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REVISED FEASIBILITY STUDY REPORT

FOR SILOS 1 AND 2

40730-RP-0001

U.S. Department of Energy
Fernald Environmental Management Project

VOLUME 1 OF 4
February 2000
Draft, Rev. B

Prepared Under DOE Contract No. DE-AC24-92OR21972
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FERNALD
Environmental Management Project

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CHANGE PAGES TO

THE REVISED FS

DECEMBER 1999, DRAFT REV. A

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ACRONYMS AND ABBREVIATIONS

A - C

ACA	Amended Consent Agreement
AEA	Atomic Energy Act
AEC	Atomic Energy Commission
AIRFA	American Indian Religious Freedom Act
ALARA	as low as reasonably achievable
ARAR	applicable or relevant and appropriate requirement
ATSDR	Agency for Toxic Substances and Disease Registry
AWR	Accelerated Waste Retrieval
AWWT	Advanced Wastewater Treatment
BAFO	best and final offer
BAT	best available technology
CAA	Clean Air Act, as amended
CAT	Critical Analysis Team
CBD	Commerce Business Daily
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act, as amended
CFR	Code of Federal Regulations
CHEM1	Removal, On-site Chemical Stabilization — Cement-based, Off-site Disposal at the NTS
CHEM2	Removal, On-site Chemical Stabilization — Other, Off-site Disposal at the NTS
CMSA	consolidated metropolitan statistical area
COC	constituent of concern
CRARE	Comprehensive Risk Assessment and Risk Evaluation
CWA	Clean Water Act, as amended

ACRONYMS AND ABBREVIATIONS (cont.)

D - L

DCG	Derived Concentration Guide
D&D	decontamination and demolition
DOE	U.S. Department of Energy
DOE-FEMP	U.S. Department of Energy-Fernald Environmental Management Project
DOT	U.S. Department of Transportation
DUR	duration
DWPF	Defense Waste Processing Facility
EIS	Environmental Impact Statement
EOC	Emergency Operations Center
EOG	emergency off-gas
EPA	U.S. Environmental Protection Agency
ESD	Explanation of Significant Differences
FAT&LC	Fernald Atomic Trades and Labor Council
FDF	Fluor Daniel Fernald, Inc.
FEMP	Fernald Environmental Management Project
FERMCO	Fernald Environmental Restoration Management Corporation
FF	finish-to-finish
FHAR	Final Hazard Analysis Report
FMPC	Feed Materials Production Center
FR	Federal Register
FS	Feasibility Study
FS/PP	Feasibility Study/Proposed Plan
FY	fiscal year
GCBCTC	Greater Cincinnati Building and Construction Trades Council
GRA	General Response Action
HEPA	high-efficiency particulate air
HI	hazard index
HQ	headquarters
HRS	Hazard Ranking System
ID	identification
IHA	Integrated Hazard Analysis
IP-2	industrial package-type 2
ILCR	incremental lifetime cancer risk
IRT	Independent Review Team
ISO	International Shipping Organization
LLRW	low-level radioactive waste
LSA	low specific activity

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ACRONYMS AND ABBREVIATIONS (cont.)

M - O

MCL	maximum contaminant level
MTC	monolith transfer container
MTD	metric ton per day
NAGPRA	Native American Graves Protection and Repatriation Act
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NEPA	National Environmental Policy Act
NESHAP	National Emissions Standards for Hazardous Air Pollutants
NHPA	National Historic Preservation Act
NLO	National Lead of Ohio
NOA	Notice of Availability
NOI	Notice of Intent
NPDES	National Pollution Discharge Elimination System
NPL	National Priorities List
NRC	Nuclear Regulatory Commission
NTS	Nevada Test Site
O&M	operations and maintenance
OAC	Ohio Administrative Code
OEPA	Ohio Environmental Protection Agency
ORIG	original
ORR	Operational Readiness Review
OSDF	On-site Disposal Facility
OU	operable unit

ACRONYMS AND ABBREVIATIONS (cont.)

P - T

PA	performance assessment
PEIC	Public Environmental Information Center
PEP	Project Execution Plan
PFD	process flow diagram
PHAR	Preliminary Hazard Analysis Report
PKG	package
PNL	Batelle-Pacific Northwest Laboratories
POP	Proof of Principle
PP	Proposed Plan
PPE	personal protective equipment
PRG	preliminary remediation goals
PRL	preliminary remediation levels
PVS	Process Vent System
RA	remedial action
RAO	remedial action objective
RCRA	Resource Conservation and Recovery Act, as amended
RCS	Radon Control System
RD	remedial design
RD/RA	remedial design/remedial action
RDWP	Remedial Design Work Plan
REM	remaining
RFP	request for proposal
RI	Remedial Investigation
RME	reasonable maximum exposure
ROD	Record of Decision
RPM	revolutions per minute
RTS	Radon Treatment System
scfm	standard cubic feet per minute
SOT	System Operability Testing
SOW	Statement of Work
SRS	Savannah River Site
TBC	to be considered
TBP	tributyl phosphate
TC	toxicity characteristic
TCLP	Toxicity Characteristic Leaching Procedure
TPC	total project cost
TRD	Technical Requirements Document
TRU	transuranic waste
TTA	Transfer Tank Area
TVS	Oak Ridge Transportable Vitrification System

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ACRONYMS AND ABBREVIATIONS (cont.)

U - Z

UCL	upper confidence level
UMTRCA	Uranium Mill Tailings Radiation Control Act
UTS	Universal Treatment Standards
VIT1	Removal, On-site Vitrification — Joule-heated, Off-site Disposal at the NTS
VIT2	Removal, On-site Vitrification — Other, Off-site Disposal at the NTS
VITPP	Vitrification Pilot Plant
VOC	volatile organic compound
VSL	The Catholic University of America Vitreous State Laboratory
WAC	waste acceptance criteria
WESP	wet electrostatic precipitator
yr(s)	year(s)

Chemical Elements

actinium (Ac-227)
barium sulfate ($BaSO_4$)
lead (Pb-210)
lime $Ca(OH)_2$
nitric oxide (NO)
nitrogen oxides (NO_x)
polonium (Po-210)
radium (Ra-226)
radium sulfate ($RaSO_4$)
radon (Rn-222)
sodium carbonate (Na_2CO_3)
sodium formate ($NaHCO_2$)
sulfuric acid (H_2SO_4)
sulfur oxides (SO_x)
thorium-230 (Th-230)
uranium oxide (U_3O_8)
uranium-235 (U-235)
uranium-238 (U-238)

Weights and Measures

		Approximate U.S. Equivalent
m	meter	39.37 inches (3.2802 feet)
g	gram	.035 ounce
cm^3	cubic centimeter	.061 cubic inch
yd^3	cubic yard	46,656 cubic inches (27 cubic feet)
ha	hectare	2.47 acres
L	liter	61.02 cubic inches (1.057 liquid quarts)
kg	kilogram (1,000 grams)	2.2046 pounds
mg	milligram (.001 grams)	0.015 grain

		Approximate Metric Equivalent
gal	gallon	3.785 liters
gal/min	gallon per minute	3.785 liters per minute
lb	pound	0.435 kilogram
lb/hr	pound per hour	0.435 kilogram/hour
ft	foot	0.3048 meters

g/cc	grams per cubic centimeter
mrem/hr	milli-Roentgen equivalent man (10^{-3} rem) per hour
Ci	curie (unit of radioactivity equal to 3.7×10^{10} disintegrations per second)
pCi/g	picoCuries per gram
pCi/m^2	picoCuries per square meter
$pCi/m^2 \cdot s$	picoCuries per square meter second
ppm	parts per million
ppb	parts per billion
psi	pounds per square inch

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Above-grade dismantlement includes the removal of process equipment [e.g., Radon Control System (RCS) and the abandoned RTS], electrical equipment, piping, water lines, gas lines, tanks [e.g., Transfer Tank Area (TTA)], heating ventilation and air conditioning ductwork, and electrical lines. The last steps of the dismantling action depend on the structure, but generally involve the removal of any air filtration apparatus and the removal of the roof, exterior walls, and structural members. Once an acceptable area has been cleared down to grade level, at- and below-grade remediation (e.g., removal of OU4 foundations, storage pads, ponds, basins, underground utilities) begins.

Operable Unit 4 Integration With the Operable Unit 5 ROD

Discrete data points were collected as part of the OU5 RI (FEMP 1994d) to characterize the nature and extent of contamination in environmental media of the site, including the OU4 area; the results of the data analyses are summarized in the OU5 FS (FEMP 1995b) and are briefly discussed below.

The OU5 RI/FS examined soil on a sitewide basis. Soil at the FEMP that is not contemplated to be exhumed as part of a remedy for OUs 1 through 4 is considered within the scope of OU5. Soils considered include soil under and adjacent to the waste pits, burn pit, and Clearwell (OU1); soil within OU2 but outside the proposed on-property disposal facility; soil underlying and adjacent to the Silos 1, 2, 3, and 4 including the earthen berms (OU4); and soil presently stored in piles and containers in or near the former production area (OU3). This approach has been adopted to allow the examination of soil on a sitewide basis such that comprehensive remedial alternatives could be formulated and evaluated. This approach is consistent with presentations in the FS reports for OUs 1, 2, and 4.

The ROD for OU4 (EPA 1994) established operable unit-specific soil preliminary remediation levels (PRLs) that were revisited by OU5. The OU5 ROD established final remediation levels for the sitewide soils, including OU4, based on a future land-use scenario. The OU5 ROD (FEMP 1996b) modified the OU4 soil remediation levels, which are in some cases more restrictive that the original OU4 PRLs. A more detailed discussion is provided in **Appendix F.**

The OU5 RI/FS process examined perched groundwater on a sitewide basis. It should be noted, however, that the ACA provides that each OU address perched groundwater envisioned to be encountered as a consequence of conducting RAs. An example of such an incidence is the collection of perched groundwater in deep excavations completed to remove underground tank systems (e.g., Silos 1 and 2 Decant Sump Tank System), pits, or foundations. This collected water will be directed to OU5 Wastewater Treatment Systems.

Process wastewaters generated during RAs conducted by the FEMP OUs will be directed to OU5 treatment systems [i.e., Advanced Wastewater Treatment (AWWT) facility]. OU5 has established pretreatment requirements to ensure that available treatment capabilities will not be exceeded by incoming wastewater streams. These requirements have been included in the **Design Basis and Description (Appendix G)** for the alternatives evaluated by this revised FS. These projected process wastewater streams have been factored into each OU4 remedial alternative presented in this report.

Integration with the Operable Unit 2 ROD

The FEMP On-Site Disposal Facility (OSDF) has a waste acceptance criteria (WAC) for soils and debris that ensures that materials disposed within its confines are protective of human health and the environment. The OSDF will be available for disposal of the existing Silos 3 and 4 structures, and associated facilities (i.e., the silo superstructures and the RTS). Soil and debris from D&D activities associated with these facilities will be disposed in the OSDF if they meet the WAC for disposal. The ability of this soil and debris to meet the OSDF WAC is discussed in more detail in **Section 3**. Due to its prolonged contact with the Silos 1 and 2 material, the likelihood of contaminant migration to the interior of the concrete, and the uncertainty in the effort and cost required to adequately decontaminate it, the concrete from Silos 1 and 2 is more appropriately managed in the same manner as "Category C, Processed-related Metals" as defined in the OU3 ROD. Therefore, concrete from Silos 1 and 2 will be administratively excluded from disposal at the FEMP OSDF. The interior surface of Silos 1 and 2 will be gross decontaminated to remove visible Silos 1 and 2 material before the structures are demolished, size reduced, and packaged for off-site disposal.

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Based upon the current operating schedule for the OSDF, the OSDF is not identified to be available to receive any soils and debris from the D&D of the Silos 1 and 2 remediation facilities, which includes the Decant Sump Tank System, other below-grade appurtenances, and OU4 Area 7 soils (see **Figure 1.3-3**). Therefore for cost estimating purposes, this revised FS assumes that all soil and debris generated from D&D of the Silos 1 and 2 remediation facilities will be disposed at the NTS. In the event that the OSDF becomes available, the soil and debris from D&D of the remediation facilities could be disposed at the OSDF if they meet the OSDF WAC. Therefore, on-site disposal of soil and debris from D&D activities is protective of human health and the environment. This issue is discussed in more detail in **Section 3.2.4**.

Development and Preliminary Screening of Alternatives

This revised FS presents information to support the selection of the most appropriate treatment technologies for the Silos 1 and 2 material. The alternatives for remediation in this FS were developed in accordance with the NCP, as well as EPA guidance and public input by following a series of logical steps that involved developing, in succession, more specific definitions of potential remedial alternatives (**Section 2**). The steps included the following:

- The identification and screening of alternatives for this revised FS was first presented to the stakeholders in August 1997 and was revised with their input and presented again in December 1997 during public meetings.
- A Commerce Business Daily (CBD) announcement was issued in November 1997 to solicit input regarding demonstrated technologies from commercial vendors.
- A preliminary screening determined which alternatives would be analyzed more fully in the detailed analysis phase of this revised FS.

Based upon the screening of potential treatment technologies, vitrification and chemical stabilization were identified for further evaluation. For the purposes of the detailed analysis of alternatives (**Section 3**), each technology will be represented by two processes resulting in four alternatives as follows:

- Vitrification – Joule-heated (VIT1);
- Vitrification – Other (VIT2);
- Chemical Stabilization – Cement-based (CHEM1); and
- Chemical Stabilization – Other (CHEM2).

The lack of current off-site facilities with both the capacity and necessary permits and licensing for treatment of Silos 1 and 2 material precludes a site-specific evaluation of implementability and short-term effectiveness. Therefore, the high risk of not being able to implement off-site treatment under the current schedule is considered unacceptable. Additionally, the selection of an off-site facility during the post-ROD procurement process limits the involvement of the EPA, OEPA, in selection of the facility. Therefore, off-site treatment is being excluded from further consideration as an alternative for the Silos 1 and 2 material.

Detailed/Comparative Analysis of Feasible Alternatives

The detailed analysis of alternatives was performed on those alternatives that were retained through the screening of alternative steps described above. The detailed and comparative analyses consisted of the analysis and presentation of the relevant information needed to allow decision makers to select a remedial alternative. The alternatives selected for further evaluation in the detailed analysis of alternatives are discussed next.

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Objective

The objective of this revised FS is to gather and present information to support an informed remedy selection for the treatment of the Silos 1 and 2 material.

The goal of the OU4 remedial action (RA) is to safely remediate the OU4 components in a timely, efficient, and cost-effective manner, that ensures compliance with all applicable or relevant and appropriate requirements (ARARs) and that is protective of human health and the environment. After the OU4 RAs are complete, the former waste storage area will be restored to a natural habitat in accordance with the *FEMP Natural Resource Restoration Plan, Draft* (FEMP 1998d). The complete remediation of the OU4 area will eliminate the FEMP's most significant inventory of contaminated (activity) material and chronic source term of radon emissions at the FEMP site.

1.1 Circumstances Giving Rise to Modifying the Selected Remedy for the Remediation of Silos 1, 2 and 3 Materials

Following approval of the original OU4 ROD, the DOE-FEMP prepared and submitted the *Work Plan for the Operable Unit 4 Remedial Design* (RDWP) that identified the approach for the implementation of the selected remedy (FEMP 1995a). The RDWP was approved by the U.S. Environmental Protection Agency (EPA) in June 1995. As part of the OU4 remedial design (RD) process, a treatability study program was initiated in May 1996 to collect quantitative performance data to support full-scale application of the joule-heated vitrification technology to the silos material.

The joule-heated Vitrification Pilot Plant (VITPP) treatability study program involved processing non-radioactive surrogate material with selected chemical and physical properties of the combined Silos 1, 2, and 3 materials. The joule-heated VITPP testing program consisted of three campaigns with the following objectives: (1) to determine (using surrogates) whether it was more economical to vitrify the Silos 1, 2, and 3 materials together or separately; (2) to gain experience vitrifying silos material and handling high-sulfate, barium and lead concentrations and BentoGrout™; and (3) and to determine maximum production rates through induced agitation (via bubbling tubes) in the molten glass bath to increase production.

During the joule-heated VITPP testing program, many technical and operational difficulties were encountered. Most of the technical and operational difficulties of running the VITPP were not related to making glass in the melter. For example, most of the problems centered around delivering the feed to the melter and the discharge of glass to make gems. Particulate build-up problems in the off-gas system were also encountered; however, these were resolved by installing a film cooler.

Results of the joule-heated VITPP treatability study indicated that the beneficial fluxing (ability to lower the glass's melting point) anticipated by the properties of Silo 3 were overwhelmed by the chemistry and operational problems of handling its high-sulfate content (18 wt% vs. 2 wt% for the Silos 1 and 2 material). The major problem encountered was foaming of the bath at high production rates. Chemical reductants were used to help increase the production rate; but, the problem was not eliminated. This, along with the relatively low concentrations of hazardous and radiological constituents in the Silo 3 material, became a key factor later in the decision to treat the Silo 3 material separately from the Silos 1 and 2 material.

Attempts to resolve technical and operational issues during VITPP operations resulted in documented schedule and cost increases.

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In September 1996, DOE formally requested extension of enforceable milestones associated with implementing vitrification of the silos material. In October 1996, EPA denied DOE's request. EPA and DOE then initiated the formal dispute resolution process under the Amended Consent Agreement (ACA) and began reevaluating the path forward for remediation of the silos material. In November 1996, the DOE-FEMP convened the Silos Project Independent Review Team (IRT) as a technical resource to assist the DOE-FEMP in this reevaluation. The IRT was comprised of technical representatives from throughout the DOE-FEMP complex and private industry with expertise in various aspects of chemical stabilization, vitrification, and other treatment technologies.

During the final stages of the last campaign to demonstrate lower temperature processing (<1200°C) of Silos 1 and 2 material, the melter hardware failed (December 26, 1996). The reason for the failure was attributed to the molybdenum disilicide bubbler tubes (used for agitation) located at the bottom of the melter chamber. The bubbler tubes quickly dissolved away once lead (via the surrogate) was introduced into the molten glass by chemically reducing the molten glass to form metallic lead. A hole formed in the bottom of the melter refractory where the bubblers were located, which allowed a pathway for the molten glass and precipitated lead to erode at the understructure of the melter until containment was lost. VITPP testing was suspended following the December 26, 1996 hardware failure.

The recommendations of the IRT (Silos Project IRT 1997) - along with the evaluation of the December 26, 1996, melter hardware failure (FEMP 1997a) by DOE and EPA, and stakeholder input supported a decision that vitrification of the Silo 3 material (although possible) is not practical or necessary because of its significant cost and extension to the cleanup schedule. This, and the fact that the concentrations of hazardous and radiological constituents in Silo 3 material are relatively low compared to the levels present in Silos 1 and 2 material, became additional key factors later in the decision to treat the Silo 3 material separately from the Silos 1 and 2 material.

In addition, the evaluations concluded that separating the Silos 1 and 2 material from Silo 3 material would reduce the technical uncertainties and programmatic risks of developing an effective treatment process for each wastestream. Therefore, DOE-FEMP and EPA made the decision with input from the public that Silo 3 material should be treated separately from the Silos 1 and 2 material. Together DOE-FEMP and stakeholders decided that an alternate remedy should be considered for treatment and disposal of the Silo 3 material. On July 22, 1997, the DOE-FEMP and the EPA formally approved an "Agreement Resolving Dispute Concerning Denial of Request for Extension of Time for Certain OU4 Milestones," hereafter referred to as "the Settlement" resolving disputes concerning the schedule and path forward for the remediation of the Silos 1, 2, and 3 materials. In the Settlement, EPA and DOE-FEMP agreed that DOE-FEMP would prepare a revised FS, Proposed Plan (PP), and Record of Decision (ROD) amendment to reevaluate the treatment remedy for Silos 1 and 2 material, and an Explanation of Significant Differences (ESD) identifying the RA changes for Silo 3 material.

An ESD was completed by DOE-FEMP and approved by the EPA in March 1998 to document the change in remedy for treatment and disposal of the Silo 3 material (FEMP 1998a).

The DOE-FEMP is preparing this revised FS and subsequent PP to recommend a RA for the Silos 1 and 2 material. The Settlement specifies that the draft revised FS and PP must be submitted to the EPA for review and approval on or before February 1, 2000. This revised FS and the PP will be available for stakeholder review. This revised FS and PP will provide the basis for selection of the final remedy, which will be documented and approved in an amendment to the original OU4 ROD, for Silos 1 and 2.

1.3.2 Scope of OU4 Remedial Action and the Remaining Decision

To establish the legal framework by which to address the releases and threats of hazardous substances from containers and facilities at the FEMP, the DOE-FEMP as the lead agency for the remediation of the FEMP site, and the EPA entered into a Consent Agreement in 1990, as amended in 1991. The Consent Agreement as Amended Under CERCLA Sections 120 and 106(a) (ACA) is the legal basis that administratively governs the proper management and restoration of the FEMP site.

To promote a more structured and expeditious cleanup, the facility and associated environmental issues of the FEMP site are being managed as five operable units (OUs). An OU is a term employed under federal environmental regulation to represent a logical grouping of environmental issues at a cleanup site. Separate RI/FS documentation was prepared and issued for the five OUs at the FEMP. The five OUs, for which RI/FS documents have been compiled, are defined within the ACA as:

- OU1: Waste Pits 1 through 6, the Clearwell, burn pit, berms, liners, and soil to a determined depth (estimated to be approximately 3 feet) beneath the waste pits.
- OU2: Other waste units including the flyash piles, other South Field disposal areas, lime sludge ponds, solid waste landfills, berms, liners, and soil within the OU boundary.
- OU3: Former production area and production-associated facilities and equipment (includes all above- and below-grade improvements) including, but not limited to, all structures, equipment, utilities, drums, tanks, solid waste, waste product, thorium, effluent lines, a portion of the Silos 1 and 2 material transfer line, wastewater treatment facilities, fire training facilities, scrap metal piles, feedstocks, and the coal pile.
- OU4: Silos 1, 2, 3, and 4, their contents, berms, and the Decant Sump Tank System; Radon Treatment System (RTS); a portion of concrete trench and Silos 1 and 2 material transfer line within the boundary of OU4; miscellaneous pads and concrete structures; soils beneath and immediately surrounding Silos 1 through 4; and, perched groundwater near the silos that may be encountered during the implementation of cleanup activities.

- OU5: Environmental media including groundwater (both perched and the Great Miami Aquifer), surface water, soil not included in the definitions of OUs 1 through 4, sediment, flora, and fauna.

Currently, the five OUs (including OU4) have completed the RI/FS process and are conducting RAs in accordance with their respective EPA-approved final RODs.

1.3.2.1 Scope of OU4

OU4 is commonly referred to as the "Silos Project," distinguished by the four concrete silos, three of which contain low-level waste. OU4, as depicted in **Figure 1.3-1**, consists of the following FEMP facilities and associated environmental media:

- Silos 1 and 2 and their contents (also termed *K-65 Silos*).
- Silo 3 and its contents (also termed *cold metal oxide silo*).
- Silo 4 (empty except for rainwater).
- Silos 1 and 2 Decant Sump Tank System, its contents, and associated Silos Underdrain System.
- A RTS.
- The portion of a concrete pipe trench within the boundaries of OU4, and other concrete structures.
- An earthen berm surrounding Silos 1 and 2.
- Soils beneath and immediately adjacent to Silos 1, 2, 3 and 4.

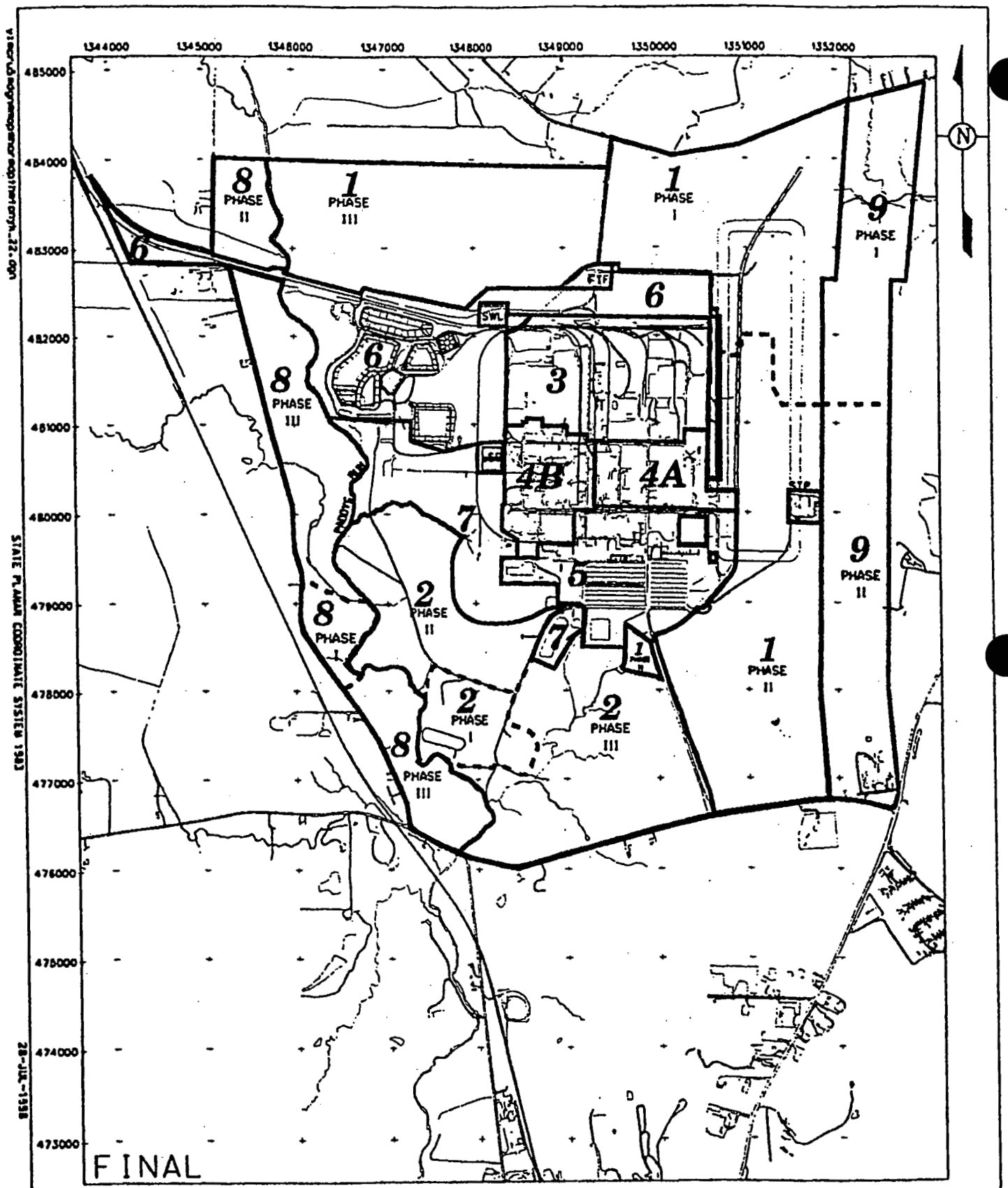
Integration with OU2

The FEMP On-Site Disposal Facility (OSDF) has a WAC for soils and debris that ensures that materials disposed within its confines, are protective of human health and the environment. The OSDF will be available for disposal of the existing Silos 3 and 4 structures and associated facilities (i.e., the silos superstructures and the RTS). Soil and debris from D&D activities associated with these facilities will be disposed in the OSDF if they meet the WAC for disposal. The basis for protective disposal of this soil and debris in accordance with the OSDF WAC is discussed in more detail in **Section 3.2.4**. Due to its prolonged contact with the Silos 1 and 2 material, the likelihood of contaminant migration to the interior of the concrete, and the uncertainty in the effort and cost required to adequately decontaminate it, the concrete from Silos 1 and 2 is more appropriately managed in the same manner as "Category C, Processed-related Metals" as defined in the OU3 ROD. Therefore, concrete from Silos 1 and 2 will be administratively excluded from disposal at the FEMP OSDF. The interior surface of Silos 1 and 2 will be gross decontaminated to remove visible Silos 1 and 2 material before the structures are demolished, size reduced, and packaged for off-site disposal.

