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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 3 OF 4
December 1999

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

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8074

CONTENTS
VOLUME 3 OF 4

VOLUME 3

Appendices	D	NEPA Supplemental Analysis
	E	Summary of Packaging and Transportation Evaluation
	F	OU4 Decision Making Process Supplement
	G	Design Basis and Description

CCCC08

8074

Appendix D

8074

APPENDIX D

NEPA SUPPLEMENT ANALYSIS

8074

TABLE OF CONTENTS

APPENDIX D

Page d-

List of Acronyms & Abbreviations ii

Page D-

D.1.0 NEPA SUPPPLEMENT ANALYSIS 1-1

D.1.1 Requirements for Conducting a Supplement Analysis 1-1
D.1.2 Relevant Regulations 1-2
D.1.3 Evaluating Proposed Changes 1-2
D.1.4 Applying the "Rule of Reason" 1-3
D.1.5 Approval of a Supplement Analysis and SEIS by DOE 1-3

D.2.0 EVALUATION OF ALTERNATIVES 2-1

D.2.1 On-site Joule-heated Vitrification - Off-site Disposal at the NTS (VIT1) 2-1
D.2.2 On-site Vitrification other than Joule-heated - Off-site Disposal at the NTS (VIT2) 2-2
D.2.3 On-site Chemical Stabilization Cement-based - Off-site Disposal at the NTS (CHEM1) .. 2-4
D.2.4 On-site Chemical Stabilization other than Cement-based - Off-site Disposal at the NTS (CHEM2) 2-5

D.3.0 CONCLUSION 3-1

D.4.0 REFERENCES 4-1

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

8074

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 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) 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). 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.

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.

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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 Nevada Test Site (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.**

8074

The treatment and disposal aspects of vitrification were fully 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 the January 9, 1996, Supplement Analysis and is reviewed again in this revised FS. Although the type of melter evaluated in this alternative is not a joule-heated melter, this alternative does not represent a significant change in scope from the evaluation in the original OU4 FS/PP-EIS.

Potential environmental impacts, including human health risks, are consistent with those evaluated in the original EIS for vitrification. 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 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 3.3.4** and **3.3.6**.

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D.2.3 On-site Chemical Stabilization Cement-based - Off-site Disposal at the NTS (CHEM1)

This alternative involves the removal, on-site treatment through chemical stabilization by a cementation process, and off-site disposal at the NTS of the treated Silos 1 and 2 material through cement-based chemical stabilization. Included in this alternative is construction of a feed preparation system to prepare and deliver a feed slurry containing both silos material and cement-based additives to the mixer, a nominal 80-ton per day mixer, and an air emissions system to provide necessary treatment of radionuclide particulate. The full-scale treatment facility also includes many support systems such as product curing, off-specification material rework, building ventilation, and personnel support systems. 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 waste shipping program. This alternative involves the packaging, loading, and shipping of cement-based stabilized material for disposal at the NTS via truck or intermodal transportation. A detailed discussion of this alternative is available in **Section 3.4.1**.

The treatment and disposal aspects of this alternative were fully 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 the January 9, 1996, Supplement Analysis and is reviewed again in this revised FS. This alternative does not represent a significant change in scope from the evaluation in the original 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 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 3.4.4** and **3.4.6**.

D.2.4 On-site Chemical Stabilization other than Cement-based - Off-site Disposal at the NTS (CHEM2)

This alternative is identical to the alternative presented in **Section D.2.3** with the exception of the type of chemical stabilization process that is utilized. A chemical stabilization process other than a cement-based process stabilizes the 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 chemical additives to the container with built-in agitation, three container lines make up the nominal 105-ton per day processing plant, and an air emissions system to provide necessary treatment of radionuclide particulate. The full-scale treatment facility also includes many support systems such as product curing, 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 waste shipping program. This alternative involves the packaging, loading, and shipping of stabilized material for disposal at the NTS via truck or intermodal transportation. A detailed discussion of this alternative is available in **Section 3.5.1**.

The use of a cement-based process to stabilize the Silos 1 and 2 material was evaluated in the OU4 FS/PP-EIS. This alternative does not utilize a cement-based process to stabilize the constituents of concern (COCs); however, the chemical stabilization process is similar to cement-based stabilization with the exception of the additives used to immobilize the COCs. In addition, the scenario of transporting treated silos material to the NTS via truck was evaluated in the January 9, 1996, Supplement Analysis and is reviewed again in this revised FS. Therefore, this alternative does not represent a significant change in scope from the evaluation in the original 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 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 3.5.4** and **3.5.6**.

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8074

D.3.0 CONCLUSION

As required under the DOE NEPA regulations, DOE conducted this Supplement Analysis to determine whether a SEIS needs to be conducted for the revised FS for remediation of the Silos 1 and 2 material. Based upon the results of this analysis, DOE has determined that the proposed alternatives for remediation of the Silos 1 and 2 material do not constitute a substantial change in project scope or result in significant, new information related to environmental impacts from the original EIS alternatives. Therefore, a SEIS is not recommended for the proposed alternatives.

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U.S. Environmental Protection Agency (EPA). 1994. *Record of Decision for Operable Unit 4.* EPA ID OH6890008976; ROD ID EPA/ROD/R05-95/287. ([1]AR Index No. U-006-501.5.) [abstract at http://www.epa.gov/superfund/sites/rodsites/0504934.htm]

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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.

