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Engineering Report for Interim Closure of Tank 241-C-106 and the 241-C Farm 200-Series Tanks

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Abstract: This engineering report supplements the Accelerated Tank Closure Demonstration Basis of Design Report (RPP-12331) and provides additional detail relative to durations of Phase 1 and Phase II fill optinos, use of existing onsite ventilation systems, waste retrieval project integration, and discussion of tank temperature during and after tank fill activities.

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ENGINEERING REPORT FOR INTERIM CLOSURE OF TANK 241-C-106 AND THE 241-C FARM 200-SERIES TANKS

February 11, 2003

Prepared By
CH2M HILL Hanford Group, Inc.
Richland, Washington

ENGINEERING REPORT FOR INTERIM CLOSURE OF TANK 241-C-106 AND THE 241-C FARM 200-SERIES TANKS

February 11, 2003

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CONTENTS

1.0 PURPOSE AND INTRODUCTION 1

2.0 INTERIM REQUIREMENTS 2

3.0 GROUT DELIVERY/PRODUCTION 3

4.0 VENTILATION ASSESSMENT 7
- 4.1 REQUIREMENTS 8
- 4.2 EVALUATION 11
  - 4.2.1 296-C-006 Ventilation System 11
  - 4.2.2 296-P-16 Ventilation System 11
  - 4.2.3 Portable Exhausters POR-004, -005, and -006 11
  - 4.2.4 Portable Exhausters POR-007 and -008 12
  - 4.2.5 Characterization Project Operations Portable Exhausters 12
- 4.3 RECOMMENDATION 12

5.0 VOID SPACES 13
- 5.1 VOIDS WITHIN THE TANK FILL MATERIAL 14
- 5.2 VOIDS BETWEEN THE TANK AND THE FILL 14
- 5.3 VOIDS WITHIN RISERS NOT IN PITS 14
  - 5.3.1 Tank 241-C-106 15
  - 5.3.2 241-C Farm 200-Series Tanks 15
- 5.4 VOIDS WITHIN RISERS IN PITS 16
  - 5.4.1 Tank 241-C-106 Sluice Pit 16
  - 5.4.2 Tank 241-C-106 Heel Pit 16
  - 5.4.3 Tank 241-C-106 Pump Pit 17
  - 5.4.4 Jet Pump Pit on 200-Series Tanks 17
- 5.5 OTHER VOIDS 17

6.0 RETRIEVAL INTEGRATION 18

7.0 INTERIM CLOSURE THERMAL ANALYSIS 20

8.0 TANK ACCESS 20

9.0 REFERENCES 21

APPENDICES

A COST AND SCHEDULE DETAIL ..... A-i

B GROUT DELIVERY/PLACEMENT EVALUATION CRITERIA AND CONCEPT SELECTION PROCESS ..... B-i

C CALCULATIONS ..... C-i

D SKETCHES ..... D-i

FIGURE

1. Tank 241-C-106 Waste Retrieval Concept 18

LIST OF TERMS

GEMS	gas effluent monitoring system
HEPA	high-efficiency particulate air
SST	single-shell tank

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1.0 PURPOSE AND INTRODUCTION

This engineering report supplements the Accelerated Tank Closure Demonstration Basis of Design Report completed in September 2002 for closing tanks 241-C-106, -201, -202, -203, and -204 (RPP-12331). Following completion of RPP-12331 a number of issues were identified that warranted further evaluation and development. These issues include:

- Separation in time between Phase 1 (residual waste stabilization) and Phase 2 (bulk tank structural fill)
- Evaluation of options to use existing onsite ventilation equipment to support interim tank closure activities associated with Phase 1 waste stabilization
- Further evaluation of void spaces internal to and surrounding equipment and the need/requirements for filling with stabilizing material
- Further integration with the waste retrieval project as additional detail was developed
- Temperature concerns associated with radionuclide decay heat remaining in the tank following interim closure.

The separation in time between Phase 1 and Phase 2 grouting activities results in the need to evaluate interim actions that would need to be completed to manage the tanks over the period between interim and final tank closure. The separation also results in the need to reevaluate the delivery, production, and placement of stabilizing material in the tanks since much smaller volumes of material are placed in the tanks to stabilize the post-retrieval residual waste compared to filling the tanks.

Based on the approach for the tank 241-C-106 closure demonstration described in *Draft Environmental Assessment for the Accelerated Tank Retrieval and Closure Demonstration Project* (DOE/EA-1462) and the tank 241-C-106 draft interim *Resource Conservation and Recovery Act of 1976* closure plan, interim closure is defined as stabilization of the post-retrieval residual waste remaining in the tank and isolation measures taken to prevent water from intruding into the tank. Using this definition for interim closure, this report focuses on Phase 1 activities and evaluation of the issues identified previously. Phase 1 activities involve stabilizing the residual waste and isolating the tank to prevent liquids from entering the tank.

This engineering report utilizes the following document structure:

- **Section 1.0** – Introduction.
- **Section 2.0** – Identification of interim requirements for monitoring the stabilized waste following completion of waste stabilization and before completion of final tank closure.
- **Section 3.0** – Evaluation and recommendation of an approach to delivering, producing, and placing waste stabilization grout in the tanks.

- **Section 4.0** – Evaluation of ventilation system requirements and options during waste stabilization activities.
- **Section 5.0** – Evaluation of potential void spaces that will likely occur during bulk tank filling (Phase 2) and the basis for requirements to fill void spaces.
- **Section 6.0** – Identification of integration points with planned waste retrieval activities to identify interfaces and reduce overall project costs.
- **Section 7.0** – Potential temperature effects associated with stabilization of the residual waste.
- **Appendix A** – Cost and schedule data for completing interim closure actions. This appendix presents an update to the cost and schedule presented in RPP-12331 to focus on execution of the Phase 1 interim closure activities.
- **Appendix B** – Identification and evaluation of options for delivering, producing, and placing waste stabilization grout.
- **Appendix C** – Calculations performed to support the evaluation of issues.
- **Appendix D** – Sketches developed for the tank closure concept.

2.0 INTERIM REQUIREMENTS

RPP-12331 assumed that Phase 2 (bulk tank filling) of the closure demonstrations would take place immediately following Phase 1 (waste stabilization). A decision to implement Phase 2 is dependent on *National Environmental Policy Act of 1969* evaluations (Tank Closure EIS) and ongoing regulatory negotiations. The tank 241-C-106 interim closure plan identifies Phase 1 activities as interim closure activities associated with post-retrieval residuals remaining in the tank. The tank 241-C-106 interim closure plan does not propose final closure of tank 241-C-106 and defers final closure to future decisions. Based on the current *National Environmental Policy Act of 1969* and regulatory strategy it is reasonable to assume that there will be a period of time between the Phase 1 and Phase 2 of the closure demonstrations.

Since the time lapse between Phase 1 and Phase 2 is uncertain and assuming that the lapse time to Phase 2 is at least one year, isolation measures and limited tank monitoring activities should be implemented as a part of Phase 1 pending completion of Phase 2 activities. Following completion of waste stabilization activities, the ventilation system used to support Phase 1 operations will be removed and breather filters installed. Additionally, the tanks will be interim isolated in accordance with the requirements of HNF-IP-0842, Volume 4, Section 4.2. Interim isolation measures include:

- Sealing risers terminating above grade or less than 3 feet below grade to withstand a pressure of 12 inches of water
- Weather sealing at tank pits to withstand a minimum pressure of 12 inches of water

- Sealing pipelines entering the tank with closure devices (designed to prevent unauthorized removal and capable of withstanding a pressure of 12 inches of water).

Interim requirements between Phase 2 and final tank farm closure were previously identified in RPP-12331. Since the tanks will be isolated and the residual waste will be stabilized the tanks will not be actively storing waste and are not subject to intank monitoring requirements. Periodic monitoring of the tank dome elevations would be maintained pending completion of Phase 2. Therefore, following completion of the Phase 1 activities, the tanks can be reclassified as interim closed and removed from the list of active tanks.

3.0 GROUT DELIVERY/PRODUCTION

Concepts for delivery, production, and placement of grout to stabilize the residual waste and provide bulk tank fill to stabilize the tank void space within the closure demonstration tanks are documented in RPP-12331. That evaluation assumed that Phase 2 would occur directly after Phase 1. That evaluation also did not account for the addition of dry solids to stabilize the waste heel and eliminate free standing liquid. A new evaluation, contained in Appendix B, incorporates new assumptions that dry cement will be required as the initial step for absorption and immobilization of the liquid waste remaining in tank 241-C-106. This requirement is based on the uncertainty in the physical form of the residual waste that will remain in the tank following retrieval and lessons learned from Savannah River Site Tank closures. There is some uncertainty in how effective the dry material will be in absorbing all the liquid, however, the objective of the dry material is to minimize the potential for the wet grout to push the residual waste out to the edge of the tank. The new evaluation also assumes that a two-phase approach will be utilized (i.e., residual waste heel stabilization and bulk tank fill) with a period of time between the implementation of each phase.

The decision criteria used to evaluate the options contained in Appendix E of RPP-12331 included:

- Safety
- Compliance with the technical requirements in the Level 2 Specification (RPP-11094)
- Operability
- Technical risk
- Programmatic risk
- Deployment schedule risk
- Cost.

It is assumed that macroencapsulation will stabilize the residual waste sufficiently to meet the technical requirements in RPP-11094. In the RPP-12331, Appendix E evaluation, compliance is ranked with the technical requirements. Macroencapsulation, microencapsulation, in situ chemical treatment, or a combination of chemical treatment and encapsulation were considered.

Macroencapsulation has been deemed acceptable for residual waste stabilization; therefore, the ability to stabilize the waste in any other way is no longer a discriminating factor and, as such, macroencapsulation is not a decision criterion for the new evaluation contained in Appendix B of

this document. In the RPP-12331, Appendix E evaluation, each option was assigned a programmatic risk based on its ability to obtain regulatory approval. It was subsequently determined that the programmatic risk involved with obtaining regulatory approval for macroencapsulation, microencapsulation, in situ chemical treatment, or a combination of chemical treatment and encapsulation of the residual waste was identical. As such, this risk was determined to be a nondiscriminating factor between the different options and was removed from the decision criteria. The new decision criteria used to evaluate the options contained in Appendix B include:

- Safety
- Operability
- Technical risk
- Deployment schedule risk
- Cost.

For Phase 1, four components to delivery and placement of grout into the tanks for residual waste stabilization were considered in identifying and developing options: (1) dry grout placement in the tank, (2) production and delivery of wet grout mixture to the site, (3) delivery of wet grout mixture to the tank, and (4) wet grout placement/stabilization in the tank. It is assumed that the evaluation and selection of a method of grout production, delivery, and placement for Phase 2 described in RPP-12331 remains unchanged.

The options identified for dry material placement in the tank included the following:

- **Pneumatic delivery into the tank through a single, central riser** – Involves pneumatic introduction of the dry cement through a slick-line to a single riser located in the center of the tank.

- **Hopper delivery into the tank through a single, central riser** – Involves the placement of a hopper over the tanks central riser and gravity dumping the dry cement or dry grout mixture into the tank. The dry material would be transported to the hopper via a super sack® (i.e., commercially available bulk material handling bag) and a crane.

- **Pneumatic delivery into the tank through multiple riser locations** – Involves pneumatic introduction of the dry cement through a slick-line to multiple locations on the tank to attempt to more evenly distribute the dry cement over the bottom of the tank.

- **Hopper delivery into the tank through multiple riser locations** – Involves the placement of a hopper over multiple locations and gravity dump the dry cement or dry grout mixture to attempt to more evenly distribute the dry material over the bottom of the tank. The dry material would be transported to the hopper via a super sack® and a crane.

The options identified for the production and delivery of wet grout to the site (to the tank farm) include the following:

- **Concrete mixer trucks delivering grout to the site** – Involves offsite production of the grout mix and delivery to the site in trucks with capacities of 8 to 10 cubic yards ready for placement into the tank.

- **Onsite centrally located batch plant combined with onsite trucking** – Involves the construction of a centrally located facility designed to support future tank closures. This would be a permanent facility that would require staffing, permitting, and maintenance for future use. Onsite trucks would be used to transport the grout mixture from the batch plant to the tank farm.

- **Portable batch plant located at the tank farm** – Involves setting up a portable batch plant next to or near the 241-C tank farm. The batch plant would be used to mix and produce grout in a batch mode for placement in the tanks.

- **Portable continuous batch/mix plant at the tank farm** – Involves setting up a portable plant designed to produce a continuous mixture of grout for placement in the tanks.

The options identified for the delivery of wet grout mixture to the tank for waste stabilization included the following:

- **Truck delivery to the tank riser** – Involves bringing the concrete mixer trucks into the 241-C tank farm and delivering the grout mixture to the tank riser(s).

- **Pipeline delivery by pumping grout from outside the tank through a slick-line** – Involves placement of a grout pump outside the tank farm fence line and pumping grout to the tank through a pipe or hose located on the ground.

- **Pipeline delivery by pumping grout using a truck-mounted boom pump** – Involves using a pump truck with a long reach boom. For tank 241-C-106, the distance from the tank farm fenceline to the tank is such that the boom truck would need to be located within the gate. The grout feed hopper would be placed outside the fenceline so that the concrete mixer trucks would not be required to enter the radiologically controlled area. For the 241-C farm 200-series tanks, neither the pump truck nor the mixer truck would enter the radiologically controlled area.

Eleven options were considered for placement of grout in the tanks to stabilize the residual waste following dry material introduction. Eight of these options were previously evaluated in RPP-12331. Three additional options were considered including a centrally located rotating nozzle, centrally located distribution lines, and a centrally located cantilevered tremie. Options considered included:

- **Gravity fill with a tremie (hose) from one location in a single lift** – Involves placement of a predetermined amount of grout into the tank through a single, central location to stabilize the residual heel in a single step macroencapsulating the waste between the tank bottom and the emplaced grout.

- **Gravity fill with a tremie from one location in two lifts** – Involves placement of grout into the tank through a single, central location to stabilize the residual heel in two lifts with the intention of sandwiching any residual waste displaced by the first lift with the second lift to macroencapsulate the waste that was not captured within the dry material.

- **Gravity fill with a tremie from one location in multiple lifts** – Similar to the two-lift option with the exception that multiple lifts would be utilized to displace/mix the residual waste that was not captured within the dry material.

- **Gravity fill with a tremie from multiple locations, two or more lifts** – Involves placement of grout into the tank through multiple locations in an attempt to move the residual waste that was not captured within the dry material toward the center of the tank and macroencapsulate the waste.

- **Centrally located rotating nozzle** – Involves placement of the grout through a nozzle, which would have the capability to be aimed horizontal towards the tank wall and rotated through 360°. The grout would be sprayed towards the tank wall and allowed to flow over the residual waste and dry material mixture and macroencapsulate the waste.

- **Centrally located distribution lines, gravity fill** – Similar to the rotating nozzle with the exception that the grout will be introduced via gravity and the distribution lines will not need to be manually manipulated.

- **Centrally located cantilevered tremie, gravity fill** – Similar to distribution lines with the exception that the cantilevered tremie would require manipulation to direct the grout at various locations within the tank.

- **Single point injection using low pressure (approximately 350 lb/in^2)** – Involves injecting grout into the tank through a rotating nozzle with the intent of using the grout stream to mobilize and mix the residual waste and microencapsulate the residual waste that is not captured within the dry material.

- **Multi-point injection using high pressure (approximately 6,000 lb/in^2)** – Involves using the patented Multi-Point Injection™ system with multiple nozzles and high-pressure injection to aggressively mobilize, mix, and microencapsulate the residual waste.

- **In-tank mechanical mixing** – Involves placement of grout into the tank followed by deployment of mechanical mixing equipment (robotics or mechanical mixers) to stir the grout in an attempt to mix the residual waste not captured within the dry material and wet grout material before the grout sets.

- **In-tank mixer pump** – Involves utilizing a recirculating mixer pump (similar in concept to the double-shell tank mixer pumps) to mix the residual waste not captured within the dry material and wet grout material before the grout sets.

Based on the alternative evaluation and ranking described in Appendix B, the grout delivery and placement system selected for waste stabilization of tank 241-C-106 and presented in this report for Phase 1 and Phase 2 comprises the following:

- **Phase 1 Liquid Waste Immobilization** (dry material):
  - Pneumatic delivery from a single/central location. It is recognized that this method will result in uneven distribution of the dry material however placement from a central location will place the majority of the material near the tank center where any liquids or sludge would be expected and the dispersive nature of the delivery method would provide for placement of lesser amounts over the outer edges of the tank bottom.
- **Phase 1 Waste Stabilization** (wet grout):
  - Grout delivery to the site utilizing concrete mixer trucks
  - Delivery of the grout to the tanks by pumping the grout through a slick-line to the tank
  - Gravity placement in the tanks through a single location using a single lift.
- **Phase 2 Bulk Tank Fill**:
  - A continuous batching/mixing plant located just outside the tank farm
  - Delivery of the grout to the tanks by pumping the grout through a slick-line to the tank.

The planned waste retrieval concept for deployment in the 241-C farm 200-series tanks uses the articulated mast portion of the mobile retrieval system being developed for retrieving the waste from tank 241-C-104. This system utilizes a vacuum system to remove waste from the tank and has a 3-inch vacuum tube that extends over the full length of the mast from the pit down to near the bottom of the tank. Following completion of waste retrieval current plans call for abandoning the articulated mast systems in-place. It is assumed that the articulated mast systems would be used to support Phase 1 grouting activities in the 200-series tanks. The articulated mast systems are designed to support the weight of the waste and therefore would be suitable to support the weight of the stabilizing grout. Features to pump grout through the articulated mast could be included in the initial design (a Y and a valve in the discharge line) or retrofitted following retrieval. This concept would rely on the same grout production and delivery concept selected for tank 241-C-106. If design changes or alternative waste retrieval methods are selected for the 241-C farm 200-series tanks, access to the tank would require removal of equipment or installation of a new riser as described in Section 8.0.

4.0 VENTILATION ASSESSMENT

Active ventilation will be required during the Phase 1 and Phase 2 closure operations. Tank 241-C-106 is currently passively ventilated through an existing high-efficiency particulate air (HEPA) filter installed on riser R-15. The proposed ventilation system for the tank 241-C-106 closure (combined Phase 1 and Phase 2) is described in RPP-12331. RPP-12331

states that a 500 ft^3/min portable exhauster would replace the existing 296-P-16 portable exhauster and connect to the existing ductwork.

The purpose of this evaluation is to determine the ventilation requirements, evaluate existing on-site portable exhauster units, and identify a viable option for actively ventilating tank 241-C-106 during both Phase 1 and Phase 2 closure operations. The requirements for the tank 241-C-106 active ventilation system are identified in the tank 241-C-106 ventilation assessment calculation (Appendix C). Based on the results of the calculation, the ventilation system must be capable of the following during wet grout placement:

- Maintaining a minimum airflow of 80 ft^3/min to keep the tank headspace at a negative pressure to allow open riser maintenance and keep the tank headspace free from aerosols and particulates. Doing so will greatly improve conditions that affect the in-tank camera's field of vision.

- Have a demister capable of removing aerosols at the rate of 92 lbm/hr.

For the purposes of this evaluation, it will be assumed that the exhauster utilized to actively ventilate the tanks during retrieval will also be utilized to actively ventilate the tanks during Phase 1 closure activities. It is assumed that the exhauster installed on tank 241-C-106 will remain in place and will not require relocation and startup. Due to the uncertainties with the 241-C farm 200-series tanks waste retrieval schedule, an allowance is included for reinstallation of the portable exhauster to each of the 241-C farm 200-series tanks. Since the portable exhausters would be used during waste retrieval no ventilation duct or inlet filter modifications would be required.

The onsite exhausters identified for potential use and contained in this evaluation are:

- 296-C-006
- 296-P-16
- Portable exhausters POR-004, POR-005, POR-006
- Portable exhausters POR-007, POR-008
- Characterization project operations exhausters (2 total).

A compilation of the ventilation requirements, evaluation of existing onsite portable exhausters, and recommendation for actively ventilating the tanks during closure operations is discussed in the following sections.

4.1 REQUIREMENTS

The following requirements were extrapolated directly from *Tank Closure Fill System for Interim Closure of Five Selected 241-C Farm Tanks Level 2 Specification* (RPP-11094).

- **3.2.1.2.1 Control Gaseous Discharges from Tanks** – The tank closure fill system (TCFS) shall control the vapor space pressure and control emissions to the environment. Control includes monitoring discharges to the environment, comparing monitored values to set limits, and controlling discharges to the limits specified in Section 3.3.6.3. It is anticipated that a Notice of Construction will need to be prepared to obtain air permit approvals from the Washington State

Department of Ecology and Department of Health. The Notice of Construction approval order will indicate the required monitoring.

a. **Air Treatment Requirements**. Air treatment shall include, at a minimum, at least two stages of HEPA filtration. Air inlets to the actively ventilated tank shall also have HEPA filtration, and shall provide a means of passive breathing when active ventilation is shut down. If the tank is passively ventilated, a HEPA breather filter with heated air intake as required shall be provided. Additional effluent treatment (e.g., charcoal filtration) may be required to meet regulatory requirements for other gaseous effluents, to be determined as part of design. Effluent treatment systems shall meet the design standards specified in Section 3.3.1.3, and all HEPA filters shall meet efficiency and testing requirements set forth in Section 13.2.2 of OSD-T-151-00013.

b. **Tank Exhauster Stack Continuous Air Monitor Interlock**. The ventilation system discharge shall include a compliant record sampler and continuous air monitor stack interlock, or other feature to support shutdown of the ventilation system fan in the event of a HEPA filter failure, in accordance with OSD-T-151-00013, Section 13.2.2, and HNF-SD-WM-TSR-006, Limiting Condition for Operation (LCO) 3.1.4.

c. **Flammable Gas Control Requirements**. Sufficient air exchange shall be provided in the SST vapor space, by passive or active ventilation, to prevent the accumulation of flammable gases, in accordance with HNF-SD-WM-TSR-006, LCOs 3.2.2 and 3.2.3 if this requirement is still applicable following waste retrieval.

- **3.2.1.2.2 Control Tank Structure Temperature** – The TCFS shall control the tank structure temperatures to prevent structural damage to the tanks. The tank temperature controls include design and operation of the ventilation system, selection and control of the waste stabilization and fill material formulations, and process controls.

  a. **Design Temperature Limits – Tank 241-C-106**
     - Maximum of 250 °F dome temperature
     - Maximum of 10 °F for through-wall temperature gradient.

  b. **Design Temperature Limits – 241-C Farm 200-Series Tanks**
     - Maximum of [TBD-RPP-11314] °F dome temperature
     - Maximum of [TBD-RPP-11314] °F vapor space temperature
     - Maximum of [TBD-RPP-11314] °F tank walls and bottom temperature
     - Maximum of [TBD-RPP-11314] °F for through-wall temperature gradient.

- **3.2.1.2.3 Control Tank Vapor Space Pressure** – The TCFS shall control the vapor space pressure in the tank within the following specific design limits to prevent structural damage to the tank. Control may include monitoring vapor space pressure, comparing monitored values to set limits, and maintaining vapor space pressure within the set limits.

  a. **Design Vapor Space Pressure Limits – Tank 241-C-106**
     - Minimum Pressure: -9 in. wg
     - Maximum Pressure: +60 in. wg

b. **Design Vapor Space Pressure Limits – 241-C Farm 200-Series Tanks**
   - Minimum Pressure: [TBD-RPP-11315] in. wg
   - *Maximum Pressure:* [TBD-RPP-11315] in. wg.

- **3.2.4.1 Natural Environments**

  a. **Natural Environments**. The TFCS shall be designed for the natural environmental conditions specified in TFC-ENG-STD-06.

  b. **Natural Phenomena Hazards**. The TFCS shall be designed to withstand the natural phenomena hazards conditions specified in TFC-ENG-STD-06.

- **3.2.5 Transportability** – Contractor-furnished equipment shall be designed to be transportable and be compatible with the *Hanford Site Hoisting and Rigging Manual* (DOE-RL-92-36)

- **3.2.6 Flexibility and Expansion** – The TFCS design shall consider features that allow for operational flexibility between tank closures.

- **3.3.1.3 Air and Gas Treatment System Design** – The TFCS ventilation subsystems and connecting ductwork shall be designed in accordance with the performance and design requirements of ANSI/ASME N13.1, ANSI/ASME N509, ANSI/ASME N510, and ANSI/ASME AG-1.

- **3.3.3 Nameplates, Product Markings, and Labels** – New equipment and/or modifications to existing equipment shall be labeled in a standardized format in accordance with the tank farm labeling program as specified in HNF-IP-0842, Volume 2, Section 6.1, Rev. 1; WAC 173-303-395(6); and WAC 173-303-640(5)(d).

- **3.3.5 Equipment Standardization** – The TFCS design and equipment selection shall incorporate (as practical) standardization of like-function components and consider documented performance history from use in similar environments.

- **3.3.6.3 Environmental Safety** – The TFCS shall be designed to protect the public and environment in accordance with the requirements of this section.

  c. **Non-Radioactive Airborne Emissions**. The system shall be designed to comply with the non-radioactive airborne emissions requirements contained in "General Regulation for Pollution Sources" (WAC 173-400) and "Controls for New Sources of Toxic Air Pollutants" (WAC 173-460)

  d. **Radioactive Airborne Emissions**. The system shall be designed to comply with radioactive airborne emissions requirements contained in "Radiation Air Emissions Program" (WAC 246-247)

  e. **Radiation Protection of the Public and Environment**. The system shall incorporate design features that limit the combined radioactive ambient airborne emissions from all River Protection Project facilities in compliance with "NRC Standards for Protection Against Radiation" (10 CFR 20) and WAC 246-247. Radioactive airborne emissions from other Hanford Site major facilities shall be considered when designing the system to be in compliance with HNF-IP-0842, Volume 6, Section 1.7.

- LCO 3.1.4, "Ventilation Stack Continuous Air Monitor (CAM) Interlock Systems": Active ventilation in tank 241-C-106 would require continuous air monitors as long as the cascade line is open. (It may be applicable at all times depending on the safety basis controls in place after the tank cleanout activities have been completed.)

- LCO 3.2.2, "SST Ventilation Systems – Active": Active ventilation in tank 241-C-106 is considered equipment important to safety as long as the cascade line is open. (It may be applicable at all times depending on the safety basis controls in place after the tank cleanout activities have been completed.)

4.2 EVALUATION

4.2.1 296-C-006 Ventilation System

The 296-C-006 ventilation system was designed for use during tank 241-C-106 waste retrieval under Project W-320. It provides a minimum once-through flow for tank cooling and a recirculation flow loop, which was to provide de-fogging of the dome space during sluicing. The 296-C-006 exhaust fan is capable of 360 ft^3/min flow with a recirculation flow rate of up to 860 ft^3/min. The recirculation portion of the system was used to provide the needed tank cooling during the sluicing campaign. The exhaust portion of the system maintained the required negative pressure in the tank and flammable gas dilution during the sluicing operations.

During operation, the 296-C-006 ventilation system did not provide adequate flow to allow for large riser maintenance activities in the tank (RPP-5687). The 296-C-006 ventilation system is currently located in the C farm and has been placed in a lay-up but could be placed back into service. Charcoal filters were designed for the system but never installed. Also, components have been removed from the 296-C-006 ventilation system as they have been needed for other equipment.

For this system to be a viable option for ventilating the tanks during closure operations, a series of events must occur: (1) the magnitude of components missing would have to be assessed, (2) the missing components would have to be replaced, (3) a gas effluent monitoring system (GEMS) would have to be installed, and (4) the system would have to be started up.

4.2.2 296-P-16 Ventilation System

The 296-P-16 exhauster is currently located in the C farm near tank 241-C-106 and was shut down due to radioactive air emissions compliance issues. Upgrades, repairs, and maintenance would be required for this exhauster to meet the applicable design requirements and be a viable option for use during closure operations.

4.2.3 Portable Exhausters POR-004, -005, and -006

Portable exhausters POR-004, POR-005, and POR-006 are identical systems that were fabricated to support saltwell pumping. The nominal flow capacity of the exhausters is 500 ft^3/min. During periods where the exhausters were not being utilized, they were stored and maintained per the criteria established in *Portable Exhausters POR-004-SKID B, POR-005-SKID C, POR-006-SKID D Storage Plan* (HNF-SD-WM-RPT-302). The exhausters are also subject to

preventative maintenance programs, routine component calibrations, HEPA filter aerosol tests, and system interlock functional tests. These exhaust systems are not equipped with a demister.

Currently portable exhauster POR-004 is scheduled to support retrieval of tank 241-S-112 and POR-005 and 006 are installed at the 244-AR vault.

For portable exhauster POR-004, POR-005, or POR-006 to be a viable option for supporting the closure operations, in-line demisters would have to be designed and fabricated to be installed upstream of the exhauster units. Coordination with key personnel for ongoing projects where these exhausters are required would also be needed.

4.2.4 Portable Exhausters POR-007 and -008

Portable exhausters POR-007 and POR-008 are identical systems that were fabricated to support saltwell pumping. The nominal flow capacities of the exhausters are 1,000 ft^3/min. These exhausters consist of a heater section, a cartridge type prefilter, and two HEPA filters in series. During periods where the exhausters were not being utilized, they were stored and maintained per the criteria established in HNF-SD-WM-RPT-302. The exhausters are also subject to preventative maintenance programs, routine component calibrations, HEPA filter aerosol tests, and system interlock functional tests. Each of the exhausters is equipped with its own demister.

To become compliant for radioactive air emissions, portable exhauster POR-007 would require the installation of a GEMS. Portable exhauster POR-008 is currently having a GEMS installed. Portable exhauster POR-007 is currently installed in the 241-SY tank farm. After the upgrades to portable exhauster POR-008 are complete, it will be transported to the 241-C tank farm and connected to tank 241-C-106 for the waste retrieval operations.

The only requirement for either of these portable exhauster units to be a viable option for closure operations would be the installation of a GEMS on portable exhauster POR-007.

4.2.5 Characterization Project Operations Portable Exhausters

The characterization project currently has two portable exhausters. Each are identical with the exception that one requires the installation of a continuous air monitor interlock. Each exhauster has a nominal flow capacity of 200 ft^3/min which are controlled by internal electronics and set points that could be modified to accommodate up to around 1,000 ft^3/min. To date, the characterization project has approval to use the portable exhausters for in core sampling and also for support of saltwell pumping. The exhausters are not equipped with a demister, but have heaters installed upstream of the HEPA filter banks. Both exhausters are recalled for preventative maintenance every 6 months.

4.3 RECOMMENDATION

For Phase 1 interim closure of tank 241-C-106, it is recommended that portable exhauster POR-008 remain in place following tank waste retrieval and be utilized as-is. For Phase 1 interim closure of the 241-C farm 200-series tanks, it is recommended that the portable exhausters used to support waste retrieval be left in place and utilized as-is. At the completion of waste heel stabilization in tank 241-C-106, portable exhauster POR-008 could be moved and

utilized for interim closure of the 241-C farm 200-series tanks depending on other project needs for exhausters. Utilization of portable exhauster POR-008 would minimize the schedule impacts of upgrading and moving another existing onsite portable exhauster or procuring a new exhauster for this activity. Additionally, if the exhauster was to continue operation between the retrieval and closure operations of tank 241-C-106, startup costs could be mitigated.

Ventilation system issues that will need to be addressed during detail design include the removal of particulates during dry material placement and accommodation of the air stream from the dry material delivery system. These issues have been considered in recommending utilization of the POR-008 during the placement of dry grout material in the tank. As discussed in the ventilation assessment calculation (Appendix C), the pre-filter will capture nearly all of the cement particulates drawn through the ventilation system. Additionally this system operating at 1,000 cfm should accommodate the airflow associated with pneumatic delivery of the dry grout material to the tank. Additionally, the heater can be used to raise the relative humidity and reduce concerns of moisture and cement reacting on the prefilter. Particulate loadings, operating strategies for replacement of the prefilter, and delivery system operating parameters (i.e., airflows and durations) will need to be considered during detail design.

Based on the potential time frame that could occur between Phase 1 and Phase 2 closure operations for the five selected tanks, it is unlikely that ventilation system for Phase 1 will remain in place. An evaluation should be performed to reassess the best alternative for ventilating the tanks during Phase 2 closure operations at that time.

5.0 VOID SPACES

Final tank closure will be performed on a tank farm basis. Closure of a tank farm will be done after all the tanks within a tank farm have been stabilized in accordance with Phase 2 interim closure requirements. Final closure includes dispositioning of the single-shell tank (SST) ancillary equipment and placement of a closure surface barrier. The closure barrier consists of multiple layers of earthen materials placed over the tank farm and represents a significant structural overburden. The closure barrier, the tank stabilization fill, and the stabilization of ancillary and in-tank equipment serve to limit the amount of surface water reaching the stabilized residual waste and reduce the potential for intrusion. Void spaces within the closed SST system that could result in damage to the closure surface barrier due to subsidence or present a direct pathway for water to the stabilized waste must be addressed to ensure that the long-term performance of the closed SST system is not adversely affected. The potential void spaces within the closed SST system are listed below and discussed in the following text:

- Within the tank fill material
- Between the tank and the fill material
- Within the risers not in pits
- Within the annular space between in-tank equipment and the riser
- Within the in-tank equipment extending into the stabilized waste
- Within the in-tank equipment extending only into the bulk tank fill.

5.1 VOIDS WITHIN THE TANK FILL MATERIAL

The fill material for both Phase 1 and Phase 2 interim closure operations is specified to be a flowable, self-leveling, non-shrinking, and self-compacting grout. The residual waste stabilization grout (Phase 1) will be placed in a single lift through a central or near-central riser, encapsulating the waste between the bottom of the tank and the emplaced grout. Bulk tank fill and hard cap fill (Phase 2) will be placed in a number of lifts as required to satisfy tank structural and thermal limitations. Successive lifts may be placed once the grout in the prior lift has set. Given the specified fill material properties and the fill process, voids within the tank fill are expected to be minimal and require no further consideration.

5.2 VOIDS BETWEEN THE TANK AND THE FILL

Voids between the tank and the fill could include those caused by shrinkage of the grout fill material and incomplete tank fill. Shrinkage of the grout could result in void space at the tank walls and roof. The void space can be limited by either fill process or use of a non-shrinkage grout formulation. As the majority of shrinkage will have occurred when the grout sets, voids at the tank walls will be partially alleviated by placement of the successive grout lift. Void space at the roof of the tank can be limited by specifying the final lift as a small volume lift. Given that the Level 2 Specification (RPP-11094) specifies the use of a non-shrinkage grout and the placement of a hard cap grout at the top of the tank, void space due to grout shrinkage is expected to be insignificant.

Void spaces due to incomplete tank fill can result from either trapped air spaces or an uneven surface of the emplaced grout. Tank 241-C-106 has a domed tank roof with the grout introduced through an existing central or new, near-central riser. The surface of the grout will likely be conical with the apex at the point of introduction. The slope of the grout surface will be minimized with the use of the specified self-leveling grout, and is not expected to result in void spaces along the domed surface of tank 241-C-106. The existing central riser extends into the tank headspace by approximately 3 inches, creating a potential area for trapped air. Conceptually, a tool would be inserted in the riser that would allow the trapped air to escape and the hydraulic head of the grout in the riser would force the grout into the airspace, resulting in complete filling of the tank.

The 241-C farm 200-series tanks have flat roofs. Conceptually, trapped air due to the riser extending into the tanks' headspace will be displaced by the grout as described for tank 241-C-106. Due to the conically shaped surface of the emplaced grout and the flat roof of the 200-series tanks, there is a potential that air would be trapped in the corner of the tank, resulting in incomplete tank fill. The magnitude of this potential void space will need to be addressed during detail design when the self-leveling properties of the grout fill can be quantified.

5.3 VOIDS WITHIN RISERS NOT IN PITS

The void spaces addressed in the following sections are blind spaces between equipment and the tank risers.

5.3.1 Tank 241-C-106

Tank 241-C-106 has five risers that are not within a pit:

- **Riser R-1**: 4-inch diameter with an installed retractable plummet
- **Riser R-2**: 12-inch diameter with attached ventilation ductwork
- **Riser R-7**: 12-inch diameter used for in-tank imaging system
- **Riser R-8**: 4-inch diameter with an installed temperature probe
- **Riser R-14**: 4-inch diameter with an installed temperature probe.

Risers R-1, R-7, and R-2 have void volumes of 1.3, 11.3, and 10.9 ft^3, respectively. Both risers R-1 and R-2 have mounted equipment that would need to be removed for the placement of the closure surface barrier. It is assumed that the in-tank imaging system would be removed for use on other tank operations. After removal of the mounted equipment, grout can be poured into the open risers to the top of the riser. Filling riser R-1 with grout may not be justified given that this riser does not present a water pathway to the stabilized residual waste and the small void volume of riser R-1 presents a limited potential subsidence affect on the surface closure barrier.

The temperature probes within risers R-8 and R-14 present potential direct water pathways to the stabilized residual waste. The temperature probe is a 2-inch-diameter pipe extending to near the bottom of the tank. There are three options for eliminating this potential direct pathway that will be decided during detail design; remove the temperature probe before bulk tank fill, pour grout into the temperature probe, or cut the pipe off just inside the tank dome and allow the severed section to fall into the tank. Removal of the temperature probe (or in tank disposal) will leave an empty riser having a void volume of approximately 1.2 and 0.7 ft^3 for risers R-8 and R-14, respectively. Pouring grout into the temperature probe or cutting the probe off just below the tank dome would eliminate the direct water pathway to the stabilized residual waste and would result in an annular void space of approximately 0.9 and 0.4 ft^3 for risers R-8 and R-14, respectively. Due to the small void volume of either the empty risers or the annular space, the potential subsidence affect on the surface closure barrier may not justify grout filling.

5.3.2 241-C Farm 200-Series Tanks

The four 241-C farm 200-series tanks each have four risers that are not within a pit:

- **Riser R-5**: 4-inch diameter with either a breather filter or a retractable plummet installed
- **Riser R-6**: 12-inch diameter with an installed temperature probe except for 241-C-204 which is empty
- **Riser R-7**: 12-inch diameter used for in-tank imaging system
- **Riser R-8**: 4-inch diameter with either a breather filter or a retractable plummet installed.

Risers R-5 and R-8 have a void volume of 1.2 ft^3. Riser R-7 has a void volume of 10.6 ft^3. Both risers R-5 and R-8 have mounted equipment that would need to be removed for the placement of the closure surface barrier. It is assumed that the in-tank imaging system would be removed for

use on other tank operations. After removal of the mounted equipment, grout can be poured into the open risers to the top of the riser. Filling risers R-5 and R-8 with grout may not be justified given that these risers do not present a water pathway to the stabilized residual waste and the small void volumes present a limited potential subsidence affect on the surface closure barrier.

The temperature probes within riser R-6 presents potential direct water pathways to the stabilized residual waste. The temperature probe is a 2-inch-diameter pipe extending to near the bottom of the tank. There are two options for eliminating this potential direct pathway that will be decided during detail design; remove the temperature probe before bulk tank fill or pour grout into the temperature probe. Pouring grout into the temperature probe would eliminate the direct water pathway to the stabilized residual waste and would result in an annular void space of approximately 10.6 ft^3. The void space in either the annular space or the empty riser can be stabilized by pouring in grout to the top of the riser.

5.4 VOIDS WITHIN RISERS IN PITS

5.4.1 Tank 241-C-106 Sluice Pit

There are two risers within the tank 241-C-106 sluice pit:

- **Riser R-3**: 12-inch diameter with installed sluicer assembly
- **Riser R-4**: 4-inch diameter with installed recirculating dip leg.

Risers R-3 and R-4 have void volumes of 6.3 and 0.6 ft^3, respectively. Neither of these pieces of in-tank equipment present a potential direct water pathway to the stabilized waste as they do not extend to the stabilized waste. Due to the small void volume of riser R-4, the potential subsidence affect on the surface closure barrier may not justify grout filling. Grout will pour into the sluicer assembly when the sluice pit is grout filled, leaving an annular void volume between the sluicer and riser R-3 of approximately 5.3 ft^3. Riser R-3 is 8 feet long. The riser extension into the tank headspace is 12 inches, the tank dome is 15-inches thick, and the floor of the sluice pit is approximately 18-inches thick. This leaves approximately 4.25 feet of the riser between the bottom of the pit floor and the tank dome that is exposed to the soil with a corresponding void volume of 2.8 ft^3. The potential subsidence affect on the surface closure barrier may require grout filling. Although requirements for filling these void spaces have not been specified, it is reasonable to assume that methods could be developed for injecting grout into these spaces.

5.4.2 Tank 241-C-106 Heel Pit

Riser R13 is the only riser within the heel pit. This riser is planned for use by the closure retrieval project which will leave a slurry pump in place. It is assumed that the void space between the slurry pump and the riser will be similar in design to that in riser R-9 and will not present a water pathway to the stabilized residual waste. Riser R-13 is a 5-foot long, 12-inch diameter riser with a void volume of 4.0 ft^3. The tank dome is 15 inches thick and the floor of the heel pit is approximately 18 inches thick. This leaves approximately 2.25 feet of the riser between the bottom of the pit floor and the tank dome that is exposed to the soil with a corresponding void volume of 1.8 ft^3. Due to the small void volume, the potential subsidence affect on the surface closure barrier may not justify grout filling.

Due to the construction details of the riser, there is a small void space that does not communicate with either the tank or the pit (see CE-SK-02-111 in Appendix F of RPP-12331). This small void volume would have a negligible impact to the surface closure barrier and would not need to be stabilized.

