S

JUN 15 2000

ENGINEERING DATA TRANSMITTAL

1. EDT 629063

2. To: (Receiving Organization) Distribution	3. From: (Originating Organization) Retrieval System Development	4. Related EDT No.: NA
5. Proj./Prog./Dept./Div.: RPP/Retrieval System Development	6. Design Authority/Design Agent/Cog. Engr.: W.L. Willis	7. Purchase Order No.: NA
8. Originator Remarks: For approval and release.		9. Equip./Component No.: NA
		10. System/Bldg./Facility: Tk AY101&102,AZ101&102
		12. Major Assm. Dwg. No.: NA
11. Receiver Remarks:	11A. Design Baseline Document? ☐ Yes ☒ No	13. Permit/Permit Application No.: NA
		14. Required Response Date: NA

15. DATA TRANSMITTED

(A) Item No.	(B) Document/Drawing No.	(C) Sheet No.	(D) Rev. No.	(E) Title or Description of Data Transmitted	(F) Approval Designator	(G) Reason for Transmittal	(H) Originator Disposition	(I) Receiver Disposition
1	RPP-4433	--	0	Alternatives Generation and Analysis for Heat Removal from High-Level Waste Tanks	NA	1 2	1	-

16. KEY

Approval Designator (F)	Reason for Transmittal (G)	Disposition (H) & (I)
E, S, Q, D OR N/A (See WHC-CM-3-5, Sec. 12.7)	1. Approval 2. Release 3. Information 4. Review 5. Post-Review 6. Dist. (Receipt Acknow. Required)	1. Approved 2. Approved w/comment 3. Disapproved w/comment 4. Reviewed no/comment 5. Reviewed w/comment 6. Receipt acknowledged

17. SIGNATURE/DISTRIBUTION (See Approval Designator for required signatures)

(G) Reason	(H) Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN	(G) Reason	(H) Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN
		Design Authority				1	1	A.F. Choho	for, [signature]	6/14/00	R3/73
		Design Agent									
1	1	Cog. Eng. W.L. Willis	[signature]	6/13/00	R3/73						
1	1	Cog. Mgr. For P.J. Certa	E. PACQUET [signature]	6/14/00							
		QA									
		Safety									
		Env.									

18.	19.	20.	21. DOE APPROVAL (if required)
[signature] W.L. Willis 6/14/00 Signature of EDT Originator / Date	[signature] 6/14/00 Tom Conrads Authorized Representative for Receiving Organization / Date	[signature] For E.A. PACQUET P.J. Certa 6/14/00 Design Authority/ Cognizant Manager / Date	Ctrl No. ______ ☐ Approved ☐ Approved w/comments ☐ Disapproved w/comments

Alternatives Generation and Analysis for Heat Removal from High-Level Waste Tanks

W.L. Willis, NHC; W.J. Millsap & J. B. Truitt, FHI; & J.L. Poe, E2
for Numatec Hanford Corporation
Richland, WA 99352
U.S. Department of Energy Contract DE-AC06-99RL14047

EDT/ECN: 629063 UC: 721
Cost Center: 6N100 Charge Code: 110350/BA10
B&R Code: EW3130000 Total Pages: 70

Key Words:
Retrieval, mixer pump, sludge, fluffed sludge, fluffing factor, thermal analysis, GOTH_SNF, settling

Abstract: This document addresses the preferred combination of design and operational configurations to provide heat removal from high-level waste tanks during Phase 1 waste feed delivery to prevent the waste temperature from exceeding tank safety requirement limits. An interim decision for the preferred method to remove the heat from the high-level waste tanks during waste feed delivery operations is presented herein.

Release Approval 6/14/00 Date

DATE: HANFORD RELEASE
STA: 4 ID: 2
JUN 15 2000
Release Stamp

Approved For Public Release

RPP-4433
Revision 0

Alternatives Generation and Analysis for Heat Removal from High-Level Waste Tanks

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

CH2MHILL
Hanford Group, Inc.
Richland, Washington

Contractor for the U.S. Department of Energy
Office of River Protection under Contract DE-AC06-99RL14047

This report has been reproduced from the best available copy.
Available in paper copy and microfiche.

Available electronically at
http://www.doe.gov/bridge. Available for a processing fee to the U.S. Department of Energy and its contractors, in paper, from:
U.S. Department of Energy
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831-0062
phone: 865-576-8401
fax: 865-576-5728
email: reports@adonis.osti.gov(423) 576-8401

Available for sale to the public, in paper, from:
U.S. Department of Commerce
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Phone: 800-553-6847
fax: 703-605-6900
email: orders@ ntis.fedworld.gov
online ordering:
http://www.ntis.gov/ordering.htm

Printed in the United States of America

RPP-4433
Revision 0

Alternatives Generation and Analysis for Heat Removal from High-Level Waste Tanks

Prepared by:
W. L. Willis
Numatec Hanford Corporation
Richland, Washington

W. J. Millsap
J. B. Truitt
Fluor Hanford, Inc.
Richland, Washington

J. L. Poe
E2 Consulting Engineers, Inc.
Richland, Washington

Date Published
June 2000

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

CH2MHILL
Hanford Group, Inc.
P. O. Box 1500
Richland, Washington

Contractor for the U.S. Department of Energy
Office of River Protection under Contract DE-AC06-99RL14047

This page intentionally left blank.

EXECUTIVE SUMMARY

The Waste Feed Delivery Program plans to deliver high-level waste feed to a treatment facility for eventual conversion into an immobilized form (glass) appropriate for long-term storage. The high-level waste feed is currently stored underground in Tanks 241-AY-101, 241-AY-102, 241-AZ-101, and 241-AZ-102 or will be transferred into these tanks before delivery to the treatment facility.

The high-level waste consists of settled solids (also known as sludge) and supernatant liquid. Before retrieval for delivery to the treatment facility, the waste in the tanks will be mixed to mobilize and suspend the solids into the supernatant liquid. The mixing process heats the waste, causing the temperature to rise. If the mixed waste is allowed to resettle, the solids initially settle to a "fluffed" state from which they slowly compact to the premixed condition. This fluffed sludge slows the transfer of heat, causing higher temperatures within the sludge layer.

The technical safety requirement (HNF-SD-WM-TSR-006, Tank Waste Remediation System Technical Safety Requirements*) contains temperature limits imposed to avoid a tank bump accident. The technical safety requirement includes a safety limit (SL 2.1.1) for waste temperature and a related limiting condition of operation (LCO 3.3.2). The temperatures of the waste are currently within the technical safety requirement limits, but the concern is that temperature limits may be exceeded during waste-retrieval activities.*

This alternatives generation and analysis addresses the following question:

> *What is the preferred combination of design and operational configurations to provide heat removal from high-level waste tanks during Phase 1 feed delivery to prevent the waste temperature from exceeding tank safety requirement limits as specified in the technical safety requirements?*

Upon consideration of various alternatives, Retrieval Engineering's recommendation for the removal of heat from the aging-waste facility tanks during Phase 1 of waste feed delivery is to implement the following:

- *Primary Ventilation Systems*
  - *The minimum required once-through flow rate of noncooled air through the headspaces of Tanks 241-AY-101, 241-AY-102, 241-AZ-101, and 241-AZ-102 will be 0.24 m^3/s (500 ft^3/min) per tank when undergoing mixing and settling.*
  - *The primary ventilation systems—specifically, the equipment performing the heat-removal function—for each of the four high-level waste tanks will be assumed to be designated safety significant for the tank bump accident.*
- *Annulus (Secondary) Ventilation Systems*
  - *The minimum required once-through flow rate of noncooled air through the cooling channels (slots) of Tanks 241-AY-101, 241-AY-102, 241-AZ-101, and 241-AZ-102 is 0.40 m^3/s (850 ft^3/min) per tank; the nominal design flow rate is 0.47 m^3/s (1,000 ft^3/min).*
  - *The annulus ventilation systems—specifically, the equipment performing the heat-removal function—for each of the four high-level waste tanks will be assumed to be designated safety significant for the tank bump accident.*

This recommendation implies that these systems will eventually have to be designated safety significant for the tank bump accident.

Thermal analyses performed for this alternatives generation and analysis document demonstrate that the recommended alternative will ensure that the waste temperatures are within the technical safety requirement limits.

The following risks associated with the use of the ventilation systems for heat removal are identified:

- *Thermal analyses may estimate waste temperature inaccurately.*
  - *This risk is deemed to be acceptable. It is recommended that the apparent discrepancies between heat estimates for Tank 241-AY-102 are reconciled.*
- *The primary ventilation system is minimally adequate to process one tank at a time, which may introduce operational restrictions.*
  - *This risk is deemed to be acceptable. The ability to tolerate potential operational restrictions will be evaluated after the final decision has been made.*
- *Some of the slots in the insulating concrete through which the annulus ventilation airflow passes may be blocked, causing hot spots in the waste.*
  - *This risk is deemed to be acceptable. This issue will be considered during the amendment of the authorization basis.*
- *The buried AY Tank Farm ventilation piping was severely corroded and was replaced in the 1980s. The condition of the AZ Tank Farm piping is not known and may require replacement.*
  - *This risk is deemed to be acceptable. This issue will be addressed during system functionality verifications (walk downs) of AY and AZ Tank Farms.*
- *The allowable differential pressure in the ventilation systems for Tanks 241-AY-101, 241-AZ-101, and 241-AZ–102 has not been analyzed in detail. A flow rate through the annulus ventilation system of 0.47 m^3/s (1,000 ft^3/min) may not be possible without exceeding the differential pressure limits in these tanks.*
  - *This risk is deemed to be acceptable. Analyses performed for Tank 241-AY-102, which demonstrate capability to withstand the differential pressure necessary to*

support the higher flow rates, are applicable to the other tanks because of similarities in design.

- *There are several cross-ties between the primary and annulus ventilation systems that may allow contamination into the annulus if they fail when operated under high differential pressure. One example is the packing gland on the side-fill lines for the primary tank.*
  - *This risk is deemed to be acceptable. This issue will be addressed at a later time as an operational consideration during implementation.*
- *The implied constraint on tank contents imposed by the cases analyzed may limit operational flexibility. It is possible, but not likely, that this would impose limits on the amount of waste that could be staged in these tanks under future retrieval sequences and blending strategies.*
  - *This risk is deemed to be acceptable. The modeled cases were selected to bound the waste currently in the tanks and are expected to cover the most realistic retrieval sequences and blending strategies.*
- *It is not clear what flow rates can be realistically achieved in the annular slots with maintenance and minor modifications. The goal is to avoid unnecessary upgrades while ensuring adequate flow.*
  - *The fact that the Tank 241-AY-101 annulus ventilation system has previously achieved a flow of 0.47 m^3/s (1000 ft^3/min) has been considered in the evaluation. Although the AZ annulus ventilation system has not functioned for several years, it was designed to provide flow rates higher than the 0.47 m^3/s (1,000 ft^3/min). The AZ annulus ventilation system will need to be returned to operation, and the Tank 241-AY-101 ventilation ducting will probably need to be modified to route all annulus ventilation airflow to the tank bottom. No other upgrades are anticipated at this time.*

CONTENTS

APPENDIXES

FIGURES

TABLES

This page intentionally left blank.

TERMS

AGA	alternatives generation and analysis
ALC	airlift circulator
AWF	aging-waste facility
GOTH and GOTH_SNF	Versions of a general purpose thermal hydraulic computer program developed by John Marvin, Inc. (JMI)
HEPA	high-efficiency particulate air (filter)
HLW	high-level waste
JMI	John Marvin, Inc.
LCO	limiting condition for operation
PUREX	Plutonium Uranium Extraction (facility)
SL	safety limit
TSR	technical safety requirement (HNF-SD-WM-TSR-006)
WFD	waste feed delivery

GLOSSARY

Assumption	Interim guide imposed by the decision maker (e.g., performance characteristics of a process, circumstances under which the outcome of the decision will be implemented). The assumption is a credible, nonvalidated requirement or architecture selection. Assumptions are used to reduce extremely complex situations to problems of manageable proportion.
Best-Basis Inventory	Waste inventory, performed for each tank, based on best-available sampling data and historical information.
Compacted Sludge	Solids that have settled to the bottom of a waste tank over a long period of time and will not become more dense (more compact) with more time.
Constraint	An externally imposed restriction or requirement. Constraints are beyond the control of the manager/decision maker.
Fluff Factor	Ratio of the depth of fluffed sludge to the depth of the same sludge once fully compacted.

Fluffed Sludge	Solids that have settled to the bottom of a waste tank in a short period of time and that will continue to settle, becoming more compact, in a long period of time.
GOTH Computer Model	General purpose thermal hydraulic computer program developed by John Marvin, Inc. (JMI)
GOTH_SNF Computer Model	General purpose thermal hydraulic computer program developed by John Marvin, Inc. (JMI).
Interacting Decisions	Prior decision outcomes upon which the current decision depends or subsequent/parallel decisions that will be constrained by the decision outcome.
Quasi-settled State	State in which a waste tank contains fluffed sludge, solids that have settled to the bottom of the tank a short period of time and will continue to settle, becoming more compact, in a long period of time.
Requirement	How well products must perform in quantitative terms and the environment in which they must operate; the extent to which the mission or function must be executed.
Sludge	Solids that have settled to the bottom of a waste tank.
Supernatant Liquid	Clarified liquid that remains in the upper portion of a waste tank after the solids have settled to the bottom.
Treatment Facility	Facility at which waste is treated by separating radionuclides and immobilizing the waste for conversion into a form appropriate for long-term storage.

1.0 INTRODUCTION

1.1 PROBLEM STATEMENT

This alternatives generation and analysis (AGA) addresses the following question:

> What is the preferred combination of design and operational configurations to provide heat removal from high-level waste (HLW) tanks during Phase 1 feed delivery to prevent the waste temperature from exceeding tank safety requirement limits as specified in the technical safety requirements (TSR) (HNF-SD-WM-TSR-006, *Tank Waste Remediation System Technical Safety Requirements*)?

The temperature limits in the TSRs are imposed to avoid the tank bump accident, which may result in the release of radioactive material onsite. The TSR includes a safety limit (SL), SL 2.1.1, which states:

> "The WASTE temperature shall be ≤250°F."

The TSR also includes a related limiting condition of operation (LCO), LCO 3.3.2, which states:

> "The WASTE temperature shall be either:
> (1) ≤195 °F in all levels of the WASTE
> OR
> (2) ≤195 °F in the top 15 ft of the WASTE
> AND
> ≤215 °F in the WASTE below 15 ft."

The problem statement is confined by the boundaries presented in Section 1.2 of this AGA.

1.2 BOUNDARIES OF THE DECISION

This AGA addresses the heat-removal requirements associated with mixing and retrieving HLW during Phase 1 waste feed delivery (WFD). The four aging-waste facility (AWF) tanks—241-AY-101, 241-AY-102, 241-AZ-101, and 241-AZ-102—and the following wastes are being addressed:

1. Current contents of Tank 241-AZ-101
2. Current contents of Tank 241-AZ-102
3. Current contents of Tank 241-AY-102, including waste transferred during 1999
4. Future contents of Tank 241-AY-102 following receipt of wastes from Tank 241-C-102 or Tank 241-C-104.