8074

Appendix E

8074

APPENDIX E

SUMMARY OF PACKAGING AND TRANSPORTATION EVALUATION

8074

TABLE OF CONTENTS

APPENDIX E

Page e-

List of Tables iii
List of Figures iii
List of Acronyms & Abbreviations iv

Page E-

E.1.0 INTRODUCTION 1-1

E.1.1 Background of the Silos 1 and 2 Material 1-1
E.1.2 Organization of Appendix 1-4

E.2.0 DOT CLASSIFICATION 2-1

E.2.1 Low Specific Activity – Type II Material Determination 2-1
E.2.2 Fissile-Exempt Material Determination 2-6
E.2.3 Container Requirements 2-10
E.2.4 Container Optimization 2-12

E.3.0 TRANSPORTATION ROUTES – DIRECT TRUCK 3-1

E.3.1 Proposed Routes 3-1
E.3.1.1 Baseline Truck Route 3-2
E.3.1.2 Northern Truck Routes 3-2
E.3.1.3 Southern Truck Routes 3-4
E.3.2 Evaluation of Risk 3-6
E.3.3 Results 3-11

E.4.0 TRANSPORTATION ROUTES – INTERMODAL 4-1

E.4.1 Proposed Routes 4-1
E.4.1.1 Intermodal Facility - Cincinnati 4-2
E.4.1.2 Intermodal Facility - Chicago 4-3
E.4.2 Evaluation of Risk 4-3
E.4.3 Results 4-5

E.5.0 CONCLUSIONS 5-1

E.5.1 Direct Truck and Intermodal Evaluation 5-1

LIST OF TABLES

Page E-

TABLE E.2.1-1 Raw K-65 Material LSA-II Solid Determination 2-3
TABLE E.2.4-1 Proposed Container Design 2-2-14
TABLE E.3.2-1 Package-specific and Vehicle-specific Parameters for Radtran Analysis, Truck 3-7
TABLE E.3.2-2 Radionuclide Contents for Treatment Alternatives 3-8
TABLE E.3.2-3 Regional Fraction of Accident Severity Occurences, Truck 3-10
TABLE E.3.2-4 Accident Release Fractions 3-11
TABLE E.3.3-1 Estimated Non-Radiological Risks, Occupational 3-12
TABLE E.3.3-2 Estimated Non-Radiological Risks, Public 3-12
TABLE E.3.3-3 Collective Dose Equivalent, Transportation Crew 3-14
TABLE E.3.3-4 Collective Dose Equivalent, Public - Incident Free and Stops 3-14
TABLE E.3.3-5 Collective Dose Equivalent, Public - Accident 3-15
TABLE E.4.2-1 Package-specific and Vehicle-specific Parameters for Radtran Analysis 4-4
TABLE E.4.2-2 Regional Fraction of Accident Severity Occurences, Rail 4-5
TABLE E.4.3-1 Estimated Non-radiological Risks, Occupational 4-6
TABLE E.4.3-2 Estimated Non-radiological Risks, Public 4-6
TABLE E.4.3-3 Collective Dose Equivalent, Transportation Crew 4-8
TABLE E.4.3-4 Collective Dose Equivalent, Public - Incident Free and Stops 4-8
TABLE E.4.3-5 Collective Dose Equivalent, Public - Accident 4-9

LIST OF FIGURES

Page E-

FIGURE E.5.1-1 Southern Route #3 5-4
FIGURE E.5.1-2 Intermodal Route #1 5-5

000021

ACRONYMS & ABBREVIATIONS

8074

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.1.0 INTRODUCTION

This appendix evaluates the transportation options available to the Fernald Environmental Management Project (FEMP) for shipping treated Silos 1 and 2 material to the Nevada Test Site (NTS) for disposal.

E.1.1 Background of the Silos 1 and 2 Material

The material contained in Silos 1 and 2 is 11(e)(2) by-product material resulting from the processing of uranium ore concentrates and is specifically exempt, as defined, from regulation as solid waste under the Resource Conservation and Recovery Act (RCRA) 40 Code of Federal Regulations (CFR) Part 261.4(a)(4). The referenced exclusion applies to "... source, special nuclear or by-product material as defined in the Atomic Energy Act of 1954 as amended, 42 U.S.C. 2011 *et seq.*" The Atomic Energy Act (AEA) defines by-product material as: "(1) any radioactive material (except special nuclear material) yielded in or made radioactive by exposure to the radiation incident to the process of producing or utilizing special nuclear material, and (2) the tailings or waste produced by the extraction or concentration of uranium or thorium from any ore processed primarily for its source material content" [AEA Section 11(e)(1) and (2)]. Since a material must first be a solid waste in order to be a hazardous waste, and since the material is excluded from regulation as solid waste, the subject material cannot be considered hazardous waste.

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The Silos 1 and 2 material falls under the 11(e)(2) classification of by-product material. Silos 1 and 2 only contain materials from the chemical extraction (beneficiation) of uranium from ores; no other solid or hazardous wastes were added to the silos or to the residues. Therefore, the contents of Silos 1 and 2 are pure "by-product materials" by definition, and not solid wastes or hazardous wastes subject to regulation under RCRA. The metals found in the material were present in the natural ore, and were unintentionally extracted from the parent ore along with the uranium during the process of beneficiation, becoming more concentrated in the residue after the uranium was removed. The presence of naturally occurring metals is expected in by-product material, and does not invalidate either the definition or the exclusion. In addition, no metals from a non-ore source were added to the stream at any point in the beneficiation process, also, no hazardous waste or waste constituent was added or created at any time during the beneficiation process. The fact that lead in the untreated material fails the RCRA toxicity characteristic leaching procedure (TCLP) does not cause the material to become subject to RCRA regulation due to a hazardous waste characteristic, since the metals are not from an external source, but are associated with the parent material (whose residues, including any ancillary metals, are excluded from the definition of solid waste).

The Fernald Site was placed on the National Priorities List (NPL) under the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) in November 1989. As a result, contamination at the Fernald Site is undergoing remediation pursuant to the Comprehensive Environmental Response Compensation and Liability Act, as amended (CERCLA). The material in Silos 1 and 2 are considered "pollutants or contaminants" as that term is defined under CERCLA and the NCP.

8074

CERCLA provides guidance on the specific cleanup standards that should be applied to a remedial action, or to the criteria for choosing among remedial alternatives when implementing regulations for CERCLA under 40 CFR Part 300, which is the NCP. Nine selection criteria for choosing among remedial actions are presented in Subpart E – Hazardous Substance Response, 40 CFR Part 300.430(e)(9). One of these nine criteria states that the action will comply with applicable or relevant and appropriate requirements (ARARs). The NCP further defines the criteria for remediation of a facility by requiring that on-site remedial actions attain or exceed the ARARs in federal and state environmental and public health laws. A discussion of the ARARs that have been identified for remediation of Silos 1 and 2 material is provided in **Appendix A**.

In addition to the types and classes of ARARs described in **Appendix A**, other requirements exist that are not environmental requirements subject to waiver and negotiation. Included in this category are off-site transportation requirements found in Department of Transportation (DOT) regulations. These requirements are identified to facilitate a thorough evaluation and comprehensive comparison of the remedial alternatives.