5.4.3 Tank 241-C-106 Pump Pit

There are three risers in the tank 241-C-106 pump pit:

- **Riser R-5**: 4-inch diameter with an installed shield plug
- **Riser R-6**: 12-inch diameter with a sluicer assembly assumed to be installed and abandoned by the closure retrieval project
- **Riser R-9**: 36-inch diameter with an installed slurry pump.

The shield plug in riser R-5 will be removed and grout will be poured into the riser when the pit is filled with grout. Riser R-6 will have the same remaining void space as riser R-3 which also contains a sluicer assembly.

Riser R-9 has a void volume of approximately 43.4 ft^3 and is approximately 6.1 feet in length. The riser extension into the tank headspace is 12 inches, the tank dome is 15 inches thick, and the floor of the sluice pit is approximately 18 inches thick. This leaves approximately 2.4 feet of the riser between the bottom of the pit floor and the tank dome that is exposed to the soil with a corresponding void volume of 17 ft^3. The potential subsidence affect on the surface closure barrier may require grout filling. Although requirements for filling these void spaces have not been specified, it is reasonable to assume that methods could be developed for injecting grout into these spaces.

5.4.4 Jet Pump Pit on 200-Series Tanks

The jet pump pit has two 12-inch diameter risers, R-9 and R-10. Both risers R-9 and R-10 are 4.3-feet in length with a void volume of 3.4 ft^3. Riser R-9 in tank 241-C-203 is empty. The other tanks have an eductor installed in riser R-9. Tank 241-C-204 has a pump installed in riser R-10. Riser R-10 is empty for the other tanks. These risers are not exposed to the soil and will be fully encapsulated with grout when the jet pump pit and associated piping is filled with grout.

5.5 OTHER VOIDS

Tank 241-C-106 has a 42-inch-diameter manhole that is partially shadowed by the sluice pit. Given that the tank dome is 15-inches thick and the inset of the manhole cover is 3 inches, the void volume is 9.6 ft^3. The potential subsidence affect on the surface closure barrier should be further evaluated during detail design.

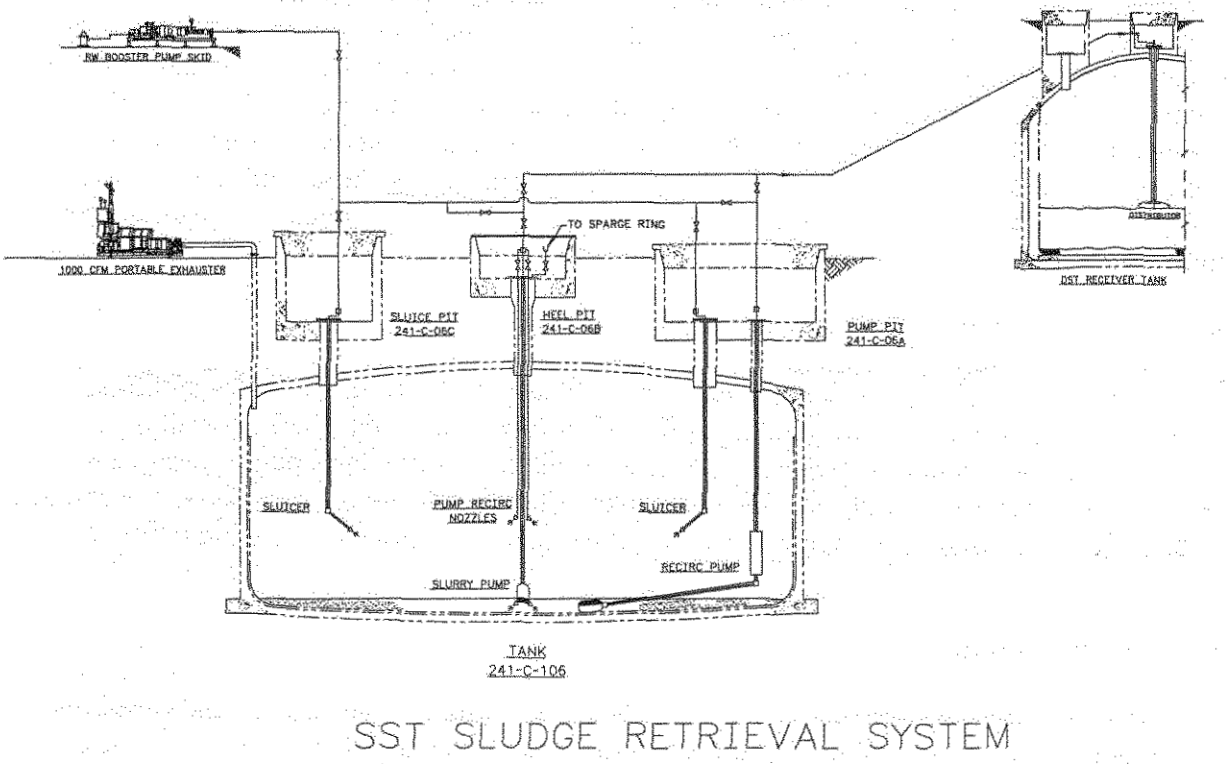
The 241-C farm 200-series tanks each have a 42-inch manhole in the approximately 10-inch-thick tank cover slab. The manhole is not inset into the cover slab. The associated void volume is 8.0 ft^3. The potential subsidence affect on the surface closure barrier should be further

evaluated during detail design. Although requirements for filling these void spaces have not been specified, it is reasonable to assume that methods could be developed for injecting grout into these spaces.

6.0 RETRIEVAL INTEGRATION

The current approach for waste retrieval from tank 241-C-106 involves deployment of a modified sluicing system (Figure 1). Based on preliminary engineering information from the tank 241-C-106 retrieval project the modified sluicing system will be similar to the waste retrieval sluicing system that was previously installed in tank 241-C-106 as a part of Project W-320. The planned enhanced sluicing system will use two sluicing nozzles instead of the one nozzle used previously. The current plan also includes upgrading an existing onsite portable exhauster and installing it for use in providing active ventilation during waste retrieval activities. This portable exhauster could also be used during waste stabilization activities. Following completion of the waste retrieval activities the retrieval project plans to abandon all in-tank equipment in place. Void spaces associated with abandoning waste retrieval equipment are discussed in Section 5.0.

Figure 1. Tank 241-C-106 Waste Retrieval Concept



The existing heel pump in riser R-13 will be removed and a new slurry pump will be installed. Retrieval efforts will remove equipment and install a sluicer in riser R-6 and a slurry pump in riser R-13. The existing sluicer in riser R-3 will be reused. Riser R-15 will remain as the air inlet riser. Riser R-7 will continue to be used for camera access. Riser R-4 will serve as a

second or alternate location for tank volume measurement. Riser R-2 will be used for ventilation and riser R-1 will be used for tank level measurements.

The retrieval system will require installation of equipment in all three of the tank 241-C-106 pits. These pits will be decontaminated and a spray on liner applied. The pit cover blocks will be replaced with new modified pit covers made of plate steel. Holes will be provided in the pit covers for the over-ground transfer lines.

Current plans for retrieving waste from the four 241-C farm 200-series tanks involve deployment of a vacuum technology that uses an articulated mast system. The articulated mast system is one of the components of the mobile retrieval system that will be used to retrieve waste from tank 241-C-104. Current plans require the use of four risers in each of the 241-C farm 200-series tanks: one for the articulated mast system (likely Riser 7), two for ventilation, and 1 for a camera. Retrieval plans also include the use of a 500 ft^3/min portable exhauster to provide for ventilation of the 200-series tanks during waste retrieval operations.

Specific areas of integration that could serve to facilitate interim closure and reduce overall project costs include:

- Integration of space and access within the tank farm. It is anticipated that waste stabilization activities will closely follow waste retrieval activities. Access requirements for the delivery and placement of grout in the tanks will require access to the tank for installation of a new riser, and routing of the grout slickline before initiating grout placement operations. Integration of access and space requirements will require continued integration and definition as the retrieval and closure designs progress.

- Integration of waste retrieval and closure tank preparation. This function should consider the combined in-tank equipment removal needs for both waste retrieval and closure. Impacts to the central waste complex should also be addressed.

- Continued use of the ventilation system installed for waste retrieval. Use of the portable exhauster installed on tank 241-C-106 and the 241-C farm 200-series tanks could be utilized to support interim closure of tank 241-C-106 and the four 241-C farm 200-series tanks. This would avoid having to procure a new exhauster or modify an existing one to support interim tank closure. There is a need to have an integrated ventilation team to ensure integration and utilization of exhausters between tanks for waste retrieval and closure.

- Reuse of cameras installed in the tanks to monitor waste retrieval. RPP-12331 includes costs for procuring and installing cameras in the tanks to visually monitor waste stabilization. The cameras installed for retrieval could be reused to monitor the placement of grout.

- Based on further development of the interim tank closure concept there may be an opportunity to integrate cover plate features for the closure program into the new cover plates that will be fabricated in support of waste retrieval efforts.

7.0 INTERIM CLOSURE THERMAL ANALYSIS

Steady state thermal analyses were performed to provide a scoping level indication of the potential thermal conditions. It is recognized that the heat of hydration is time dependent however, a transient analyses would be necessary to evaluate these time dependent effects. Transient analyses were beyond the scope of this engineering report.

A thermal analysis was conducted to investigate the effects of decay heat from the residual waste and heat of hydration from Phase 1 and Phase 2 grouting. A steady state thermal model was developed to evaluate temperature profiles following placement of the waste stabilization grout. Additional calculations were performed to investigate limitations on lift height as a result of the heat of hydration. The details of the thermal calculations are provided in Appendix C.

The steady state analysis results for the Phase 1 indicate that the maximum predicted tank temperatures will be approximately 120 °F at the bottom of the tank. The calculation was performed as a steady state assuming continual heat generation from the waste residuals (assumed at 360 ft^3) and from the cement in the stabilizing grout. From a steady state perspective this is conservative because the heat evolved from the hydration of the grout will occur shortly after placement in the tank and will then taper off. The thermal load from the decay heat is larger than the heat of hydration from the assumed residual waste stabilization grout layer.

To evaluate the potential thermal effects associated with placing a large grout pour into the tanks and determine whether measures would need to be taken during Phase 2 to limit temperatures, a conservative steady state analysis was conducted. This analysis was done to evaluate the potential steady state temperature in the Phase 2 grout as a result of the hydration reaction resulting from filling tank 241-C-106 with approximately 17 feet of grout in a single pour. The results of this analysis indicate that temperatures within the grout would exceed temperature limits in the Level 2 Specification and that thermal effects need to be considered during the Phase 2 tank closure design. This can be accomplished by tailoring the grout formulation to limit the heat of hydration, limiting the lift height, providing cooling to maintain acceptable temperatures, or by a combination of these efforts.

8.0 TANK ACCESS

RPP-12331 assumes that no new tank risers would be installed and that grout placement would occur through one of the existing tank risers. For both tank 241-C-106 and the 241-C farm 200-series tanks this required the removal of long-length retrieval equipment from the risers. The removal and disposition of in-tank equipment was included in the cost estimate developed for RPP-12331. Inherent in the estimated cost of removing the retrieval equipment was an assumption that mock up experience in the installation and removal of equipment would be gained through the planned cold testing of the articulated mast system. Mock up and planning for removal of the pump from tank 241-AW-104 involved considerable resources. The switch from the articulated mast system to the enhanced sluicing system for retrieval reduces or eliminates the potential benefits to the closure program from the cold testing efforts. The impact of this change on the cost for equipment removal has not been assessed.

Review of the articulated mast system to be deployed in the 241-C farm 200-series tanks indicated that the mast would be suitable for use in placement of the Phase 1 grout. Use of the articulated mast system for placement of Phase 1 grout in the 241-C farm 200-series tanks would eliminate the access problems and the need to consider removing in-tank equipment or installation of new risers. Use of the articulated mast system would not be suitable for Phase 2 grouting and options for obtaining tank access would need to be evaluated as a part of the Phase 2 closure design. In the event that design changes preclude the use of the articulated mast system for grout placement, new risers or equipment removal would be required.

Subsequent to the release of RPP-12331 a technique for installing a new riser on an SST was identified by the Tank Farm Vadose Zone Group. This technique utilizes existing onsite equipment (rotary drill rig and guzzler vacuum truck) to install a tank riser. The guzzler truck is used to vacuum soil and set a 24-inch-diameter steel casing down to the tank dome. The drill rig is then used to cut a shallow groove 18 inches in diameter in the top of the dome and an 18-inch-diameter casing is placed into the groove and grouted to provide a seal. A retainer is then installed in the portion of the tank dome that is to be cored. Next the dome is core drilled and the retained concrete plug is removed. The last step is to set a 12-inch-diameter riser inside the 18-inch-diameter casing and grout it in place. This technique was successfully demonstrated in 1995/1996 at the 100-C reactor area (WHC-SD-WM-ER-557).

The estimated cost for installation of a new riser using this technique was recently developed by the Tank Farm Vadose Zone Group and was compared against the cost estimate developed for removing the retrieval equipment in RPP-12331. Both of these estimates included common planning functions (i.e., plant forces work review, notice of construction) that would have to be completed for tank closure with or without the installation of a new riser. When the common planning functions were removed from the new riser estimate the cost was $280,000 per riser. This compares to a cost of $225,000 estimated for removal of the articulated mast system in RPP-12331. Based on the uncertainties associated with equipment removal, installation of a new riser in tank 241-C-106 is selected for the purposes of this engineering report. A detailed review and work planning effort is recommended during detail design to evaluate and compare new riser installation versus equipment removal.

9.0 REFERENCES

10 CFR 20, "NRC Standards for Protection Against Radiation," *Code of Federal Regulations*, as amended.

ANSI/ASME AG-1, 1997, *Code on Nuclear Air and Gas Treatment*, American National Standards Institute, Washington, D.C.

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APPENDIX A
COST AND SCHEDULE DETAIL

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CONTENTS

A1.0 INTRODUCTION A-1

A2.0 COST ESTIMATE SUMMARY A-1

A3.0 PROJECT SCHEDULE A-1

A4.0 ESTIMATING ASSUMPTIONS AND EXCLUSIONS A-1

A5.0 COST ESTIMATING INPUT SHEETS A-2

ATTACHMENT

A1 COST ESTIMATING INPUT SHEETS A1-i

FIGURE

A.1. Phase 1 Interim Closure Project Schedule A-5

TABLE

A.1. Phase 1 Interim Closure Cost Estimate Summary A-3

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APPENDIX A
COST AND SCHEDULE DETAIL

A1.0 INTRODUCTION

The planning/study cost estimate in this appendix was developed from the estimate provided in the Basis of Design report (RPP-12331) and modified by the evaluations described in main sections of this engineering report. The schedule and estimate reflect performing only the Phase 1 activities associated with interim tank closure. The U.S. Department of Energy brackets this stage of estimate within the accuracy of -30% to +60%.

The estimate was prepared using activity-based cost methodology. It is important to note that the cost estimate covers only those work elements described in the Cost Estimating Input Sheets and is not a Total Project Cost.

A2.0 COST ESTIMATE SUMMARY

A summary of the cost estimate for Phase 1 interim closure of tank 241-C-106 and the four 241-C farm 200-series tanks is provided in Table A.1 with a breakout by work breakdown structure element.

A3.0 PROJECT SCHEDULE

A project schedule was developed to support development of the planned approach to executing activities for Phase 1 interim closing the five tanks. The project schedule is provided as Figure A.1. It is recognized that the current schedule for waste retrieval of the four 241-C 200-series tanks does not support interim closure in the timeframe shown.

A4.0 ESTIMATING ASSUMPTIONS AND EXCLUSIONS

Several major estimating assumptions and exclusions have been made for the development of this estimate. Major estimating assumptions include a method of accomplishment employing several contracting strategies. These include procurement vendors, construction management and construction forces services, architect/engineer design and engineering services, and CH2M HILL Hanford Group, Inc. plant forces staffing. It has been assumed that the overall management of the project and the individual contracting of vendor services and materials for the project will be performed by CH2M HILL Hanford Group, Inc. More specific assumptions can be found in the individual cost estimating input sheets. Major exclusions from the estimate are the estimates for work breakdown structure elements:

- Project Management
- Project Definition
- Detailed Design

- Readiness Review
- Nuclear Safety & Licensing.

These estimates are being prepared and compiled by the Closure Project outside of this engineering report. Additionally, the costs for Phase 2 interim closure are not included in the cost estimate. No CH2M HILL Hanford Group, Inc. fee is included in the cost estimate. Also, the monitoring and surveillance activities that would occur between Phase 1 and Phase 2 are not included in the cost. It is important to note that this estimate is not a total project cost and does not include a number of activities associated with the project (i.e., waste retrieval). The intent of the cost estimate in this engineering report is to provide a cost estimate for the field activities associated with interim tank closure that could be used as an input to improve the basis of the overall project cost estimate.

A5.0 COST ESTIMATING INPUT SHEETS

The cost estimating input sheets in Attachment A1 are organized by work breakdown structure number and contain the basis for the cost estimate at the detail level.

Table A.1. Phase 1 Interim Closure Cost Estimate Summary (2 Sheets)

WBS Number	Title	Base Est. FY02 dollars	Escalation to FY04 at 4.45%	Contingency at 40%	Total Estimated Cost
5.8.6.6.06.9	Interim Close C-106 Tank				
5.8.6.6.06.9.1	Procurement -C-106				
5.8.6.6.06.9.1.1	Contract Const. Forces	$7,455	$332	$3,115	$10,901
5.8.6.6.06.9.1.2	Contract Grouting Svcs	$16,396	$730	$6,850	$23,976
5.8.6.6.06.9.1.3	Tank Risers	$32,000	$1,424	$13,370	$46,794
	5.8.6.6.06.9.1 Subtotal C-106	$55,851	$2,485	$23,335	$81,671
5.8.6.6.06.9.2	Construction - C-106				
5.8.6.6.06.9.2.1	Const. Mgmt	$49,700	$2,212	$20,765	$72,676
5.8.6.6.06.9.2.2	Acceptance Insp.	$24,850	$1,106	$10,382	$36,338
5.8.6.6.06.9.2.3	Grout delivery, prep, product.	$43,000	$1,914	$17,965	$62,879
5.8.6.6.06.9.2.5	Pre Grouting Tank Prep	$406,527	$18,090	$169,847	$594,464
5.8.6.6.06.9.2.6	Engineering Support	$53,531	$2,382	$22,365	$78,278
	5.8.6.6.06.9.2 Subtotal C-106	$577,608	$25,704	$241,325	$844,636
5.8.6.6.06.9.3	Tank Farm Ops Support-C-106				
5.8.6.6.06.9.3.1	Ops Mgmt and Planning Suppt	$122,292	$5,442	$51,094	$178,828
5.8.6.6.06.9.3.2	Construction Support	$24,600	$1,095	$10,278	$35,973
5.8.6.6.06.9.3.3	Ops Training	$20,040	$892	$8,373	$29,304
5.8.6.6.06.9.3.4	Stabilize Heel C-106	$99,338	$4,421	$41,503	$145,262
5.8.6.6.06.9.3.5	Restore Surf/Demob	$117,475	$5,228	$49,081	$171,784
5.8.6.6.06.9.3 Subtotal C-106		$383,745	$17,077	$160,329	$561,150
5.8.6.6.06.9 Tank C-106 Subtotal		$1,017,204	$45,266	$424,988	$1,487,457
5.8.6.6.13.9	Interim Close C-200s Tanks				
5.8.6.6.13.9.1	Procurement C-200s				
5.8.6.6.13.9.1.1	Contract Const. Forces	$8,418	$375	$3,517	$12,310
	5.8.6.6.13.9.1 Subtotal C-200s	$8,418	$375	$3,517	$12,310
5.8.6.6.13.9.2	Construction C-200s				
5.8.6.6.13.9.2.1	Const. Mgmt	$56,120	$2,497	$23,447	$82,064
5.8.6.6.13.9.2.2	Acceptance Insp.	$28,060	$1,249	$11,723	$41,032
5.8.6.6.13.9.2.3	Grout delivery, prep, product.	$13,600	$605	$5,682	$19,887
5.8.6.6.13.9.2.4	Pre Grouting Tank Prep	$280,566	$12,485	$117,220	$410,272
5.8.6.6.13.9.2.5	Engineering Support	$41,178	$1,832	$17,204	$60,215
	5.8.6.6.13.9.2 Subtotal C-200s	$419,524	$18,669	$175,277	$613,470

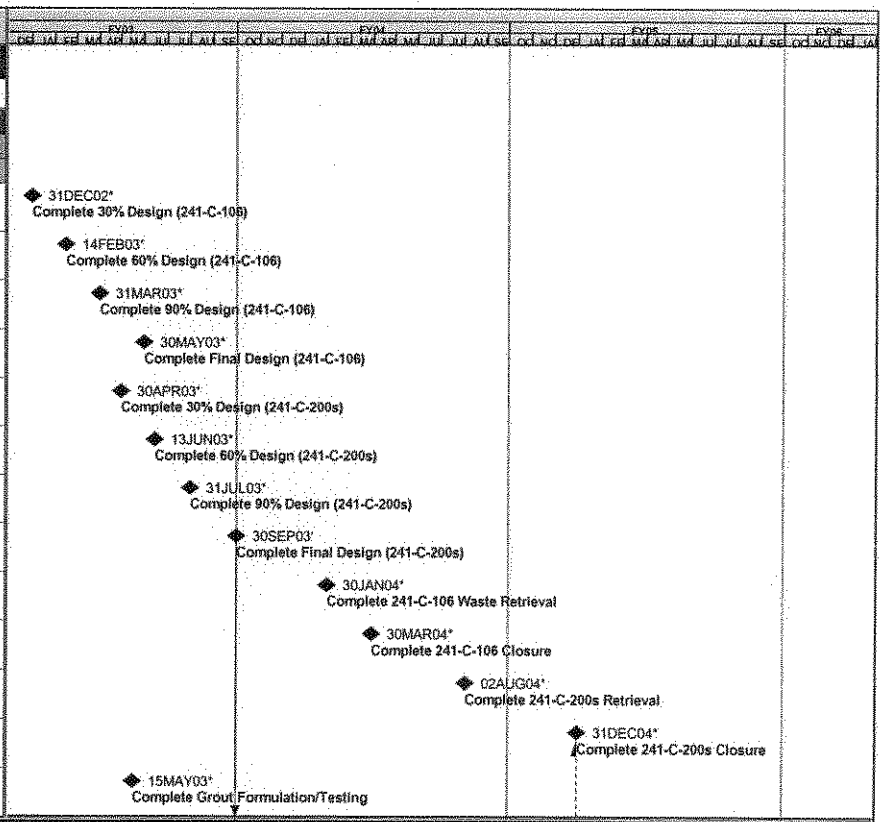
Table A.1. Phase 1 Interim Closure Cost Estimate Summary (2 Sheets)

WBS Number	Title	Base Est. FY02 dollars	Escalation to FY04 at 4.45%	Contingency at 40%	Total Estimated Cost
5.8.6.6.13.9.3	Tank Farm Ops Support C-200s				
5.8.6.6.13.9.3.1	Ops Mgmt and Planning Suppt	$109,511	$4,873	$45,754	$160,138
5.8.6.6.13.9.3.2	Construction Support	$46,534	$2,071	$19,442	$68,047
5.8.6.6.13.9.3.3	Stabilize Heel C-200's	$158,940	$7,073	$66,405	$232,418
5.8.6.6.13.9.3.4	Restore Surf/Demob	$114,550	$5,097	$47,859	$167,506
	5.5.1.2.3.6.4 Subtotal C-200s	$429,535	$19,114	$179,460	$628,109
5.8.6.6.13.9 Closure C-200 Series Subtotal		$857,477	$38,158	$358,254	$1,253,889
5.8.6.6.14.1	Closeout C-106 + C-200s				
5.8.6.6.14.1.1	Final As-Builts	$28,310	$1,260	$11,828	$41,398
5.8.6.6.14.1.2	Modify Documents	$18,505	$823	$7,731	$27,060
5.8.6.6.14.1.3	Lessons Learned	$17,637	$785	$7,369	$25,791
	5.8.6.6.14.1 Subtotal C-106 and C-200s	$64,452	$2,868	$26,928	$94,248
5.8.6.6.14.2	Other Project Costs C-106 and C-200s				
5.8.6.6.14.2.1	Environmental and Permitting	$32,942	$1,466	$13,763	$48,171
5.8.6.6.14.2.2	System Eng Support	$64,340	$2,863	$26,881	$94,084
	5.8.6.14.2 Subtotal C-106 and C-200s	$97,282	$4,329	$40,644	$142,255
Total Estimate		$2,037,000	$91,000	$851,000	$2,978,000

FY = fiscal year.
WBS = work breakdown structure.

Figure A.1. Phase 1 Interim Closure Project Schedule (5 Sheets)

Activity ID	Activity Description	Orig Dur	Early Start	Early Finish
5 River Protection Project				
5.8 Retrieve and Close				
5.8.6 SST Retrieve and Close/East Area				
5.8.6.6 C Farm Retrieve and Close				
5.8.6.6.00 Milestones				
00M01	Complete 30% Design (241-C-106)	0		31DEC02*
00M02	Complete 60% Design (241-C-106)	0		14FEB03*
00M03	Complete 90% Design (241-C-106)	0		31MAR03*
00M04	Complete Final Design (241-C-106)	0		30MAY03*
00M05	Complete 30% Design (241-C-200s)	0		30APR03*
00M06	Complete 60% Design (241-C-200s)	0		13JUN03*
00M07	Complete 90% Design (241-C-200s)	0		31JUL03*
00M08	Complete Final Design (241-C-200s)	0		30SEP03*
00M09	Complete 241-C-106 Waste Retrieval	0		30JAN04*
00M10	Complete 241-C-106 Closure	0		30MAR04*
00M11	Complete 241-C-200s Retrieval	0		02AUG04*
00M12	Complete 241-C-200s Closure	0		31DEC04*
00M13	Complete Grout Formulation/Testing	0		15MAY03*



Start Date	01OCT99	Early Bar	
Finish Date	08MAR05	Progress Bar	
Data Date	01OCT00		
Run Date	31JAN03 13:24		

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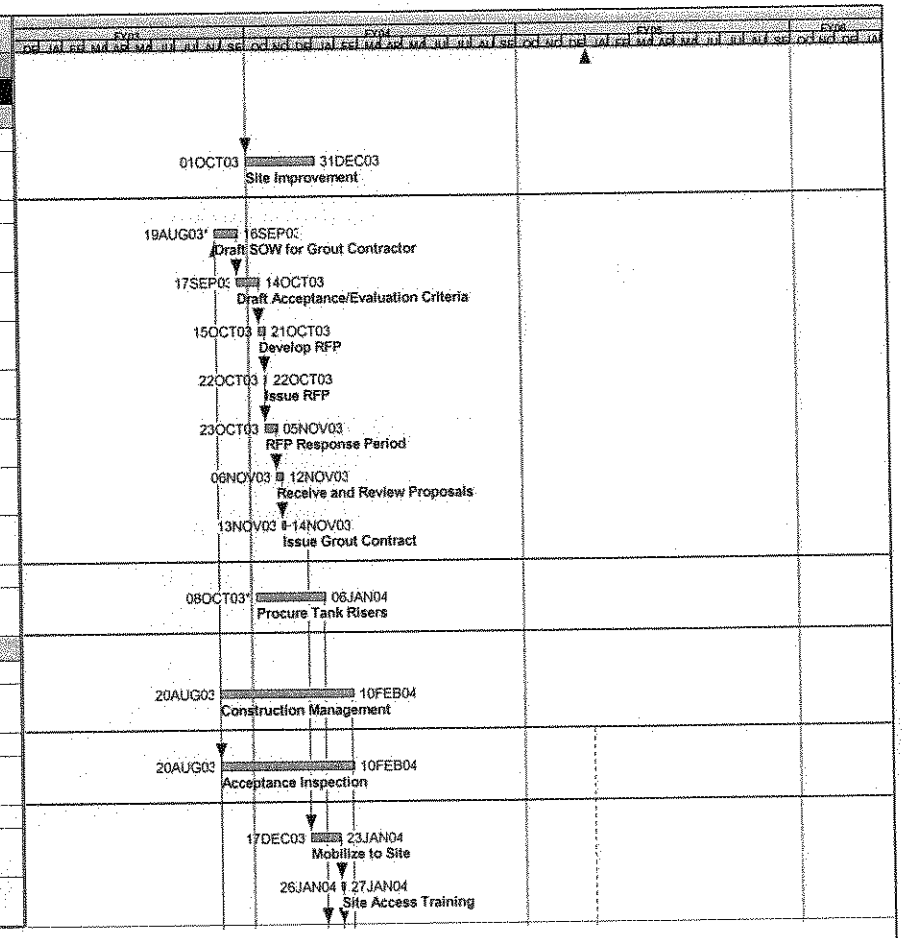
OPS3 Sheet 1 of 5

Figure A.1
Interim Closure
(Phase I Waste Stabilization)

January 31, 2003

Figure A.1. Phase 1 Interim Closure Project Schedule (5 Sheets)

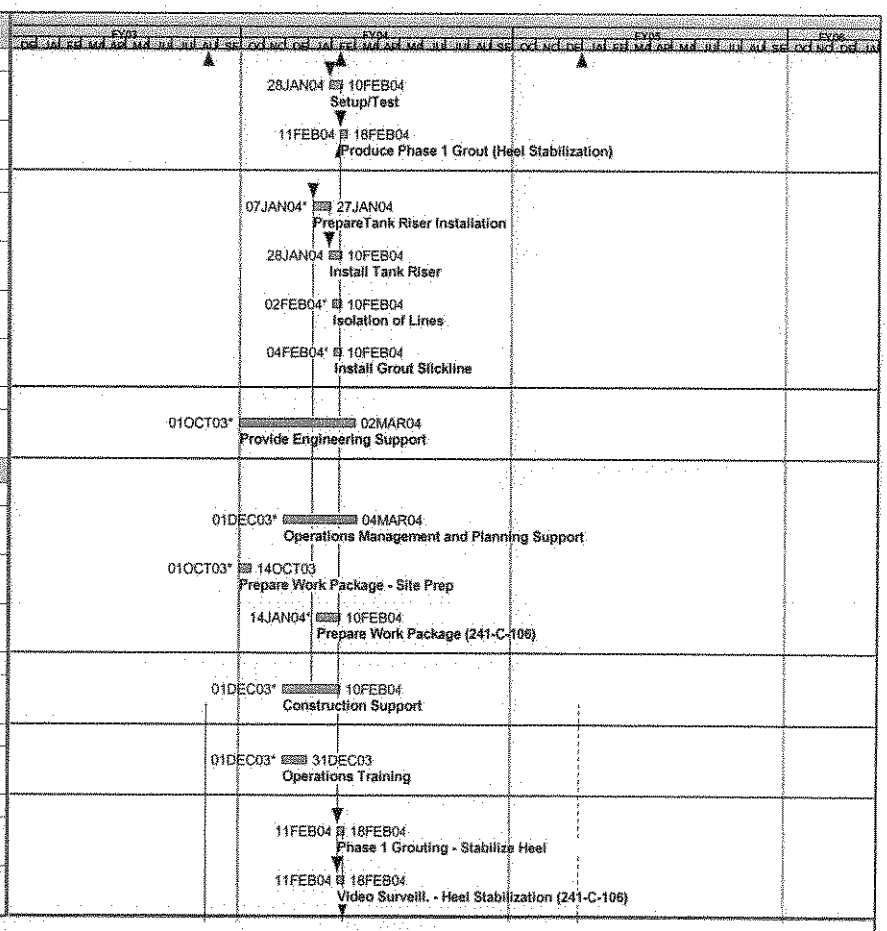
Activity ID	Activity Description	Orig Dur	Early Start	Early Finish
5.8.6.6.06 C-106				
5.8.6.6.06.9 Interim Close Tank (241-C-106)				
5.8.6.6.06.9.1 Procurement (241-C-106)				
5.8.6.6.06.9.1.1 Constructions Forces Contract (Site Improvement)				
52101	Site Improvement	62	01OCT03	31DEC03
5.8.6.6.06.9.1.2 Contract Grout Contractor				
52201	Draft SOW for Grout Contractor	20	19AUG03*	16SEP03
52202	Draft Acceptance/Evaluation Criteria	20	17SEP03	14OCT03
52203	Develop RFP	5	15OCT03	21OCT03
52204	Issue RFP	1	22OCT03	22OCT03
52205	RFP Response Period	10	23OCT03	05NOV03
52206	Receive and Review Proposals	5	06NOV03	12NOV03
52207	Issue Grout Contract	2	13NOV03	14NOV03
5.8.6.6.06.9.1.3 Procure Tank Risers				
52208	Procure Tank Risers	60*	08OCT03*	06JAN04
5.8.6.6.06.9.2 Construction (241-C-106)				
5.8.6.6.06.9.2.1 Construction Management				
53101	Construction Management	119	20AUG03	10FEB04
5.8.6.6.06.9.2.2 Acceptance Inspection				
53201	Acceptance Inspection	119	20AUG03	10FEB04
5.8.6.6.06.9.2.3 Grout Delivery, Preparation, and Production				
53301	Mobilize to Site	25	17DEC03	23JAN04
53302	Site Access Training	2	26JAN04	27JAN04



Sheet 2 of 5

Figure A.1. Phase 1 Interim Closure Project Schedule (5 Sheets)

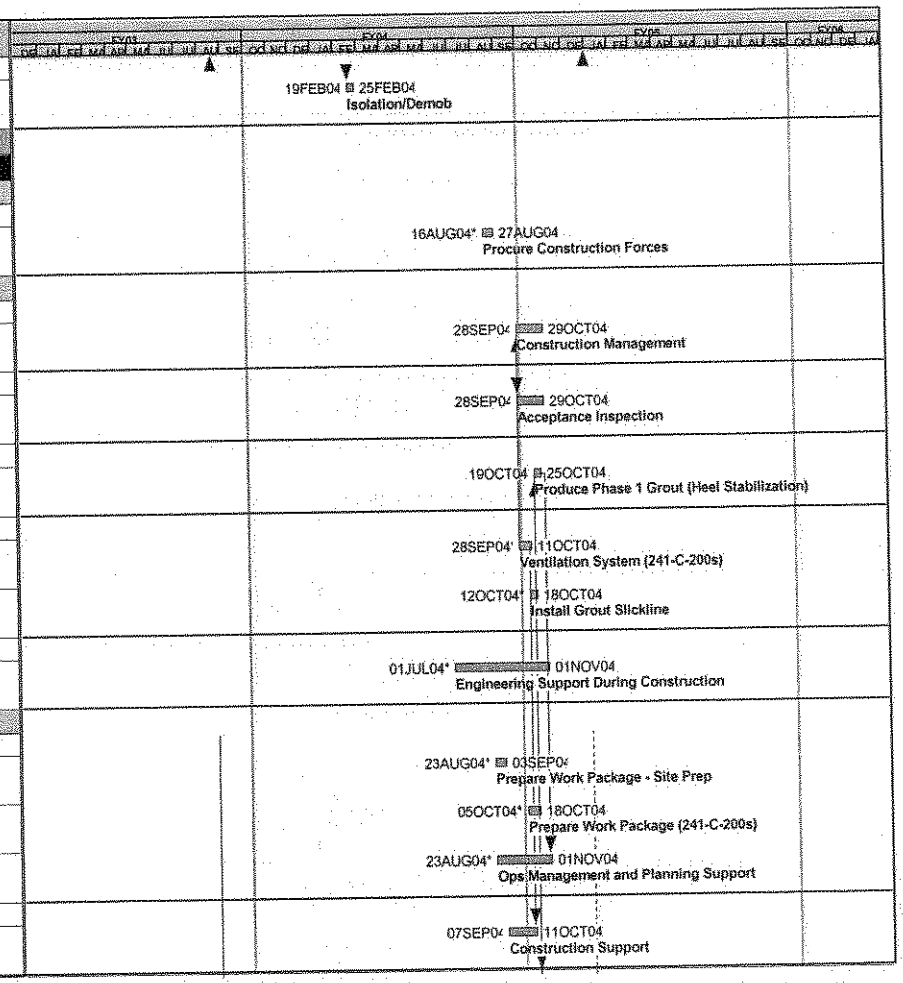
Activity ID	Activity Description	Orig Dur	Early Start	Early Finish
5.8.6.6.06.9.2.3 Grout Delivery, Preparation, and Production				
53303	Setup/Test	10	28JAN04	10FEB04
53304	Produce Phase 1 Grout (Heel Stabilization)	5	11FEB04	18FEB04
5.8.6.6.06.9.2.5 Pre Grouting Tank Preparation				
53502	PrepareTank Riser Installation	15	07JAN04*	27JAN04
53503	Install Tank Riser	10	28JAN04	10FEB04
53506	Isolation of Lines	7	02FEB04*	10FEB04
53507	Install Grout Slickline	5	04FEB04*	10FEB04
5.8.6.6.06.9.2.6 Engineering Support During Construction				
53601	Provide Engineering Support	104	01OCT03*	02MAR04
5.8.6.6.06.9.3 Tank Farm Operations Support (241-C-106)				
5.8.6.6.06.9.3.1 Ops Management and Planning Support				
54101	Operations Management and Planning Support	65*	01DEC03*	04MAR04
54102	Prepare Work Package - Site Prep	10	01OCT03*	14OCT03
54103	Prepare Work Package (241-C-106)	20	14JAN04*	10FEB04
5.8.6.6.06.9.3.2 Construction Support				
54201	Construction Support	49*	01DEC03*	10FEB04
5.8.6.6.06.9.3.3 Operations Training				
54301	Operations Training	21*	01DEC03*	31DEC03
5.8.6.6.06.9.3.4 Stabilize Heel (241-C-106)				
54401	Phase 1 Grouting - Stabilize Heel	5	11FEB04	18FEB04
54402	Video Surveill. - Heel Stabilization (241-C-106)	5	11FEB04	18FEB04



Sheet 3 of 5

Figure A.1. Phase 1 Interim Closure Project Schedule (5 Sheets)

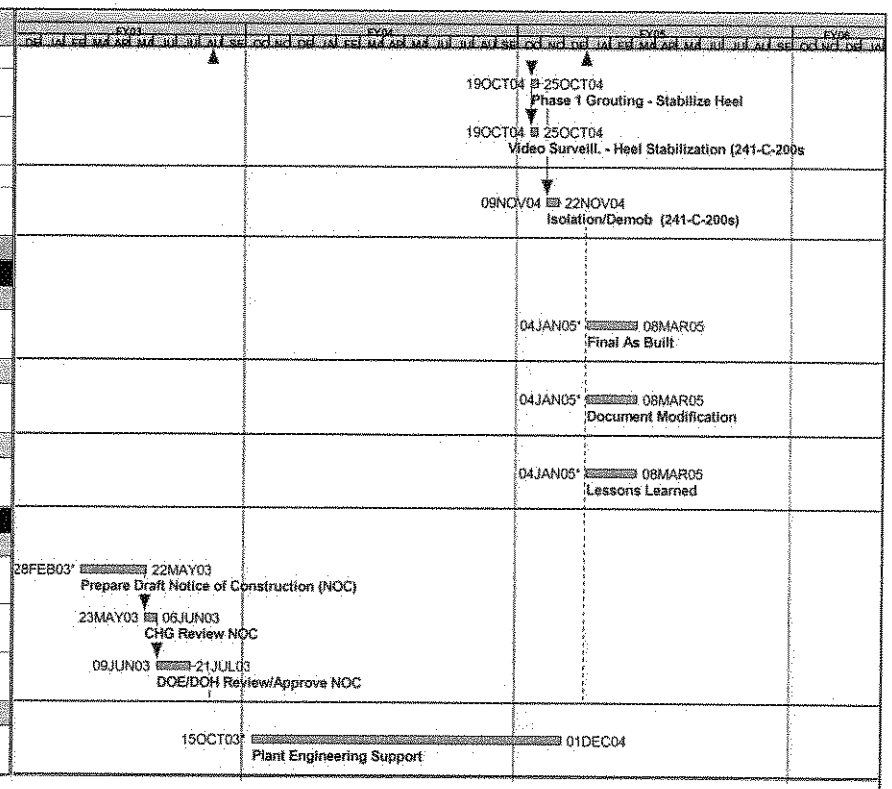
Activity ID	Activity Description	Orig Dur	Early Start	Early Finish
5.8.6.6.06.9.3.5 Restore 241-C-106 and Demob From Farm				
54801	Isolation/Demob	5	19FEB04	25FEB04
5.8.6.6.13 C-200s				
5.8.6.6.13.9 Interim Close Tank (241-C-200s)				
5.8.6.6.13.9.1 Procurement (241-C-200s)				
5.8.6.6.13.9.1.1 Site Improvement				
62101	Procure Construction Forces	10	16AUG04*	27AUG04
5.8.6.6.13.9.2 Construction (241-C-200s)				
5.8.6.6.13.9.2.1 Construction Management				
63101	Construction Management	24*	28SEP04	29OCT04
5.8.6.6.13.9.2.2 Acceptance Inspection				
63201	Acceptance Inspection	24*	28SEP04	29OCT04
5.8.6.6.13.9.2.3 Grout Delivery, Preparation, and Production				
63301	Produce Phase 1 Grout (Heel Stabilization)	5	19OCT04	25OCT04
5.8.6.6.13.9.2.4 Pre Grouting Tank Preparation				
63401	Ventilation System (241-C-200s)	10	28SEP04*	11OCT04
63406	Install Grout Slickline	5	12OCT04*	18OCT04
5.8.6.6.13.9.2.5 Engineering Support During Construction				
63501	Engineering Support During Construction	86*	01JUL04*	01NOV04
5.8.6.6.13.9.3 Tank Farm Operations Support (241-C-200s)				
5.8.6.6.13.9.3.1 Ops Management and Planning Support				
64102	Prepare Work Package - Site Prep	10	23AUG04*	03SEP04
64103	Prepare Work Package (241-C-200s)	10	05OCT04*	18OCT04
64104	Ops Management and Planning Support	50	23AUG04*	01NOV04
5.8.6.6.13.9.3.2 Construction Support				
64201	Construction Support	25	07SEP04	11OCT04



Sheet 4 of 5

Figure A.1. Phase 1 Interim Closure Project Schedule (5 Sheets)

Activity ID	Activity Description	Orig Dur	Early Start	Early Finish
5.8.6.6.13.9.3.3 Stabilize Heel (241-C-200s)				
64401	Phase 1 Grouting - Stabilize Heel	5	19OCT04	25OCT04
64402	Video Surveill. - Heel Stabilization (241-C-200s	5	19OCT04	25OCT04
5.8.6.6.13.9.3.4 Restore 241-C-200s and Demob From Farm				
64801	Isolation/Demob (241-C-200s)	10	09NOV04	22NOV04
5.8.6.6.14 Closeout & Other Project Costs				
5.8.6.6.14.1 Closeout				
5.8.6.6.14.1.1 Final As-Built Drawings				
7101	Final As Built	45	04JAN05*	08MAR05
5.8.6.6.14.1.2 Modify Relevent Documents				
7201	Document Modification	45	04JAN05*	08MAR05
5.8.6.6.14.1.3 Lessons Learned				
7301	Lessons Learned	45	04JAN05*	08MAR05
5.8.6.6.14.2 Other Project Costs				
5.8.6.6.14.2.1 Environmental and Permitting				
8101	Prepare Draft Notice of Construction (NOC)	60	28FEB03*	22MAY03
8102	CHG Review NOC	10	23MAY03	06JUN03
8103	DOE/DOH Review/Approve NOC	30	09JUN03	21JUL03
5.8.6.6.14.2.2 Plant Engineering Support				
8201	Plant Engineering Support	285*	15OCT03*	01DEC04



Sheet 5 of 5

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ATTACHMENT A1
COST ESTIMATING INPUT SHEETS

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Cost Estimating Input Sheet

Page 1 of

WBS#	5.8.6.6.06.9.1.1	WBS Title:	Site Improvement			
Prepared By:	J Payne	Rev #	0	Date:	1/31/03	

Scope Description:

Procurement of construction forces service for Pre Grouting Tank Preparation, WBS 5.8.6.6.06.9.2.5.