The temperatures in the sludge layer of two of the tanks, 241-AY-102 and 241-AZ-102, are expected to be bounding after mixing and settling. The temperature in the sludge layer is a function of three variables of the layer: radiolytic heat generation, thickness, and thermal conductivity. Tank 241-AZ-101 has the highest heat-generation rate of any tank, approximately 79,400 W (271,000 Btu/h). However, thermal modeling predicts Tank 241-AZ-102, with a heat-generation rate of approximately 59,000 W (200,000 Btu/h), has a higher maximum temperature because of its deeper sludge layer. Tank 241-AY-102 is anticipated to have the thickest layer of sludge (3.7 *m to* 4.3 *m [*12 *ft to* 14 *ft] of fluffed sludge after mixing and resettling*) and a relatively high heat load (approximately 34,000 W [116,000 Btu/h]). The thickness of the mixed sludge layer has a very strong effect on the maximum temperature within the sludge. Therefore, most of the modeling effort was focused on the current contents of Tanks 241-AY-102 and 241-AZ-102, and the results are asserted to be bounding for all waste currently planned for retrieval and transfer to the treatment facility. It is important to note that it would be possible to combine the contents of tanks in ways that would result in higher bounding values.

The time period covered by this AGA is from the start of mobilization activities through the end of Phase 1. Tank 241-AZ-101 is the first tank of HLW scheduled for delivery to the treatment facility. Tank 241-AZ-102 is the second and Tank 241-AY-102 is the third tank of HLW scheduled for delivery to the treatment facility.

1.3 BACKGROUND OF THE DECISION

This section briefly describes the components of the AWF that are important to this decision, the waste properties that lead to excessive temperatures in the tanks, and the germane regulatory requirements.

1.3.1 Planned Sequence of Waste Retrieval

Waste retrieval will take place in two basic steps: (1) the waste will be mixed, sampled, and certified for delivery to the treatment facility; and (2) the waste will be sent to the treatment facility in batches of approximately *380* m^3 *(100,000* gal) each. Following certification sampling, the tank may remain idle for as long as a year or more before the waste is remixed for transfer to the treatment facility. During the interim, the waste may be allowed to resettle. The waste also may be allowed to resettle between the transfer of batches to the treatment facility. The temperature in the waste will rise during mixing because of the energy generated from the mixer pumps. It is anticipated that the maximum temperature in the tank will occur in the fluffed sludge that develops after mixing and resettling.

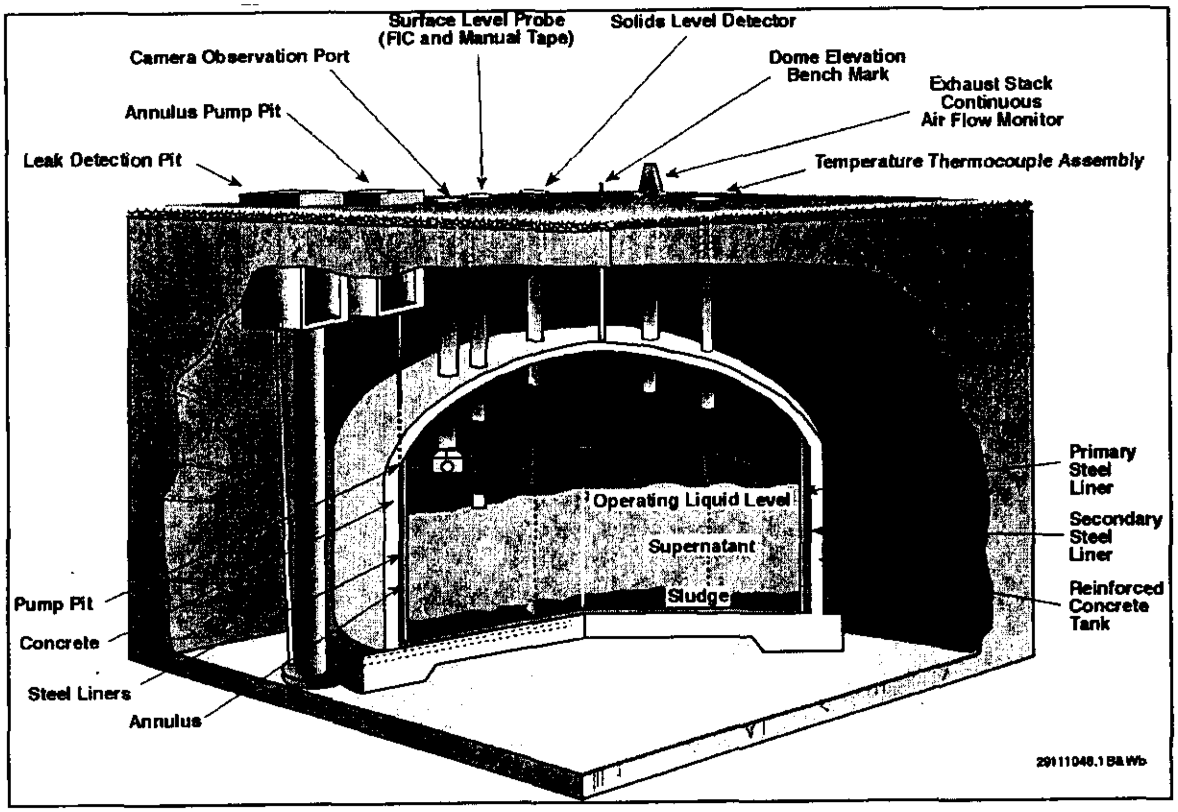
1.3.2 Aging-Waste Facility

The AWF comprises the four HLW tanks (241-AY-101, 241-AY-102, 241-AZ-101, and 241-AZ-102), the primary and annulus ventilation systems, the mixer pumps, the waste-transfer system (e.g, transfer pumps, piping, valve pits), and other systems. For the purposes of this AGA, only the tanks (including airlift circulators [ALC]), the ventilation systems, and the mixer pumps are addressed because the transfer system used does not directly affect waste cooling.

1.3.2.1 Description of High-Level Waste Tank

The HLW tanks consist of a concrete shell surrounding two carbon steel shells. There is an annulus region between the two steel shells. The innermost steel shell sits on a refractory concrete pad with a series of channels. The tanks have a domed top of concrete. A series of penetrations (known as risers) were constructed through the tops of the tanks. These risers are used to introduce the waste into the tanks and to place pumps (both mixer pumps and transfer pumps), temperature- and level-monitoring instrumentation, ALCs, and other equipment into the tank. A sketch of a HLW tank is shown in Figure 1-1.

Figure 1-1. Sketch of a High-Level Waste Tank.

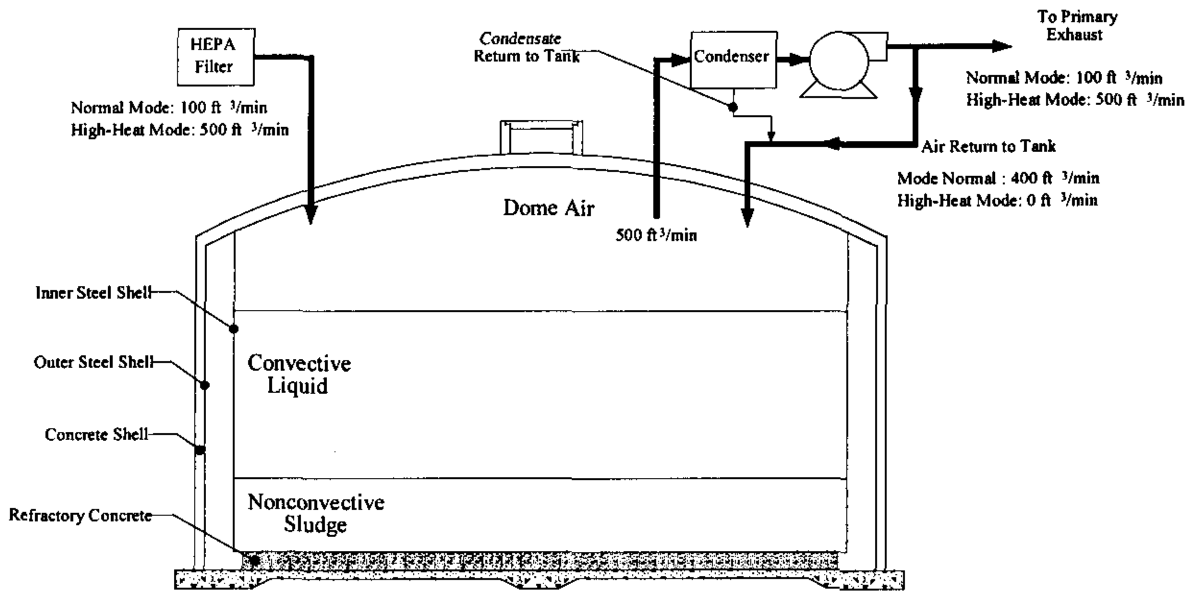


1.3.2.2 Primary Ventilation System

The primary ventilation system ventilates the dome space of the tanks. The primary ventilation system consists of inlet filters, condenser, and recirculation fans for each tank and combined condensers, blowers, and a single discharge stack for all four tanks. The air that passes through the inlet filters into the dome space is heated and humidified by contact with the upper surface of the waste. Heat is removed from the waste by heating the air and by evaporation from the waste surface. The heated air is drawn from the tank dome space into the condenser, where the air is cooled and some of the moisture is removed. The liquid removed from the air is returned to the tank. The air exiting the condenser is either reintroduced into the tank or discharged to the combined stack. The primary ventilation system has two operational modes: normal mode and high-heat mode. In normal mode, approximately 0.05 m^3/s (100 ft^3/min) of outside air is drawn into the tank dome space and 0.24 m^3/s (500 ft^3/min) of air is withdrawn from the tank. Of the 0.24 m^3/s (500 ft^3/min) drawn from the tank and passed through the condenser, 0.19 m^3/s (400 ft^3/min) is returned to the tank. The remaining 0.05 m^3/s (100 ft^3/min) is discharged through the common discharge stack after high-efficiency particulate air (HEPA) filtration. In high-heat mode, 0.24 m^3/s (500 ft^3/min) of outside air is drawn into the tank and 0.24 m^3/s (500 ft^3/min) of heated moist air is withdrawn from the tank into the condenser. From the condenser, all 0.24 m^3/s (500 ft^3/min) is discharged through the common stack.

The primary ventilation system is capable of removing at least 290,000 W (1,000,000 Btu/h) from each tank. The rate of heat removal from the tank is dependent on the ambient temperature and humidity of the inlet air and the temperature of the waste. The greater the difference between the temperature of the waste and the temperature of the inlet air, the greater the rate of heat removal. A sketch of the HLW primary ventilation system is shown in Figure 1-2.

Figure 1-2. Sketch of the High-Level Waste Primary Ventilation System.



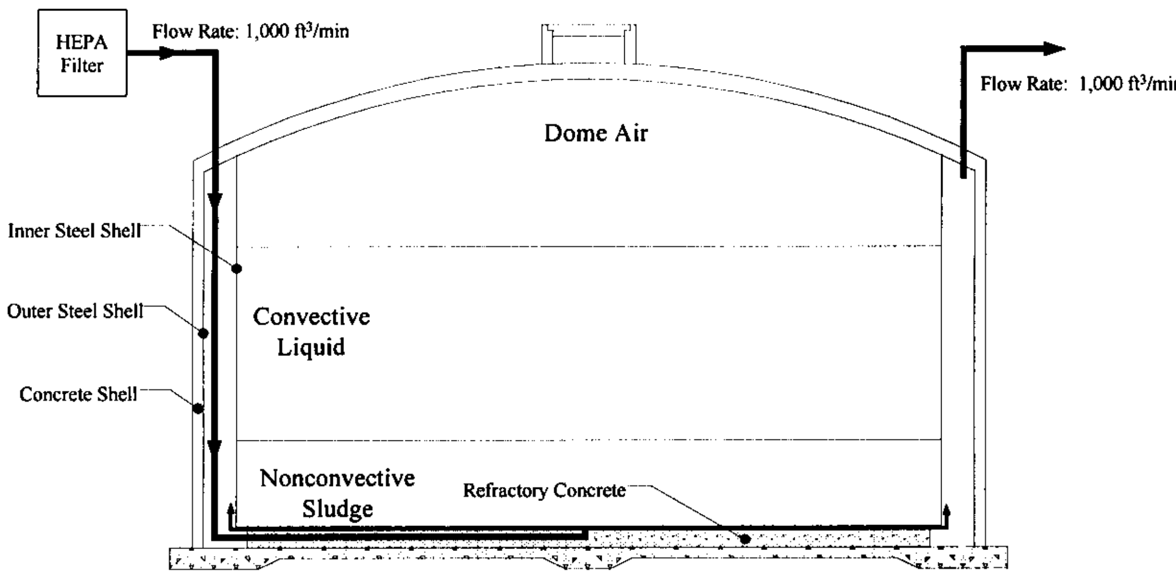
Note: Measurements were taken using the English unit ft ³/min. To convert to the metric unit m ³/s, multiply by 4.719 E-04.

HEPA = high-efficiency particulate air.

1.3.2.3 Annulus Ventilation System

The annulus ventilation system ventilates the annulus between the two steel shells. Outside air is drawn into the annulus through inlet filters, drawn from the annulus and passed through HEPA filters, and discharged. Each of the AY tanks has their own annulus ventilation system. The AZ tanks have a combined annulus ventilation system. The annulus ventilation system draws air through 150 mm (6-in.) lines into the mid-wall region of the tanks and through 100 mm (4-in.) lines to the center of the tank bottom in the refractory concrete. If the 150 mm (6-in.) lines remain open, most of the annulus ventilation flow is routed to the center of the tank wall and only a small percent goes to the tank bottom. There are valves in the AZ Tank Farm that allow the 150 mm (6-in.) lines to be closed. There are no such valves in the AY Tank Farm. The lines in Tank 241-AY-102 were excavated, and the 150 mm (6-in.) lines were plugged. In Tank 241-AY-101, the 150 mm (6-in.) lines remain open. If the flow is needed at the tank bottom, the 150 mm (6-in.) lines in Tank 241-AY-101 will need to be plugged. The air that passes through the annulus ventilation systems is heated, which removes heat from the waste. A sketch of an annulus ventilation system is shown in Figure 1-3.

Figure 1-3. Sketch of an Annulus Ventilation System.



Note: Measurements were taken using the English unit ft^3/min. To convert to the metric unit m^3/s, multiply by 4.719 E-04.

HEPA = high-efficiency particulate air.

1.3.2.4 Airlift Circulators

Each of the four AWF tanks contains 22 ALCs. An ALC consists of a 150 mm (6-in.) pipe open at both ends suspended vertically in the tanks. The bottom of the 150 mm (6-in.) pipe is suspended several inches above the tank floor. A smaller pipe (25 mm [1-in.]) is centered in the 150 mm (6-in.) pipe and carries air to near the bottom opening of the 150 mm (6-in.) pipe. A diffuser is located at the bottom of the 25 mm (1-in.) pipe to ensure that the air coming out of the 25 mm (1-in.) pipe is in small bubbles. The air bubbles from the diffuser rise through the 150 mm (6-in.) pipe, coalesce, and expand. The air motion through the 150 mm (6-in.) pipe carries liquid from the bottom of the tank and discharges the liquid from the top of the ALC. This circulation keeps the tank liquids mixed. This circulation is expected to be sufficient to prevent insoluble solids from resettling.

