procedure	One operation at a time to eliminate gas release	If intrusive device is over the riser, do not continue installation. Terminate activities as soon as intrusive device is lowered to a safe place and wait for cessation of other activities (observe 4-h interval after gas-releasing operations). If intrusive device is in the riser, continue installation until complete. The riser should be covered ASAP
-Communication with DACS (Tank Farm)	Tank conditions must be monitored during installation activities via established continuous communication	Visual verification and routine inspection	The person in charge shall be in continuous communication with personnel in the DACS trailer	To monitor general tank conditions	If the intrusive device is over the open riser, do not continue installation. Riser must be covered and communications restored or established before operation can continue
Dome Space Conditions					
- Dome Pressure	≤0.0 in. w.g.	DACS	Alarm at 0.0 in. w.g.	SA OSR limit 0.0 in. w.g.[5]	Terminate activities and remove personnel from riser area until the dome pressure is confirmed negative and the ventilation flow is confirmed as 400 ft^3/min

TABLE 6-1 (CONT)

MITIGATION ACTIVITIES STANDARD CONTROLS FOR OPEN-TANK CONDITIONS

System or Condition	SCO	Surveillance Monitoring	Administrative Procedures	Basis for Control	Safe Shutdown Definition
Radiation Survey					
-Radiation at or near Riser Containing RGS System	Radiation survey conducted and area appropriately posted	Survey completed	Following RGS system installation, a radiation survey shall be conducted and the area posted as required by standard WHC procedures. Tank farm operations shall verify signs appropriately posted as part of normal rounds	WHC standard controls	Terminate activities, and verify all applicable conditions before restarting activities
Tank Water Addition					
- Volume	All water additions must be approved by TRG	Monitor flow totalizers on supply truck	Maintain log of all water additions to tank. Check waste level to ensure 422-in. level (OSD-T-151-00007) not exceeded	Ref. 6	If water addition in excess of determined limit accidentally occurs, terminate all activities and hold for TRG approval
- Water Temperature	Temperature shall be ≤130°F	Check water tank temperature	Ensure that water temperature is below limits	Ref. 6	Terminate activities, correct water temperature, and hold for TRG approval before restarting operations
RGS Riser Access or Any Other Riser Access Usage					
- Flammable Gas Concentration	If concentration <20% of LFL	Approved measuring device (see HASP Manual[2])	If any of the flammability limits exceed 20% of the LFL, work shall stop. A grab sample shall be taken, and laboratory analysis shall be performed. Work shall not continue until the flammability level drops below 20% of LFL	WHC standard controls (HASP Manual[2])	Terminate activities and remove personnel from riser area until combustible gas concentrations are within limits
Breaking of Tank Containment	5-min pause in activity if tank containment broken	Visual observation or data logger reading of Tank 101-SY dome pressure to confirm breaking of containment	Alarm at tank pressure of -0.25 in. w.g.	WHC standard controls	Terminate activities until procedural control problem has been corrected

TABLE 6-1 (CONT)

MITIGATION ACTIVITIES STANDARD CONTROLS FOR OPEN-TANK CONDITIONS

System or Condition	SCO	Surveillance Monitoring	Administrative Procedures	Basis for Control	Safe Shutdown Definition
Respiratory Protection					
- Supplied Air Close to Riser	For work within containment tent or within 28 ft of an open riser, personnel are required to use supplied air		Ensure that air respirators are supplied for all personnel operating near open riser	WHC standard controls (HASP Manual)[2]	Terminate activities and wait for proper respiratory protection to be available
- Personnel Elsewhere in Tank Farm	Only essential workers shall be permitted access to the areas where ammonia has the potential to exceed the IDLH limit of 500 ppm . Evacuation plans and briefings shall be conducted. Appropriate respiratory, eye, and skin protection shall be available and utilized, as directed by industrial health and safety		Comply with HASP (Safe Work Practice) and emergency response requirements in addition to personnel orientation and training requirements	WHC standard controls (HASP Manual),[2] Mixer Pump SA[1]	Remove nonessential personnel in the tank farm. Terminate activities until proper respiratory protection is available
Gas Monitoring while Containment Broken					
- Flammable Gases, Organic or Toxic Vapors	Shall not exceed limits of HASP Manual[2]	Monitor in accordance with HASP Manual[2]	Measure in accordance with HASP Manual[2]	WHC standard controls	Terminate activities and remove personnel from riser area until gas concentrations are within limits
Electrical and Spark Protection					
- Electrical Equipment in the Dome	All electrical equipment that does not meet NEC classification for a Class I, Div. I environment must be de-energized whenever tank conditions are such that this equipment could see flammable gas concentrations in excess of 60% of the LFL	DACS	TRG will determine if tank conditions are such that a gas release of sufficient size will cause the flammable gas concentrations in the dome to exceed 60% of the LFL. Any equipment not meeting Class I, Div. I requirements must be de-energized	Mixer Pump SA[1]	If any electrical equipment is energized that does not meet the applicable requirements, de-energize the equipment immediately