Estimating Assumptions & Exclusions :

Basis of Estimate:

Standard 3% procurement costs for implementing a construction forces service contract

Contingency: Level of Confidence/Risks Identification

Contingency is addressed at the summary estimate level for all tank closure activities.

Estimating notes:(including identification of environmental/productivity factors):

1. Pre Grouting Tank Preparation, WBS 5.8.6.6.06.9.2.5

6.0 Resource Requirements:

Act. #	Activity Description	Res Code	Res Type	FY	Note #	Bud.Qty.	BQ Rate	Factors	$
52101	Site Improvement	LP00E	CHG Professic	2004	1	248.5	1,000	3%	$7,455
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
								WBS Estimate Total	$7,455

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Site Improvement (5.8.6.6.06.9.1.1) / CEIdTemplat

Cost Estimating Input Sheet

WBS#	5.8.6.6.06.9.1.2	WBS Title:	Grout Contractor		
Prepart C Henderson		Rev #	0	Date:	11/15/02

Scope Description:

Procure services from grout production vendor for Phase I.

Estimating Assumptions & Exclusions :

Procurement of grout contractor to be used for C-106 and the C-200 series tanks.

Basis of Estimate:

Engineering judgment

Contingency: Level of Confidence/Risks Identification

Contingency is addressed at the summary estimate level for all tank closure activities.

Estimating notes:(including identification of environmental/productivity factors):

6.0 Resource Requirements:

Act. #	Activity Description	Res Code	Res Type	FY	Note #	Bud.Qty.	BQ Rate	Factors	$
52201	Draft SOW for Grout Contractor	LE13E	engineer	2003		80	64.34	0%	$5,147
		LP00E	Professional	2003		8	47.30	0%	$378
52202	Draft Acceptance/Evaluation Criteria	LE13E	engineer	2003		60	64.34	0%	$3,860
		LP00E	Professional	2003		8	47.30	0%	$378
52203	Develop RFP	LP00E	Professional	2004		16	47.30	0%	$757
52204	Issue RFP								$0
52205	RFP Response Period								$0
52206	Receive and Review Proposals	LE13E	engineer	2004		50	64.34	0%	$3,217
		LM02E	mgmt	2004		20	76.14	0%	$1,523
		LP00E	Professional	2004		8	47.30	0%	$378
52207	Issue Grout Contract	LP00E	Professional	2004		16	47.30	0%	$757
									$0
									$0
									$0
									$0
									$0
									$0
									$0
						WBS Estimate Total			16,395

Grout Contractor (5.8.6.6.06.9.1.2) / CEISTemplate

2/11/2003 - 10:15 AM

Cost Estimating Input Sheet

WBS#	5.8.6.6.06.9.1.3	WBS Title:	Procure Tank Risers		
		Rev #	0	Date:	1/31/03

Procurement of miscellaneous equipment to support tank fill.

Estimating Assumptions & Exclusions :

Basis of Estimate:

Engineering judgment.

Contingency: Level of Confidence/Risks Identification

Contingency is addressed at the summary estimate level for all tank closure activities.

Estimating notes:(including identification of environmental/productivity factors):

1. This activity provides for design, procurement, and acceptance inspection of a riser for installation on tank C-106.

6.0 Resource Requirements:

		Res Code	Res Type	FY	Note #	Bud.Qty.	BQ Rate	Factors	$
52208	Riser	21L	Material	2004	1	32	1000.00	0%	32,000
									0
									0
									0
									0
									0
									0
									0
									0
									0
									0
									0
									0
									0
									0
							WBS Estimate Total		32,000

10:15 AM

Risers (5.8.6.6.06.9.1.3) / CEISTemplate

Cost Estimating Input Sheet

Page 1 of 1

WBS#	5.8.6.6.06.9.2.1	WBS Title:	Construction Management			
Prepared By:	J Payne		Rev #	0	Date:	11/15/02

Scope Description:

Management of construction forces service for Pre Grouting Tank Preparation, WBS 5.8.6.6.06.9.2.5

Estimating Assumptions & Exclusions :

Construction management of grout vendor activities is not required

Basis of Estimate:

Standard 20% construction management costs for implementing a construction forces service contract

Contingency: Level of Confidence/Risks Identification

Contingency is addressed at the summary estimate level for all tank closure activities.

Estimating notes:(including identification of environmental/productivity factors):

1 Pre Grouting Tank Preparation, WBS 5.8.6.6.06.9.2.5

6.0 Resource Requirements:

Act. #		Res Code	Res Type	FY	Note #	Bud.Qty.	BQ Rate	Factors	$
53101	Construction Management	21L	CF services	2004	1	248.5	1,000	20%	$49,700
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
								WBS Estimate Total	49,700

/2003 16 AM

Construction Management (5.8.6.6.06.9.2.1) / CEISTemplet

Cost Estimating Input Sheet

Page 1 of

WBS#	5.8.6.6.06.9.2.2	WBS Title:	Acceptance Inspection				
Prepare J Payne			Rev #	0	Date:	1/31/03	

Scope Description:

Acceptance inspection of construction forces service for Pre Grouting Tank Preparation, WBS 5.8.6.6.06.9.2.5

Estimating Assumptions & Exclusions :

Acceptance inspection of grout vendor is not required. Quality control of grout production is accomplished through the approved vendor's QA program with oversight by Hanford Site QA.

Basis of Estimate:

Standard 10% acceptance inspection costs for a construction forces service contract

Contingency: Level of Confidence/Risks Identification

Contingency is addressed at the summary estimate level for all tank closure activities.

Estimating notes:(including identification of environmental/productivity factors):

1. Pre Grouting Tank Preparation, WBS 5.8.6.6.06.9.2.5

6.0 Resource Requirements:

Act. #	Activity Description	Res Code	Res Type	FY	Note #	Bud.Qty.	BQ Rate	Factors	$
53201	Acceptance Inspection	21L	CF services	2004	1	248.5	1,000	10%	$24,850
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
								WBS Estimate Total	24,850

2/11/2003 - 10:16 AM

Acceptance Inspection (5.8.6.6.06.9.2.2) / CEISTemplat

Cost Estimating Input Sheet

WBS#	5.8.6.6.06.9.2.3	WBS Title:	Grout Delivery, Preparation, and Production		
Prepare	LB Ulbricht	Rev #	0	Date:	1/31/03

Scope Description:

Vendor to develop grout formulation per specification, perform testing of grout properties and placement characteristics, supply grout pump, supply grout, and deliver grout to 241-C-Farm via mixer trucks.

Estimating Assumptions & Exclusions :

The vendor is contracted to provide services throughout the operating period and does not enter the radiologically controlled area.

Basis of Estimate:

ROM estimate from potential vendor, estimates from similar inquiries, and engineering judgment.

Contingency: Level of Confidence/Risks Identification

Contingency is addressed at the summary estimate level for all tank closure activities.

Estimating notes:(including identification of environmental/productivity factors):

1. Assumes 10 vendor employees (including truck drivers) use 8 hours each at $50/hr to obtain a Hanford Site badge.
2. Assumes 3 vendor employees for 5 days at $50/hr for setup/testing.
3. Based on estimate from Throop Co.
4. Assumes 165 cu. yd. of grout at $115/cu. yd.
5. Assumes 20 mixer truck loads at $300/delivery.
6. ROM estimate for rental of blower for dry mix delivery.

6.0 Resource Requirements:

		Res Code	Res Type	IFY	Note #	Bud.Qty.	BQ Rate	Factors	$
53302	site access training	21L			1	4	1000.00		4,000
53303	Develop and Test Grout Formulation	21L			2	6	1000.00		6,000
53304	Supply grout pump	21L			3	3	1000.00		3,000
53304	produce heel stabilization grout	21L			4	10	1000.00		10,000
53304	Deliver grout to site	21L			5	6	1000.00		6,000
53304	Supply dry grout delivery system	21L			6	5	1000.00		5,000
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
							WBS Estimate Total		$43,000

Grout Delivery, Preparation, and Production (5.8.6.6.06.9.2.3) / CEIS Template

Cost Estimating Input Sheet

WBS#	5.8.6.6.06.9.2.5	WBS Title:	Pre Grouting Tank Preparation		
Prepare	C Henderson	Rev #	0	Date:	1/31/03

Scope Description:

This activity involves installing a new riser for access to tank C-106 and isolating the cascade line. It is assumed that the ventilation system (POR-008 portable exhauster) and in-tank camera installed as a part of C-106 waste retrieval will remain in place to support ventilation requirements for waste stabilization as a part of interim tank closure.

Estimating Assumptions & Exclusions :

Supporting detail for removal of the slurry pump is on page 2 of this CEIS. It is assumed that the ventilation system installed as a part of the waste retrieval activities will be available for use during interim closure of the tank.

Basis of Estimate:

Estimate assumes work is contracted to construction forces. Engineering judgment coupled with other project cost estimates.
A factor of 50% is applied for SWP work and a factor of 30% is applied to delays in field activities caused by inclement weather (factor = 1.5*1.3 = 1.95)

Contingency: Level of Confidence/Risks Identification

Contingency is addressed at the summary estimate level for all tank closure activities.

Estimating notes:(including identification of environmental/productivity factors):

1. Per 241-S-103 trenching and laying hose in hose waste transfer line cost is $40/ft. Estimate uses 300 feet of pipe at $30/ft, subtracting $10/ft because no trenching or shielding required.
2. Projected from 241-S-103 estimates for pit & riser entries of $25,000.
3. Budget quantity is sum of 21L total costs for activities 53503 through 53507.
4. See CEIS sheet 2 for detail

Assume that the in-tank camera installed to support waste retrieval will remain in the tank for use during phase 1 closure.
All estimates include support from operations and HPT personnel.

6.0 Resource Requirements:

Act. #	Activity Description	Res Code	Res Type	FY	Note #	Bud.Qty.	BQ Rate	Factors	$
53503	install new riser	21L	subcontract	2004	4	248.5	1000	0%	$248,500
53507	install grout slickline in farm	21	install slickline	2004	1	350.0	30	195.0%	$20,475
53506	isolation of lines	21L	cascade line	2004	2	20.0	1000	195%	$39,000
		21L	general condit	2004	3	308.0	1000	20.0%	$51,595
		21L	consumables	2004	3	308.0	1000	4.0%	$12,319
		21L	foreman	2004	3	308.0	1000	8.0%	$24,638
	TOTAL OF 21L ACTIVITIES								406,527
									$0
									$0
									$0
									$0
						WBS Estimate Total			406,527

Cost Estimating Input Sheet

WBS#	5.8.6.6.06.9.2.5	WBS Title:	Pre Grouting Tank Preparation		
Prepare C Henderson		Rev #	0	Date:	1/31/03

Scope Description:

This activity involves installation of a new riser near the center of tank C-106 to provide an access point for placment of waste stabilizing grout. Installation of a new riser would be accomplished by using a guzzler vacuum truck and a rotary drill rig to set a 24 inch steel casing to the top of the tank dome, installing a 18 inch inner casing, core drilling through the tank dome, and installing a 12 inch riser.

Estimating Assumptions & Exclusions :

This estimate is based on the approach documented in WHC-SD-WM-ER-557, Rev. 0 and input from the CHG Tank Farm Vadose Zone Group. It is assumed that a number of the planning activities associated with riser installation would be captured by the planning for interim tank closure including: plant forces work review, USQ evaluation, prep of eng. documents, work package preparation, NOC preparation, Enhanced work package planning.

Factors for SWP and weather are included at 50% for SWP and 30% for weather for CHG labor.

Contingency: Level of Confidence/Risks Identification

Contingency is addressed at the summary estimate level for all tank closure activities.

Estimating notes:(including identification of environmental/productivity factors):

1. Includes ground penetrating radar (2.5K), Mobilization (15.96K), and Vadose Zone proj mgmt and tech suppt (48K)
2. Includes CHG support crew (fieldwork supv, 2 NCOs, 2 HPT, IH tech - 33K); 16 drums plus disposal cost (39K); Duratek federal services plus drilling subcontractor (89.2K); WSCF lab cost air filter analysis (2K); Senior supv watch (12K); guzzler cost (5K for potential repairs and 1.6K operator). Assumed that subcontract estimate includes allowances for SWP and weather.

Drilling subcontractor assumptions - drilling placement of 18" (or less) diameter using govt owned drill (B-61); work will be Davis Bacon covered union work force; work will be performed on 8-9's schedule; no special shielding costs are included; use of govt owned guzzler and support equipment for soil excavation.

6.0 Resource Requirements:

Act. #	Activity Description	Res Code	Res Type	FY	Note #	Bud Qty.	BQ Rate	Factors	$
53502	Prep Tank Riser Installation	21	Summary	2004	1	66.5	1000.00	0%	66,500
53503	Install Tank Riser	21	subcontract	2004	2	91.2	1000.00	0%	91,200
		LM01E	First Line Supervisor	2004	2	72.0	39.58	195%	8,407
		LR00B	Operators	2004	2	84.0	44.31	195%	10,980
		LP08E	Health Physicists	2004	2	72.0	53.79	195%	11,425
		LP09E	In Hygienists	2004	2	25	54.06	195%	3,987
		10L	Material	2004	2	44	1000.00	0%	44,000
		LM00E	Managers	2004	2	168	71.26	0%	11,972
							WBS Estimate Total		248,470

/2003 - 10:20 AM

Pre Grouting Tank Preparation (5.8.6.6.06.9.2.5) / CEIS-page 2

Cost Estimating Input Sheet

Page 1 of 1

WBS#:	5.8.6.6.06.9.2.6	WBS Title:	Engineering Support During Construction
Prepare	LB Ulbricht	Rev #	0
Date:	11/15/02		

Scope Description:

Provide engineering support to the field during construction activities.

Estimating Assumptions & Exclusions :

Basis of Estimate:

Engineering judgment

Contingency: Level of Confidence/Risks Identification

Contingency is addressed at the summary estimate level for all tank closure activities.

Estimating notes:(including identification of environmental/productivity factors):

1. Provide full time field engineer support with support from engineering office for preparation of ECNs, construction interface, and vendor interface. The support from the engineering office is assumed to be equivalent to one engineer working full time. Construction period assumed to be from 10/01/03 to 3/2/04. (104 days x 8hrs = 832 hours)

6.0 Resource Requirements:

Act. #	Activity Description	Res Code	Res Type	FY	Note #	Bud.Qty.	BQ Rate	Factors	$
53601	Provide Engineering Support	LE13E	Engineer	2004	1	832	64.34	0%	53,531
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
								WBS Estimate Total	53,531

2/11/2003 - 10:20 AM

Engineering Support During Construction (5.8.6.6.06.9.2.6) / CEISTemplate

Cost Estimating Input Sheet

Page 1 of

WBS#	5.8.6.6.06.9.3.1	WBS Title:	Ops Management and Planning Support		
Prepared By: C. Henderson		Rev	0	Date:	11/15/02

Scope Description:

This work scope provides for operations management and work package preparation to support tank closure activities conducted in the tank farm. Operations management includes provisions for management reporting, coordination, scheduling, and issues management. Planning support includes JCS work package preparation for all activities conducted in and around the tank farms.

Estimating Assumptions & Exclusions :

Management includes 1 Operations Manager and 1 Radcon Manager at an average 1/2 time level of effort.
Management support begins approximately 2 months prior to field work to support planning and preparation efforts and continues through to project closeout.
Planning support includes the preparation of 3 work packages: 1 for site preparation outside the tank farm, 1 to incorporate the construction (site prep) planning into the JCS system, and 1 for activities to be conducted inside the tank farm to close 241-C-106. Dedicated planning support is assumed for the project.

Basis of Estimate:

Estimate is based on engineering judgment.

Contingency: Level of Confidence/Risks Identification

Contingency is addressed at the summary estimate level for all tank closure activities.

Estimating notes:(including identification of environmental/productivity factors):

1. Labor hour estimate based on 3 months x 160 hrs/month x 1/2 time = 240 hours
2 Labor hour estimate based on 1 FTE for a period of 2 months. 2 months x 160 hrs/month = 320 hrs.

4. Enhanced work package planning includes 1/2 day field walk down and 1/2 day planning session with 2 operators, two field work supervisors, 2 HPTs, 2 IH Techs, 2 Riggers, and 1 Ops Manager.
5. Assume 1 simple, 1 moderate, and 1 complex work packages will be required. Cost for a simple work package = $15K, moderate= $20K, and complex $25K. These do not include ECN and USQ preparation which are covered by other activities.

6.0 Resource Requirements:

Act. #	Activity Description	Res Code	Res Type	FY	Note #	Bud.Qty	BQ Rate	Factors	$
54101	Tank Farm Ops Management	LM02E	Ops Mgr	2004	1	240	76.14	0%	$18,274
54102	Tank Farm Ops Management	LM02E	RadCon Mgr	2004	1	240	76.14	0%	$18,274
54103	Provide planning support	LE13E	Planner	2004	2	320	64.34	0%	$20,589
54103	Enhanced Work Package Planning	LM02E	Field Supv	2004	4	18	76.14	0%	$1,371
54103	Enhanced Work Package Planning	LR05B	Operators	2004	4	18	44.76	0%	$806
54103	Enhanced Work Package Planning	LT05B	HPT	2004	4	18	41.86	0%	$753
54103	Enhanced Work Package Planning	LT06B	IH Tech	2004	4	18	42.70	0%	$769
54103	Enhanced Work Package Planning	LC00B	Rigger	2004	4	18	42.90	0%	$772
54103	Enhanced Work Package Planning	LM02E	Ops Mgr	2004	4	9	76.14	0%	$685
54103	Work package preparation		CHG	2004	5	60	1000.00	0%	$60,000
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
							WBS Estimate Total		$122,292

OpsMgmtandPlanningSupport(586608931) / CEISTemplate

Cost Estimating Input Sheet

Page 1 of 1

WBS#	5.8.6.6.06.9.3.2	WBS Title:	Construction Support		
Prepared By: C. Henderson			Rev #	0	Date: 11/15/02

Scope Description:

This work scope provides for operations support during tank farm preparation work prior to placement of fill into tank C-106. It is assumed that the preparation work would be performed by construction forces.

Estimating Assumptions & Exclusions :

It is assumed that operations support will be required during construction activities will include 2 Operators, 2 HPTs, 2 IH techs, 1 Radcon Eng, and 1 clerk.
Operations management and radcon management is covered separately under WBS 5.8.6.6.06.3.1.

Basis of Estimate:

Estimate is based on current tank farm operating requirements. A factor of 50% is applied for SWP work and a factor of 30% is applied to delays in field activities caused by inclement weather (factor=1.5*1.3 = 1.95).

Contingency: Level of Confidence/Risks Identification

Contingency is addressed at the summary estimate level for all tank closure activities.

Estimating notes:(including identification of environmental/productivity factors):

1. Labor estimate is based on dedicated support for a period of 10 days.
2. Labor estimate is based on 1/2 time support for a period of 10 days.

6.0 Resource Requirements:

Act. #	Activity Description	Res Code	Res Type	FY	Note #	Bud Qty	BQ Rate	Factors	$
54201	Operations Support during Const.	LR05B	Operators (2)	2004	1	80	44.76	195%	$6,983
54201	Operations Support during Const.	LT05B	HPTs (2)	2004	1	80	41.86	195%	$6,530
54201	Operations Support during Const.	LT06B	IH Tech (2)	2004	1	80	42.70	195%	$6,661
54201	Operations Support during Const.	LE13E	Radcon Eng	2004	1	40	64.34	0%	$2,574
54201	Operations Support during Const.	LG02N	Clerk	2004	1	80	23.16	0%	$1,853
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
							WBS Estimate Total		$24,600

2/11/2003 - 10:22 AM

ConstructionSupport (586606932) / CEISTemplate

Cost Estimating Input Sheet

Page 1 of

WBS#	5.6.6.6.06.9.3.3	WBS Title:	Operations Training		
Prepared By: C. Henderson		Rev #	0	Date: 11/15/02	

Scope Description:

This work scope provides for training of the operations staff supporting the tank closure activities. Training materials will be prepared to provide an overview of the project, objectives of the heel stabilization and tank fill steps, and the grout delivery/production system.

Estimating Assumptions & Exclusions :

Training materials will be prepared by 2 professional staff over a period of 1 week.
Training will be conducted in a 1 day training session that includes 2 times the standard operations support crew to accommodate the potential for multiple shifts and absences.

Basis of Estimate:

Estimate is based on engineering judgment. It is assumed that training would not include mock up and cold testing. No factors are applied to this work as it is not performed in the field.

Contingency: Level of Confidence/Risks Identification

Contingency is addressed at the summary estimate level for all tank closure activities.

Estimating notes:(including identification of environmental/productivity factors):

1. Estimate based on 2 professional staff * 40 hrs/week * 1 week = 80 hrs
2. Estimate based on 2 professional staff * 8 hrs/day * 2 days = 32 hrs
3. Estimate based on 4 operators * 8 hrs/day * 2 days = 64 hrs
4. Estimate based on 4 HPTs * 8 hrs/day * 2 days = 64 hrs
5. Estimate based on 4 IH techs * 8 hrs/day * 2 days = 64 hrs
6. Estimate based on 1 radcon eng * 8 hrs/day * 2 days = 16 hrs
7. Estimate based on 1 operation manager * 8 hrs/day * 2 days = 16 hrs
8. Estimate based on 1 radcon manager * 8 hrs/day * 2 days = 16 hrs
9. Training materials estimated at 15 students x $200/student = $3,000

6.0 Resource Requirements:

Act. #	Activity Description	Res Code	Res Type	FY	Note #	Bud.Qty	BQ Rate	Factors	$
54301	Prepare training materials	LP00E	Professional	2004	1	80	47.30	0%	$3,784
54301	Conduct training	LP00E	Professional	2004	2	32	47.30	0%	$1,514
54301	Attend training	LR05B	Operators	2004	3	64	44.76	0%	$2,865
54301	Attend training	LT05B	HPTs	2004	4	64	41.86	0%	$2,679
54301	Attend training	LT06B	IH Techs	2004	5	64	42.70	0%	$2,733
54301	Attend training	LE13E	Radcon Eng	2004	6	16	64.34	0%	$1,029
54301	Attend training	LM02E	Ops Managar	2004	7	16	76.14	0%	$1,218
54301	Attend training	LM02E	Radcon Mgr	2004	8	16	76.14	0%	$1,218
54301	Training Materials	21L	Training Matl.	2004	9	3	1000.00	0%	$3,000
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
							WBS Estimate Total		$20,040

2/11/2003 - 10:22 AM

OperationsTraining(556806933) / CEISTemplate

Cost Estimating Input Sheet

WBS#	5.8.6.6.06.9.3.4	WBS Title:	Stabilize Heel - 241-C-106		
Prepared By: C. Henderson		Rev #	0	Date: 11/15/02	

Scope Description:

This activity involves placement of the grout material into 241-C-106 to stabilize the residual waste heel. The grout will be prepared outside the tank farm by a subcontractor and pumped to the tank through slicklines (pipe or hose). During grouting operations the operations crew will monitor in tank conditions, monitor the grout line and tank ventilation system, and access the tank as required to remove and install grout tremie lines (flex hose) used to pump grout into the tank. This activity also includes video surveillance of the waste stabilization within the tank.

Estimating Assumptions & Exclusions :

It is assumed that separate crews will be utilized to provide for longer grout operating shifts. Once the grout plant is operating it is beneficial to run for longer durations to minimize cleanup and secondary waste generation. The camera crew consists of 4 operators, 1 field work supervisor, 2 craft, 1 HPT, and 1 IH tech. It is assumed that the entire waste stabilization effort will be videotaped. The operations crew to support grout placement consists of 1 field work supervisor, 2 operators and 1 HPT to verify integrity of the grout line and perform routine surveillance on the exhauster.

Basis of Estimate:

Engineering judgment. This is a first of a kind activity. A factor of 50% is applied for SWP and a factor of 30% is applied to account for field delays due to inclement weather (factor = 1.5*1.3=1.95).

Contingency: Level of Confidence/Risks Identification

Contingency is addressed at the summary estimate level for all tank closure activities.

Estimating notes:(including identification of environmental/productivity factors):

1. Labor estimate is based on dedicated support from 2 operators x 2 shifts x 5 days x 8 hrs/day = 160 hrs
2. Labor estimate is based on dedicated support from 1 HPT/shift x 2 shifts x 5 days x 8 hrs = 80 hrs.
3. Labor estimate is based on dedicated support from 1 IH tech/shift x 2 shifts x 5 days x 8 hrs = 80 hrs
4. Labor estimate is based on 4 operators x 2 shifts x 5 days x 8 hrs/day = 320 hrs
5. Labor estimate is based on 1 field work supervisor x 2 shifts x 5 days x 8 hrs/day = 80 hrs
6. Labor estimate is based on 2 craft (filter/instrument tech) x 2 shifts x 5 days x 8 hrs/day = 160 hrs
7. Labor estimate is based on 1 HPT x 2 shifts x 5 days x 8 hrs/day = 80 hrs
8. Labor estimate is based on 1 IH tech x 2 shifts x 5 days x 8 hrs/day = 80 hrs

6.0 Resource Requirements:

Act. #	Activity Description	Res Code	Res Type	FY	Note #	Bud.Qty	BQ Rate	Factors	$
54401	Waste heel stabilization	LR05B	Operators	FY04	1	160	44.76	195%	$13,965
54401	Waste heel stabilization	LT05B	HPTs	FY04	2	80	41.86	195%	$6,530
54401	Waste heel stabilization	LM02E	Field Supv	FY04	3	80	76.14	195%	$11,878
									$0
54402	In tank video stabilization	LR05B	Operators		4	320	44.76		
54402	In tank video stabilization	LM02E	Field Supv		5	80			
54402	In tank video stabilization		Craft		6	160	44.76	195%	$13,965
54402	In tank video stabilization	LT05B	HPT		7	80	41.86	195%	$6,530
54402	In tank video stabilization	LT06B	IH Tech		8	80	42.70	195%	$6,661
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
						WBS Estimate Total			$99,338

2/11/2003 - 10:22 AM

StabilizeHeel(586606934) / CEISTemplate

Cost Estimating Input Sheet

WBS#	5.8.6.6.06.9.3.5	WBS Title:	Tank Farm Surface Restoration and Demob		
Prepared By: C. Henderson			Rev #	1	Date: 11/15/02

Scope Description:

This activity involves providing intrusion/isolation measures for the tank following waste heel stabilization to prevent water intrusion into the tank during the interim period of time between Phase 1 (interim closure) and Phase 2 (bulk fill of the tank).

Estimating Assumptions & Exclusions :

It is assumed that isolation of the tank is similar to isolation measures performed following interim stabilization. The cost for isolation of C-106 is assumed to be equal to the planning basis for isolation of AX-101 in the program baseline (P3 Activity ID SS23285A1). The isolation estimate for AX-101 includes all planning efforts, work package preparation, design, and field work associated with sealing pits and isolating lines following interim stabilization.

Basis of Estimate:

Estimate is based on existing planning data and the assumption that isolation of C-106 is similar to isolation of AX-101

Contingency: Level of Confidence/Risks Identification

Contingency is addressed at the summary estimate level for all tank closure activities

Estimating notes:(including identification of environmental/productivity factors):

1. estimate taken from existing planning estimates for isolation of tank AX-101
2. cost for removal of the grout slickline is assumed to be the same as the installation cost.

6.0 Resource Requirements:

Act. #	Activity Description	Res Code	Res Type	FY	Note #	Bud.Qty	BQ Rate	Factors	$
54801	isolate tank C-106	21	Multiple	FY04	1	97	1000.00	0%	$97,000
54801	remove grout slickline	21	contract	FY04	2	20.475	1000.00	0%	$20,475
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
								WBS Estimate Total	117,475

RestoreandDemob(5.8.6.6.06.9.3.5) / CEISTemplate

Cost Estimating Input Sheet

WBS#	5.8.6.6.13.9.1.1	WBS Title:	Site Improvement		
Prepare	J Payne	Rev #	0	Date:	1/31/03

Scope Description:

Procurement of construction forces service for WBS 5.8.6.6.06.13.9.2.4, Pre Grouting Tank Preparation.

Estimating Assumptions & Exclusions :

Basis of Estimate:

Standard 3% procurement costs for implementing a construction forces service contract

Contingency: Level of Confidence/Risks Identification

Contingency is addressed at the summary estimate level for all tank closure activities.

Estimating notes:(including identification of environmental/productivity factors):

1. Pre Grouting Tank Preparation, WBS 5.8.6.6.06.13.9.2.4

6.0 Resource Requirements:

		Res Code	Res Type	FY	Note #	Bud.Qty.	BQ Rate	Factors	$
62101	Site Improvement	LP00E	CHG Professic	2004	1	280.6	1,000	3%	$8,418
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
								WBS Estimate Total	$8,418

2/11/2003 - 10:24 AM

Site Improvement (5.8.6.6.06.9.1.1) / CEISTemplate

Cost Estimating Input Sheet

Page 1 of 1

WBS#	5.8.6.6.13.9.2.1	WBS Title:	Construction Management		
Prepare	LE Ulbrich	Rev #	0	Date:	11/15/02

Scope Description:

Management of construction forces service for WBS 5.8.6.6.13.9.2.4, Pre Grouting Tank Preparation.

Estimating Assumptions & Exclusions :

Basis of Estimate:

Standard 20% construction management costs for implementing a construction forces service contract

Contingency: Level of Confidence/Risks Identification

Contingency is addressed at the summary estimate level for all tank closure activities.

Estimating notes:(including identification of environmental/productivity factors):

1. Pre Grouting Tank Preparation, WBS 5.8.6.6.13.9.2.4

6.0 Resource Requirements:

Act. #	Activity Description	Res Code	Res Type	FY	Note #	Bud.Qty.	BQ Rate	Factors	$
63101	Construction Management	21L	CF services	2004	1	280.6	1,000	20%	56,120
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
								WBS Estimate Total	56,120

Construction Management (5.8.6.6.13.9.2.1) / CEISTemplate

Cost Estimating Input Sheet

WBS#	5.8.6.6.13.9.2.2	WBS Title:	Acceptance Inspection			
Prepare	LB Ulbricht	Rev #	0	Date:	11/18/02	

Scope Description:

Acceptance inspection of construction forces service for WBS 5.8.6.6.13.9.2.4, Pre Grouting Tank Preparation.

Estimating Assumptions & Exclusions :

Basis of Estimate:

Standard 10% acceptance inspection costs for a construction forces service contract

Contingency: Level of Confidence/Risks Identification

Contingency is addressed at the summary estimate level for all tank closure activities.

Estimating notes:(including identification of environmental/productivity factors):

1. Pre Grouting Tank Preparation, WBS 5.8.6.6.13.9.2.4

6.0 Resource Requirements:

Act. #	Activity Description	Res Code	Res Type	FY	Note #	Bud.Qty.	BQ Rate	Factors	$
63201	Acceptance Inspection	21L	CF services	2004	1	280.6	1,000	10%	28,060
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
						WBS Estimate Total			28,060

Acceptance Inspection (5.8.6.6.13.9.2.2) | CEISTemplat

Cost Estimating Input Sheet

WBS#	5.8.6.6.13.9.2.3	WBS Title:	Grout Delivery, Preparation, and Production		
Prepare	LE Ulbricht	Rev #	0	Date:	1/31/03

Scope Description:

Vendor to supply grout pump, supply grout, and deliver grout to 241-C-Farm via mixer trucks.

Estimating Assumptions & Exclusions :

The vendor is contracted to provide services throughout the operating period and does not enter the radiologically controlled area.

Assumes the grout formulation has been developed under the 241-C-106 closure.

Basis of Estimate:

ROM estimate from potential vendor, estimates from similar inquiries, and engineering judgment.

Contingency: Level of Confidence/Risks Identification

Contingency is addressed at the summary estimate level for all tank closure activities.

Estimating notes:(including identification of environmental/productivity factors):

1. Assumes 2 vendor employees (including truck drivers) use 8 hours each at $50/hr to obtain a Hanford Site badge.
2. Based on estimate from Throop Co.
3. Assumes 8 cu. yd. of grout at $115/cu. yd.
4. Assumes 1 mixer truck load per tank at $300/delivery.
5. ROM estimate for vendor to supply blower for delivery of dry grout mixture

6.0 Resource Requirements:

Act. #	Activity Description	Res Code	Res Type	FY	Note #	Bud.Qty	BQ Rate	Factors	$
63301	site access training				1	0.8	1000.00		$800
63301	supply grout pump				2	3	1000.00		$3,000
63301	Produce Heel Stabilization Grout (241-C-201)				3	0.9	1000.00		$900
63301	Deliver grout to site (241-C-201)				4	0.3	1000.00		$300
63301	Produce Heel Stabilization Grout (241-C-202)				3	0.9	1000.00		$900
63301	Deliver grout to site (241-C-202)				4	.3	1000.00		$300
63301	Produce Heel Stabilization Grout (241-C-203)				3	0.9	1000.00		$900
63301	Deliver grout to site (241-C-203)				4	0.3	1000.00		$300
63301	Produce Heel Stabilization Grout (241-C-204)				3	0.9	1000.00		$900
63301	Deliver grout to site (241-C-204)				4	0.3	1000.00		$300
63301	Supply dry matl delivery system				5	5	1000.00		$5,000
									$0
									$0
									$0
									$0
									$0
									$0
						WBS Estimate Total			$13,600

2/11/2003 - 10:24 AM

Grout Delivery, Preparation, and Production (5.8.6.6.13.9.2.3) / CEISTemplate

Cost Estimating Input Sheet

Page 1

WBS#	5.8.6.6.13.9.2.4	WBS	Pre Grouting Tank Preparation		
Prepar	R Dunham		Rev #	0	Date: 1/31/03

Scope Description:

Prepare tanks for placement of waste stabilizing grout. Install portable exhauster to each tank and install slick-line.

Estimating Assumptions & Exclusions :

Basis of Estimate:

Estimate assumes work is contracted to construction forces. Engineering judgment coupled with other project cost estimates.
A factor of 50% is applied for SWP work and a factor of 30% is applied to delays in field activities caused by inclement weather (factor = 1.5*1.3 = 1.95)

Contingency: Level of Confidence/Risks Identification

Contingency is addressed at the summary estimate level for all tank closure activities.

Estimating notes:(including identification of environmental/productivity factors):

1. Assumes portable exhauster would need to be relocated to tank and started up. No mods to tank vent system assumed following portable exhauster use during waste retrieval activities.
2. Budget quantity is sum of 21L total costs for activities 63501 through 63509 and 63404.
3. Per 241-S-103 trenching and laying hose in hose waste transfer line cost is $40/ft. Estimate uses 300 feet of pipe at $30/ft, subtracting $10/ft because no trenching or shielding required. Assume removal is same cost as installation.

Assume camera used during waste retrieval will remain in place and be used to support phase 1 closure.

6.0 Resource Requirements:

Act. #	Activity Description	Res C	Res Type	FY	Note #	Bud.Qty.	BQ Rate	Factors	$
63401	Install ventilation system (241-C-201)	21L	install port exhauster	2004	1	25.0	1000.00	195%	48,750
63401	Install ventilation system (241-C-202)	21L	install port exhauster	2004	1	25.0	1000.00	195%	48,750
63401	Install ventilation system (241-C-203)	21L	install port exhauster	2004	1	25.0	1000.00	195%	48,750
63401	Install ventilation system (241-C-204)	21L	install port exhauster	2004	1	25.0	1000.00	195%	48,750
63406	install grout slickline in farm	21L	install slickline	2004	3	30.0	300.00	195.0%	$17,550
		21L	general conditions	2004	2	212.6	1000.00	20.0%	42,510
		21L	consumables	2004	2	212.6	1000.00	4.0%	8,502
		21L	foreman	2004	2	212.6	1000.00	8.0%	17,004
	TOTAL OF 21L ACTIVITIES								280,566
							WBS Estimate Total		$280,566

2/11/2003 - 10:29 AM

Pre Grouting Tank Preparation (5.8.6.6.13.9.2.4) / CEISTemplate

Cost Estimating Input Sheet

WBS#	5.8.6.6.13.9.2.5	WBS Title:	Engineering Support During Construction		
Prepare	LB Ulbricht	Rev #	0	Date:	11/15/02

Scope Description:

Provide engineering support to the field during construction activities.

Estimating Assumptions & Exclusions :

Basis of Estimate:

Engineering judgment

Contingency: Level of Confidence/Risks Identification

Contingency is addressed at the summary estimate level for all tank closure activities.

Estimating notes:(including identification of environmental/productivity factors):

1. Provide full time field engineer support with support from engineering office for preparation of ECNs, construction interface, and vendor interface. The support from the engineering office is assumed to be equivalent to one engineer working full time. Construction period assumed to be from 7/01/04 to 10/31/04.

6.0 Resource Requirements:

Act. #	Activity Description	Res Code	Res Type	FY	Note #	Bud.Qty.	BQ Rate	Factors	$
63601	Provide Engineering Support	LE13E	Engineer	2005	1	640	64.34	0%	41,178
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
								WBS Estimate Total	41,178

2/11/2003 - 10:25 AM

Engineering Support During Construction (586613925) / CEI6Template

Cost Estimating Input Sheet

WBS#	5.8.8.8.13.9.3.1	WBS Title:	Ops Management and Planning Support		
Prepared By: C. Henderson		Rev	0	Date:	11/15/02

Scope Description:

This work scope provides work package preparation and planning support for tank closure activities for the 241-C-200 series C farm tanks. Planning support includes JCS work package preparation for all activities conducted in and around the tank farms.

Estimating Assumptions & Exclusions :

Planning support includes the preparation of work packages for stabilizing the 200 series tanks. Dedicated planning support is assumed for the project over a duration of 5 months following completion of the initial work packages to accommodate changes and updates.
Assume that the work package is relatively complex and requires development, enhanced work planning, review and approval, and closeout. The estimated cost for preparation of a complex work package is $23K and does not include ECN or USQ preparation (these are estimated elsewhere).

Basis of Estimate:

Estimate is based on engineering judgment.

Contingency: Level of Confidence/Risks Identification

Contingency is addressed at the summary estimate level for all tank closure activities.

Estimating notes:(including identification of environmental/productivity factors):

1. Work package preparation review, approval, and closeout of a "complex" work package.
2. Labor hour estimate based on 1 FTE for a period of 5 months. 5 months x 160 hrs/month =800 hrs.
3. Labor hour estimate based on 8 months x 160 hrs/month x 1/2 time = 640 hours
4. Enhanced work package planning includes 1/2 day field walk down and 1/2 day planning session with 2 operators, two field work supervisors, 2 HPTs, 2 IH Techs, 2 Riggers, and 1 Ops Manager.
5. Labor hour estimate based on 10 weeks x 40 hrs/week x 1/2 time = 200 hrs.