Based upon the current operating schedule for the OSDF, the OSDF is not identified to be available to receive any soils and debris from the D&D of the Silos 1 and 2 remediation facilities, which include the Decant Sump Tank System, other below-grade appurtenances, and OU4 Area 7 soils (**Figure 1.3-3**). Therefore, this FS assumes that all soil and debris generated from D&D of the Silos 1 and 2 remediation facilities will be disposed at the NTS. In the event that the OSDF becomes available due to programmatic changes, the soil and debris from D&D of the remediation facilities could be disposed at the OSDF if they meet the WAC for disposal. Therefore, on-site disposal of soil and debris from D&D activities would continue to be protective of human health and the environment. This issue is discussed in more detail in **Section 3.2.4**.

1.3.4 Remedial Design/Remedial Action (RD/RA) Process

The RI/FS process is focused on developing technical data associated with remedial alternatives to the extent necessary to support an evaluation of each alternative against criteria established by federal guidelines. The alternative development process is typically completed at a preconceptual design level. While developing alternatives to this extent in the FS is sufficient to support remedy selection, a significant level of additional detail is required for the field implementation of the selected alternative. The process to provide this additional detail on the selected alternative is the RD. The purpose of RD is to complete the necessary engineering designs, specifications, and bid packages to enable the safe and cost-effective implementation of the selected alternative.



Legend:

——— Remediation Area Boundary

------- Phase Boundary Within A Remediation Area

Figure 1.3-3
Generalized Sitewide Remediating Areas - Sitewide Characterization and Excavation Project

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1.4.8 Post-ROD Information Base

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Since the approval of the OU4 ROD in December 1994 by the EPA, the DOE-FEMP has developed an expanded information base with respect to the various treatment technologies and their application toward the remediation of the Silos 1 and 2 material. This information has been used in this FS for the preliminary screening and re-evaluation of treatment technologies for the silos material. The various documents comprising this information base are identified in the bibliography (**Section 5**) and are available in the Administrative Record for inspection.

1.4.8.1 Vitrification Pilot Plant Final Reports

The FEMP joule-heated VITPP treatability study program consisted of three test campaigns with the following objectives: (1) to determine (using surrogates) whether it was more economical to vitrify the Silos 1, 2, and 3 materials together or separately; (2) to gain experience vitrifying silos material and handling high-sulfate, high-barium and lead concentrations, and BentoGrout™; and (3) to determine maximum production rates through induced agitation (via bubbling tubes) in the molten glass bath to increase production.

The results of the three test campaigns have been published in three separate reports (FEMP 1996c, 1996d, 1997b). The results of the testing have been factored in the development of the alternatives' design basis, cost estimates, and the implementability evaluation for the vitrification technologies.

1.4.8.2 Melter Incident Report

The *VITPP Melter Incident Report* (FEMP 1997a) summarizes the findings of three investigative teams who evaluated the failure of the FEMP VITPP melter hardware and subsequent leakage of non-radioactive surrogate glass. The report identifies both the causal and contributing factors which lead to the melter failure, and identifies lessons learned for future consideration for the application of the vitrification technology for the DOE-FEMP silos material and complex-wide.

1.4.8.3 Independent Review Team Report

Fluor Daniel Fernald, Inc. (FDF) convened the Silos Project IRT in November 1996, to provide recommendations to FDF and the DOE-FEMP as an aid in an internal decision process. Specifically, the IRT was tasked to assist and advise FDF, the DOE, the public and regulatory agencies in recommending a path forward for immobilization and disposal of the materials contained in Silos 1, 2 and 3 in OU4 of the FEMP.

The IRT was composed of 11 members, having backgrounds and experience in several areas including vitrification, glass furnaces and glass making, cementation, projects and project management, regulatory, environmental and safety.

Based on the information provided through reports, discussions, presentations and site tours, and supplemented by individual knowledge and study, the IRT came to several unified recommendations as published in their final report (Silos Project IRT 1997):

- Do not vitrify Silos 1, 2 and 3 waste together (proposed Alternative I). The waste contained in these silos have competing glass chemistry requirements, and measures taken to alleviate one will most likely exacerbate the other. Specifically, the high-sulfate concentration in Silo 3, and the high and varying lead content in Silos 1 and 2.
- If the Silos 1 and 2 material is treated separate from Silo 3 material, then both treated wasteforms (vitrification and stabilization; e.g., cementation) will meet existing regulatory and waste disposal requirements.
- Immobilize the Silo 3 waste through a cementation process. This waste has been calcined and is dry; it contains high sulfate concentrations which are not conducive to vitrification; similar Fernald waste materials have previously been successfully cemented by FDF; and, the high radium concentrations characteristic of Silos 1 and 2 material are not associated with the Silo 3 waste.
- If vitrification is selected for Silos 1 and 2 material, proceed with a low temperature process (1150°C).
- Additional characterization of the silos material is needed to better understand what is in the silos, and to assist in developing treatment process recipes.
- Immediate attention should be given to silos material retrieval and heel-out. Little has been done to ensure this effort will proceed safely, easily and at the rate anticipated to support the treatment processes.
- Regardless of the treatment process selected, FDF should actively pursue some form of commercial involvement rather than in-house design, construction, and operation of a new facility. Commercial involvement might include turnkey subcontracting or some form of privatization, similar to other successful FDF contracts.

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3.2 Removal, On-site Vitrification — Joule-heated, Off-site Disposal at the NTS (VIT1)

3.2.1 Description of Alternative

The following is a summary description of this alternative. Additional conceptual engineering design details [e.g., process flow diagrams (PFDs), General Arrangement Layouts] and assumptions can be found in **Appendix G, Design Basis and Description.**

The design details presented in this revised FS are conceptual, based on information from POP testing **(Appendix H)**, and have been prepared for the sole purpose of providing a technical basis for evaluating the alternatives.

3.2.1.1 Introduction

This alternative (VIT1) involves the removal, on-site vitrification using a joule-heated melter, and off-site disposal at the NTS of the treated Silos 1 and 2 material. The Silos 1 and 2 material is removed from the TTA as a slurry containing approximately 10 wt% solids for the VIT1 process. The VIT1 **(Figure 3.2-1)** process involves dewatering of the Silos 1 and 2 material slurry to minimize the volume of material to be stabilized, followed by remediation of the de-watered material.

The representative process used to evaluate this alternative during POP testing produces a solid stabilized wasteform that has a waste loading of approximately 90 wt% Silos 1 and 2 material. The treated material is packaged in concrete shipping and disposal containers with 6-inch thick walls. Based on Microshield® Modeling, a container of this type reduces the radiation levels associated with treated Silos 1 and 2 material at 90 wt% waste loading to approximately 70 mrem/hr on contact with the surface of the container.

The facility design is based on a plant availability factor of 70% over a total operating period of three years. The plant operating basis is 24 hr/day, 7 days/week with a design capacity of approximately 15 TPD. Each operating day, a maximum of 3.6 loaded shipping and disposal containers is produced. Each shipping and disposal container contains four steel MTCs filled with vitrified Silos 1 and 2 material. Samples that were collected at the monolith forming step are tested for compliance with the NTS WAC. Upon verification that the samples of treated Silos 1 and 2 material meet the NTS WAC, the shipping and disposal containers are readied and transported to the NTS for final disposal. Interim storage capacity for approximately 144 loaded disposal containers (a 45 calendar day period at design capacity, 22 disposal containers per week) is provided as part of the treatment facility. Based on 90 wt% waste loading, and assuming 1% of the containers will fail to meet the NTS WAC and will need to be re-processed, a total of 2,398 containers will require shipment to the NTS for disposal.

The VIT1 Feed Preparation System is designed to increase the solids content of the incoming slurry from 10 wt% solids to approximately 30 wt% solids using a clarifier tank. The slurry is received from the TTA and inventoried in a receiving tank to homogenize the material before it is fed to the clarifier. The clarifier produces an underflow slurry of approximately 30 wt% solids that is discharged to a surge tank where it is held before being transferred to the feed preparation mix tanks.

The Feed Preparation System also includes the bins and transfer equipment to inventory and transfer the vitrification reagents to the feed preparation tanks. Enough storage is provided to inventory a four-week supply of vitrification reagents.

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OAC air requirements govern both fugitive and point source emissions during construction, operation, and facility shutdown and dismantlement. OAC 3745-31-05(a)(3) requires new emission sources to use best available technology (BAT) to control air emissions. Design and operation meet BAT requirements by minimizing releases to the atmosphere.

Site preparation and construction activities minimize the creation and dispersion of dust to meet the requirements of OAC 3745-17-07 and OAC 3745-17-08 through implementation of BAT as specified in the site dust control policy.

Solid waste may be generated during construction and operation of the facility. While the Silos 1 and 2 material has been characterized, other wastes generated during the project are placed in compatible containers pending characterization and disposal. Management of secondary solid waste is in accordance with RCRA and existing FEMP site procedures, and includes characterization, staging, segregation, containment, and treatment (if necessary) before disposal. Secondary waste destined for shipment off-site is surveyed for radionuclide contamination before shipment or disposal as solid waste. Radioactive solid wastes will be managed in accordance with ARARs. Secondary waste that is destined for off-site disposal is packaged in containers appropriate for the material's DOT hazard classification as defined in 49 CFR Subchapter C, *Hazardous Materials Regulations*, and the WAC for the disposal facility.

3.2.4 Long-term Effectiveness and Permanence

3.2.4.1 Magnitude of Residual Risk

Silos 1 and 2 Material

The implementation of this alternative reduces the residual risk to viable receptors to meet the CERCLA criteria of a hazard index (HI) of less than 0.2 and an ILCR of less than 10^{-6}. Because the material is removed from the site, residual risk from Silos 1 and 2 material at the FEMP site is nonexistent. Residual risk at the NTS is limited by a treatment process that effectively minimized leachability of COCs, the placement of the treated Silos 1 and 2 material in an engineered disposal facility's institutional controls, and the arid environment.

Soil and Debris

The OSDF will be available for disposal of debris from the existing Silos 3 and 4 structures and associated facilities (i.e., the silo superstructures and the RTS). Soil and debris from D&D activities associated with these facilities will be disposed in the OSDF if they meet the WAC for disposal.

Criteria for disposal of waste materials into the OSDF are documented in the *Waste Acceptance Criteria Attainment Plan for the On-site Disposal Facility* (FEMP 1998c). The current version was issued in June 1998 following approval by the EPA and Ohio EPA. The WAC for debris were established in the OU3 ROD (FEMP 1996a). The WAC Attainment Plan provides that these criteria can be applied to debris for other OUs, including OU4, consistent with provisions of the ROD for each OU.

The OU3 ROD classified debris into ten distinct material categories based upon similar or inherent properties and configuration. Two categories, Category C – Process-related Metals and Category J – Product, Residues, and Special Materials, were administratively excluded from on-site disposal. In evaluating on-site disposal for concrete (Category E), the OU3 ROD focused primarily on structural concrete. The evaluation did not consider the potential impact of prolonged contact with residues or other contaminants, such as a concrete storage silo.

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The concrete in Silos 1 and 2 has been in contact with contaminated material for over 30 years. Because of the relatively mobile COCs and the high moisture content associated with the Silos 1 and 2 material, there is a significant potential for migration of contaminants into the concrete. The depth and extent of the migration of the COCs into the concrete and the ability and cost of adequately decontaminating the concrete is uncertain.

Therefore, the concrete from Silos 1 and 2 has been administratively excluded from disposal in the OSDF. The concrete from Silos 1 and 2 will undergo gross decontamination followed by demolition, size reduction, and packaging for off-site disposal. Disposal of concrete from Silos 1 and 2 will be at the NTS or an appropriately licensed commercial facility.

Based on the current operating schedule, the FEMP OSDF will not be available for disposal of soil and debris generated from D&D of the Silos 1 and 2 remediation facilities, which include the Decant Sump Tank System, other below-grade appurtenances, and OU4 Area 7 soils. Therefore, this FS assumes that all soil and debris from D&D of the Silos 1 and 2 remediation facilities will be disposed at the NTS. However, should programmatic changes occur and the OSDF become available, soil and debris meeting the OSDF WAC would be disposed in the OSDF in the same manner as discussed above for silo structures and area 7 soils.

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3.2.4.2 Adequacy and Reliability of Controls

The TCLP test, which is intended to simulate conditions of rainwater leaching through a solid waste landfill, indicates that VIT1 produced wasteforms which consistently met the NTS WAC and were durable based on leach rate data. The TCLP test is utilized to simulate the leaching effects of acidic groundwater infiltrating the disposal cell and contacting disposed waste. This test serves as a measure of the stabilized waste particles ability to resist leaching, even if the original wasteform (e.g., monolith) has been compromised. This reduction in leachability, combined with the additional protection provided by the engineered disposal cell provide a durable disposal configuration that provides long-term protection of human health and the environment.

Off-site disposal at the NTS has enhanced reliability because the facility is currently owned and used by DOE for LLRW disposal. The facility indicated that the Silos 1 and 2 material wastestream will be acceptable for disposal provided its treated Silos 1 and 2 material form meets the NTS WAC. An addendum to the PA for the selected disposal area will be prepared to demonstrate that the disposal configuration meets the applicable performance objectives. The institutional controls and potential for adequate facility maintenance are reliable at the NTS. Additionally, if there was a release at the NTS, the climate, hydrologic, and geologic characteristics considerably reduce the potential for contaminant migration. The low population density of the area surrounding the NTS also reduces the potential for direct contact with released materials.

Long-term environmental impacts associated with on-site treatment and off-site disposal of the treated Silos 1 and 2 material at the NTS are presented in the following sections.

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3.3 Removal, On-site Vitrification — Other, Off-site Disposal at the NTS (VIT2)

3.3.1 Description of Alternative

The following is a summary description of this alternative. Additional conceptual engineering design details (e.g., PFDs, General Arrangement Layouts) and assumptions can be found in **Appendix G/Design Basis and Description.**

The design details presented in this revised FS are conceptual, based on information provided by the POP testing, and have been prepared for the sole purpose of providing a technical basis for evaluating the alternatives.

3.3.1.1 Introduction

This alternative (VIT2) involves the removal, on-site vitrification using a non-joule-heated (in this case, combustion) melter, and off-site disposal at the NTS of the treated Silos 1 and 2 material. The Silos 1 and 2 material is removed from the TTA as a slurry containing approximately 10 wt% solids for the VIT2 process. The representative process used to evaluate this alternative **(Figure 3.3-1)** involves dewatering and drying of the Silos 1 and 2 material slurry to minimize the volume of material to be stabilized, followed by vitrification of the dried material. The VIT2 process produces a solid product that has a waste loading of approximately 87 wt% Silos 1 and 2 material. The treated material is packaged in concrete shipping and disposal containers with 5-inch thick walls. Based on Microshield® Modeling, a container of this type reduces the radiation levels associated with treated Silos 1 and 2 material at 87 wt% waste loading to approximately 70 mrem/hr on contact with the surface of the container.

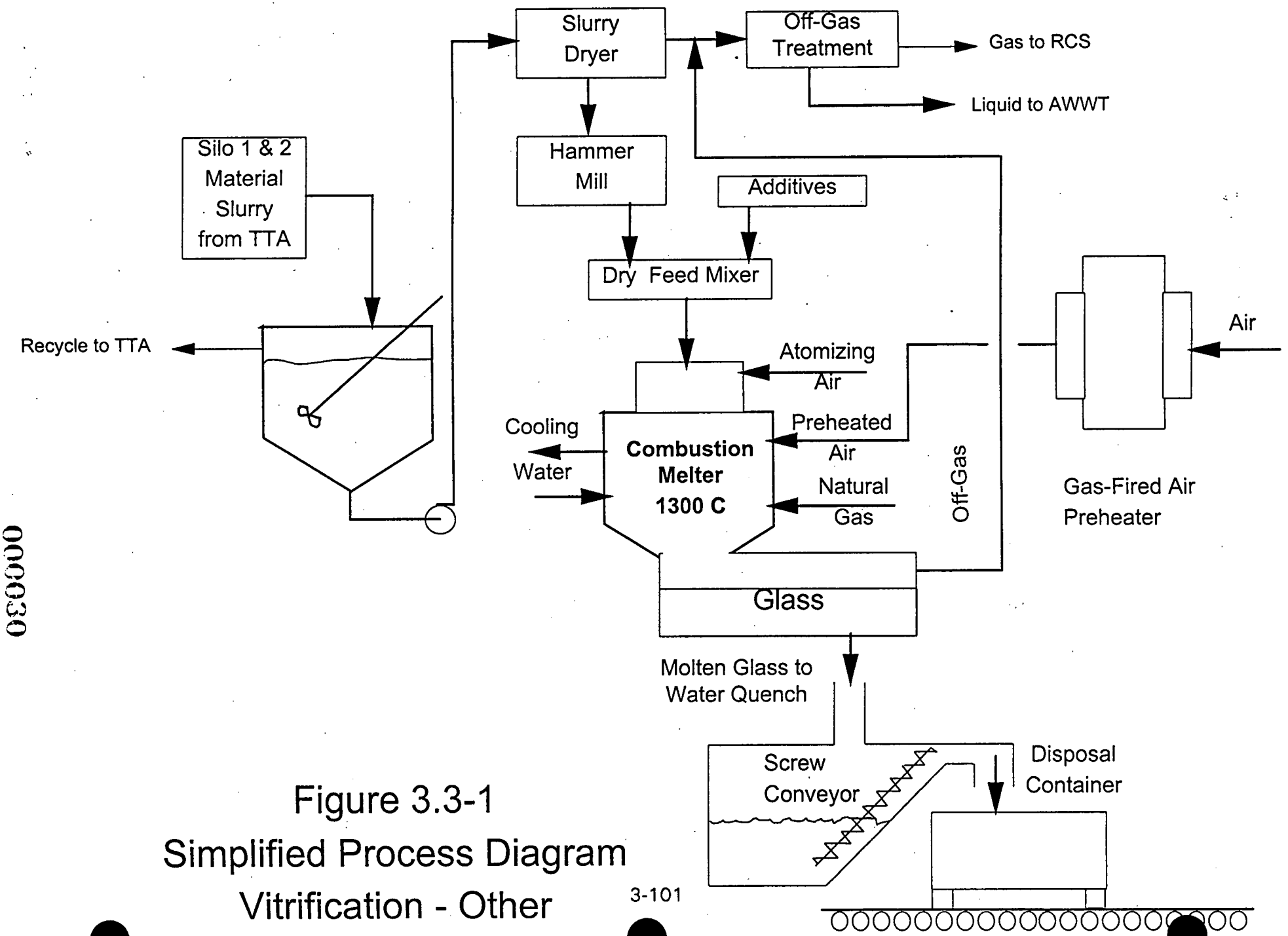

Figure 3.3-1
Simplified Process Diagram
Vitrification - Other

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The batch mixer combines the formulated amount of filter cake and stabilization reagents (and water, if necessary). Once the constituents have been thoroughly mixed, a discharge chute on the bottom of the mixer is opened and the grout is transferred to the disposal container. Next, the filled container is moved to the adjacent room where a sample of treated material is obtained, an absorbent mat is added to the top of the grout mixture, and the lid is placed on the container. Once the lid is in place, the container is conveyed through the decontamination station to remove any contaminants on its exterior surface. The disposal container is then conveyed to the curing room where it is lifted by an overhead crane and placed in a designated curing location.

A rework facility has been provided to re-process the off-specification waste which does not meet the NTS WAC. A Process Vent System (PVS) is designed to maintain a negative pressure in the treatment facility vessels and in the filling and lidding rooms to contain airborne contaminants, including particulates and radon. PVS vent lines from all vessels that contain Silos 1 and 2 material are connected to a common header that routes the vent air to the existing RCS (500 scfm capacity). The resulting negative pressure ensures that the system will not leak gases into the local environment.

A Flush Water System uses recycle water from the TTA to flush all slurry lines and equipment in order to reduce the risk of plugging process lines and equipment. The flush water discharge is then routed back to the TTA.

The CHEM1 secondary wastestreams include filter press filtrate, residual water from waste retrieval operations, RCS carbon, empty rework container, and PPE **(Table 3.4-1)**. As noted in **Table 3.4-1**, the recycled wastestreams include the decant water from the clarifier tank and the out of specification treated material. These wastestreams are processed and do not contribute to the volume of secondary waste to be disposed.