The NCP under 40 CFR Part 300.430(f)(1)(ii)(E) requires that "each remedial action shall utilize permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable." Preference shall be given to alternatives that provide treatment as a principle element and the bias against off-site land disposal of untreated waste. The selected alternative shall be able to provide long-term protectiveness of human health and the environment, be able to meet all ARARs that are identified in the Record of Decision, and provide the best balance of trade-offs among alternatives in terms of the five balancing criteria.

One of the five balancing criteria is an evaluation of short-term effectiveness. This includes consideration of potential short-term risks to the public and workers during treatment of Silos 1 and 2 material and transportation of treated waste to the NTS.

E.1.2 Organization of Appendix

The remainder of this appendix presents a discussion on the regulatory requirements the treated waste must meet during transportation and evaluates the risk posed to the public and workers during transportation.

Section E.2 presents a discussion on the proper classification for the Silos 1 and 2 material, under the DOT shipping regulations, and discusses the proper packaging based on the classification. **Sections E.3 and E.4** evaluate direct truck and intermodal (combined rail and truck) transport routes, respectively. **Section E.5** presents a recommendation for shipping Silos 1 and 2 material to the NTS.

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8074

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:

TABLE 1. *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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8074

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				

8074

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©. 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.

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 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©] 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.

000037

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.

000039

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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2

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

<END OF SECTION>

000041

E.3.0 TRANSPORTATION ROUTES – DIRECT TRUCK

Treated Silos 1 and 2 material will be shipped to the NTS for disposal. The NTS is a DOE-managed disposal site for low-level radioactive waste. It is located approximately 105 kilometers (65 miles) northwest of Las Vegas, Nevada.

DOT regulation 49 CFR Part 397.101(a)(1) requires carriers of radioactive material to utilize routes that minimize radiological risk to the general public and workers.

This section evaluates the radiological risk posed to the general public and workers by the alternative truck routes proposed for transporting radioactive material from Fernald to the NTS. FDF evaluated eight direct truck routes. A discussion of these routes is presented below.

E.3.1 Proposed Routes

Historically, radioactive waste generated at Fernald has been shipped to the NTS by direct truck. The former route used by transporters passed over the Hoover Dam and through Las Vegas, Nevada on US95. Due to the concerns of stakeholders in the Las Vegas metropolitan area regarding transportation of radioactive material, DOE has established alternate routes, which avoid Hoover Dam and Las Vegas, for use. Furthermore, stakeholders have suggested that DOE might reduce transportation costs and enhance public safety by using rail transportation. Potential intermodal routes are discussed in **Section E.4**.

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E.3.1.1 Baseline Truck Route

For purposes of this evaluation, the former truck route will be used as the baseline truck route. The former route to the NTS consisted of traveling on Interstate (I)-74 and I-275 in Ohio to I-71 through Kentucky to I-64 through Indiana and Illinois to I-44 through Missouri to I-40 through Oklahoma, Texas, New Mexico, and Arizona to United States (US)93 and US95 in Nevada to the NTS.

This route passes through the following major cities: Cincinnati on I-74 and I-275 through Ohio; Louisville, Kentucky when transferring from I-71 to I-64; St. Louis, Missouri when transferring from I-64 to I-44; Springfield and Joplin on I-44 through Missouri; Tulsa on I-44 through Oklahoma; Oklahoma City, Oklahoma when transferring from I-44 to I-40; Amarillo on I-40 through Texas; Albuquerque on I-40 through New Mexico; Flagstaff on I-40 through Arizona; and then over Hoover Dam and through Las Vegas on US95 in Nevada.

Because of the stakeholder concerns regarding transportation of radioactive material over Hoover Dam and through Las Vegas, this is not considered a preferred route to the NTS. FDF has established the use of alternate routes bypassing these two areas. Based on input from potential shippers, three northern truck routes and four southern truck routes have been proposed and are discussed below.

E.3.1.2 Northern Truck Routes

<u>Northern Truck Route #1</u>

This proposed route to the NTS consists of traveling I-74 through Ohio, Indiana, and Illinois to I-80 through Iowa, Nebraska, Wyoming, and Utah into Nevada to US93A, US50, US6 and US95 to the NTS.

This route passes through the following major cities: Indianapolis on I-74 through Indiana; Bloomington and Peoria on I-74 through Illinois; Davenport, Iowa when transferring from I-74 to I-80; Des Moines on I-80 through Iowa; Omaha and Lincoln on I-80 through Nebraska; Cheyenne on I-80 through Wyoming; and Salt Lake City on I-80 through Utah.

Northern Truck Route #2

This proposed route to the NTS consists of traveling I-74 and I-275 through Ohio and Indiana to I-75/I-71 in Kentucky to I-64 through Indiana and Illinois to I-70 through Missouri to I-29 up through Iowa to I-80 through Nebraska, Wyoming, and Utah into Nevada to US93, US50, US6 and US95 to the NTS.

This route passes through the following major cities: Louisville, Kentucky when transferring from I-71 to I-64; St. Louis, Missouri when transferring from I-64 to I-70; Columbia on I-70 through Missouri; Kansas City, Missouri when transferring from I-70 to I-29; St. Joseph on I-29 through Missouri; Omaha, Nebraska when transferring from I-29 to I-80; Lincoln on I-80 through Nebraska; Cheyenne on I-80 through Wyoming; and Salt Lake City on I-80 through Utah.

Northern Truck Route #3

This proposed route to the NTS consists of traveling I-74 through Ohio and Indiana to I-70 through Indiana, Illinois, Missouri, Kansas, Colorado, and Utah to I-15 and Utah State Route 56 transferring over to Nevada State Route (NSR) 319, US93, NSR 375, US6, and US95 to the NTS.

This route passes through the following major cities: Indianapolis, Indiana when transferring from I-74 to I-70; Terre Haute on I-70 through Indiana; St. Louis, Columbia and Kansas City on I-70 through Missouri; Topeka and Salina on I-70 through Kansas; and Denver and Grand Junction on I-70 through Colorado.