6.0 Resource Requirements:

Act. #	Activity Description	Res Code	Res Type	FY	Note #	Bud.Qty	BQ Rate	Factors	$
64102/3	Prepare work package	21L		2004	1	23	1000.00	0%	$23,000
64102/3	Planning support	LE13E	Planner	2004/5	2	800	64.34	0%	$51,472
									$0
									$0
64102	Enhanced Work Package Planning	LM02E	Field Supv	2004	4	16	76.14	0%	$1,218
64102	Enhanced Work Package Planning	LR05B	Operators	2004	4	16	44.75	0%	$716
64102	Enhanced Work Package Planning	LT05B	HPT	2004	4	16	41.86	0%	$670
64102	Enhanced Work Package Planning	LT06B	IH Tech	2004	4	16	42.70	0%	$683
64102	Enhanced Work Package Planning	LC00B	Rigger	2004	4	16	42.90	0%	$686
64102	Enhanced Work Package Planning	LM02E	Ops Mgr	2004	4	8	76.14	0%	$609
									$0
64104	Ops Management and Planning Suppo	LM02E	Ops Mgr	2004/5	5	200	76.14	0%	$15,228
		LM02E	RadConMgr	2004/5	5	200	76.14	0%	$15,228
									$0
									$0
									$0
									$0
									$0
									$0
						WBS Estimate Total			$109,511

2/11/2003 - 10:26 AM

OpsMgmtandPlanningSupport(586613931) / CEISTemplate

Cost Estimating Input Sheet

Page 1 of

WBS#	6.8.6.6.13.9.3.2	WBS Title:	Construction Support	
		Rev #	0	Date: 11/15/02

Scope Description:

This work scope provides for operations support during tank farm preparation work prior to placement of fill into the 241-200 series C Farm tanks. It is assumed that the preparation work would be performed by construction forces. The principal activity involves installation and testing of ventilation systems to the tanks.

Estimating Assumptions & Exclusions :

It is assumed that operations support will be required during construction activities will include 2 Operators, 2 HPTs, 2 IH techs, 1 Radcon Eng, and 1 clerk.

Basis of Estimate:

Estimate is based on current tank farm operating requirements. A factor of 50% is applied for SWP work and a factor of 30% is applied to delays in field activities caused by inclement weather (factor=1.5*1.3 = 1.95).

Contingency: Level of Confidence/Risks Identification

Contingency is addressed at the summary estimate level for all tank closure activities.

Estimating notes:(including identification of environmental/productivity factors):

1. Labor estimate is based on dedicated support for a period of 10 days.
2. Labor estimate is based on 1/2 time support for a period of 10 days.

6.0 Resource Requirements:

Act. #	Activity Description	Res Code	Res Type	FY	Note #	Bud.Qty	BQ Rate	Factors	$
64201	Operations Support during Const.	LR05B	Operators (2)	2004	1	160	44.76	195%	$13,965
64201	Operations Support during Const.	LT05B	HPTs (2)	2004	1	160	41.86	195%	$13,060
64201	Operations Support during Const.	LT06B	IH Tech (2)	2004	1	160	42.70	195%	$13,322
64201	Operations Support during Const.	LE13E	Radcon Eng	2004	2	40	64.34	0%	$2,574
64201	Operations Support during Const.	LG02N	Clerk	2004	1	80	23.16	195%	$3,613
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
								WBS Estimate Total	$46,534

2/11/2003 - 10:27 AM

ConstructionSupport (586613932) / CEISTemplate

Cost Estimating Input Sheet

Page 1 of 1

WBS#	5.8.6.6.13.9.3.3	WBS Title:	Stabilize Heel - 241-C-200s
		Rev #	0
		Date:	11/15/02

Scope Description:

This activity involves placement of the grout material into the 241-200 series tanks to stabilize the residual waste heel. The grout will be prepared outside the tank farm by a subcontractor and pumped to the tank through slicklines (pipe or hose). During grouting operations the operations crew will monitor in tank conditions, monitor the grout line and tank ventilation system, and remove and install grout tremie lines (flex hose) used to pump grout into the tank. This activity also includes video surveillance of the waste stabilization within the tank.

Estimating Assumptions & Exclusions :

It is assumed that separate crews will be utilized to provide for longer grout operating shifts. Once the grout pump is operating it is beneficial to run for longer durations to minimize cleanup and secondary waste generation. The camera crew consists of 4 operators, 1 field work supervisor, 2 craft, 1 HPT, and 1 IH tech. It is assumed that the entire waste stabilization effort will be videotaped. The operations crew to support grout placement consists of 1 field work supervisor, 2 operators and 1 HPT to verify integrity of the grout line and perform routine surveillance on the exhauster.

Basis of Estimate:

Engineering judgment. This is a first of a kind activity. A factor of 50% is applied for SWP and a factor of 30% is applied to account for field delays due to inclement weather (factor = 1.5*1.3=1.95).

Contingency: Level of Confidence/Risks identification

Contingency is addressed at the summary estimate level for all tank closure activities.

Estimating notes:(including identification of environmental/productivity factors):

1. Labor estimate is based on dedicated support from 2 operators x 2 shifts x 2 days/tank x 4 tanks x 8 hrs/day = 256 hrs
2. Labor estimate is based on dedicated support from 1 HPT/shift x 2 shifts x 2 days/tank x 4 tanks x 8 hrs/day = 128 hrs.
3. Labor estimate is based on dedicated support from 1 IH tech/shift x 2 shifts x 2 days/tank x 4 tanks x 8 hrs/day = 128 hrs
4. Labor estimate is based on 4 operators x 2 shifts x 2 days/tank x 4 tanks x 8 hrs/day = 512 hrs
5. Labor estimate is based on 1 field work supervisor x 2 shifts x 2 days/tank x 4 tanks x 8 hrs/day = 128 hrs
6. Labor estimate is based on 2 craft (fitter/instrument tech) x 2 shifts x 2 days/tank x 4 tanks x 8 hrs/day = 256 hrs
7. Labor estimate is based on 1 HPT x 2 shifts x 2 days/tank x 4 tanks x 8 hrs/day = 128 hrs
8. Labor estimate is based on 1 IH tech x 2 shifts x 2 days/tank x 4 tanks x 8 hrs/day = 128 hrs

6.0 Resource Requirements:

Act. #	Activity Description	Res Code	Res Type	FY	Note #	Bud.Qty	BQ Rate	Factors	$
64401	Waste heel stabilization	LR05B	Operators	2004/5	1	256	44.76	195%	$22,344
64401	Waste heel stabilization	LT05B	HPTs	2004/5	2	128	41.86	195%	$10,448
64401	Waste heel stabilization	LM02E	Field Supv	2004/5	3	128	76.14	195%	$19,005
									$0
64402	In tank video stabilization	LR05B	Operators		4	512	44.76	195%	$44,688
64402	In tank video stabilization	LM02E	Field Supv		5	128	76.14	195%	$19,005
64402	In tank video stabilization		Craft		6	256	44.76	195%	$22,344
64402	In tank video stabilization	LT05B	HPT		7	128	41.86	195%	$10,448
64402	In tank video stabilization	LT06B	IH Tech		8	128	42.70	195%	$10,658
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
						WBS Estimate Total			$158,940

2/11/2003 - 10:27 AM

StabilizeHeel(585613933) / CEIS Template

Cost Estimating Input Sheet

WBS#	5.8.6.6.13.9.3.4	WBS Title:	Tank Farm Surface Restoration and Demob	
Prepared By: C Henderson		Rev #	0	Date:11/15/02

Scope Description:

This activity involves providing intrusion/isolation measures for the tank following waste stabilization to prevent intrusion of water between completion of Phase 1 (waste stabilization activities) and Phase 2 (bulk tank fill).

Estimating Assumptions & Exclusions :

It is assumed that isolation measures would be similar to isolation measures conducted on the SSTs following completion of Interim stabilization. It is assumed that the isolation of the 4 241-C-200 series tanks will be similar to the isolation of AX-101.

Basis of Estimate:

Estimate is based on existing planning estimates for isolation of tank AX-101.

Contingency: Level of Confidence/Risks Identification

Contingency is addressed at the summary estimate level for all tank closure activities

Estimating notes:(including identification of environmental/productivity factors):

1. Estimate taken from existing planning estimates for isolation of tank AX-101.
2. Assume that removal of the grout slickline costs the same as the installation.

6.0 Resource Requirements:

Act #	Activity Description	Res Code	Res Type	FY	Note #	Bud Qty	BQ Rate	Factors	$
64561	isolate 200 series tanks	21	Multiple	FY04	1	97	1000.00	0%	$97,000
64561	remove grout slickline	21	subcontract	FY04	2	17.55	1000.00	0%	$17,550
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
							WBS Estimate Total		$114,550

1/2003 - 10:28 AM

RestorasandDemob(5.8.6.6.13.9.3.4) / CEISTemplate

Cost Estimating Input Sheet

Page 1 of 1

WBS#	5.8.6.6.14.1.1	WBS Title:	Final As-Built Drawings
		Rev #	0 Date: 9/12/02

Scope Description:

This activity provides for modifying the design drawings as necessary to reflect the final configuration of the tanks following closure.

Estimating Assumptions & Exclusions :

It is assumed that 10 moderately complex ECNs and 5 simple ECNs will be required to document the as built condition of the tanks following closure.

Basis of Estimate:

Engineering judgment. A moderately complex ECN requires 80 hours to complete. A simple ECN requires 60 hours to complete.

Contingency: Level of Confidence/Risks Identification

Contingency is addressed at the summary estimate level for all tank closure activities.

Estimating notes:(including identification of environmental/productivity factors):

1. 4 Moderately complex ECNs x 80 hrs/ECN = 320 hours and 2 simple ECNs x 60 hrs/ECN = 120 hours (total = 440 hours)

6.0 Resource Requirements:

Act. #	Activity Description	Res Code	Res Type	FY	Note #	Bud.Qty	BQ Rate	Factors	$
7101	As built	LE13E	Engineer	2005	1	440	64.34	0%	$28,310
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
								WBS Estimate Total	28309.6

Final asbuilt drawings (5.8.6.6.14.1.1) / CEISTemplate

Cost Estimating Input Sheet

WBS#	5.5.5.5.14.1.2	WBS Title:	Modify Relevant Documents
		Rev #	0
		Date:	11/15/02

Scope Description:

This activity provides for modifying existing documents to the extent necessary to reflect the change in status/ configuration of the 5 demonstration tanks following interim closure.

Estimating Assumptions & Exclusions :

Assume that there are 5 documents that will warrant revision following tank closure. Document changes are assumed to require an average of 40 hours/document plus technical editing.

Basis of Estimate:

Engineering judgment

Contingency: Level of Confidence/Risks Identification

Contingency is addressed at the summary estimate level for all tank closure activities.

Estimating notes: (including identification of environmental/productivity factors):

1. Labor estimate is based on 5 documents x 40 hrs/document = 200 hrs
2. Labor estimate is based on 10 documents x 16 hrs/document = 80 hrs

6.0 Resource Requirements:

Act. #	Activity Description	Res Code	Res Type	FY	Note #	Bud.Qty	BQ Rate	Factors	$
7201	Revise documents	LE13E	Eng	2005	1	200	64.34	0%	$12,868
7201	Revise documents	LP00E	Tech Editor	2005	2	80	47.30	0%	$3,784
7201	Revise documents	LG02N	Word Proc.	2005	2	80	23.16	0%	$1,853
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
								WBS Estimate Total	$18,505

2/11/2003 - 10:30 AM

ModifyRelevantDocuments(5.5.5.5.14.1.2) / CEISTemplate

Cost Estimating Input Sheet

WBS#	5.8.6.6.14.1.3	WBS Title:	Lessons Learned		
Prepared By: C Henderson			Rev #	0	Date: 11/16/02

Scope Description:

This activity provides for collecting and documenting lessons learned from closure activities.

Estimating Assumptions & Exclusions :

It is assumed that lessons learned will be collected in a 1 day working session with representatives from the involved organizations.

Basis of Estimate:

Engineering judgment.

Contingency: Level of Confidence/Risks Identification

Contingency is addressed at the summary estimate level for all tank closure activities.

Estimating notes:(including identification of environmental/productivity factors):

1. Assume a 2 day working session.
2. Prepare a lessons learned report.
3. Lessons learned report document production
4. Lessons learned report review and approval.

6.0 Resource Requirements:

Act. #	Activity Description	Res Code	Res Type	FY	Note #	Bud.Qty	BQ Rate	Factors	$
7301	Lessons learned workshop		Operator	2005	1	16	44.76	0%	$716
7301	Lessons learned workshop		Operator	2005	1	16	44.76	0%	$716
7301	Lessons learned workshop		HPT	2005	1	16	41.86	0%	$670
7301	Lessons learned workshop		IH tech	2005	1	16	42.70	0%	$683
7301	Lessons learned workshop		Field Supv	2005	1	16	76.14	0%	$1,218
7301	Lessons learned workshop		Ops Manager	2005	1	16	76.14	0%	$1,218
7301	Lessons learned workshop		Sys Eng	2005	1	16	64.34	0%	$1,029
7301	Lessons learned workshop		Rad Con Eng	2005	1	16	64.34	0%	$1,029
7301	Lessons learned workshop		Clerk	2005	1	16	23.16	0%	$371
7301	Lessons learned workshop		QA	2005	1	16	47.30	0%	$757
									$0
7301	Prepare Lessons Learned Doc		Eng	2005	2	80	64.34	0%	$5,147
7301	Prepare Lessons Learned Doc		Tech Edit	2005	3	32	47.30	0%	$1,514
7301	Prepare Lessons Learned Doc		Clerk	2005	3	32	23.16	0%	$741
7301	Review /Approve Document		Manager	2005	4	24	76.14	0%	$1,827
									$0
									$0
									$0
									$0
									$0
							WBS Estimate Total		$17,637

2/11/2003 - 10:30 AM

LessonsLearned (5.8.6.6.14.1.3) / CEISTemplate

Cost Estimating Input Sheet

WBS#	5.8.6.6.14.2.1	WBS Title:	Environmental Permitting	
		Rev #	0	Date: 11/15/02

Scope Description:

This activity involves the preparation, review, and approval of the Notice of Construction permits required to close the tanks. This activity is assumed to require a complex NOC and subsequently has a higher cost than routine NOCs. It is assumed that both radiological and nonradiological NOCs will be required. The NOC process includes: 1) gather NOC data, 2)prepare draft NOC, 3)conduct internal CHG NOC review, 4) conduct ORP/Regulatory NOC review, 5) negotiate NOC, 6) provide regulatory NOC approval, and 7) implement NOC.

Estimating Assumptions & Exclusions :

Sample analyses, source term, and process data is either not available or requires significant manipulation to support NOC development.
Significant technical unknowns or other significant risks impacting the potential to emit may be identified

Basis of Estimate:

Estimate is developed from an NOC CEIS template developed by the CHG environmental and permitting group for preparation of a "complex" NOC.

Contingency: Level of Confidence/Risks Identification

Estimating notes:(including identification of environmental/productivity factors):

A single composite hour estimate of 512 hrs was summarized from historical CEIS data for preparation of a complex NOC.

6.0 Resource Requirements:

Act. #	Activity Description	Res Code	Res Type	FY	Note #	Bud.Qty	BQ Rate	Factor%	$
8101-3	Develop/Implement NOCs	LE13E	Env Engineer	2004	1	512	64.34	0%	$32,942
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
							WBS Estimate Total		$32,942

2/11/2003 - 10:31 AM

Environmental and Permitting (5.8.6.6.14.2.1) / CEISTemplate

Cost Estimating Input Sheet

Page 1 of 1

WBS#	5.8.6.6.14.2.2	WBS Title:	System Engineering Support
		Rev #	0	Date: 11/15/02

Scope Description:

This activity provides for tank farm engineering support during grout operations to prepare ECNs and process changes if/as required.

Estimating Assumptions & Exclusions :

The equivalent of one tank farm system engineer will support grout placement operations.

Basis of Estimate:

Engineering judgment

Contingency: Level of Confidence/Risks Identification

Contingency is addressed at the summary estimate level for all tank closure activities.

Estimating notes:(including identification of environmental/productivity factors):

1. The labor hour estimate is for the equivalent of 1 FTE at 1/2 time to provide tank farm system engineering support to the tank closure project.

6.0 Resource Requirements:

Act. #	Activity Description	Res Code	Res Type	FY	Note #	Bud.Qty	BQ Rate	Factors	$
0201	Plant Eng Support	LE13E	Engineer	2004	1	1000	64.34	0%	$64,340
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
									$0
							WBS Estimate Total		$64,340

2/11/2003 - 10:31 AM

System Engineering Support (5.8.6.6.14.2.2) / CEISTemplate

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APPENDIX B
GROUT DELIVERY/PLACEMENT EVALUATION CRITERIA AND CONCEPT SELECTION PROCESS

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CONTENTS

B1.0 INTRODUCTION B-1

B2.0 GROUT DELIVERY AND PLACEMENT REQUIREMENTS B-1

B3.0 DECISION CRITERIA B-1

B4.0 GROUT DELIVERY AND PLACEMENT ALTERNATIVES B-3
- B4.1 ASSUMPTIONS AND SYSTEM CONSTRAINTS B-3
- B4.2 GROUT DELIVERY AND PLACEMENT SYSTEM OPTIONS B-5
  - B4.2.1 Delivery to Site Options B-6
  - B4.2.2 Delivery to Tank Options B-11
  - B4.2.3 Dry Cement Placement for Stabilization Options B-15
  - B4.2.4 Wet Grout Placement for Stabilization Options B-19
- B4.3 BALANCE OF TANK FILL B-29

B5.0 EVALUATION B-29

B6.0 ALTERNATIVE SELECTION B-36

B7.0 REFERENCES B-36

TABLES

B.1. Sample Design Criteria Evaluation Form B-3
B.2. Waste Stabilization Wet Grout Delivery to the Site for 165 cubic yards B-30
B.3. Waste Stabilization Wet Grout Delivery to the Site for 500 cubic yards B-30
B.4. Wet Grout Delivery to the Site for Bulk Tank Fill B-31
B.5. Waste Stabilization Wet Grout Delivery to the Tank for 165 cubic yards B-31
B.6. Waste Stabilization Wet Grout Delivery to the Tank for 500 cubic yards B-32
B.7. Wet Grout Delivery to the Tank for Bulk Tank Fill B-32
B.8. Waste Immobilization Dry Cement Placement B-33
B.9. Waste Stabilization Wet Grout Placement B-34

LIST OF TERMS

FY	fiscal year
MPI	Multi-Point Injection System™
SRS	Savannah River Site
SST	single-shell tank

B1.0 INTRODUCTION

Preliminary engineering efforts have been initiated in support of the definition of closure concepts for demonstration in tank 241-C-106 and follow on implementation in the four 241-C 200-series tanks. It has been assumed that the five tanks would be closed in place with a two-phase grout fill for the tanks:

- **Phase 1** – Initial layer(s) of grout will be placed into the tanks to stabilize and encapsulate the residual waste heel in the tank
- **Phase 2** – Bulk fill the remaining tank volume to minimize water infiltration, prevent long-term degradation of the surface barrier due to subsidence, and discourage intruder access.

For the purpose of this report it is assumed that Phase 2 would not occur immediately following Phase 1; at least 1 and up to 20 years could elapse between Phase 1 and Phase 2.

The purpose of this appendix is to identify, evaluate, and select a concept for delivery, production, and placement of grout (dry and wet) for Phase 1 and Phase 2 closure of the five demonstration tanks.

B2.0 GROUT DELIVERY AND PLACEMENT REQUIREMENTS

Tank Closure Fill System for Interim Closure of Selected 241-C Farm Tanks Level 2 Specification (RPP-11094), hereafter referred to as the Level 2 Specification, establishes the performance specifications for project definition and preliminary engineering of a tank closure fill system. The performance objectives defined in the Level 2 Specification relevant to grout delivery and placement include:

- Minimizing the solubility and mobility of key contaminants
- Providing structural support for bulk tank fill
- Allowing retrieval of waste stabilization fill.

B3.0 DECISION CRITERIA

The preliminary engineering effort needs to determine the most appropriate grout delivery and placement system concept for tank closure demonstrations that best meets the evaluation criteria. The decision criteria used to select a single grout delivery and placement concept for use in preliminary engineering should be measurable, independent from other criteria, and conducive to ranking and scoring.

The preliminary decision criteria for use in selecting a recommended grout delivery and placement system include:

- **Safety** – Safety issues to be considered include construction, operation, and demobilization of the grout delivery and placement system. A low score would correspond to significant safety concerns and/or the requirement to design and implement engineering controls. A high score would correspond to a system that has limited safety concerns.

- **Operability** – The ease and/or difficulty in operating a given system is assigned a value with a lower value corresponding to a difficult system to operate and a higher value corresponding to an easy system to operate.

- **Technical risk** – Technical risk criteria provide a means to measure the level of confidence that a given concept will work and as a measure of how well it meets the technical requirements (i.e., macroencapsulation). A low value corresponds to a low level of confidence while a high value corresponds to a high level of confidence (i.e., the system has been deployed either in U.S. Department of Energy or commercial applications).

- **Deployment schedule risk** – The potential for deployment of a given concept on a schedule that is compatible with the overall Accelerated Tank Closure Demonstration Project schedule is assigned a value based on the level of confidence (high= 5, medium high=4, medium=3, medium low=2, low=1) in meeting project schedule constraints.

- **Cost** – A cost value is assigned based on engineering judgment for the life cycle cost (capital and operating) of an option.

The decision strategy involves development and evaluation of a reasonable range of alternatives for the delivery and placement of grout into the closure demonstration tanks. Review of concepts developed at other U.S. Department of Energy sites and brainstorming sessions were used to identify a range of alternatives for delivery and placement of the grout. It is expected that one grout delivery and placement concept will be selected for each phase of interim closure for further development in preliminary engineering.

For each grout delivery and placement system concept the individual decision criterion will be assigned a value from 1 to 5. A weighting factor between 1 and 5 will be developed for each decision criterion and a weighted score will be calculated for each option based on the raw score and the weighting factor. These weighted scores will then be added together and the options will be ranked based on numerical value. Table B.1 provides a sample evaluation form.

Table B.1. Sample Design Criteria Evaluation Form

	Safety	Operability	Technical Risk	Deployment Schedule	Cost	Total
Raw Scores						
Option A						
Option B						
Option C						
Weighted Scores						
Weighting factor						
Option A						
Option B						
Option C						

B4.0 GROUT DELIVERY AND PLACEMENT ALTERNATIVES

B4.1 ASSUMPTIONS AND SYSTEM CONSTRAINTS

To evaluate options for grout delivery and placement systems a number of assumptions and system constraints warrant identification. These assumptions and constraints include the following:

- Each of the tanks will be retrieved to the *Hanford Federal Facility Agreement and Consent Order* (HFFACO; Ecology et al. 1989) interim retrieval requirement of 360 cubic feet (tank 241-C-106) and 30 cubic feet for each of the 200-series tanks (Milestone M-45-00). Following retrieval the residual waste will consist of wet solids, liquids, dry solids, hard heel, or any combination thereof. Residual waste characteristics and volumes will be evaluated during post-retrieval sampling and analysis.

- Because of the uncertainty in the physical form of the residual waste that will remain following retrieval and the general interest in preventing any liquid or loose sludge from being pushed to the outer edge of the tank, it is assumed that dry cement will be added to the tank before adding the wet grout. Dry cement will be added to each tank as the first step toward the residual waste stabilization process if, and only if, a wet sludge or liquid remains in the tank. If the tank is declared dry (i.e., no free liquids or wet sludge), this method will not be utilized and the introduction of wet grout will be utilized from the onset of closure operations. For the purposes of this evaluation, it will be assumed that tank 241-C-106 will require the dry cement placement (i.e., will have liquids remaining) and the C farm 200-series tanks will not require the introduction of dry cement (i.e., will be dry). The purpose for introducing the dry cement will be to absorb and immobilize the anticipated liquids and immobilize non-adherent solids remaining in the dished tank bottom after the completion of the waste retrieval effort. It will be assumed that there

will be approximately 3 inches (at the tank center) of liquid remaining in tank 241-C-106 at the completion of the retrieval effort. The 3 inches of liquid remaining in the bottom of the tank will equate to approximately 830 gallons. For low compressive strength concrete, the water/cement ratio is approximately 0.82 (Mark's Standard Handbook for Mechanical Engineers, Ninth edition, pg 6-182). Utilizing this ratio for calculating the volume of cement required to absorb the liquids yields approximately 3.5 cubic yards of cement. For conservatism, it will be assumed that this volume will be doubled and 7 yards of dry cement will have to be added to tank 241-C-106 to absorb and stabilize the remaining liquid waste.

- The project schedule for field deployment of the waste stabilization for tank 241-C-106 is from February through March 2004.

- The project schedule for field deployment of the waste stabilization for tanks 241-C-201, -202, -203, and -204 follows the deployment in tank 241-C-106, is dependent on the C farm 200-series retrieval schedule, and must be completed by December 30, 2004.

- The volume of grout needed to stabilize the waste residual is yet to be determined; however, it is assumed that stabilization of the residual waste would be accomplished with a 10- to 12-inch layer (approximately 165 cubic yards) of stabilizing material. This volume would result in a nominal 10% waste loading in the stabilizing grout. Additional grout beyond the 10- to 12-inches may be required to meet waste classification requirements for the residual waste.

- In-tank equipment will be encapsulated in the grout.

- Ready access for each of the tanks is available at the center or near-center riser. Additional access, if required, would involve removal of equipment from other riser(s) or installation of new access risers.

- The stabilizing grout is an adaptation of the Savannah River Site (SRS) all-in-one zero bleed reducing fill/grout system with the mix proportions adjusted to meet the retrievability criteria. This formulation can be readily pumped, is self leveling, and produces no bleed water.

- Macroencapsulation will be the preferred alternative for declaring the residual waste heel stabilized.

- The programmatic risks associated with grout placement in a tank (residual waste stabilization and bulk tank fill) are those from a regulatory standpoint. For the purposes of this evaluation, they will be assumed the same for all options and will not be a discriminating factor.

- For the evaluations where cement/grout (dry/wet) is being introduced in multiple locations, it will be assumed that four tank penetrations (risers) at 90° intervals around the tank perimeter will be utilized for grout introduction. Tank 241-C-106 does not have any risers on the west edge, as such it will be assumed that for these options that one new riser will be installed.

- For the evaluations where cement/grout (dry/wet) is being introduced in multiple locations, it will be assumed that for the three locations where existing risers will be utilized that the in-tank equipment will be removed or cut off and disposed of in the tank.
- The concrete mixer trucks will be able to be washed out and deposit the remnant grout at a designated location in the 200 East Area. This existing location was utilized for concrete mixer truck cleaning during Projects W-211 and W-314.
- Rejected concrete mixer trucks of grout originating from an offsite grout facility will not require dumping onsite. The grout will be able to be diluted and returned to the grout mixing facility offsite.
- The strength of the dry cement and liquid waste mixture will be no greater than that of the stabilization wet grout layer (50 to 300 lb/in^2).
- Phase 2 interim closure will occur between 1 and 20 years following Phase 1 interim closure.

B4.2 GROUT DELIVERY AND PLACEMENT SYSTEM OPTIONS

The following outline the grout delivery and placement system options.

Material Delivery to Site

1. Concrete mixer trucks from the local concrete suppliers at 8 to 10 yards each
2. Dry material delivered to a batch plant on or near the Hanford Site plus trucking to the tank farm
3. Batch plant located at the tank farm (no trucking)
4. Continuous batching and mixing plant at the tank farm (no trucking).

Wet Grout Delivery to the Tank

1. Truck delivery to the tank riser (concrete mixer trucks)
2. Pump grout from outside the tank farm through a slickline
3. Pump grout from outside the tank farm by boom pump truck.

Placement of Dry Waste Stabilization Cement

1. Pneumatic delivery of dry cement material through a single central riser location (liquid absorption)
2. Hopper delivery of dry cement material through a single central riser (liquid absorption)
3. Pneumatic delivery of dry cement material through multiple riser locations located toward the edge of the tank (liquid absorption)

4. Hopper delivery of dry cement material through multiple riser locations located toward the edge of the tank (liquid absorption).

Placement of Wet Waste Stabilization Grout

1. Gravity fill with tremie from one location single lift (macroencapsulate between grout layer and tank structure)
2. Gravity fill with tremie from one location in two lifts (i.e., attempt to macroencapsulate between grout layers)
3. Gravity fill with tremie from one location, multiple lifts (attempt to mix)
4. Gravity fill with tremie from multiple locations using two or more lifts (i.e., attempt to macroencapsulate)
5. Rotating nozzle located in the central riser (attempt to direct the grout to the edge of the tank from the central location and macroencapsulate)
6. Gravity fill using distribution lines (attempt to direct grout to the edge of the tank from the central location and macroencapsulate)
7. Gravity fill using a cantilevered tremie line (attempt to direct grout to the edge of the tank from the central location and macroencapsulate)
8. Single-point injection with low pressure grout (less than 350 lb/in^2)
9. Multi-Point Injection System™ (MPI) with high pressure grout (approximately 6,000 lb/in^2)
10. In-tank mechanical mixing using robotic mixers
11. In-tank mixer pump.

Placement of Tank Fill Grout

1. Gravity fill with tremie from one location, multiple lifts as required to limit temperature.

B4.2.1 Delivery to Site Options

The following sections define the delivery to site options of (1) concrete mixer trucks from offsite batch plant, (2) concrete mixer trucks from central onsite batch plant, (3) local portable onsite batch plant, and (4) local portable continuous mixing plant.

It is unknown how the residual waste remaining in the tank will be dispersed over the bottom of the tank. Optimally, the retrieval operations would move the insolubles to the center of the tank and they would be distributed over the center of the tank (in a dished-bottom 100-series tank, a depth of 5-inches at the center and extending out to a diameter of approximately 44 feet equates to approximately 360 cubic feet of waste). For this condition, a 10- to 12-inch thick layer of

grout will be placed to stabilize the residual waste (approximately 165 cubic yards). However, it is likely that after the tank retrievals, there will be remaining waste bergs of unknown height located at various positions on the tank floor. As such, each delivery site option will be evaluated for residual waste stabilization grout volumes of 165 and 500 cubic yards as well as for the bulk filling of the tank with grout. For a 200-series tank, a 10- to 12-inch-thick waste stabilization grout layer equates to approximately 8 cubic yards. For conservatism, the volumes were evaluated for the largest of the five tanks, tank 241-C-106.

Similar tank closure activities have been conducted at the SRS. Methods used to produce and place grout material in HLW tanks at the SRS are described in DOE/EM-0449.

B4.2.1.1 Concrete Mixer Trucks from Offsite Batch Plant

A local, commercially operated concrete batch plant would be contracted to provide grout batching. Concrete mixer trucks would mix and transport the grout to the Hanford tank farms. Nominally, a concrete mixer truck holds 8 cubic yards (1,600 gallons) of concrete. For a nominal grout placement lift of approximately 10 inches (165 cubic yards for 100-series tanks) for residual waste stabilization, approximately 20 concrete mixer truck loads are required for tank 241-C-106, and 1 concrete mixer truck load is required for a 241-C farm 200-series tank. For a nominal grout placement lift of approximately 500 cubic yards for residual waste stabilization, approximately 62 concrete mixer truck loads are required for tank 241-C-106, and 6 concrete mixer truck loads are required for a 241-C farm 200-series tank.

The internal volume of tank 241-C-106 is approximately 849,000 gallons with a nominal operating capacity of 530,000 gallons. Excluding risers and in-tank equipment, approximately 530 concrete mixer truck loads would be required to fill tank 241-C-106 (includes waste stabilization volumes). The 241-C farm 200-series tanks have an approximate internal volume of 60,000 gallons. Again excluding risers and in-tank equipment, each 241-C farm 200-series tank would require approximately 38 concrete mixer truck loads to fill the tank (includes waste stabilization volumes).

Safety:

Residual Waste Stabilization: This option requires that concrete mixer trucks transport the grout over roadways that provide the only access to the Hanford Site from Richland. The main travel route also serves as the primary access to the Hanford Site's 300 and 400 Areas and Energy Northwest's Columbia Generating Station. Other Hanford Site construction activities including the Waste Treatment Plant, environmental remediation activities, and Hanford tank farm upgrades will continue to burden these access routes with heavy truck traffic. For the tank residual waste stabilization lift option of approximately 165 cubic yards (20 concrete mixer truck loads), delivery of the grout could be scheduled so that it would not occur at peak traffic times due to the minimal loads required. For the tank residual waste stabilization lift option of approximately 500 cubic yards (62 concrete mixer truck loads), it is likely that grout deliveries would conflict with at least one to two peak traffic times.

Bulk tank fill: This option requires a large number of concrete trucks to transport the grout over roadways that provide the only access to the Hanford Site from the Richland area. The main travel route also serves as the primary access to the Hanford Site's 300 and 400 Areas and

Energy Northwest's Columbia Generating Station. Other Hanford Site construction activities including the Waste Treatment Plant, environmental remediation activities, and Hanford tank farm upgrades will continue to burden these access routes with heavy truck traffic. The production schedule would likely require grout delivery at peak traffic times during bulk tank fill operations.

Operability: For both of the waste stabilization lift options of approximately 165 cubic yards (20 concrete mixer truck loads) and approximately 500 cubic yards (62 concrete mixer truck loads) and for bulk filling of the tank, there could be transportation delays due to random searches at the Hanford Site guard gate which would result in unacceptable delays in placement of the grout in the tank or rejection of the load at the delivery point. For both waste stabilization options and for bulk tank fill, flushing of the delivery system to the tank would be required by excessive delays in truck arrival. Due to travel time from an offsite batch plant and time limits from mixing to placement of the grout, there would have to be precise coordination between the grout contractor and the construction project manager to help ensure that minimal interruptions would be encountered during the residual waste stabilization process. Additional delays could be encountered due to mechanical failures of either the concrete mixer trucks or the system delivering the grout to the tank.

For waste stabilization using grout injection technologies, large volumes of grout are introduced to the tank in a short time span. The logistics of supplying such a large volume of grout in the short operational duration using concrete mixer trucks would be problematic.

Technical Risk: For both Phase 1 and Phase 2, the properties of the wet grout mixture are time dependent. Delays in transport of the grout due to congested traffic during peak traffic times or due to random searches at the Hanford Site guard gate could result in rejection of the concrete mixer truck load of grout at the delivery point.

Deployment Schedule Risk: None identified.

Cost: No discriminating costs.

B4.2.1.2 Concrete Mixer Trucks from Central Onsite Batch Plant

A grout batch plant would be erected on the site for operation by tank farms personnel. The batch plant would be centrally located between the 200 West and the 200 East Area tank farms and would be a dedicated facility with a 30-year design life to service closure of all of the Hanford waste storage tanks. Concrete mixer trucks would mix and transport the grout to the tank farms. The number of concrete mixer trucks required for stabilization and tank fill is as described in the concrete mixer Trucks from Offsite Batch Plant option (Section B.4.2.1.1). The batch plant would require site services including electrical power and water. Dry grout mix components would be trucked to the batch plant from offsite suppliers. For this option, an existing onsite facility/designated location would be utilized for dumping rejected grout loads.

Safety: For both Phase 1 and Phase 2, the same number of concrete mixer trucks for deliver of the wet grout to the tank farms would be required. It is likely that the onsite batch plant could be placed in a location to minimize and/or mitigate concrete mixer truck travel on high traffic roadways. For both phases, trucks would still be required to travel from Richland to the Hanford

Site to deliver the dry grout mix ingredients to storage silos located at the batch plant. These deliveries could be scheduled for non-peak traffic periods.

Operability: For both Phase 1 and Phase 2, the onsite batch plant would be operated by Hanford Site personnel and would be subject to limiting conditions of existing labor agreements and air operating permits.

For waste stabilization using grout injection technologies, large volumes of grout are introduced to the tank in a short time span. The logistics of supplying such a large volume of grout in the short operational duration using concrete mixer trucks would be problematic.

Technical Risk: None identified.

Deployment Schedule Risk:

Residual Waste Stabilization: This would be a capital construction; obtaining project authorization, plant siting, plant construction and operating permits, qualified construction employees, and operations employee training within schedule parameters is not reasonable for Phase 1 of tank closure.

Bulk Tank Fill: None identified.

Cost: For both Phase 1 and Phase 2, capital costs would be high for the construction of the batch plant. Additional costs would be incurred for the buying and operating the concrete mixer trucks. Transportation of the dry grout mix would be provided by the offsite vendors of such materials. Operations costs would also be high for this option as the operation of the batch plant and concrete mixer trucks would be by Hanford Site personnel per existing Hanford Site labor agreements.

This option also requires consideration of maintenance and decommissioning costs. There may be a number of months or even years between the residual waste stabilization, the bulk tank fill operations, and the next closure operation. The batch plant would have to be maintained during periods of non-production and the plant operators and support personnel would have to be temporarily reassigned to other projects.

B4.2.1.3 Local Portable Onsite Batch Plant

A portable grout batch plant would be mobilized at a staging area adjacent to the tank farm in a non-radiologically controlled area. The portable batch plant would include portable generators that would provide the needed electrical power. Permitting for the portable generators would be required if diesel powered generators in excess of 500-horse power were required. Site services would provide water to the batch plant. Dry grout mix components would be trucked to the batch plant from offsite suppliers. The batch plant would need to be flushed after completion of, or extended delay in, the grout production campaign. Existing facilities/designated locations would be utilized for dumping a load of grout that cannot be delivered to the tank due to mechanical failure, administrative hold, or other production interruption.

Safety: For both Phase 1 and Phase 2, the same number of concrete mixer trucks for deliver of the wet grout to the tank farms would be required. It is likely that the onsite batch plant could be

placed in a location to minimize and/or mitigate concrete mixer truck travel on high traffic roadways. For both phases, trucks would still be required to travel from Richland to the Hanford Site to deliver the dry grout mix ingredients to storage silos located at the batch plant. These deliveries could be scheduled for non-peak traffic periods.

Operability: For both Phase1 and Phase 2, delays in the delivery of the grout to the tank due to mechanical failure or administrative hold could result in the need to dump batch loads of grout and flush the wet side of the batch plant causing additional schedule delays. An offsite vendor would provide all batch plant equipment and provide all operating personnel.

For Phase 2 of closure and future closure operations, capital equipment acquisition with operation by Hanford Site personnel should be considered.

Due to time limits from mixing to placement of the grout, delays in delivery of the grout to the tank due to mechanical failure or administrative hold could result in the need to dump batch loads of grout and flush the wet side of the batch plant causing additional schedule delays.

Technical Risk: None identified.

Deployment Schedule Risk:

Residual Waste Stabilization: Even though these services would be contracted to be provided by a vendor, there is a slight risk involved with getting all of the required components in place and operating on the Hanford Site at the time of Phase 1.

Bulk Tank Fill: None identified.

Cost: For both Phase1 and Phase 2, a vendor will be contracted to provide a service including all equipment to perform that service. As such there are no capital costs or employee-related operational costs associated with either phase of closure. Operational costs associated with dumping a batch of grout due to production interruptions should be limited with a local batch plant.

B4.2.1.4 Local Portable Continuous Mixing Plant

A portable continuous mixing plant will be mobilized at a staging area adjacent to the tank farm in a non-radiologically controlled area. The continuous mixing plant would include portable generators that would provide the needed electrical power. Permitting for the portable generators would be required if diesel powered generators in excess of 500-horse power were required. Site services would provide water to the mixing plant. Dry grout mix components would be trucked to the mixing plant from offsite suppliers. Water is added to the mix of dry components in a hopper that feeds the discharge pump. The discharge pump and its feed hopper would need to be flushed after completion of, or extended delay in, the grout production campaign. The continuous mixing operation does not require the collection of large volumes of wet grout; therefore, facilities for dumping a load of grout are not required.

Safety: For both Phase 1 and Phase 2, the number of trucks required to travel on the primary Hanford Site access routes from the Richland area compared to the option with an offsite batch plant would be reduced by approximately two-thirds. With a local batch plant, trucking of the

wet grout can be eliminated entirely by delivering to the tank by a slickline or a boom pump truck, but would require the same number of concrete mixer trucks as the offsite or central onsite batch plants if the preferred delivery option to the tank is by concrete mixer trucks. The trucks traveling from the Richland area would supply the dry grout mix ingredients to storage silos at the continuous mixing plant with deliveries scheduled for non-peak traffic periods.

Operability: For both Phase 1 and Phase 2, the continuous mixing plant would not require the storage of wet grout, as such delays in delivery of the grout to the tank due to mechanical failure or administrative hold would not result in the need to dump batch loads of grout. However, extensive delays would require flushing of the mixing hopper and discharge pump. Flushing of the wet side of the continuous mixing plant is a relatively simple operation that is unlikely to cause additional schedule delays.

For both phases of tank closure, an offsite vendor would provide all continuous mixing plant equipment and provide all operating personnel. For Phase 2 of the closure demonstration and future closure operations, capital equipment acquisition with operation by Hanford Site personnel should be considered.

Technical Risk: None identified.

Deployment Schedule Risk:

Residual Waste Stabilization: Even though these services would be contracted to be provided by a vendor, there is a slight risk involved with getting all of the required components in place and operating on the Hanford Site at the time of Phase 1.

Bulk Tank Fill: None identified.

Cost: For both Phase 1 and Phase 2, a vendor will be contracted to provide a service including all equipment to perform that service. As such there are no capital costs or employee-related operational costs associated with either phase of closure.

B4.2.2 Delivery to Tank Options

The following sections define delivery to tank options: (1) truck delivery to tank riser, (2) pipeline from outside of the tank farm, and (3) boom pump truck.