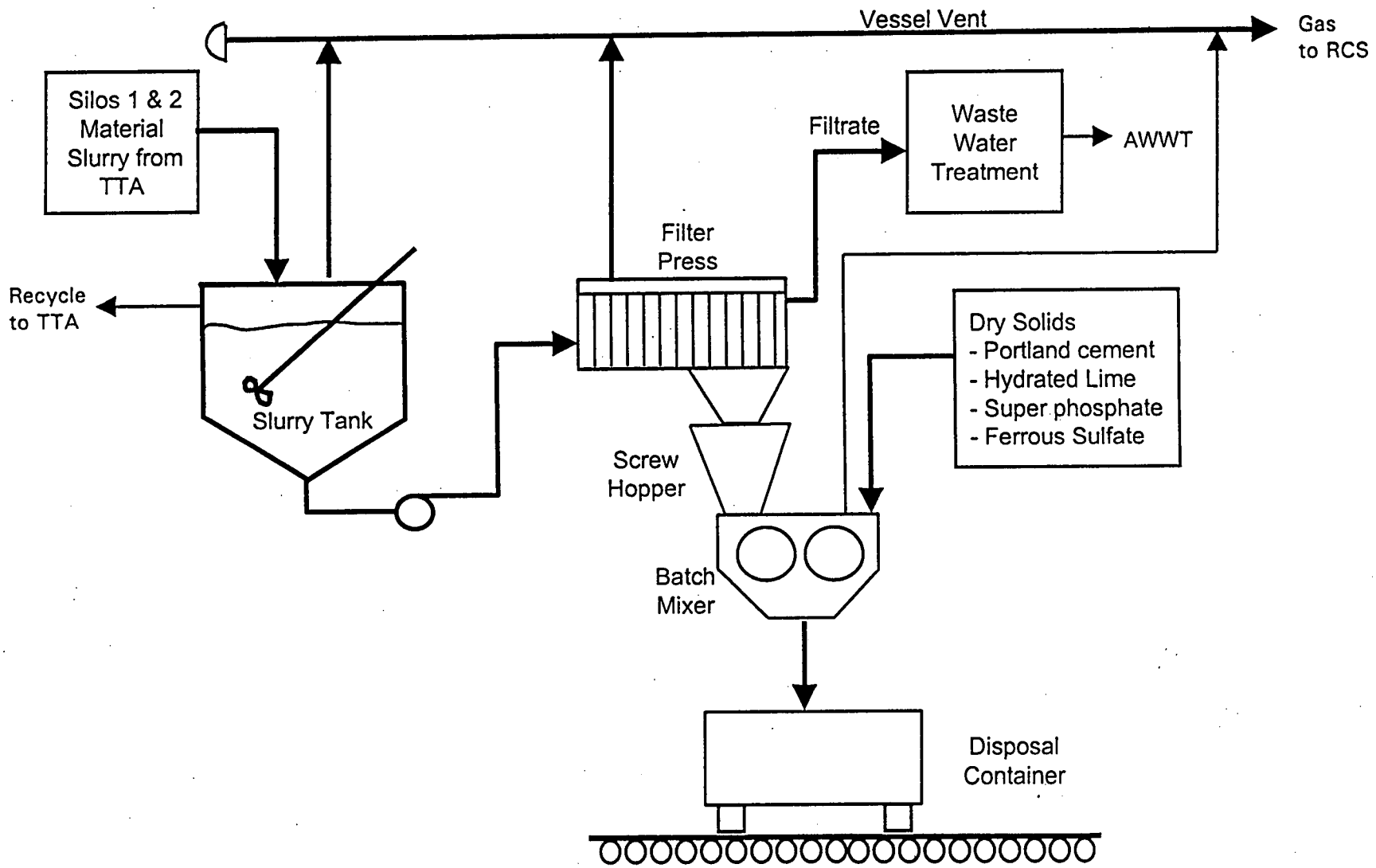

Figure 3.4-1
Simplified Process Diagram
Chemical Stabilization - Cement-based

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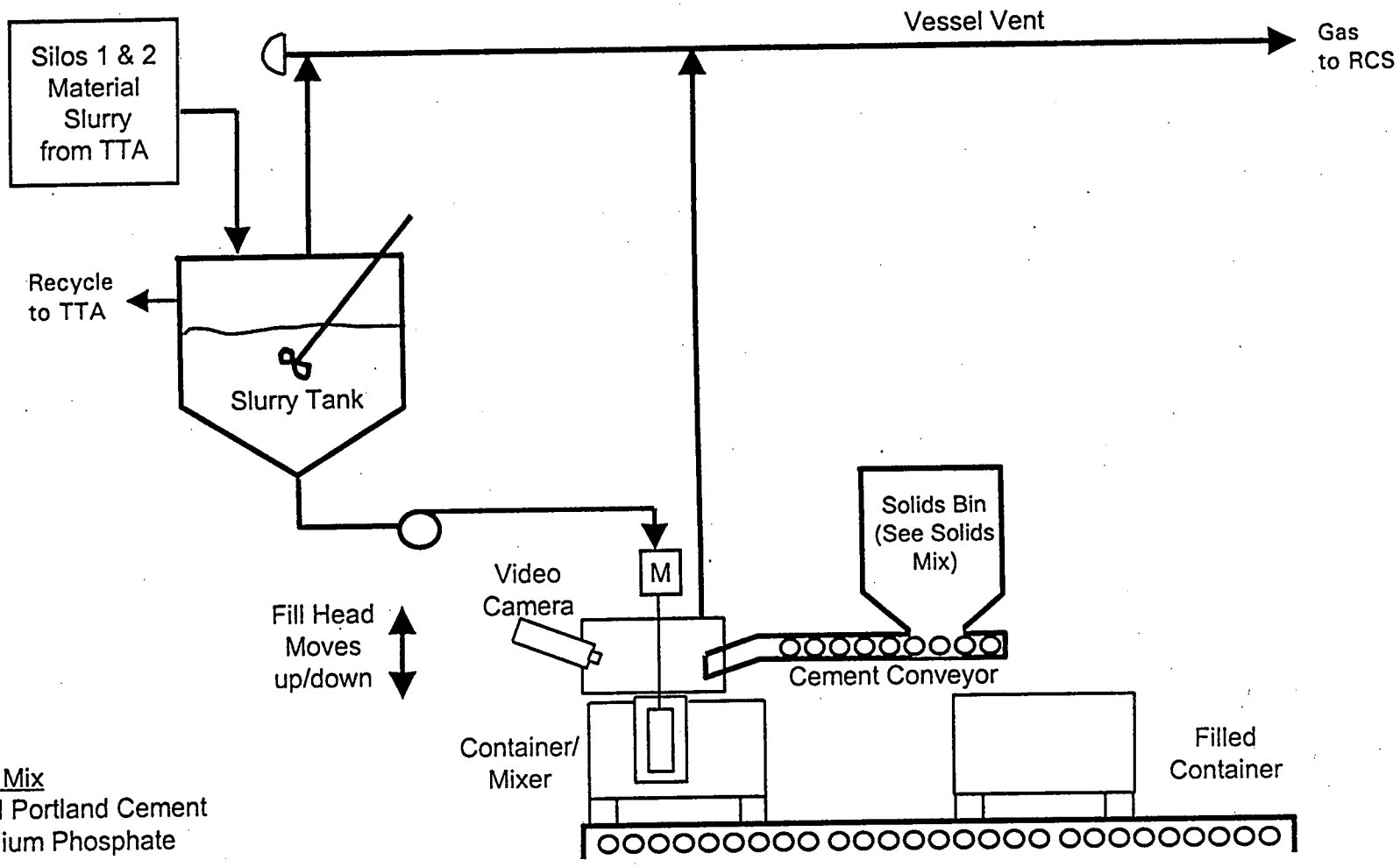

Solids Mix
Type II Portland Cement
TriSodium Phosphate
Flyash

Figure 3.5-1
Simplified Process Diagram
Chemical Stabilization - Other

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The water decanted from the clarifier tank is recycled back to the TTA at 30 gpm during normal process operations. Out of specification treated material (one reject container every 2 to 3 weeks) is reduced in size and re-processed during the 3-year operating schedule. All process gas vented from the treatment process that contains radon is discharged to the RCS. The number of containers required to treat the water remaining in the TTA is included in the total number of containers to dispose at the NTS (reference **Figure G.1.3-9** and supporting calculations attached to **Appendix G**).

3.5.1.2 Project Schedule

Table 3.5-2 summarizes the individual project activities and their estimated durations for the implementation of Alternative CHEM2. A more detailed description of the individual project activities can be found in **Appendix G, Section G.2.21**. The activity durations were developed considering the following factors:

- Proposed activity durations provided by commercial contractors;
- Specified regulatory document review and approval cycles outlined in the FEMP ACA;
- Procedural and administrative requirements for conducting procurement activities at the DOE-FEMP site;
- Historical project management experience and lessons learned while performing environmental remediation activities at the DOE-FEMP site; and
- Historical experience with the start-up of chemical stabilization facilities within the DOE-complex.

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FIGURE 4.1-2
SUMMARY OF DISCRIMINATING CRITERIA AND THEIR COMPONENTS

ITEM	VIT1/VIT2			CHEM1/CHEM2	
	Strongly Favors	Favors	Neutral	Favors	Strongly Favors
REDUCTION OF TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT					
Treated Waste Volume					
Secondary Waste Generation					
Reduction in Mobility of COCs					
Radon Attenuation by Treated Wasteform					
SHORT-TERM EFFECTIVENESS					
Worker Risk					
Transportation Risk					
Off-site/Environmental Impact					
Time to Achieve Protection					
IMPLEMENTABILITY					
Scaleup					
Commercial Demonstration					
Operability					
Ease of Acceleration					
Constructability					
COST					

4.2 Summary of Comparative Analysis

4.2.1 Threshold Criteria

4.2.1.1 Overall Protection of Human Health and the Environment

All four alternatives attain this threshold criterion.

The *Environmental Assessment for Proposed Final Land Use at the Fernald Environmental Management Project* (DOE 1999b) establishes the future land use of the FEMP, which is continued use under federal ownership with the area of OU4 being restored to a riparian and upland forest. This scenario is similar to the one evaluated in the original OU4 FS (FEMP 1994a). In addition, the alternatives being evaluated in this revised FS are the same as those evaluated in the original OU4 FS. As was the case in the original OU4 FS, the alternatives specify that the Silos 1 and 2 material will be treated and removed from the FEMP to the NTS for disposal; and, all surrounding soil will be excavated, removed and disposed to meet final remediation levels documented in the OU2 ROD (FEMP 1995c) and the OU5 ROD (FEMP 1995b). Therefore, the residual risk results from the original OU4 FS are still applicable to the evaluation of the current alternatives. The results of the original analyses stated that long-term risk to the public is within CERCLA guidelines because the Silos 1 and 2 material and contaminated soil are treated and removed from the OU4 area.

All four alternatives provide Overall Protection of Human Health and the Environment. Each alternative limits exposure to contaminants by removing the sources of contamination, treating the source materials to minimize contaminant mobility, and protective disposal the treated material at the NTS.

The VIT1, VIT2, CHEM1 and CHEM2 treatment processes produce a stabilized material that resists leaching and therefore reduces the potential for contaminant migration. As discussed in **Section 4.2.2.1**, TCLP results demonstrate that all four alternatives provide adequate prevention of contaminant mobility even in the event that the integrity of the original wasteform is degraded.

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4.2.2 Primary Balancing Criteria

4.2.2.1 Long-term Effectiveness and Permanence

All four alternatives ensure long-term protectiveness of human health and the environment through treatment. TCLP analysis indicates that all four alternatives produced wasteforms that consistently met the NTS WAC and were durable based on leach rate data. The TCLP test is used to simulate the leaching effects of acidic groundwater infiltrating the disposal cell and contacting disposed waste. This test serves as a measure of the stabilized waste particles ability to resist leaching, even if the original wasteform (e.g., monolith) has been compromised.

Off-site disposal at the NTS provides additional protection by eliminating access to the treated materials and preventing migration of constituents from the materials. The NTS disposal facility is located in a sparsely populated, arid environment with a reduced potential for leachate generation, contaminant migration, and direct contact with contaminants. Because the NTS is maintained by DOE and used for the disposal of low-level wastes from other DOE sites, the uncertainties associated with institutional controls are minimal. As the result of a low average annual precipitation and depth to groundwater, impacts to human health and the environment from possible engineering and institutional controls failure are minimal.

There are no long-term environmental impacts at the FEMP site pertaining to the removal of the Silos 1 and 2 material and treatment processes. The projected FEMP site residual risk to viable receptors is less than 10^{-6} (ILCR), and non-carcinogenic effects are expected to be below 0.2 (HI) for both alternatives. Long-term environmental impacts at the NTS include some permanent disturbance of soils (i.e., acquisition of borrow material) associated with disposal activities. Significant long-term impacts to water quality and hydrology, air quality, biotic resources, socioeconomics and land use, or cultural resources are not expected. No Wetland or floodplain areas have been delineated at the NTS.

The FEMP OSDF will be available for disposal of the existing Silos 3 and 4 structures and associated facilities (i.e., the silos superstructures and the RTS). Soil and debris from D&D activities associated with these facilities will be disposed in the OSDF, provided they meet the WAC for disposal. The basis for disposal of this soil and debris in accordance with the OSDF WAC is discussed in more detail in **Section 3.2.4.**

Due to its prolonged contact with the Silos 1 and 2 material, the likelihood of contaminant migration to the interior of the concrete, and the uncertainty in the cost and effort required to adequately decontaminate it, the concrete from Silos 1 and 2 is more appropriately managed in the same manner as "Category C, Processed-related Metals" as defined in the OU3 ROD. Therefore, concrete from Silos 1 and 2 will be administratively excluded from disposal at the FEMP OSDF. The interior surface of Silos 1 and 2 will be gross decontaminated to remove visible Silos 1 and 2 material before the structures are demolished, size reduced, and packaged for off-site disposal.

Based on the current operating schedule, the FEMP OSDF is not identified to be available to receive any soil and debris generated from D&D of the Silos 1 and 2 remediation facilities, which include the Decant Sump Tank System, other below-grade appurtenances, and OU4 Area 7 soils. Should programmatic changes occur and the FEMP OSDF become available, soil and debris meeting the FEMP OSDF WAC would be disposed in the available cell.

4.2.2.2 Reduction of Toxicity, Mobility, or Volume through Treatment

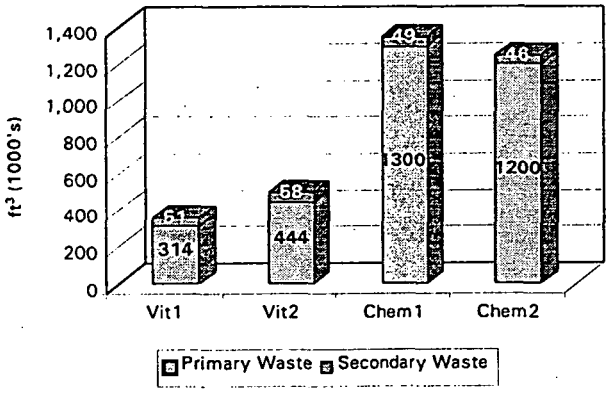
Overall, this criterion favors VIT1 and VIT2 due to the relative reduction in treated material volume.

The volume of solid waste requiring disposal for the VIT1, VIT2, CHEM1 and CHEM2 alternatives is summarized in **Figure 4.2-1**. The consideration of solid secondary wastestreams does not significantly affect the differences in the total volume of treated waste requiring disposal between the VIT1, VIT2, CHEM1 and CHEM2 alternatives. However, the VIT1 and VIT2 alternatives have the greater potential to generate secondary wastestreams that are more difficult to handle and treat for disposal (i.e., salts, reduced metals, spent refractory).

All four alternatives are effective at reducing the mobility of COCs in the Silos 1 and 2 material through treatment. TCLP tests conducted on the treated surrogate material during POP testing indicate that all alternatives can reduce the leachate concentrations of hazardous metals to below regulatory limits established under 40 CFR Part 261.24 and OAC Chapter 3745-51-24. The VIT1 and VIT2 alternatives chemically bind or entrain the contaminants in a glass-like matrix that significantly reduces contaminant mobility. The CHEM1 and CHEM2 alternatives reduce the mobility of contaminants by either converting the contaminants into a less soluble form or by chemically binding them into a stabilized matrix.

Proof of Principle testing of the VIT1 and VIT2 alternatives have demonstrated that the treatment method results in a reduction in volume of the Silos 1 and 2 material sent to the NTS for disposal. The range in volume reduction is dependent on the waste loading and wasteform (frit monolith) produced. Greater volume reductions can be achieved with a monolith wasteform than with a frit or gem wasteform because there are fewer air pockets and void spaces associated with the monolith wasteform. An overall increase in disposal volume (compared to the original volume of material in Silos 1 and 2) results from placing the treated material in thick-walled concrete disposal containers, which are required to provide the shielding necessary for protection of the public and workers during transportation and container handling activities.

FIGURE 4.2-1
TOTAL SOLID WASTE VOLUME SUMMARY



Because of the chemical additives and fixatives added to the Silos 1 and 2 material for the CHEM1 and CHEM2 alternatives, there is a resultant increase in volume of the treated material being sent to the NTS for disposal, compared to the original volume of material in Silos 1 and 2. The volume increase is dependent on the waste loading of the Silos 1 and 2 material in the treatment formulation. An additional increase in overall disposal volume results from placing the treated material in thick-walled disposal containers in order to provide similar protection to the public and workers during container handling and transportation activities.

Vitrification of the Silos 1 and 2 material is more effective at reducing radon emanation than chemically stabilized material. This is physically accomplished by two separate means. First, the vitrification process essentially liberates the radon in the Silos 1 and 2 material during the vitrification process and treats it in the RCS. Secondly, the radium is entrained into the glass matrix and limits the emanation of radon from only that radium which is at the surface of the glass. However, the combination of radon mitigation provided by the chemically stabilized material plus the engineered barriers and packaging associated with the disposal of treated materials, effectively controls radon emanation. All four alternatives provide effective control of radon emanation from the treated Silos 1 and 2 material. The impact of radon emissions during remediation is evaluated as part of the short-term effectiveness criterion **(Section 4.2.2.3)**.

Table 4.2-1 provides a summary of the comparison of the radon flux and radiation dose associated with the VIT1, VIT2, CHEM1 and CHEM2 activities.

4.2.2.3 Short-term Effectiveness

Short-term risks are calculated to assess the potential impacts to the public and RA workers during implementation of all four alternatives. The basis for determination of risks is detailed in **Appendices B** and **E**.

TABLE 4.2-1
REDUCTION IN RADON FLUX AND RADIATION DOSE

		Treated Silos 1 and 2 Material			
	Untreated Silos 1 and 2 Material	Unpackaged		Packaged	
		Vitrification	Chemical Stabilization	Vitrification	Chemical Stabilization
Radon Flux[1] (pCi/m^2s)	1,985 - 7,314	0.001 - 0.06	220 - 1,400	<0.001	<0.001
On-contact Radiation Dose[1] (mrem/hr)	~900	520 - 550	180 - 270	45 - 70	50 -70

[1]Data taken from the original OU4 FS.

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Although each alternative is favored in individual aspects of short-term effectiveness, from an overall perspective this criterion favors CHEM1 and CHEM2 alternatives. Short-term environmental impacts are essentially equivalent for all alternatives. Due to the greater number of person-hours required to complete treatment, and physical hazards inherent to the vitrification process, the VIT1 and VIT2 alternatives pose greater risk to on-site workers. Conversely, due to the greater number of shipments required to ship the larger volume of treated material for the CHEM1 and CHEM2 alternatives equates to an incrementally higher transportation risk for these alternatives. Due to a shorter design-construction start-up period, and a more feasible schedule acceleration, CHEM1 and CHEM2 alternatives are preferred with respect to time to achieve protection.

Short-term impacts associated with all four alternatives include temporary disruption of several acres of land at the FEMP site for construction of the treatment facility, and material handling. There is a potential for increased fugitive dust during construction activities; however, the appropriate controls minimize the potential short-term impacts.

The radiological risks from remediation activities (i.e., construction, operation, and D&D) are essentially the same for VIT1, VIT2, CHEM1 and CHEM2 alternatives (approximately 3×10^{-4} ILCR). However, VIT1 and VIT2 present an increased non-radiological risk to the worker during on-site operations due to the greater number of person-hours estimated to complete remediation and physical hazards in the work place. An occupational hazard analysis of the proposed design for each full-scale treatment facility was performed with respect for the workers involved with the on-site O&M activities **(Appendix B)**. **Table 4.2-2** presents a summary of discriminating hazards posed to workers as determined by the analyses of all four alternatives.

Chemical stabilization presents a marginal increase in risk during shipment preparation activities due to the greater number of containers resulting in more person-hours of exposure.

TABLE 4.2-2
SUMMARY OF KEY HAZARDS TO ON-SITE WORKERS

Physical hazards due to vehicle and container movement.	Greater hazard for chemical stabilization due to greater number of containers.
Fall Hazards	Greater hazard for vitrification due to more elevated equipment.
Exposure to hazardous chemicals and toxicants.	Greater hazard for vitrification due to toxic constituents (So_x, NO_x, lead - storage of caustic for scrubber, and gases).
Electrical Shock	Greater hazard for vitrification due to higher power requirements and more complex electrical system.
Human Hazards	Greater hazard for vitrification due to greater number of work hours.
High or Changing Pressure	Greater hazard for vitrification due to remote potential for over-pressurization of the melter and potential releases from the EOG System.
Thermal Hazards	Greater hazard for vitrification due to high temperature in the melter, handling of molten glass, and high temperature off-gas.
Spills/Loss of Containment	Greater hazard for vitrification due to molten glass, toxic off-gas constituents, higher radon concentrations, and caustic storage that results in greater consequences for spills, leaks, etc.

For all alternatives, transportation to the NTS will comply with DOT regulations and DOE guidelines. The transportation of the Silos 1 and 2 material to the NTS by either truck or intermodal shipments is protective of human health and the environment in accordance with CERCLA guidelines. The radiological and non-radiological risks from transportation of the treated material to the NTS are marginally higher for the CHEM1 and CHEM2 alternatives than for VIT1 and VIT2 because of the greater number of shipments required to ship the larger volume of treated material. In the event of a transportation accident and a subsequent loss of containment, the vitrified wasteform presents a higher risk to emergency response workers due to its higher contact dose.

The VIT1 and VIT2 processes liberate essentially all of the radon from the Silos 1 and 2 material during treatment process. The CHEM1 and CHEM2 alternatives liberate less radon during the treatment process, but continue to generate radon during subsequent product handling operations. In all cases, sufficient radon control mitigates radon releases and attain environmental and worker protection limits.

The vitrification facilities are equipped with an EOG System to protect against over pressurization of the Melter System. In the event the EOG System is activated, the feed to the melter would be shut down to prevent a continuous unmitigated release of radon into the atmosphere. Although there would be a release of radon from the EOG System, the release would be limited to the contents of the melter. It is expected that a release of radon from the contents of the melter would not significantly impact the FEMP fenceline regulatory requirements or the public.

All four alternatives are able to meet the radon flux limit of 20 $pCi/m^2 \cdot s$ during interim storage at the FEMP and after disposal at the NTS.

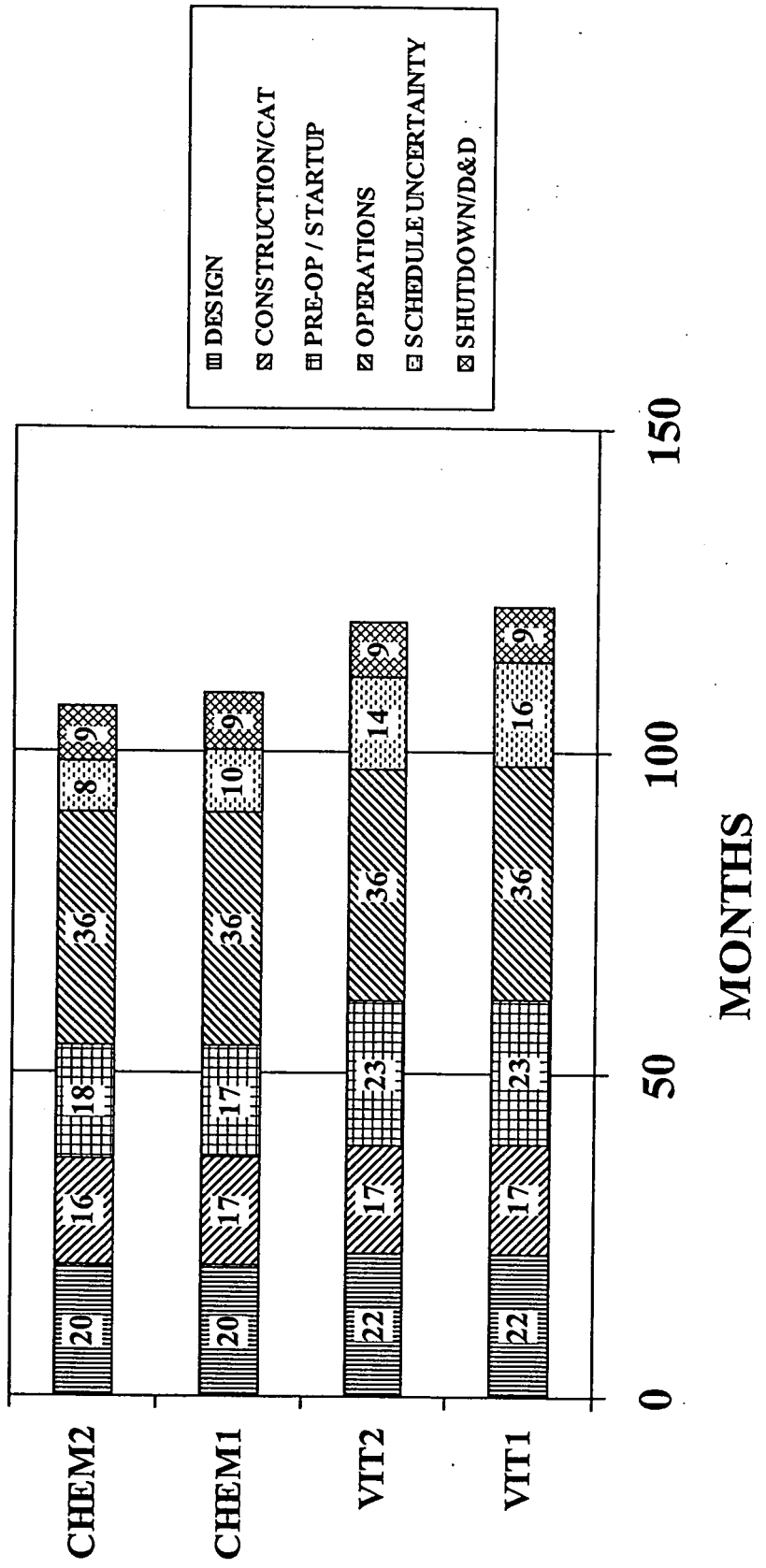
The time required to achieve protection through the implementation of the remedial alternatives varies between the VIT1 and VIT2 and the CHEM1 and CHEM2 alternatives. **Figure 4.2-2** presents a comparative summary of the schedules for each alternative.

The time period between the approval of the ROD Amendment and the initiation of treatment operations (design, construction, construction acceptance testing, preoperations and start-up) for the Silos 1 and 2 remediation is estimated to be 62 months for vitrification, compared to 54 months for chemical stabilization. The difference of eight months between the two schedules is primarily attributed to the time required, based upon lessons learned during start-up of DOE vitrification facilities, to perform Proof of Process testing during the start-up of the VIT1 and VIT2 alternative's facilities.

The durations of the operations schedule for each alternative were fixed at 36 months based on a common design basis assumption **(Appendix G, Section G.1)**.

FIGURE 4.2-2

TIME TO ACHIEVE PROTECTION
SCHEDULE COMPARISON



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The ability of the alternative to achieve the 3-year operational schedule carried a certain risk based on the contractor's proposed design for the full-scale treatment facility. Based on commercial demonstration and DOE experience, the O&M activities having the potential to delay the treatment of the Silos 1 and 2 material were evaluated for schedule risk. The failure mode, likely schedule consequences and their probability of occurrence, were evaluated to determine operations schedule risk for the four alternatives. The CHEM1 and CHEM2 alternatives present less O&M uncertainty (8-10 months) compared to VIT1 and VIT2 (14-16 months) due to technical uncertainties associated with the thermal treatment operations and off-gas systems.

While the VIT1 and VIT2 alternatives require full-time (24 hr/day, 7 days/week) operation to complete treatment within the specified 3-year period, the CHEM1 and CHEM2 alternatives can complete treatment within three years, with less than full-time operation. Less than full-time operation leaves 'excess' operating time (shifts per day or days per week) available to recover from unplanned downtime. This excess operating time results in higher confidence in the ability of the CHEM1 and CHEM2 alternatives to complete treatment within the 3-year period.

4.2.2.4 Implementability

Figure 4.2-3 summarizes the implementability analysis. Overall, this criterion favors CHEM1 and CHEM2 due to a greater degree of commercial demonstration of the treatment technology, less complexity of integrated systems, and greater confidence in their ability to be successfully implemented.