E.3.1.3 Southern Truck Routes

Southern Truck Route #1

This proposed route to the NTS consists of traveling I-74 and I-275 in Ohio to I-71 through Kentucky to I-64 through Indiana and Illinois to I-44 through Missouri to I-40 through Oklahoma, Texas, New Mexico, and Arizona to US95 in California into Nevada to NSR 164, transferring to Nipton Road in California to I-15 to California SR (CSR) 127, transferring to NSR 373 in Nevada and US95 to the NTS.

This route passes through the following major cities: Cincinnati on I-74 and I-275 through Ohio; Louisville, Kentucky when transferring from I-71 to I-64; St. Louis, Missouri when transferring from I-64 to I-44; Springfield and Joplin on I-44 through Missouri; Tulsa on I-44 through Oklahoma; Oklahoma City, Oklahoma when transferring from I-44 to I-40; Amarillo on I-40 through Texas; Albuquerque on I-40 through New Mexico; and Flagstaff on I-40 through Arizona.

Southern Truck Route #2

This proposed route to the NTS consists of traveling I-74 through Ohio and Indiana to I-70 through Indiana and Illinois to I-44 through Missouri to I-40 through Oklahoma, Texas, New Mexico, and Arizona to US95 in California into Nevada to NSR 164, transferring to Nipton Road in California to I-15 to CSR 127, transferring to NSR 373 in Nevada and to US95 to the NTS.

This route passes through the following major cities: Indianapolis, Indiana when transferring from I-74 to I-70; Terre Haute on I-70 through Indiana; St. Louis, Missouri when transferring from I-70 to I-44; Springfield and Joplin on I-44 through Missouri; Tulsa on I-44 through Oklahoma; Oklahoma City, Oklahoma when transferring from I-44 to I-40; Amarillo on I-40 through Texas; Albuquerque on I-40 through New Mexico; and Flagstaff on I-40 through Arizona.

Southern Truck Route #3

This proposed route to the NTS consists of traveling I-74 and I-275 through Ohio to I-75, I-71, and I-64 through Kentucky to I-65 through Kentucky and Tennessee to I-40 through Arkansas, Oklahoma, Texas, New Mexico, and Arizona to US95 in California to NSR 164, transferring to Nipton Road in California to I-15 to CSR 127, transferring to NSR 373 in Nevada and to US95 to the NTS.

This route passes through the following major cities: Cincinnati on I-275 through Ohio; Louisville when transferring from I-71 to I-65; Nashville, Tennessee when transferring from I-65 to I-40; Jackson and Memphis on I-40 through Tennessee; Little Rock and Fort Smith on I-40 through Arkansas; Oklahoma City on I-40 through Oklahoma; Amarillo on I-40 through Texas; Albuquerque on I-40 through New Mexico; and Flagstaff on I-40 through Arizona.

Southern Truck Route #4

This proposed route to the NTS consists of traveling I-74 and I-275 through Ohio to I-71 through Kentucky to I-64 through Indiana and Illinois to I-44 through Missouri to I-40 through Oklahoma, Texas, New Mexico, and Arizona to US95 in California into Nevada to NSR 164, transferring to Nipton Road in California to I-15 to NSR 160 and to US95 to the NTS.

This route passes through the following major cities: Cincinnati on I-74 and I-275 through Ohio; Louisville, Kentucky when transferring from I-71 to I-64; St. Louis, Missouri when transferring from I-70 to I-44; Springfield and Joplin on I-44 through Missouri; Tulsa on I-44 through Oklahoma; Oklahoma City, Oklahoma when transferring from I-44 to I-40; Amarillo on I-40 through Texas; Albuquerque on I-40 through New Mexico; and Flagstaff on I-40 through Arizona.

E.3.2 Evaluation of Risk

As stated previously, DOT requires carriers to utilize routes that minimize radiological risk when transporting radiological material. When determining radiological risk, DOT regulation 49 CFR Part 397.101(a)(2) requires the carrier to consider available information, such as, accident rates, population densities, and transit time.

The estimated radiological risk to the public and workers during transportation was calculated using the RADTRAN5® computer model developed by Sandia National Laboratories. RADTRAN5® produces estimates of incident-free population dose, accident dose-risk, nonradiological mortality, as well as individual dose estimates. Calculation of incident-free population dose considers persons adjacent to the route, persons in vehicles sharing the route, crew members, and persons at stops. Potential dose-risks are also calculated for populations that are downwind from hypothetical releases associated with accidents of varying severity or within stated radial distances of loss-of-shielding accidents of varying severity.

Where possible, "standard" RADTRAN5® values for parameters were used if they were not specific to the radioactive material, package, vehicle, or route.

RADTRAN5® relies on various parameters, which are defined by the user, for calculating dose. This information relates to the radioactive material, the package, the vehicle, and the route. It includes parameters for the number of shipments, the number of containers per shipment, the radionuclide content of the container, the radiation dose associated with the container, and the radiation dose associated with the shipment. **Table E.3.2-1** presents the user-defined package-specific and vehicle-specific parameters associated with the four treatment alternatives.

000047

TABLE E. 3.2-1
PACKAGE-SPECIFIC AND VEHICLE-SPECIFIC PARAMETERS
FOR RADTRAN5® ANALYSIS, TRUCK

Parameter	VIT1	VIT2	CHEM1	CHEM2
Number of Shipments	1,199	1,081	3,039	3,053
Number of Containers per Shipment	2	2	2	2
Dose Rate 1 m from Package (mrem/hr)	23.3	40.7	19.7	18.0
Characteristic Package Dimension (m)	2.72	3.13	3.16	1.71
Dose Rate 1 m from Vehicle (mrem/hr)	20.2	40.0	19.4	27.3
Characteristic Vehicle Dimension (m)	12.20	12.20	12.20	12.20
Number of Crew Members	2	2	2	2
Average Distance from Package to Crew Members (m)	7.62	7.62	7.62	7.62
Crew View Package Dimension (m)	1.52	1.42	1.60	1.93

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Table E.3.2-2 presents the radionuclide content for each treatment alternative. The curie content for each alternative is based on the waste loading for the treatment alternative, the packaging density of the treated material, and the volume of treated material in each container.