The 22 ALCs are spaced evenly throughout the tank: 1 in the center of the tank, 7 at a radius of 4.42 m (14.5 ft) from the center of the tank, and the remaining 14 at a radius of 8.2 m (27 ft) from the center of the tank. Of the 22 ALCs, 5 are 5.33 m (17.5 ft) long and the others are 6.71 m (22 ft) long. For the liquids (and potentially the solids) to be circulated, the top of the 150 mm (6-in.) pipe must be submerged in the liquid. The 5 shorter ALCs require a liquid depth of 594 cm (234 in.), which corresponds to a volume of approximately 2.44 mL (644,000 gal) of waste. The longer ALCs require a liquid depth of 749 cm (295 in.), which corresponds to a volume of approximately 3.067 mL (810,000 gal).

1.3.2.5 Mixer Pumps

Each of the AWF tanks will have mixer pumps installed. The purpose of the mixer pumps is to mobilize and suspend the solids into the liquid in the tanks so that the solids can be transferred to the treatment facility.

The mixer pumps are single-stage centrifugal pumps. Two sizes of mixer pumps are planned for the AWF tanks. Two 224 kW (300-hp) mixer pumps are planned for each of the AZ tanks, and four 112 kW (150-hp) pumps are planned for each AY tank. The 224 kW (300-hp) pumps have a maximum flow rate of approximately 0.63 m^3/s (10,000 gal/min), and the 112 kW (150-hp) pumps have a maximum flow rate of approximately 0.32 m^3/s (5,000 gal/min). The pump energy heats the waste in the tanks.

1.3.2.6 Transfer Pumps

Transfer pumps are planned for each of the four AWF tanks. The transfer pumps are multistage centrifugal pumps. For the purpose of this AGA, transfer pumps are important because current planning is for the tank wastes to be retrieved in several batches. As the batches are retrieved, the liquid level in the tank will drop.

1.3.3 *Waste Behavior*

The HLW tanks were used to receive first-cycle fuel reprocessing waste from the Plutonium Uranium Extraction (PUREX) plant. The waste originally contained high levels of fission products. In the years since reprocessing, the short-lived radionuclides have decayed into stable nuclides. Only the longer-lived radionuclides are left in the tank wastes. Some nuclides, most notably ^{137}Cs and ^{90}Sr, remain in relatively high concentrations and decay with sufficiently high particulate energy to release significant heat in the tank waste. The cesium is very soluble and is found predominantly in the liquid portion of the waste; the strontium is insoluble and is found predominantly in the settled sludge.

With the exception of Tank 241-AY-102, the waste in the AWF tanks has been in place for many years. The waste in Tank 241-AY-102 includes material sluiced from Tank 241-C-106 in calendar year 1999. After settling for a long period of time (years), the settled sludge becomes compacted; in other words, the depth of the bed of settled sludge will stop decreasing over time. However, when the solids are mobilized (through transfer as in the case of the sluicing of Tank 241-C-106 into Tank 241-AY-102 or through mixing) and then allowed to resettle, the depth of the initially settled sludge will be greater than the depth before mobilization. This phenomenon is referred to as fluffing of the sludge. After accounting for the soluble portion of the Tank 241-C-106 material, the solids transferred into Tank 241-AY-102 are thought to have settled initially to approximately twice the original depth in Tank 241-C-106. In other words, the sludge was fluffed to twice its original depth or experienced a fluff factor of two.

The peak temperature in the waste depends on the heat generation in the waste and on heat transfer through the waste. The heat generation in the waste is dependent on the radiolytic decay occurring in the waste and heat input from external sources (i.e., mixer pumps). One type of heat transfer, convection, occurs in the liquid portion of the waste. Another type of heat transfer, conduction, occurs in the sludge. Because of the nature of conduction, the deeper the sludge layer, the higher the maximum temperature that will occur for a given heat-generation rate. The consequence of fluffing of the sludge and conduction rather than convection occurring in the sludge is that the peak temperature in the sludge increases following mixing and resettling of the waste.

In the tank, the temperature is reasonably constant in the liquid layer. In the sludge layer, however, the temperature increases from the interface with the liquid to the center of the sludge layer, and then decreases from the center to the tank bottom. When mixing occurs, it is anticipated that the temperature of the entire tank contents will become uniform. Because mixing adds heat to the tank, the uniform temperature of the tank will increase during mixer pump operation. This temperature increase will continue until a steady state is reached where all of the heat generated in the tank is transferred to the surroundings. It is important to remember that heat transfer is a function of the temperature difference between the hot object and the surroundings. As the temperature of the waste increases, the heat-transfer rate also increases until the heat-transfer rate is equal to the heat-generation rate; at that point (known as steady state), the temperature will stop increasing.

Section 4.2 of this AGA addresses the approach and calculations used to determine the preferred ventilation requirements.

1.3.4 Regulatory Requirements

For this analysis, the primary regulatory requirement is the TSR to prevent the waste from reaching SL 2.1.1 and the related LCO 3.3.2. The TSR temperature limits are imposed to avoid the tank bump accident, which is assumed to occur when the waste reaches the saturation temperature. The LCO implies that the temperature of the waste while mixing must not exceed 90.6 °C (195 °F) and the peak sludge temperature must not exceed 102 °C (215 °F).

1.4 APPROACH USED TO MAKE THE DECISION

The development and assessment of alternatives was performed using the following steps:

1. *Initial alternatives developed.* Initial alternatives were developed by representatives from the Retrieval System Development, Projects, and Operations groups and by engineering consultants.

2. *Initial alternatives compared to requirements and constraints; and alternatives that fail removed.* The initial alternatives were screened, or tested, against the requirements and constraints. In this case, all alternatives except one were eliminated: the use of the

primary and annulus ventilation systems with the flow rates and potential cooling of the inlet air to be determined.

3. *Preferred specific case of the general alternative determined.* Various combinations of primary and annulus flow rates, as well as cooling the inlet air to the annulus ventilation system, were investigated. Preferred airflow rates were determined.

4. *Interim decision by senior review group.* A senior review group reviewed the preferred alternative and the risks associated with it. A consensus was reached on the preferred alternative for an interim decision. The review group determined that all but one risk were acceptable and, if that one was analyzed and determined to be acceptable, the interim decision would be adequate for a final decision.

5. *Preferred alternative evaluated against WFD fundamental objectives.* The preferred (interim) alternative was evaluated against the WFD fundamental objectives and found to be acceptable.

6. *Risks of the preferred alternative reviewed.* Programmatic and technical risks of the remaining alternative were assessed, and risk-handling actions were identified. The alternative was judged to have acceptable risk.

7. *Preferred (interim) alternative recommended as the final alternative.* The preferred (interim) alternative was recommended as the final alternative based on the evaluation and risk assessment.

8. *Other recommendations.* Some additional recommendations were made based on engineering judgment concerning issues raised during the course of the AGA.

1.5 INTERACTING DECISIONS AND ACTIVITIES

A number of activities and decisions may affect the outcome of the analysis presented in this AGA. The following decisions are under way or pending:

1. Tank 241-AZ-101 mixer pump test

   The outcome of the Tank 241-AZ-101 mixer pump test may be used to assess the degree of conservatism (or nonconservatism) in the modeling used for this AGA. This will be discussed further in the risk discussion in Section 7.0.

2. Any changes to the inventories of the four AWF tanks before retrieval of the waste currently in the tanks

   Strategies are being explored for early retrieval of waste from single-shell tanks. These strategies may include transferring the single-shell tank wastes into the four AWF tanks before the current waste in the AWF tanks is retrieved. Any addition of heat-generating waste or waste that increases the sludge depth may invalidate the results of this AGA.

2.0 ASSUMPTIONS, CONSTRAINTS, AND REQUIREMENTS

2.1 ASSUMPTIONS

The following assumptions are made for this analysis of alternatives:

1. The GOTH_SNF thermal modeling results accurately reflect the tank waste-temperature profiles under the conditions assumed in the model cases (RPP-5637, *Parametric Analyses of Heat Removal from High-Level Waste Tanks*).

2. The characterization of the tanks is sufficiently mature to provide an accurate understanding of the heat generation in any tank containing HLW feed. The tanks modeled in this AGA are bounding for the combination of sludge depth and heat generation on any single tank given that the characterization data are correct and mature.

3. Other than the current planning basis, no additional waste that would increase the heat generation or the sludge depth will be added to the AWF tanks before the retrieval of the waste currently in the tanks.

2.2 CONSTRAINTS

The only constraints that have been identified for this AGA are the TSR temperature limits SL 2.1.1 and LCO 3.3.2. These constraints are imposed to avoid the tank bump accident, which is asserted to occur at the saturation temperature.

2.3 REQUIREMENTS

The following are requirements for the HLW heat-removal decision that might distinguish between alternatives:

1. The primary ventilation system must maintain the tank dome pressure below atmospheric pressure.

2. The annulus ventilation system must operate within the tank pressure design limits.

3. The AY and AZ tank heat-removal systems must be capable of removing the bounding heat load and limiting the maximum temperature in the tank, including the temperature in the settled sludge.

4. An acceptable alternative must be capable of being made safety significant.

This page intentionally left blank.

3.0 DEVELOPMENT AND SCREENING OF ALTERNATIVES

3.1 DEVELOPMENT OF ALTERNATIVES

3.1.1 Alternative 1: Use the Primary and Annulus Ventilation Systems to Cool the Waste

3.1.1.1 Description

This alternative uses the existing primary and annulus ventilation systems (assuming that they are restored to functionality) or some easily attainable enhancement of these systems to provide the necessary cooling once the waste is mobilized and mixed by mixer pumps. The enhancements might be increased airflow over that originally planned, cooling of the air before it is introduced into either the primary or annulus ventilation system, or both.

3.1.1.2 Screening

Operation of the primary and annulus ventilation systems has been shown to satisfy all of the requirements and constraints listed in Section 2.0. Section 4.0 contains information on a previous study performed to determine flow rates and inlet temperatures of the ventilation systems necessary to keep the waste temperatures within the limits.

3.1.2 Alternative 2: Use the Airlift Circulators to Keep Solids in Suspension

3.1.2.1 Description

In this alternative, the ALCs are used to maintain solids in suspension following mobilization and mixing using the mixer pumps. Because the solids are not allowed to settle, the increased temperatures caused by fluffed sludge never occur. The primary and annulus ventilation systems are used to remove the heat resulting from mixer pump operations and radioactive decay. Mixer pump operation is not limited and can be used as needed to mobilize and initially mix the waste.

ALC operation provides agitation of the waste solution in the tanks. It is assumed that operation of the ALCs will be sufficient to maintain the solids in suspension following mobilization of the solids by the mixer pumps.

3.1.2.2 Screening

This alternative would keep the waste cool only as long as the tanks were two-thirds full because the ALCs must be submerged to function. When the waste volume in the tanks drops below 2.44 mL (644,000 gal), the ALCs would no longer be submerged. Because this would prevent the system from fulfilling its primary mission of delivering waste to the treatment facility, this alternative does not satisfy the constraints and requirements. Therefore, this alternative is dropped from further consideration.

3.1.3 Alternative 3: Use Heat Exchangers to Cool the Waste

3.1.3.1 Description

Case 1: In this alternative, a closed-loop heat exchanger is submerged into the tank waste and is operated in conjunction with the existing primary and annulus ventilation systems for heat removal. Mixer pumps can be used as needed to mobilize and mix the waste. The heat-exchanger system would be designed to remove all heat resulting from radioactive decay and pump operation.

Case 2: For this alternative, a closed-loop heat exchanger is incorporated as an integral part of the mixer pump. This type of heat exchanger takes a volume of waste from the mixer pump outlet and cools the waste with chilled fluid. The cooled waste is then returned to the tank. This equipment is operated in conjunction with the existing primary and annulus ventilation systems for heat removal. Mixer pumps can be used as needed to mobilize and mix the waste.

3.1.3.2 Screening

Any heat exchanger used to cool the waste would need to be installed through an existing riser. Because the thermal conductivity of the settled waste sludge is low, the largest possible heat exchanger installed through even the largest existing riser could only impact the temperature in a localized area. Such a configuration would not limit the overall peak temperature in the waste and does not meet the constraint identified in Section 2.2. Therefore, the heat exchanger identified in Case 1 is dropped from further consideration.

The heat exchanger described in Case 2 relies on mixer pump operation to cool the waste. The analysis (RPP-5637) shows that cooling is not required while the mixer pumps are operating. The heat exchanger is only operational when it is not needed. Therefore, the heat exchanger identified in Case 2 is dropped from further consideration.

3.1.4 Alternative 4: Use Mixer Pumps to Keep Solids in Suspension

3.1.4.1 Description

In this alternative, the mixer pumps are used to mobilize solids and are operated either continuously or intermittently to maintain solids in suspension. Because the solids are not allowed to settle, the increased temperatures caused by fluffed sludge never occur. The primary and annulus ventilation systems are used to remove the heat resulting from mixer pump operation and radioactive decay.

3.1.4.2 Screening

To make these pumps safety significant—which would be the case if they were the primary means of controlling waste temperature—it would be necessary to show that they could be replaced before the waste exceeds the SL 2.1.1 temperature limit. The estimated time to reach the temperature limit after cooling is lost is 60 days in Tank 241-AY-102 and 48 days in Tank 241-AZ-102. The best-estimated time to replace a mixer pump is approximately 70 days. Therefore, it is very unlikely that the pumps could be replaced before the waste exceeds the temperature limit, and this alternative is removed from further consideration.

3.1.5 Alternative 5: Delay Decision Pending the Tank 241-AZ-101 Mixer Pump Test

3.1.5.1 Description

This alternative delays any decision on HLW heat removal until the Tank 241-AZ-101 mixer pump test is conducted. This test will provide another test of the GOTH_SNF model, including some potential insights into settling and fluff factors and the extent of mobilization, suspension, and waste pumpability.

3.1.5.2 Screening

This delay is not necessary. Although the mixer pump test should be modeled, the model was validated sufficiently. This alternative is removed from further consideration.

3.1.6 Alternative 6: Alter the Technical Safety Requirement and Limiting Conditions of Operation Requirements

3.1.6.1 Description

This alternative proposes to raise the TSR temperature limit and the associated LCOs so that the temperatures in the waste would be essentially unconstrained by these limits. The present TSR temperature limit is intended to be below the waste saturation temperature (to avoid the tank bump accident), and the LCO is 102 °C (215 °F) in the settled sludge.

3.1.6.2 Screening

The saturation temperature in the sludge in Tank 241-AY-102 is calculated to be 117 °C (243 °F), and the saturation temperature in the sludge in Tank 241-AZ-102 is calculated to be 123 °C (254 °F). Once mixed and resettled, the sludge would reach these temperatures without active cooling. The Nuclear Safety and Licensing group has concluded that it would be impractical to seek relief from the requirement to prevent the waste from reaching the saturation temperature. Therefore, this alternative is removed from further consideration.