TABLE 6-1 (CONT)

MITIGATION ACTIVITIES STANDARD CONTROLS FOR OPEN-TANK CONDITIONS

System or Condition	SCO	Surveillance Monitoring	Administrative Procedures	Basis for Control	Safe Shutdown Definition
- Riser Bonding to Tank to Reduce Electrostatic Spark Sources	Electrical bonding strap in place. Resistance between tank and riser cover ≤25 Ω	Ohmmeter	Ensure electrical bonding straps in place	NEC Article 250-84, IEEE Standard 142-1991	Ensure electrical bonding straps in place
- Removal of Riser Bolts to Prevent Mechanical Sparks	Use only spark-resistant tools (exception: on loosening first full turn and final tightening torque)		Ensure that spark-resistant tools are used (exceptions noted)	WHC standard controls	Ensure that spark-resistant tools are used (exceptions noted)
- In-Tanks Equipment Electrically Bonded and Grounded	All in-tank equipment or any intrusive device must be electrically bonded to tank and grounded. Resistance between tank and in-tank equipment must be ≤25 Ω	Ohmmeter	Ensure all in-tank equipment is electrically bonded to tank, grounded, and meets all existing requirements	NEC Article 250-84, IEEE Standard 142-1991	Terminate activities until equipment is properly installed
- Ground and Tank Bonding for Objects 10 ft Tall or More during Installation and Removal Activities for Lightning Protection	Electrical bonding to ground and tank for installation and removal activities. Resistance between tank and equipment must be <10 Ω	Ohmmeter	Ensure that electrical bonding and ground in place	WHC standard controls	Ensure that electrical bonding and ground in place
External Events					
- Range Fire	No range fires within 15 mi of Tank 101-SY when riser is open	Visual. A lookout shall determine whether activities should be terminated	Before starting activities, DACS personnel shall contact the appropriate site authority and request verification that no range fires exist within 15 miles of the tank farm	Mixer Pump SA[1]	Terminate activities in the most timely way and place tank in a safe shutdown condition ASAP (note: this may entail completing the planned operations)

TABLE 6-1 (CONT)

MITIGATION ACTIVITIES STANDARD CONTROLS FOR OPEN-TANK CONDITIONS

System or Condition	SCO	Surveillance Monitoring	Administrative Procedures	Basis for Control	Safe Shutdown Definition
- Lightning	No significant thunderstorm activity reported or predicted to occur within 8 h of opening riser	Visual. A lookout shall determine whether activities should be terminated	Before starting activities, DACS personnel shall contact the site meteorological station and verify that no thunderstorm activity is reported or predicted to occur in the vicinity of the S Complex during the expected time of activities	Mixer Pump SA[1]	Terminate activities in the most timely way, cover the riser ASAP, and place tank in a safe shutdown condition ASAP (note: this may entail completing the planned operations)
- Earthquakes	No significant seismic activity. If seismic activity occurs, terminate activities and put tank in safe shutdown mode		Before activity proceeds, there should be no indication of seismic activity	Mixer Pump SA[1]	Terminate activities in the most timely way and place tank in a safe shutdown condition ASAP (note: this may entail completing the planned operations)
- Tornadoes	No conditions present for tornadoes	Visual. A lookout shall determine whether activities should be terminated	Before starting activities, DACS personnel shall contact the site meteorological station and verify that no significant bad-weather activity is reported or predicted to occur in the vicinity of the S Complex during the expected time of activities	Mixer Pump SA[1]	Terminate activities in the most timely way and place tank in a safe shutdown condition ASAP (note: this may entail completing the planned operations)
-Winds	No winds above 15 mph	As reported by weather station	PIC checks weather forecast to determine that no winds >15 mph are expected within the operational period	Crane operations limit	Do not initiate installation until forecast is for winds <15 mph for a 2-h period