B4.2.2.1 Truck Delivery to Tank Riser

Concrete mixer trucks would enter the tank farm radiologically controlled area along predetermined and controlled travel paths to be staged adjacent to the tank. The grout delivery chute would be positioned above the receipt hopper and the load would be discharged. Upon delivery of the load, the truck would move along predetermined and controlled travel paths to the tank farm exit staging area for a radiological survey and decontamination, as required. When cleared for exit from the radiologically controlled area, the truck would travel to the flushing facility for removal of residual grout within the truck. A truck decontamination facility with collection of radiologically contaminated decontamination fluids would need to be erected within the tank farm radiologically controlled area. Transport or piping of the contaminated fluids to the onsite treatment and disposal facility would need to be provided.

Safety: The safety concerns described in this section apply to both Phase 1 and Phase 2. Strict dome loading requirements are in place for all Hanford tanks. Designated travel paths for the heavy concrete mixer trucks would have to be established and controlled. The potential for human error likely will require failsafe and redundant systems and constraining administrative controls to allow entry into the tank farm.

The potential for contamination spread is high given the required number of trucks and the frequency of access. Although the number of trucks will be minimal for Phase 1, the likelihood for contamination spread is still high. Contamination spread and waste generation is also likely due to the potential of spillage associated with chute positioning and delivery of the grout.

This method of grout delivery requires a relatively large number of employees in the radiologically controlled area including the truck driver who would remain in the truck cab due to entry and exit requirements, truck spotters, workers to position and clean the grout chute, and Health Physics Technicians to survey the trucks before exiting the radiologically controlled area.

Operability: For both Phase 1 and Phase 2, there are several operability difficulties associated with entering the radiologically controlled area as discussed in the section addressing safety.

Schedule delays are very likely for both phases with this option due to entry and exit requirements of a radiologically controlled area. Should a concrete mixer truck become contaminated, efforts to decontaminate the truck would be taken and if unsuccessful would require purchase of the truck. In either event extended production delays would be certain.

For bulk tank filling, grout injection technologies introduce a large volume of grout in a short time span. The logistics of supplying such a large volume of grout in the short operational duration using concrete mixer trucks would be problematic.

Technical Risk: *None identified.*

Deployment Schedule Risk: For both Phase 1 and Phase 2, completing the safety case analyses and obtaining the safety authorization basis modifications necessary to allow the concrete mixer truck to drive into the tank farm may be difficult to achieve within the constraints of the schedule.

Cost: For both Phase 1 and Phase 2, operations costs are high for this option due to extensive operations within the radiologically controlled area. Capital costs are moderately high due to the need for a truck exit staging area and decontamination facilities. In addition, if a concrete mixer truck could not be adequately decontaminated, the cost of the truck would be burdened by the project.

B4.2.2.2 Pipeline from Outside of the Tank Farm

A grout slickline would be constructed from the grout pump located adjacent to and outside of the radiologically controlled area fence to the tank riser. The slickline consists of 10-foot sections clamped together and placed on grade and would cross the radiological control barrier. Scaffolding support may be required adjacent to the riser pit and other locations that the ground does not provide continuous support of the slickline. Grout would be fed into the pump feed hopper and pumped to the tank riser. Flushing of the pump and slickline would be required at

the completion of a grouting campaign or upon extended delays. The slickline flush water would be discharged into the single-shell tank (SST). The pump would be removed to the flushing facility for extensive flushing.

Safety: For both Phase 1 and Phase 2, operations within the radiologically controlled area are limited to construction of the slickline.

Operability: The operability constraints described below apply to both Phase 1 and Phase 2.

This method of grout delivery to the tank provides flexibility in operations from outside the radiologically controlled area. Upon completion of the waste stabilization grouting campaign, personnel would be required to enter the radiologically controlled area and disconnect and remove each individual 10-foot section of slickline from the radiologically controlled area. Upon commencement of the bulk tank fill grouting campaign, personnel would be required to enter the radiologically controlled area and set the slicklines back up unless bulk tank fill is performed upon completion of waste stabilization.

Because the slickline delivery method requires no storage of wet grout, delays in delivery of the grout to the tank due to mechanical failure or administrative hold would not result in the need to dump batch loads of grout, but extensive delays would require flushing of the pump and slickline. Flushing of the pump and slickline is a relatively simple operation that uses compressed air. This method of delivery is unlikely to cause additional schedule delays.

Technical Risk: None identified.

Deployment Schedule Risk: None identified.

Cost: The cost described in this section holds true for both Phase 1 and Phase 2.

Capital costs are limited to those for the slickline and the pump. Both of these components can be reused on future closure operations. The slickline within the radiologically controlled area may become contaminated, but contamination would not preclude reuse in other contaminated environments.

The slickline would be constructed in the radiologically controlled area. Slickline construction is relatively simple; consisting of 10-foot sections of pipe that are clamped together and laid on grade with local scaffolding support as required. Construction costs are expected to be low.

There are limited operations associated with a slickline delivery method. Operation costs are low.

B4.2.2.3 Boom Pump Truck

For discharge to tank 241-C-106, a boom pump truck would be staged inside the radiologically controlled area southeast corner gate. The boom truck would be located within the gate such that the hopper would be the only portion outside of the radiologically controlled area boundary so that the concrete mixer trucks would not be required to enter the radiologically controlled area. From this location, the boom would have the capability to reach a hopper located at the central riser on tank 241-C-106. For discharge to the 241-C farm 200-series tanks, the boom pump truck

would be staged adjacent to and outside of the tank farm radiologically controlled area fence. Grout would be delivered to the hopper on the boom pump truck and discharged into a receipt hopper at the tank riser. The boom would need to be flushed after completion of a grouting campaign or upon extended production delays. Flush water would be discharged into the SST or the boom could be repositioned to a flush water receipt tank located outside of the radiologically controlled area.

All of the tanks selected for the closure demonstration (tanks 241-C-106, -201, -202, -203, and -204) are located along the east side of the tank farm. The central riser of tank 241-C-106 and the 241-C farm 200-series tanks are located approximately 190 and 100 feet, respectively, from the radiologically controlled area fence. Boom pump trucks with a horizontal reach up to 157 feet are commercially available.

Due to the limited reach, the boom pump truck option is not a valid option if the grout is to be placed in the tank through multiple risers near the tank wall. Also due to the limited reach capability, this option is not applicable to all future tank closure operations. For example, grout could not be delivered to tank 241-C-105 using the boom pump truck option as described here.

Safety: The safety constraints described below apply to both Phase 1 and Phase 2.

There is a potential for contamination spread and waste generation due to the potential of spillage associated with movement of the boom. Boom placement of concrete is common in the construction industry with known and acceptable personnel hazards. The boom truck operator and Hanford personnel would be required to be located in the radiologically controlled area for boom positioning and placement for tank 241-C-106. The boom truck operator would be outside of the radiologically controlled area for grout placement in the 241-C farm 200-series tanks.

Operability: The operability constraints described below apply to both Phase 1 and Phase 2. For tank 241-C-106, the boom truck operator and Hanford personnel located within the radiologically controlled area would be required for positioning of the boom. Personnel would be required to secure and crimp the boom hose upon completion of a grouting campaign before moving the boom outside of the radiologically controlled area to minimize spilling the grout. The boom truck operator would be outside of the radiologically controlled area for grout placement in the 241-C farm 200-series tanks.

Because the boom pump delivery method requires no storage of wet grout, delays in delivery of the grout to the tank due to mechanical failure or administrative hold would not result in the need to dump batch loads of grout, but extensive delays would require flushing of the boom pump. Flushing of the boom pump may require moving the boom out of the radiologically controlled area. This method of delivery is unlikely to cause significant schedule delays.

Technical Risk: None identified.

Deployment Schedule Risk: None identified.

Cost: A vendor will be contracted to provide a service including all equipment to perform that service. As such, there are no capital costs for Phase 1 and Phase 2 of the tank closure demonstration. Workers inside the radiologically controlled area are required for positioning of

the boom. Radiological surveys of the boom truck would be required before leaving the radiological controlled area. Although unlikely, if the boom truck became contaminated, decontamination costs would be incurred for the boom truck.

B4.2.3 Dry Cement Placement for Stabilization Options

The following sections define the dry cement placement for stabilization options: (1) single central location, pneumatic delivery; (2) single central location, hopper delivery; (3) multiple locations, pneumatic delivery; and (4) multiple locations, hopper delivery.

B4.2.3.1 Single Central Location, Pneumatic Delivery

Dry cement will be pneumatically blown into the tank via the central riser using a tremie lowered into the headspace. The tremie will be lowered to the elevation where the riser penetrates the dome space. For this option, drop height is not a concern and must be maintained at a maximum to disperse the dry cement over as much of the bottom of the tank as possible. The dry cement will be utilized to absorb and immobilize the remaining liquid waste and wet sludge on the tank floor. Successive layers of dry cement will be blown into the tank until no visible liquid remains.

The dry cement will be trucked in from an offsite vendor. The truck would be staged adjacent to and outside of the tank farm radiologically controlled area fence. A grout slickline would be constructed from the truck to the tank riser. The truck will be equipped with its own pump to provide the pneumatic force to get the cement from the truck to the tank.

Safety: Introduction of dry cement into the tank will generate a cloud of particulates which, when drawn through the ventilation system, could plug the pre-filters. Personnel will be required to enter the radiologically controlled area for routine ventilation surveillances and to change the pre-filters as they become congested. Personnel will also be required to enter the radiologically controlled area for construction and removal of the slickline.

Operability: Introduction of dry mixture into a tank will generate a cloud of particulates that will be drawn through the ventilation system. Personnel will be required to enter the radiologically controlled area to monitor and change the filters as required on a routine basis throughout the dry cement introduction campaign as well as for construction and removal of the slickline.

Technical Risk: Placing the dry cement down the central riser could provide limited dispersement of the dry cement material over the bottom of the tank with the bulk falling directly to the center of the tank bottom. It is anticipated that the pneumatic delivery will enhance the dispersement over the bottom of the tank. With a dished bottom tank, the liquids will reside in the center of the tank. As such, the risk associated with the introducing cement through a central riser will be low.

Based on the uncertainty of how the dry cement/liquid waste mixture will cure, it is unknown if the stabilizing layer will be of sufficient strength to support the wet grout lifts thereafter.

Based on the assumption that the strength of the dry cement and liquid waste combination will be no greater than that of the stabilization layer, and the relatively low volume of dry cement

required to absorb the remaining liquid waste, the risk associated with the retrievability of the waste under this option is low. Further evaluation of the strength of the dry cement and liquid waste combination should be performed during detail design to ensure that retrievability requirements are met.

Deployment Schedule Risk: None identified.

Cost: Operational costs would be incurred for the routine ventilation checks and potential filter cleaning campaigns and placement and removal of the slickline. Costs for procurement of the slickline would also be incurred as it would likely be contaminated upon completion of the addition of dry cement to the tank.

B4.2.3.2 Single Central Location, Hopper Delivery

Dry cement will be gravity dumped into the tank via the central riser using a tremie lowered into the headspace. The tremie will be lowered to the elevation where the riser penetrates the dome space. For this option, drop height is not a concern and must be maintained at a maximum to disperse the dry cement over as much of the bottom of the tank as possible. The dry cement will be utilized to absorb and immobilize the remaining liquid waste and wet sludge on the tank floor. Successive layers of dry cement will be discharged into the tank until no visible liquid pools remain.

The dry cement mixture would be trucked to the Hanford site from an offsite vendor on a flatbed truck. The dry cement would be packaged in a super sack® (i.e., commercially available bulk material handling bag) container. A crane located in the radiologically controlled area would lift the super sack® and suspend it over a hopper located on the central riser. The super sack® would be opened allowing the dry cement to discharge into the hopper and into the tank.

Safety: Introduction of dry cement into the tank will generate a cloud of particulates which, when drawn through the ventilation system, could plug the pre-filters. Personnel will be required to enter the radiologically controlled area for routine ventilation surveillances and to change the pre-filters as they become congested. Personnel will also be required to place the hopper, operate the crane, signal the crane, and open the super sack® to discharge the cement.

Operability: Introduction of dry cement into a tank will generate a cloud of particulates that will be drawn through the ventilation system. Personnel will be required to enter the radiologically controlled area to monitor and change the filters as required on a routine basis throughout the dry cement introduction campaign. Personnel will also be required to place the hopper, operate the crane, signal the crane, and open the super sack® to discharge the cement. Due to the particulates from the dry cement, personnel opening the super sack would be required to wear masks.

Technical Risk: Placing the dry cement down the central riser could provide limited dispersement of the dry cement material over the bottom of the tank with the bulk falling directly to the center of the tank bottom. With a dished bottom tank, the liquids will reside in the center of the tank. As such, the risk associated with the introducing cement through a central riser will be low.

Based on the uncertainty of how the dry cement/liquid waste mixture will cure, it is unknown if the stabilizing layer will be of sufficient strength to support the wet grout lifts thereafter.

Based on the assumption that the strength of the dry cement and liquid waste combination will be no greater than that of the stabilization layer, and the relatively low volume of dry cement required to absorb the remaining liquid waste, the risk associated with the retrievability of the waste under this option is low.

Deployment Schedule Risk: None identified.

Cost: Operational costs would be incurred for the routine ventilation checks and potential filter cleaning campaigns and crane operations. Costs for procurement of the super sacks® would also be incurred as it would likely be contaminated upon completion of the addition of dry cement to the tank.

B4.2.3.3 Multiple Locations, Pneumatic Delivery

Dry cement will be pneumatically blown into the tank at several locations near the tank wall in a star pattern using a tremie lowered into the headspace. The tremie will be lowered to the elevation where the riser penetrates the dome space. For this option, drop height is not a concern and must be maintained at a maximum to disperse the dry cement over as much of the bottom of the tank as possible. The dry cement will be utilized to absorb and immobilize the remaining liquid waste and wet sludge on the tank floor. Successive layers of dry cement will be blown into the tank until no visible liquid pools remain.

The dry cement will be trucked in from an offsite vendor. The truck would be staged adjacent to and outside of the tank farm radiologically controlled area fence. A grout slickline would be constructed from the truck to the tank riser. The truck will be equipped with its own pump to provide the pneumatic force to get the cement from the truck to the tank.

Safety: Introduction of dry cement into the tank will generate a cloud of particulates which, when drawn through the ventilation system, could plug the pre-filters. Also, multiple tank access risers are required for placement of the cement. Personnel would receive additional exposure for accessing the radiologically controlled area for preparation of the existing risers, installation of one new riser, repositioning of the dry cement delivery to each of the risers during dry cement placement, and routine ventilation surveillances. Personnel will also be required to enter the radiologically controlled area for construction and removal of the slickline.

Operability: Introduction of dry cement into a tank will generate a cloud of particulates that will be sucked through the ventilation system. Personnel will be required to enter the radiologically controlled area to monitor and change the filters as required on a routine basis throughout the dry cement introduction campaign. Additional operability concerns for this option are the need for personnel within the radiologically controlled area to relocate the dry cement delivery system and for the removal of equipment from existing risers as required as well as for construction and removal of the slickline.

Technical Risk: Placing the dry cement down multiple risers near the tank wall could provide limited dispersement of the dry cement material over the bottom of the tank with the bulk falling directly below the riser. It is anticipated that the pneumatic delivery will enhance the

dispersement over the bottom of the tank. With a dished bottom tank, the liquids will reside in the center of the tank. As such, the risk associated with the introducing cement through risers located near the tank wall will be moderately high.

Based on the uncertainty of how the dry cement/liquid waste mixture will cure, it is unknown if the stabilizing layer will be of sufficient strength to support the wet grout lifts thereafter.

Based on the assumption that the strength of the dry cement and liquid waste combination will be no greater than that of the stabilization layer, and the relatively low volume of dry cement required to absorb the remaining liquid waste, the risk associated with the retrievability of the waste under this option is low.

Deployment Schedule Risk: There is a slight schedule risk due to the preparation of the existing risers for placement of the dry cement including the removal of in-tank equipment as required. For this option, a new riser would be required along the west side of tank 241-C-106, which could result in schedule delays as well.

Cost: Construction costs are higher for this option due to the need for preparing and accessing multiple tank risers, possibly removing existing equipment, and installing one new riser. Operational costs are slightly higher than the other options due to repositioning the cement delivery system to the multiple risers and routine ventilation checks and filter cleaning campaigns and placement and removal of the slickline. Costs for procurement of the slickline would also be incurred as it would likely be contaminated upon completion of the addition of dry cement to the tank.

B4.2.3.4 Multiple Locations, Hopper Delivery

Dry cement will be gravity dumped into the tank at several locations near the tank wall in a star pattern using a tremie lowered into the headspace. The tremie will be lowered to the elevation where the riser penetrates the dome space. For this option, drop height is not a concern and must be maintained at a maximum to disperse the dry cement over as much of the bottom of the tank as possible. The dry cement will be utilized to absorb and immobilize the remaining liquid waste and wet sludge on the tank floor. Successive layers of dry cement will be discharged into the tank until no visible liquid pools remain.

The dry cement mixture would be trucked to the Hanford site from an offsite vendor on a flatbed truck. The dry cement would be packaged in a super sack® container. A crane located in the radiologically controlled area would lift the super sack® and suspend it over a hopper located on the central riser. The super sack® would be opened allowing the dry cement to discharge into the hopper and into the tank.

Safety: Introduction of dry cement into the tank will generate a cloud of particulates, which when drawn through the ventilation system, could plug the pre-filters. Also, multiple tank access risers are required for placement of the cement. Personnel would receive additional exposure for accessing the radiologically controlled area for preparation of the existing risers, installation of one new riser, repositioning of the dry cement delivery to each of the risers during cement placement, and routine ventilation surveillances. Personnel will also be required to place the hopper, operate the crane, signal the crane, and open the super sack® to discharge the cement.

Operability: Introduction of dry cement into a tank will generate a cloud of particulates that will be sucked through the ventilation system. Personnel will be required to enter the radiologically controlled area to monitor and change the filters as required on a routine basis throughout the dry cement introduction campaign. Additional operability concerns for this option are the need for personnel within the radiologically controlled area to relocate the dry cement delivery system and for the removal of equipment from existing risers as required. Personnel will also be required to place the hopper, operate the crane, signal the crane, and open the super sack® to discharge the cement. Due to the particulates from the dry cement, personnel opening the super sack® would be required to wear masks.

Technical Risk: Placing the dry cement down multiple risers could provide limited dispersement of the dry cement material over the bottom of the tank with the bulk falling directly below the riser. With a dished bottom tank, the liquids will reside in the center of the tank. As such, the risk associated with the introducing cement through risers located near the tank wall will be moderately high.

Based on the uncertainty of how the dry cement/liquid waste mixture will cure, it is unknown if the stabilizing layer will be of sufficient strength to support the wet grout lifts thereafter.

Based on the assumption that the strength of the dry cement and liquid waste combination will be no greater than that of the stabilization layer, and the relatively low volume of dry cement required to absorb the remaining liquid waste, the risk associated with the retrievability of the waste under this option is low.

Deployment Schedule Risk: There is a slight schedule risk due to the preparation of the existing risers for placement of the dry cement including the removal of in-tank equipment as required. For this option, a new riser will be required along the west side of tank 241-C-106, which could result in schedule delays as well.

Cost: Construction costs are higher for this option due to the need for preparing and accessing multiple tank risers, possibly removing existing equipment, and installing one new riser. Operational costs are slightly higher than the other options due to repositioning the cement delivery system to the multiple risers and performing routine ventilation checks and filter cleaning campaigns. Costs for procurement of the super sacks® would also be incurred as it would likely be contaminated upon completion of the addition of dry cement to the tank.

B4.2.4 Wet Grout Placement for Stabilization Options

The following sections define the wet grout placement for stabilization options (1) single location, single lift using a tremie; (2) single location, two lifts using a tremie; (3) single location, multiple lifts using a tremie; (4) multiple locations, multiple lifts using a tremie; (5) Rotating nozzle, centrally located; (6) distribution lines, centrally located; (7) cantilevered tremie, centrally located; (8) single-point injection with low pressure grout; (9) high-pressure mixing using MPI; (10) in-tank-mechanical mixing using robotic mixers; and (11) in-tank mixer pump.

The following sub-sections identify options for stabilization of the residual waste in tank 241-C-106 only. Following completion of the evaluation, the preferred option will be considered

for applicability for stabilization of the 200-series tanks. Each of the following sub-sections will be evaluated assuming that dry grout has already been introduced and that the liquid wastes have been absorbed and immobilized.

B4.2.4.1 Single Location, Single Lift Using a Tremie

Free-flowing grout would be placed into the tank via the central tank riser using a tremie extending to near the bottom of the tank to limit drop height and kinetic energy. A single lift of approximately 10 inches in depth (approximately 165 cubic yards) would be placed over the residual waste, providing macroencapsulation of the residual waste by sandwiching it between the existing tank structure and the 10-inch-thick layer of grout.

Safety: None identified.

Operability: None identified.

Technical Risk: The risk associated with the retrievability of the initial layer is low based on the volume of the stabilizing material with a compressive strength between 50 and 300 lb/in^2.

Deployment Schedule Risk: None identified.

Cost: No discriminating costs.

B4.2.4.2 Single Location, Two Lifts Using a Tremie

Free-flowing grout would be placed into the tank via the central tank riser using a tremie to limit the drop height. The density of the grout for the initial lift would be greater than that of the residual waste such that the residual waste not fixed to the tank floor and not captured within the dry grout mixture would be displaced above the approximate 10-inch-thick grout layer (approximately 165 cubic yards). A second layer of grout having a density less than that of the residual waste would be placed over the residual waste, providing macroencapsulation of the residual waste by sandwiching it between the two 10-inch-thick layers of grout.

Safety: None identified.

Operability: None identified.

Technical Risk: The risk associated with the retrievability of the initial layer is moderate based on the volume of the stabilizing material.

Deployment Schedule Risk: None Identified.

Cost: The costs for the grout, equipment rental, and operations will be twice as high as those for the single lift option.

B4.2.4.3 Single Location, Multiple Lifts Using a Tremie

Free-flowing grout would be placed into the tank via the central tank riser using a tremie to limit the drop height. The density of the grout would be greater than that of the residual waste such that the residual waste not captured within the dry grout mixture and not fixed to the tank floor would be displaced above the approximate 10-inch-thick (approximately 165 cubic yards) grout

layer. Successive layers of grout also having a density greater than that of the residual waste would be placed over the residual waste. Each successive 10-inch-grout layer would capture a portion of the residual waste at the grout to residual waste interface and upon multiple lifts would provide encapsulation of the residual waste simulating microencapsulation of a homogeneously mixed waste form.

Safety: None identified.

Operability: None identified.

Technical Risk: The risk associated with the retrievability of the initial layer is high based on the volume of the stabilizing material.

Deployment Schedule Risk: None identified.

Cost: The costs for the grout, equipment rental, and operations will be slightly higher than those for the two-lift option.

B4.2.4.4 Multiple Locations, Multiple Lifts Using a Tremie

Non-free-flowing grout would be placed into the tank at several locations near the tank wall in a star pattern using a tremie to limit the drop height. The density of this grout would be greater than that of the residual waste not captured within the dry cement mixture such that the residual waste would be displaced toward the center of the tank. A cover layer of free-flowing grout having a density less than that of the residual waste would be placed over the residual waste, providing macroencapsulation of the residual waste by surrounding it between the grout placed at the wall of the tank and the cover layer of grout. The cover layer would be free-flowing grout placed into the tank via the central tank riser using a tremie to limit the drop height. Also, grout delivery by a boom pump truck is not applicable to this option.

Safety: Multiple tank access risers are required for placement of the grout. As such, personnel would receive additional exposure for accessing the radiologically controlled area for preparation of the existing risers, in-tank equipment removal, installation of one new riser, and repositioning of the grout delivery to each of the risers during grout placement.

Operability: Operability concerns for this option are limited to the need for personnel within the radiologically controlled area to relocate the grout delivery system.

Technical Risk: The risk associated with the retrievability of this option is moderate based on the volume of the stabilizing material. Displacement of the residual waste is dependent on its physical properties. This method may result in macroencapsulation similar to a single lift from a single central location.

Deployment Schedule Risk: There is a slight schedule risk due to the preparation of the existing risers for placement of the wet grout including the removal of in-tank equipment as required. For this option, a new riser will be required along the west side of tank 241-C-106 which could result in schedule delays as well.

Cost: Construction costs are higher for this option due to the need for preparing and accessing multiple tank risers including removal of in-tank equipment and installing one new riser. Operational costs are slightly higher than the other options due to repositioning the grout delivery system to the multiple risers.

B4.2.4.5 Rotating Nozzle, Centrally Located

Free-flowing grout would be placed into the tank via the central tank riser using a rotating nozzle. The nozzle would have the capability to be manually rotated through 360°. The grout would be introduced through the nozzle at low pressures (less than 100 lb/in^2 gauge) and aimed horizontally towards the tank wall. The grout would likely flow from outside the waste and over the top, providing macroencapsulation of the residual waste by sandwiching it between the existing tank structure and the grout.

Safety: The forces created from directing the grout horizontally from a mast could induce undesirable forces on the existing central riser. It is likely that the introduction of the wet grout will initially aggravate some of the residual dry cement remaining on the bottom of the tank. The airborne dry cement particulates could be drawn into the ventilation and plug the pre-filters. Operations personnel would also be required to remain in the radiologically controlled area for extended durations to manipulate the rotating nozzle assembly and perform routine ventilation surveillances.

Operability: Operability concerns for this option include the need for personnel within the radiologically controlled area to manipulate the rotating nozzle and perform routine ventilation surveillances. The nozzle assembly may require cleaning, which could become problematic.

Technical Risk: The risk associated with the retrievability of this option is low based on the volume of the stabilizing material. Also, the risk associated with the complexity of the system would be high.

Deployment Schedule Risk: Application of a rotating nozzle would require engineering, procurement, fabrication and testing of the nozzle and delivery system. These would all be required to be completed in fiscal year (FY) 2003. Utilizing similar existing designs (i.e., S-112 retrieval) could help shorten the entire duration. Based on this, there would be a moderate deployment schedule risk associated with deployment of this technology.

Cost: Cost considerations associated with the rotating nozzle technology include design, procurement, fabrication, testing, and operations for manipulating the nozzle, performing routing ventilation surveillances, and for the construction of a structure to offset the reacting moment loads. Also, the rotating nozzle assembly would need to be removed for subsequent bulk tank fill operations.

B4.2.4.6 Distribution Lines, Centrally Located

Free-flowing grout would be placed into the tank via the central tank riser using grout distribution lines. The distribution lines would be installed on a mast that could be extended towards the tank wall to introduce the grout away from center of the tank. The grout would be gravity fed through the distribution lines. The grout would likely flow from outside the waste

and over the top, providing macroencapsulation of the residual waste by sandwiching it between the existing tank structure and the grout.

Safety: None identified.

Operability: Operability concerns for this option are limited to the need for personnel within the radiologically controlled area to perform routine ventilation surveillances.

Technical Risk: The risk associated with the retrievability of this option is low based on the limited volume of the stabilizing material. Also, the risk associated with the complexity of the system would be moderate.

Deployment Schedule Risk: Application of a mast with distribution lines would require engineering, procurement, fabrication, and testing of the system. These would all be required to be completed in FY 2003. Based on the simplicity of the system, there would be a moderate deployment schedule risk associated with deployment of this technology.

Cost: Cost considerations associated with the distribution line technology include design, procurement, fabrication, and testing. Also, the distribution lines mast would need to be removed for subsequent bulk tank fill operations.

B4.2.4.7 Cantilevered Tremie, Centrally Located

Free-flowing grout would be placed into the tank via the central tank riser using a tremie that could be cantilevered to the horizontal position. The cantilevered tremie would introduce the grout away from center of the tank. The grout would be gravity fed through the cantilevered tremie. The grout would likely flow from outside the waste and over the top, providing macroencapsulation of the residual waste by sandwiching it between the existing tank structure and the grout.

Safety: It is likely that the introduction of the wet grout will initially aggravate some of the residual dry cement remaining on the bottom of the tank. The airborne dry cement particulates could be drawn into the ventilation and plug the pre-filters. Operations personnel would be required to enter the radiologically controlled area to perform routine ventilation surveillances and maneuver the tremie. Also, large moments would need to be reacted by a grade level structure to prevent moment transmission to the existing riser.

Operability: Operability concerns for this option are limited to the need for personnel within the radiologically controlled area to manipulate the cantilevered tremie and perform routine ventilation surveillances.

Technical Risk: The risk associated with the retrievability of this option is low based on the limited volume of the stabilizing material. Also, the risk associated with the complexity of the system would be low.

Deployment Schedule Risk: Application of a cantilevered tremie would require engineering, procurement, fabrication and testing of the system. These would all be required to be completed in FY 2003.

Cost: Cost considerations associated with the distribution line technology include design, procurement, fabrication, testing and operations performing routine ventilation surveillances. The grade level structure to react the induced moments would require engineering and construction. Also, the cantilevered tremie would need to be removed for subsequent bulk tank fill operations.

B4.2.4.8 Single-Point Injection with Low-Pressure Grout

Single-point injection with low-pressure grout (less than 350 lb/in^2) is a concept based on bench scale testing conducted by Pacific Northwest National Laboratory. In the tests grout was introduced to the tank through a horizontally oriented nozzle for the purpose of mixing a surrogate sludge waste with the grout to create a waste form that microencapsulated the waste. Three grout injection tests were conducted. Nozzle diameters of 0.5 and 0.875 inches were used at pressures ranging from 117 to 307 lb/in^2 and grout flow rates from 65 to 138 gal/min. Each test was conducted in a 9 foot diameter tank with the nozzle on one side of the tank. In each test 2 inches of kaolin clay paste were placed on the tank floor and covered with 4 inches of water. The test results were better than expected and the effective cleaning radius of the grout injection system which was originally estimated at 9 feet was adjusted to 16 feet when density and maximum flow rates were accounted for.

After injection the grout was allowed to set and the grout monolith was broken up for evaluation. In all three test cases the single-point injection was very effective at mobilizing the sludge and mixing with the grout. It was concluded that this system should be scaled up to potential use in the 75-foot-diameter SSTs. Extrapolation of the experimental data to a 75-foot-diameter tank result in nozzle diameter and flow rates of approximately 1.4 inches and 740 gal/min. As an alternative, two to three injection locations could be used to provide coverage of the tank bottom. Note that the operating parameters of the configuration tested are suitable for deployment in the 200-series tanks.

To accommodate the injection rate of 740 gal/min, a continuous batch plant with this capacity would be required.

Deployment of this type of system in the tanks would provide for a moderate to high degree of success in macroencapsulating/microencapsulating the residual waste.

Safety: Operation of this system would involve injecting grout into the tank at relatively high rates and moderate pressures. Worker safety issues would be a concern and would require evaluation during design with potential controls to reduce the potential for accidents. Safety issues with the tank structure should be minor at the grout injection pressure. Also, large moments would need to be reacted by a grade level structure to prevent moment transmission to the existing riser. It is likely that the introduction of the wet grout will initially aggravate some of the residual dry cement remaining on the bottom of the tank. The airborne dry cement particulates could be drawn into the ventilation and plug the pre-filters. Operations personnel would be required to enter the radiologically controlled area to perform routine ventilation surveillances.

Operability: Operation of the single-point injection system would require rotation of the nozzle to ensure coverage of the mixing stream over the bottom of the tank. Personnel would also be required to enter the radiologically controlled area to perform routine ventilation surveillances.

Technical Risk: Given the requirements, there is little technical risk associated with if or how well the system mixes the waste with the grout. Even without development and testing the system could be designed to provide some degree of beneficial mixing. The technical risk would be mitigated through additional development and cold testing to optimize the grout flow rate and nozzle diameter to achieve the necessary radius. Also, the risk associated with the complexity of the system would be moderate.

Deployment Schedule Risk: Application of the single-point injection with low-pressure grout would require development and testing in FY 2003 to define design and operating parameters. Development and testing activities would need to occur early in FY 2003 to ensure data is available to support design efforts. There would be a moderate deployment schedule risk associated with deployment of this technology. However, the design could be developed with currently available information and data collected as a part of the demonstration effort.

Cost: Cost considerations associated with the single-point injection system include additional design, construction, and operations associated with grout placement. Operational costs would also be incurred for routine ventilation surveillances and possible filter changes.
The single-point injection system would be moderately more complicated than the gravity fill system. The grade level structure to react the induced moments would require engineering and construction. Also, the assembly would need to be removed for subsequent bulk tank fill operations.

B4.2.4.9 High Pressure Mixing Using Multi-Point Injection System™

The MPI is a patented technology exclusively licensed to Ground Environmental Services, Inc. The MPI is a high-energy grouting system designed to microencapsulate residual waste remaining in tanks. The MPI relies on the interaction of multiple, high-speed mono-directional jets to turbulently mix the waste with grout (ORNL/TM-2000/8). The jet nozzles are placed near the bottom of the tank and oriented to project the jet streams horizontally. For shallow tank sludge (2 to 3 feet deep), the injection tools do not need to be lifted to achieve mixing.

Placement of the jetting tools within a large-diameter tank can be accomplished by drilling small diameter holes through the dome of the tank for deployment of vertical jetting tools or, optionally, all tooling can be deployed through a single tank riser.

Deployment of an MPI through a single riser in the center of a large-diameter (85-foot) SRS tank has been considered. The configuration involved placement of 18 tool strings oriented radially from the center of the tank out similar to the spokes of a wheel. Each tool string would have approximately 20 jets and require about 270 gal/min of grout at 6,000 lb/in^2. Grouting operations were estimated to use 8 tool strings (or spokes) simultaneously for a total flow rate of 2,000 gal/min, which would require approximately 7,200 hp of pumping capacity. Each tool set would be operated for approximately 1 minute introducing approximately 2,000 gallons of grout into the tank. Based on this pumping rate and the assumptions made for the amount of grout

needed to encapsulate the tank waste (approximately 3.5 times the original waste volume), the grouting operation would be completed in a single 10- to 12-hour shift.

Application of the MPI to the Hanford Site closure demonstration tanks would be similar in configuration to the system envisioned for the SRS tank. The number of jets required would be less because of the difference in tank diameters and the volume of grout required to microencapsulate the waste heel could be less than the 105,000 gallons of grout assumed for the SRS deployment. Adding approximately 10 inches of grout to tank 241-C-106 would result in an approximately 10% waste loading by volume. Note that at the operating parameters identified for large-diameter tanks, this volume of grout would be injected into the tank in approximately 14 minutes of actual injection time.

Implementation of the MPI would require a batch mixing plant that would have the capacity to supply the MPI with material. Because the MPI is only operated for short bursts of time, the grout mixing and delivery system would need to supply batches on the order of 2,000 gallons. In addition to the grout delivery and mixing systems the MPI would require multiple high-pressure pumps to meet the flow/pressure requirements. The concept identified for the SRS called for 2,000 gal/min of grout at 6,000 lb/in^2 which required four 1,800-hp pumps or six 1,200-hp pumps. The configuration and layout of the in-tank portion of the MPI comprised of the high-pressure grout lines and the injection tools would have to be defined and installed in the tank. In-tank obstructions could interfere with the placement of the injection tools in the desired locations across the floor of the tank.

Deployment of the MPI in a large-diameter tank would require further development and cold testing of the system configuration for a large-diameter tank.

Safety: Based on the nature of the system with high-pressure (approximately 6,000 lb/in^2) grout and large volumes it is believed that there would be a number of safety issues and corresponding engineering controls that would need to be worked before deployment in an SST. It is likely that the introduction of the wet grout will initially aggravate some of the residual dry cement remaining on the bottom of the tank. The airborne dry cement particulates could be drawn into the ventilation and plug the pre-filters. Operations personnel would be required to enter the radiologically controlled area to perform routine ventilation surveillances.

Operability: The MPI would be difficult to operate in relation to the other systems. There would be significant effort to install, configure, and verify the MPI within the tank. Additionally, there would be a number of operational steps involved in making connections, injecting grout for short durations in a portion of the system, and moving connections to connect to remaining portions of the system. Cleaning of the MPI would be problematic. Personnel would also be required to enter the radiologically controlled area for routine ventilation surveillances.

Technical Risk: Since the Level 2 Specification (RPP-11094) requirement is for macroencapsulation of the residual waste and there is not a requirement for microencapsulating the waste there is little technical risk that the MPI at a minimum would serve as a vehicle for placement of grout into the tank. Also, the risk associated with the complexity of the system would be high.

Deployment Schedule Risk: There is significant schedule risk with this technology for the deployment schedule identified. This is a proprietary technology that would require further testing and system design for application to a large-diameter tank.

Cost: This grout placement system is significantly more complex than the gravity fill system and involves the use of proprietary technology. Cost considerations include additional costs to design, procure, and install the MPI; additional costs for the grout pumping system; and additional costs associated with operating the MPI. The MPI would also require removal for bulk tank fill operations. Operational costs would also be incurred for routine ventilation surveillances and possible filter changes.

B4.2.4.10 In-Tank Mechanical Mixing Using Robotic Mixers

Mechanical mixing using robotic mixers is a concept that could be used to physically mix portions of the residual waste heel with the stabilizing grout. Long reach arms or vehicle-based systems could be utilized to mix localized waste piles into the grout matrix. Vehicle-based pumps could also be used to move material around and incidentally mix the residual waste with the grout material. These systems would be used to incorporate residual waste into the grout material and would then be abandoned in the tank.

These technologies would likely not be effective at mobilizing and mixing thin layers of waste distributed over large areas of the tank liner. Additionally, mechanical mixing systems may encounter interference with in-tank equipment.

Any robotic system would have to be designed to provide the necessary mixing action across the entire area of interest (base area of the tank) before the grout set time.

No existing concepts for mechanical mixing of residual waste with stabilizing grout have been found to date.

Safety: There would be safety considerations necessary for the installation and deployment of robotic mixers in the tanks. These considerations, along with the appropriate engineering controls, would be evaluated during the design phase. It is likely that the introduction of the wet grout will initially aggravate some of the residual dry cement remaining on the bottom of the tank. The airborne dry cement particulates could be drawn into the ventilation and plug the pre-filters. Operations personnel would be required to enter the radiologically controlled area to perform routine ventilation surveillances.

Operability: A number of operational issues are potential problems. Following grout placement, a work stoppage in the tank farm could result in the grout setting up before the in-tank mixers could be deployed. Personnel would also be required to enter the radiologically controlled area for routine ventilation surveillances.

Technical Risk: Since there is no requirement for microencapsulation of the residual waste, the technical risk is limited. Substantial development would be required to create in-tank robotic mixers. The dished bottom of tank 241-C-106, coupled with the in-tank hardware, would interfere with effective mixing of low volumes of residual waste remaining in the tank. Also, the risk associated with the complexity of the system would be high.

Deployment Schedule Risk: There would be substantial schedule risk associated with deployment of in-tank mechanical mixing with robotic mixers. Robotic mixers, along with all the associated support equipment (i.e., controls, instrumentation, procedures, safety documentation), would require development, testing, and procurement in FY 2003 to support a deployment in early FY 2004.

Cost: Cost considerations associated with the in-tank mechanical mixers include the additional design, development, testing, and procurement of the mixers. This system would be more complex than the gravity fill system. Operational costs would also be incurred for routine ventilation surveillances and possible filter changes.

B4.2.4.11 In-Tank Mixer Pump

An in-tank mixer pump could be utilized to recirculate the grout and mobilize/mix residual waste before the grout set time. The general concept would be similar to the mixer pumps that have been installed in the double-shell tanks and the mixing action would be the same as that described for the single-point injection with low-pressure grout. The difference between the in-tank mixer pump and the single-point injection system is that the mixer pump could be operated for a longer period of time to provide for increased mixing. A mixer pump could be operated for several hours but would need to be shut off before the set time of the grout mix. The single-point injection system would only allow for mixing action while introducing grout into the tank.

The in-tank mixing concept would provide for greater flexibility in the grout delivery and placement system in that the mixing system would not drive batch plant production and grout delivery flow rates.

Given the technical issues and development time that was required to develop and deploy mixer pumps in the double-shell tanks it is likely that comparable development time would be required for in-tank mixer pumps for grout mixing.

Safety: Operation of this system would involve injecting grout into the tank at relatively high rates and low pressures. Worker safety issues would be a concern and would require evaluation during design with potential controls to reduce the potential for accidents. Safety issues with the tank structure should be minor at the grout injection pressure. It is likely that the introduction of the wet grout will initially aggravate some of the residual dry cement remaining on the bottom of the tank. The airborne dry cement particulates could be drawn into the ventilation and plug the pre-filters. Operations personnel would be required to enter the radiologically controlled area to perform routine ventilation surveillances.

Operability: A number of operational issues are potential problems. Following grout placement, a work stoppage in the tank farm could result in the grout setting up before the mixer pump could be deployed. Personnel would also be required to enter the radiologically controlled area for routine ventilation surveillances.

Technical Risk: Since there is no requirement to microencapsulation of the residual waste, the technical risk is limited. Substantial development would be required to create an in-tank mixer

pump. Technical problems during pump startup or operation once the grout had been placed in the tank would be a problem.

Deployment Schedule Risk: There would be substantial schedule risk associated with deployment of in-tank mixer pumps. In-tank mixer pumps along with all the associated support equipment (i.e., controls, instrumentation, procedures, safety documentation), would require development, testing, and procurement in FY 2003 to support a deployment in early FY 2004.

Cost: Cost considerations associated with the in-tank mixer pumps includes the incremental cost for additional design, development, testing, and procurement of the mixer pumps. The capital cost associated with these pumps would be substantial. This system would need to be removed for bulk tank fill. Operational costs would also be incurred for routine ventilation surveillances and possible filter changes.