3.2 DESCRIPTION OF THE ALTERNATIVE MEETING THE CONSTRAINTS AND REQUIREMENTS: COMBINATION OF PRIMARY AND ANNULUS VENTILATION

As discussed in Section 3.1, only one alternative was determined to be acceptable: use the existing (after they have been restored to functionality) primary and annulus ventilation systems or some readily attainable enhancement of these systems to cool the waste. The basic options that could be used to improve the heat-removal capability of these systems are to increase the airflow rate, to cool the air being introduced into the systems, or both.

Section 4.0 addresses the preferred airflow rates and air temperatures for use in this alternative.

4.0 THERMAL ANALYSES OF VENTILATION SYSTEMS

The thermal analyses proceeded in two steps. The first step included preliminary modeling documented in HNF-5386, *Thermal Hydraulic Analysis of High-Level Waste Tanks for Phase 1 Waste Feed Delivery,* that showed that the primary and annulus ventilation systems could control the sludge temperature in the bounding cases. The preliminary modeling indicated that the annulus ventilation systems would require upgrades to provide flow rates of 0.83 m^3/s (1,750 ft^3/min) at an inlet temperature of 4.4 °C (40 °F) to limit the bounding waste temperature to within the LCO 3.3.2 limits.

The second step included more refined calculations in a parametric analysis and related work, as documented in RPP-5637. These calculations were performed to validate the input parameters and results of the preliminary calculations and to better define flow rates and inlet temperatures needed to prevent the peak waste temperatures from exceeding the LCO 3.3.2 limits.

4.1 PRELIMINARY MODELING ACTIVITIES (HNF-5386)

4.1.1 Approach Used

The GOTH computer code (an earlier version of GOTH_SNF) was used to calculate the supernatant liquid and fluffed sludge temperature after 5 days of full-power mixing with two 224 kW (300-hp) mixer pumps. The fluffed sludge depth was assumed to be twice the original fully compacted sludge depth (i.e., a fluff factor of 2 was used).

4.1.2 Thermal Source Term and Bounding Tank

The bounding (most severe) thermal conditions were assumed to be the contents of Tank 241-AY-102 with all the contents of Tank 241-C-106 added. This resulted in the most restrictive combination of heat generation and sludge depth expected based on MacLean (1998).

The thermal source term used comprised two parts: heat resulting from the mixer pumps and heat resulting from radioactive decay of ^{137}Cs and ^{90}Sr. The mixer pump heat was that resulting from 5 days of full-power operation of two 224 kW (300-hp) pumps. The radioactive decay heat source term was the ^{137}Cs and ^{90}Sr inventories of Tanks 241-AY-102 and 241-C-106 as determined by MacLean (1998).

4.1.3 Results

The calculations showed that the peak temperature in the fluffed sludge would be 101 °C (213 °F), with the primary ventilation systems running at 0.24 m^3/s (500 ft^3/min) in the once-through mode and the annulus system running at 0.83 m^3/s (1,750 ft^3/min) with the inlet air cooled to 4.4 °C (40 °F). Because these results demonstrated that it would be practical to cool the fluffed sludge with the ventilation systems, it was decided to proceed with more refined calculations and a parametric analysis to determine exact flow rates.

4.2 REFINED MODELING ACTIVITIES (RPP-5637)

After demonstrating that the fluffed sludge could be adequately cooled using the primary and annulus ventilation systems, a more refined and more carefully documented set of calculations were performed to determine the preferred ventilation requirements.

The refined thermal analyses proceeded in three main steps:

1. Parametric analyses.

   John Marvin Inc. (JMI) performed the parametric analysis by modeling the tank with GOTH_SNF, a general purpose, thermal-hydraulics computer program. GOTH_SNF was used for the parametric analyses because it is well developed and is an accepted method for performing thermal analyses of tank wastes. The code meets Hanford Site quality assurance requirements and has been used for safety analysis calculations. This code, if properly used, gives the most defensible results of all approaches.

   Once the model was developed, parameters were changed to determine the temperature response under various conditions. Specifically, the flow rate and inlet temperatures of the primary and annulus ventilation systems were changed. The details of the modeling are documented in RPP-5637.

2. Estimates of conservatisms and uncertainties in the model analyses.

   The GOTH_SNF model runs demonstrated that the use of the primary and annulus ventilation systems at or below their expected flow rates (with ambient air) would keep the resettled sludge temperature below 121 °C (250 °F). Therefore, SL 2.1.1 was satisfied. The peak waste temperature for the resettled sludge in Tank 241-AY-102 was demonstrated to be below the 102 °C (215 °F) LCO 3.3.2 limit by 1.7 °C (3 °F). However, the modeling predicted that, with the expected flow rates of ambient air in the primary and annulus ventilation systems, the peak waste temperature in Tank 241-AZ-102 would exceed the LCO 3.3.2 limit by 7.2 °C (13 °F).

   Given these nearly satisfactory results, the analysts concluded that, in all likelihood, there was sufficient conservatism in the model to account for the excesses in Tank 241-AZ-102 and that the actual peak temperatures would likely be less than the LCO. To investigate this, the conservatisms and uncertainties in the code were estimated and their likely effects on peak temperatures were evaluated.

The assessment of conservatisms and uncertainties demonstrated that peak waste temperatures are anticipated to be less than the LCO 3.3.2 limits given a primary ventilation system flow rate of 0.24 m^3/s (500 ft^3/min) and an annulus ventilation system flow rate of 0.47 m^3/s (1,000 ft^3/min).

3. Linear extrapolations of the final values.

   Although the annulus systems are expected to have a flow rate of 0.47 m^3/s (1,000 ft^3/min), the flow rate sometimes drops below 0.47 m^3/s (1,000 ft^3/min) because of flow interference such as filter loading. Therefore, estimates had to be made of whether the peak waste temperature would be unacceptably high if the annulus flow rates were reduced to 0.40 m^3/s (850 ft^3/min). These estimates indicated that the reduction in annulus flow rate from 0.47 m^3/s (1,000 ft^3/min) to 0.40 m^3/s (850 ft^3/min) likely would have only a small effect (a degree or two) on the peak waste temperature and were, therefore, acceptable.

4.2.1 Parametric Analyses

4.2.1.1 Approach Used

HLW passes through four states during mixing and settling. These states are illustrated in Figure 4-1. Figure 4-2 illustrates the temperatures of the waste as a function of time during mixing and settling of the HLW. Each of the four states identified in Figure 4-1 is discussed below, with references given to the corresponding temperature-versus-time locations given in Figure 4-2.

State 1. Initial Fully Settled State

In the analyses, the waste is assumed to be fully settled with the sludge compacted and the supernatant liquid clarified. The temperature in the supernatant liquid is T1, and the peak temperature in the compacted sludge is T2. The temperature in the supernatant liquid is nearly uniform throughout the depth and will be lower than the peak temperature in the compacted sludge. Both the primary and annulus ventilation systems are running; the primary system is running in the once-through mode, and the annulus system is running with all flow going through the slots (see State 1 in Figure 4-1 and the portion labeled "Before Mixing" in Figure 4-2).

State 2. Fully Mixed State

When the mixer pumps are turned on, solids and supernatant liquid start to mix (shown as T3 on Figure 4-2). The temperature of the waste rises during mixing because of the energy generated from the mixer pumps, which are modeled to have a total power of 448 kW (600 hp). Because the time required to mix the waste is not known, the mixer pumps are operated until the waste temperature approaches steady state with the ventilation system and the tank surroundings. This temperature is shown as T4 in State 2 on Figure 4-1 and the portion labeled "During Mixing" on Figure 4-2.

Figure 4-1. States of High-Level Waste During Mixing and Settling.

This graphic illustrates the four states through which the high-level waste passes during mixing and settling. T1, T2, T4, T5, and T6 illustrate the locations in the waste where the temperatures shown in Figure 4-2 will occur.

State 1
Initial Fully Settled State

Before mixing, and after long-term settling, the sludge is fully compacted.

State 2
Fully Mixed State

At the end of mixing, the supernatant liquid and sludge are fully mixed. The temperature increased as a result of the heat added during mixing.

State 3
Quasi-Settled (Fluffed) State

After the waste is mixed and the pumps are turned off, the solids settle to a fluffed sludge relatively quickly. The temperature in the sludge is higher than in the compacted sludge in State 1.

State 4
Fully Settled State

After long-term settling, the tank returns to its initial fully settled state. This state is the same as State 1.

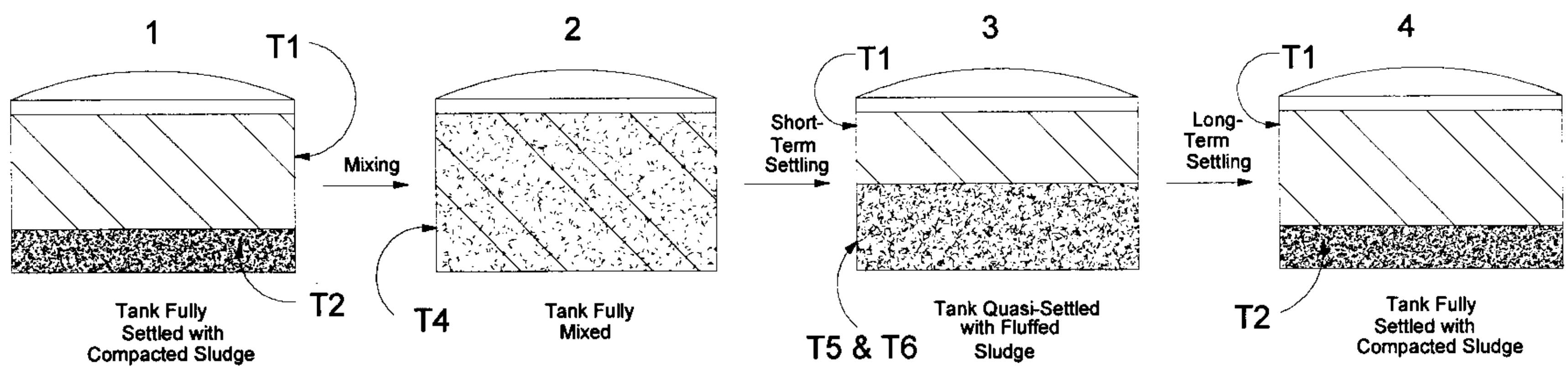
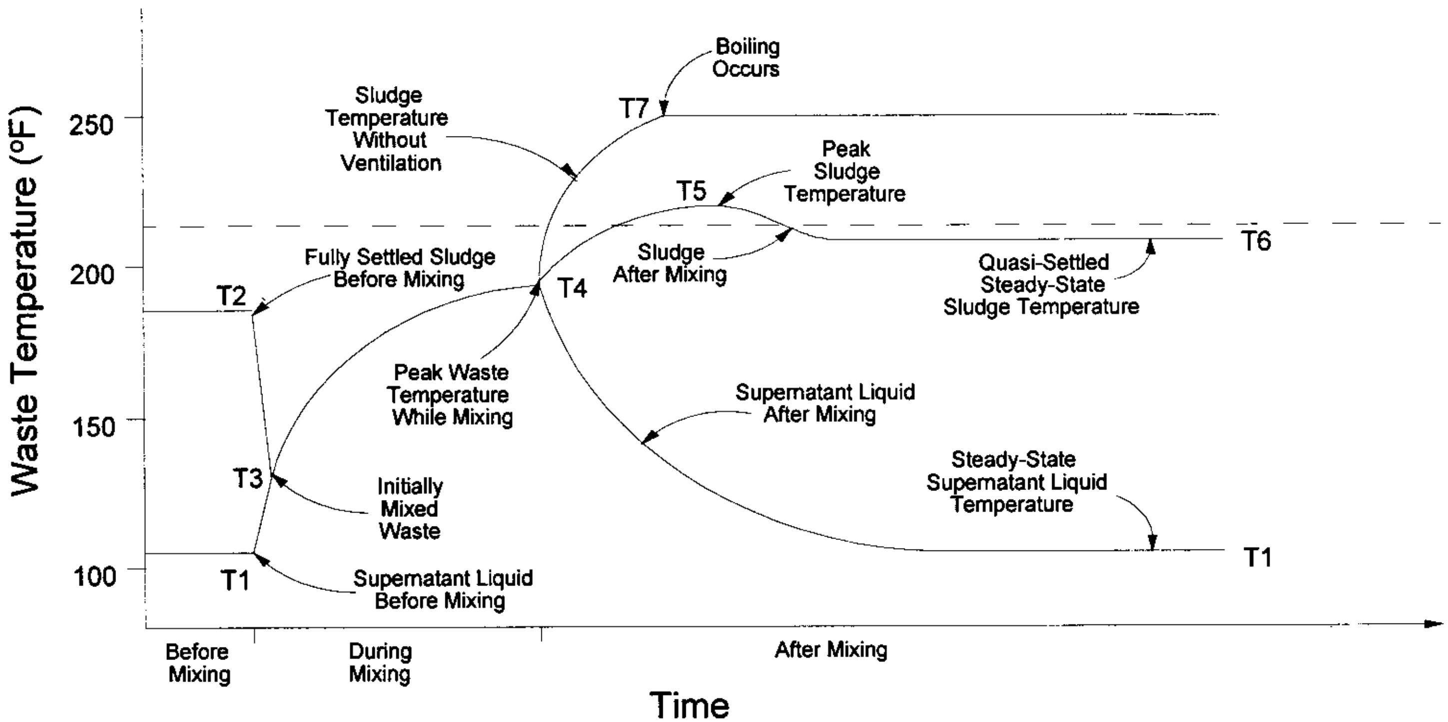


Figure 4-2. Waste Temperature vs. Time During Mixing and Settling of High-Level Waste.



This figure illustrates the temperatures in the high-level waste before, during, and after mixing.
Primary and annular ventilation systems are operating, except as noted.

Temperatures are noted as follows:

T1 = supernatant liquid temperature before mixing and after settling.
T2 = fully settled sludge temperature before mixing.
T3 = initial temperature of waste after mixing has started.
T4 = steady-state temperature with mixer pumps on.
T5 = peak sludge temperature after initial settling.
T6 = quasi-settled (fluffed) sludge temperature.
T7 = peak temperature reached in sludge with no ventilation.

Note: Measurements were taken in °F. To convert to °C, use the following equation: °C = (°F – 32)/1.8.

State 3. Quasi-settled (Fluffed) State

When the mixing is complete, the pumps are turned off (the ventilation systems continue to run) and the solids are allowed to resettle. However, the solids do not immediately settle to fully compacted state, but pass through a rapid initial settling followed by a slow compaction. Following the initial settling, the sludge is often referred to as being "fluffed," because the sludge then is less dense and deeper. The ratio of the depth of the fluffed sludge to the depth of the fully compacted sludge is called the fluff factor. The temperature in fluffed sludge rises to a higher level than in fully compacted sludge because temperature in the sludge is a function of both the energy being released into the sludge (in this case from radioactive decay) and the depth of the sludge. Because the fluffed sludge is deeper, the temperature in the center of the sludge exceeds that in the center of the compacted sludge. This is illustrated in Figure 4-1 as State 3 "Quasi-settled (Fluffed) State"; note that the depth of the sludge in State 3 is shown to be greater than the depth on State 1. In Figure 4-2, this part of the process is called "After Mixing." The temperature of the supernatant liquid drops reasonably rapidly to its premixed value (T1) because the supernatant liquid is being cooled by the primary ventilation system and there is little change in its nature. The temperature of the sludge, however, continues to climb until the pump heat has been dissipated by the ventilation systems (T5) and then slowly settles to a near steady state (T6) as the sludge settles to the fluffed condition. The steady-state temperature is entirely the result of radioactive decay because all pump heat has been dissipated. The temperatures T5 and T6 are greater than the temperature T2.