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FIGURE 4.2-3
IMPLEMENTABILITY SUMMARY TABLE

ITEM	VIT1/VIT2			CHEM1/CHEM2	
	Strongly Favors	Favors	Neutral	Favors	Strongly Favors
Technical Feasibility					
Scaleup			↓		
Commercial Demonstration				↓	
Operability					
Ease of Operation				↓	
Reliability				↓	
Maintainability				↓	
Complexity				↓	
Ease of Acceleration				↓	
Constructability (Ease of Construction/Fabrication, Ease of D&D)				↓	
Administrative Feasibility (Licensing and Programmatic)			↓		
Availability of Services (Contractors, Equipment and Utilities)			↓		

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Operability

The CHEM1 and CHEM2 alternatives are easier to operate than VIT1 and VIT2 due to ease of process control, less complexity, fewer unit operations, and the ability to recover from upset conditions. **Table 4.2-3** presents a summary of the unit operations for each alternative. The operability characteristics of vitrification increase uncertainty in its ability to be successfully implemented. The integrated operation of complex systems increases the likelihood of process upsets and resulting downtime for VIT1 and VIT2. Complex process control parameters complicate melter operation (viscosity, electrical conductivity, liquidus temperature, sulfate formation). The hazards inherent to the vitrification process (high temperature) increase risks during maintenance and make recovery from upsets more difficult.

For the same reasons, the CHEM1 and CHEM2 alternatives are easier to maintain and less complex overall.

All four alternatives are comprised of reliable individual components; however, the reliability of the integrated systems adapted for remote operation has not been demonstrated. DOE vitrification projects (DWPF, West Valley, NY and Savannah River M-Area) have experienced significant reliability concerns during start-up and initial operations. The VIT1 and VIT2 alternatives include additional unit operations (off-gas) that have unknown reliability as an integrated system. For these reasons, the CHEM1 and CHEM2 alternatives are favored for reliability.

From the standpoint of ease of acceleration of the operation schedule, the CHEM1 and CHEM2 alternatives are favored. The CHEM1 and CHEM2 alternatives could accelerate/recover schedule by increasing the operating schedule from 16 hr/day, 5 days/week and 24 hr/day, 5 days/week, respectively, to 24 hr/day, 7 days/week; while the VIT1 and VIT2 alternatives are already operating at the maximum capacity of 24 hr/day, 7 days/week. **Figure 4.2-4** illustrates this by summarizing the total required number of operational hours over the 3-year period. Acceleration results in additional cost to increase the plant capacity by increasing product curing and storage space. The VIT1 and VIT2 alternatives require additional melter trains or increased melter capacity combined with increased feed drying/preparation components, a larger Normal Off-gas System, and additional cooling and storage space to increase plant capacity.

TABLE 4.2-3
SUMMARY OF KEY UNIT OPERATIONS

VIT1	VIT2	CHEM1	CHEM2
Feed Preparation/Additive Mixing	Feed Preparation/Additive Mixing	Clarifier	Clarifier
Melter	Slurry Dryer	Slurry Tank	Slurry tank
Glass Packaging - Product Cooling	Hammermill	Filter Press	Mix-fill Head
Film Cooler	Combustion Melter	Batch Mixer	Rework System
Quench Tower	Combustion Air Preheater	Treated Waste Packaging	
Caustic Scrubber	Frit Tank and Conveyor	Wastewater Treatment	
Electrostatic Precipitator	Quench Tower	Rework System	
NO_x Removal System	Caustic Scrubber		
Condenser	Electrostatic Precipitator		
EOG System	Filter Press		
Cooling Tower	NO_x Removal System		
Wastewater treatment	Condenser		
Rework System	EOG System		
	Cooling Tower		
	Additional Radon Control		
	Wastewater Treatment		
	Rework System		

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4.2.2.4.3 Availability of Services

Contractors are available to competitively bid the design, procurement of materials and equipment, and construct and operate the remediation facilities needed to implement each alternative.

The NTS is an approved off-site disposal facility that has the equipment and facilities to safely dispose of and manage the treated Silos 1 and 2 material.

4.2.2.5 Cost

The cost evaluation is based on estimates that were developed from the four preconceptual designs presented in **Appendix G** and the technology-specific POP testing information presented in **Appendix H**, using a variety of cost-estimating methods. The cost estimates were developed for (1) capital costs; (2) O&M costs; (3) waste shipping and disposal costs; (4) D&D costs; (5) engineering costs; (6) project management costs; and (7) cost of money. The cost estimates are prepared as "bottom up" estimates, which evaluate and estimate each cost element identified in the preconceptual design. Therefore, the accuracy of the estimates is a function of the preconceptual designs. The accuracy of the four estimates is between +50% to -30%, consistent with CERCLA guidance. Since potential contractors will be given the opportunity to propose their unique designs based on their commercial experience, the actual design may change significantly. The +50/-30% accuracy establishes a range that is likely to capture that which is ultimately bid in response to a RFP to remediate the Silos 1 and 2 material. All estimates were developed in FY99 dollars so that the alternatives with costs incurred over differing time periods can be evaluated on an equivalent basis.

Table 4.2-4 and **Figure 4.2-5** summarize the major cost elements for the four alternatives.

TABLE 4.2-4
FEASIBILITY STUDY SUMMARY COST DATA (ALL ALTERNATIVES)
($ MILLIONS)

Alternative	Vitrification		Chemical Stabilization	
Process Option	VIT1	VIT2	CHEM1	CHEM2
Capital Cost	69	67	55	56
Operation and Maintenance Cost	134	133	77	83
Waste Shipping and Disposal Cost				
Packaging	17	12	34	33
Transportation	5	5	14	13
Disposal	3	3	10	9
D&D Cost	35	38	34	36
Engineering Cost	25	25	24	24
Project Management Cost	22	22	21	21
Cost of Money	46	37	28	28
Summary cost (un-escalated)	356	342	297	303

In general, all four process options are cost effective. That is, the costs appear proportional to the overall protectiveness provided by the alternatives, both during and following the remediation period. The cost differential between the VIT1 and VIT2 alternatives and the CHEM1 and CHEM2 alternatives is approximately 16%, with the cost of CHEM1 and CHEM2 being lower. The following discussion identifies the differences between the four alternatives for the key cost elements.

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1 Documentation of Remedial Investigation/Feasibility Study activities for each OU is made available for public review. The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Administrative Records for the FEMP site are located at the Public Environmental Information Center (PEIC) in Harrison, OH. (513) 648-7480.

2 Documents can be ordered from the National Technical Information Service at 1-800-553-6847.

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TABLE A.1.3-1

POTENTIAL ARARS FOR SILOS 1 AND 2 MATERIAL REMEDIAL ACTION ALTERNATIVES, CHEMICAL-SPECIFIC

Medium	Clean Air Act (CAA)	Requirement	ARAR/TBC	Rationale for Implementation	Alternative Number
Air	Radionuclide Emissions (Except Airborne Radon-222), 40 CFR Part 61 Subpart H.	Emissions of radionuclides to the ambient air from DOE facilities shall not exceed those amounts that might cause any member of the public to receive, in any year, an effective dose equivalent (EDE) of 10 mrem or greater per year. Monitoring is required at release points having potential to discharge radionuclides that could cause an EDE in excess of 1% of the standard (0.1 mrem/yr) to any member of the public.	Applicable	Radioactive materials within Silos 1 and 2 might contribute to the dosage to members of the public from the air pathway during implementation of remedial actions since the National Emissions Standards for Hazardous Air Pollutants (NESHAP) applies to operating units.	VIT1 VIT2 CHEM1 CHEM2
Air	Radon-222 Emissions, 40 CFR Part 61 Subpart Q.	No source at a DOE facility shall emit more than 20 pCi/m^2·s of radon-222 as an average for the entire source during periods of storage and disposal.	Applicable	Facilities such as Silos 1 and 2 qualify as sources since they contain radium-226 in sufficient concentrations to emit radon-222. This requirement is applicable only to storage and disposal of radium-bearing by-product material.	VIT1 VIT2 CHEM1 CHEM2
Medium	**DOE**	**Requirement**	**ARAR/TBC**	**Rationale for Implementation**	**Alternative Number**
Air	Residual Radioactive Material, DOE Order 5400.5 Chap. IV, 6.b (proposed 10 CFR Part 834).	<u>Interim Storage</u> The above-background concentration of radon-222 in air above an interim storage facility must not exceed: 100 pCi/L at any point, an annual average of 30 pCi/L over the facility, or an annual average of 0.5 pCi/L above background or above any location outside the site.	To be considered	Management of radium and thorium bearing waste might result in the release of radon gas to the environment.	VIT1 VIT2 CHEM1 CHEM2

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TABLE A.1.3-1 (continued)

Medium	DOE (continued)	Requirement	ARAR/TBC	Rationale for Implementation	Alternative Number
Air	Radiation Protection of the Public and the Environment, Proposed 10 CFR Part 834.	Residual concentrations of radionuclides in the air within uncontrolled areas are limited to those listed below (for known mixtures of radionuclides, the sum of the ratios of the observed concentration of each radionuclide to its corresponding limit must not exceed 1.0.). Derived Concentration Guide (μCi/mL) Isotope — D[a] — W — Y Actinium-227 — 2×10^{-15} — 7×10^{-15} — 1×10^{-14} Lead-210 — 9×10^{-13} — ------[b] — ------ Polonium-210 — 1×10^{-12} — 1×10^{-12} — ------ Protactinium-231 — ------ — 9×10^{-15} — 1×10^{-14} Radium-224 — ------ — 4×10^{-12} — ------ Radium-226 — ------ — 1×10^{-12} — ------ Radium-228 — ------ — 3×10^{-12} — ------ Technetium-99 — 1×10^{-8} — 2×10^{-9} — ------ Strontium-90[c] — 5×10^{-11} — ------ — 9×10^{-12} Thorium-228 — ------ — 5×10^{-14} — 4×10^{-14} Thorium-230 — ------ — 4×10^{-14} — 5×10^{-14} Thorium-232 — ------ — 7×10^{-15} — 1×10^{-14} Uranium-234 — 4×10^{-12} — 2×10^{-12} — 9×10^{-14} Uranium-235 — 5×10^{-12} — 2×10^{-12} — 1×10^{-13} Uranium-236 — 5×10^{-12} — 2×10^{-12} — 1×10^{-13} Uranium-238 — 5×10^{-12} — 2×10^{-12} — 1×10^{-14} [a] D, W, and Y (days, weeks, years) represent lung retention classes; removal halftimes assigned to the compounds with classes D, W, and Y are 0.5, 50, and 500 days, respectively. Exposure conditions assume an inhalation rate of 8,400 m^3 of air per year (based on an exposure over 24 hours per day, 365 days per year). [b] A dashed line means that no limit has been established. [c] The value shown for daily derived concentration guide (DCG) is for strontium radionuclides with a f_1 value of 3×10^{-1}. The value shown for yearly DCG is for strontium radionuclides for a f_1 value of 1×10^{-2}.	To be considered	Remediation of the Silos 1 and 2 material has the potential to release radionuclides.	VIT1 VIT2 CHEM1 CHEM2

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TABLE A.1.3-1 (continued)

Medium	DOE (continued)	Requirement	ARAR/TBC	Rationale for Implementation	Alternative Number
Water	Radiation Protection of the Public and the Environment, Proposed 10 CFR Part 834.	Residual concentrations of radionuclides in water that may be ingested are listed below. These DCGs for the COCs are based on a committed EDE of 100 mrem/yr, assuming ingestion of 2 liters/day. Note that these DCGs apply only if ingestion is the single pathway of exposure. Ingested Water DCGs Isotope — (µCi/mL) Actinium-227 — $1x10^{-8}$ Lead-210 — $3x10^{-8}$ Polonium-210 — $8x10^{-8}$ Protactinium-231 — $1x10^{-8}$ Radium-224 — $4x10^{-7}$ Radium-226 — $1x10^{-7}$ Radium-228 — $1x10^{-7}$ Technetium-99 — $1x10^{-4}$ Strontium-90 — $1x10^{-6}$ Thorium-228 — $4x10^{-7}$ Thorium-230 — $3x10^{-7}$ Thorium-232 — $5x10^{-8}$ Uranium-234 — $5x10^{-7}$ Uranium-235 — $6x10^{-7}$ Uranium-236 — $5x10^{-7}$ Uranium-238 — $6x10^{-7}$	To be considered	Remediation of the Silos 1 and 2 material has the potential to release radionuclides.	VIT1 VIT2 CHEM1 CHEM2

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TABLE A.1.3-1 (continued)

Medium	CWA	Requirement	ARAR/TBC	Rationale for Implementation	Alternative Number
Water	Ohio Water Quality Standards, Ohio Administrative Code (OAC) 3745-1-04.	"Five Freedoms" for surface water: Surface waters of the state shall be free from: • objectionable suspended solids; • floating debris, oil and scum; • materials that create a nuisance; • toxic, harmful or lethal substances; and • nutrients that create nuisance growth.	Relevant and Appropriate	Pertains to discharges to surface waters as a result of remediation and to on-site surface waters affected by site conditions.	VIT1 VIT2 CHEM1 CHEM2
Water	Ohio Water Quality Standards, OAC 3745-1-07.	<u>Use Designations and Criteria</u> All pollutants or combinations of pollutants shall not exceed, outside the mixing zone, the Numerical and Narrative Criteria for Aquatic Life Habitat and Water Supply Use Designations listed in Tables 7-1 through 7-15 of this rule. The following constituents of concern (COCs) for Operable Unit 4 have warm water habitat criteria concentrations outside the mixing zone as follows: 30-day Criteria / average conc.[a] / conc. Constituent / (ug/1) / (ug/1) antimony / 650 / 190 arsenic / 360 / 190 beryllium / Tab. 7-10[b] / Tab. 7-11[c] cadmium / Tab. 7-10 / Tab. 7-11 chromium / Tab. 7-10 / Tab. 7-11 copper / Tab. 7-10 / Tab. 7-11 cyanide / 46 / 12 lead / Tab. 7-10 / Tab. 7-11 mercury / 1.1 / 0.20 nickel / Tab. 7-10 / Tab. 7-11 selenium / 20 / 5.0 silver / Tab. 7-10 / 1.3 thallium / 71 / 16			

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TABLE A.1.3-3 (continued)

RCRA Subtitle C (continued)	Requirement	ARAR/TBC	Rationale for Implementation	Alternative Number
Containment Buildings, 40 CFR Part 264 Subpart DD and 40 CFR Part 264.1101, .1102.	Hazardous waste and debris might be placed into units known as containment buildings for the purpose of interim storage or treatment. Containment buildings must be fully enclosed to prevent exposure to the elements and ensure containment of managed wastes. Floor and containment walls must be designed and constructed of materials of sufficient strength and thickness to support themselves, the waste contents, and any personnel and heavy equipment that operate within the unit. Surfaces coming in contact with hazardous waste must be chemically compatible with waste. Primary barriers must be constructed to prevent migration of hazardous constituents into barrier. Secondary containment systems including secondary barriers and leak detection systems must also be constructed for containment buildings used to manage wastes containing free liquids. Controls must be implemented to ensure: the primary barrier is free of significant cracks, corrosion, or other deterioration that may allow release of hazardous waste; the level of hazardous waste does not exceed height of containment walls and is otherwise maintained within containment walls; tracking of waste out of unit by personnel or equipment used in handling waste is prevented; and fugitive dust emissions are controlled at the level of no visible emissions.	Relevant and Appropriate (This requirement will be applicable to non-excluded solid wastes that exhibit a hazardous characteristic.)	During the process of remediation, waste materials might require temporary management for the purpose of staging or treating the material. Some of the waste material might exhibit a RCRA characteristic, or otherwise be sufficiently similar to hazardous waste to make this requirement relevant and appropriate.	VIT1 VIT2 CHEM1 CHEM2

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TABLE A.1.3-3 (continued)

RCRA Subtitle C (continued)	Requirement	ARAR/TBC	Rationale for Implementation	Alternative Number
Radiation Dose Limit (All Pathways), Proposed 10 CFR Part 834.	The exposure of members of the public to radiation sources as a consequence of all routine DOE activities shall not cause, in a year, an EDE greater than 100 mrem from all exposure pathways.	To be considered	Radiation sources from this OU (i.e., a DOE-owned facility) might contribute to the total dosage to members of the public.	VIT1 VIT2 CHEM1 CHEM2
CAA	**Requirement**	**ARAR/TBC**	**Rationale for Implementation**	**Alternative Number**
Control of Fugitive Dust, OAC 3745-17-08.	Visible emissions of fugitive dust generated during grading, loading, or construction operations and other practices that emit fugitive dust shall be minimized or eliminated.	Relevant and Appropriate	The implementation of remedial action alternatives will require the movement of dirt and other material likely to result in fugitive dust emissions. This requirement is relevant and appropriate because the FEMP is not located in an area subject to this regulation.	VIT1 VIT2 CHEM1 CHEM2
Prevention of Air Pollution Nuisance, ORC 3704.01-.05 and OAC 3745-15-07.	Measures shall be taken to adopt and maintain a program for the prevention, control, and abatement of air pollution in order to protect and enhance the quality of the state's air resource so as to promote the public health, welfare, and economic vitality of the people of the state. The emission or escape into open air from any source whatsoever of smoke, ashes, dust, dirt, grime, acids, fumes, gases, vapors, odors, and combinations of the above in such a manner or in such amounts as to endanger the health, safety, or welfare of the public or to cause unreasonable injury or damage to property shall be declared a public nuisance and is prohibited.	Applicable	During the remediation process, some potential exists for emissions of radionuclides and toxic chemicals to the air, which might endanger individuals or damage property.	VIT1 VIT2 CHEM1 CHEM2

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An initial listing of potential ARARs was included in the *Initial Screening of Alternatives (ISA) for Operable Unit 4 (OU4) Task 12 Report* (DOE 1990). A comprehensive listing of potential ARARs and TBCs was jointly developed by DOE, EPA, and the Ohio Environmental Protection Agency (OEPA) in October 1990. The ISA listing was refined using the comprehensive listing, the *Remedial Investigation (RI) Report for Operable Unit 4 (OU4)* (FEMP 1993), and alternative descriptions to produce the ARAR/TBC tables presented in the original *Feasibility Study (FS) Report for Operable Unit 4 (OU4)* (FEMP 1994). Included in these tables were ARARs and TBCs for a remedial alternative that identified vitrification of the Silos 1 and 2 material with final disposition at the NTS. This alternative was identified as "3A.1" in the tables of the original OU4 FS (see **Appendix F**) and was selected as the preferred alternative for remediation of the Silos 1 and 2 material in the OU4 ROD.

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A.2.1 Types of ARARs

EPA guidance directs the identification of three types of ARARs: chemical-specific, location-specific, and action-specific. The identification of potential ARARs is discussed by type in the subsections that follow; **Tables A.1.3-1** through **A.1.3-3** segregate the potential ARARs and TBCs into three separate tables by ARAR type. **Table A.1.3-1** contains chemical-specific ARARs/TBCs; **Table A.1.3-2**, location-specific ARARs/TBCs; and **Table A.1.3-3**, the action-specific ARARs/TBCs. **Table A.1.3-1** (chemical-specific ARARs) further classifies potential ARARs based on the media affected. Only those alternatives that passed the initial screening and are detailed in this document are listed in these tables. The ARARs in each table are arranged within each ARAR type by the legislative act that establishes the requirements. The major acts listed in **Table A.1.3-1** include the AEA, Clean Water Act (CWA), Clean Air Act (CAA), RCRA, National Environmental Policy Act (NEPA), and Uranium Mill Tailings Radiation Control Act (UMTRCA). Where a single regulatory citation appears for an ARAR in these tables, the citation or reference is more stringent than its state or federal counterpart (or a counterpart does not exist). In addition, **Table A.1.3-4** contains "other requirements," which include DOE Orders pertaining to worker protection and safety, NEPA implementation, transportation requirements, and quality assurance during remediation of the Silos 1 and 2 material.

A.2.2 Compliance of ARARs

Compliance evaluations for each alternative, subjected to detailed analysis relative to the identified ARARs, are presented in **Table A.2.2-1**. Compliance is indicated when the standard is met, or where the remedial activities associated with that alternative will not violate the requirement. In cases of potential noncompliance, a brief explanation of the expected reason for noncompliance is provided.

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A.5.0 REFERENCES

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[summary fact sheet at http://www.epa.gov/region5/pdf/fernald.pdf]

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1 Documentation of Remedial Investigation/Feasibility Study (RI/FS) activities for each operable unit is made available for public review. The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Administrative Records for the FEMP site are located at the Public Environmental Information Center (PEIC) in Harrison, OH. 513-648-7480.

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B.1.0 INTRODUCTION

This appendix presents the estimated risks associated with implementing the four alternative treatment technologies being considered for stabilizing the Fernald Environmental Management Project (FEMP) Operable Unit 4 (OU4) Silos 1 and 2 material. The purpose of this risk assessment is to assess and discuss to the extent practical the short-term and long-term effectiveness associated with each treatment alternative. The results of this assessment are presented in terms of risk to the workers and members of the public from facility construction, operation, decontamination and demolition (D&D), and waste transportation. Both quantitative and qualitative analyses are used to estimate the risks from each alternative. It should be noted that assumptions used for this risk assessment are conservative in perspective and are consistently applied to the four treatment alternatives under evaluation. The use of conservative assumptions result in an upper bound estimate for the risk associated with the implementation of these alternatives. Therefore, the risk values calculated in this assessment are not as important as the differences in values between the four alternatives.

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Although the purpose of this risk assessment includes assessing long-term risks, this appendix does not estimate these risks. Under the Comprehensive Environmental Compensation and Liability Act (CERCLA), long-term risks are related to the residual Silos 1 and 2 material (source term) and treated waste that remains at the FEMP site following remediation. All alternatives considered in this evaluation involve off-site disposal of the treated waste in engineered facilities designed and operated to manage the waste in the long-term. Since there will be no source term remaining at the FEMP from the remediation of the Silos 1 and 2 material, the long-term impacts from residual wastes are assumed to be the same for all alternatives considered here. These impacts were assessed in the original *Feasibility Study (FS) Report for Operable Unit 4 (OU4)* (FEMP 1994) and are summarized in **Appendix F** of this document. As a result, this appendix presents only short-term risks associated with the four alternatives.

B.3.0 ALTERNATIVES EVALUATION RISK ASSESSMENT

This section comprises the main section of the risk assessment. It presents the remedial alternatives; the potential receptors, pathways, and exposure parameters; and the conceptual and mathematical models for the analyses.

B.3.1 Description of Alternatives

The potential risks from implementing four processing alternatives have been estimated here. The four processing alternatives are:

1. Alternative VIT1 – For this alternative, the Silos 1 and 2 material is combined with glass forming agents in a joule-heated melter. Electrodes are used to heat the combined materials to form a glass matrix. The process molds the glass into monoliths. The monoliths are then placed into reinforced concrete containers.

2. Alternative VIT2 – For this alternative, the Silos 1 and 2 material is made into a glass matrix using a process other than a joule-heated melter. In this case, a combustion melter is utilized to vitrify the Silos 1 and 2 material. The process forms glass cullets that are formed by quenching the vitrified material in water. The cullets are then placed into high-density concrete containers.

3. Alternative CHEM1 – For this alternative, the Silos 1 and 2 material is combined with cement-forming additives and solidified in a cement matrix. The matrix is then placed into high-density concrete containers.

4. Alternative CHEM2 - For this alternative, the Silos 1 and 2 material is combined with other chemical additives to form a solid matrix similar to cement. The stabilized matrix is then placed into cylindrical, steel containers.

In each case, the processed materials are shipped to the NTS for disposal. **Section 3.0** and **Appendix G** of this revised FS describe each alternative in greater detail.

B.3.2 Potential Receptors, Pathways and Exposure Parameters

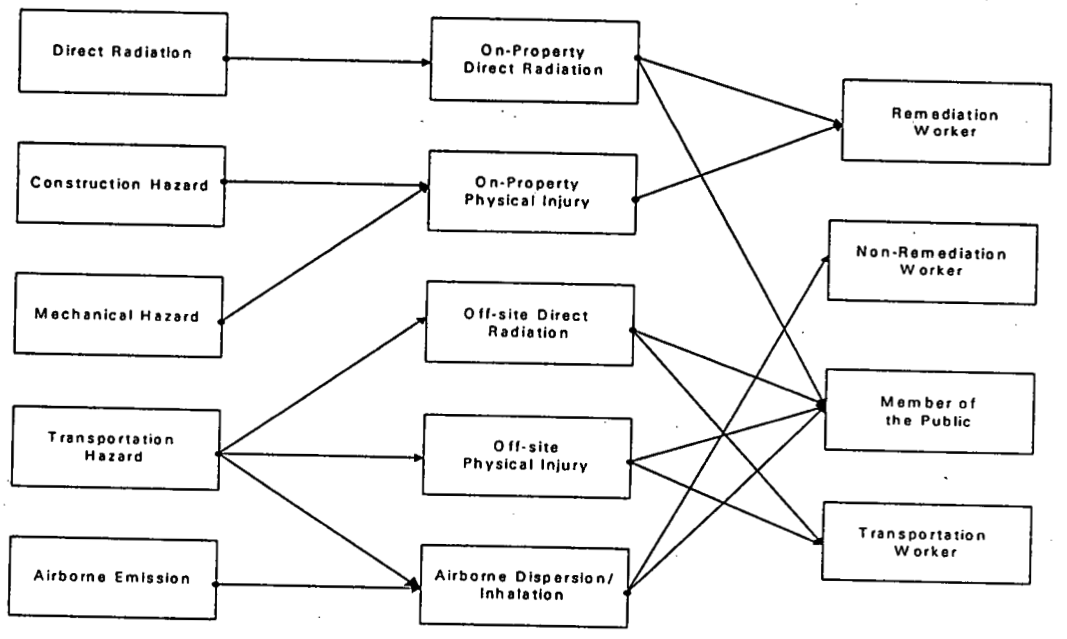
Remedial action risks are short-term risks associated with implementing remedial action alternatives and are present for the duration of the remediation. The risks are described in terms of lifetime cancer risks associated with the short-term exposure to ionizing radiation and mechanical injuries and fatalities associated with construction, operation, and D&D activities. This risk assessment estimates risks delivered to three groups of individuals: process workers, non-remediation workers, and the general public. Process workers are those workers placed at risk by a specific component of a remedial alternative while implementing that component (e.g., process equipment operators, transportation workers, construction workers, and health and safety staff). Non-remediation workers are those workers at the FEMP site that are not directly working in support of remediating the Silos 1 and 2 material. The general public is defined as those individuals living adjacent to the FEMP site, who are placed at risk from the release of radioactive material resulting from treatment of the Silos 1 and 2 material. The general public living adjacent to or sharing the transport route for the Silos 1 and 2 material are placed at risk from direct radiation associated with transport containers and the accidental release of waste material during transportation.