TABLE E. 3.2-2
RADIONUCLIDE CONTENTS FOR TREATMENT ALTERNATIVES

	Curies per Container				
Radionuclide	Raw Material PCi/g	VIT1	VIT2	CHEM1	CHEM2
Ac-227	7.67E-09	2.61E-02	2.91E-02	1.17E-02	1.21E-02
Ac-228	1.11E-09	3.78E-03	4.21E-03	1.69E-03	1.76E-03
B-210	2.02E-07	6.88E-01	7.66E-01	3.08E-01	3.20E-01
B-211	7.67E-09	2.61E-02	2.91E-02	1.17E-02	1.21E-02
Bi-212	7.36E-09	2.51E-02	2.79E-02	1.12E-02	1.17E-02
B-214	4.77E-07	1.63E-00	1.81E-00	7.27E-01	7.56E-01
Fr-223	1.10E-10	3.75E-04	4.17E-04	1.68E-04	1.74E-04
Pa-231	4.04E-09	1.38E-02	1.53E-02	6.16E-03	6.40E-03
Pa-234	1.79E-12	6.10E-06	6.79E-06	2.73E-06	2.84E-06
Pa-234m	1.12E-09	3.82E-03	4.25E-03	1.71E-03	1.77E-03
Pb-210	2.02E-07	6.88E-01	7.66E-01	3.08E-01	3.20E-01
Pb-211	7.67E-09	2.61E-02	2.91E-02	1.17E-02	1.21E-02
Pb-212	7.36E-09	2.51E-02	2.79E-02	1.12E-02	1.17E-02
Pb-214	4.77E-07	1.63E-00	1.81E-00	7.27E-01	7.56E-01
Po-210	2.81E-07	9.58E-01	1.07E-00	4.29E-01	4.45E-01
Po-211	2.30E-11	7.84E-05	8.72E-05	3.51E-05	3.64E-05
Po-212	1.70E-09	5.79E-03	6.44E-03	2.59E-03	2.69E-03
Po-214	4.41E-07	1.50E-00	1.67E-00	6.73E-01	6.99E-01
Po-215	7.67E-09	2.61E-02	2.91E-02	1.17E-02	1.21E-02
Po-216	7.36E-09	2.51E-02	2.79E-02	1.12E-02	1.17E-02
Po-218	4.77E-07	1.63E-00	1.81E-00	7.27E-01	7.56E-01
Ra-223	7.67E-09	2.61E-02	2.91E-02	1.17E-02	1.21E-02
Ra-224	7.36E-09	2.51E-02	2.79E-02	1.12E-02	1.17E-02
Ra-226	4.77E-07	1.63E-00	1.81E-00	7.27E-01	7.56E-01
Ra-228	1.11E-09	3.78E-03	4.21E-03	1.69E-03	1.76E-03
Rn-219	7.67E-09	2.61E-02	2.91E-02	1.17E-02	1.21E-02
Rn-220	7.36E-09	2.51E-02	2.79E-02	1.12E-02	1.17E-02
Rn-222	4.77E-07	1.63E-00	1.81E-00	7.27E-01	7.56E-01

TABLE E.3.2-2 (continued)

	Curies per Container				
Radionuclide	Raw Material PCi/g	VIT1	VIT2	CHEM1	CHEM2
Th-227	7.56E-09	2.58E-02	2.87E-02	1.15E-02	1.20E-02
Th-228	7.36E-09	2.51E-02	2.79E-02	1.12E-02	1.17E-02
Th-230	7.62E-08	2.60E-01	2.89E-01	1.16E-01	1.21E-01
Th-231	9.40E-11	3.20E-04	3.56E-04	1.43E-04	1.49E-04
Th-232	1.11E-09	3.78E-03	4.21E-03	1.69E-03	1.76E-03
Th-234	1.12E-09	3.82E-03	4.25E-03	1.71E-03	1.77E-03
Tl-207	7.65E-09	2.61E-02	2.90E-02	1.17E-02	1.21E-02
Tl-208	2.65E-09	9.03E-03	1.00E-02	4.04E-03	4.20E-03
Tl-210	9.50E-11	3.24E-04	3.60E-04	1.45E-04	1.50E-04
U-234	1.16E-09	3.95E-03	4.40E-03	1.77E-03	1.84E-03
U-235	9.40E-11	3.20E-04	3.56E-04	1.43E-04	1.49E-04
U-238	1.12E-09	3.82E-03	4.25E-03	1.71E-03	1.77E-03

RADTRAN5® requires data that expresses the likelihood of accidents of a given severity for urban, suburban, and rural population areas. Accident severity categories with their respective probabilities of occurrence for each population area were obtained from the Nuclear Regulatory Commission document, "Final Environmental Statement on the Transportation of Radioactive Material by Air and other Modes," (NUREG-0170) and are presented in **Table E.3.2-3. Table E.3.2-3** is arranged from high probability, low speed, low impact accidents (Severity Category 1) that are more likely to occur in urban areas to low probability, high speed, high impact accidents (Severity Category 8) that are more likely to occur in rural areas.

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TABLE E. 3.2-3
REGIONAL FRACTION OF ACCIDENT SEVERITY OCCURENCES, TRUCK

Severity Category	Rural	Suburban	Urban
1	0.055	0.055	0.44
2	0.036	0.036	0.288
3	0.021	0.028	0.021
4	0.0048	0.0064	0.0048
5	0.0014	0.00084	0.00056
6	0.00077	0.00022	0.00011
7	0.000068	0.0000085	0.0000085
8	0.0000135	0.00000075	0.00000075

In addition, for each accident severity category, the user inputs data on the fraction of material that could be expected to be released from a container during an accident, the fraction of material released that can become aerosol, and the fraction of aerosol material that can become respirable. The accident release fractions for treated Silos 1 and 2 material is presented in **Table E.3.2-4**.

<END OF PAGE>

TABLE E. 3.2-4
ACCIDENT RELEASE FRACTIONS

Severity Category	Release Fraction	Aerosol Fraction	Respirable Fraction
1	0.0	N/A	N/A
2	0.01	0.000007	1
3	0.1	0.00002	1
4	1	0.00009	1
5	1	0.0002	1
6	1	0.0004	1
7	1	0.001	1
8	1	0.002	1

E.3.3 Results

As stated previously, RADTRAN5® estimates the risk of fatalities to workers and the public due to non-radiological accidents, dose to workers and the public resulting from incident-free transport of radiological material, and dose to populations that are downwind from hypothetical releases associated with accidents of varying severity.