State 4. Fully Settled State.

Left alone for a long enough period of time, the sludge will return to its fully compacted state; illustrated as State 4 in Figure 4-1. The temperature in the compacted sludge then would be something very close to the original premixed temperature (the only difference would be a result of the decay of the radioactive material in the sludge). The fully settled state is not illustrated in Figure 4-2.

4.2.1.2 Results

The results obtained from the GOTH_SNF calculations are shown in Table 4-1 and are discussed below.

1. For Tank 241-AY-102, the first calculation for 0.24 m^3/s (500 ft^3/min) once-through primary flow rate and 0.47 m^3/s (1,000 ft^3/min) annulus flow of ambient air through the slots resulted in peak and resettled steady-state temperatures of 100 °C (212 °F). This satisfies the requirement to be less than the LCO limit of 102 °C (215 °F). This value, therefore, is acceptable. The results are shown in Case 1 in Table 4-1.

Table 4-1. Predicted Waste Temperatures under Various Conditions of Ventilation.

Bounding Case (No.) Tank	Ventilation System	Assumed Flow, m^3/s (ft^3/min)	Air Inlet Temperature, °C (°F)	Predicted Waste Temperature, °C (°F)			Boiling Point, °C (°F)
				Peak (GOTH_SNF)	Quasi-settled Steady state (GOTH_SNF)	Peak (Consensus Estimate)	
(1) 241-AY-102	Primary	0.24 (500)	Ambient	100 (212)	100 (212)	36 (97)	117 (243)
	Annulus	0.47 (1,000)	Ambient				
(2) 241-AZ-102	Primary	0.24 (500)	Ambient	109 (228)	108 (226)	99 (211)	123 (254)
	Annulus	0.47 (1,000)	Ambient				
(3) 241-AZ-102	Primary	0.24 (500)	Ambient	105 (221)	101 (214)	--	123 (254)
	Annulus	0.47 (1,000)	4.44 (40) (Chiller)				
(4) 241-AZ-102	Primary	0.24 (500)	Ambient	105 (221)	103 (217)	--	
	Annulus	0.94 (2,000)	Ambient				
(5) 241-AZ-102	Primary	0.24 (500)	Ambient	101 (214)	92.0 (197)	--	
	Annulus	0.94 (2,000)	4.44 (40) (Chiller)				
Bounding Case (No.) Tank	Ventilation System	Air Flow, m^3/s (ft^3/min)	Inlet Air Temperature, °C (°F)	Peak Temperature Estimate by Linear Extrapolation, °C (°F)			
(6) 241-AY-102	Primary	0.24 (500)	Ambient	92.0 (198)			
	Annulus	0.41 (850)	Ambient				
(7) 241-AZ-102	Primary	0.24 (500)	Ambient	100 (212)			
	Annulus	0.41 (850)	Ambient				

2. The first three efforts to find a combination of ventilation requirements for Tank 241-AZ-102 that would keep the peak and quasi-settled steady-state temperatures below the LCO (102 °C [215 °F]) failed. These results are shown in Cases 2, 3, and 4 in Table 4-1. The LCO temperature value for the peak and/or quasi-settled steady-state values were not met using 0.47 m^3/s (1,000 ft^3/min) of air chilled to 4.44 °C (40 °F) or using 0.94 m^3/s (2,000 ft^3/min) of ambient air. As seen in Case 5 in Table 4-1, 0.24 m^3/s (500 ft^3/min) ambient primary cooling and 0.94 m^3/s (2,000 ft^3/min) 4.4 °C (40 °F) airflow through the annulus slots were required to keep the peak value to 101 °C (214 °F), just below the 102 °C (215 °F) LCO limit.

4.2.2 Assessment of Conservatisms and Uncertainties

4.2.2.1 Motivation to Assess Conservatisms and Uncertainties

The peak and steady-state waste temperature for the case representing the existing ventilation system for Tank 241-AZ-102 (primary system at 0.24 m^3/s (500 ft^3/min), annulus system at 0.47 m^3/s (1,000 ft^3/min) ambient inlet air temperature) are only a few percent above the limit of 102 °C (215 °F). The analysts concluded that it was highly likely that the calculations would show peak and steady-state temperatures below 102 °C (215 °F) if some of the known conservatisms were removed.

The conservative character of results shown in Table 4-1 is illustrated by the GOTH model benchmark analysis for Tank 241-AY-102 (RPP-5637, Appendix D). As an example, the calculated-versus-measured waste temperatures in the sludge at a point near the bottom of the tank are shown in Figure 4-3. The calculated temperature was approximately 13 °C (24 °F) greater than the measured temperature plus three standard deviations of the measured temperature. Thus, this analysis demonstrates that the calculations performed for Tank 241-AY-102 were conservative. Because similar conservative assumptions were used in the analyses for this study, the results were expected to be conservative.

4.2.2.2 Approach Used

The approach used to assess the conservatisms and uncertainties in the calculations was simple and comprises the following steps:

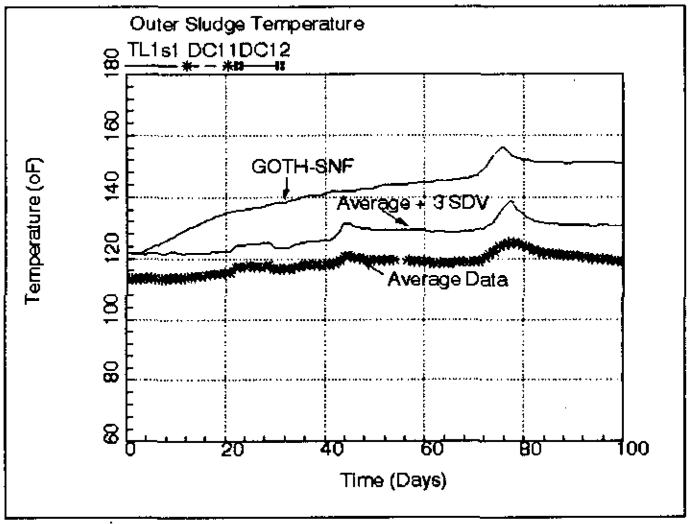
1. Determine the conservative elements that have a significant effect on the peak waste temperature as calculated by the GOTH_SNF code.

2. Determine the elements that have significant uncertainty.

3. Estimate the reductions in peak temperature that would occur if the conservative elements were removed from the calculation.

4. Estimate the uncertainty for each of the elements in the GOTH_SNF calculations.

Figure 4-3. Calculated-Versus-Measured Waste Temperatures in the Sludge at a Point Near the Bottom of the Tank.



NOTE: Measurements were taken in °F. To convert to °C, use the following equation: °C = (°F - 32)/1.8.

GOTH_SNF = general purpose thermal hydraulic computer program.
SDV = standard deviation.

5. Obtain the best-estimate peak waste temperature by removing the estimated reductions in peak temperature determined by Step 3.

6. Combine the uncertainty for each conservative element to obtain the total uncertainty in the GOTH_SNF calculations.

7. Determine the maximum expected peak waste temperature by adding the total uncertainty to the best-estimate peak waste temperature.

A group[1] of individuals who are familiar with the waste and the GOTH_SNF code determined the conservatisms and uncertainties in the GOTH_SNF calculations. The group reached consensus on the values of the conservatisms and uncertainties used.

[1] The group comprised the following members:

Mr. Marvin J. Thurgood —Mr. Thurgood is the lead thermal hydraulic analyst for the HLW tank thermal analyses. He is the author of the GOTH, COBRA_TRAC, and COBRA-TFS computer codes, which are applied nationally and internationally to perform thermal-hydraulic nuclear reactor safety analyses. Mr. Thurgood has 27 yr of thermal analysis experience.

Mr. Blaine A. Crea—Mr. Crea, the independent reviewer for HLW tank thermal analyses, has 25 yr of thermal analysis experience. He has performed numerous thermal analyses for various Hanford Site waste tanks.

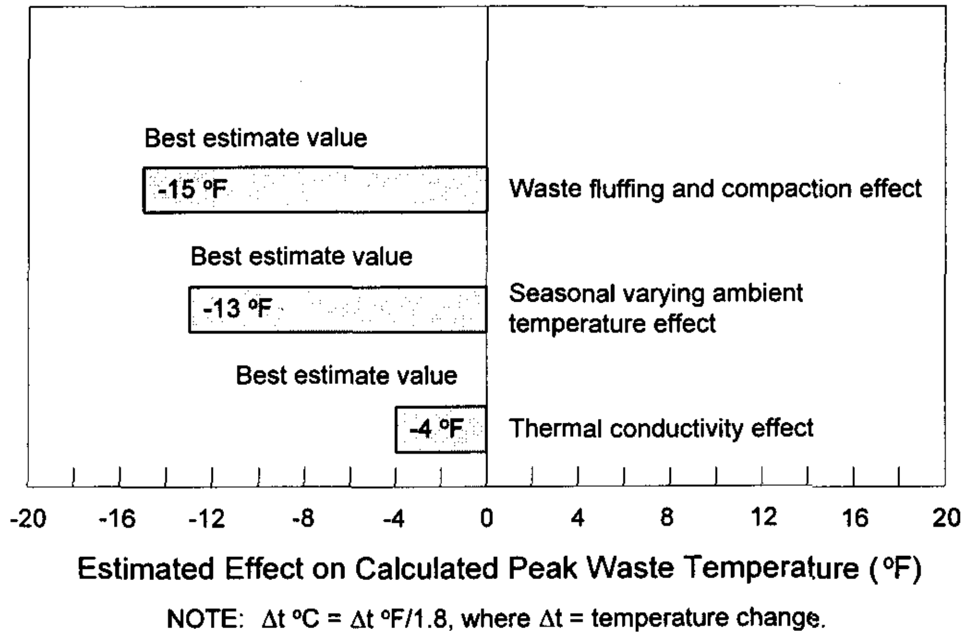
Mr. William J. Millsap—Mr. Millsap oversaw this decision process for Retrieval Engineering. He has 25 yr of experience in various aspects of nuclear safety.

Mr. James B. Truitt—Mr. Truitt, the lead engineer for the HLW tanks thermal analyses and the associated AGA when this work was done, has 33 yr of experience in engineering analysis. Mr. Truitt has been associated with several tank analyses that involved significant thermal analysis.

4.2.2.3 Method to Assess Conservatism

The group identified the three conservative elements that have the greatest effects on the peak waste temperatures calculated by the GOTH_SNF computer code: (1) waste fluffing and long-term compaction, (2) cooling air inlet temperature, and (3) the model for thermal conductivity. The group estimated the magnitude of these conservatisms and the reductions in peak temperature that would occur if these conservatisms were removed from the calculation. These conservatisms and their effects on peak temperature are illustrated in Figure 4-4.

Figure 4-4. Conservatisms and their Effects on Peak Temperature.



The greatest conservative element in the GOTH analysis is waste fluffing and long-term compaction. The best-estimate temperature change associated with this effect for Tank 241-AZ-102 was -8.3 °C (-15 °F). The sludge fluffing and long-term compaction effect was not an issue for Tank 241-AY-102 because sludge fluffing and settling measurements were available.

The second greatest conservative element in the GOTH analysis is the value of ambient temperature used in the analysis. The ambient temperature was set at a constant 28 °C (82 °F) — the average temperature for the hottest week of the hottest year on record. In effect, the constant ambient temperature is equivalent to maintaining the waste tanks in a perpetual summer environment. The best-estimate temperature change associated with introducing a seasonal varying ambient temperature was -7.2 °C (-13 °F). This effect was applicable to both Tank 241-AY-102 and Tank 241-AZ-102.

The third most significant conservative element in the GOTH analysis is the thermal conductivity model used in the analysis. The best-estimate temperature change resulting from the thermal conductivity model was -2.2 °C (-4 °F). This assessment was applicable to both Tank 241-AY-102 and Tank 241-AZ-102.

The best estimates of the effects for each of the remaining input parameters were considerably less than the effect resulting from thermal conductivity and were neglected in this estimate.

4.2.2.4 Method to Assess Uncertainty

The group estimated the uncertainties for two of the conservative input parameters that significantly affected the GOTH calculations: (1) waste fluffing and long-term compaction and (2) thermal conductivity parameters. No uncertainty was attributed to the ambient temperature effect. The group qualitatively determined the uncertainty and provided a consensus of the value for each element. Their consensus of the uncertainty of the element on the peak waste temperature was that it is no greater than 50% of the total conservative effect. Accordingly, the elemental uncertainty on the peak waste temperature resulting from waste fluffing and long-term compaction is 4.2 °C (7.5 °F);[2] the elemental uncertainty resulting from waste thermal conductivity is 1.1 °C(2 °F).

The group also estimated a minimum uncertainty on the magnitude of the radioactive decay heat rate in Tank 241-AZ-102 at 10%. The consensus was that the uncertainty in the radioactive decay heat rate on the peak waste temperature was no greater than 6.7 °C (12 °F).

The total uncertainty in the GOTH calculations was obtained by combining the elemental uncertainties. The group agreed that the total uncertainty would be adequately estimated by using the square root of the sum of the squares of the elemental uncertainties, a commonly used technique. Accordingly, the total uncertainty on the peak waste temperature in Tank 241-AZ-102 was 7.98 °C (14.29 °F) $\{[(1.1\ °C)^2 + (4.2\ °C)^2 + (6.7\ °C)^2]^{1/2}$ or $[(2\ °F)^2 + (7.5\ °F)^2 + (12°F)^2]^{1/2}\}$. For Tank 241-AY-102, the total uncertainty was 1.1 °C (2 °F) $\{[(1.1\ °C)^2]^{1/2}$).or $[(2\ °F)^2]^{1/2}\}$.