To estimate remedial action risks, this risk assessment examines four distinct remedial alternative components: construction of support and processing facilities; retrieval and processing of the Silos 1 and 2 material from the Transfer Tank Area (TTA); D&D of the support and processing facilities, including the TTA and the Radon Control System (RCS); and transport of the treated Silos 1 and 2 material from the FEMP to the Nevada Test Site (NTS). These components represent the operations that have the potential for contributing to the remedial action short-term risks. Each component is briefly described below. **Section B.3.2.2** of this risk assessment describes the exposure pathways.

TABLE B. 3.2-1
EXPOSURE SCENARIO RISK ASSESSMENT SUMMARY

HAZARD	PATHWAY	RECEPTOR	EXPOSURE ASSESSMENT METHOD
Direct Radiation	-	Remediation Worker	Quantitatively
Construction Hazard	Physical Injury	Remediation Worker	Quantitatively
Mechanical Hazard	Physical Injury	Remediation Worker	Quantitatively
Transportation Hazard	Direct Radiation	Transportation Worker	Quantitatively
Transportation Hazard	Direct Radiation	Member of the Public	Quantitatively
Transportation Hazard	Non-radiological Impacts	Transportation Worker	Quantitatively
Transportation Hazard	Non-radiological Impacts	Member of the Public	Quantitatively
Transportation Hazard	Airborne Dispersion	Member of the Public	Quantitatively
Operations Airborne Emission	Airborne Dispersion	Remediation Worker	Qualitatively
Operations Airborne Emission	Airborne Dispersion	Non-Remediation Worker	Qualitatively
Operations Airborne Emission	Airborne Dispersion	Member of the Public	Qualitatively

FIGURE B. 3.2-1
EXPOSURE PATHWAYS



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B.3.2.6 Exposure Parameters for Remedial Action Risks

This section tabulates the exposure parameters used in the quantitative assessment. Similar sets of parameters, e.g., risk factors, exposure durations, et cetera, have been grouped together. References for the parameter values have been provided.

Table B.3.2-7 presents the risk factors for the analysis. The factors include the CRF for radiation exposure and the physical injury risk factors for remediation workers.

Table B.3.2-8 presents the transportation pathway parameters. These parameters include the dose rates from the Microshield® analyses, the number of packages, and the number of trucks.

TABLE B. 3.2-7
RISK FACTORS

Parameter	Value	Units	Reference
CRF (worker)	4.0×10^{-4}	Latent cancer fatalities Per person-rem	RADTRAN5®
CRF (public)	5.0×10^{-4}	Latent cancer fatalities Per person-rem	RADTRAN5®
MHRF (injury)	3.4×10^{-5}	Injuries per person-hour	OU4 FS
MHRF (fatality)	5.0×10^{-7}	Fatalities per person-hour	OU4 FS

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TABLE B. 3.2-8
TRANSPORTATION PARAMETERS

	Dose Rates, mrem/hr			
Parameter	VIT1	VIT2	CHEM1	CHEM2
Package @ 2 ft	37.8	63.15	30.5	28.23
Package @ 1 m	23.3	40.7	19.7	18.0
Truck @ 3 ft	20.2	40	19.4	27.3
Truck @ 10 ft	5.68	11.52	5.5	6.0
Truck @ 20 ft	1.9	3.84	1.8	1.96
# of Packages	2,398	2,162	6,078	6,106
# of Trucks	1,199	1,081	3,039	3,053

<END OF SECTION>

B.5.0 SHORT-TERM EXPOSURE RISKS

This section presents the short-term risk results. **Section B.5.1** tabulates the impacts. **Section B.5.2** discusses the qualitative risks in terms of hazard ratings. **Section B.5.3** summarizes the risks in text.

B.5.1 Quantitative Analysis

Table B.5.1-1 presents the collective dose equivalent from construction, operation, and D&D activities. The collective dose equivalent is the sum of the individual doses estimated to be received by each worker. For example, during the 307,147 person-hours estimated to construct the joule-heated vitrification facility (VIT1), the sum of the individual radiation doses received by each worker is estimated to be 7.68 person-rem. **Table B.5.1-2** presents the collective dose equivalent from transportation support operations. For example, the sum of the individual radiation doses estimated to be received by each worker involved with strapping packages containing combustion vitrified Silos 1 and 2 material (VIT2) to the transport vehicles is 21.6 person-rem during the life of the project.

Table B.5.1-3 presents the risk of injury and fatality for construction, operation, and D&D activities. For example, based on 923,905 person-hours for cement-based stabilization operations (CHEM1), there is a potential for 31.4 injuries and 0.462 fatalities.

Table B.5.1-4 presents the collective dose equivalents to transportation receptors using the representative Southern Route #3. For example, the sum of the individual radiation doses received by each member of the general public either living along the proposed route, sharing the road, or occupying stops at the same time as normal transport (estimated to be 1.24 million people) of chemical stabilized Silos 1 and 2 material (CHEM2) is 5,220 person-rem. **Table B.5.1-5** presents the non-radiological risk of fatality from transportation.

There are two types of risk to the public for non-radiological fatalities. One risk is fatality resulting from an accident and the other risk is fatality resulting from exhaust emissions from the operation of a motor vehicle.

TABLE B. 5.1-1
COLLECTIVE DOSE EQUIVALENT, PLANT OPERATIONS

	Collective Dose Equivalent, person-rem			
Activity	VIT1	VIT2	CHEM1	CHEM2
Construction	7.68E+00	9.73E+00	8.84E+00	8.12E+00
Uncontrolled (0.025 mrem/hr)	5.73E+00	5.44E+00	3.17E+00	4.03E+00
Uncontrolled (0.05 mrem/hr)	4.39E+01	4.82E+01	3.02E+01	2.02E+01
Zone 1 Operations	1.29E+02	1.40E+02	6.99E+01	8.87E+01
Zone 2 Operations	2.82E+01	2.92E+01	1.15E+01	1.52E+01
Zone 3 Operations	7.10E+01	8.62E+01	5.82E+01	6.88E+01
D&D	5.01E+00	5.28E+00	5.05E+00	5.19E+00

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TABLE B. 5.1-2
COLLECTIVE DOSE EQUIVALENT, TRANSPORTATION SUPPORT

	Collective Dose Equivalent, person-rem			
Activity	VIT1	VIT2	CHEM1	CHEM2
Blocking	1.51E+01	2.28E+01	3.09E+01	2.87E+01
Strapping	1.21E+01	2.16E+01	2.95E+01	4.17E+01
Radiological Control	2.02E+00	3.60E+00	4.91E+00	6.93E+00
Supervision	2.28E+00	4.11E+00	5.47E+00	1.83E+01
HazMat Operator	3.78E+00	5.68E+00	7.72E+00	7.17E+00
Quality Assurance	1.14E+00	2.07E+00	2.78E+00	3.05E+00

TABLE B. 5.1-3
RISK OF MECHANICAL INJURY OR FATALITY

	Risk of Injury			
Activity	VIT1	VIT2	CHEM1	CHEM2
Construction	10.4	13.2	12.0	11.0
Operation	49.5	53.1	31.4	37.8
D&D	3.4	3.6	3.4	3.5
	Risk of Fatality			
Activity	VIT1	VIT2	CHEM1	CHEM2
Construction	1.54E-01	1.95E-01	1.77E-01	1.62E-01
Operation	7.28E-01	7.81E-01	4.62E-01	5.56E-01
D&D	5.01E-02	5.28E-02	5.05E-02	5.19E-02

TABLE B. 5.1-4

COLLECTIVE DOSE EQUIVALENT
WASTE TRANSPORTATION SOUTHERN ROUTE #3

	Collective Dose Equivalent, person-rem			
Exposed Individual	VIT1	VIT2	CHEM1	CHEM2
Crew	1.02E+02	1.71E+02	2.47E+02	4.39E+02
Public, Incident Free & Stops	2.04E+03	1.85E+03	5.20E+03	5.22E+03
Maximum Exposed Individual	2.38E-03	4.25E-03	5.80E-03	8.20E-03
Public, Accident Release	6.83E-02	6.86E-02	7.75E-02	8.08E-02

TABLE B. 5.1-5

ESTIMATED NON-RADIOLOGICAL FATALITIES
WASTE TRANSPORTATION SOUTHERN ROUTE #3

	Estimated Non-radiological Fatalities			
	VIT1	VIT2	CHEM1	CHEM2
Occupational, Accident	5.75E-02	5.20E-02	1.46E-01	1.47E-01
Public, Normal Transport	7.90E-03	7.15E-03	2.01E-02	2.02E-02
Public, Accident	2.04E-01	1.84E-01	5.70E-01	5.70E-01

The collective dose equivalent can be converted to an estimate of potential LCFs that occur using Equation 4 and using a conversion factor of 4.0E-04 LCFs per person-rem for workers and 5.0E-04 LCFs per person-rem for the general public. The estimated number of LCFs that could potentially occur during remediation shipment activities to the NTS can then be converted to an ILCR by comparing the LCFs to the total population estimated to be exposed.

Based on population density data used for the RADTRAN5® computer model, the total population estimated by the RADTRAN5® computer model to be either living along or sharing the proposed Southern Route #3 is approximately 1.24 million people. Based on evacuation times and response actions, as well as population density data, it is estimated by the RADTRAN5® computer model that the total number of individuals that would be expected to be exposed as a result of hypothetical accident releases is approximately 41.9 million people. **Table B.5.1-6** presents the ILCR for the general public during transportation of material to the NTS. For comparison, an ILCR of 10^{-4} to 10^{-6} is an acceptable risk range under CERCLA.

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TABLE B. 5.1-6

ESTIMATED INCREMENTAL LIFETIME CANCER RISKS
WASTE TRANSPORTATION SOUTHERN ROUTE #3

	Incremental Lifetime Cancer Risk			
	VIT1	VIT2	CHEM1	CHEM2
Public, Incident-Free & Stops	8.23E-07	7.46E-07	2.10E-06	2.10E-06
Maximum Exposed Individual	1.19E-06	2.14E-06	2.90E-06	4.10E-06
Public, Accident Release	8.15E-13	8.19E-13	9.25E-13	9.64E-13

The ILCR for the transportation crew was calculated on a per shipment basis where a crew of two individuals would be responsible for the transport of one shipment of treated Silos 1 and 2 material to the NTS. **Table B.5.1-7** presents the ILCR for transportation workers, as well as the date used to obtain the ILCR.

TABLE B. 5.1-7

ESTIMATED INCREMENTAL LIFETIME CANCER RISK
TRANSPORTATION CREW

	Incremental Lifetime Cancer Risk			
	VIT1	VIT2	CHEM1	CHEM2
Required Number of Shipments	1,199	1,081	3,039	3,053
Number of Transport Workers per Shipment	2	2	2	2
ILCR per Worker per Shipment	1.70E-05	3.16E-05	1.62E-05	2.88E-05

To determine the ILCR for on-site remediation workers, the estimated number of potential LCFs was compared to the projected workforce required from construction through D&D for the four alternatives being evaluated in this revised FS. Table B.5.1-8 presents the ILCR for the on-site remediation worker, as well as the data used to obtain the ILCR.

TABLE B. 5.1-8

ESTIMATED INCREMENTAL LIFETIME CANCER RISKS
REMEDIATION WORKERS

	Incremental Lifetime Cancer Risk			
	VIT1	VIT2	CHEM1	CHEM2
Projected Workforce	394	439	349	382
ILCR	3.32E-04	3.50E-04	3.07E-04	3.31E-04

B.5.2 Qualitative Analysis Results

Two exposure modes, inhalation/immersion from processing and direct radiation from the OSDF, are analyzed in this section.

B.5.2.1 Inhalation/Immersion

One exposure mode, inhalation of particulates and radon, is analyzed here. The RCS will control radon emissions and all processing alternatives to below established limits. The use of BAT on the Normal Off-gas Treatment Systems will preclude the release of other radioactive material, resulting in negligible risk of inhalation of particulates and radon.

A disruption in the Normal Off-gas Treatment System would only impact the vitrification technologies. In the event of disruption of the Normal Off-gas Treatment System, facility operations would immediately shut down until the problem was resolved in order to minimize the amount of material released. Off-gas would be sent through an Emergency Off-gas System consisting of a knockout tank and HEPA filter to treat the particulate. Because the Feed System would shut down upon disruption of the Normal Off-gas Treatment System, the radon released would be limited to that present in the vitrification process. Based on the conceptual designs presented in this revised FS, it is estimated that activation of the Emergency Off-gas System would result in less than a 1 mrem dose to the maximally exposed individual. Therefore, the occurrence of inhalation of particulates and radon during the lifetime of the project is unlikely.

B.5.2.2 Simplified Hazard Analysis of Proposed Treatment Technologies

This section discusses the results of the general IHA performed to determine the worker hazards associated with the four design concepts evaluated in support of this revised FS. The purpose of the analysis was to qualitatively rate the unmitigated hazards to workers based on the conceptual design of the treatment processes so that differences regarding worker risks could be better understood.

The conceptual designs were analyzed against a master list of 21 types of hazards including, SIH, health hazards, biological hazards, toxicity, and radiological hazards. If a treatment technology was evaluated to impose less of a particular hazard, then that technology was rated to be "favored" for that hazard type. If the hazard was considered equal among the treatment technologies, then that hazard type was rated as "neutral". It is important to note that weighting factors were not assigned to the hazards analyzed, neither were the probability or consequence considered for the hazard being analyzed.

The results of the general IHA are presented in **Tables B.5.2-1** and **B.5.2-2**. **Table B.5.2-1** presents the findings for all 21 hazards analyzed. **Table B.5.2-2** presents a summary of those hazards in which a difference was evaluated to exist between the treatment technologies.

TABLE B. 5.2-1
WORKER HAZARDS COMPARISON

Item	Hazard	Definition	Potential Accident/Effect	Vit ←Favors			Chem Favors→		Comments
				SF	F	N	F	SF	
1	Acceleration/ Impact	Change in velocity, impact energy of vehicles, components or fluids	1. Structural deformation 2. Breakage by impact 3. Displacement of part or piping 4. Seating or unseating of valves or electrical contacts 5. Loss of fluid pressure head (cavitation) 6. Pressure surges 7. Explosions or detonations		X				Hazard is considered higher for chemical stabilization based on increased material handling and shipping due to waste volume.
2	Potential Energy/ Elevation	Potential to fall	1. Falling of individuals from elevated locations 2. Falling of elevated objects, striking and injuring people, or damaging structures or equipment 3. Falling due to lack of handrails/ladder enclosures that could prevent falls				X		Vitrification technologies have more elevated equipment and work from elevated platforms.

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TABLE B. 5.2-1 (continued)

Item	Hazard	Definition	Potential Accident/Effect	Vit ←Favors			Chem Favors→		Comments
				SF	F	N	F	SF	
3	Chemical Energy/ Reactivity	Chemical Reactions	1. Fire 2. Explosion/detonation 3. Exothermic reactions 4. Production of toxic/flammable gases				X		Vitrification technologies result in by-product toxic off-gas constituents (SO_2, NOx, volatilized lead, etc.). Combustion vitrification utilizes natural gas for feed-prep and treatment.
4	Contamination	Introduction of Contamination	1. Clogging of mechanical components 2. Friction between moving parts 3. Component degradation 4. Making equipment/structures/ components unusable because of contamination			X			Considered neutral. Chemical stabilization is expected to require more contamination control during operations however vitrification technologies are believed to be more difficult to control contamination during maintenance activities. Cement mixer maintenance - chronic Centrifuge maintenance - chronic Refractory replacement - dry feed system Favors VIT1 and CHEM2 Does not favor VIT2 and CHEM1

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TABLE B. 5.2-1 (continued)

Item	Hazard	Definition	Potential Accident/Effect	Vit ←Favors			Chem Favors→		Comments
				SF	F	N	F	SF	
5	Electrical Energy	Electrical component release or failure, shock	1. Electrocution 2. Involuntary personnel reaction 3. Personnel burns 4. Ignition of combustibles 5. Inadvertent activation of equipment 6. Disabling of electric emergency/safety equipment 7. Interruption of communications				X		Vitrification technologies require a more complex electrical distribution system (more equipment). Joule melter power is not an issue.
6	Human Capability	Human Factors	1. Personnel injury due to lifting too much or improperly 2. Personnel injury due to: a. Restricted/excessive hours b. Hazardous location c. Inadequate visual/audible warnings 3. Equipment damage by improper operation due to: a. Inadequate training b. Inaccessible control c. Inadequate control display/identification d. Inadequate procedures			X			Vitrification technologies will result in more man-hours worked plus more equipment that requires maintenance. Chemical stabilization results in remote operations that are more repetitive and tedious.

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TABLE B. 5.2-1 (continued)

Item	Hazard	Definition	Potential Accident/Effect	Vit ←Favors			Chem Favors→		Comments
				SF	F	N	F	SF	
7	Interface Interaction	Compatibility between systems/ subsystems	1. Incompatible materials reaction 2. Interfacing reactions 3. Unintended operations caused by software			X			No significant differences between technology families.
8	Human Hazards	Conditions that can cause human injury	1. Personnel injury due to: a. Sharp edges/corners b. Limited work area 2. Damaged walking/working surfaces that can cause tripping injuries 3. Unguarded equipment				X		More man-hours worked for vitrification technologies.
9	Kinetic Energy	System/ component linear or rotary motion	1. Linear impact 2. Disintegration of rotating components			X			No significant differences between rotating equipment (mixer vs. centrifuge).

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TABLE B. 5.2-1 (continued)

Item	Hazard	Definition	Potential Accident/Effect	Vit ←Favors			Chem Favors→		Comments
				SF	F	N	F	SF	
10	Material Deformation	Degradation of material by corrosion, aging, embrittlement, oxidation, etc.	1. Change in physical or chemical properties 2. Structural failure 3. Electrical insulation breakdown 4. Erosion of lines or components 5. Component failures 6. Collapse/loss of containment				X		Equipment failure from chemical interactions such as corrosion is considered more plausible with vitrification technologies due to heat, redox conditions, acid gases, and the use of caustic.
11	Mechanical Energy	System/ Components Energy	1. Personnel injury/equipment damage from energy release of component such as a spring 2. Personnel injury due to being caught/crushed by moving parts		X				Chemical stabilization will result in more container handling and shipping activities.

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TABLE B. 5.2-1 (continued)

Item	Hazard	Definition	Potential Accident/Effect	Vit ←Favors			Chem Favors→		Comments
				SF	F	N	F	SF	
12	Natural Phenomena	Lightning, high winds, projectiles, earthquakes, floods, tornadoes	1. Structural damage from wind/tornadoes 2. Collapse and loss of containment from earthquakes, wind and tornadoes 3. Electric discharge 4. Dimensional changes from solar heating 5. Personnel injury/death from projectiles 6. Equipment/structural damage from projectiles 7. Personnel injuries/death from flooding/high water 8. Equipment/structural damage from flooding/high water 9. Damage and injuries due to lightning			X			No significant differences in consequence.

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TABLE B. 5.2-1 (continued)

Item	Hazard	Definition	Potential Accident/Effect	Vit ←Favors			Chem Favors→		Comments
				SF	F	N	F	SF	
13	Pressure	System/ component energized by high low or changing pressure	1. Fragments/noise and pressure pulse from over pressurized container rupture 2. Line/hose whipping 3. Container implosion 4. System leaks 5. Aeroembolism, bends, choking or shock 6. Deformation due to stress failure				X		Vitrification technologies have a remote potential for over pressurization from upset conditions in the melter (i.e., steam excursion). Mitigation is provided by the emergency off-gas systems.
14	Radiation	Radiation exposure and conditions including electromagnetic, ionizing, thermal or ultraviolet radiation	1. Criticality 2. Radiation exposures, both internal and external 3. Charring of organic materials 4. Decomposition of chlorinated hydrocarbons into toxic gases 5. Ozone or nitrogen oxide generation 6. Contamination of personnel, equipment, and/or facilities		X				Majority of project dose is the result of material handling and shipping activities.

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TABLE B. 5.2-1 (continued)

Item	Hazard	Definition	Potential Accident/Effect	Vit ←Favors			Chem Favors→		Comments
				SF	F	N	F	SF	
15	Thermal	High and low and changing temperature	1. Ignition of combustibles 2. Initiation of other reactions 3. Distortion of parts 4. Expansion/contraction of fluids and solids 5. Liquid compound stratification 6. Personnel injury/stress				X		Vitrification technologies deal with extremely high temperatures.
16	Toxicants	Adverse human effects of inhalants or ingesta, and adverse effects on biota	1. Respiratory system damage 2. Blood system damage 3. Body organ damage 4. Skin irritation or damage 5. Nervous system effects				X		Vitrification - Off-gas constituents (Pb, SO_x, NO_x), refractory, caustic treatment.
17	Biohazards	Adverse human effects	1. Insect sting/bites 2. Histoplasmosis 3. Snake bites			X			No significant differences.

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TABLE B. 5.2-1 (continued)

Item	Hazard	Definition	Potential Accident/Effect	Vit ←Favors			Chem Favors→		Comments
				SF	F	N	F	SF	
18	Vibration/ Sound	System/ Component Produced Energy	1. Material fatigue 2. Personnel fatigue or injury 3. Pressure/shock wave effects 4. Loosening of parts 5. Chattering of valves or contacts 6. Communication interference 7. Impairment or failure of displays 8. Hearing loss, both acute and long term			X			No significant differences.
19	Caustic/Acidic	Chemical reactions due to chemical energy	1. Burns 2. Chemical reactions			X			Large quantity of caustic for off-gas treatment Phosphoric acid for CHEM1 process.

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TABLE B. 5.2-1 (continued)

Item	Hazard	Definition	Potential Accident/Effect	Vit ←Favors			Chem Favors→		Comments
				SF	F	N	F	SF	
20	Spill/Loss of Containment	Release of hazardous materials	1. Personnel injury 2. Costly clean-up 3. Damage to components/property 4. Off-site transport of contaminant 5. Environmental or ecosystem damage				X		Consequence of a melter loss of confinement exceeds that of chemical stabilization. More systems to provide for confinement with vitrification. Toxic gases require confinement.
21	Industrial/ Construction Hazards	Hazards encountered in industrial work environments, such as confined spaces, welding, etc.	1. Personnel injury/death 2. Loss of work/production				X		Vitrification technologies require construction of more complex systems and more field fabrication. Chemical stabilization technologies can utilize pre-fab structures, systems, and components more readily.

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TABLE B. 5.2-2
SUMMARY OF WORKER HAZARDS COMPARISON

Hazard	Definition	Vit	Chem	Comments
		← Favors →		
Acceleration/ Impact	Change in velocity, impact energy of vehicles, components or fluids	X		Hazard is considered higher for chemical stabilization based on increased material handling and shipping due to waste volume differences.
Potential Energy/ Elevation	Potential to fall		X	Vitrification technologies have more elevated equipment and work from elevated platforms.
Chemical Energy/ Reactivity	Chemical reactions		X	Vitrification technologies result in by-product toxic off-gas constituents (SO_2, NO_x, volatilized lead, etc.). Combustion vitrification utilizes natural gas resulting in combustion gases.
Electrical Energy	Electrical component release or failure, shock		X	Vitrification technologies require a more complex electrical distribution system (more equipment).
Human Hazards	Conditions that can cause human injury		X	More man-hours worked for vitrification technologies.
Material Deformation	Degradation of material by corrosion, aging, embrittlement, oxidation, etc		X	Equipment failure from chemical interactions such as corrosion is considered more plausible with vitrification technologies due to heat, melter redox conditions, acid gases, and the use of caustic.
Mechanical Energy	System/ components energy	X		Chemical stabilization will result in more container handling and shipping activities.
Pressure	System/ component energized by high low or changing pressure		X	Vitrification technologies have a remote potential for over pressurization from upset conditions in the melter (i.e., steam excursion). Mitigation is provided by the emergency off-gas systems.

TABLE 5.2-2 (continued)

Hazard	Definition	Vit	Chem	Comments
		← Favors →		
Radiation	Radiation exposure and conditions including electromagnetic, ionizing, thermal or ultraviolet radiation	X		Majority of project dose is the result of radiation exposure during material handling and shipping activities.
Thermal	High and low and changing temperature		X	Vitrification technologies deal with extremely high temperatures.
Toxicants	Adverse human effects of inhalants or ingesta, and adverse effects on biota		X	Vitrification - Off-gas constituents (Pb, SO_x, NO_x), possibility of refractory, caustic treatment.
Spill/Loss of Containment	Release of hazardous materials		X	Consequence of a melter loss of confinement exceeds that of chemical stabilization. More systems to provide for confinement with vitrification. Toxic gases require confinement.
Industrial/ Construction Hazards	Hazards encountered in industrial work environments, such as confined spaces, welding, etc		X	Vitrification technologies require construction of more complex systems and more field fabrication. Chemical stabilization technologies can use pre-fab structures, systems, and components more readily.

B.5.3 Conclusions

Based on the risk analysis presented above, the risks associated with implementation of each alternative are within the acceptable risk range established under CERCLA.

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B.7.0 REFERENCES

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1 Documentation of Remedial Investigation/Feasibility Study activities for each operable unit is made available for public review. The Comprehensive Environmental Response Compensation, and Liability Act (CERCLA) Administrative Records for the FEMP site are located at the Public Environmental Information Center (PEIC) in Harrison, OH. 513-648-7480.