Tables E.3.3-1 and **E.3.3-2** present data on the non-radiological risk of fatality to workers and the public for each of the proposed routes. There are two types of risk to the public for non-radiological fatalities. One is the risk of a fatality resulting from an accident and the other is the risk of a fatality resulting from exhaust emissions from the operation of a motor vehicle.

TABLE E. 3.3-1

ESTIMATED NON-RADIOLOGICAL FATALITIES, OCCUPATIONAL

	Estimated Non-Radiological Fatalities			
Route	VIT1	VIT2	CHEM1	CHEM2
Baseline Route	5.05E-02	4.57E-02	1.29E-01	1.29E-01
Southern Route #1	5.60E-02	5.05E-02	1.47E-01	1.47E-01
Southern Route #2	5.50E-02	4.95E-02	1.39E-01	1.40E-01
Southern Route #3	5.75E-02	5.07E-02	1.46E-01	1.47E-01
Southern Route #4	5.55E-02	5.00E-02	1.41E-01	1.42E-01
Northern Route #1	5.85E-02	5.08E-02	1.48E-01	1.49E-01
Northern Route #2	6.30E-02	5.65E-02	1.59E-01	1.60E-01
Northern Route #3	5.85E-02	5.08E-02	1.48E-01	1.48E-01

TABLE E. 3.3-2

ESTIMATED NON-RADIOLOGICAL FATALITIES, PUBLIC

	Estimated Non-Radiological Fatalities			
Route	VIT1	VIT2	CHEM1	CHEM2
Baseline Route	1.89E-01	1.69E-01	4.76E-01	4.78E-01
Southern Route #1	2.03E-01	1.84E-01	5.15E-01	5.16E-01
Southern Route #2	2.00E-01	1.79E-01	5.05E-01	5.07E-01
Southern Route #3	2.12E-01	1.91E-01	5.35E-01	5.40E-01
Southern Route #4	2.03E-01	1.82E-01	5.10E-01	5.15E-01
Northern Route #1	2.09E-01	1.89E-01	5.33E-01	5.33E-01
Northern Route #2	2.29E-01	2.07E-01	5.78E-01	5.83E-01
Northern Route #3	2.11E-01	1.91E-01	5.34E-01	5.39E-01

Tables E.3.3-3 and **E.3.3-4** present data on the estimated collective dose equivalent received by workers and the public resulting from incident-free transport of treated Silos 1 and 2 material. In the case of the public, the collective dose equivalent includes individuals living along the proposed route (off-link) and individuals sharing the road (on-link), as well as individuals exposed during vehicular stops (e.g., refueling, eating, and sleeping). The collective dose equivalent is the sum of the estimated individual doses received by each transportation crew member or member of the public. For example, the sum of the estimated individual radiation doses received by each transportation crew member during the 1,199 shipments of joule-heated vitrified material (VIT1) over proposed Southern Route #1 is 48.9 person-rem. The sum of the estimated individual radiation doses received by each member of the public either living along, sharing the road, or occupying stops at the same time as normal transport of the 1,199 shipments of the joule-heated vitrified material over proposed Southern Route #1 is 1,950 person-rem.

Table E.3.3-5 presents data on the estimated collective dose equivalent from releases resulting from accidents. For example, the sum of the individual radiation doses estimated to be received by members of the public due to hypothetical releases resulting from an accident while shipping combustion vitrified material (VIT2) over proposed Southern Route #2 is 0.0567 person-rem.

<END OF PAGE>

TABLE E. 3.3-3

COLLECTIVE DOSE EQUIVALENT, TRANSPORTATION CREW

	Collective Dose Equivalent, person-rem			
Route	VIT1	VIT2	CHEM1	CHEM2
Baseline Route	9.34E+01	1.56E+02	2.24E+02	4.00E+02
Southern Route #1	9.78E+01	1.64E+02	2.35E+02	4.19E+02
Southern Route #2	9.62E+01	1.61E+02	2.32E+02	4.13E+02
Southern Route #3	1.02E+02	1.71E+02	2.46E+02	4.39E+02
Southern Route #4	9.66E+01	1.63E+02	2.32E+02	4.15E+02
Northern Route #1	1.00E+02	1.69E+02	2.42E+02	4.30E+02
Northern Route #2	1.09E+02	1.82E+02	2.62E+02	4.68E+02
Northern Route #3	1.01E+02	1.70E+02	2.44E+02	4.33E+02

TABLE E. 3.3-4

COLLECTIVE DOSE EQUIVALENT, PUBLIC - INCIDENT FREE AND STOPS

	Collective Dose Equivalent, person-rem			
Route	VIT1	VIT2	CHEM1	CHEM2
Baseline Route	1.91E+03	1.72E+03	4.86E+03	4.88E+03
Southern Route #1	1.95E+03	1.76E+03	4.95E+03	4.97E+03
Southern Route #2	1.92E+03	1.73E+03	4.85E+03	4.89E+03
Southern Route #3	2.05E+03	1.85E+03	5.20E+03	5.22E+03
Southern Route #4	1.92E+03	1.72E+03	4.85E+03	4.87E+03
Northern Route #1	1.91E+03	1.73E+03	4.86E+03	4.88E+03
Northern Route #2	2.09E+03	1.89E+03	5.30E+03	5.32E+03
Northern Route #3	1.95E+03	1.76E+03	4.95E+03	4.97E+03

TABLE E. 3.3-5

COLLECTIVE DOSE EQUIVALENT, PUBLIC - ACCIDENT

	Collective Dose Equivalent, person-rem			
Route	VIT1	VIT2	CHEM1	CHEM2
Baseline Route	6.57E-02	6.60E-02	7.45E-02	7.77E-02
Southern Route #1	6.11E-02	6.13E-02	6.93E-02	7.22E-02
Southern Route #2	5.65E-02	5.67E-02	6.40E-02	6.67E-02
Southern Route #3	6.83E-02	6.86E-02	7.75E-02	8.08E-02
Southern Route #4	6.16E-02	6.18E-02	6.99E-02	7.28E-02
Northern Route #1	3.88E-02	3.89E-02	4.40E-02	4.58E-02
Northern Route #2	4.67E-02	4.68E-02	5.29E-02	5.52E-02
Northern Route #3	4.96E-02	4.98E-02	5.63E-02	5.87E-02

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E.4.0 TRANSPORTATION ROUTES – INTERMODAL

This section evaluates the radiological risk posed to the general public and workers by the intermodal (i.e., combination truck and rail shipments) routes proposed for transporting radioactive material from Fernald to the NTS. FDF evaluated five intermodal routes. A discussion of these routes is presented below.