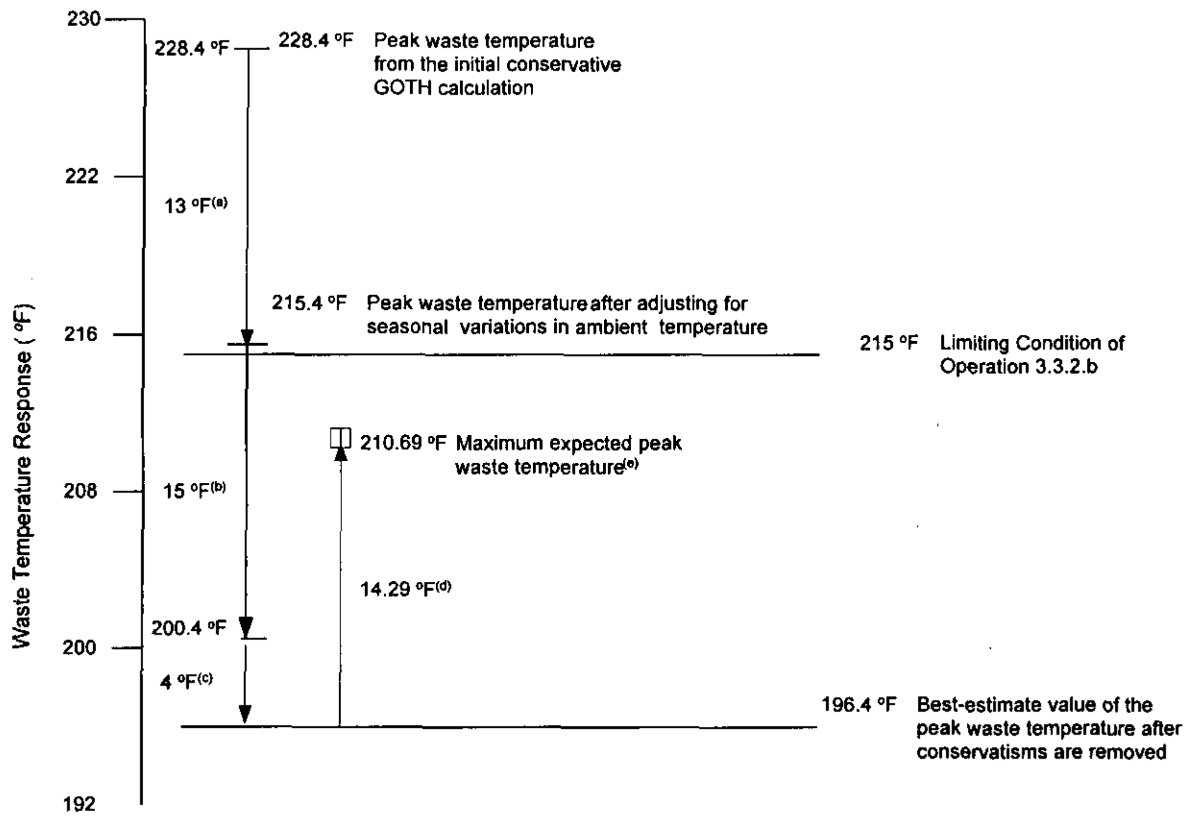
4.2.2.5 Results of the Assessment of Conservatisms and Uncertainties in the GOTH_SNF Calculations

The maximum expected peak waste temperatures were determined for Tank 241-AY-102 and Tank 241-AZ-102 by removing the conservative elemental effects identified in Section 4.2.2.3 and by adding the total uncertainties that are shown in Section 4.2.2.4.

For Tank 241-AZ-102, the maximum expected peak waste temperature was estimated to be 99.3 °C (210.69 °F), which is the high end of the expected range of 91.3 °C ± 7.98 °C (196.4°F ± 14.29°F). As illustrated in Figure 4-5, the conservative effects were removed to obtain the best-estimate peak waste temperature (91.3 °C [196.4 °F]), and the total uncertainty (7.98 °C [14.29 °F]) was added to obtain the maximum expected peak waste temperature (99.3 °C [210.69 °F]).

[2] The number of significant figures shown in this report is provided to clarify the calculations (i.e., to enable the reader to follow the calculation process). Final results include a statement of accuracy.

Figure 4-5. Schematic Showing the Calculation Used to Determine the Maximum Expected Peak Waste Temperature in High-Level Waste Tank 241-AZ-102.



NOTE: Δt °C = Δt °F/1.8, where Δt = temperature change.

(a) Conservatism Due to Constant Ambient Temperature: Estimate of the adjustment to the initial conservative GOTH calculation to account for seasonal variations in ambient temperature.

(b) Conservatism Due to Constant Fluffing Factor: Estimate of the reduction in the initial conservative GOTH calculation (which applied a constant fluffing factor) that is attributable to the application of a variable fluffing factor that characterizes the combined effect of fluffing and post-settling compaction. The estimate of the uncertainty associated with this effect is that the uncertainty is not more than one-half of the effect (e.g., 1/2 x 15°F = 75 °F).

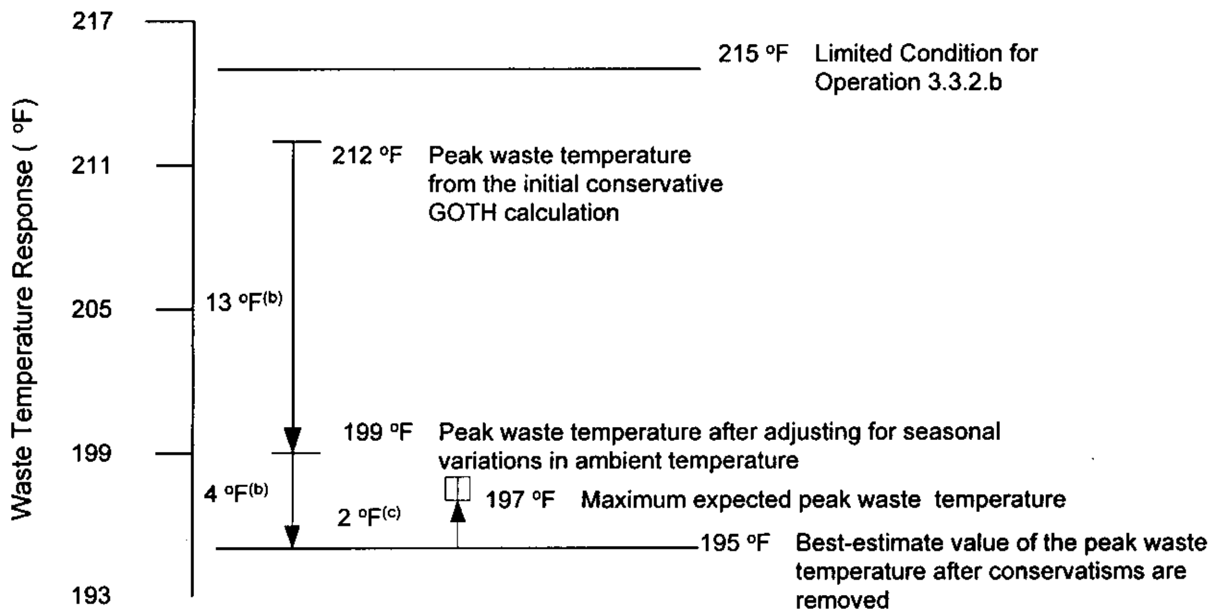
(c) Conservatism Due to Thermal Conductivity: Estimate of the reduction in the initial conservative GOTH calculation that is attributable to application of an enhanced thermal conductivity model. The estimate of the uncertainty associated with this effect is that the uncertainty is not more than one-half of the effect (e.g., 1/2 x 4°F = 2 °F).

(d) The Total Uncertainty Due to the Uncertainty in Items (b) and (c) and to Elemental Uncertainty on Radioactivity Heat Rate: The total uncertainty is equal to the square root of the sum of the squares of the uncertainty attributable to each item (e.g., $[(2\ °F)^2 + (7.5\ °F) + (12\ °F)^2]^{1/2} = 14.29\ °F$).

(e) The Expected Maximum Peak Waste Temperature: The expected maximum peak waste temperature is equal to the best-estimate value plus the total uncertainty [Item (d)].

For Tank 241-AY-102, the maximum expected peak waste temperature is 91.7 °C (197 °F), which is the high end of the expected range of 90.6 °C ± 1.1 °C (195 °F ± 2 °F). The process is illustrated in Figure 4-6, where the conservative effects were removed to obtain the best-estimate waste temperature (90.6 °C [195 °F]), and the total uncertainty (1.1°C [2 °F]) was added to obtain the maximum expected peak waste temperature (91.7°C [197 °F]).

Figure 4-6. Schematic Showing the Calculation Used to Determine the Maximum Expected Peak Waste Temperature in High-Level Waste Tank 241-AY-102.



NOTE: Δt °C = Δt °F/1.8, where Δt = temperature change.

(a) Conservatism Due to Constant Ambient Temperature: Estimate of the adjustment to the initial conservative GOTH calculation to account for seasonal variations in ambient temperature.

(b) Conservatism Due to Thermal Conductivity: Estimate of the reduction in the initial conservative GOTH calculation that is attributable to application of an enhanced thermal conductivity model. The estimate of the uncertainty associated with this effect is that the uncertainty is not more than one-half of the effect (e.g., 1/2 x 4 °F = 2 °F).

(c) The Total Uncertainty Due to the Uncertainty in Item (b): The total uncertainty is equal to the square root of the sum of the squares of the uncertainty attributable to each item (e.g., $[(2\ °F)^2]^{1/2}$ = 2 °F).

(d) The Expected Maximum Peak Waste Temperature: The expected maximum peak waste temperature is equal to the best-estimate value plus the total uncertainty [Item (c)].

4.2.3 Linear Extrapolations of Sludge Temperatures at Given Flow Rates

4.2.3.1 Tank 241-AY-102

The annulus flow rate in Tank 241-AY-102 usually varies 0.05 m^3/s (100 ft^3/min) to 0.1 m^3/s (200 ft^3/min) around a central value of 0.47 m^3/s (1,000 ft^3/min) (Case 1). To account for these variations, the group estimated the increase in peak temperature that would likely result if the annulus flow rate was reduced to 0.40 m^3/s (850 ft^3/min). The group estimated this increase to be about 0.6°C (1 °F), thereby increasing the maximum expected peak waste temperature from 91.7°C to 92.2°C (197 °F to 198 °F). The method used to determine the magnitude of the increase is provided in the following paragraphs.

The GOTH_SNF results for Tank 241-AZ-102, shown in Table 4-1, may be scaled to calculate the change in Tank 241-AY-102 waste temperature resulting from the reduced annulus flow rate. This approximation is possible because the conductive heat transfer is approximately equal for the two HLW tanks and because the waste temperature as a function of annulus flow rate is believed to be linear in the region around 0.47 m^3/s (1,000 ft^3/min). The correction to the Tank 241-AY-102 maximum expected peak waste temperature is the Tank 241-AZ-102 temperature gradient—change in temperature resulting from a change in annulus ventilation flow rate—multiplied by the change in flow rate. The correction was added to the maximum Tank 241-AY-102 expected peak waste temperature.

The peak waste temperature gradient for Tank 241-AZ-102 was determined from the data in Table 4-1. The GOTH-calculated Tank 241-AZ-102 peak waste temperatures for the 0.47 m^3/s (1,000 ft^3/min) (Case 2) and for the 0.94 m^3/s (2,000 ft^3/min) (Case 4) annulus flow rates are 109 °C (228.4 °F) and 105.2 °C (221.3 °F), respectively. The peak waste temperature gradient was determined as follows: (109.1 °C - 105.2 °C)/(0.94 m^3/s – 0.47 m^3/s) = 3.9 °C/0.47 m^3/s or (228.4 °F – 221.3 °F)/(2,000 ft^3/min - 1,000 ft^3/min) = 7.1 °F/1,000 ft^3/min.

Accordingly, the correction to the Tank 241-AY-102 maximum expected peak waste temperature, the gradient multiplied by the change in flow rate, is 0.59 °C (1.07 °F): {[(Δ3.94 °C/0.47 m^3/s) x (0.071 m^3/s) = 0.59 °C] or [(Δ7.1 °F/1,000 ft^3/min) x (150 ft^3/min) = 1.07 °F]}. The corrected maximum expected peak waste temperature is 92.26 °C (198.07 °F) [(91.67 °C +0.59 °C = 92.26 °C) or (197°F + 1.07 °F = 198.07 °F)].

4.2.4 Summary of Results from Thermal Analyses

The results of the thermal analyses are summarized in Table 4-1. The thermal analyses, taken together, support the following conclusions:

1. In the AY and AZ Tank Farms, a primary flow rate of 0.24 m^3/s (500 ft^3/min) of ambient air and an annulus flow rate of 0.47 m^3/s (1,000 ft^3/min) of ambient air will prevent the waste from boiling and, therefore, satisfy SL 2.1.1.

2. In the AY and AZ Tank Farms, a primary flow rate of 0.24 m^3/s (500 ft^3/min) ambient air and an annulus flow rate of 0.47 m^3/s (1,000 ft^3/min) ambient air will prevent the waste from exceeding 102 °C (215 °F) and, therefore, satisfy LCO 3.3.2. In Tank 241-AY-102, a flow rate as low as 0.40 m^3/s (850 ft^3/min) is likely allowable.

5.0 REVIEW OF INTERIM RECOMMENDATION BY SENIOR REVIEW GROUP

When the analyses described in Section 4.0 were completed and the risks discussed in Section 7.0 had been initially reviewed, a meeting was held with responsible stakeholders (senior review group). The agenda of the meeting, held on March 2, 2000, was to review the methods of the analyses, the results of the analyses, and the risks associated with the recommendation. The purpose of the meeting was to reach a consensus on an interim decision. An interim decision was needed to support the Level 2 specifications, which were needed to support Project W-521. The following organizations were represented at the meeting: Retrieval Operations; Nuclear Safety and Licensing; Technical Operations; Life-Cycle Projects; Process Engineering; Equipment Engineering; John Marvin, Inc.; Retrieval Engineering; Retrieval Project Definition; and Retrieval System Development. The actual attendees are given in the meeting minutes from the HLW heat-removal interim decision, which are appended to this AGA as Appendix A.

The senior review group reached consensus on the interim decision and agreed that the interim decision would become the final decision if no further problems were uncovered during the final development of the AGA report. The interim decision that was agreed to is that given in Section 8.1.

The senior review group also considered the risks discussed in Sections 7.1.2 through 7.1.8. The risk-handling actions recommended by the group also are given in Sections 7.1.2 through 7.1.8.

This page intentionally left blank.

6.0 COMPLIANCE OF PREFERRED ALTERNATIVE WITH WASTE FEED DELIVERY FUNDAMENTAL OBJECTIVES

The fundamental objectives of the WFD Program are those things that are of basic importance in carrying out its task. To ensure that the objectives are considered in making decisions, the objectives are explicitly stated and then potential alternatives are compared against them. Because there is only one remaining alternative, this alternative will be qualitatively compared against the basic objectives to ensure that the alternative does not severely challenge any of the objectives.

6.1 WASTE FEED DELIVERY FUNDAMENTAL OBJECTIVES

The following four highest-level fundamental objectives have been identified for the WFD Program:

1. Maximize safety (environmental, worker, and public)
2. Maximize compliance with regulations
3. Minimize life-cycle cost
4. Maximize the reliability of feed delivery to the treatment facility.

(Note that the terms "maximize" and "minimize" are used in the sense of "to increase to a maximum" or "to reduce to a minimum" with due weight given to all other legitimate—and sometimes conflicting—objectives. The terms do not mean "to make the maximum" or "to make the minimum" without regard to other objectives.)

In summary, the overall objective of the WFD Program is to deliver the proper waste feed to the treatment plant on time and in the right amount. While doing this, the safety of the environment, public, and workers must be protected; the cost must be minimized; and the regulations of external organizations must be met.

Each of these high-level fundamental objectives can be further subdivided into lower-level fundamental objectives. The complete set of objectives is shown in Table 6-1.

Table 6-1. Fundamental Objectives Hierarchy for Tank Waste Feed Delivery System.