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REVISED FEASIBILITY STUDY REPORT

FOR SILOS 1 AND 2

40730-RP-0001

U.S. Department of Energy
Fernald Environmental Management Project

VOLUME 2 OF 4
February 2000
Draft, Rev. B

Prepared Under DOE Contract No. DE-AC24-92OR21972
By Fluor Daniel Fernald

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C.2.0 VITRIFICATION – JOULE-HEATED

C.2.1 Cost Estimate Summary: Vitrification – Joule-heated

C.2.1.1 Introduction

The summary cost for the Vitrification — Joule-heated alternative (VIT1) is $354,745,840 in FY99 dollars, as shown in **Table C.2.1-1.**

TABLE C. 2.1-1
SUMMARY COST ESTIMATE FOR
VITRIFICATION — JOULE-HEATED

Section	Cost Element	Estimated Cost
C.2.2	Capital Cost	$69,084,413
C.2.3	Engineering Cost	$25,050,900
C.2.4	O&M	$133,854,320
C.2.5	D&D Cost	$34,503,692
C.2.6	Project Management Cost	$22,145,800
C.2.7	Waste Disposal Cost	$24,532,105
C.2.8	Cost of Money	$45,574,610
C.2.1	Summary Cost (Un-escalated)	$354,745,840

Supporting information for the Vitrification – Joule-heated (VIT1) cost estimate elements are provided in **Sections C.2.2** through **C.2.8.**

C.2.1.2 Attachment

The cost estimate summary for the Vitrification – Joule-heated alternative (VIT1), prepared by the FDF cost estimating team, is attached to this section.

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Therefore, the total material cost is summarized in **Table C.2.4-5** as follows: — 8108

TABLE C. 2.4-5
SUMMARY OF MATERIAL COSTS

Material	Expenditure	Cost
Spare Parts	$297,352 @ 4.0 years	$1,189,408
Consumables	$1,914,203 @ 4.0 years	$7,656,804
Total	$2,211,553 @ 4.0 years	$8,846,212

C.2.4.2.4.3 Utility Cost

Utility cost is the cost for utilities to support the start-up, proof of process, and operation of the Silos 1 and 2 material full-scale remediation activities. This cost includes electricity, natural gas, and oxygen. Cost of water is included in the FEMP site support cost, which is not included in this estimate.

The following **Table C.2.4-6** is a summary of the annual cost for utilities based on information from the *EnVitCo POP Final Report* **(Appendix H, Attachment H1)** and **the Basis of Design and Description (Appendix G)**.

TABLE C. 2.4-6
ANNUAL UTILITY COST FOR VITRIFICATION – JOULE-HEATED

Electrical	24,655,742 kWhr	@.06/kWhr	$1,479,345	per year

Based on the Vitrification – Joule-heated operation and start-up schedule assumptions, the utility costs are summarized in **Table C.2.4-7**.

TABLE C. 2.4-7
UTILITY COST FOR VITRIFICATION – JOULE-HEATED

O&M	$1,479,345 @ 3.5 years	$5,177,708
Start-up and Training	$1,479,345 @ 0.5 years	$739,672
Total Utility Cost	$1,479,345 @ 4.0 years	$5,917,380

C.2.4.2.4.4 Contractor's Technical Support Cost

The contractor's technical support cost includes the contractor's cost to support start-up and operation of the Silos 1 and 2 material full-scale treatment facility. This cost includes technology-specific laboratory support, training support labor, start-up technical oversight labor, and operational technical oversight labor.

The contractor's estimated technical support cost for Vitrification – Joule-heated is based on the *EnVitCo POP Final Report* **(Appendix H); it is** summarized in **Table C.2.4-8** as follows:

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TABLE C. 4.4-8
CONTRACTOR'S TOTAL TECHNICAL SUPPORT COSTS

Contractor Support for O&M	$2,208,960
Contractor Support for Start-up Cost	$1,154,320
Total Technical Support Cost	$3,363,280

C.4.4.2.4.5 Risk Budget

Risk budget is added to the estimate to provide for risks and uncertainties associated with the O&M of the Silos 1 and 2 material full-scale treatment facility.

C.4.4.2.4.6 Secondary Waste Cost

Secondary waste cost is defined as those costs accrued for the treatment, sizing, packaging, transportation and disposal of the solid secondary waste generated during Silos 1 and 2 waste remediation operation.

C.4.4.2.5 Methodology

The methods used to prepare the O&M cost estimate are discussed next.

FDF Labor Cost

An activity-based level-of-effort support estimate was developed using the basis of design, preconceptual design drawings, and the technical judgement of senior FDF operation, maintenance, and waste management supervisory personnel. The FY99 plan labor rates were then applied to the estimated resources to obtain the FDF O&M labor cost estimate.

Material Cost

The material (consumables and spare parts) cost estimate is based on information provided by the POP contractor's final report.

Utility Cost

The utility cost estimates is based on information provided by the POP contractor's final report.

Contractor's Technical Support Cost

The contractor's technical support cost estimate is based on information provided by the POP contractor's final report.

Risk Budget

Risk budget is the cost allowance for risk and uncertainties associated with the O&M of the Chemical Stabilization — Cement-based facility. The risk budget was developed following analyses of the probability of schedule delays based on technology, historical data and professional judgement (see **Table C.4.4-9**).

The O&M risk budget was determined to be 24% of operation, maintenance, and project management cost. The 24% risk factor is calculated using the FEMP cost risk analysis program; it is based on an operational schedule risk of 10.2 months of delay due to potential start-up problems and downtime associated with spare parts of specialized equipment.

Secondary Waste Cost

The secondary waste cost is estimated as the volume of the spare parts, filter, and PPE material cost. All secondary waste is packaged and disposed of the NTS.

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ACRONYMS & ABBREVIATIONS

CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
COC	constituents of concern
DOE	U.S. Department of Energy
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
FS/PP-EIS	Feasibility Study/Proposed Plan-Environmental Impact Statement
NEPA	National Environmental Policy Act
NTS	Nevada Test Site
OU	operable unit
ROD	Record of Decision
SEIS	Supplemental Environmental Impact Statement

D.1.0 NEPA SUPPPLEMENT ANALYSIS

D.1.1 Requirements for Conducting a Supplement Analysis

This appendix provides an evaluation of the alternatives being considered for the remediation of the Silos 1 and 2 material and a recommendation as to the appropriate level of National Environmental Policy Act (NEPA) evaluation required for the action. The remediation of the Fernald silos was evaluated in the Operable Unit 4 (OU4) Feasibility Study/Proposed Plan-Environmental Impact Statement (FS/PP-EIS) (FEMP 1994).

The FS/PP-EIS evaluated the following alternatives for Silos 1 and 2:

- No action;
- Removal, vitrification, on-property disposal of Silos 1 and 2 material;
- Removal, cement stabilization, on-property disposal of Silos 1 and 2 material;
- Removal, vitrification, and off-site disposal at the Nevada Test Site (NTS) for Silos 1 and 2 material; and
- Removal, cement stabilization, and off-site disposal at the NTS for Silos 1 and 2 material.

The FS/PP-EIS was approved by the U.S. Department of Energy (DOE) and the U.S. Environmental Protection Agency (EPA) through the issuance of a Record of Decision (ROD), which identified vitrification followed by off-site shipment and disposal at the NTS as the selected remedy, on December 7, 1994 (EPA 1994).

After issuance of the ROD, it was determined that a modest cost savings could be achieved by shipping material for disposal via truck as opposed to the combination of rail/truck evaluated in the OU4 FS/PP-EIS. Therefore, a Supplement Analysis (FEMP 1995) to the original EIS was prepared and approved on January 9, 1996 by DOE concluding that preparation of a full Supplemental Environmental Impact Statement (SEIS) was not required.

The post-ROD treatability studies determined that the implementability of the vitrification technology is more difficult than originally anticipated. Although the studies indicated that vitrification of the Silo 3 material is technically feasible, they also demonstrated that continuous processing of the Silo 3 material by vitrification is hindered by the high concentrations of sulfates in the material. In addition, data from the pilot-scale studies and other post-ROD information indicate that the cost estimate for implementation of vitrification for the Silos 1 and 2 material has substantially increased compared to the cost estimate presented in the OU4 FS/PP-EIS.

As a result of the above findings, the EPA and DOE agreed to (1) select a treatment technology other than vitrification for the remediation of the Silo 3 material, and (2) to re-evaluate vitrification against other remediation technologies, with an emphasis on implementation costs, for the Silos 1 and 2 material. In addition, during the reevaluation of the path forward for remediation of OU4, it was identified that accelerating the waste retrieval portion of the Silos 1 and 2 remedial alternative could potentially result in significant programmatic and environmental benefit.

Accordingly, a Supplement Analysis evaluating the Silo 3 remediation alternatives was prepared and approved by DOE on August 20, 1996 (FEMP 1996), and a Supplement Analysis for the Accelerated Waste Retrieval of the Silos 1 and 2 material was approved March 3, 1998 (FEMP 1998).

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This fourth Supplement Analysis to the OU4 FS/PP-EIS also serves as a revised FS for consideration of alternatives for the remediation of the Silos 1 and 2 material. The alternatives evaluated in the revised FS are similar to those evaluated in the original FS/PP-EIS; they involve treatment of the Silos 1 and 2 material by either vitrification or chemical stabilization followed by off-site shipment and disposal at the NTS. The following alternatives are evaluated in the revised FS:

- Removal, On-site Vitrification — Joule-heated, Off-site Disposal at the NTS;
- Removal, On-site Vitrification — Other, Off-site Disposal at the NTS;
- Removal, On-site Chemical Stabilization — Cement-based, Off-site Disposal at the NTS; and
- Removal, On-site Chemical Stabilization — Other, Off-site Disposal at the NTS.

D.1.2 Relevant Regulations

There are two relevant regulations dealing with the decision of whether or not to prepare a SEIS: (1) the Council on Environmental Quality's (CEQ's) NEPA implementation regulations [40 Code of Federal Regulations (CFR) Part 1500]; and (2) the DOE's NEPA implementing regulations (10 CFR Part 1021).

D.1.3 Evaluating Proposed Changes

Both the CEQ and DOE regulations require an agency to prepare a SEIS when the agency has made a substantial change in a proposed action, or if there are new significant circumstances in the proposed EIS action that are relevant to environmental concerns. The agency may also prepare a SEIS if it determines that the purposes of NEPA would be furthered by the supplement.

In addition, the DOE NEPA regulations require the preparation of a "Supplement Analysis" where the decision to prepare a SEIS is unclear (10 CFR Part 1021.314). The Supplement Analysis should discuss changed or new circumstances that are pertinent in determining whether or not to prepare a SEIS. The discussion should therefore contain sufficient information for DOE to determine that new NEPA documentation **is not** required, or that a SEIS or new EIS **is** required.

D.1.4 Applying the "Rule of Reason"

It is inevitable that new information is learned after the finalization of an EIS; and, NEPA case law confirms that an agency does not need to supplement an EIS every time new information comes to light. The agency should, however, take a hard look at the environmental impacts of its planned action. It should apply a "rule of reason" in deciding whether or not to prepare a SEIS.

In applying this rule of reason, the agency should evaluate factors related to the new information or circumstances for the action. These factors might include the environmental significance and probable accuracy of the new information or circumstances, the care that the agency used to evaluate the information and its impact, and the degree to which the information supports the agency's decision of whether to prepare a SEIS.

D.1.5 Approval of a Supplement Analysis and SEIS by DOE

If a Supplement Analysis is developed for determination of whether to prepare a SEIS, this information should be made available to the public. If the Supplement Analysis supports the decision to supplement the original EIS, DOE must meet the same requirements for filing an EIS (e.g., preparing a ROD). One exception here is that the public scoping requirements are optional if the scope of the proposed action has not changed from the original EIS.

D.2.0 EVALUATION OF ALTERNATIVES

D.2.1 On-site Joule-heated Vitrification - Off-site Disposal at the NTS (VIT1)

This alternative involves the removal, on-site treatment through Vitrification - Joule-heated, and off-site disposal at the NTS of the treated Silos 1 and 2 material. Included in this alternative is construction of a feed preparation system to prepare and deliver a feed slurry containing both silos material and glass-formers to the melter, a nominal 15-ton per day joule-heated melter, and a melter off-gas system to provide necessary treatment of effluent gases. The full-scale treatment facility also includes many support systems such as product cooling, wastewater treatment, off-specification material rework, building ventilation, and personnel support facilities. Additionally, the remediation facility includes an interim storage facility capable of handling 45 days of production capacity in order to accommodate the waste verification process and intermittent disruptions in the FEMP shipping program. This alternative involves the packaging, loading, and shipping of vitrified material for disposal at the NTS via truck or intermodal transportation. A detailed discussion of this alternative is available in **Section 3.2.1.**

The treatment and disposal aspects of this alternative were evaluated in the original OU4 FS/PP-EIS. In addition, the scenario of transporting treated silos material to the NTS via truck was evaluated in a Supplement Analysis to the OU4 FS/PP-EIS that was approved by DOE on January 9, 1996 and is reviewed again in this revised FS. This alternative does not represent a significant change in scope from the evaluation in the OU4 FS/PP-EIS.

Potential environmental impacts, including human health risks, are consistent with those evaluated in the original EIS. Impacts are limited because the project is carried out in previously disturbed areas and employs the appropriate engineering controls. Short- and long-term human health risks, to both workers and the public, associated with this alternative fall within the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) target risk range of 10^{-4} - 10^{-6}; this includes risks associated with transportation and disposal of the treated material. A full discussion of the potential environmental impacts is included in **Sections 3.2.4** and **3.2.6.**

D.2.2 On-site Vitrification other than Joule-heated - Off-site Disposal at the NTS (VIT2)

This alternative is identical to the alternative presented in **Section D.2.1** with the exception of the type of melter that is utilized. A melter, other than a joule-heated melter, vitrifies the Silos 1 and 2 material. Included in this alternative is construction of a feed preparation system to prepare and deliver a dry feed containing both silos material and glass-formers to the melter, a nominal 15-ton per day combustion-heated melter, and a melter off-gas system to provide necessary treatment of effluent gases. The full-scale treatment facility also includes many support systems such as product forming, wastewater treatment, off-specification material rework, building ventilation, and personnel support facilities. Additionally, the remediation facility includes an interim storage facility capable of handling 45 days of production capacity in order to accommodate the waste verification process and intermittent disruptions in the FEMP shipping program. This alternative involves the packaging, loading, and shipping of vitrified material for disposal at the NTS via truck or intermodal transportation. A detailed discussion of this alternative is available in **Section 3.3.1.**

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D.4.0 REFERENCES

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1 Documentation of Remedial Investigation/Feasibility Study activities for each operable unit is made available for public review. The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Administrative Records for the FEMP site are located at the Public Environmental Information Center (PEIC) in Harrison, OH. 513-648-7480.

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ACRONYMS & ABBREVIATIONS

AEA	Atomic Energy Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
Ci/g	curies per gram
DOT	U.S. Department of Transportation
FEMP	Fernald Environmental Management Project
ILCR	incremental lifetime cancer risk
ISO	international shipping organization
LCF	latent cancer fatalities
LSA	low specific activity
mrem/hr	millirem per hour
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NPL	National Priorities List
NTS	Nevada Test Site
pCi/g	picoCuries/gram
rem/h	roentgen equivalent man per hour
WAC	waste acceptance criteria

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E.2.0 DOT CLASSIFICATION

As stated previously, for purposes of waste management and proper disposal at the NTS, the Silos 1 and 2 material is classified as by-product material as defined in Section 11(e)(2) of the AEA of 1954. For purposes of proper transportation, the material is governed by the DOT regulations under 49 CFR Subtitle B Other Regulations Relating to Transportation; Chapter I, Research and Special Programs Administration, Subchapter C, Hazardous Materials Regulations.

E.2.1 Low Specific Activity – Type II Material Determination

DOT regulations, under 49 CFR Part 173.403 categorize low specific activity (LSA) material into three classifications: LSA-I, LSA-II, and LSA-III. To be considered LSA material, the material need only meet one of the criteria under one of the classifications.

LSA-II material can be:

i) Water with a tritium concentration up to 20 Ci/L; or

ii) Other material in which the radioactive material is distributed throughout and the estimated average specific activity does not exceed 10^{-4} A_2/g for solids and gases, and 10^{-5} A_2/g for liquids.

The A_2 value is defined as the maximum activity of radioactive material, other than special form or low specific activity radioactive material, permitted in a Type A package. A list of A_2 values for most radionuclides is presented in 49 CFR Part 173.435. In addition, the A_2 value for a mixture of radionuclides can be determined in accordance with 49 CFR Part 173.433(d).

The OU4 silo material is not aqueous and does not contain tritium. Therefore, silo material does not meet the first criterion for LSA-II.

Evaluation of the radionuclide content for Silos 1 and 2 material indicates that it meets the second criterion for LSA-II material. Therefore, Silos 1 and 2 material could be classified as LSA-II material under DOT regulations. The results of the LSA-II determination on Silos 1 and 2 material are presented in **Table E.2.1-1** and discussed below.

Table E.2.1-1 presents the source term for the Silos 1 and 2 material, as well as the LSA-II classification determination. Columns 2 and 3 present the activity for each radionuclide in picoCuries/gram (pCi/g) and curies per gram (Ci/g), respectively. The activities in Column 3 were summed together to provide a total activity for the mixture of radionuclides. This value is presented at the bottom of Column 3. Column 4 presents the fractional contribution (f_i) of each radionuclide by dividing the activity for each radionuclide in the Silos 1 and 2 material by the total activity. For Silos 1 and 2 material, the total activity is approximately 3.71×10^{-6} Ci/g.

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TABLE E. 2.1-1

RAW K-65 MATERIAL LSA-II SOLID DETERMINATION

Radionuclide	Source Term K-65 Mat. (pCi/g)	Source Term K-65 Mat. (Ci/g)	f(I)	A_2 Limit (Ci)	$f(I)/A_2$ (Ci^{-1})	LSA-II Limit $10^{-4} \times A_2$ (Ci/g)	Fraction of LSA-II Limit
Ac-227	7.67E+03	7.67E-09	2.07E-03	5.41E-04	3.82E+00	1.10E-05	6.97E-04
Ac-228	1.11E+03	1.11E-09	2.99E-04				
Bi-210	2.02E+05	2.02E-07	5.44E-02				
Bi-211	7.67E+03	7.67E-09	2.07E-03				
Bi-212	7.36E+03	7.36E-09	1.98E-03				
Bi-214	4.77E+05	4.77E-07	1.29E-01				
Fr-223	1.10E+02	1.10E-10	2.96E-05				
Pa-231	4.04E+03	4.04E-09	1.09E-03	1.62E-03	6.72E-01	1.10E-05	3.67E-04
Pa-234	1.79E+00	1.79E-12	4.82E-07				
Pa-234m	1.12E+03	1.12E-09	3.02E-04				
Pb-210	2.02E+05	2.02E-07	5.44E-02	2.43E-01	2.24E-01	1.10E-05	1.84E-02
Pb-211	7.67E+03	7.67E-09	2.07E-03				
Pb-212	7.36E+03	7.36E-09	1.98E-03				
Pb-214	4.77E+05	4.77E-07	1.29E-01				
Po-210	2.81E+05	2.81E-07	7.57E-02	5.41E-01	1.40E-01	1.10E-05	2.55E-02
Po-211	2.30E+01	2.30E-11	6.20E-06				
Po-212	1.70E+03	1.70E-09	4.58E-04				
Po-214	4.41E+05	4.41E-07	1.19E-01				

TABLE E. 2.1-1 (continued)

Radionuclide	Source Term K-65 Mat. (pCi/g)	Source Term K-65 Mat. (Ci/g)	f(I)	A_2 Limit (Ci)	$f(I)/A_2$ (Ci^{-1})	LSA-II Limit $10^{-4} \times A_2$ (Ci/g)	Fraction of LSA-II Limit
Po-215	7.67E+03	7.67E-09	2.07E-03				
Po-216	7.36E+03	7.36E-09	1.98E-03				
Po-218	4.77E+05	4.77E-07	1.29E-01				
Ra-223	7.67E+03	7.67E-09	2.07E-03	8.11E-01	2.55E-03	1.10E-05	6.97E-04
Ra-224	7.36E+03	7.36E-09	1.98E-03				
Ra-226	4.77E+05	4.77E-07	1.29E-01	5.41E-01	2.38E-01	1.10E-05	4.34E-02
Ra-228	1.11E+03	1.11E-09	2.99E-04	1.08E+00	2.77E-04	1.10E-05	1.01E-04
Rn-219	7.67E+03	7.67E-09	2.07E-03				
Rn-220	7.36E+03	7.36E-09	1.98E-03				
Rn-222	4.77E+05	4.77E-07	1.29E-01				
Th-227	7.56E+03	7.56E-09	2.04E-03	2.70E-01	7.54E-03	1.10E-05	6.88E-04
Th-228	7.36E+03	7.36E-09	1.98E-03	1.08E-02	1.84E-01	1.10E-05	6.69E-04
Th-230	7.62E+04	7.62E-08	2.05E-02	5.41E-03	3.80E+00	1.10E-05	6.93E-03
Th-231	9.40E+01	9.40E-11	2.53E-05				
Th-232	1.11E+03	1.11E-09	2.99E-04	unlimited			
Th-234	1.12E+03	1.12E-09	3.02E-04	5.41E+00	5.58E-05	1.10E-05	1.02E-04
Tl-207	7.65E+03	7.65E-09	2.06E-03				
Tl-208	2.65E+03	2.65E-09	7.14E-04				

TABLE E. 2.1-1 (continued)

Radionuclide	Source Term K-65 Mat. (pCi/g)	Source Term K-65 Mat. (Ci/g)	f(I)	A_2 Limit (Ci)	$f(I)/A_2$ (Ci^{-1})	LSA-II Limit $10^{-4} \times A_2$ (Ci/g)	Fraction of LSA-II Limit
U-234	1.16E+03	1.16E-09	3.13E-04	2.70E-02	1.16E-02	1.10E-05	1.05E-04
U-235	9.40E+01	9.40E-11	2.53E-05	unlimited			
U-238	1.12E+03	1.12E-09	3.02E-04	unlimited			
Sum		3.71E-06			9.09		9.76E-02
		A_2 (Ci) =		Sum^{-1} =	0.110		
		LSA-II limit =	$10^{-4} \times A_2$	(Ci/g) =	1.10E-05		

The A_2 value for the mixture was determined in accordance with 49 CFR Part 173.433(d)(2)(ii):

$$A_2 = 1/(\sum_I f_{(I)}/A_{2(I)}) \qquad \text{(Eq.1)}$$

where f_i/A_{2I} is the fraction of activity of nuclide "I" in the mixture compared to the radionuclide's respective A_2 value.

There are three decay chains associated with Silos 1 and 2 material: uranium-238, uranium-235, and thorium-232. These three decay chains were divided into "sub-chains" in which each parent nuclide had a half-life greater than 10 days. Radionuclides with a half-life less than 10 days were considered to be in secular equilibrium with their parent nuclide so only the A_2 value associated with the parent nuclide was used in determining the A_2 value for the mixture, as allowed under 49 CFR Part 173.433(c). Column 5 of the Table provides the A_2 value for those radionuclides with a half-life greater than 10 days.

Column 6 presents the fraction of activity for each radionuclide compared to the radionuclide's respective A_2 value (Column 4 values divided by Column 5 values). The inverse of the sum of these values equals the A_2 value for the mixture. This calculation is provided at the bottom of Column 6. For Silos 1 and 2 material, the A_2 value is determined to be approximately 0.11 Ci.

One of the definitions for LSA-II material requires that the activity of a material be less than 10^{-4} times the calculated A_2 value per gram (10^{-4} A_2/g). This value is calculated at the bottom of Column 6 and presented in Column 7. For Silos 1 and 2 material, the LSA-II limit is determined to be approximately 1.1×10^{-5} Ci/g.

Column 8 then calculates the fraction of activity for each radionuclide compared to the calculated LSA-II limit determined for the mixture (Column 3 values divided by Column 7 values). For a mixture of radionuclides, the sum of the fractions must be less than "1" to be classified as LSA-II material. The sum of the fractions for Silos 1 and 2 material is determined to be approximately 0.0976. Therefore, Silos 1 and 2 material qualifies as LSA-II material. Documented discussions with DOT representatives have verified this determination.

E.2.2 Fissile-Exempt Material Determination

Similar to the approach used for determining whether Silos 1 and 2 material meets the criteria for LSA material, an evaluation was performed to determine whether the Silos 1 and 2 material should be classified as fissile material or fissile-exempt material under the DOT regulations.

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The definition for fissile material under the DOT regulations excludes; "Unirradiated natural uranium and depleted uranium and natural or depleted uranium which has been irradiated in thermal reactors." The material in Silos 1 and 2 is by-product material resulting from the processing of natural uranium ore. In addition, the material in Silos 1 and 2 is unirradiated. Therefore, by definition, Silos 1 and 2 material should be "fissile exempt." However, because the material in Silos 1 and 2 has been processed to remove the uranium content, further evidence of Silos 1 and 2 material being "fissile exempt" has been evaluated against the requirements under 49 CFR Part 173.453.

Since silo material contains uranium-235, a fissile radionuclide, the exceptions under 49 CFR Part 173.453 must be evaluated to determine whether the Silos 1 and 2 material needs to be classified as fissile. To be considered "fissile exempt," only one of the criteria listed in the exceptions under 49 CFR Part 173.453 must be met.

49 CFR Part 173.453 states that the requirements of §173.451 through 173.459 do not apply to the following:

(a) A package containing not more than 15 grams of fissile radionuclides. If the material is transported in bulk, the quantity limitation applies to the conveyance.

(b) A package containing homogenous solutions or mixtures where

(i) The minimum ratio of the number of hydrogen atoms to the number of atoms of fissile radionuclides (H/X) is 5200;

(ii) The maximum concentration of fissile radionuclides is 5 grams per liter; and

(iii) The maximum mass of fissile radionuclides in the package is 500 grams, except that for a mixture in which the total mass of plutonium and uranium-233 does not exceed 1% of the mass of uranium-235, the limit is 800 grams. If the material is transported in bulk, the quantity limitations apply to the conveyance.