B4.3 BALANCE OF TANK FILL

Following stabilization of the residual waste in the bottom of the tank, it is assumed that the remaining void space in the tank would be filled using a self-leveling flowable fill. Under this assumption, gravity filling the tank with a tremie to limit drop height from a single location is the only option that warrants further consideration.

Safety: There are no safety implications identified for this option.

Operability: There would be limited operability issues associated with this technology.

Technical Risk: Technical risk associated with this method of tank filling would be minor.

Deployment Schedule Risk: Little or no deployment schedule risk would be associated with this technology.

Cost: Cost considerations associated with this option are limited to the operations cost associated with mixing and pumping the grout to the tank.

B5.0 EVALUATION

The evaluation results are presented in the following tables:

- Table B.2 for waste stabilization wet grout delivery to the site for 165 cubic yards
- Table B.3 for waste stabilization wet grout delivery to the site for 500 cubic yards
- Table B.4 for wet grout delivery to the site for bulk tank fill
- Table B.5 for waste stabilization wet grout delivery to the tank for 165 cubic yards
- Table B.6 for waste stabilization wet grout delivery to the tank for 500 cubic yards
- Table B.7 for wet grout delivery to the tank for the bulk tank fill
- Table B.8 for the waste immobilization dry cement placement
- Table B.9 for waste stabilization wet grout placement.

Table B.2. Waste Stabilization Wet Grout Delivery to the Site for 165 cubic yards

Options	Safety	Operability	Technical Risk	Deployment Schedule	Cost	Total
Raw Scores (1 to 5) with a higher score being more favorable to the criteria						
Concrete Mixer Trucks	3	2	4	5	5	19
Batch Plant Onsite (central)	3	2	5	1	1	12
Batch Plant at Tank Farm	4	3	5	3	3	18
Continuous Batching/Mixing Plant	4	4	5	3	3	19
Weighted Scores (factor 1 to 5 – based on relative importance to decision)						
Weighting Factor	5	2	1	3	3	
Concrete Mixer Trucks	15	4	4	15	15	53
Batch Plan Onsite (central)	15	4	5	3	3	30
Batch Plant at Tank Farm	20	6	5	9	9	49
Continuous Batching/Mixing Plant	20	8	5	9	9	51

Table B.3. Waste Stabilization Wet Grout Delivery to the Site for 500 cubic yards

Options	Safety	Operability	Technical Risk	Deployment Schedule	Cost	Total
Raw Scores (1 to 5) with a higher score being more favorable to the criteria						
Concrete Mixer Trucks	3	2	4	5	5	19
Batch Plant Onsite (central)	3	2	5	1	1	12
Batch Plant at Tank Farm	4	3	5	3	3	18
Continuous Batching/Mixing Plant	4	4	5	3	3	19
Weighted Scores (factor 1 to 5 – based on relative importance to decision)						
Weighting Factor	5	2	1	3	3	
Concrete Trucks	15	4	4	15	15	53
Batch Plan Onsite (central)	15	4	5	3	3	30
Batch Plant at Tank Farm	20	6	5	9	9	49
Continuous Batching/Mixing Plant	20	8	5	9	9	51

Table B.4. Wet Grout Delivery to the Site for Bulk Tank Fill

Options	Safety	Operability	Technical Risk	Deployment Schedule	Cost	Total
Raw Scores (1 to 5) with a higher score being more favorable to the criteria						
Concrete Mixer Trucks	1	1	4	5	5	16
Batch Plant Onsite (central)	3	2	5	3	2	15
Batch Plant at Tank Farm	4	4	5	5	3	21
Continuous Batching/Mixing Plant	4	5	5	5	3	22
Weighted Scores (factor 1 to 5 – based on relative importance to decision)						
Weighting Factor	5	2	1	3	3	
Concrete Mixer Trucks	5	2	4	15	15	41
Batch Plan Onsite (central)	15	4	5	9	6	39
Batch Plant at Tank Farm	20	8	5	15	9	57
Continuous Batching/Mixing Plant	20	10	5	15	9	59

Table B.5. Waste Stabilization Wet Grout Delivery to the Tank for 165 cubic yards

Options	Safety	Operability	Technical Risk	Deployment Schedule	Cost	Total
Raw Scores (1 to 5) with a higher score being more favorable to the criteria						
Truck Delivery to Tank Riser	1	1	5	3	3	13
Pump Grout from Outside Tank Farm	4	3	5	5	3	20
Boom Truck	3	3	5	5	3	19
Weighted Scores (factor 1 to 5 – based on relative importance to decision)						
Weighting Factor	5	2	1	3	3	
Truck Delivery to Tank Riser	5	2	5	9	9	30
Pump Grout from Outside Tank Farm	20	6	5	15	9	55
Boom Truck	15	6	5	15	9	50

Table B.6. Waste Stabilization Wet Grout Delivery to the Tank for 500 cubic yards

Options	Safety	Operability	Technical Risk	Deployment Schedule	Cost	Total
Raw Scores (1 to 5) with a higher score being more favorable to the criteria						
Truck Delivery to Tank Riser	1	1	5	3	3	13
Pump Grout from Outside Tank Farm	4	3	5	5	3	20
Boom Truck	3	3	5	5	3	19
Weighted Scores (factor 1 to 5 – based on relative importance to decision)						
Weighting Factor	5	2	1	3	3	
Truck Delivery to Tank Riser	5	2	5	9	9	30
Pump Grout from Outside Tank Farm	20	6	5	15	9	55
Boom Truck	15	6	5	15	9	50

Table B.7. Wet Grout Delivery to the Tank for Bulk Tank Fill

Options	Safety	Operability	Technical Risk	Deployment Schedule	Cost	Total
Raw Scores (1 to 5) with a higher score being more favorable to the criteria						
Truck Delivery to Tank Riser	1	1	5	5	3	15
Pump Grout from Outside Tank Farm	5	5	5	5	5	25
Boom Truck	3	4	5	5	4	21
Weighted Scores (factor 1 to 5 – based on relative importance to decision)						
Weighting Factor	5	2	1	3	3	
Truck Delivery to Tank Riser	5	2	5	15	9	36
Pump Grout from Outside Tank Farm	25	10	5	15	15	70
Boom Truck	15	8	5	15	12	55

Table B.8. Waste Immobilization Dry Cement Placement

Options	Safety	Operability	Technical Risk	Deployment Schedule	Cost	Total
Raw Scores (1 to 5) with a higher score being more favorable to the criteria						
Dry mix placement - pneumatic delivery - central location	4	5	5	5	4	23
Dry mix placement - hopper delivery - central location	4	4	4	5	4	21
Dry mix placement - pneumatic delivery - multiple locations - edge of tank	2	3	3	3	2	13
Dry mix placement - hopper delivery - multiple locations - edge of tank	2	3	2	3	2	12
Weighted Scores (factor 1 to 5 – based on relative importance to decision)						
Weighting Factor	5	2	1	3	3	
Dry mix placement - pneumatic delivery - central location	20	10	5	15	12	62
Dry mix placement - hopper delivery - central location	20	8	4	15	12	59
Dry mix placement - pneumatic delivery - multiple locations - edge of tank	10	6	3	9	6	34
Dry mix placement - hopper delivery - multiple locations - edge of tank	10	6	2	9	6	33

Table B.9. Waste Stabilization Wet Grout Placement (2 Sheets)

Options	Safety	Operability	Technical Risk	Deployment Schedule	Cost	Total
Raw Scores (1 to 5) with a higher score being more favorable to the criteria						
Gravity Fill - 1 location	4	5	5	5	5	24
Gravity Fill - 1 location, 2 lifts	4	4	5	5	5	23
Gravity Fill - 1 location, multiple lifts	4	4	5	5	5	23
Gravity Fill - multiple locations-edge of tank- 2 or more lifts	1	3	5	4	3	16
Rotating Nozzle in central riser - direct grout toward edge of tank	3	3	3	2	3	14
In tank distribution lines in central riser - direct grout towards edge of tank	4	4	4	3	4	19
Cantilevered tremie line - central location - direct grout towards edge of tank	3	3	4	3	4	17
Single Point Injection - Low Pressure Grout	2	3	4	3	2	14
Multi Point Injection - High Pressure Grout	1	1	3	1	1	7
In Tank Mechanical Mixing	3	2	3	1	1	10
In Tank Mixer Pump	3	3	2	1	1	10
Weighted Scores (factor 1 to 5 - based on relative importance to decision)						
Weighting Factor	5	2	1	3	3	
Gravity Fill - 1 location	20	10	5	15	15	65
Gravity Fill - 1 location, 2 lifts	20	8	5	15	15	63
Gravity Fill - 1 location, multiple lifts	20	8	5	15	15	63
Gravity Fill - multiple locations-edge of tank- 2 or more lifts	5	6	5	12	9	37
Rotating Nozzle in central riser - direct grout toward edge of tank	15	6	3	6	9	39
In tank distribution lines in central riser - direct grout towards edge of tank	20	8	4	9	12	53
Cantilevered tremie line - central location - direct grout towards edge of tank	15	6	4	9	12	46

Table B.9. Waste Stabilization Wet Grout Placement (2 Sheets)

Options	Safety	Operability	Technical Risk	Deployment Schedule	Cost	Total
Weighted Scores (factor 1 to 5 – based on relative importance to decision) (Cont'd)						
Single Point Injection - Low Pressure Grout	10	6	4	9	6	35
Multi Point Injection - High Pressure Grout	5	2	3	3	3	16
In Tank Mechanical Mixing	15	4	3	3	3	28
In Tank Mixer Pump	15	6	2	3	3	29

B6.0 ALTERNATIVE SELECTION

Based on the scoring completed in Tables B.2 through B.9, the recommended grout delivery and placement system for further definition during detail design comprises the following:

Waste Immobilization (dry cement):

1. Pneumatic delivery from a single/central location.

Waste Stabilization (wet grout):

1. Grout delivery to the site utilizing concrete mixer trucks
2. Delivery of the grout to the tanks by pumping the grout through a slickline to the tank
3. Gravity filling the tanks from a single location using a single lift.

Bulk Tank Fill:

1. A continuous batching/mixing plant located just outside the tank farm
2. Delivery of the grout to the tanks by pumping the grout through a slickline to the tank.

The recommended methods above were conservatively based off of closure of the largest tank, 241-C-106. Based on these recommendations, it is assumed that the optimal method for closure of the 241-C farm 200-series tanks will occur in similar fashion. The equipment that will be utilized for the closure of tank 241-C-106 will already be in place at the time closure operations are performed on the 241-C farm 200-series tanks.

B7.0 REFERENCES

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APPENDIX C
CALCULATIONS

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	Calculation Cover Sheet	Page: 1 of 8 Date: _11/12/02____
Calculation No.:	Calculation Title: C-106 Ventilation Assessment	
Project No.: 15733	Project Title: C-106 Closure Project	

Original and Revised Calculation/Analysis Approval

	Rev. __A__ Name/Signature/Date	Rev. _____ Name/Signature/Date	Rev. _____ Name/Signature/Date
Originator:	R. Dunham		
Checked by:	L. Ulbricht		
Approved by:			
Other:			

Affected Documents

Document Number	Document Title	Revision Number

Record of Revision

Revision	Reason for Revision
A	Initial Release

Attachment A - High Temperature Psychometric Chart (1 page)
Attachment B – Characteristics of Particles and Particle Dispersoids (1 page)
Attachment C – Concrete Technology Today, Vol. 18, No. 2 (4 pages)

C-106 aersol study Cover_Sheet.revA3

	Design Calculation Sheet	Project No.: 15733 Page: 2 of 8
Calculation No.:	Performed by: R. Dunham	
Rev. No.: A	Date: 11/15/02	
Calculation Title: C-106 Ventilation Assessment	Checked by: L. Ulbricht	
	Date: 11/15/02	

INTRODUCTION

Purpose The purpose of this calculation is to provide preliminary estimates of the required airflow rate through the tank headspace to remove any fog that is generated during the introduction of grout into tank C-106 during the closure campaign.

Scope The scope of this calculation determines the minimum required airflow, the maximum temperature the tank headspace could achieve during curing of the concrete with a maximum ventilation flow rate, and preliminary demister sizing to strip the moisture from the air stream prior to the exhauster unit.

DESIGN BASIS

Design Inputs

1. Maximum heat of hydration is 106.1 cal/gm of Type I Portland cement. (Concrete Technology Today, pg. 2)
2. Critical velocity of clouds and fog is 2×10^{-2} cm/sec (ASHRAE, pg. 12.3)
3. General tank measurements (HNF-SD-WM-ER-313, pg. F-12)
4. Maximum exhauster flows are 500 and 1000 cfm (WHC-SD-WM-DB-035, Rev. 1 pg. 5)

Criteria Determine minimum required flow rate, maximum tank temperature, and demister sizing.

Assumptions

1. The tank headspace temperature will be 60°F (near expected ground temperature).
2. The grout mixture will be introduced to the tank at approximately 70°F.
3. The grout will be introduced to the tank wet.
4. The maximum heat generated with the grout mixture occurs over the first 72 hours after introduction.
5. Conservative case that 28 day Type I Portland cement will be used in the grout mixture which provides most heat of hydration
6. The conservative tank atmospheric conditions are at maximum headspace temperature during curing time and at 100% relative humidity because of the water content in the grout.
7. The tank is fully empty at the beginning of grout introduction.
8. Cascade lines from C-105 to C-106 are plug and provide no infiltration.
9. Heat generated during grout curing is attributed to all latent heat with no sensible heat.
10. Maximum concrete pour is 490 yd^3

	Design Calculation Sheet	Project No.: 15733 Page: 3 of 8
Calculation No.:	Performed by: R. Dunham	
Rev. No.: A	Date: 11/13/02	
Calculation Title: C-106 Ventilation Assessment	Checked by: L. Ulbricht	
	Date: 11/15/02	

REFERENCES

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2. HNF-SD-WM-ER-313, *Supporting Document for the Historical Tank Content Estimate for C-Tank Farm*, Rev. 1B, PNNL, 1997.
3. ASHRAE, *Fundamentals*, IP edition, 1997.
4. Roberson/Crowe, *Engineering Fluid Mechanics*, 3rd edition, 1985
5. Concrete Technology Today, Portland Cement, *Concrete, and Heat of Hydration*, Vol. 18, No. 2, July, 1997

METHODS

Hand calculations using MathCAD, utilizing known formulas and basis established in ASHRAE Fundamentals and Mechanical Engineering references.

RESULTS AND CONCLUSIONS

In order to maintain visibility during grout introduction into tank C-106, the minimum air velocity in the tank headspace to remove fog possibly generated during that activity can be achieved with air flows above 80 cfm. The portable exhausters available to the project (POR-04, POR-05, POR-06) can exhaust up to 500 cfm or (POR-07, POR-08) 1000 cfm. At these flow rates the internal tank temperature may get as high as 104 or 89 deg F, respectively during the curing time of the grout given ambient ground temperatures as an initial starting condition for the tank headspace temperatures. At these flow rates, the exhauster, and subsequent mist eliminator will need to remove 92 lbm/hr of water vapor at that temperature.

If the grout were introduced dry to the tank along with active ventilation provide for visibility, cement dust particles are in the same order of magnitude in size as the fog as shown in ASHRAE, pg. 12.3. These particles range from 3 to 100 microns, which will be easily captured by the 85% pre-filters already available on the Hanford portable 500 cfm exhausters. Other methods of particulate removal, such as cloud chamber scrubbers, can also be utilized to perform this function but most likely at a much higher cost than replacing pre-filters.

The tank headspace can be maintained well above the –9 inches w.g. maximum vacuum on the tank given a clean inlet HEPA filter. The tank headspace pressure depends on the inlet filter differential pressure. The higher the inlet filter dP, the lower the tank headspace pressure. Generally, the tank inlet filters are sized to match the exhauster unit with a maximum of 1 inch w.g. clean differential. The Hanford portable exhausters are provided with pressure interlocks to provide assurances that the system will not pull the tank under too much vacuum. When the grout introduction begins, active ventilation may provide too much vacuum and start challenging the structural integrity of the bottom of the tank. The project may have to rely on passive ventilation until the first inch or two is distributed across the bottom of the tank.

Design Calculation Title: C-106 Ventilation Assesment Project No. and Title: C-106 Closure Project	**DESIGN CALCULATION SHEET**	Calc #: Rev.: A Page: 4 of 8 Orig: R. Dunham Date: 11/13/2002 Checker: L. Ulbricht Date: 11/15/02

1.0 PROBLEM: Determine the ventilation flow rate to remove a fog generated during the closure process where warmer grout mixture will be added to a cool tank atmosphere. Also determine the amount of ventilation flow rate in order to maintain the tank headspace temperature at approximately 60 deg F during the curing process.

2.0 GIVEN:

$T_{headspace} := 60 \cdot degF$ — Assumed Tank Headspace Temperature (near equilibrium ground temperature)

$\rho_{water} := 1.94 \cdot \frac{slug}{ft^3}$ — Water Density at 70°F Roberson/Crowe Table A-5

$\rho_{water} = 62.418 \frac{lb_v}{ft^3}$

$\rho_{air} := 0.00247 \cdot \frac{slug}{ft^3}$ — Air Density at 60°F Roberson/Crowe Table A-3

$\rho_{air} = 0.079 \frac{lb_a}{ft^3}$

$c_{pair} := 0.24 \cdot \frac{BTU}{lb_a \cdot degF}$ — Air Specific Heat Roberson/Crowe Table A-2

2.1 MathCAD Definitions

$lb_a \equiv lb$ — Pound mass of air

$lb_v \equiv lb$ — Pound mass of water vapor

$degF \equiv 1$ — Degrees Fahrenheit

$BTUH \equiv \frac{BTU}{hr}$ — British Thermal Units per hour

$cfm \equiv \frac{ft^3}{min}$ — Cubic feet per minute

3.0 SOLUTION:

3.1 Given the critical velocity of a fog, determine the amount of air flow necessary through the tank headspace to remove an aerosol from the tank headspace.

$V_{co} := 2 \cdot 10^{-2} \cdot \frac{cm}{sec}$ — Critical Velocity of a cloud or fog (ASHRAE, Figure 1, pg. 12.3)

Design Calculation Title: C-106 Ventilation Assesment Project No. and Title: C-106 Closure Project	**DESIGN CALCULATION SHEET**	Calc #: Rev.: A Page: 5 of 8 Orig: R. Dunham Date: 11/13/2002 Checker: L. Ulbricht Date: 11/15/02

$V_{\infty} = 6.562 \times 10^{-4} \frac{ft}{sec}$

$d_{riser} := 12 \cdot in$ — 12 in. Riser Diameter

$A_{riser} := \frac{\pi \cdot d_{riser}^2}{4}$

$Q_{riser} := V_{\infty} \cdot A_{riser}$

$Q_{riser} = 0.031 \frac{ft^3}{min}$ — Required flow through riser to remove the aerosol at Critical Velocity

$d_{tank} := 75 \cdot ft$ — SST Tank Diameter (HNF-SD-WM-ER-313, Rev. 1, pg. F-12)

$h_{waste} := 0 \cdot ft$ — Conservative Concrete Level

$h_{wall} := 18 \cdot ft$ — SST Tank Wall Height (HNF-SD-WM-ER-313, Rev. 1, pg. F-12)

$h_{dome} := 13.25 \cdot ft - 1.25 \cdot ft$ — SST Tank Dome Height (HNF-SD-WM-ER-313, Rev. 1, pg. F-12)

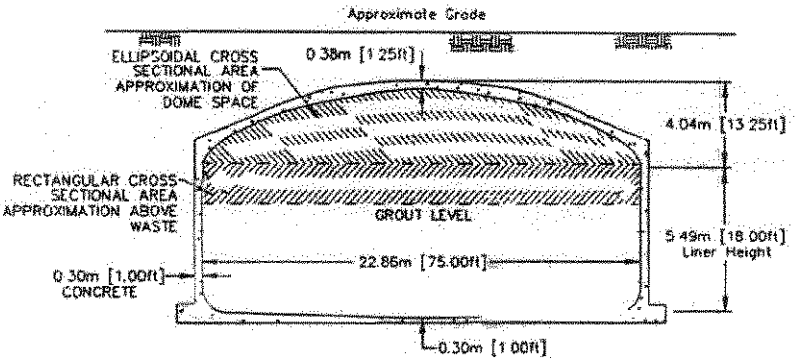


Figure 1. 241-C-106 Ventilation Cross-sectional Area Approximation

$A_{section} := d_{tank} \cdot (h_{wall} - h_{waste}) + \frac{\pi \cdot \frac{d_{tank}}{2} \cdot h_{dome}}{2}$ — Area of rectangle above waste plus 1/2 area of ellipse for tank cross sectional area dome model.

Design Calculation Title: C-106 Ventilation Assesment Project No. and Title: C-106 Closure Project	**DESIGN CALCULATION SHEET**	Calc #: Rev.: A Page: 6 of 8 Orig: R. Dunham Date: 11/13/2002 Checker: L. Ulbricht Date: 11/15/02

$A_{section} = 2.057 \times 10^3\ ft^2$

$Q_{tank} := V_{co} \cdot A_{section}$

$Q_{tank} = 81 \frac{ft^3}{min}$ Required flow through tank to move aerosol fog from the tank headspace

3.2 Determine the amount of water vapor entrained into the air stream leaving the tank for demister sizing.

$Q_{cfm} := \begin{pmatrix} 500 \\ 1000 \end{pmatrix} cfm$ Maximum Flowrate of 500 cfm Exhausters (WHC-SD-WM-DB-035, Rev. 1 pg. 5)

$m_{dotair} := Q_{cfm} \cdot \rho_{air}$

$m_{dotair} = \begin{pmatrix} 2.384 \cdot 10^3 \\ 4.768 \cdot 10^3 \end{pmatrix} \frac{lb_a}{hr}$

$W_i := 0.0112 \cdot \frac{lb_v}{lb_a}$ Humidity Ratio for 60 deg F and 100% RH. Determined from psychometric chart (Attachment A)

$m_{dotv1} := m_{dotair} \cdot W_i$

$m_{dotv1} = \begin{pmatrix} 26.7 \\ 53.4 \end{pmatrix} \frac{lb_v}{hr}$

3.3 Determine the headspace temperature with 500 cfm of ventilation flow removing the cement curing heat load from the tank. Also determine the maximum headspace temperatures given an exhauster flow.

3.3.1 Determine the Maximum Concrete Heat Loss

$V_{lift} := 490 \cdot yd^3$ Volume of Concrete in specific pour (Assumption #10)

$\rho_{conc} := 75 \cdot \frac{lb}{ft^3}$

$m_{conc} := V_{lift} \cdot \rho_{conc}$

$m_{conc} = 3.675 \times 10^4\ lb$

$L_v := 106.1 \cdot \frac{cal}{gm}$ Cement Heat of Hydration Type I Cement (Concrete Technology Today, Vol. 18, No. 2, pg. 2)

Design Calculation Title: C-106 Ventilation Assesment Project No. and Title: C-106 Closure Project	**DESIGN CALCULATION SHEET**	Calc #: Rev.: A Page: 7 of 8 Orig: R. Dunham Date: 11/13/2002 Checker: L. Ulbricht Date: 11/15/02

$q := m_{conc} \cdot L_v$

$q = 1.77 \times 10^9 \text{ cal}$

$q = 7.019 \times 10^6 \text{ BTU}$

3.3.2 Determine Tank Headspace Temperature Maximum given an Exhauster with Maximum Flow

$q_{dot} := \frac{q}{[illegible]}$ — Amount of heat generated from grout

$q_{dot} = 9.748 \times 10^4 \text{ BTUH}$

$q_{dot} = Q_{cfm} \cdot \rho_{air} \cdot \Delta W \cdot h_{fg}$ — Air to remove Latent Heat Gains for Fan Sizing (Lindeburg Eq 39.7, pg. 39-4)

$h_{fg} := 1059.6 \cdot \frac{BTU}{lb}$ — Steam Average Fluid/Gas Enthalpy @ 60 deg F (Lindeburg, pg. A-44)

$\Delta W := \frac{q_{dot}}{(Q_{cfm} \cdot \rho_{air} \cdot h_{fg})}$ — Solving Equation 39.7 from above for ΔW

$\Delta W = \begin{bmatrix} 0.039 \\ 0.019 \end{bmatrix} \frac{lb_a}{lb_v}$

$\Delta W = W_f - W_i$

$W_f := \Delta W + W_i$

$W_f = \begin{bmatrix} 0.05 \\ 0.03 \end{bmatrix} \frac{lb_a}{lb_v}$

$T_{f500} := 104.3 \cdot degF$ — Humidity Ratio of 0.05 lbma/lbmv and assumed 100% RH. Determined from psychometric chart (Attachment A)

$T_{f1000} := 88.6 \cdot degF$ — Humidity Ratio of 0.03 lbma/lbmv and assumed 100% RH. Determined from psychometric chart (Attachment A)

Design Calculation Title: C-106 Ventilation Assesment Project No. and Title: C-106 Closure Project	**DESIGN CALCULATION SHEET**	Calc #: Rev.: A Page: 8 of 8 Orig: R. Dunham Date: 11/13/2002 Checker: L. Ulbricht Date: 11/15/02

3.3.3 *Determine the amount of water vapor to be removed from tank headspace after the grout is poured and setting up.*

$m_{dotvf500} := m_{dotair_0} \cdot \Delta W_0$

$m_{dotvf500} = 92 \frac{lb_v}{hr}$

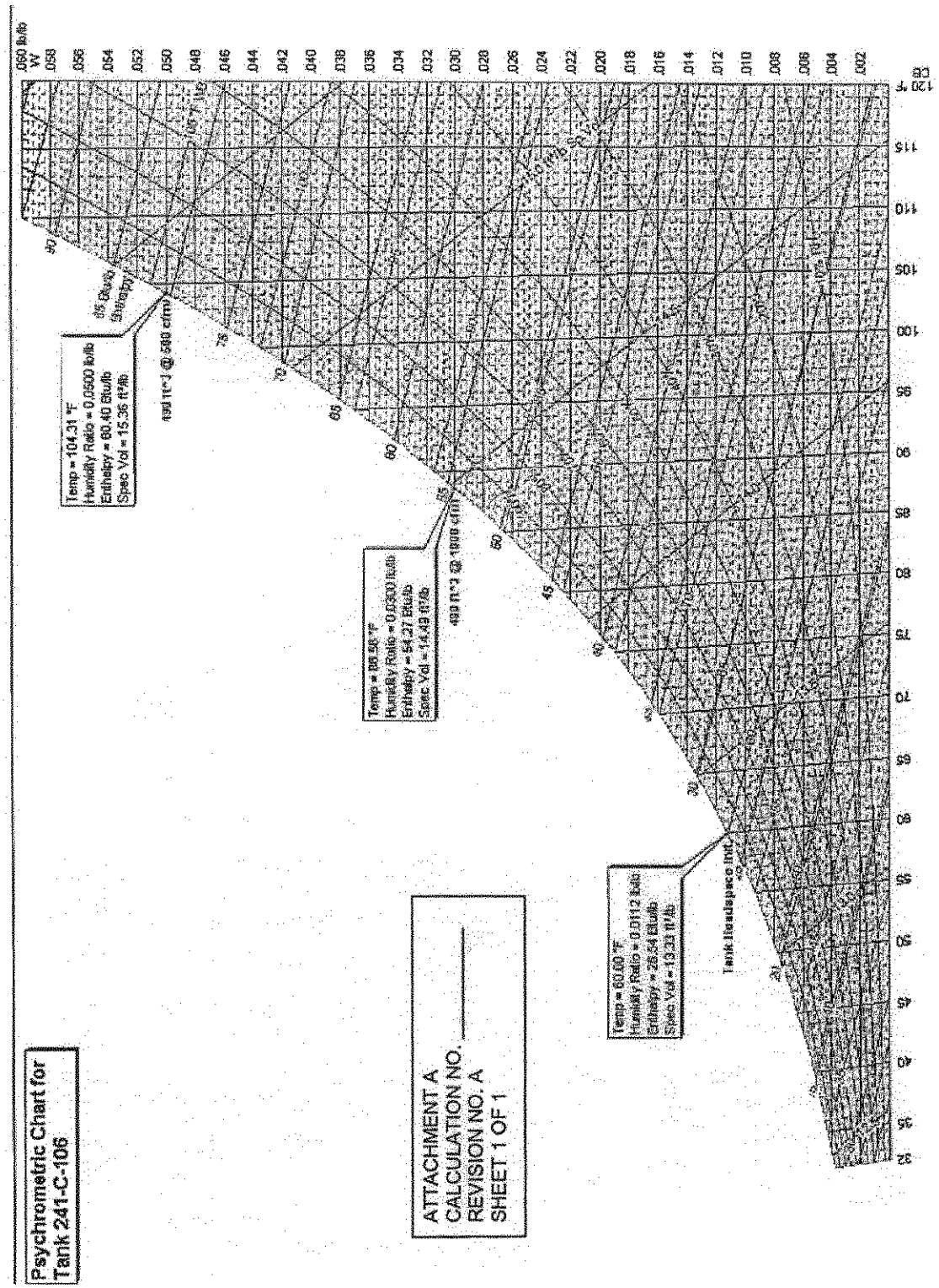
The amount of vapor being removed from the tank with the headspace at 104.3 deg F and 100% RH with 500 cfm

$m_{dotvf1000} := m_{dotair_1} \cdot \Delta W_1$

$m_{dotvf1000} = 92 \frac{lb_v}{hr}$

The amount of vapor being removed from the tank with the headspace at 88.6 deg F and 100% RH with 1000 cfm

4.0 CONCLUSION: In order to maintain visibility during grout introduction into tank C-106, the minimum air velocity in the tank headspace to remove fog possibly generated during that activity can be achieved with air flows above 80 cfm. The portable exhausters available to the project can exhaust up to 500 cfm or 1000 cfm. At these flow rates the internal tank temperature may get as high as 104 or 89 deg F, respectively during the curing time of the grout given ambient ground temperatures as an initial starting condition for the tank headspace temperatures. At these flow rates, the exhauster and subsequent mist eliminator will need to remove 92 lbm/hr of water vapor at that temperature.


Psychrometric Chart for
Tank 241-C-106
Temp = 104.31 °F
Humidity Ratio = 0.0500 lb/lb
Enthalpy = 60.40 Btu/lb
Spec Vol = 15.36 ft³/lb
Temp = 86.56 °F
Humidity Ratio = 0.0300 lb/lb
Enthalpy = 54.27 Btu/lb
Spec Vol = 14.49 ft³/lb
Temp = 60.00 °F
Humidity Ratio = 0.0112 lb/lb
Enthalpy = 28.54 Btu/lb
Spec Vol = 13.33 ft³/lb
Tank headspace int.
ATTACHMENT A
CALCULATION NO. _____
REVISION NO. A
SHEET 1 OF 1

Air Contaminants 12.3

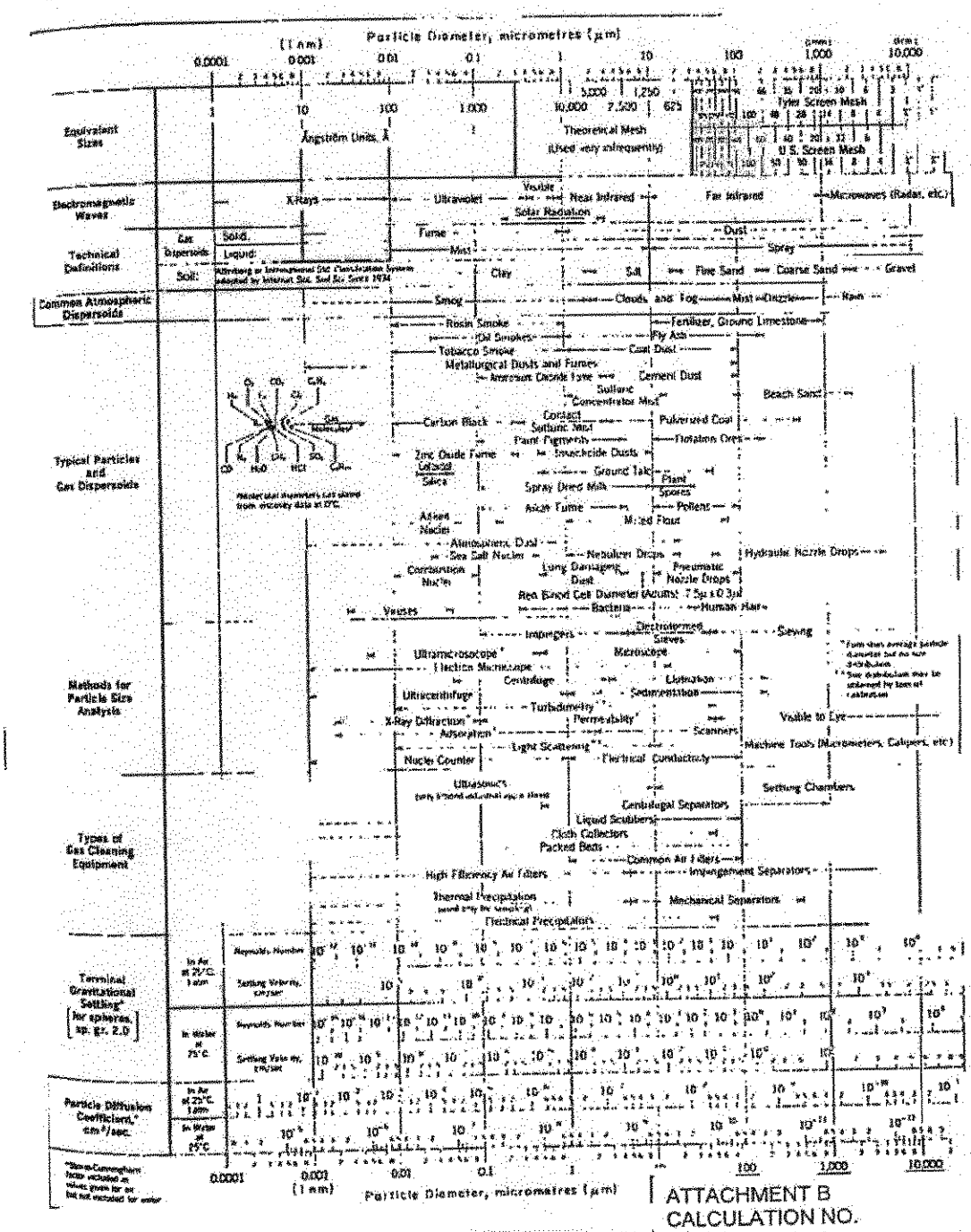


Fig. 1 Characteristics of Particles and Particle Di
(Courtesy of Stanford Research Institute)

ATTACHMENT B
CALCULATION NO.
REVISION NO. A
SHEET 1 OF 1

Portland Cement Association

CONCRETE TECHNOLOGY TODAY

Volume 15 Number 2

July 1994

Contents

Portland Cement, Concrete, and Heat of Hydration

Cement

Continuing Study of Concrete Highway Pavements Reinforced with Epoxy-Coated Bars

Portland Cement, Concrete, and Heat of Hydration

When portland cement is mixed with water, heat is liberated. This heat is called the heat of hydration, the result of the exothermic chemical reaction between cement and water. The heat generated by the cement's hydration raises the temperature of concrete.

During normal concrete construction, the heat is dissipated into the soil or the air and resulting temperature changes within the structure are not significant. However, in some situations, particularly in massive structures, such as dams, mat foundations, or any element more than about a meter or yard thick, the heat can not be readily released. The mass concrete may then attain high internal temperatures, especially during hot weather construction, or if high cement contents are used.

Fig.1 demonstrates the effect of element size on concrete temperature with time due to the heat of hydration.

Temperature rises of 55°C (100°F) have been observed with high cement content mixes.[2] These temperature rises cause expansion while the concrete is hardening. If the temperature rise is significantly high and the concrete undergoes nonuniform or rapid cooling, stresses due to thermal contraction in conjunction with structural restraint can result in cracking before or after the concrete eventually cools to the surrounding temperature. Contractors often insulate massive elements to control temperature changes. As a rule of thumb, the maximum temperature differential between the interior and exterior concrete should not exceed

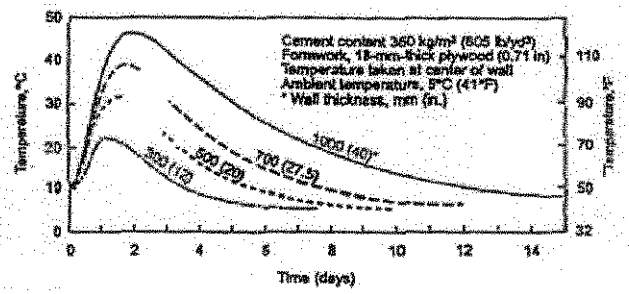


Fig. 1. Effect of member thickness on [illegible] concrete. Reference 1.

ATTACHMENT C
CALCULATION NO. _____
REVISION NO. A
SHEET 1 OF 4

Return To Index

20°C (36°F) to avoid crack development.[3] The potential for thermal cracking is dependent on the concrete's tensile strength, coefficient of thermal expansion, temperature difference within the concrete, and restraint on the member.

Concrete placed in cold conditions benefits from the heat generated by cement hydration, helping protect it from freezing and providing a more favorable curing temperature. Adding insulation to the formwork helps trap the heat in the concrete, allowing it to achieve the required strength.

Heat of Hydration of Portland Cements

The heat of hydration of cement is usually determined in accordance with ASTM C 186, *Standard Test Method for Heat of Hydration of Hydraulic Cement* (see box). Table 1 has heat of hydration values for a variety of portland cements from 1992 to 1996. Although this data is very limited, it confirms the general trends expected: Type III cement has higher heat of hydration than other cement types (average = 88.5 cal/g at 7 days) and Type IV has the lowest (average = 55.7 cal/g at 7 days).

Portland cement evolves heat for a long time.[4] Reference 4 and Fig. 2 present heat of hydration data out to 13 years. Fig. 2 shows that the rate of heat generation is greatest at early ages. Usually, the greatest rate of heat liberation occurs within the first 24 hours and a large amount of heat evolves within the first 3 days. For most concrete elements, such as pavements, long-term heat generation is not a concern as this heat is dissipated into the environment.

Factors Affecting Heat of Hydration

Materials can be selected to minimize or maximize the heat of hydration, depending on the need. Cements with higher contents of tricalcium silicate and tricalcium aluminate, as well as a higher fineness, such as Type III cements, have higher rates of heat generation than other cements.

Tricalcium silicate and tricalcium aluminate chemically generate more heat, and at a faster rate, than dicalcium silicate or other cement compounds. Sulfate content, in its relation to controlling the hydration of calcium aluminate, participates in the rate of heat liberation.

Higher fineness provides a greater surface area to be wetted, resulting in an acceleration of the reaction between cement and water. This causes an increase in the

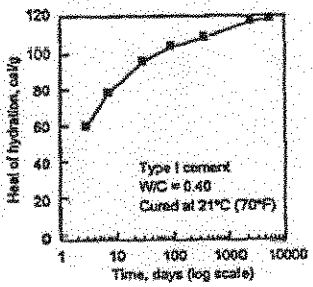


Fig. 2. Average heat of hydration of a Type I cement at various ages to 13 years. Reference 4.

Table 1. ASTM C 186 Heat of hydration for selected portland cements, calories per gram*

Type I cement			Type II cement		Type II (moderate heat) cement		Type III cement			Type IV cement			Type V cement	
No.	7 day	28 day	7 day		No.		No.	7 day	28 day	7 day				7 day
	82.0	—**	77.7	101.4	32		36	88.0	95.0	60.0	—		41	81.5
	85.6	—	82.6	88.8	33		37	89.0	95.0	57.3	—		42	66.5
	81.5	—	88.7	89.4	34					49.7	65.5		43	79.3
	80.2	—	88.0	—	35								44	80.4
	78.4	—	73.6	—									45	76.1
	88.3	90.2	88.5	—									46	61.4
	88.2	106.1	77.1	89.7										
	87.7	93.5	87.3	—										
	88.9	97.7	81.9	100.3										
	76.4	91.7	88.3	99.4										
	84.4	91.7	86.5	96.8										
	84.4	98.5	79.5	—										
	83.5	—	79.4	—										
	79.5	—	80.0	—										
	83.0	—	80.0	—										
			77.6	—										
Avg.	83.5	95.6	[illegible]		Avg.	62.9		88.5	97.0	Avg.	55.7	NM	Avg.	74.2
Max.	88.9	106.1	[illegible]		Max.	54.3		NM	NM	Max.	49.7	NM	Max.	81.5
Min.	76.4	90.2	[illegible]		Min.	67.6		NM	NM	Min.	60.0	NM	Min.	61.4

ATTACHMENT C
CALCULATION NO. _____
REVISION NO. A
SHEET 2 OF 4

2

Return To Index

Testing for Heat of Hydration

[illegible]

rate of heat liberation at early ages, but may not influence the total amount of heat developed over several weeks.

Other factors influencing heat development in concrete include the cement content, water-cement ratio, placing and curing temperature, the presence of mineral and chemical admixtures, and the dimensions of the structural element.

In general, higher cement contents result in more heat development. ACI 211.1, *Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete*, states that as a rough guide, hydration of cement will generate a concrete temperature rise of about 4.7°C to 7.0°C per 50 kg of cement per m³ of concrete (10°F to 15°F per 100 lb of cement per yd³ of concrete) in 18 to 72 hours.