1. Maximize Safety	1.1 Maximize Public Safety	1.1(a) Radiation Releases	1.1(a)i Chronic Exposure
			1.1(a)ii Accidental Exposure
		1.1(b) Chemical Releases	1.1(b)i Chronic Exposure
			1.1(b)ii Accidental Exposure
	1.2 Maximize Worker Safety	1.2(a) Radiation Exposure	1.2(a)i Chronic Exposure
			1.2(a)ii Accidental Exposure
		1.2(b) Chemical Exposure	1.2(b)i Chronic Exposure
			1.2(b)ii Accidental Exposure
		1.2.(c) Industrial Safety	
	1.3 Maximize Environment Safety	1.3(a) Protection of Biota	
		1.3(b) Groundwater and Vadose Zone Protection	1.3(b)i Chronic Releases
			1.3(b)ii Accidental Releases
		1.3(c) Atmospheric Protection	1.3(c)i Chronic Releases
			1.3(c)ii Accidental Releases
2. Maximize Regulatory Compliance	2.1 U.S. Department of Energy		
	2.2 Washington Dept of Ecology and U.S. Environmental Protection Agency		
	2.3 Washington Dept of Health and U.S. Environmental Protection Agency		
3. Minimize Life-cycle Cost	3.1 Design and Construction Cost		
	3.2 Operating Cost		
	3.3 Decontamination and Decommissioning		
4. Maximize Feed Delivery Reliability	4.1 Feed Delivery On Time	4.1(a) Initial Delivery	
		4.1(b) Routine Delivery	
	4.2 Proper Quantity of Feed	4.2(a) Initial Quantity	
		4.2(b) Routine Quantity	
	4.3 Feed Within Specifications		
	4.4 Obligations and Milestones	4.4(a) Contractual Obligations	
		4.4(b) Tri-Party Agreement Milestones (Ecology et al. 1996)	

6.2 COMPARISON OF PREFERRED ALTERNATIVE WITH WASTE FEED DELIVERY FUNDAMENTAL OBJECTIVES

6.2.1 Safety

The fact that the primary ventilation system and the annulus ventilation system for Tank 241-AY-102 are functioning today and that the other annulus systems have functioned in the past indicates that there are no severe operational safety problems with the use of these systems. To prevent any accidental exposure to workers, the waste is not allowed to boil, thus preventing a tank bump. Radiological and industrial safety controls will have to be exercised during the replacement of any components; however, these controls have been exercised before and are well within normal controls.

6.2.2 Regulatory Compliance

The fact that the primary and annulus systems are and have been operated in the past is also evidence that there are no severe regulatory obstacles to their future operation. The ventilation system, if functioning properly, will keep the waste temperatures below the SL 2.1.1 and LCO 3.3.2 requirements.

6.2.3 Life-Cycle Cost

The only additional costs, with the exception of routine operating costs, are the costs of restoring the ventilation system to full functionality. In the 1980s, it was discovered that the buried ventilation piping in the AY Tank Farm was corroded. The part of the piping that serves Tank 241-AY-102 had to be replaced. This same repair may be necessary for Tank 241-AY-101. Furthermore, if the buried piping in the AZ Tank Farm also is corroded, the piping also will need to be replaced. These costs associated with the replacement are not unusual for construction work in the tank farms and are acceptable. Further, these costs are associated with maintenance activities that, if necessary, are independent of this AGA. Therefore, there are no life-cycle costs associated with the preferred alternative.

6.2.4 Reliability of Feed Delivery

The proposed alternative should not reduce the reliability of feed delivery in any way. It is estimated that the ventilation system, if it fails, could be repaired within 50 h. Such a repair time would not threaten the reliability of feed delivery.

This page intentionally left blank.

7.0 RISKS ASSOCIATED WITH THE PREFERRED ALTERNATIVE

This section discusses programmatic and technical risks associated with the remaining alternative. The programmatic and technical risks of the preferred alternative are acceptable provided the actions presented in this section are implemented.

7.1 DISCUSSION OF RISKS

Sections 7.1.1 though 7.1.8 address identified risks associated with the remaining alternative for heat removal.

7.1.1 Modeling Underestimating or Overestimating Waste Temperatures

Modeling inaccuracy may be a result of model inputs or assumptions. Most of the conservatisms in the modeling were addressed in Section 4.0. One potential remaining risk is that the characterization on some of the tanks may not be fully mature; therefore, the model inputs may be inaccurate.

There are two ways for the modeling to inaccurately estimate temperature response: (1) overestimating the temperatures and (2) underestimating the temperatures.

7.1.1.1 Model Overestimating Waste Temperatures.

If the modeling predicts temperatures higher than actually occur in the tank, the equipment installed to maintain temperatures below the LCO would not be needed. In this scenario, the LCO temperature would not be exceeded and the ability of the WFD Program to deliver feed to the treatment facility would not be challenged.

Risk: The cost of restoring the annulus ventilation systems to functionality in Tank 241-AY-101 and the AZ Tank Farm may have been unnecessary.

Action: This risk is acceptable. Much of the conservatism already has been removed from the results. Additionally, the preferred alternative does not involve costly system upgrades.

7.1.1.2 Model Underestimating Waste Temperatures.

If the modeling projects temperatures lower than actually occur in the tank, the equipment installed to maintain temperatures below the LCO limits may be incapable of doing so.

Risk: Actions necessary to limit the waste temperatures below LCO 3.3.2 limits may inhibit the ability of the WFD Program to deliver feed to the treatment facility.

Action: This risk is acceptable. Even with much of the conservatism removed, the model validation effort shows that the model still is likely overestimating the waste temperature. However, there are apparent discrepancies between heat estimates for Tank 241-AY-102 that should be investigated. The best-basis inventory for Tank 241-AY-102 accounts for an estimated decay heat of approximately 38,700 W (132,000 Btu/h), while the thermocouple data from Tank 241-AY-102 only account for an estimated thermal source term of 34,000 W (116,000 Btu/h). Other estimates of the decay heat in Tank 241-AY-102 range from as low as 29,000 W (100,000 Btu/h) to as high as 44,000 W (150,000 Btu/h). It is important to note, however, that the HLW from Tank 241-AY-102 is not scheduled to be retrieved until 2009. Normal radiolytic decay that will occur in the interim will limit the heat to below the 34,000 W (116,000 Btu/h) used in the parametric study (RPP-5637), even for the highest estimated current decay heat.

7.1.2 Primary System Minimally Adequate

Risk: The current primary ventilation system is minimally adequate to process one tank at a time. The primary ventilation system can maintain a flow rate of 0.24 m^3/s (500 ft^3/min) on one tank and keep the other three below atmospheric pressure (requiring approximately 0.05 m^3/s [100 ft^3/min] each) with very little margin for any activity that would reduce the system flow rate.

Action: The risk is acceptable. The ability to tolerate potential operational restrictions will be evaluated after the final decision has been made. However, the ability to deploy one of the 0.47 m^3/s (1,000 ft^3/min) backup portable exhausters should be maintained.

7.1.3 Cooling Slot Plugging

Risk: Tank 241-AY-102 is known to have plugged cooling slots; Tank 241-AY-101 could also have some plugged slots. Tanks 241-AZ-101 and 241-AZ-102 are not known to have plugged slots, but there is the potential for this being the case.

Action: This risk is acceptable. This risk issue will be considered during the amendment of the authorization basis.

7.1.4 Condition of Buried AZ Ventilation Pipe

Risk: The buried AY ventilation piping was found to be severely corroded in the 1980s and was replaced at a cost of approximately \$5 million. At that time, cathodic protection was installed on the AY buried ventilation piping. The condition of the buried AZ ventilation piping is unknown, and it may have to be replaced.

Action: This risk is acceptable. This risk issue will be addressed during the system functionality verifications (walk downs) of AY and AZ Tank Farms.

7.1.5 Allowable Differential Pressure for AY and AZ Tanks to Prevent Tank Damage

Risk: The differential pressure across the tank wall between the headspace and the annulus must be controlled to prevent components from failing because of excess pressure. The allowable pressure for Tank 241-AY-102 has been analyzed to be 5 kPa (20 in.) water gauge. Tank 241-AY-102 develops approximately 4 kPa (16 in.) water gauge when operating at 0.47 m^3/s (1,000 ft^3/min). Tanks 241-AY-101, 241-AZ-101, and 241-AZ-102 have not been analyzed to determine the allowable differential pressure.

Action: The senior review group determined that this risk would be acceptable if a qualitative analysis of the other three tanks shows that they would be able to tolerate 5 kPa (20 in.) water gauge differential pressure. A subsequent review concluded that Tanks 241-AY-101, 241-AZ-101, and 241-AZ-102 would be able to tolerate the allowable differential pressure of 5 kPa (20 in.) water gauge (see Appendix B).

7.1.6 Cross-ties Between the Primary and Annulus Ventilation Systems

Risk: There are several cross-ties between the primary and annulus ventilation systems on all four HLW tanks. These cross-ties might leak under higher differential pressures required to maintained the recommended annulus flow rates.

Action: This risk is acceptable. The risk issue will be addressed at a later time as an operational consideration during implementation.

7.1.7 Constraint on Tank Heat Contents

Risk: The constraint on tank contents imposed by the cases analyzed poses some risk to operational flexibility. It is possible—but quite unlikely—that this would prevent retrieval sequences proposed in the future from being used without further thermal analyses.

Action: This risk is acceptable because the modeled cases were selected to bound the waste currently in the tanks and are expected to bound most realistic retrieval sequences and blending strategies.

7.1.8 Capacity of Existing Ventilation Systems

Risk: There is some small risk that it will not be possible to develop the required annulus flow rates in Tanks 241-AY-101, 241-AZ-101, and 241-AZ-102 because they have not operated for some time and the practical flow rates are not actually known.

Action: This risk is acceptable. The fact that the 241-AY-101 annulus ventilation system previously has achieved a flow of 0.47 m^3/s (1,000 ft^3/min) was already considered in the decision. Although it has not functioned in several years, the AZ annulus ventilation system was designed to provide higher flow rates than the 0.47 m^3/s (1,000 ft^3/min). The AZ annulus ventilation system will need to be returned to operational status, and the Tank 241-AY-101 ventilation ducting likely will need to be modified to route all of the annulus ventilation airflow to the tank bottom. No other upgrades are anticipated at this time.

8.0 RECOMMENDATIONS

8.1 RECOMMENDED ALTERNATIVE

Retrieval Engineering's recommendation for the removal of heat from the AWF tanks during Phase 1 of WFD is provided in Sections 8.1.1 and 8.1.2.

8.1.1 Primary Ventilation Systems

The following conditions for the primary ventilation systems should be implemented:

1. The minimum required once-through flow rate of noncooled air through the headspaces of Tanks 241-AY-101, 241-AY-102, 241-AZ-101, and 241-AZ-102 will be 0.24 m^3/s (500 ft^3/min) per tank when undergoing mixing and settling.

2. The primary ventilation systems—specifically, the equipment performing the heat-removal function—for each of the four HLW tanks will be assumed to be designated safety significant for the tank bump accident.

8.1.2 Annulus (Secondary) Ventilation Systems

The following conditions for the annulus (secondary) ventilation systems should be implemented:

1. The minimum required once-through flow rate of noncooled air through the cooling channels (slots) of Tanks 241-AY-101, 241-AY-102, 241-AZ-101, and 241-AZ-102 is 0.40 m^3/s (850 ft^3/min) per tank; the nominal design flow rate is 0.47 m^3/s (1,000 ft^3/min).

2. The annulus ventilation systems—specifically, the equipment performing the heat-removal function—for each of the four HLW tanks will be assumed to be designated safety significant for the tank bump accident.

It is assumed that these systems eventually will be designated safety significant for the tank bump accident. The actual determination will be made by the Control Decision Board as part of the authorization basis amendment process.

This page intentionally left blank.

9.0 REFERENCES

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

HNF-5386, 2000, *Thermal Hydraulic Analysis of High-Level Waste Tanks for Phase 1 Waste Feed Delivery*, Rev. 0, Fluor Hanford, Inc., Richland, Washington.

HNF-SD-WM-TSR-006, 1999, *Tank Waste Remediation System Technical Safety Requirements*, Rev. 0T, Fluor Daniel Hanford, Inc., Richland, Washington.

MacLean, G. T., 1998, *Parameters for Use in CFD Simulation of Leaching 241-AZ-101 Waste*, (Internal Memo SESC-98-067 to K. Sathyanarayana, January 28), SGN Eurisys Services Corporation, Richland, Washington.

RPP-5637, 2000, *Parametric Analyses of Heat Removal from High-Level Waste Tanks*, Rev. 0 CH2M Hill Hanford Group, Inc., Richland, Washington.

This page intentionally left blank.

APPENDIX A

INTERIM DECISION MEMORANDUM

This page intentionally left blank.

MEMORANDUM **CH2MHILL**

79C00-00-012

HIGH-LEVE WASTE HEAT REMOVAL INTERIM DECISION

TO:	A. F. Choho	R3-73
COPIES:	P. J. Certa	R3-73
	T. J. Conrads	R3-73
	GPD LB/File	R3-72
FROM:	Project Definition Operations	
DATE:	March 20, 2000	
RESPOND BY:		

Please use the high-level waste heat removal interim decision, as described in the attached meeting minutes, for the development of Level 2 specifications until a final decision is reached. It is possible, but unlikely, that the final decision will differ from this interim decision.

If you have any questions, please contact me at 376-6008.

G. P. Duncan
Project/Program Manager

cjh

Attachment

Meeting Minutes Subject: High-Level Waste Heat Removal Interim Decision					
To: Distribution		Building: MO-276			Meeting Minutes No. MM-6N100-00-003
From: W. J. Millsap		Chairman: P. J. Certa			
Department – Operation-Component WFD Program – Retrieval Engineering	Area 200E	Shift Days		Date of Meeting 2 March 2000	Number Attending 17

Distribution

Name	MSIN	Representing
J. W. Bailey (for JW Lentsch)*	R3-25	Life Cycle Projects (W314)
D. R. Bratzel*	R1-44	Nuclear Safety and Licensing
A. B. Carlson	R3-73	Retrieval System Development
P. J. Certa*	R3-73	Retrieval System Development
A. F. Choho*	R3-73	Retrieval Engineering
T. J. Conrads*	R3-73	Retrieval Project Definition
C. Defigh-Price (for RS Popielarczyk)*	R2-12	Process Engineering
G. C. DeWeese*	R3-73	Waste Feed Delivery
R. A. Dodd	R3-72	Retrieval Support Operations
G. P. Duncan (for Ryan Dodd)*	R3-72	Retrieval Operations
J. D. Galbraith*	R3-73	Retrieval System Development
T. G. Goetz*	R1-49	Nuclear Safety and Licensing
K. M. Hodgson*	R2-11	Process Engineering
C. E. Leach	R1-44	Nuclear Safety and Licensing
J. W. Lentsch	R3-25	Life Cycle Projects
J. E. Meacham (for CE Leach)*	R1-49	Nuclear Safety and Licensing
W. J. Millsap*	R3-73	Retrieval System Development
D. M. Ogden*		John Marvin Inc.
R. S. Popielarczyk	R2-58	Technical Operations
G. A. Symons	R3-73	Retrieval System Development
W. T. Thompson	R3-73	Project Implementation
M. Thurgood*		John Marvin, Inc.
R. L. Treat	H6-64	Waste Feed Delivery
J. B. Truitt*	R3-83	Equipment Engineering
W. L. Willis*	R3-73	Retrieval System Development
* = attended meeting		

Introduction

On Thursday, 2 March 2000, a meeting was held to discuss and reach consensus on the proposed interim decision for the preferred method to remove the heat from the high-level waste tanks during Waste Feed Delivery operations. The purpose of the interim decision is to provide requirements to be included in the Ventilation Level 2 Specification, which needs to be issued shortly to support completion of the W-521 CDR.