Historically, radioactive waste generated at Fernald has been shipped to the NTS by direct truck. The former route went over the Hoover Dam and through Las Vegas, Nevada on US95. Due to the concerns of stakeholders in the Las Vegas metropolitan area regarding transportation of radioactive material, DOE has established alternate routes, which avoid Hoover Dam and Las Vegas, for use. Furthermore, stakeholders have suggested that DOE might reduce transportation costs and enhance public safety by using rail transportation.

Since the NTS does not have a direct rail line onto its facility, containers would need to be transferred to truck for final movement to the NTS. In addition, Fernald does not currently have the infrastructure in place to load flatbed railcars. Therefore, this study will evaluate intermodal shipments consisting of a truck-rail-truck scenario.

E.4.1 Proposed Routes

The proposed intermodal routes include an evaluation of two intermodal facility options in the east (i.e., Chicago, Illinois and Cincinnati, Ohio) and four intermodal facility options in the west (i.e., Barstow, California; Caliente, Nevada; North Las Vegas, Nevada; and Salt Lake City, Utah). Cincinnati was selected for evaluation because of its close proximity to the FEMP while Chicago was selected because vendors whom had been interviewed suggested possible cost savings by shipping out of Chicago. Sites in the west were selected because of their proximity to the NTS and/or their intermodal capabilities. In addition, the site in North Las Vegas was evaluated at the request of Nye County in Nevada.

E.4.1.1 Intermodal Facility - Cincinnati

Intermodal Route #1 - Rail from Cincinnati to Barstow

This proposed route to the NTS consists of traveling I-275 to I-74 to I-75 to Queensgate. At the Queensgate facility, shipments would be transferred over to rail for shipment to Barstow. In Barstow, shipments would be transferred back over to truck. Trucks would then travel up I-15 to CSR 127 into Nevada to NSR 373 to US95 to the NTS.

Intermodal Route #2 - Rail from Cincinnati to Caliente

This proposed route to the NTS consists of traveling I-275 to I-74 to I-75 to Queensgate. At the Queensgate facility, shipments would be transferred over to rail for shipment to Caliente. In Caliente, shipments would be transferred back over to truck. Trucks would then travel US93 to NSR 375 to US6 to US95 to the NTS.

Intermodal Route #3 - Rail from Cincinnati to North Las Vegas

This proposed route to the NTS consists of traveling I-275 to I-74 to I-75 to Queensgate. At the Queensgate facility, shipments would be transferred over to rail for shipment to North Las Vegas. In North Las Vegas, shipments would be transferred back over to truck. Trucks would then travel I-15 to US95 to the NTS.

Intermodal Route #4 - Rail from Cincinnati to Salt Lake City

This proposed route to the NTS consists of traveling I-275 to I-74 to I-75 to Queensgate. At the Queensgate facility, shipments would be transferred over to rail for shipment to Salt Lake City. In Salt Lake City, shipments would be transferred back over to truck. Trucks would then travel I-80 into Nevada to US93 Alternate to US50 to US6 to US95 to the NTS.

000059

E.4.1.2 Intermodal Facility - Chicago

Intermodal Route #5 – Rail from Chicago to Caliente

This proposed route to the NTS consists of traveling I-74 through Ohio and Indiana to I-465 in Indianapolis to I-65 to I-80 into Illinois to I-94 to Thornton Junction. At the Thornton Junction facility, shipments would be transferred over to rail for shipment to one of the aforementioned western intermodal facilities. For purposes of this document, only the Caliente facility was evaluated. At Caliente, shipments would be transferred back over to truck. Trucks would then travel US93 to NSR 375 to US6 to US95 to the NTS.

E.4.2 Evaluation of Risk

As with the direct truck routes, the estimated radiological risk to the public and workers during transportation was calculated using the RADTRAN5® computer model developed by Sandia National Laboratories. Where possible, "standard" RADTRAN5® values for parameters were used if they were not specific to the radioactive material, package, vehicle, or route.

Many of the parameters utilized for calculating risk associated with direct truck routes were also used for evaluating risk associated with intermodal routes. **Table E.4.2-1** presents the user-defined package-specific and vehicle-specific parameters associated with the four treatment alternatives.

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TABLE E. 4.2-1
PACKAGE-SPECIFIC AND VEHICLE-SPECIFIC PARAMETERS FOR RADTRAN5® ANALYSIS, RAIL

Parameters	VIT1	VIT2	CHEM1	CHEM2
Number of Truck Shipments	1,199	1,081	3,039	3,053
Number of Rail Shipments	600	541	1,520	1,527
Number of Containers per Truck Shipment	2	2	2	2
Number of Containers per Rail Shipment	4	4	4	4
Dose Rate 1 m from Package (mrem/hr)	23.3	40.7	19.7	18.0
Characteristic Package Dimension (m)	2.72	3.13	3.16	1.71
Dose Rate 1 m from Vehicle (mrem/hr)	20.2	40.0	19.4	27.3
Characteristic Vehicle Dimension, Truck (m)	12.20	12.20	12.20	12.20
Characteristic Vehicle Dimension, Rail (m)	24.38	24.38	24.38	24.38
Number of Crew Members	2	2	2	2
Average Distance from Package to Crew Members, Truck (m)	7.62	7.62	7.62	7.62
Average Distance from Package to Crew Members, Rail (m)	100	100	100	100
Crew View Package Dimension (m)	1.52	1.42	1.60	1.93

The radionuclide content for each treatment alternative presented in **Table E.3.2-2** would not differ between intermodal and direct truck options. The curie content for each alternative is based on the waste loading for the treatment alternative, the packaging density of the treated material, and the volume of treated material in each container.