When comparing concretes of equal cement content but different water-cement ratios, mixes with higher water-cement ratios have more water and microstructural space available for hydration of the cement (more of the cement hydrates and it hydrates at a faster rate), resulting in an increased rate of heat development. The increase in heat of hydration at 7 days resulting from an increase in water-cement ratio from 0.4 to 0.6 is about 11% for Type I cement. The effect is minimal for moderate- and low-heat cements.[10] The water-cement ratio effect is minor compared to the effect of cement content. However, a lower water-cement ratio in concrete achieved by increasing the cement content results in greater heat generation.

Higher temperatures greatly accelerate the rate of hydration and the rate of heat liberation at early ages (less than 7 days). Chemical admixtures that accelerate hydration also accelerate heat liberation and admixtures that retard hydration delay heat development. Mineral admixtures, such as fly ash, can significantly reduce the rate and amount of heat development.

Specifications for Reduced Heat Cements

When heat generation must be minimized in concrete, one way to achieve this is to choose a lower heat cement, such as a Type II cement with the optional moderate heat of hydration requirements. Not all Type II cements are made for a moderate level of heat development, however, so the moderate heat option must be specifically required (see Table 1). Type IV, low heat of hydration cement, can also be used to control temperature rise, but it is rarely available.

ASTM C 150, *Standard Specification for Portland Cement*, allows two independent approaches to control heat of hydration in cement. The first method is to specify chemical requirements. For Type II cement, an optional limit on the sum of the tricalcium silicate (C_3S) and tricalcium aluminate (C_3A) contents is set at 58%. For Type IV cement, limits are placed on the C_3S and C_3A contents at a maximum of 35% and 7%, respectively, while maintaining a minimum dicalcium silicate (C_2S) content of 40%. The second method uses physical requirements. For Type II cement, the optional maximum heat of hydration is 70 calories per gram (290 kJ/kg) at 7 days. For Type IV cement, the maximum heat of hydration is limited to 60 calories per gram (250 kJ/kg) at 7 days and 70 calories per gram (290 kJ/kg) at 28 days. Either the chemical approach or the physical approach should be specified, but not both.

ASTM C 595, *Standard Specification for Blended Hydraulic Cements*, and ASTM C 1157, *Standard Performance Specification for Blended Hydraulic Cement*, both provide the option of specifying moderate- and low-heat of hydration cements using physical limits. For moderate heat of hydration, C 595 adds the suffix MH to the cement type, calling out limits of 70 calories per gram (290 kJ/kg) at 7 days and 80 calories per gram (330 kJ/kg) at 28 days, while C 1157 (cement Type MH) has limits of 70 calories per gram (290 kJ/kg) at 7 days as the only requirement. For low heat of hydration, both C 595 (LH suffix) and C 1157 (Type LH) have limits of 60 calories per gram (250 kJ/kg) at 7 days and 70 calories per gram (290 kJ/kg) at 28 days.

Controlling Concrete Temperature Rise

The temperature rise of concrete can be controlled by selecting appropriate materials and construction practices. For cold weather, ACI 306R, *Cold Weather Concreting*, recommends minimum mixing and placing temperatures based on the size of the concrete member and the ambient air temperature. (As temperatures and member thickness decrease, conditions become more critical.) ACI 306R offers guidance on increasing the temperature of fresh concrete, including heating aggregates and mixing water. Other options include reducing the length of the required protection period by using Type III cement, by using an accelerating admixture, or by using an extra 60 kg/m³ (100 lb/yd³) of cement. Also, insulation could be used to trap the heat in the fresh concrete,

Return To Index

ATTACHMENT C
CALCULATION NO. _____
REVISION NO. A
SHEET 3 OF 4

thereby protecting it.

For massive structures, or to control temperature rise in hot weather, ACI 305R, *Hot Weather Concreting*, recommends controlling mixing and placing procedures to minimize delays and to use the cooler parts of the day for placing operations. There are numerous methods to minimize the concrete temperature rise. These include cooling the mixing water, using ice as part of the mixing water, using a moderate-heat Type II (ASTM C 150) portland cement or moderate- or low-heat blended cement (ASTM C 595 or C 1157), and keeping cement contents to a minimum level. A fly ash or other pozzolan or slag can be used, chemical admixtures (retarder, water-reducer/retarder) can be used, or the aggregate can be cooled. Also, water curing controls temperature increases better than other curing methods. Reference 1 discusses the effect of formwork material on temperature rise. Steel formwork retains the least heat.

A proposed concrete mixture can be tested for temperature rise in a mock-up sample in a laboratory or the field. Fig. 3 presents results from such a mock-up, showing how the temperature rise differs between the interior and exterior of a massive member for a high-cement-content mixture. The Army Corps of Engineers' *Test Method for Temperature Rise in Concrete*, CRD C 38, is a procedure to evaluate preconstruction mixes for heat development.

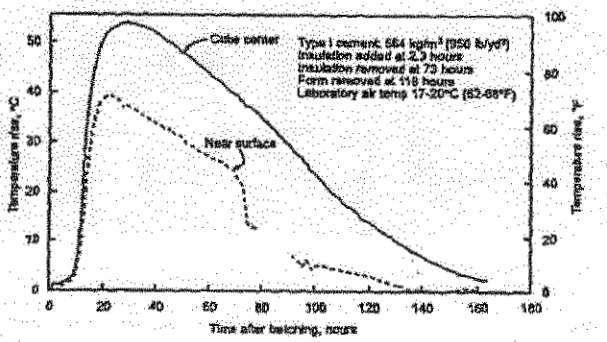


Fig. 3. Temperature rise of a high-cement-content 1.2-meter (4-ft) test cube. Reference 2.

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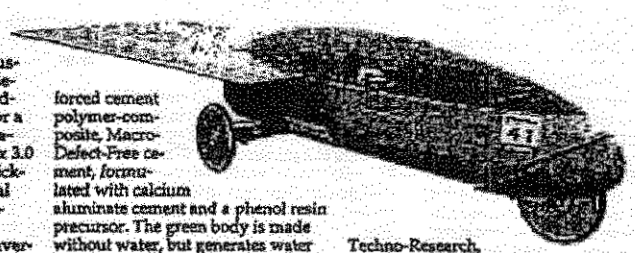
Cement on the Go



Researchers of MAETA Techno-Research, Inc., a subsidiary of MAETA Concrete Industry Ltd., Yamagata, Japan have developed a car body made of an advanced cement-based material for a solar-powered car. The body measures 3.6 x 0.7 x 0.9 m (11.8 x 2.3 x 3.0 ft). The molded panels have a thickness of 2.5 mm (0.1 in.) and a total weight of 33 kg (73 lb). The solar-powered car ran in the 500 km World Solar Car Rally in Akita, averaging 45 km/h (27 mph). The trial run was made to study the feasibility of utilizing cements in the transportation industry. The car received the "Hans Tholstrup" award for its outstanding achievement as an earth-friendly, low-energy material body. The material is a fiber reinforced cement polymer-composite, Macro-Defect-Free cement, formulated with calcium aluminate cement and a phenol resin precursor. The green body is made without water, but generates water during the heating process that initiates cross-linking of the phenol resin precursor. The material was invented by a research group of MAETA Concrete Industry Ltd. in 1992, and patent applications have been granted in the United States and Europe. Researchers of MAETA Techno-Research, Inc. are now working on further developments of applications in the transportation industry.

The car was exhibited at the MAETA Workshop on High Flexural Polymer-Cement Composite, held October 17, 1996 in Sakata,

4

Return To Index

ATTACHMENT C
CALCULATION NO. _____
REVISION NO. A
SHEET 4 OF 4

Tank 241 C-106 Closure
Thermal Analysis

November 27, 2002

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Prepared by M. D. Northey 11/27/02
Checked by K. L. Stoops 11-27-02

M&D Professional Services	CALCULATION SHEET	Page No. 1 of 10
Client / Location: Columbia Energy	Prepared By / Date: MD Northey 11/27/02 MDN	Calculation No. M&D-02-0033
Subject: Tank 241 C-106 Closure Preliminary Thermal Analysis	Checked By / Date: KL Stoops 11/27/02 KLS	Revision No. 0
Ref. Drawing(s): No. 900 H-2-602	Revised By / Date:	Contract No. CEES 002-002, Task 2

1.0 INTRODUCTION

Tank 241 C-106 has a current sludge volume of 6076 gallons. This volume will be reduced to a post retrieval volume of 2700 gallons and stabilized with 165 yards of low strength grout (Phase 1). Eventually, the remaining void space within the tank will be filled with a low strength grout stabilizing material (Phase 2). Heat generation from both the decay heat and from the heat of hydration of the grout will lead to an elevated temperature profile in the tank and surrounding soil. The purpose of this analysis is to determine two steady state temperature profiles for 241 C-106. The analysis is run in two load cases. The first load case includes the heel only (Phase 1), the second load case includes the heel and remaining grout fill (Phase 2).

2.0 LOADS

The Post Retrieval Inventory of 2700 gallons (13.3 yds) generates a total heat load of 5,964 Btu/hr. The stabilizing grout material will have a formulation of 75 lb cement/yard. Using a heat of hydration of 95 cal/gram and 165 yards (33,323 gal) of stabilizing grout cured over 28 days, a heat generation rate can be calculated for the heel.

Convert, heat per pound of cement	95 cal/gram = 171 Btu/lb
Total cement	75 lb cement/yard x 165 yards = 12375 lb cement
Total heat generated over 28 days	171 Btu/lb x 12375 lb = 2.116E+6 Btu
Heel Hydration Heat Rate	2.116E+6 Btu/(28 x 24) = 3149 Btu/hr

The remaining fill (Phase 2) will have 150 lbs cement/yard. For the purposes of this analysis, the depth is taken as 11 inches below the inside of the haunch. The majority of the fill above this level will require a separate process as risers and penetrations become involved. The 37.5-foot inside radius tank has an area of 4418 ft^2. The depth from the haunch is 18 feet 11 inches and the depth of the heel is 13.08 inches. This leaves 16.91 feet of fill up to the haunch or 74,708 ft^3 or 2767 yards.

Total cement	150 lb cement/yard x 2767 yards = 415,050 lb cement
Total heat generated over 28 days	171 Btu/lb x 415,050 lb = 70.974E+6 Btu
Fill Hydration Heat Rate	70.974E+6 Btu/(28 x 24) = 105,615 Btu/hr

M&D Professional Services	CALCULATION SHEET	Page No. 2 of 10
Client / Location: Columbia Energy	Prepared By / Date: MD Northey 11/27/02 MDN	Calculation No. M&D-02-0033
Subject: Tank 241 C-106 Closure Preliminary Thermal Analysis	Checked By / Date: KL Stoops 11/27/02 KLS	Revision No. 0
Ref. Drawing(s): No. 900 H-2-602	Revised By / Date:	Contract No. CEES 002-002, Task 2

	Volume	Depth (Area=4418 ft^2)	Total Heat Rate	Volumetric Heat Rate
Post Ret. Inventory	2700 gal 361 ft^3 623743 in^3	0.082 ft 0.98 in	5,964 Btu/hr	9.56E-3 Btu/hr in^3
Heel	165 yds 4455 ft^3 7698240 in^3	1.008 ft 12.10 in	3,149 Btu/hr	0.41E-3 Btu/hr in^3
Fill	2767 yds 74708 ft^3 129.095E+6 in^3	16.91 ft 202.93 in	105,615 Btu/hr	0.818E-3 Btu/hr in^3
Current Sludge Inventory	6076 gal 812.3 ft^3 1403653 in^3	0.184 ft 2.206 in	13,390 Btu/hr	9.539E-3 Btu/hr in^3

Table 1 Heat Generation Loads

3.0 MODEL DESCRIPTION

The ANSYS Finite Element Model consists of PLANE55 axisymmetric elements. The surrounding soil is modeled to a depth of 200 feet and a radius of 100 feet. The tank geometry was taken from drawing No. 900 H-2-602, "Composite Tank Typical concrete Details 242-BX," which applies to C-Farm tanks. The geometry was simplified to a flat bottom tank to facilitate meshing. The simplifications will not affect the critical results such as maximum temperature and through wall gradients. The decay heat load is larger than the heat of hydration. To account for possible concentration of the Post Retrieval Inventory, the waste is modeled in the center of the stabilizing heel. The stabilizing grout with the appropriate heat of hydration is modeled as a concentric volume surrounding the waste. The void space is modeled with air with a thermal conductivity corresponding to an air temperature of 100°F.

4.0 MATERIAL PROPERTIES

The steady state analysis only requires conductivity properties for the various materials used in the model. The following table provides the properties used in this analysis. The sources are included in the attachment.

	Conductivity (Btu/hr ft °F)	Conductivity (Btu/hr in °F)
Soil	0.50	0.042
Structural Concrete	0.54	0.045
Heel Grout	0.30	0.025
Fill Grout	0.30	0.025
Air	0.0154	0.00128

Table 2 Material Properties

M&D Professional Services	CALCULATION SHEET	Page No. 3 of 10
Client / Location: Columbia Energy	Prepared By / Date: MD Northey 11/27/02	Calculation No. M&D-02-0033
Subject: Tank 241 C-106 Closure Preliminary Thermal Analysis	Checked By / Date: KL Stoops 11/27/02	Revision No. 0
Ref. Drawing(s): No. 900 H-2-602	Revised By / Date	Contract No. CEES 002-002, Task 2

5.0 BOUNDARY CONDITIONS

- Tank spacing is 100 feet from center to center. Modeling a 50-foot radius adiabatic boundary condition is overly conservative as the actual adiabatic boundaries are rectangular and thus the areas at both the surface and ground water are more than the areas for a cylinder. Also, tank 241 C-106 is at the edge of an array of tanks. An adiabatic boundary is set a radial distance of 100 feet from the center of the tank.
- An isothermal boundary is set 200 feet below the surface at 55°F.
- Forced convection heat transfer at the earth's surface is modeled with a convection coefficient of 1.8 Btu/hr ft^2 °F (0.0125 Btu/hr in^2 °F). This is based on a average wind speed of 5 fps.
- Thermal radiation from the heel (Phase 1) or fill (Phase 2) surface to the tank exposed walls and dome is modeled using the /AUX12 routine in ANSYS to calculate view factors. The emissivity value used for all surfaces was 0.9 which is representative of oxidized steel as well as the rough surface of the waste and concrete dome.
- (Phase 1) The Stabilizing heel has a volume of 4816 ft^3 combined waste and stabilizing grout and a depth of 13.08 inches. The 361 ft^3 of Post Retrieval Waste is modeled at the radial center of the cylindrical volume with the heel grout making up the remaining volume. This will concentrate the relatively high heat generation of the waste in the center and is conservative.
- (Phase 2) The Post Retrieval Waste is modeled similarly to Phase 1. The remaining volume to a depth of 16.91 feet is modeled as fill grout. The heat of hydration of the grout that has already set is removed. The heat of hydration is calculated for a 28-day cycle. This assumes all the heat of hydration has dissipated after 28 days and is constant throughout the cycle. For the steady state analysis, this heat load is applied as a constant heat generation rate.

M&D Professional Services	CALCULATION SHEET	Page No. 4 of 10
Client / Location: Columbia Energy	Prepared By / Date: MD Northey 11/27/02 MDN	Calculation No. M&D-02-0033
Subject: Tank 241 C-106 Closure Preliminary Thermal Analysis	Checked By / Date: KL Stoops 11/27/02 KLS	Revision No. 0
Ref. Drawing(s): No. 900 H-2-602	Revised By / Date	Contract No. CEES 002-002, Task 2

6.0 CURRENT INVENTORY BASELINE MODEL

To gain confidence in the model and to assure conservatism, a baseline model was generated that simulates the current sludge inventory as presented in Table 1. The results were compared to thermocouple data taken from tank C-106 from November of 1999 to November of 2002. Two runs were made to determine the effect of value of the soil conductivity. Dry sandy soil has a minimal conductivity of 0.30 Btu/hr ft °F. Using this value of soil conductivity for a steady state analysis of the current inventory leads to temperatures in the dome air space of about 106°F.

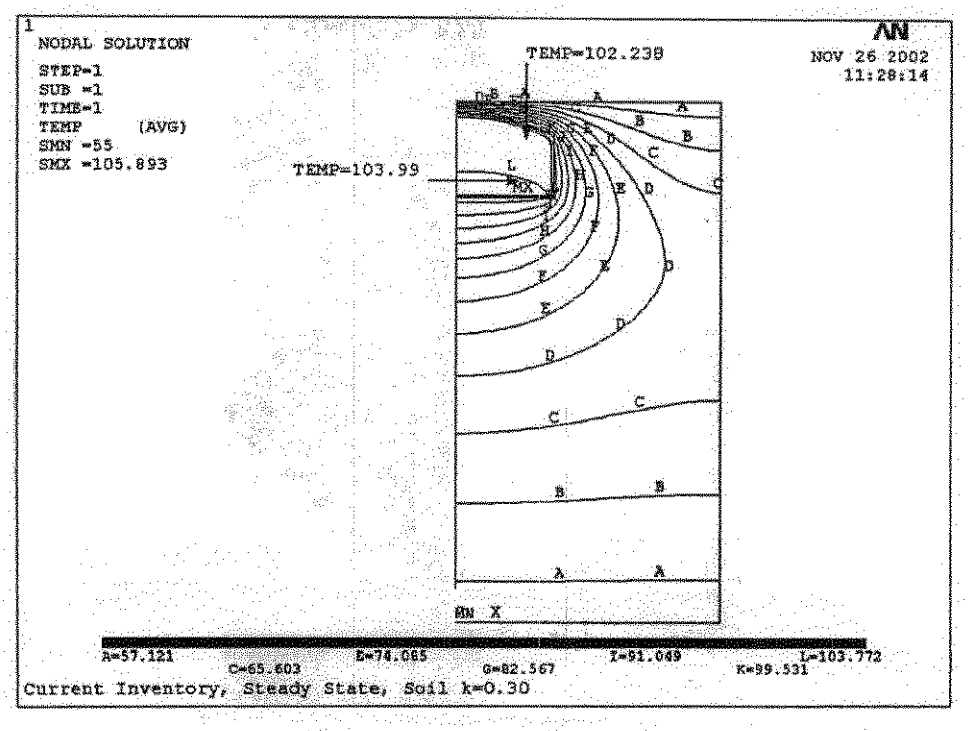

Figure 1 Baseline Results, Soil Conductivity = 0.30 Btu/hr ft °F

M&D Professional Services	CALCULATION SHEET	Page No. 5 of 10
Client / Location: Columbia Energy	Prepared By / Date: MD Northey 11/27/02	Calculation No.: M&D-02-0033
Subject: Tank 241 C-106 Closure Preliminary Thermal Analysis	Checked By / Date: KL Stoops 11/27/02	Revision No.: 0
Ref. Drawing(s): No. 900 H-2-602	Revised By / Date:	Contract No.: CEES 002-002, Task 2

Recorded thermocouple data show the dome air space to be between 80°F and 90°F. The difference between the reported and calculated values using a soil conductivity of 0.30 is considered overly conservative and a more realistic soil conductivity of 0.50 Btu/hr ft °F is used for the second run. The results from Figure 2 show that the dome air space temperature is about 84°F. The results match well for magnitude and location and provide confidence in the model for the given parameters. For successive runs, a value of 0.50 Btu/hr ft °F is used for the conductivity of the soil.

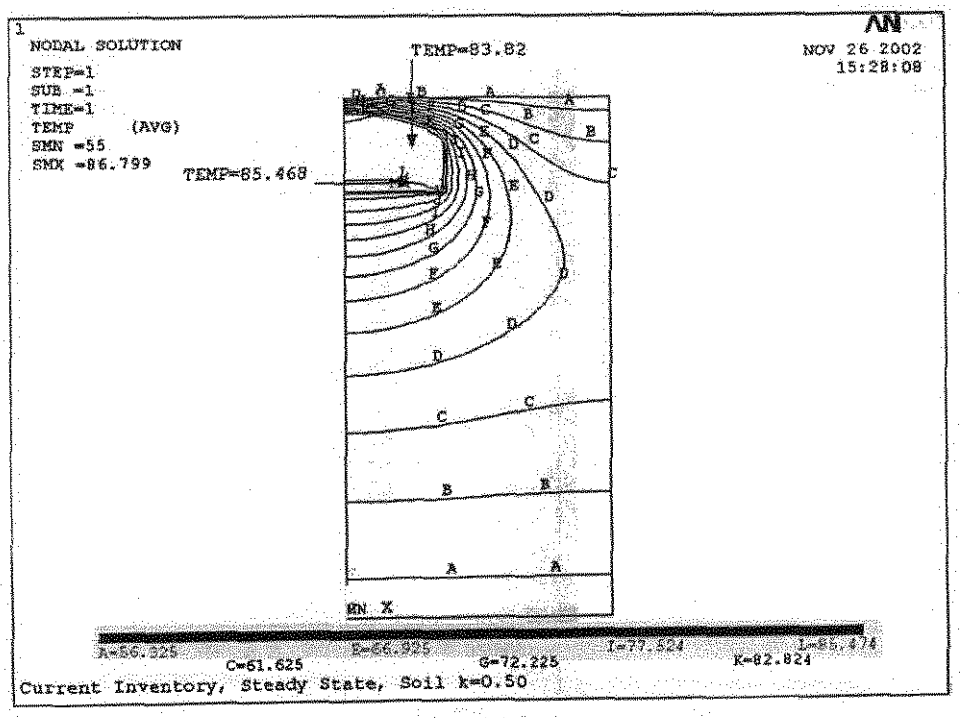

Figure 2 Baseline Results, Soil Conductivity = 0.50 Btu/hr ft °F

M&D Professional Services	CALCULATION SHEET	Page No. 6 of 10
Client / Location: Columbia Energy	Prepared By / Date: MD Northey 11/27/02 MDN	Calculation No. M&D-02-0033
Subject: Tank 241 C-106 Closure Preliminary Thermal Analysis	Checked By / Date: KL Stoops 11/27/02 KLS	Revision No. 0
Ref. Drawing(s): No. 900 H-2-602	Revised By / Date:	Contract No. CEES 002-002, Task 2

7.0 PHASE 1 RESULTS

The results of the steady state analysis representing phase 1 is shown in Figure 3. Note how the high temperature zone is concentrated around the high heat zone where the decay heat dominates.

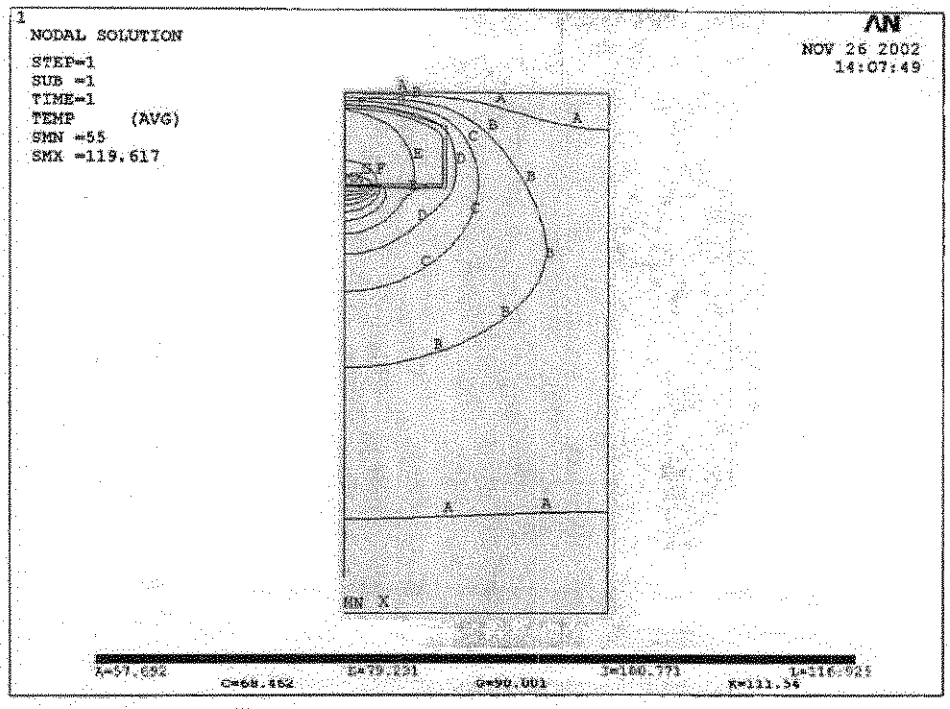

Figure 3 Phase 1 Results, Peak Temperatures

M&D Professional Services	CALCULATION SHEET	Page No. 7 of 10
Client / Location: Columbia Energy	Prepared By / Date: MD Northey 11/27/02 MDN	Calculation No. M&D-02-0033
Subject: Tank 241 C-106 Closure Preliminary Thermal Analysis	Checked By / Date: KL Stoops 11/27/02 KLS	Revision No. 0
Ref. Drawing(s): No. 900 H-2-602	Revised By / Date:	Contract No. CEES 002-002, Task 2

Through wall temperature gradients are shown in Figure 4. The largest gradient is in the dome and is 4.5°F. Note also the peak structural concrete temperature of 119.6°F located at the bottom in the center.

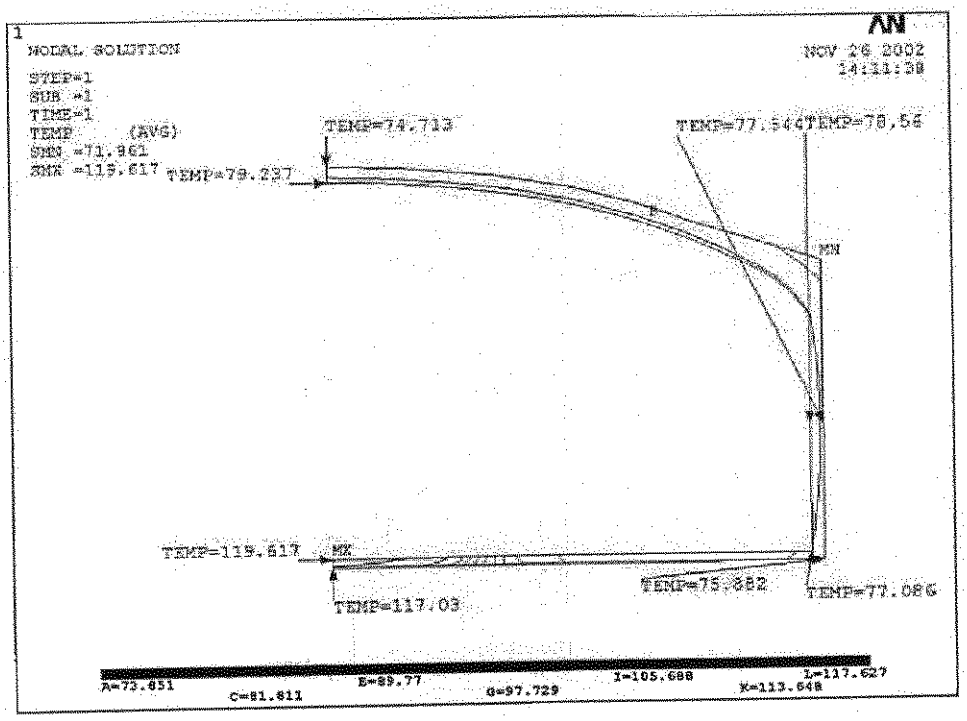

Figure 4 Phase 1 Results, Temperature Gradients

M&D Professional Services	CALCULATION SHEET	Page No. 8 of 10
Client / Location: Columbia Energy	Prepared By / Date: MD Northey 11/27/02 MDN	Calculation No. M&D-02-0033
Subject: Tank 241 C-106 Closure Preliminary Thermal Analysis	Checked By / Date: KL Stoops 11/27/02 KLS	Revision No. 0
Ref. Drawing(s): No. 900 H-2-602	Revised By / Date	Contract No. CEES 002-002, Task 2

8.0 PHASE 2 RESULTS

In Phase 2, the remaining fill is added in one lift. The depth is just below the beginning of the haunch. Note from Table 1 that the total heat generated is about 106,000 Btu/hr. This is comparable to when the tank was in service with the exception that no ventilation is present in this analysis. The lack of ventilation coupled with the relatively low conductivity of the low strength grout leads to a high peak temperature of 747°F. This is well above the established criteria therefore a smaller lift is required.

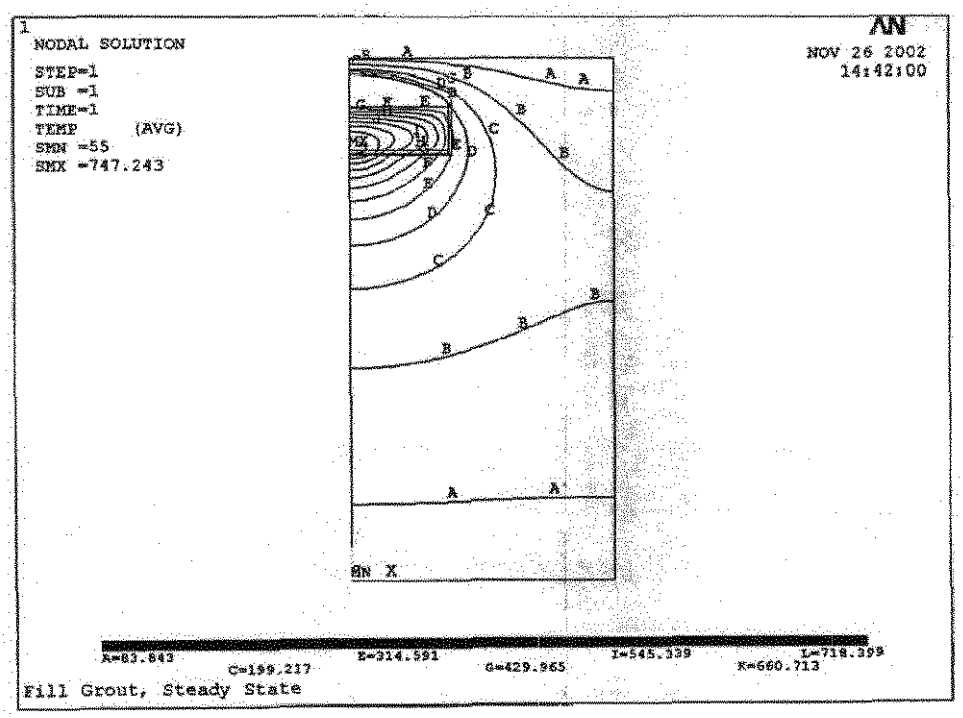

Figure 5 Phase 2 Results, Full Depth

M&D Professional Services	CALCULATION SHEET	Page No. 9 of 10
Client / Location: Columbia Energy	Prepared By / Date: MD Northey 11/27/02 MDN	Calculation No. M&D-02-0033
Subject: Tank 241 C-106 Closure Preliminary Thermal Analysis	Checked By / Date: KL Stoops 11/27/02 KLS	Revision No. 0
Ref. Drawing(s): No. 900 H-2-602	Revised By / Date:	Contract No. CEES 002-002, Task 2

After several iterations, a second Phase 2 was run with a fill depth of 22 inches. Note the peak temperature in the grout for the steady state solution is less than 200°F. The peak temperature of 203°F occurs in the waste.

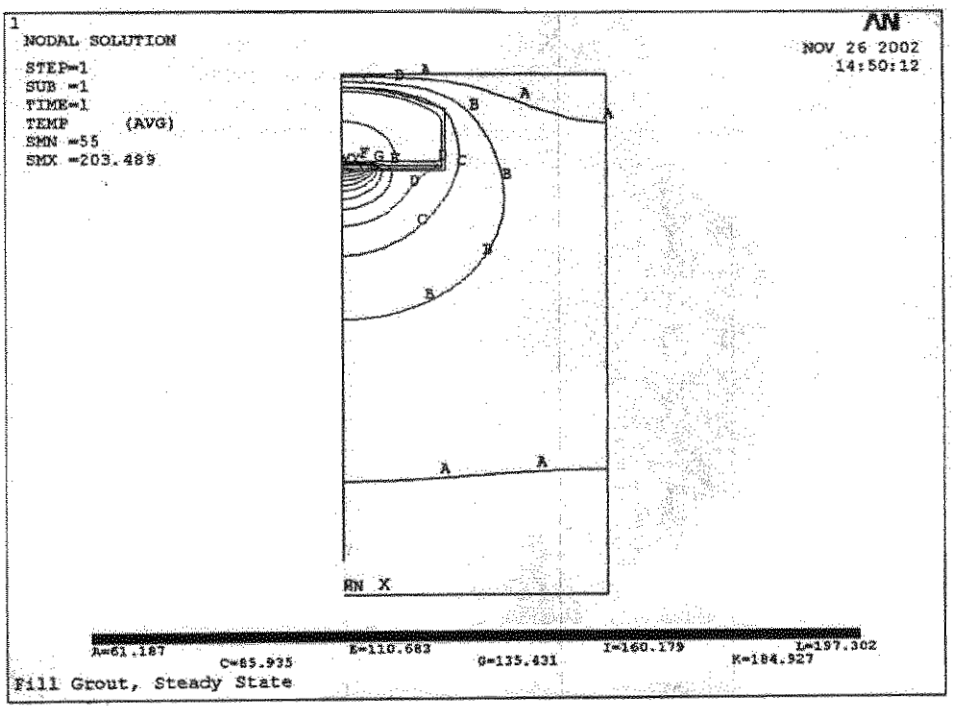

Figure 6 Phase 2 Results, 22 inches of Fill

M&D Professional Services	CALCULATION SHEET	Page No. 10 of 10
Client / Location: Columbia Energy	Prepared By / Date: MD Northey 11/27/02	Calculation No. M&D-02-0033
Subject: Tank 241 C-106 Closure Preliminary Thermal Analysis	Checked By / Date: KL Stoops 11/27/02	Revision No. 0
Ref. Drawing(s): No. 900 H-2-602	Revised By / Date:	Contract No. CEES 002-002, Task 2

The maximum through-wall gradient is in the dome and is 7.4°F. The maximum grout temperature is 191°F. This is a steady state analysis and a transient would account for the thermal mass of the soil to absorb heat. Since the heat of hydration essentially reduces to 0 after 28 days, the first lift would see a lower peak temperature than predicted by the steady state analysis. Eventually, as the surroundings are heated up, the effectiveness as a heat sink will diminish and successive lifts would need to be less than the first or use longer time intervals between lifts. If it is desired to maximize the lift heights, it is recommended to perform a continuous transient analysis as each lift is added. It is also recommended to consider active cooling and specialized grout mixtures.

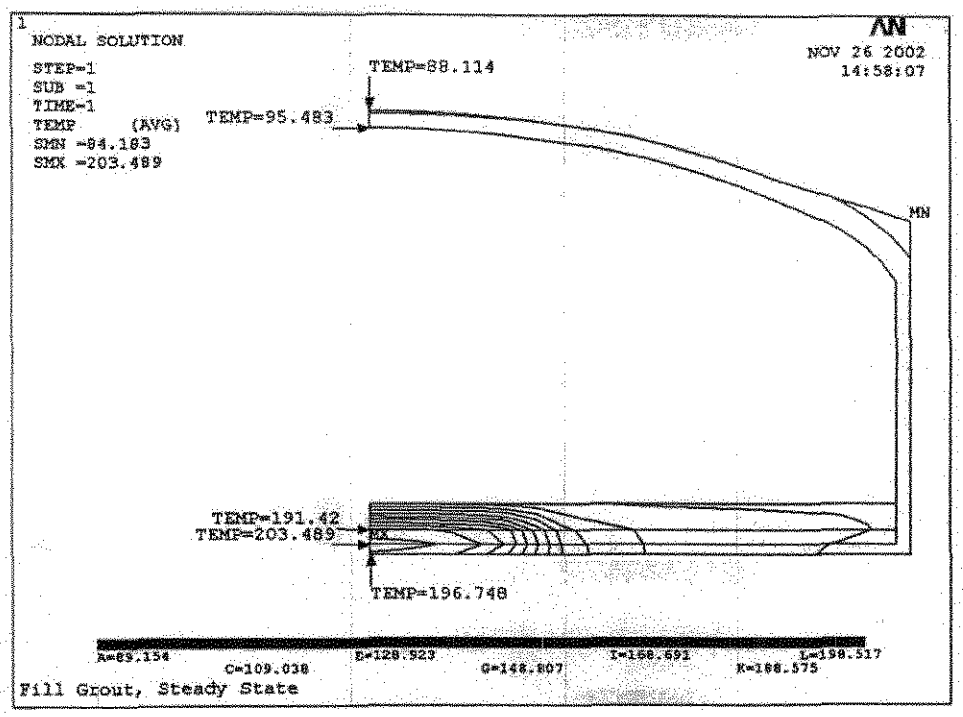

Figure 7 Phase 2 Results, 22 inches of Fill

ATTACHMENT

MATERIAL PROPERTIES
BASELINE THERMALCOUPLE DATA
REVIEW HANDCALCULATIONS

Principles of
Heat Transfer

FRANK KREITH

Professor of
Mechanical Engineering

UNIVERSITY OF COLORADO

International Textbook Company · Scranton

FRANK KREITH, "PRINCIPLES of HEAT TRANFER"

TABLE A-2

PHYSICAL PROPERTIES OF SOME NONMETALS

Material	Average Temperature (F)	k (Btu/hr ft F)	c (Btu/lb$_m$F)	ρ (lb$_m$/cu ft)	α (sq ft/hr)
Insulating Materials					
Asbestos	32	0.087	0.25	36	~0.01
	392	0.12	....	36	~0.01
Cork	86	0.025	0.04	10	~0.006
Cotton, fabric	200	0.046			
Diatomaceous earth, powdered	100	0.030	0.21	14	~0.01
	300	0.036	....		
	600	0.046	....		
Molded pipe covering	400	0.051	....	26	
	1600	0.088	....		
Glass wool					
Fine	20	0.022			
	100	0.031		1.5	
	200	0.043			
Packed	20	0.016			
	100	0.022		6.0	
	200	0.029			
Hair felt	100	0.027		8.2	
Kaolin insulating brick	932	0.15		27	
	2102	0.26			
Kaolin insulating firebrick	392	0.05	....	19	
	1400	0.11	....		
85% magnesia	32	0.032	....	17	
	200	0.037	....	17	
Rock wool	20	0.017	....	8	
	200	0.030	....		
Rubber	32	0.087	0.48	75	0.0024
Building Materials					
Brick					
Fire-clay	392	0.58	0.20	144	0.02
	1832	0.95			
Masonry	70	0.38	0.20	106	0.018
Zirconia	392	0.84	....	304	
	1832	1.13	....		
Chrome brick	392	0.82	....	246	
	1832	0.96			
Concrete					
Stone	~70	0.54	0.20	144	0.019
10% moisture	~70	0.70	....	140	~0.025
Glass, window	~70	~0.45	0.2	170	0.013
Limestone, dry	70	0.40	0.22	105	0.017
Sand					
Dry	68	0.20	....	95	
10% H_2O	68	0.60	....	100	
Soil					
Dry	70	~0.20	0.44	....	~0.01
Wet	70	~1.5	....	.....	~0.03
Wood					
Oak ⊥ to grain	70	0.12	0.57	51	0.0041
‖ to grain	70	0.20	0.57	51	0.0069
Pine ⊥ to grain	70	0.06	0.67	31	0.0029
‖ to grain	70	0.14	0.67	31	0.0067
Ice	32	1.28	0.46	57	0.048

534

TABLE A-3

PHYSICAL PROPERTIES OF GASES, LIQUIDS, AND LIQUID METALS
(All Gas Properties Are for Atmospheric Pressure)

functions of pressure

GASES

T (F)	ρ (lbm/cu ft)	c_p (Btu/lbm F)	$\mu \times 10^6$ (lbm/ft sec)	$\nu \times 10^6$ (sq ft/sec)	k (Btu/hr ft F)	Pr	α (sq ft/hr)	$\beta \times 10^6$ (1/F)	$\frac{\rho^2 g \beta}{\mu^2}$ (1/F cu ft)
Air									
0	0.086	0.239	1.110	0.130	0.0133	0.73	0.646	2.18	4.2×10^6
32	0.081	0.240	1.165	0.145	0.0140	0.72	0.720	2.03	3.16
100	0.071	0.240	1.285	0.180	0.0154	0.72	0.905	1.79	1.76
200	0.060	0.241	1.440	0.239	0.0174	0.72	1.20	1.52	0.850
300	0.052	0.243	1.610	0.306	0.0193	0.71	1.53	1.32	0.444
400	0.046	0.245	1.750	0.378	0.0212	0.689	1.88	1.16	0.258
500	0.0412	0.247	1.890	0.455	0.0231	0.683	2.27	1.04	0.159
600	0.0373	0.250	2.000	0.540	0.0250	0.685	2.68	0.943	0.106
700	0.0341	0.253	2.14	0.625	0.0268	0.690	3.10	0.862	70.4×10^3
800	0.0314	0.256	2.35	0.717	0.0286	0.697	3.56	0.794	49.8
900	0.0291	0.259	2.36	0.815	0.0303	0.705	4.02	0.735	36.0
1000	0.0271	0.262	2.47	0.917	0.0319	0.713	4.50	0.685	26.5
1500	0.0202	0.276	3.00	1.47	0.0400	0.739	7.19	0.510	7.45
2000	0.0161	0.286	3.45	2.14	0.0471	0.753	10.2	0.406	2.84
2500	0.0133	0.292	3.89	2.80	0.051	0.763	13.1	0.338	1.41
3000	0.0114	0.297	3.88	3.39	0.054	0.765	16.0	0.289	0.815
Steam									
212	0.0372	0.451	0.870	0.234	0.0145	0.96	0.864	1.49	0.377×10^6
300	0.0328	0.456	1.000	0.303	0.0171	0.95	1.14	1.32	0.459
400	0.0288	0.462	1.130	0.395	0.0200	0.94	1.50	1.16	0.243
500	0.0258	0.470	1.285	0.490	0.0225	0.94	1.88	1.04	0.139
600	0.0233	0.477	1.420	0.610	0.0257	0.94	2.31	0.943	82×10^3
700	0.0213	0.485	1.555	0.725	0.0288	0.93	2.79	0.862	52.1
800	0.0196	0.494	1.700	0.855	0.0321	0.92	3.32	0.794	34.0
900	0.0181	0.50	1.810	0.987	0.0355	0.91	3.93	0.735	23.6
1000	0.0169	0.51	1.920	1.13	0.0388	0.91	4.50	0.685	17.1
1200	0.0149	0.53	2.14	1.44	0.0457	0.88	5.80	0.603	9.4
1400	0.0133	0.55	2.30	1.78	0.053	0.87	7.25	0.537	5.49
1600	0.0120	0.56	2.58	2.14	0.061	0.87	9.07	0.485	3.33
1800	0.0109	0.58	2.81	2.58	0.068	0.87	10.8	0.442	2.14
2000	0.0100	0.60	3.03	3.03	0.076	0.86	12.7	0.406	1.43
2500	0.0083	0.64	3.58	4.30	0.096	0.86	18.1	0.338	0.603
3000	0.0071	0.67	4.00	5.75	0.114	0.86	24.0	0.289	0.293
Oxygen									
0	0.0955	0.2185	1.215	0.127	0.0131	0.73	0.627	2.18	4.33×10^6
100	0.0785	0.2300	1.420	0.181	0.0159	0.71	0.880	1.79	1.76
200	0.0666	0.2228	1.610	0.242	0.0179	0.722	1.20	1.52	0.84
400	0.0511	0.2905	1.955	0.382	0.0228	0.710	1.94	1.16	0.256
600	0.0415	0.2990	2.26	0.545	0.0277	0.704	2.70	0.943	0.103
800	0.0349	0.2465	2.53	0.725	0.0324	0.695	3.75	0.794	48.5×10^3
1000	0.0301	0.2528	2.78	0.924	0.0366	0.690	4.80	0.685	25.8
1500	0.0224	0.2635	3.39	1.480	0.0465	0.677	7.88	0.510	7.50

535

STP 1331

The Design and Application of Controlled Low-Strength Materials (Flowable Fill)

Amster K. Howard and Jennifer L. Hitch, Editors

ASTM Stock #: STP1331

ASTM
100 Barr Harbor Drive
West Conshohocken, PA 19428-2959

Printed in the U.S.A.