(c) A package containing uranium enriched in uranium-235 to a maximum of 1% by mass, and with a total plutonium and uranium-233 content of up to 1% of the mass of uranium-235, if the fissile radionuclides are distributed homogeneously throughout the package contents, and do not form a lattice arrangement within the package.

(d) A package containing not more than 5 grams of fissile radionuclides in any 10-liter volume, provided that the material is contained in packages that will maintain the limitation on fissile radionuclide distribution during normal conditions of transport.

(e) A package containing one kilogram or less of plutonium of which 20% or less by mass may consist of plutonium-239, plutonium-241, or any combination of those radionuclides.

(f) A package containing liquid solutions of uranyl nitrate enriched in uranium-235 to a maximum of 2% by mass, with total plutonium and uranium-233 not exceeding 0.1% of the mass of uranium-235 with a nitrogen-to-uranium atomic ratio (N/U) of 2.

Treated Silos 1 and 2 material, for the four alternatives, will meet exception criterion (d).

The proposed container for joule-heated vitrified waste will have a payload of approximately 9,000 pounds (4.08×10^6 grams). The activity of uranium-235 per unit mass of joule-heated vitrified Silos 1 and 2 material is approximately 8.46×10^{-11} Ci/g, based on a source term of 9.4×10^{-11} Ci/g and a waste loading of 90 wt%. A container filled to capacity would include approximately 3.45×10^{-4} Ci of uranium-235 in each package. The specific activity of uranium-235 is 2.20×10^{-6} Ci/g as presented in the table under 49 CFR Part 173.435. As a result, approximately 157 grams of uranium-235 would be in each customized container (3.45×10^{-4} Ci x 1 g/2.20×10^{-6} Ci). The volume capacity of the customized container for joule-heated vitrified waste is approximately 61 ft^3 (1,728 liters). As a result, the concentration of uranium-235 from joule-heated vitrified Silos 1 and 2 material would be 0.091 g/L.

The proposed container for the combustion-heated vitrified waste will have a payload of approximately 9,800 pounds (4.44×10^6 grams). The activity of uranium-235 per unit mass of combustion-heated vitrified Silos 1 and 2 material is approximately 8.18×10^{-11} Ci/g based on a source term of 9.4×10^{-11} Ci/g and a waste loading of 87 wt%. A container filled to capacity would include approximately 3.63×10^{-4} Ci of uranium-235 in each package. Using the specific activity for uranium-235 of 2.20×10^{-6} Ci/g, approximately 165 grams of uranium-235 would be in each package. The volume capacity of the customized container for combustion-heated vitrified waste is approximately 121 ft^3 (3,427 liters). As a result, the concentration of uranium-235 from combustion-heated vitrified Silos 1 and 2 material would be approximately 0.048 g/L.

The proposed container for chemically stabilized cement-based waste will have a payload of approximately 11,483 pounds (5.21×10^6 grams). The activity of uranium-235 per unit mass of cement-based stabilized Silos 1 and 2 material is approximately 2.82×10^{-11} Ci/g based on a source term of 9.4×10^{-11} Ci/g and a waste loading of 30 wt%. A container filled to capacity would include approximately 1.47×10^{-4} Ci of uranium-235 in each package. Using the specific activity for uranium-235 of 2.20×10^{-6} Ci/g, approximately 67 grams of uranium-235 would be in each customized container. The volume capacity of the customized container for cement-based stabilized waste is approximately 138.6 ft^3 (3,925 liters). As a result, the concentration of uranium-235 from cement-based stabilized Silos 1 and 2 material would be 0.017 g/L.

The proposed container for chemically stabilized waste will have a payload of approximately 14,536 pounds (6.59×10^6 grams). The activity of uranium-235 per unit mass of chemically stabilized Silos 1 and 2 material is approximately 2.26×10^{-11} Ci/g, based on a source term of 9.4×10^{-11} Ci/g and a waste loading of 24 wt%. A container filled to capacity would include approximately 1.49×10^{-4} Ci of uranium-235 in each package. Using the specific activity for uranium-235 of 2.20×10^{-6} Ci/g, approximately 68 grams of uranium-235 will be in each customized container. The volume capacity of the customized container for chemically stabilized waste is approximately 166.5 ft^3 (4,715 liters). As a result, the concentration of uranium-235 from Silos 1 and 2 material would be 0.014 g/L.

Since the uranium-235 concentration is less than 5 grams per 10 liters (0.5 g/L) for the different wasteforms evaluated, this criterion can be used to classify Silos 1 and 2 material as fissile exempt.

E.2.3 Container Requirements

As stated previously, Silos 1 and 2 material is classified as LSA-II material under DOT regulations. DOT regulations restrict the quantity of LSA material in a single package so that the external radiation level at 3 meter (m) from the unshielded material does not exceed 1 roentgen equivalent man per hour (rem/h).

The maximum radiation level associated with the unshielded Silos 1 and 2 material is approximately 900 mrem/h on contact. This level would decrease over 3 meters so that Silos 1 and 2 material would meet the LSA dose requirements with any size packaging. In addition, a limit per conveyance has not been established for non-flammable solid LSA-II material.

As a minimum, the regulations require that an industrial package-type 2 (IP-2) container be used for shipments of LSA-II material. IP-2 containers must meet the general design requirements for hazardous material shipping containers established in 49 CFR Part 173.24 and the general design requirements for radioactive material shipping containers established in 49 CFR Part 173.410 of the regulations. In addition, the regulations require that IP-2 containers undergo the free drop test [49 CFR Part 173.465(c)] and the stacking test [49 CFR Part 173.465(d)] preventing loss or dispersal of the radioactive contents and preventing an increase of 20% in the radiation levels recorded or calculated at the external surface of the container prior to the tests.

In addition to the requirements established by the DOT, the container must be designed to meet the requirements established in the NTS waste acceptance criteria (WAC). Because of the shielding necessary to meet DOT radiation level limits for protection of workers and the public and the goal to minimize packaging and shipments, an exemption from two NTS WAC requirements would be necessary. Exemptions would be needed to allow for a container larger than a 4 foot by 4 foot by 7 foot container and to allow for a container with a gross weight greater than 9,000 pounds. Given the quantity of containers associated with the disposal of Silos 1 and 2 material and the intent of these requirements in the NTS WAC, the NTS has expressed a willingness to waive the requirements for Silos 1 and 2 material. However, the container would be designed to meet a compression test of 3,375 pounds per cubic foot in order to prevent subsidence of soil after disposal.

The quantity of material that would be placed in a single container would be limited by the rated capacity of the container, while the quantity placed on each truck would be limited to an amount that maintains each shipment within legal weight limits.

The FEMP generally places a payload limit of 42,000 pounds to account for the weight of the truck, fuel, tiedown and other factors (e.g., ice buildup) to keep the gross weight of the vehicle below 80,000 pounds. As a result, two full IP-2 containers weighing approximately 21,000 pounds each could be placed on each truck. In addition, if treated Silos 1 and 2 material is shipped to the NTS by intermodal transport (combination truck and rail), two IP-2 containers could be placed into an international shipping organization (ISO) container with one ISO container per truck and two ISO containers per railcar.

DOT has established a radiation level limit of 200 millirem per hour (mrem/hr) for the external surface of a package and a transport index limit of 10 for each package of radioactive material offered for transportation [49 CFR Part 173.441(a)]. Packages exceeding either of these radiation level limits must be shipped as "exclusive use" with the following radiation level limitations:

- 200 mrem/hr on the external surface of the package;
- close transport requirements;
- 200 mrem/hr at any point on the outer surfaces of the transport vehicle, including the top and underside of the vehicle;
- 10 mrem/hr at any point two meters from the outer lateral surface of the transport vehicle, excluding the top and underside of the vehicle; and
- 2 mrem/hr in any normally occupied space, except where private carriers operate under a State or federally regulated radiation protection program and the personnel wear radiation dosimetry devices.

Containers of treated Silos 1 and 2 material will be shipped under exclusive use conditions due to exceeding the transport index limit of 10. As stated previously, one of the requirements for shipping under exclusive use conditions is a radiation level limit of 10 mrem/hr at a point 2 m from the outer lateral surface of the transport vehicle. Based on the "Final Report on Container Optimization for Vitrified K-65 and Silo 3 Residues," issued by Foster-Wheeler Environmental, February 1995, as well as, the development of a prototype container performed under the DOE Program Research and Development Announcement contract by Scientific Ecology Group, it was determined that to meet this requirement the surface radiation level of a container could not exceed 70 mrem/hr. Placing two containers with surface radiation levels greater than 70 mrem/hr on a transport vehicle would limit the ability to meet DOT radiation level limits without additional shielding. Therefore, the FEMP has set an administrative limit for surface radiation level limits of 70 mrem/hr.

E.2.4 Container Optimization

Containers for shipping and disposing of treated Silos 1 and 2 material have been optimized to ensure that the maximum amount of stabilized material is being shipped with each container, thus minimizing the total number of containers to be disposed and reducing the total life cycle cost. The container size was optimized for shielding and payload based on the proposed waste loading for the treatment alternative, as well as, the estimated packaging density calculated for each treated wasteform.

The containers proposed for the four respective treatment alternatives were optimized with the intention of having a gross container weight that would not exceed 9,555 kg (21,000 lb). This would allow two containers to be loaded on each shipment and still comply with the 19,110 kg (42,000 lb) payload limit established in FEMP Site Procedure PT-0006, Packaging Low-Level Radioactive Waste in ISO Containers. This limit was established based on the 36,288 kg (80,000 lb) gross vehicle weight (i.e., trailer, fuel, tie-down equipment, payload, etc.) limit for over-the-road shipments.

The density and waste loading of the treated material were factored into the design of the containers for minimization of void space while optimizing payload and shielding present in each container. In September 1996, an optimization study for vitrified gems entitled "SEG Design Completion Report Enduropak SIFCON Concrete Packaging for OU4 Vitrified Materials" determined that existing containers on the commercial market either (1) offer the necessary amount of shielding but result in an excess amount of void space or (2) allow for an optimum payload but fail to provide enough shielding to meet the DOT requirements. In addition, the container designed for vitrified gems was not optimized for the chemical stabilization alternatives because it offered an excessive amount of shielding at the expense of payload.

The containers proposed for the four alternatives were designed to minimize void space to less than 10% of the allowable volume of the container and thereby maximize payload. In addition, the containers were designed to maintain radiation levels within the DOT requirements under 49 CFR Part 173.441 and the FDF administrative radiation level limit of 70 mrem/hr for the surface of the container.

Table E.2.4-1 presents the proposed container design for the four treatment alternatives being evaluated. Detailed descriptions and drawings of the containers proposed for each treatment technology alternative are presented in **Appendix G** of this document.

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TABLE E. 2.4-1
PROPOSED CONTAINER DESIGN

	VIT1	VIT2	CHEM1	CHEM2
Material of Construction	Concrete Slurry Reinforced with Steel Fibers	High Density Concrete	High Density Concrete	Carbon Steel
Internal Dimensions (m)	1.07 x 1.52 x 1.07	1.73 x 1.42 x 1.40	1.78 x 1.50 x 1.47	1.89 x 1.68
External Dimensions (m)	1.37 x 1.83 x 1.47	1.98 x 1.68 x 1.75	1.98 x 1.70 x 1.78	1.93 x 1.71
Wall Thickness (cm)	15.24	12.7	10.16	1.905

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F.6.1.6 Disposition of Demolished Structures and Debris

F.6.1.6.1 OU4 ROD Selected Remedy

The selected remedy as defined under Alternative 2C specified on-property disposal for OU4 contaminated rubble and debris. However, this final action was held in abeyance until a decision was reached in the OU3 ROD (FEMP 1996a) for the final treatment and disposal of rubble and debris. The final decision on disposal of rubble and debris, generated from the demolition of the OU4 silos and other facilities, was determined as part of the ROD for OU3. The OU4 waste was to be managed consistent with the disposal remedy put forth in the OU3 ROD for contaminated rubble and debris. In the unlikely event that unforeseen circumstances preclude the integration of OU4 rubble and debris into the OU3 treatment and disposal decision, the disposal decision for OU4 rubble and debris would be documented in a ROD amendment for OU4 in accordance with Section 117(c) of CERCLA and EPA guidance. The ROD amendment would provide the public and the EPA further opportunity to review and comment on the on-property disposal option for OU4 rubble and debris. A ROD amendment to the OU4 ROD would not be necessary in the event that the OU3 remedy for rubble and debris could be feasibly implemented by OU4.

F.6.1.6.2 Post-OU4 ROD Activities

The OSDF will be available for disposal of debris from the existing Silos 3 and 4 structures and associated facilities (superstructures and RTS). Soil and debris from D&D activities associated with these facilities will be disposed in the OSDF if they meet the OSDF WAC for disposal. Any soils and debris that do not satisfy the OSDF WAC will be disposed at the NTS or an appropriately licensed commercial facility.

Criteria for the disposal of waste materials into the OSDF are documented in the *Waste Acceptance Criteria Attainment Plan for the On-site Disposal Facility* (FEMP 1998). The current version was issued in June 1998 following approval by the EPA and OEPA. The OSDF WAC for debris were established in the OU3 ROD (FEMP 1996a). The OSDF WAC Attainment Plan provides that these criteria can be applied to debris for other OUs, including OU4, consistent with the provisions of the ROD for each OU.

The OU3 ROD classified debris into ten distinct material categories based upon similar or inherent properties and configuration. Two categories, Category C – Process-related Metals and Category J – Product, Residues, and Special Materials, were administratively excluded from on-site disposal. In evaluating on-site disposal for concrete (Category E), the OU3 ROD focused primarily on structural concrete. The evaluation did not consider the potential impact of prolonged contact with residues or other contaminants, such as a concrete storage silo.

<END OF PAGE>

The concrete in Silos 1 and 2 has been in contact with contaminated material for over 30 years. Because of the relatively mobile COCs and the high moisture content associated with the Silos 1 and 2 material, there is a significant potential for migration of contaminants into the concrete. The depth and extent of the migration of the COCs into the concrete and the ability and cost of adequately decontaminating the concrete is uncertain.

Therefore, the concrete from Silos 1 and 2 has been administratively excluded from disposal in the OSDF. The concrete from Silos 1 and 2 will undergo gross decontamination followed by demolition, size reduction, and packaging for off-site disposal. Disposal of concrete from Silos 1 and 2 will be at the NTS or an appropriately licensed commercial facility.

Based on the current operating schedule, the FEMP OSDF will not be available for disposal of soil and debris generated from D&D of the Silos 1 and 2 remediation facilities. Therefore, for costing purposes, the revised FS and PP assume that all soil and debris from D&D of the OU4 remediation facilities will be disposed at the NTS. However, should programmatic changes occur and the OSDF become available, soil and debris meeting the OSDF WAC would be disposed in the OSDF in the same manner as discussed above for Silos 3 and 4 and associated facilities.

<END OF PAGE>

F.6.1.6.3 Summary of Disposition of OU4 Structures and Debris

Holding the OU4 on-property disposal decision in abeyance fostered an integrated site-wide disposal program for rubble and debris. The volume of rubble and debris to be generated from OU4 was anticipated to be less than 1% of the volume expected to be generated site-wide. The largest volume of rubble and debris from the site would be generated from OU3, making it more appropriate to fully develop the on-property disposal option for rubble and debris through the OU3 ROD (FEMP 1996a). Additionally, OU4 has been able to take advantage of any available waste minimization initiatives developed for rubble and debris that are identified in the OU3 ROD and subsequent remedial design documentation.

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[1] Documentation of Remedial Investigation/Feasibility Study activities for each operable unit is made available for public review. The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Administrative Records for the FEMP site are located at the Public Environmental Information Center (PEIC) in Harrison, OH. 513-648-7480.

G.1.0 INTRODUCTION AND TECHNOLOGIES SUMMARIES

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G.1.1 Introduction

Per order of the U.S. Environmental Protection Agency (EPA), Silos 1 and 2, along with the material stored in them, are required to be removed, stabilized, packaged, and shipped for disposal off-site ([1]EPA 1991). This document contains design criteria and design descriptions of four alternative methods for accomplishing this task.

G.1.1.1 Silos Background

Silos 1 and 2 contain thorium- and radium- bearing Silos 1 and 2 material, known as "K-65 residues," which are the remains left from the processing of Belgian Congo and Australian pitchblende ores. he Silos 1 and 2 material is contained in two large silos, which are often referred to as the *K-65 Silos* or *Silos 1 and 2*, located at the Fernald Environmental Management Project (FEMP). The K-65 residue (or material) is also referred to as *silos material(s), residue(s)*, or waste(s). The Silos 1 and 2 material is a major source of radon because of its high radium curie (Ci) concentrations. The Silos 1 and 2 material also contain high curie concentrations of radioactive lead and thorium, Lead-210, and Thorium-230. The amounts of radioactive constituents are given in **Section 2**. The Ci concentrations in the Silos 1 and 2 material are high; but, their presence accounts for little of the bulk mass of the constituents. The bulk constituents are described in **Section 2**. Samples of the Silos 1 and 2 material have exceeded the EPA Toxicity Characteristic Leaching Procedure (TCLP)[2] Test limit of five parts per million (ppm) for lead. Silo 1 leached an average of 614 ppm lead[3], while Silo 2 leached an average of 516 ppm lead[2].

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[1] U.S. Environmental Protection Agency (EPA). 1991. *Consent Agreement as Amended under CERCLA Sections 120 and 106(a) in Matter of: U.S. Department of Energy Feed Materials Production Center, Fernald, Ohio*. Chicago, IL: Office of Public Affairs, Region 5. (*AR Index No. G-000-710.12)

[2] The TCLP is given in 40 CFR Part 261, Appendix II. [http://www.epa.gov/epaoswer/hazwaste/test/1311.pdf]

[3] Fernald Environmental Management Project (FEMP). 1993. *Remedial Investigation Report for Operable Unit 4*. Prepared under contract for the U.S. Department of Energy: Fernald Field Office, Fernald, OH. (*AR Index Numbers Vol. I-III: U-006-304.15 – 17)

* Documentation of Remedial Investigation/Feasibility Study activities for each operable unit is made available for public review. The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Administrative Records for the FEMP site are located at the Public Environmental Information Center (PEIC) in Harrison, OH. 513-648-7480.

A hydrated BentoGrout™ clay (a bentonite product of Cetco) layer was placed in the silos in order to form a cap over the silos material that would attenuate the release of radon. The BentoGrout™ has become contaminated with Silos 1 and 2 material and now requires treatment also.

G.1.1.2 Purpose

The purpose of this document is to provide a basis for the conceptual designs, and document the conceptual process and facility designs, for four technologies being evaluated in this Revised Feasibility Study (FS) for the remediation of the Silos 1 and 2 material. The four stabilization technologies being evaluated are:

- Vitrification — Joule-heated;
- Vitrification — Other;
- Chemical Stabilization — Cement-based; and
- Chemical Stabilization — Other.

These conceptual designs will be used to establish cost estimates and allow for comparison of the four technologies in the FS process.

G.1.1.3 Structure of this Document and Presentation of the Technologies

This document is divided into seven sections. The contents of each section are briefly described below.

Section G.1 Introduction and Technology Summaries

This section gives a brief description of Operable Unit 4's (OU4) remedial requirements, the materials involved, and an introduction of the potential technologies for remediation. A brief description, with pictorials, for each technology is given. Expected quantities produced (with supporting calculations) are given for each technology.

G.1.3 Technology Summaries

The Silos 1 and 2 material, staged in the TTA, will be treated using one of the four technologies. Figures that present the quantities expected to be produced by a given technology are included in the summaries; the supporting calculations for the quantities are contained in **Attachment G-1**. The calculated quantities are based on criteria given in this document. **Table G.1.3-1**, organized by technologies, presents a summary of the quantities of treated materials produced and the number of containers required to ship it to the disposal site. The term "Waste Loading" represents the unit dry weight of Silos 1 and 2 material per unit weight of treated materials.

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TABLE G.1.3-1
ESTIMATED QUANTITIES OF TREATED MATERIALS AND CONTAINERS PRODUCED BY THE TECHNOLOGIES

Technology	Treated Form/ Container	Total Treated Waste[4], tons (without container)	Waste Loading, %	No. of Containers	Disposal Amounts (with container)		Overall Bulking Factor, %
					tons	yd^3	
Vitrification — Joule-heated	glass monoliths 4 per Scientific Ecology Group (SEG) box	9,955	90	2,398	25,179	11,635	+31
Vitrification — Other	glass frit Concrete box	10,298	87	2,162	22,461	16,450	+84
Chem. Stab. — Cement-based	grout Concrete box	33,183	30	6,078	63,637	47,652	+436
Chem. Stab. — Other	grout Steel cylinder	41,479	24	6,106	64,352	43,352	+388

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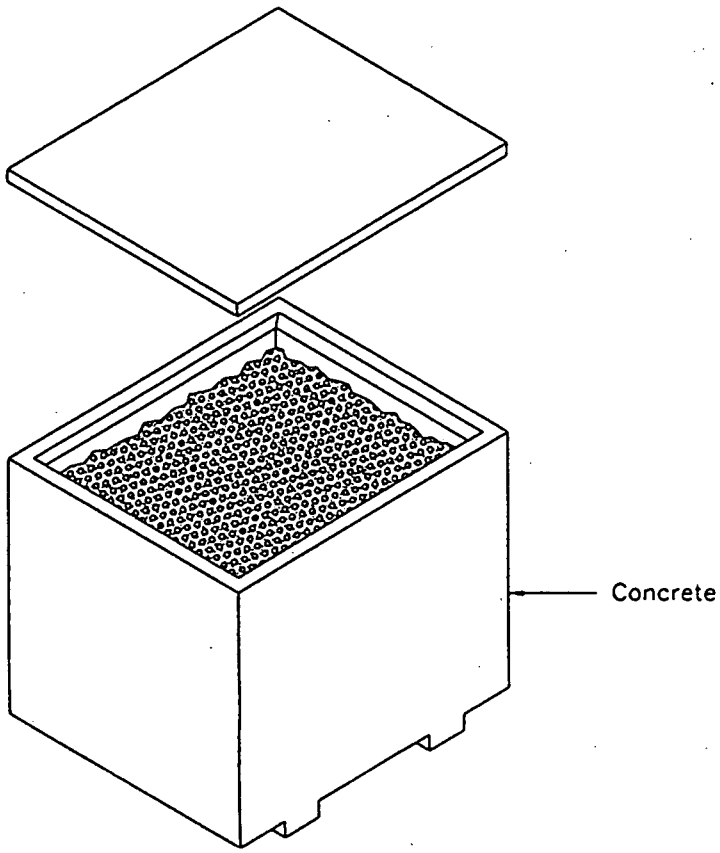
[4] The amount of Silos 1 and 2 material and BentoGrout™ requiring treatment is 14,787 tons at 30 wt% moisture or 9,955 tons dry.

FIGURE G.1.3-7
SHIPPING AND DISPOSAL CONTAINER
VITRIFICATION — OTHER



Outside Dimensions: 78" L x 66" W x 69" H x 5" wall

Vitrification – Other (Frit)

Weight of Waste per Container: 9,577 lbs

External Volume of Container: 205.6 cu. ft.

2,162 Concrete Containers

FILENAME: SHIP_BOXES

INITIALS: RWR DATE: 11/9/99

G.1.3.3 Chemical Stabilization — Cement-based

The Chemical Stabilization — Cement-based technology involves using inorganic chemicals to produce both stabilization and solidification. This technology uses Portland cement and other hydraulic binders that react with water to form a solid product. The following additives may be used: fly ash, granulated blast furnace slag, clays, pozzolans, gypsum, micro silica, or other chemical additives that reduce volume, reduce porosity (which reduces leachability), chemically alters the Silos 1 and 2 material to reduce leaching, or increases compressive strength. Also, the technology may include pretreatment to produce similar effects.

The process and facility for this technology were developed based on input from the contractor's POP report. **Appendix H, Attachment H3** contains the contractor's summary report and **Appendix H, Section H.3** contains the list of changes from the contractor's design and reasons for the changes.

The contractor representing this technology chose to mix the grout (mixture of Silos 1 and 2 material, water, and additives) in a separate batch mixer and then place the grout into the shipping and disposal container. This will be referred as "external" mixing. The container considered in this report has 4-inch concrete walls for radiation shielding purposes.[6] A dewatering step is required to increase waste loading in the final product. The contractor accommodated this requirement by running the slurry through a filter press. Slaked lime (calcium hydroxide) was added to inhibit the gelling properties of BentoGrout™ that tend to plug the filter. Iron (II) sulfate was also used to reduce the chromium (Cr^{+6}) in the slurry to chromium (Cr^{+3}) so it could be filtered with the solids and not be expelled with the filtrate. Some lead becomes soluble in the decant because of the increased pH from the calcium hydroxide addition. Chemical treatment is needed to remove lead (as a minimum) from the water before release. The solids from the filter press (filter cake) are placed into a paddle mixer. The contractor then adds additional lime and iron (II) sulfate and Portland cement with

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6 Fernald Environmental Management Project (FEMP). 1999. *Disposal Container Size Optimization Study for Chemical Stabilization — Cement*. 40730-ES-0002. Prepared under contract for the U.S. Department of Energy: Fernald Field Office, Fernald, OH. (AR Index No. U-006-409.33)

G.2.0 GENERAL DESIGN CRITERIA

Design criteria are fundamental bases or standards that a project must meet. Some criteria are intrinsic or absolute; for example, the amount of Silos 1 and 2 material that shall be treated. Other criteria are assumed values, based on best knowledge at the time, used to provide a common basis for estimating schedule and cost for the four technologies. The four technologies adhere to these criteria as much as possible in order to establish a common basis among them. The common basis allows better comparison of the technologies and their estimates. A few exceptions, necessary for a given technology, may be noted in its respective design description.

G.2.1 Silos 1 and 2 Material

This section identifies the amount of Silos 1 and 2 material and BentoGrout™ requiring treatment. It also presents the elemental composition of the material in Silos 1 and 2 as well as important characteristics, like expected moisture content and settling characteristics of the materials as slurries (i.e., K-65 materials and BentoGrout™when in the form of a slurry).