Paul Certa presented a summary of the background to the decision, the thermal analyses performed, the proposed interim decision, risk associated with the decision, and the path forward.

After the presentation, the group discussed and reached consensus on the interim decision for the preferred method to remove heat from the high-level waste tanks. The group also discussed potential decision risks and agreed upon their handling actions. Only one of the handling actions needs to be completed before a final decision is issued.

The final decision is expected to be the same as the interim decision, although the wording may be changed to improve clarity.

Interim Decision

The interim decision is:

Primary Ventilation Systems

- The minimum required once-through flow rate of non-cooled air through the headspaces of tanks AY-101, AY-102, AZ-101, and AZ-102 will be 500 scfm per tank when undergoing mixing and settling.
- The primary ventilation systems—specifically, the equipment performing the heat removal function—for each of the four high-level waste tanks will be assumed[1] to be designated as safety significant for the tank bump accident.

Annular (Secondary) Ventilation Systems

- The minimum required once-through flow rate of non-cooled air through the cooling channels (slots) of tanks AY-101, AY-102, AZ-101, and AZ-102 is 850 scfm per tank; the nominal design flow rate is 1,000 scfm.
- The annular ventilation systems—specifically, the equipment performing the heat removal function—for each of the four high-level waste tanks will be assumed[1] to be designated as safety significant for the tank bump accident.

Risks Associated with the Interim Decision

The risks associated with this decision and their handling actions are listed below:

Primary System Minimally Adequate

[1] We are assuming that these systems will eventually be designated as safety significant for the tank bump accident. The actual determination will be made by the Control Decision Board as part of the authorization basis amendment process.

Risk: The present primary ventilation system (1,000 cfm distributed over four tanks) is minimally adequate for processing one tank at a time. It can provide 500 cfm to one tank while maintaining the other three tanks below atmospheric pressure. Don Ogden explained that during mixing, most of the heat is removed via the primary ventilation system; during settling, the annulus ventilation system is the significant system for controlling the maximum waste temperature. This may introduce some minor operational restrictions on the timing of maintenance activities and on the overlap of high-level waste feed staging activities if the primary ventilation system is called on to cool two tanks that are being simultaneously mixed.

Handling Action: No action is required prior to the final decision on HLW heat removal; the ability to tolerate potential operational restrictions will be evaluated after the final decision has been made. However, we should maintain the ability to deploy one of the spare portable 1,000 scfm exhausters.

Slot Plugging

Risk: AY-102 has some plugged cooling slots; AY-101, AZ-101 and AZ-102 may also have plugged slots. The degree of plugging and associated consequences have not been evaluated.

Handling Action: No action is required prior to the final decision on HLW heat removal. This issue will be considered during the amendment of the authorization basis.

Condition of Buried AZ Ventilation Piping

Risk: The buried AY-Farm ventilation piping was found to be severely corroded and was replaced in the 1980s at a cost of about $5M. The condition of the buried AZ-Farm piping is not known. There are access points to do a visual inspection.

Handling Action: No action is required prior to the final decision on HLW heat removal. This issue will be addressed during the system functionality verifications (walk downs) of AY- and AZ-Farms.

Allowable Differential Pressure for AY & AZ Tanks to Prevent Tank Damage

Risk: The allowable differential pressure in the ventilation systems for AY-101, AZ-101 and AZ-102 have not been analyzed in detail; they can presently go up to 6 inches water gauge. AY-102 has been analyzed and the allowable differential pressure is 20 inches. At an annular flow rate of 1,000 cfm, AY-102 develops about 16 inches of differential pressure. It was assumed that due to similarities in the designs, the other tanks would be able to accommodate the differential pressure at similar flow rates.

Handling Action: Prior to the final decision, qualitatively verify that the analysis performed for AY-102 is applicable to AY-101, AZ-101 and AZ-102.

Cross-Ties Between the Primary and the Annular Ventilation Systems

Risk: There are several cross-ties between the primary and annular ventilation systems that may allow contamination into the annulus if they fail when operated under high differential pressure. One example is the packing gland on the side-fill lines for the primary tank.

Handling Action: No action is required prior to the final decision on HLW heat removal. This will be addressed at a later time as an operational consideration during implementation.

Tank Solids Volume and Heat Contents

Risk: The implied constraint on tank contents imposed by the cases analyzed may limit operational flexibility. It is possible, but not likely, that this would impose limits on the amount of waste that could be staged in these tanks under future retrieval sequences and blending strategies.

Handling Action: No action is required prior to the final decision on HLW heat removal. The modeled cases were selected to bound the waste currently in the tanks and are expected to bound most realistic retrieval sequences and blending strategies. This risk is accepted without further action.

Capacity of Existing Annular Ventilation Systems

Risk: It is not clear what flow rates can be realistically achieved in the annular slots with maintenance and minor modifications. The desire is to avoid unnecessary upgrades, while ensuring adequate flow.

Handling Action: No action is required prior to the final decision on HLW heat removal. The fact that the AY-101 annulus ventilation system has previously achieved a flow of 1000 cfm was already considered in the decision. We do not expect there to be a sharp increase in upgrade costs for minimum required flow rates around 850 scfm and target design rates of 1000 scfm. Therefore, this risk is accepted without further action.

Additional points

During the course of the meeting, the following additional points were discussed:

- John Bailey stated that there are two portable 1,000 cfm exhausters (safety class) in storage at the FMEF that could be used to provide additional primary or annular ventilation if needed. John has detailed information on these units and their intended use on the AY-102 annulus.

- A study of thermocouple response may be the only viable way to assess whether there is any significant blockage of the cooling channels (slots). Cherri Defigh-Price noted that it may be necessary to specify in the FSAR a minimum number of working thermocouples in each quadrant of the refractory pads for the tanks. John Bailey noted that there are two known plugged slots in AY-102.

- John Bailey noted that during the execution of project W-320, there were concerns about leakage of radioactive contaminants from the primary system into the annular system, but none were found.

- Don Ogden explained that during mixing, most of the heat is removed via the primary vent system; during settling, the annulus ventilation system is the significant system for controlling the maximum waste temperature. However, during settling, the annulus ventilation system is only removing about 30 to 40 % of the heat.

APPENDIX B

INTERNAL MEMORANDUM ON ALLOWABLE ANNULUS PRESSURE FOR 241-AY AND 241-AZ TANKS

This page intentionally left blank.

CH2MHILL
Hanford Group, Inc.

INTEROFFICE MEMO

From:	Equipment Engineering	74700-00-LJJ-020
Phone:	376-4608	
Date:	June 8, 2000	
Subject:	ALLOWABLE ANNULUS PRESSURE FOR 241-AY AND 241-AZ TANKS TO PREVENT TANK DAMAGE	

To:	W. L. Willis	R3-73
Copies:	P. J. Certa	R3-73
	T. J. Conrads	R3-73
	A. H. Friberg	R3-83
	T. C. Oten	R3-83
	LJJ file/lb	

References:
1. Memo, G. P. Duncan to A. F. Choho, CHG, *High-Level Waste Heat Removal Interim Decision*, 79C00-00-012, dated March 20, 2000.
2. HNF-2317, *Project W-320 High Vacuum 241-AY-102 Annulus Ventilation System Operability Test Report*, Revision 0, dated March 12, 1998.
3. SD-RE-TI-008, Compilation of Basis Letters Referenced in 241-AN, AP, AW, AY, AZ, and SY Process Specifications, Revision 5, dated April 30, 1990.
4. HWS-7789, 1968, *Specification for Primary and Secondary Steel Tanks, PUREX Tank Farm Expansion Project IAP-614* (241-AY Tank Farm), Revision 2, Hanford Engineering Services, Richland, Washington.
5. HWS-8982, 1970, *Specification for Primary and Secondary Steel Tanks, PUREX Tank Farm Expansion Project HAP-647 241-AZ Tank Farm*, Hanford Engineering Services, Richland, Washington.

Per your request, in support of the High-Level Waste Heat Removal Interim Decision action item identified in Reference 1, the allowable differential pressure established for the Aging Waste Facility (AWF) 241-AY-102 Double-Shell Tank (DST) in Appendix A of Reference 2 was reviewed for applicability to the 241-AY-101, 241-AZ-101, and -102 AWF DSTs. The structural evaluation in Appendix A of Reference 2 evaluated the structural acceptability of a maximum *vacuum* annulus pressure of 20-inches water gauge for the AY-102 tank structure and its associated ventilation system components. As requested, this review addresses the applicability of the AY-102 analysis to the AY-101, AZ-101, and AZ-102 tank structures but does not address the adequacy of the associated ventilation system components of these tanks.

The finding of this review is that the evaluation of the AY-102 tank structure for a maximum vacuum annulus pressure of 20-inches water gauge as given in Appendix A of Reference 2 is also applicable to the tank structures of AY-101, AZ-101, and AZ-102. This finding is consistent with results given in Rockwell International internal letter number 65460-81-109 to T. J. Venetz from C. DeFigh-Price, *241-AY, -AZ and –SY Process Specification Review*, dated December 9, 1981, contained in Reference 3 (pages 31-37).

W. L. Willis, et al.
Page 2
June 8, 2000

74700-00-LJJ-020

The AY tanks were constructed over a period from 1968 to 1970 and the AZ tanks in 1971 and 1977. The only significant difference in the specified design loads for these tanks was that the soil cover depth for the AY tanks was 8 feet (Reference 4) compared to 7 feet for the AZ tanks (Reference 5). The design code specified for the primary steel tank and secondary steel liner was the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel (B&PV) Code, Section VIII, Division 2 (1965) and ASME B&PV Code, Section III (1968) for the AY and AZ tanks, respectively. The same material specification (ASTM A515 Grade 60) was specified for the primary steel tank and secondary steel liner for both the AY and AZ tanks. A minimum specified 28-day concrete compressive strength of 3,000 lbf/in^2 was specified for both the AY and AZ tanks. In both the AY (drawing H-2-64449) and AZ (drawing H-2-67317) tanks the secondary steel liner is attached to the outer wall and haunch region of the reinforced concrete by threaded form ties that attach to threaded (¼-inch internal diameter UNC 20 thread) studs welded to the steel liner in a 2- x 2-ft square pattern. The minimum specified plate thickness for the AY and AZ primary tanks was the same except for the bottom plates, which were ⅜-inch for the AY tanks and 1/2-inch for the AZ tanks. The minimum specified wall thickness of the secondary steel liner in the haunch region was ⅜-inch for both the AY and AZ tanks. The minimum specified wall thickness of the secondary steel liner in the cylindrical wall and bottom region was ¼-inch for the AY tanks and ⅜-inch for the AZ tanks. Hence, the AZ tank design is conservative compared to the AY tank design for the vacuum annulus pressure evaluation.

This comparison strictly applies to the adequacy of the AY and AZ tank structures for a maximum vacuum annulus pressure of 20-inches water gauge. This comparison does not address the adequacy of the corresponding ventilation system components with potential differences in designs. The ventilation system structural evaluation in Appendix A of Reference 2 was based on the ventilation system upgrades for AY-102.

If you have any further technical questions regarding this assessment, please feel free to contact the undersigned at 376-4608.

Larry J. Julyk, Principal Engineer
Equipment Engineering

rkg

DISTRIBUTION

Onsite

1	U.S. Department of Energy Richland Operations Office	
	Reading Room	H2-53
1	Pacific Northwest National Laboratories	
	Hanford Technical Library	P8-55
6	Subcontractors	
	DeWeese, G. C., MACTEC	R3-73
	Ogden, D. M.. JMI	R3-73
	Sederburg, J. P., ARES Corp.	R3-73
	Symons, G. A., COGEMA	H3-27
	Thurgood, M.. JMI	
	Treat, R. L., MACTEC	H6-64
5	Lockheed Martin Services, Inc.	
	Rice, R. L. (3)	R3-73
	Central Files	B1-07
	Document Processing Center	A3-94
2	Fluor Hanford, Inc.	
	Millsap, W. J.	H5-26
	Truitt, J. B.	T4-20
18	Numatec Hanford Corporation	
	Carlson, A. B.	R3-73
	Certa, P. J. (2)	R3-73
	Choho, A. F.	R3-73
	Conrads, T. J.	R3-73
	Galbraith, J. D.	R3-73
	Millsap, W. J.	R3-73
	G. Senetz	R3-73
	W. L. Willis (10)	R3-73

DISTRIBUTION (CONT)

14 CH2M HILL Hanford Group, Inc.

Bailey, J. W.	R3-25
Bratzel, D. R.	R1-44
Crawford, T. W.	R3-73
Defigh-Price, C.	R2-12
Dodd, R. A.	R3-72
Duncan, G. P.	R3-72
Goetz, T. G.	R1-49
Hodgson, K. M.	R2-11
Leach, C. E.	R1-44
Lentsch, J. W.	R3-25
J. E. Meacham (for CE Leach)	R1-49
Popielarczyk, R. S.	R2-58
Schmitz, P.	R3-73
Thompson, W. T.	R3-73

DISTRIBUTION

Onsite

1	U.S. Department of Energy Richland Operations Office	
	Reading Room	H2-53
1	Pacific Northwest National Laboratories	
	Hanford Technical Library	P8-55
6	Subcontractors	
	DeWeese, G. C., MACTEC	R3-73
	Ogden, D. M.. JMI	R3-73
	Sederburg, J. P., ARES Corp.	R3-73
	Symons, G. A., COGEMA	H3-27
	Thurgood, M.. JMI	
	Treat, R. L., MACTEC	H6-64
5	Lockheed Martin Services, Inc.	
	Rice, R. L. (3)	R3-73
	Central Files	B1-07
	Document Processing Center	A3-94
2	Fluor Hanford, Inc.	
	Millsap, W. J.	H5-26
	Truitt, J. B.	T4-20
18	Numatec Hanford Corporation	
	Carlson, A. B.	R3-73
	Certa, P. J. (2)	R3-73
	Choho, A. F.	R3-73
	Conrads, T. J.	R3-73
	Galbraith, J. D.	R3-73
	Millsap, W. J.	R3-73
	G. Senetz	R3-73
	W. L. Willis (10)	R3-73

DISTRIBUTION (CONT)

14	CH2M HILL Hanford Group, Inc.	
	Bailey, J. W.	R3-25
	Bratzel, D. R.	R1-44
	Crawford, T. W.	R3-73
	Defigh-Price, C.	R2-12
	Dodd, R. A.	R3-72
	Duncan, G. P.	R3-72
	Goetz, T. G.	R1-49
	Hodgson, K. M.	R2-11
	Leach, C. E.	R1-44
	Lentsch, J. W.	R3-25
	J. E. Meacham (for CE Leach)	R1-49
	Popielarczyk, R. S.	R2-58
	Schmitz, P.	R3-73
	Thompson, W. T.	R3-73