TABLE 6-1 (CONT)

MITIGATION ACTIVITIES STANDARD CONTROLS FOR OPEN-TANK CONDITIONS

System or Condition	SCO	Surveillance Monitoring	Administrative Procedures	Basis for Control	Safe Shutdown Definition
- Dust Devils	No significant dust devil activity within sight of tank farm	Visual. A lookout shall determine whether activities should be terminated	The person designated as weather observer shall contact the Hanford Meteorological Station. If dust devils seen to develop within 1 mi of tank during open-riser activities, terminate activity and put tank in safe shutdown mode	Mixer Pump SA[1]	Terminate activities in the most timely way and place tank in a safe shutdown condition ASAP (note: this may entail completing the planned operations)
- Volcanic Activity	No significant volcanic activity		Before activity proceeds, there should be no indication of volcanic activity	Mixer Pump SA[1]	Terminate activities in the most timely way, cover the riser ASAP, and place tank in a safe shutdown condition ASAP (note: this may entail completing the planned operations)

TABLE 6-2

MITIGATION ACTIVITIES STANDARD CONTROLS FOR CLOSED-TANK CONDITIONS

System or Condition	SCO	Surveillance Monitoring	Administrative Procedures	Basis for Control	Safe Shutdown Definition
Ventilation System	Both the primary and auxiliary exhausters must be available before commencing this activity	DACS, data logger or per WHC procedure	Assure both exhausters operational before commencing activity	WHC modified standard controls	If activity has not started, do not start activity unless authorized by TRG
- Primary Ventilation Flow Rate	Minimum flow 0.19 m^3/s (400 ft^3/min)	DACS	Alarm at 0.20 m^3/s (425 ft^3/min) Place tank in safe shutdown mode if primary ventilation fails and get auxiliary exhauster on line	WHC standard controls	Terminate activities and hold assembly in place while ventilation flow is <400 ft^3/min during primary exhauster investigation. If primary exhauster flow is not available within 1 h, start auxiliary exhauster for ventilation. If assembly is in the riser, continue installation with auxiliary exhauster operating at 400 ft^3/min. If assembly is not in the riser, move assembly to a holding place and wait for primary exhauster flow of 400 ft^3/min to be restored
	Maximum flow 0.33 m^3/s (700 ft^3/min)	DACS	Alarm at 0.319 m^3/s (675 ft^3/min)	WHC standard controls	Terminate activity and investigate the reasons for ventilation flow being > 700 ft^3/min from Tank 101-SY. Do not continue activities until Tank 101-SY flow is <700 ft^3/min
- Hydrogen Concentration	Initiate operations when H_2 concentration <500 ppm	DACS	Do not initiate activity if H_2 concentration > 500 ppm H_2	Mixer Pump SA[1]	Activities can be initiated only while the hydrogen concentrations are relatively low
- Minimum Flow from Tanks 102- and 103-SY	Combined minimum flow from Tanks 102- and 103-SY at least 2/3 the flow from Tank 101-SY	Data logger or per WHC procedure	Check ventilation flows for Tanks 101-, 102-, and 103-SY	WHC modified standard controls	Terminate activity and rebalance flows if it is suspected that the SCO condition is not met
Riser Covers and Pump Pit Drain	All riser covers shall be bolted down and pump pit drain plugged	Inspection	Inspection	Mixer Pump SA[1]	Terminate activities until equipment is secured

TABLE 6-2 (CONT)