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G.2.1.1 Quantities

Table G.2.1-1 - *Silos 1 and 2 Material Quantities*, presents the quantities of material to be processed:

TABLE G.2.1-1
SILOS 1 AND 2 MATERIAL QUANTITIES[9]

Material	Silo 1 Volume (actual) ft^3	Silo 2 Volume (actual) ft^3	Dry Density (estimated) lb/ft^3	Dry Weight (calculated) tons total
Silos (K-65) Material	115,887	100,437	90.00	9,735
BentoGrout™	12,606	11,100	18.50[10]	220
Total	128,493	111,537	NA	9,955

The estimated average amount of the major radioactive constituents is presented in **Table G.2.1-2 - *Major Radionuclides in the Silos 1 and 2 Material.*** Radium, radon generation, and decay daughters are assumed to be in secular equilibrium. Concentrations given are for dry Silos 1 and 2 material.

<END OF PAGE>

[9] Values from the Fluor Daniel Fernald (FDF) Report *Waste Information Manual*, Oct. 1995. (AR Index No. U-006-409.36). Values corrected for BentoGrout™ density (see next footnote).

[10] The density of BentoGrout™ is approximately 74 lb/ft^3 as a wet slurry. The BentoGrout™ slurry contains 75 wt% water as placed in the silos. Therefore, its effective in situ dry density is approximately (74 lb/ft^3)(1.00 - 0.75) = 18.50 lb/ft^3.

TABLE G.2.1-2
MAJOR RADIONUCLIDES IN THE SILOS 1 AND 2 MATERIAL[11]

Radionuclide	Silo 1 Activity Conc., (Mean) *pCi/g	Silo 2 Activity Conc., (Mean) *pCi/g	Total Activity, Ci
Actinium-227	5,960	5,100	70
Lead-210	165,000	145,000	1,800
Polonium-210	242,000	139,000	2,439
Radium-226	391,000	195,000	3,700
Thorium-228	422	645	6.6
Thorium-230	60,000	48,400	685
Thorium-232	424	402	600
* picoCuries per gram dry Silos 1 and 2 material (pCi/g)			

G.2.1.2 Characteristics

Table G.2.1-3 - ***Silos 1 and 2 Elemental Compositions/According to PNL Analysis and FDF Analysis for SO_3***, presents the elemental makeup basis of the Silos 1 and 2 material. Approximately eight years ago, samples of the Silos 1 and 2 material were collected during the Remedial Investigation/Feasibility Study (RI/FS). Small quantities of Silos 1 and 2 material were withdrawn from three zones in each silo using a vibrating core-drilling instrument. Portions of the core-drilled samples were sent to Batelle-Pacific Northwest Laboratories (PNL) for characterization; other portions were archived. Analytical results of these tests are presented in a treatability report[12] prepared by PNL; these results are summarized in

[11] Fernald Environmental Management Project (FEMP). 1993. *Remedial Investigation Report for Operable Unit 4*. Prepared under contract for the U.S. Department of Energy: Fernald Field Office, Fernald, OH. (AR Index Numbers Vol. I-III: U-006-304.15 – 17)

[12] Battelle Pacific Northwest Laboratories (PNL) and Fernald Environmental Management Project (FEMP). 1993. *Operable Unit 4 Treatability Study Report for the Vitrification of Residues from Silos 1, 2, and 3.* Prepared under contract for the U.S. Department of Energy: Fernald Field Office, Fernald, OH. (AR Index No. U-006-409.1) Note, actual Silos 1 and 2 material from various areas within the silos were analyzed and used in this study.

Table G.2.1-3. Some of the archived samples were later analyzed by the Fluor Daniel Fernald (FDF) laboratories to verify the PNL results[13]. These results were similar to the PNL results with the exception that sulfate (sulfur) measured higher: 3.40 wt% for Silo 1 and 3.50 wt% for Silo 2 (values are not normalized values). The values in **Table G.2.1-3** are used for the design basis; they present the PNL average numbers with the greater FDF values for sulfate included.

Variability seen in the sampling efforts of the Silos 1 and 2 material (Silos 1 and 2 combined) is shown in **Table G.2.1-4** - ***Variability in K-65 Samples,*** for the major *elements*. This variability includes the PNL sampling effort described above and other sampling efforts. The analytical elemental composition for BentoGrout™, and basis for placing it on the silos caps, is shown in **Table G.2.1-5** - ***Average BentoGrout™ Composition***.

<END OF PAGE>

[13] Fernald Environmental Management Project (FEMP). 1996. *Operable Unit 4 Vitrification Pilot Plant.* Phase I Interim Treatability Study Report, Campaign 2, 40110-WP-0002, Rev. 1. Prepared under contract for the U.S. Department of Energy: Fernald Field Office, Fernald, OH. (AR Index No. U-006-409.29)

TABLE G.2.1-4
VARIABILITY IN K-65 SAMPLES [14]
(Elemental makeup expressed in wt% as oxides)

Element Expressed as Oxide	Number of Samples	Mean	Standard Deviation
Si_2O	15	50.62	4.00
PbO	15	8.92	2.96
Fe_2O_3	15	4.08	2.25
BaO	15	4.36	2.06
Al_2O_3	15	3.13	0.82
CaO	15	3.11	1.60
MgO	15	1.58	0.74
SO_3	10	2.54	0.97
CO_2	8	5.22	1.03
Na_2O	14	1.33	0.58

<END OF PAGE>

[14] Dr. Donald Paine, letter No. C:WMTSP(SP):97-0064 to Ms. Nina Akgündüz, *Characterization of Silos 1 and 2 Material*, July 1, 1997. (AR Index No. U-006-409.35)

TABLE G.2.1-5
AVERAGE BENTOGROUT™ COMPOSITION [15]
(Elemental makeup expressed in wt% as oxides)

Rank	BentoGrout™		
	Component	Measured (wt%)	Normalized (wt%)[16]
1	SiO_2	65.40	67.35
2	Al_2O_3	15.80	16.27
3	MgO	6.30	6.49
4	Fe_2O_3	3.60	3.71
5	Na_2O	3.40	3.50
6	CaO	1.80	1.85
7	K_2O	0.80	0.82
Total		97.10	100.00

G.2.2 Contractor – FDF Interface

The division of responsibilities between the contractor (of a technology) and FDF for the full-scale treatment facility is presented in **Figure G.2.2-1** — ***Contractor-FDF Interface Diagram***.

[15] Battelle Pacific Northwest Laboratories (PNL) and Fernald Environmental Management Project (FEMP). 1993. *Operable Unit 4 Treatability Study Report for the Vitrification of Residues from Silos 1, 2, and 3.* Prepared under contract for the U.S. Department of Energy: Fernald Field Office, Fernald, OH. (AR Index No. U-006-409.1).

[16] Normalized means that measured wt% values have been proportioned so that they add up to100%.

calculations that include a maximum of 70% availability (uptime) for the transfer system.

C. The transfer process shall include contingencies such as low solids (<10 wt%) content during the removal/flushing of heal solids (last of the solids) in the TTA.

D. Decanted water from the slurry pumping system is recycled back to the TTA. Process water is available to provide makeup water on an as-needed basis.

E. At the end of the project, the TTA tanks are flushed and each technology processes the water and the resulting Silos 1 and 2 material at the treatment facility.

F. Given sufficient time [approximately 24 hours], the Silos 1 and 2 material will settle to 50 wt% solids with an average density of 1.5 g/cm^3. Approximately half of the BentoGrout™ portion of the solids will not settle.

Basis: (1) Settling data performed in the FEMP laboratory by John Roberts, November 1998; (2) Florida International University (FIU). Hemispheric Center for Environmental Technology. 1998. *Rheology Testing of Fernald K-65 Waste Residue Slurry*. Miami, FL. Prepared for Fluor Daniel Fernald (FDF): Fernald, OH. (AR Index No. U-006-409.40); and (3) ongoing laboratory studies at FDF.

G.2.5 Treated Silos 1 and 2 Material Acceptance Requirements

The treated Silos 1 and 2 material must pass the following tests:

A. Appearance. The treated wasteform appears uniform and homogeneous to non-magnified vision. Lumps, pockets of unmixed Silos 1 and 2 material, additives, layers, etc. will be considered failures.

B. Compressive Strength. The treated wasteform exhibits an unconfined compressive strength at least 50 psi per the American Society for Testing and Materials (ASTM) C39.

C. No Liquids. The treated wasteform does not contain any free standing liquids per ANS 55.1.

D. TCLP. The result of the TCLP analysis must be below the present Resource Conservation and Recovery Act (RCRA), as amended, in order to meet the waste acceptance criteria (WAC) for the metals listed in **Table G.2.5-1 - *RCRA TCLP Limits***. TCLP analysis is performed when samples have reached at least 50 psi, if chemically stabilized, and immediately upon cooling, if vitrified.

<END OF PAGE>

G.4.3.2 Assumptions

A. **Assumption:** Approximately 94 wt% of the Silos 1 and 2 material dissolves into the glass and 4.6 wt% passes to the Normal Off-gas System as SO_2, NO_x, and CO_2, and 1 wt% passes to the Normal Off-gas System as entrained solids.

Basis: Previous experience with glass formulation pilot studies and laboratory scale testing (reference letter from John Smets #M:SP:98-0236; AR Index No. U-006-409.25).

B. **Assumption:** Approximately 47 wt% of the additives (Li_2CO_3, Na_2CO_3, and $CaCO_3$) dissolves into the glass; 52 wt% decomposes to CO_2 and exits to the Normal Off-gas System, and an additional 1 wt% is entrained as solids in the off-gas.

Basis: FDF, PNL feasibility studies, and *EnVitCo POP Final Report* **(Appendix H, Attachment H1)**.

C. **Assumption:** FDF and contractors have produced glasses ranging from 55 – 90 wt% waste loading. An intermediate design waste loading of 70 wt% was selected from the given range to ensure adequate additive storage and handling capacity.

- Operating at a temperature from 1000 ° - 1500 °C. (An operating temperature of 1185°C was used during the POP demonstration and is assumed to provide for sufficient thermal destruction of sulfates, carbonates, and nitrates and give the SO_2, CO_2 and NO_x balance of G.4.3.2a).

Basis: FDF, PNL feasibility studies, and *EnVitCo POP Final Report* **(Appendix H, Attachment H1)**.

D. **Assumption:** The melter glass production capacity is 0.8 tons/day/m^2 using Silos 1 and 2 glass formulations.

Basis: *EnVitCo POP Final Report* **(Appendix H, Attachment H1)** was limited to this capacity by the rate of sulfate destruction.

E. **Assumption:** Air inleakage to the melter of 200 ft^3/min is assumed.

Basis: Detlef Stritzke, "Findings from the Engineering Support Services

Contract for Implementation of the Record of Decision for the Fernald Environmental Management Program Operable Unit 4," Contract No. 95SP4785.RPT. (AR Index No. U-006-409.38)

G.4.3.3 Key Equipment Descriptions

The joule-heated melter is a ceramic-lined steel tank with an exterior structural shell of water-cooled panels. The melter has overall dimensions of approximately 6.5 m (21.3 ft) wide by 9.0 m (29.5 ft) long by 4.5 m (14.8 ft) high. The melter system includes slurry feed pumps, molybdenum electrodes, resistence heaters for the plenum, a bottom drain for removal of reduced metals, a salt drain for removal of molten sulfates, dual glass drain orifices (one is a spare), and a 2.5 MW power supply.

G.4.3.4 System Interfaces

The Treatment System interfaces with the following SSC:

- Electrical power for melter power supply, instrumentation, monitors, and motors.
- Compressed air for pneumatically operated valves, instrumentation, and controls.
- Melter feed that enters via pipeline from the feed preparation system.
- Glass that is discharged from the melter glass drain orifice to the Product Handling System.
- Melter off-gas that is exhausted via two pipelines: one to the Normal Off-gas System and one to the Emergency Off-gas System.
- Recycle glass that is size- reduced and conveyed to a hopper to be fed back into the melter via a separate port from the standard feed stream. The recycle glass is diluted by incoming feed or adjusting the chemistry with required additives via the standard feed system and melter port.
- Cooling water for the melter shell that is recycled through the cooling tower.

G.4.4 Product Handling (Systems 23,24, 25 and 82)

The forming, handling, and reworking of a glass monolith in a MTC are discussed in the 1999 FEMP *OU4 Trade Study/Vitrification Waste Form Study* (AR Index No. U-006-409.14) in detail. Empty concrete shipping containers and MTCs are handled and/or conveyed using forklifts and remotely operated motorized roller conveyors. Filled MTCs and shipping containers are handled and/or conveyed by remotely operated roller conveyors, gravity roller conveyors, monorails, or bridge cranes.

The motorized roller conveyor positioning is controlled either remotely by manual switches to move and align the MTCs and/or shipping containers at the various work stations. The operators are able to view the operations by means of remote closed circuit television (CCTV) systems and/or shielded viewing windows at the various work stations.

The remotely operated monorail hoist and bridge cranes employ onboard CCTV viewing equipment to ensure positive grappling and placement of MTCs and/or filled shipping containers.

G.4.4.1 System Description

<u>Filling and Cooling Room Operations</u>

A propane powered forklift places an empty capped MTC on the load-in conveyor. The MTC is uncapped with the cap being placed onto the conveyor in front of the MTC.

The empty MTC, lead by the cap, is conveyed into the melter room and positioned at the fill station beneath the melter glass discharge orifice. The empty MTC is aligned and hydraulically lifted and sealed against the melter glass discharge orifice. A split cooling jacket, mounted on actuators, is moved into contact with the four sides of the empty MTC. The cooling jacket is designed to brace the MTC while it is being filled and to provide cooling and structural support to compensate for lost strength and rigidity in its steel walls at high temperature. The molten treated material is poured into the MTC until it is full. The motorized roller conveyors in the filling and cooling room are designed for high temperature service.

molten treated material is poured into the MTC until it is full. The motorized roller conveyors in the filling and cooling room are designed for high temperature service.

When the MTC is full, the cooling jacket retracts and the full MTC is hydraulically lowered and conveyed to the secondary cooling station where it is hydraulically lifted and secured with a split cooling jacket, mounted on actuators. At the same time, the next empty MTC is moved into the filling and cooling room and prepared for filling, as previously described. During the filling of the second MTC, the first MTC (at the secondary cooling station) is cooled to reduce the storage time requirements in the cooling room. Upon completion of the secondary cooling operation, the first MTC is released and conveyed to the capping station. The previously removed cap is lifted and installed on the MTC. The capped MTC is conveyed to the monolith cooling room through an airlock into the cooling room.

Monolith Cooling Room Operations

All routine monolith cooling room (MCR) operations are performed remotely. The filled and capped MTC is conveyed from the melter room into the cooling room. The MCR bridge crane is brought into position to grapple, lift, and move the filled and capped MTC to the designated position on the cooling rack grid. The full MTC is cooled by air that passes across its surface for approximately 48 hours. The MCR has a dedicated HVAC System. This convective cooling process reduces the MTC's surface temperature to approximately 150°F. The perimeter of the MCR is protected from excessive heat loads by insulated thermal shields placed around the lower portion of the room. After the full MTC has satisfied the minimum cooling time requirement, it is grappled by the MCR bridge crane and placed onto a motorized roller conveyor and conveyed through an airlock into the MTC staging area.

Shipping Container Area Operations

An empty concrete shipping container is placed onto the load-in conveyor within the airlock by a propane powered forklift with a rated capacity of six tons. The shipping container lid is removed and placed in front of the shipping container on the conveyor. The shipping container

G.4.5.1 System Description

Process Exhaust

Hot off-gas from the melter is introduced to the quench tower (18-PE-002) where point quench spray nozzles deliver water to cool and condense the melter off-gas. The quench spray water is recycled through the quench heat exchanger (18-HE-001), which is cooled by cooling tower water. A purge/blowdown stream is drawn off and sent to the precipitator tank (18-TK-001) for pH adjustment and then recycled to the Feed Preparation System.

The remaining air and acid gases are treated in a packed-tower scrubber (18-PE-003). Packing in the scrubber allows the caustic solution to contact the gas stream and remove the acid gases. The caustic is recycled through the scrubber heat exchanger (18-HE-002), which is cooled by cooling tower water. The pH is adjusted as needed through a caustic solution metering system. A purge stream is drawn off for wastewater treatment as necessary.

The saturated moist air from the scrubber is vented to the WESP (18-PE-001). The WESP removes the smaller particles with greater than 99% efficiency. Captured particulate from the WESP is sent to the precipitator tank for pH adjustment before being recycled to the Feed Preparation System.

The off-gas from the WESP passes to the NO_x Removal System (20-RN-003) to reduce NO_x levels to a maximum of 20 ppm. The off-gas then passes through the RCS condenser (20-HE-001) where it is cooled with chilled water/glycol solution to condense most of the remaining water that is purged to the wastewater treatment system. The off-gas is properly conditioned to be transferred to the RCS.

Process Vessel Vents

Vessels containing radon are vented to the PVV header. The PVV header vents the radon into the Normal Off-gas System downstream of the WESP.

Room Exhaust

All rooms containing Silos 1 and 2 material in process equipment are ventilated via the building HVAC system through HEPA filters to the main HVAC exhaust stack.

G.4.5.2 Assumptions

A. **Assumption:** A film cooler is not used to cool the melter off-gas; fouling and plugging are too much of a concern. The cooling can be achieved in the quench tower.

Basis: Silos Project Independent Review Team (IRT). 1996. *Vitrification Pilot Plant Process Configuration Upgrade Evaluation*. Prepared for Fluor Daniel Fernald (FDF): Fernald, OH. (AR Index No. U-006-409.39)

B. **Assumption:** The off-gas piping from the melter to the quench does not plug due to the (1) short run time and (2) large relative diameter of the piping. Also, the high temperature of the piping minimizes "plate out" of particulates.

Basis: Best management practices and engineering judgement.

C. **Assumption:** Radon in the melter off-gas was previously in secular equilibrium with the radium in the Silos 1 and 2 material, which was fed to the melter.

Basis: Battelle Pacific Northwest Laboratories (PNL) and Fernald Environmental Management Project (FEMP). 1993. *Operable Unit 4 Treatability Study Report for the Vitrification of Residues from Silos 1, 2, and 3.* Prepared under contract for the U.S. Department of Energy: Fernald Field Office, Fernald, OH. (AR Index No. U-006-409.1)

G.5.4 Product Handling (Systems 23,24, and 25)

The forming, handling, and reworking of the glass product is discussed in the 1999 FEMP *OU4 Trade Study/Vitrification Waste Form Study* (AR Index No. U-006-409.14) in detail. Empty shipping and disposal containers are handled using forklifts and motorized roller conveyors. Filled shipping and disposal containers are conveyed by remotely operated motorized roller conveyors, monorails, or bridge cranes.

The motorized roller conveyor positioning is controlled either remotely or by manual switches to move and align the shipping and disposal containers at the various work stations. The operators are able to view the operations by means of remote CCTV systems and shielded viewing windows at the various work stations.

The remotely operated monorail hoist and bridge cranes employ onboard CCTV viewing equipment to ensure positive grappling and placement of filled shipping and disposal containers.

G.5.4.1 System Description

<u>Fill Station Operations</u>

An empty shipping container is loaded onto the conveyor in the airlock adjacent to the fill station by a propane powered forklift with a rated capacity of six tons. The shipping container lid is removed using a grappling device attached to a monorail. The Conveyor System is divided into discrete sections to allow multiple and simultaneous shipping container movements at the different work stations, thus improving the efficiency of the handling system. The shipping container is conveyed into the fill room and aligned with the quench tank drag conveyor discharge. The shipping container is hydraulically lifted and sealed against the quench tank drag conveyor discharge opening. The glass frit is deposited in the shipping container until it is full. The shipping container lift is mounted on load cells to give an indication of the weight of the deposited glass frit remotely monitored in the control station. The shipping container is hydraulically lowered, sampled, and conveyed to the lidding station.

Lidding Station

The shipping container lid is remotely positioned, lowered and seated on the shipping container. The remote lid fastening wrench is used to tighten the lid bolts.

Survey and Decontamination Station

The shipping container is conveyed to the survey and decontamination station for radiological survey, and decontamination as needed. After the container passes radiological survey, the shipping container is conveyed through an enclosed passage to the interim staging facility.

Interim Staging Facility

The shipping container is removed from the conveyor by a remotely operated bridge crane and placed in the shielded staging area before being shipped off-site or returned for rework.

G.5.4.2 Assumptions

Assumption: Three to four shipping and disposal containers of frit are produced daily.
Basis: Mass Balance included in **Attachment G.5.I.**

G.5.4.3 Key Equipment Descriptions

Roller Conveyors

The roller conveyors are 5-ft or 7-ft wide heavy duty, motorized, chain driven, two-directional, roller conveyors of various lengths with a rated capacity of 21,000 lb. Standard fabrication materials are used for conveyor components; however, the conveyors are special order due to the size and load capacity required to support the filled shipping and disposal containers. The conveyors are equipped with special features for lifting containers, making right angle transfers, and weighing containers, as required. The conveyors are segmented where the conveyance must pass through an airlock or shield door, in order to establish an effective seal and to prevent shielding void spaces.

Basis: (1) Fernald Environmental Management Project (FEMP). 1993. *Remedial Investigation Report for Operable Unit 4.* Prepared under contract for the U.S. Department of Energy: Fernald Field Office, Fernald, OH. (AR Index Numbers Vol. I-III: U-006-304.15 - 17)

(2) Fernald Environmental Management Project (FEMP). 1994. *Feasibility Study for Operable Unit 4.* Prepared under contract for the U.S. Department of Energy: Fernald Field Office, Fernald, OH. (AR Index Numbers Vol. I-IV: No. U-006-404.13 - 16)

(3) Information provided in the IT POP Work Plan.

G.6.3.3 Key Equipment Descriptions

Mixer

The design of the mixer incorporates inlet connections for the Silos 1 and 2 material filter cake, cement additive mix, and water. A vent line connection to the PVS header maintains the mixer at a negative pressure. A bottom port is provided on the mixer to discharge the mixed grout to the disposal container through an enclosed chute. A separate bottom discharge is provided for the mixer flush water. It is assumed that the grout formulations produce a grout that needs to be leveled by vibrating the container as it is filled.

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G.6.3.4 System Interfaces

The Treatment System interfaces with the following SSC:

- Electrical power for instrumentation and motors.
- Compressed air for pneumatically operated valves.
- The Treatment System that receives filter cake feed, from the Feed Preparation System, on a batch basis.
- Additives that are delivered to the cement mixer from the Feed Preparation System.
- If necessary, grout water content that is adjusted using recycled water from the TTA.

G.6.4 Product Handling (Systems 25, 26 and 82)

Empty disposal containers are handled using forklifts and motorized roller conveyors (PFD 94X-5500-M-SK-6025 and -6026). Filled disposal containers are conveyed by remotely operated motorized roller conveyors or bridge cranes.

The motorized roller conveyor positioning is controlled either remotely or by manual switches to move and align the disposal containers at the various work stations. The operators are able to view the operations by means of remote CCTV systems and shielded viewing windows at the various work stations.

The remotely operated monorail hoist and bridge cranes employ onboard CCTV viewing equipment to ensure positive grappling and placement of filled containers.

G.6.4.1 System Description

A propane powered forklift, rated capacity of six tons, places an empty, lined disposal container onto the load-in conveyor in the airlock. A forklift removes the container lid and places it in front of the container. An absorbent mat is placed on top of the lid. Once the

Interim Staging Facility

The disposal container/mixer is removed from the conveyor by a remotely operated bridge crane and placed in the shielded staging area before being shipped off-site or returned for rework.

G.7.4.2 Assumptions

A. **Assumption:** A maximum of 14.4 container/mixers can be processed per day with three processing lines.

Basis: POP contractor's estimated time to position, fill, and mix one container of treated Silos 1 and 2 material is 5 hours.

B. **Assumption:** Five hundred scfm capacity from the RCS is available for use in a sweep hood to capture radon.

Basis: Fernald Environmental Management Project (FEMP). 1998. *Silos 1 and 2 Accelerated Waste Retrieval (AWR) Project Request for Proposal.* 40710-RP-0001. Prepared under contract for the U.S. Department of Energy: Fernald Field Office, Fernald, OH. (AR Index No. U-006-409.41)

C. **Assumption:** Interim storage is required for 45 calendar days.

Basis: Time required to prepare shipping documentation for disposal container transport.

G.7.4.3 Key Equipment Descriptions

Conveyors

The roller conveyors are 7-ft wide heavy duty, motorized, chain driven, two-directional, roller conveyors of various lengths with a rated capacity of 21,000 lb. Standard fabrication materials are used for conveyor components; however, the conveyors are special order due to the size and load capacity required to support the filled disposal container/mixers. They are equipped with special features for lifting disposal containers above the rollers, and for right angle transfers and weighing disposal containers, as required. The conveyors are segmented where the conveyance must pass through an airlock or shield door, in order to establish an effective seal and to prevent shielding void spaces. These conveyors differ in width from the other three processes due to the size of the disposal container/mixer.

Interim Staging Facility Crane

This crane is a remotely operated bridge crane with a rated capacity of 15 tons, a span of 120 ft, a travel of 210 ft, and a lift height of 16 ft. The crane is equipped with a special grapple device for lifting, movement, and placement of the disposal container/mixers. In addition, the bridge crane has CCTV capacity to ensure positive grappling and placement of the disposal container/mixer.

Monorail Hoist

The monorail hoist is remotely operated, with a rated capacity of 15 tons, a travel of 100 ft, and a lift height of 12 ft. The monorail travels between the lid handling airlock and the lid placement station. The crane is equipped with two special grapples; one grapple carries the absorbent mat and places it in the disposal container/mixer, and the other grapple carries the disposal container/mixer head and aligns and seats it onto the disposal container/mixer.

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REVISED FEASIBILITY STUDY REPORT

FOR SILOS 1 AND 2

40730-RP-0001

U.S. Department of Energy
Fernald Environmental Management Project

VOLUME 4 OF 4
February 2000
Draft, Rev. B

Prepared Under DOE Contract No. DE-AC24-92OR21972
By Fluor Daniel Fernald

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