'M TEST METHOD FOR PERMEABILITY OF ROCKS BY FLOWING AIR 525)

.The ASTM Test Method D 4525 measures the coefficient of specific permeability r, which can be used to predict expected flow rates of gas through fill materials. neability properties of fill used to encapsulate gas lines can be a critical material ıerty from a safety point of view (Boston Gas Company 1996).

The right hand column of Table 5 depicts air/gas permeability test results ducted on two air-modified CLSM and one non-air-modified CLSM mix. The 30 and ; air-modified CLSM mixes had coefficient of air permeability values of 18.2 and 1.3 respectively. The 30% air-modified CLSM mix had a magnitude five times faster air / rate when compared to non-air-modified CLSM mix. (K = 18.2 m^2 versus 0.0016 . These test data confirm the material property versatility obtainable via the use of modified CLSM.

TM TEST METHOD FOR STEADY-STATE HEAT FLUX MEASUREMENTS D THERMAL TRANSMISSION PROPERTIES BY MEANS OF THE HEAT OW METER APPARATUS (C 518)

The thermal conductivity of a material is defined as the amount of heat that will v through an medium when a temperature difference exits across the medium. terials with low thermal conductivity values allow small amounts of heat flow and are led thermal insulators. Materials with large thermal conductivity values allow more ıt to flow through the material under identical temperature gradients.

Table 6 depicts results of ASTM Test Method C 518 testing conducted on three kg/m^3 (100-lb/yd^3) cement factor air-modified CLSM mixes. The mixes were tested ler oven dry (0% relative humidity), saturated surface dry (SSD), and immersed in ter conditions (Holometrix, Inc. 1993).

Results showed that under dry and SSD conditions, thermal conductivity operties for air-modified CLSM mixes were similar (0.42 to 0.48 W-m/K [2.9 to 3.4 u-in/hr-F-ft^2]) and (0.51 to 0.53 W-m/K [3.5 to 3.7 Btu-in/hr-F-ft^2]). However, when mersed in water, the thermal conductivity properties increased (1.1 to 1.7 W-m/K [7.8 11.9 Btu-in/hr-F-ft^2]). Referring to the bottom of Table 6, thermal conductivity values : typical fill materials indicates that moisture content and material composition gnificantly impact thermal conductivity properties (Kersten 1992).

In summary, air-modified CLSM have good thermal insulation properties mpared to typical fill materials. However, for both CLSM and typical fills, insulation operties tend to decrease as moisture contents increase.

TABLE 6--Thermal Conductivity (ASTM C 518)
W/m-K (Btu-in./hr-F-ft^2)

Air-modified CLSM	0% Relative Humidity-Dry Condition	Saturated Surface Dry (SSD)	Immersed in water
37% Air-modified CLSM 59 kg/m^3 (100 lb/yd^3) cement,	0.43 (3.0)	n/a	1.3 (9.1)
24.6% Air-modified CLSM 59 kg/m^3 (100 lb/yd^3) cement,	0.42 (2.9) 0.306	0.53 (3.7)	1.7 (11.9)
12.3% Air-modified CLSM 59 kg/m^3 (100 lb/yd^3) cement,	0.48 (3.4) 0.295	0.51 (3.5)	1.1 (7.8)
	Btu/hr ft °F	use 0.30	
Soil Type	2% Moisture	20% Moisture	80% Moisture
silts, clays	0.007 (0.05)	0.97 (6.87)	1.5 (10.71)
sands	1.1 (7.69)	2.3 (16.5)	....
gravel	1.4 (9.68)	2.9 (20.77)	....

ASTM TEST METHODS FOR FREEZING AND THAWING COMPACTED SOIL-CEMENT MIXTURES (D 560)

ASTM Test Methods D 560 measure a fill material's ability to resist freeze-thaw cycling. The test procedure is relatively mild (12 freeze-thaw cycles), when compared to ASTM Test Method for Resistance of Concrete to Rapid Freezing and Thawing (C 666) which consists of 300 cycles. This is because relative to air-entrained 27.6-Mpa (4000-psi) concrete, both CLSM and typical fill materials will have minimal durability when exposed to surface freeze-thaw cycling (Gress 1996).

Referring to Table 7, testing was conducted on two air-modified CLSM mixes and one non-air-modified CLSM mix. Test results reveal the 21 and 30% air-modified CLSM mixes, while having significant volume loss at test completion, were significantly more durable than the non-air-modified CLSM mix. The non-air-modified CLSM mix (containing 1.4% entrapped air) suffered rapid freeze-thaw deterioration after only three cycles (1/3 of the sample broke off), and testing had to be discontinued after five cycles as a result of complete deterioration of the test sample.

Table G-4 (*Continued*)

Physical quantity	Symbol	Conversion Factor
Specific heat capacity		1 Btu/lb_m °F = 4187 J/kg K
Temperature		$T(R) = \frac{9}{5}T(K)$
		$T(°F) = \frac{9}{5}[T(°C)] + 32$
		$T(°F) = \frac{9}{5}[T(K) - 273.15] + 32$
Thermal conductivity		1 Btu/hr ft °F = 1.731 W/m K
Velocity		1 ft/sec = 0.3048 m/s
		1 mi/hr = 0.44703 m/s
		1 knot = 0.51444 m/s
Viscosity, dynamic		1 lb_m/ft sec = 1.488 N s/m^2
		1 cP = 0.00100 N s/m^2
Viscosity, kinematic		1 centistoke = 10^{-6} m^2/s
Volume		1 ft^3 = 0.02832 m^3
		1 in^3 = 1.6387×10^{-5} m^3
		1 gal (U.S.) = 0.003785 m^3
		1 gal (U.K.) = 0.004546 m^3
		1 liter = 10^{-3} m^3
Volumetric flow rate		1 ft^3/min = 0.000472 m^3/s
		1 U.S. gpm = 0.06301 liter/s
		1 U.K. gpm = 0.07577 liter/s

Multiples of SI units are designated by the standard prefixes listed in Table G-3. Some conversion factors are listed in Table G-4 and some physical constants, in Table G-5.

To illustrate the arbitrariness involved in selecting a system of units, consider the additional use of Newton's gravitational law

$$F = G\frac{m_1 m_2}{r^2}$$

to express the unit of mass in terms of length and time. Then the constant

Table G-5 Some Physical Constants in SI Units

Quantity	Symbol	Value
Avogadro constant	N_A	6.022169×10^{26} $kmol^{-1}$
Boltzmann constant	K	1.380622×10^{-23} J/K
Gas constant	R	8314.34 J/kmol K
Planck constant	h	6.626196×10^{-34} J s
Speed of light in a vacuum	c	2.997925×10^{8} m/s
Stefan–Boltzmann constant	σ	5.66961×10^{-8} W/m^2 K^4

CRC Handbook of tables for Applied Engineering Science

2nd Edition

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Table 5-38. CONVECTION HEAT TRANSFER— AIR FLOW OVER SURFACES*

These approximate forced-convection coefficients are for air at atmospheric pressure flowing over external surfaces. The coefficients were computed from $h = \text{constant} \times \frac{k}{D} \times \left(\frac{DV\rho}{\mu}\right)^{.6} \left(\frac{c\mu}{k}\right)^{.3}$. Coefficients are for 70°F mean air temperature and are somewhat high for mean temperatures above 100°F. Air properties and air velocity were measured at the mean mixed-air temperature.

Shapes, sizes, and applications	*Convection coefficient, h,[a] Btu/ft² hr °F*			
	Air velocity through free area, fps			
	5	*10*	*20*	*50*
Over a flat surface[b]	1.8	3.0	5.0	10.0
Over one row of ½-inch tubes[c]	9.1	13.9	21.0	36.5
Over one row of ¾-inch tubes[c]	6.3	9.6	14.6	25.4
Over one row of 1-inch tubes[c]	5.3	8.0	12.1	21.0
Over many rows of ⅝-inch tubes, staggered (with or without fins)[d]	10.1	15.4	23.4	40.4
Over many rows of 1-inch tubes, staggered (with or without fins)[d]	8.4	12.8	19.4	33.5
Over many rows of 1-inch tubes, in line[d]	5.9	9.0	13.6	23.6

Note: Surface area to include fins, if any. Capacities will be reduced if fin-temperature gradients are appreciable. Local turbulence produced by pin-fins, corrugated surfaces, or otherwise will increase the heat-transfer coefficient. All coefficients apply to sensible heat transfer only, no condensation on the surfaces.

*For W/m²·K multiply by 5.674.

[a]Angle between stream and surface less than 45°.

[c]Coefficients apply to normal air-stream turbulence and uniform velocity over the face area. High local turbulence increases the coefficient (even as much as 50% for a special turbulence grid mounted within 3 tube diameters upstream).

[d]Coefficients are based on logarithmic mean temperature difference air-to-surface. It is assumed that the surface temperature does not vary greatly in the direction of air flow.

*Computed; data from several sources.

Table 5-39. HEAT TRANSFER FROM SURFACES— CONVECTION PLUS RADIATION

Approximate values of the combined surface coefficient of heat transfer for natural convection and radiation in room-temperature air. Convection computed from $h_c = K\left(\frac{\Delta t}{D}\right)^{.25}$ Radiation computed from Stefan-Boltzmann law assuming total hemispherical radiation.

Orientation and size	*Combined surface coefficient, $h_c + h_r$, Btu/ft² hr °F*[a]											
	A: Non-metallic surface				*B: Dull metal*				*C: Polished metal*			
	Mean temp diff: Ts–Ta[b]				*Mean temp diff: Ts–Ta*				*Mean temp diff: Ts–Ta*			
	50	*100*	*200*	*300*	*50*	*100*	*200*	*300*	*50*	*100*	*200*	*300*
Horizontal cylinders												
½-inch diam.	3.0	3.4	4.1	4.8	2.4	2.8	3.3	3.7	2.0	2.2	2.5	2.8
¼-in. diam.	2.7	3.1	3.7	4.3	2.1	2.5	2.9	3.3	1.7	1.9	2.1	2.3
1-in. diam.	2.4	2.8	3.4	4.0	1.9	2.2	2.6	2.9	1.4	1.6	1.8	2.0
2-in. diam.	2.2	2.6	3.1	3.7	1.7	1.9	2.3	2.6	1.2	1.4	1.6	1.7
3-in. diam.	2.1	2.4	2.9	3.5	1.6	1.8	2.1	2.5	1.1	1.2	1.4	1.5
6-in. diam.	2.0	2.3	2.8	3.3	1.4	1.6	1.9	2.3	0.9	1.0	1.2	1.3
12-in. diam.	1.8	2.1	2.6	3.1	1.3	1.5	1.8	2.1	0.8	0.9	1.0	1.1
Vertical walls	1.6	1.9	2.5	3.0	1.2	1.4	1.7	2.0	0.7	0.8	0.9	1.0

Surface A: Non-metallic, any color; paint, paper, glass, masonry, oxides. Emissivity 0.90.
Surface B: Bright metallic paint; dull but clean copper, zinc, aluminum. Emissivity 0.45.
Surface C: Clean and polished brass, copper, aluminum, tin, stainless steel, nickel or chrome plate. Emissivity 0.05.
Notes: For *vertical* cylinders the tabular values are slightly high.
For *large*, vertical heated or cooled walls the values in the last line of this table are slightly high.
For small, horizontal heated plates facing upward or cooled plates facing downward, the values in the last line are approximate, but lower values should be used for hot surfaces facing downward or cold surfaces facing upward.
For a single row of horizontal or vertical tubes with wide spacing, the tabular values are only slightly high.
Approximation for 2- and 3-row natural convection coils: use values in table section "C", and add radiation to or from the rectangular envelope enclosing the coil.
Approximation for outdoor conditions, dry weather: add 50 percent to the tabular value (section "A") for each 5 mph estimated average wind velocity.

[a]For W/m²·K multiply by 5.674.

[b]Temperature differences, degrees Fahrenheit.

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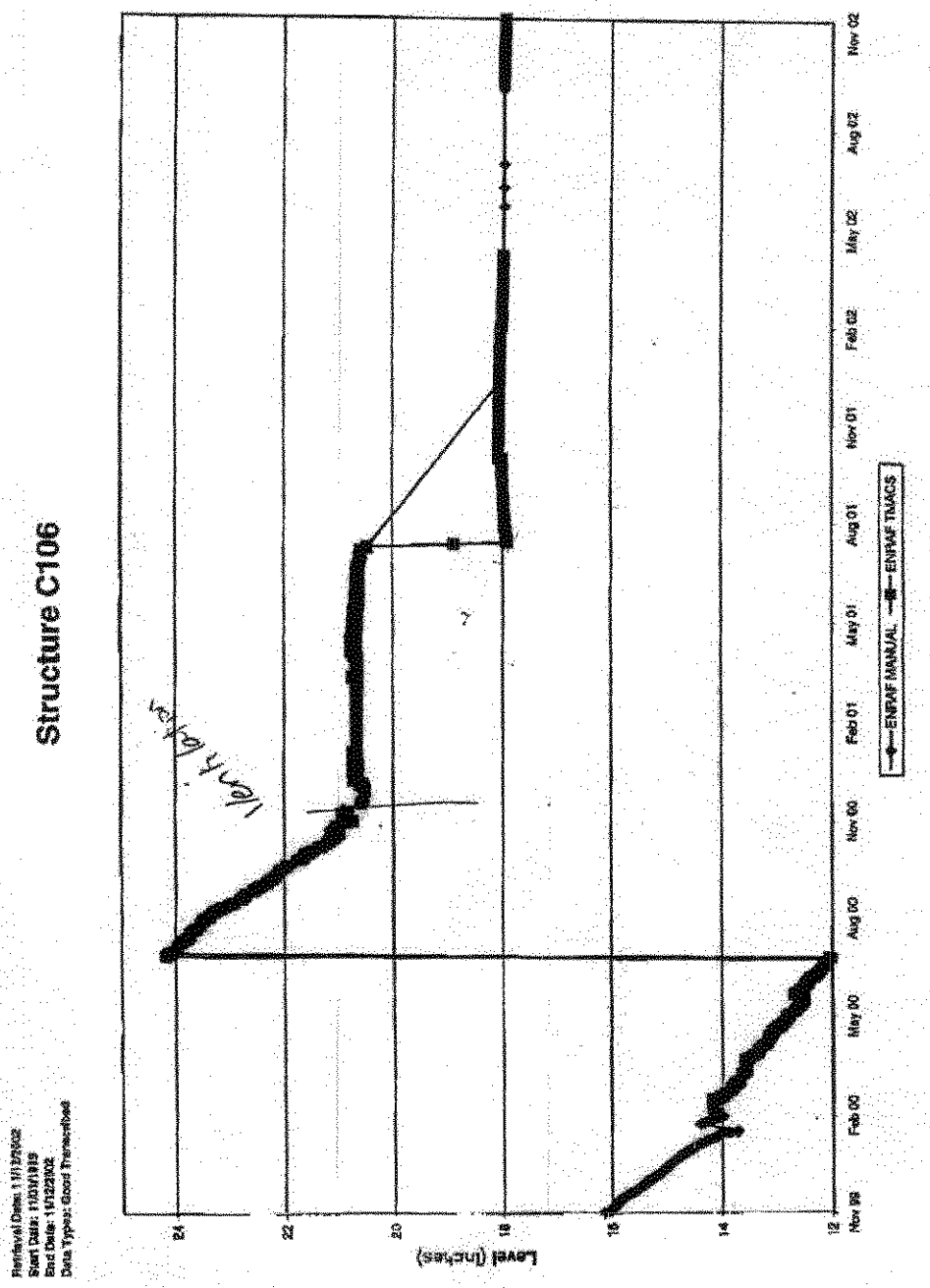

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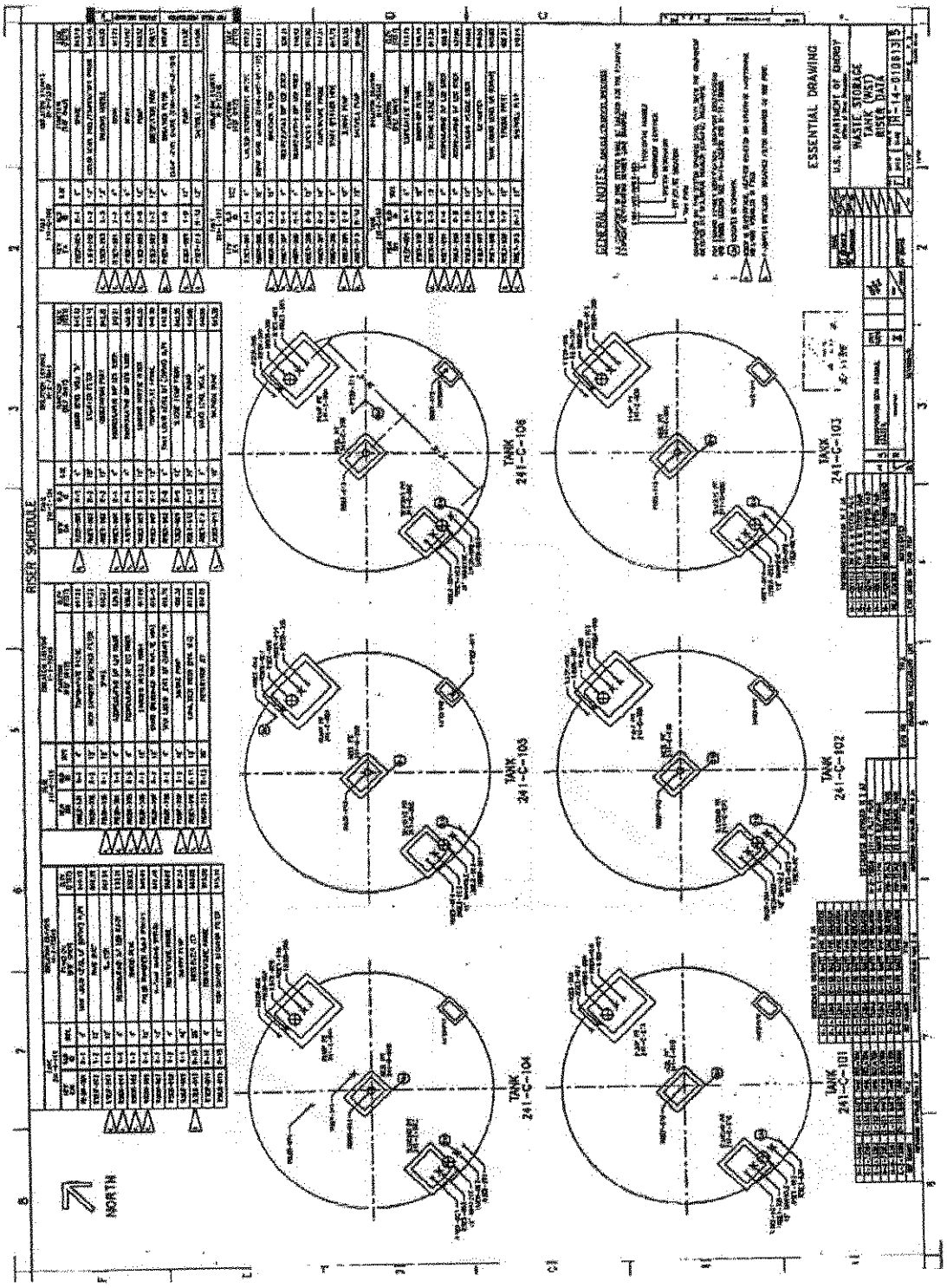

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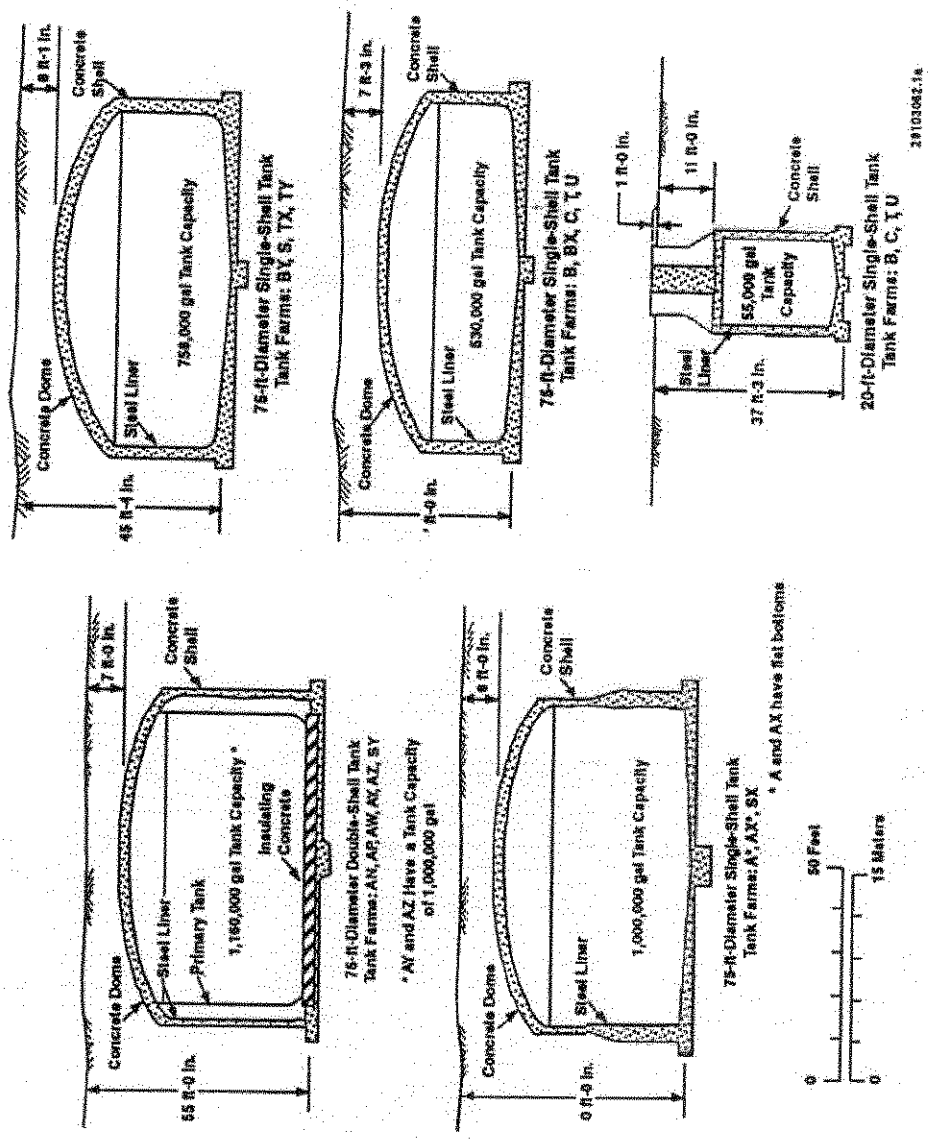
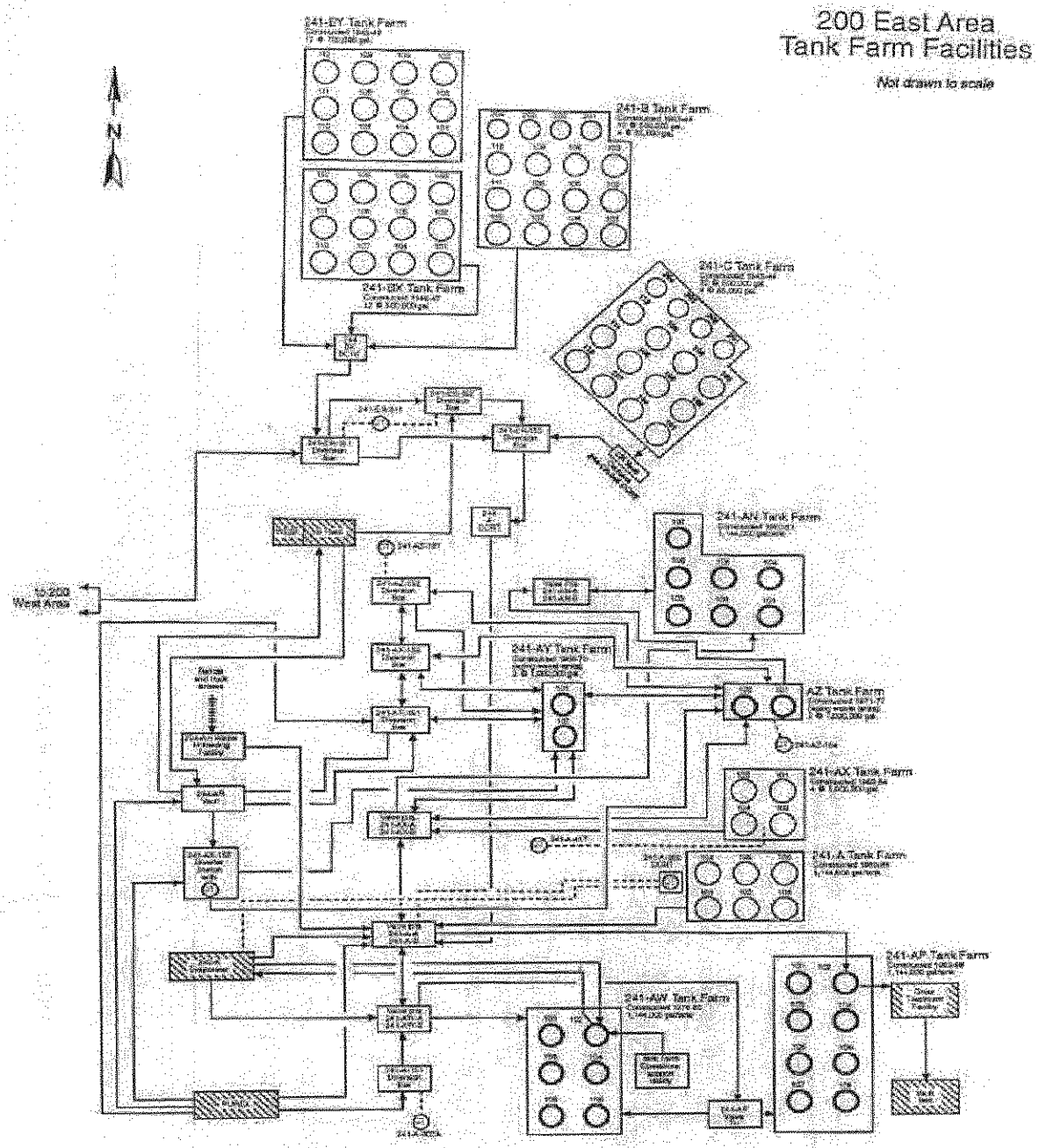


FIGURE D-1. HIGH-LEVEL WASTE TANK CONFIGURATION

D-2



To convert gallons to liters, multiply by 3.79.

DCRT = double-contained receiver tank.

PUREX = Plutonium Uranium Extraction (Facility).

WESF = Waste Encapsulation and Storage Facility.

catch tank

---- drain lines to catch tanks

—— waste transfer lines

single-shell waste tank

double-shell waste tank

non-tank farm facility

RG99030010.1
R2 SRP-2

As an alternative calculation to the ANSYS model, a simple hand calculation was performed. The temperature distribution for Phase 1 was estimated using a simple one-dimensional thermal circuit. A one-dimensional analysis should provide comparable results to the 2D FEA model. Additionally, the heat generation is assumed to be uniform over the bottom of the tank, instead of being pooled in the center.

The peak temperature at the heel is 92°F, which is reasonably close to the ANSYS result for the Phase 1 load case.

Geometry	Conductivity	Convection	Emissivity
$L_{Soiltop} := 7ft$	$k_{Air} := 0.0154 \frac{BTU}{hr \cdot ft \cdot R}$	$h_{Air} := 1.8 \frac{BTU}{hr \cdot ft^2 \cdot R}$	$\varepsilon := 0.9$
$L_{Shelltop} := 15in$	$k_{Soil} := 0.5 \frac{BTU}{hr \cdot ft \cdot R}$		$\sigma := 0.1714 \cdot 10^{-8} \frac{BTU}{hr \cdot ft^2 \cdot R^4}$
$L_{Airtank} := 29ft$	$k_{Concrete} := 0.54 \frac{BTU}{hr \cdot ft \cdot R}$	$A := 4418ft^2$	
$L_{Heel} := 12in$	$k_{Heel} := 0.3 \frac{BTU}{hr \cdot ft \cdot R}$	$T_0 := 55R + 460R$	Average air temp
$L_{Shellbot} := 8in$		$T_7 := 55R + 460R$	Deep ground temp
$L_{Soilbot} := 163ft$			

Temperatures

$56.08R + 460R$	TopSoilTop	$T_4 := 89.4R + 460R$	AirBot/Heeltop
$T_2 := 83R + 460R$	TopSoilBot/TopShellTop	$T_5 := 92.14R + 460R$	HeelBot/BotShellTop
$T_3 := 87.5R + 460R$	TopShellBot/AirTop	$T_6 := 92R + 460R$	BotShellBot/BotSoilTop

$$h_r := \varepsilon \cdot \sigma \cdot (T_4 + T_3)\left(T_4^2 + T_3^2\right)$$

$$h_r = 1.018 \frac{BTU}{hr \cdot ft^2 \cdot R}$$

$$\frac{1}{\frac{1}{h_{Air} \cdot A} + \frac{1}{k_{Soil} \cdot A} + \frac{1}{k_{Concrete} \cdot A} + \frac{1}{\left(h_r \cdot A + \frac{k_{Air} \cdot A}{L_{Airtank}}\right)}}$$

$$R_{up} = 247.476 \frac{BTU}{hr \cdot R}$$

$$R_{down} := \frac{1}{\frac{1}{\ } + \frac{1}{\ }}$$

$$R_{down} = 13.501 \frac{BTU}{hr \cdot R}$$

Generation

$$Q_{gen} := 9113 \frac{BTU}{hr}$$

$$\frac{R_{up}}{R_{down}} = 18.33 \qquad Q_{gen} \cdot \frac{1}{18} = 506.278 \frac{BTU}{hr} \qquad Q_{gen} \cdot \frac{17}{18} = 8.607 \times 10^3 \frac{BTU}{hr}$$

Heat Transfer up

$Q_{01} := \left[h_{Air} \cdot A \cdot (T_1 - T_0)\right]$ $\quad Q_{01} = 8.589 \times 10^3 \frac{BTU}{hr}$ $\quad T_1 - T_0 = 1.08\,R$

$Q_{12} := \frac{k_{Soil} \cdot A}{L_{Soiltop}} \cdot (T_2 - T_1)$ $\quad Q_{12} = 8.495 \times 10^3 \frac{BTU}{hr}$ $\quad T_2 - T_1 = 26.92\,R$

$Q_{23} := \frac{k_{Concrete} \cdot A}{L_{Shelltop}} \cdot (T_3 - T_2)$ $\quad Q_{23} = 8.589 \times 10^3 \frac{BTU}{hr}$ $\quad T_3 - T_2 = 4.5\,R$

$Q_{34} := \varepsilon \cdot \sigma \cdot A \cdot \left(T_4^{\,4} - T_3^{\,4}\right) + \frac{k_{Air} \cdot A}{L_{Airtank}} \cdot (T_4 - T_3)$ $\quad Q_{34} = 8.549 \times 10^3 \frac{BTU}{hr}$ $\quad T_4 - T_3 = 1.9\,R$

Heat Transfer down

$Q_{56} := \left[\frac{k_{Concrete} \cdot A}{L_{Shellbot}} \cdot \right]$ $\quad Q_{56} = 501.001 \frac{BTU}{hr}$ $\quad T_5 - T_6 = 0.14\,R$

$Q_{67} := \frac{k_{Soil} \cdot A}{L_{Soilbot}} \cdot (T_6 - T_7)$ $\quad Q_{67} = 501.429 \frac{BTU}{hr}$ $\quad T_6 - T_7 = 37\,R$

Total: check for balance

$Q_{tot} := Q_{01} + Q_{56}$ $\quad Q_{tot} = 9.09 \times 10^3 \frac{BTU}{hr}$ $\quad T_4 - T_0 = 34.4\,R$

$T_5 - T_7 = 37.14\,R$

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APPENDIX D
SKETCHES

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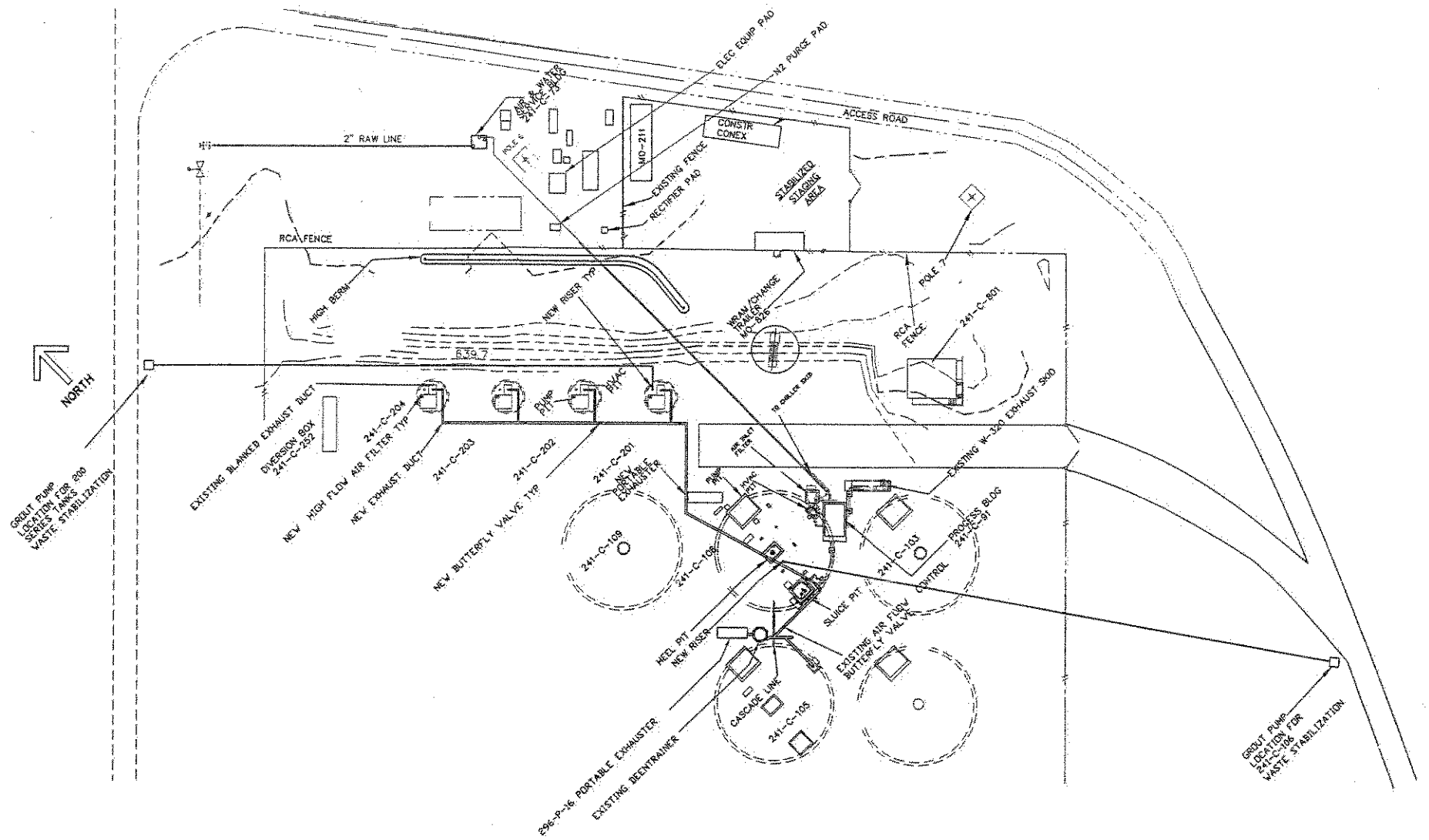

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CHK BY		
PROJ MGR		
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ATCD PRELIMINARY ENGINEERING
241-C SITE PLAN

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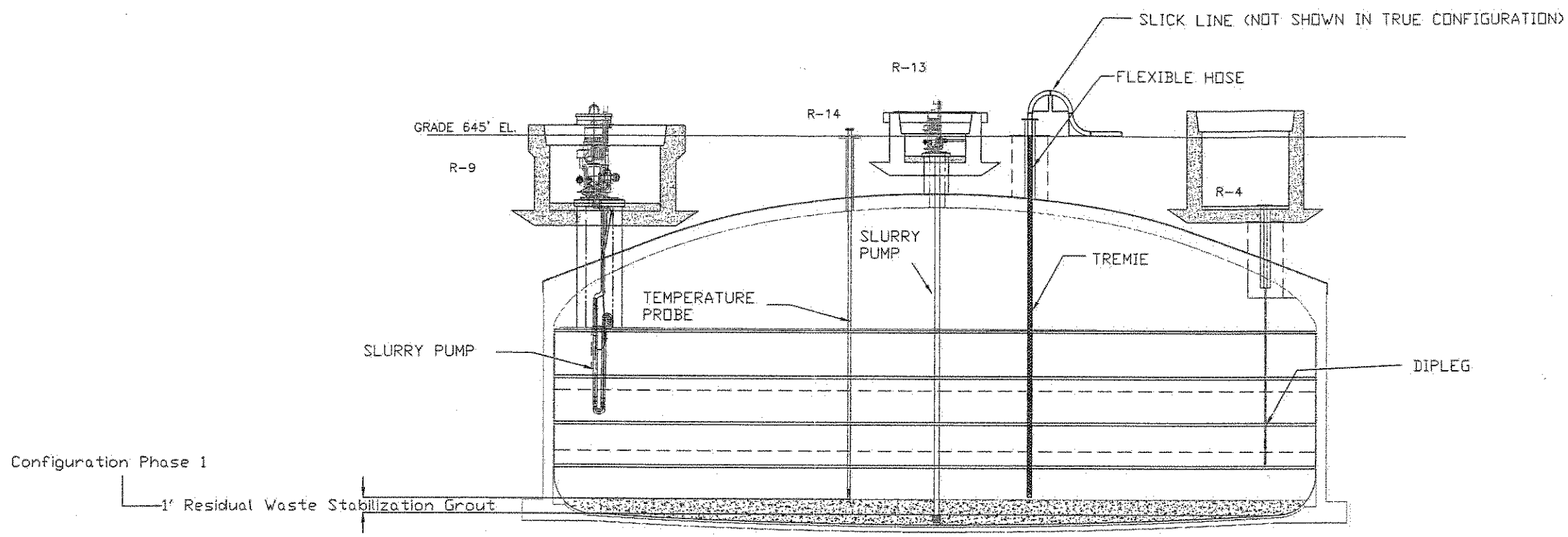
SCALE: NONE

SHEET: 1 of 1



Tank C-106 Cross Section

APPROVALS	SIGNATURE	DATE
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PROJ MGR		
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ATCD PRELIMINARY ENGINEERING
241-C-106
HEEL PIT CONFIGURATION

SIZE	BLDG NO	PROJECT	DWG NO	REV
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SCALE NONE

SHEET 1 of 1