MITIGATION ACTIVITIES STANDARD CONTROLS FOR CLOSED-TANK CONDITIONS

System or Condition	SCO	Surveillance Monitoring	Administrative Procedures	Basis for Control	Safe Shutdown Definition
Inlet HEPA Filter Piping	The piping shall be vertically oriented and vented at least 17 ft above ground	Inspection	Ensure piping geometry meets SCO requirement	Mixer Pump SA[1]	Terminate activities until equipment is properly installed
Waste Intrusion Criteria					
-No Other Tank Activities That Could Lead to a Gas Release	No operations that may lead to releases are allowed in Tanks 101-, 102- , or 103-SY while the intrusive operation is in progress	Communication at tank DACS	Approved procedure	One operation at a time to eliminate gas release	In case of concurrent waste-intrusive operations, terminate all waste-intrusive activities. Observe 4-h interval between subsequent waste-intrusive operations that can induce a gas release
-Communication with DACS (Tank Farm)	Tank conditions must be monitored during intrusion activities via established continuous communication	Visual verification and routine inspection	The person in charge shall be in continuous communication with personnel in the DACS trailer	To monitor general tank conditions	Terminate all intrusive operations until proper communication is established
- Open Riser during Intrusion	Open-tank standard controls given in Table 6-1 shall be followed during open-riser conditions	See Table 6-1	See Table 6-1	See Table 6-1	See Table 6-1
Dome Space Conditions					
- Tank Dome Pressure	< -1.0 in. w.g.	DACS	Alarm at -1.5 in. w.g. Terminate activities if SCO is violated	Mixer Pump SA[1]	Terminate all activities immediately because increasing (less negative) dome pressure is an indication of a possible flammable gas release
Electrical and Spark Protection					
- Electrical Equipment in the Dome	All electrical equipment that does not meet NEC classification for a Class I, Div. I environment must be de-energized if equipment registers flammable gas concentrations in the tank >60% of LFL	DACS	TRG will determine if the tank conditions cause a gas release of sufficient size such that flammable gas concentrations in the dome will exceed 60% of LFL. Any equipment not meeting Class I, Div. I requirements must be de-energized	Mixer Pump SA[1]	If any electrical equipment is energized that does not meet applicable requirements, de-energize equipment immediately

TABLE 6-2 (CONT)

MITIGATION ACTIVITIES STANDARD CONTROLS FOR CLOSED-TANK CONDITIONS

System or Condition	SCO	Surveillance Monitoring	Administrative Procedures	Basis for Control	Safe Shutdown Definition
- Electrical Bond and Ground In-Tank Equipment	All in-tank equipment or any intrusive device must be electrically bonded to ground. Resistance between tank and in-tank equipment must be ≤25 Ω	Inspection	Ensure all in-tank equipment is electrically bonded to grounds and meets all existing requirements	WHC standard controls	Terminate activities until equipment is properly installed
Pump Pit Ventilation Area	Pump pit ventilation area must be sufficient. The following are required: - drain pipe plugged - minimum vent area >113 in.^{2} - pit free space > 400 ft^3 - leak flow area with burn in the dome <40 in.^{2} - seal in place on pump support column - leak flow path between the dome and the pump pit shall not exceed 0.5 in.^{2}	Check before installing cover blocks	Ensure that pump pit SCO conditions are met before installing cover blocks	Mixer Pump SA[1]	Terminate activities if it is suspected that pump pit conditions are not met
RGS Riser or Any Other Riser Access Usage					
- Flammable Gas Concentration	If concentration <20% of LFL	Approved measuring device (see HASP Manual[2])	If any of the flammability limits exceed 20% of LFL, work shall stop. A grab sample shall be taken, and laboratory analysis shall be performed. Work shall not continue until the flammability level drops below 20% of LFL	WHC standard controls (HASP Manual[2])	Terminate activities and remove personnel from riser area until combustible gas concentrations are within limits

TABLE 6-2 (CONT)

MITIGATION ACTIVITIES STANDARD CONTROLS FOR CLOSED-TANK CONDITIONS

System or Condition	SCO	Surveillance Monitoring	Administrative Procedures	Basis for Control	Safe Shutdown Definition
Gas Concentrations (All Locations)					
- Maximum Hydrogen Concentration	<0.75 vol %	DACS or locally	Alarm at 75% SCO value. Terminate activity if SCO value is exceeded	DOE 5480.4 (NFPA) and Mixer Pump SA[1]	Terminate all activities until the H_2 concentration is <500 ppm
- Maximum Ammonia Concentration	<3000 ppm	DACS	Alarm if SCO is exceeded. Terminate activity if SCO value is exceeded	Mixer Pump SA[1]	Terminate all intrusive operations until the NH_3 concentration is <500 ppm.
Personnel Protection					
- Personnel in DACS Trailer	Personnel in DACS trailer must have respiratory protection, as required by industrial health and safety	Monitor tank for GRE	Emergency procedures shall be developed for DACS personnel protection during GREs	Mixer Pump SA[1]	Terminate activities if personnel protective equipment controls are not met
- Other Personnel in Tank Farm	Only essential workers shall be permitted access to areas where ammonia can exceed the IDLH limit of 500 ppm. Evacuation plans and briefings shall be conducted. Appropriate respiratory, eye, and skin protection shall be available and utilized, as directed by industrial health and safety. The exclusion distance may be changed to meet the IDLH limit based on revised analysis and/or data		Comply with HASP (Safe Work Practice) and emergency response requirements, in addition to personnel orientation and training requirements	WHC standard controls (HASP Manual);[2] Mixer Pump SA[1]	Terminate activities if personnel protective equipment controls are not met
MPR Vent Doors	Doors closed and shear retention plates installed	Daily visually inspection	The MPR shall be inspected as part of normal tank farm rounds	Mixer Pump SA[1]	Terminate all SY Tank Farm activities immediately until situation is corrected
- Seals	No deterioration of seal material	Regular annual visual inspection	The MPR shall be inspected as part of normal annual tank farm maintenance inspections	Mixer Pump SA[1]	Terminate all SY Tank Farm activities until situation is corrected

TABLE 6-2 (CONT)

MITIGATION ACTIVITIES STANDARD CONTROLS FOR CLOSED-TANK CONDITIONS

System or Condition	SCO	Surveillance Monitoring	Administrative Procedures	Basis for Control	Safe Shutdown Definition
- Obstructions	Vent doors must be free of drifting sand and snow and other obstacles	Daily visual inspections	The MPR shall be inspected as part of normal tank farm rounds	Mixer Pump SA[1]	If obstructed, correct situation ASAP
External Events					
- Range Fire	No range fires within 5 mi of Tank 101-SY during activities	DACS personnel shall determine whether activities should be terminated	Before starting activities, DACS personnel shall contact the appropriate site authority and request verification that no range fires exist within 5 miles of the tank farm	Mixer Pump SA[1]	Terminate activities in the most timely way, and place tank in a safe shutdown condition ASAP
- Lightning	No significant thunderstorm activity reported or predicted to occur within 1 h of start of activities	DACS personnel shall determine whether activities should be terminated	Before starting activities, DACS personnel shall contact the site meteorological station and verify that no thunderstorm activity is reported or predicted to occur in the vicinity of the S Complex during the expected time of activities	Mixer Pump SA[1]	Terminate activities in the most timely way, and place tank in a safe shutdown condition ASAP
- Tornadoes	No conditions present for tornadoes	DACS personnel shall determine whether activity should be terminated	Before starting activities, DACS personnel shall contact the site meteorological station and verify that no significant bad-weather activity is reported or predicted to occur in the vicinity of the S Complex during the expected time of activities	Mixer Pump SA[1]	Terminate activities in the most timely way and place tank in a safe shutdown condition ASAP
- Earthquakes	No significant seismic activity		Before activity proceeds, there shall be no indication of seismic activity	Mixer Pump SA[1]	If there are any indications of seismic activity, terminate activities and put tank in safe shutdown mode

TABLE 6-3
CONTROLS FOR RGS SYSTEM INSTALLATION, REMOVAL, AND OPERATION

System or Condition	SCO	Surveillance Monitoring	Administrative Procedures	Basis for Control	Safe Shutdown Definition
INSTALLATION/REMOVAL					
Applicability of Standard Controls for Open-Tank Operation	The controls given in Table 6-1 shall be followed for RGS system installation and removal	See Table 6-1	See Table 6-1	See Table 6-1 for basis of specific controls	See Table 6-1
Minimum Flow from Tanks 102- and 103-SY	Combined minimum flow from Tanks 102- and 103-SY at least 1/3 the flow from Tank 101-SY	Data logger or per WHC procedure	Check ventilation flows for Tanks 101-, 102-, and 103-SY	WHC modified standard controls	Terminate activity. Rebalance flows if it is suspected that the SCO condition is not met
Waste Level	No installation when the waste level is >402 in. or the TRG-determined level based on analysis or new data	Level measurement	Monitor level	Mixer Pump SA[1]	Do not start insertion/installation
Drill-String Insertion	Pneumatic foot clamp operable	Monitor pneumatic pressure and clamp actuation	Voice alarm at loss of pneumatic pressure	Prevent possible drop accident leading to loss of tank/waste confinement integrity	Remove RGS and secure riser. Terminate all activities until proper function restored
Loads - Maximum Loads for RGS System Insertion for Push Mode Removal	 Push mode: ≤5900 lb Weight plus 50%	 Monitored by load cell by PIC/operator	 Voice alarm at indicated set-points	 Prevent possible damage to the riser from lateral loads	 If the maximum load exceeds the value specified by SCO, stop motion and investigate cause. If the unusual load is caused by the bent drill-string column (after visual inspection), lower the drill string into the bottom of the tank and secure the drill string. TRG will decide how to proceed from this point
- Minimum Load during Removal	Assembly weight minus 50%	Monitored by load cell by the operator/PIC	Voice alarm at assembly weight minus 40%	Prevent a possible damage to the riser from lateral loads	Removal: If the minimum load exceeds the value, stop motion and investigate cause. Provided that the cause of the unusual load is satisfactorily determined, the TRG can approve continued activity
Decontamination of Drill-String Equipment	No more than 250 gal. of water introduced into the tank per day without TRG approval	Flow/level monitoring	Maintain log of all water additions to tank	Ref. 6	If excessive water addition detected, terminate water addition immediately, remove water connection, and wait for TRG approval before continuing operations

TABLE 6-3 (CONT)
CONTROLS FOR RGS SYSTEM INSTALLATION, REMOVAL, AND OPERATION

System or Condition	SCO	Surveillance Monitoring	Administrative Procedures	Basis for Control	Safe Shutdown Definition
Radiation Level near the Riser and Drill-String Components	The radiation level shall not exceed 100 mrem/h at a distance not to exceed 18 in. as the RGS system is being raised from the riser	Radiation monitor near RGS system	Terminate operation if radiation level exceeds value specified by SCO		Immediately cease RGS system movement and evacuate area around riser. Insert the RGS system back into the riser until the radiation level is below the SCO. Decontaminate the RGS system once more and resume upward motion. If the radiation level exceeds the SCO, repeat the process described above until the radiation level is below the SCO
OPERATION					
Applicability of Standard Controls for Closed-Tank Operation	The controls given in Table 6-2 shall be followed for RGS system operations	See Table 6-2	See Table 6-2	See Table 6-2 for basis of specific controls	See Table 6-2
Waste Level	Will be no greater than 402 in. Operation of the RGS system above this limit requires TRG-approved analysis	DACS	Alarm at 1 cm (0.4 in.) below the limit. Terminate RGS system operation if SCO is exceeded	Mixer Pump SA[1]	Terminate all RGS system operations and prepare for RGS removal. Implement removal operations and secure riser
Shielded Receiver -Ball Valve	Must seal receiver with sampler unit in place	Verify operability	Procedure in approved work plan	WHC controls	Do not initiate sampling operations if transfer cask seal is not functioning
Drill-String Hydrostatic Balance -Push Mode	Gas flow is 0.3 to 0.4 scfm	Control panel alarm	Alarm at 0.1 scfm	Prevent waste from entering drill-string column	If drill-string column hydrostatic equilibrium cannot be restored, terminate operation and proceed to decontaminate drill string. Secure riser following removal of drill string
-Rotary-Core Sampling	Rotary-core sample operation inoperable	Verify lock-out/tag-out procedure implemented	Procedure in approved work plan	WHC controls	Rotary-core sampling operation not permitted in flammable tanks because of ignition hazard
Drill-String Speed -Push Mode	0 rpm	Control panel alarm	Audible monitoring and automatic shutdown, approved work plan	Prevent rotation of drill string causing ignition of waste	Drill-string rotation implies equipment interlocks have failed. If problem cannot be resolved, immediately terminate sampling operations, remove RGS, and secure riser

TABLE 6-3 (CONT)
CONTROLS FOR RGS SYSTEM INSTALLATION, REMOVAL, AND OPERATION

System or Condition	SCO	Surveillance Monitoring	Administrative Procedures	Basis for Control	Safe Shutdown Definition
Purge Gas Temperature - Push Mode	Normal temperature range 60 to 80°F	Alarm at low of 40 and high of 90°F	Audible alarm		
Shielded Receiver Enclosure -Temperature for Push Core Sampling Mode	Normal temperature 75°F	Alarm at low of 40 and high of 90°F	Audible alarm	Temperature control needed to provide accurate data	If temperature not within limits , RGS operations must cease. Once temperature control is achieved, operations may be restored
Insertion Velocity	No more than 10 in./s	Visual observation and judgment, normal setting 7 in./s	Approved work plans	Prevent possible overheating of waste	If SCO exceeded, lower insertion velocity
Duration of Operation	No more than two shifts	Visual inspection	Maintain log of operation days	Likelihood argument is made based on the 16-h maximum operation	Terminate activities if the total operation exceeds 48 h of elapsed time. TRG approval is needed to continue activities
Drill-String Length	The length of the drill string is calculated and recorded on a calculations worksheet	The worksheet is examined, verified, and signed off by both quality control and the PIC	Approved work plans	Addition and insertion of proper lengths of drill rod in accordance with the worksheet precludes the drill string coming in contact with the tank bottom as long as the drill string is not dropped	If SCO position is violated, lower the drill string
Tank Water Addition -Volume	No more than 100 gal./d (may be increased to 200 gal./d with TRG approval) and 1000 gal. total (total includes operation and removal of RGS system components)	Monitor flow totalizers on supply truck	Maintain log of all water additions to the tank. Check waste level to ensure 422-in. level (OSD-T-151-00007) not exceeded	WHC-SD-WM-SAD-016, Rev. 2	If water addition occurs by accident outside the bounds of approved procedures, terminate all RGS system operations

TABLE 6-3 (CONT)
CONTROLS FOR RGS SYSTEM INSTALLATION, REMOVAL, AND OPERATION

System or Condition	SCO	Surveillance Monitoring	Administrative Procedures	Basis for Control	Safe Shutdown Definition
Operation in Bottom 50 in. of Tank	Engage the automatic bottom detector in bottom 50 in. of tank	Control unit actuator control and pressure transducer	Approved work plans and procedure	To prevent damage to the tank bottom	If tank bottom indicator reverses drill operation, tank bottom has been contacted. Shut down coring operations and establish cause of bottom contact. Advise TRG of situation, and initiate shutdown procedure. TRG will determine further actions

7.0. READINESS REVIEW CHECKLIST

This SA assessed safety aspects of push-mode core sampling of Tank 101-SY using the RGS. The interim SA was completed before the design and documentation of the RGS were complete. This interim SA was prepared with the knowledge that additional areas of concern must be resolved before the final document is released. This section provides a checklist of key safety items that require some additional evaluation to complete the RGS SA. The readiness review would ensure that the items listed below have been adequately addressed. Completion of these tasks are necessary before LANL would recommend push-mode core sampling in Tank 101-SY.

Readiness Review Checklist

Design Review

1. Review the final released fabrication drawings of components that potentially come into contact with the waste to verify material compatibility with the waste.

2. Review the materials chosen for the RGS sample unit drill head and shear pin that replace the frangible drill head material and the nonsparking shear pin material. Make necessary changes to SA sections.

3. Revise SA to incorporate latest weight estimate for suspended drill-string column assembly and live load imposed on the tank dome surface by the truck support equipment.

4. Review the design of the wedge-clamp feature for restraining drill string to ensure that it affects the safety retention as published.

Documentation Review

1. Evaluate RGS work plans (up-to-date plans currently do not exist) covering sampling operations in Tank 101-SY. Work plans should address remedial action plans for unexpected events (e.g., stuck sampler, recovery of bent drill string, recovery of last sample unit, and provisions for precluding ejection of waste column trapped in drill string during burn event).

   Lock-out tag-out procedure in the work plan to preclude rotary-core sampling mode in Tank 101-SY.

2. Evaluation of DACS documentation, including P&ID diagrams, for completeness and implementation of control safety features.

   - Failure effects and modes analysis for the pressure relief and pressure regulator valves.

   - Truck system interlocks to preclude untimely operation of hazardous equipment [e.g., internal combustion (gasoline) power unit during open-riser conditions].

3. Review of FDC document for the RGS. Document is in preparation and presently unavailable.

4. Interim RGS SA references for WHC documents in process must be completed following document release.

NEC Classification Review

1. Update review of RGS design and operational procedures once WHC issues an NEC classification for region surrounding the riser; revise SA accordingly.

   Consistency of operations with NEC classification for the riser and surrounding regions (classification has not been made).

2. Revise SA to incorporate the appropriate truck drilling support equipment intended for Tank 101-SY (e.g., gasoline or diesel fuel for the accessory power unit).

Radiation Environment

1. RGS SA presently assumes that the radiation environment surrounding the riser during sampling operation of RGS exceeds guidelines. Protection of worker is the responsibility of WHC Health Physics, and radiation monitoring requirements must be established by WHC and placed in RGS work plans. RGS SA must be revised to correctly address this issue. We advise that radiation dose rate calculations be performed for exposed drill-string surface operations and that the results of these calculations be incorporated into the RGS SA and RGS work plan for Tank 101-SY.