RADTRAN5® requires data that expresses the likelihood of accidents of a given severity for urban, suburban, and rural population areas. Accident severity categories with their respective probabilities of occurrence for each population area were obtained from NUREG-0170 and is presented in **Table E.4.2-2. Table E.4.2-2** is arranged from high probability, low speed, low impact accidents (Severity Category 1) that are more likely to occur in urban areas to low probability, high speed, high impact accidents (Severity Category 8) that are more likely to occur in rural areas.

000061

TABLE E. 4.2-2
REGIONAL FRACTION OF ACCIDENT SEVERITY OCCURENCES, RAIL

Severity Category	Rural	Suburban	Urban
1	0.05	0.05	0.4
2	0.03	0.03	0.24
3	0.054	0.072	0.054
4	0.0054	0.0072	0.0054
5	0.0009	0.00054	0.00036
6	0.000091	0.000026	0.000013
7	0.000048	0.000006	0.000006
8	0.000009	0.0000005	0.0000005

In addition, for each accident severity category, the user inputs data on the fraction of material that could be expected to be released from a container during an accident, the fraction of material released that can become aerosol, and the fraction of aerosol material that can become respirable. The accident release fractions for treated Silos 1 and 2 material presented in **Table E.3.2-4** would not differ between intermodal and direct truck options.

E.4.3 Results

As stated previously, RADTRAN5® estimates the risk of fatalities to workers and the public due to non-radiological accidents, dose to workers and the public resulting from incident-free transport of radiological material, and dose to populations that are downwind from hypothetical releases associated with accidents of varying severity.

Tables E.4.3-1 and **E.4.3-2** present data on the estimated risk of non-radiological fatalities to workers and the public for each of the proposed routes. As in the case of direct truck, there are two types of risk to the public for non-radiological fatalities. One is the risk of a fatality resulting from an accident and the other is the risk of a fatality resulting from exhaust emissions from operation of a transport vehicle.

TABLE E. 4.3-1
ESTIMATED NON-RADIOLOGICAL FATALITIES, OCCUPATIONAL

	Estimated Non-Radiological Fatalities			
Route	VIT1	VIT2	CHEM1	CHEM2
Intermodal Route #1	2.06E-02	1.86E-02	5.22E-02	5.24E-02
Intermodal Route #2	2.82E-02	2.54E-02	7.14E-02	7.17E-02
Intermodal Route #3	1.23E-02	1.11E-02	3.11E-02	3.13E-02
Intermodal Route #4	3.85E-02	3.47E-02	9.77E-02	9.81E-02
Intermodal Route #5	3.87E-02	3.51E-02	9.80E-02	9.85E-02

TABLE E. 4.3-2
ESTIMATED NON-RADIOLOGICAL FATALITIES, PUBLIC

	Estimated Non-Radiological Fatalities			
Route	VIT1	VIT2	CHEM1	CHEM2
Intermodal Route #1	1.73E-01	1.57E-01	4.39E-01	4.42E-01
Intermodal Route #2	1.87E-01	1.68E-01	4.74E-01	4.76E-01
Intermodal Route #3	1.35E-01	1.22E-01	3.43E-01	3.45E-01
Intermodal Route #4	2.12E-01	1.91E-01	5.38E-01	5.40E-01
Intermodal Route #5	2.25E-01	2.07E-01	5.70E-01	5.74E-01

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Tables E.4.3-3 and **E.4.3-4** present data on the estimated collective dose equivalent received by workers and the public resulting from incident-free transport of treated Silos 1 and 2 material. In the case of the public, the collective dose equivalent includes individuals living along the proposed route (off-link) and individuals sharing the route (on-link), as well as individuals exposed during vehicular stops (e.g., refueling, eating, and sleeping). For example, the sum of the estimated individual radiation doses received by the transportation crew, including handling at intermodal facilities, resulting from shipment of chemically stabilized cement-based material (CHEM1) over the proposed Intermodal Route #1 is 1,770 person-rem. The sum of the estimated radiation doses received by the public during normal transport, including stops, resulting from shipment of chemically stabilized cement-based material over proposed Intermodal Route #1 is 83,900 person-rem.

Table E.4.3-5 presents data on the estimated collective dose equivalent from releases resulting from accidents. For example, the sum of the estimated radiation doses received by the public during hypothetical releases resulting from accidents while shipping chemically stabilized cement-based material over proposed Intermodal Route #1 is 0.242 person-rem.

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TABLE E. 4.3-3

COLLECTIVE DOSE EQUIVALENT, TRANSPORTATION CREW - INCIDENT FREE AND HANDLING

	Collective Dose Equivalent, person-rem			
Route	VIT1	VIT2	CHEM1	CHEM2
Intermodal Route #1	7.50E+02	1.22E+03	1.77E+03	1.27E+03
Intermodal Route #2	7.52E+02	1.23E+03	1.77E+03	1.29E+03
Intermodal Route #3	7.39E+02	1.21E+03	1.74E+03	1.24E+03
Intermodal Route #4	7.54E+02	1.24E+03	1.78E+03	1.32E+03
Intermodal Route #5	7.61E+02	1.25E+03	1.80E+03	1.34E+03

TABLE E. 4.3-4

COLLECTIVE DOSE EQUIVALENT, PUBLIC - INCIDENT FREE AND STOPS

	Collective Dose Equivalent, persons-rem			
Route	VIT1	VIT2	CHEM1	CHEM2
Intermodal Route #1	2.98E+02	2.70E+02	7.56E+02	7.60E+02
Intermodal Route #2	4.01E+02	3.61E+02	1.01E+03	1.02E+03
Intermodal Route #3	2.24E+02	2.02E+02	5.67E+02	5.71E+02
Intermodal Route #4	5.56E+02	5.02E+02	1.41E+03	1.41E+03
Intermodal Route #5	6.42E+02	5.81E+02	1.63E+03	1.64E+03

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TABLE E. 4.3-5
COLLECTIVE DOSE EQUIVALENT, PUBLIC - ACCIDENT

	Collective Dose Equivalent, person-rem			
Route	VIT1	VIT2	CHEM1	CHEM2
Intermodal Route #1	2.13E-01	2.14E-01	2.42E-01	2.52E-01
Intermodal Route #2	1.83E-01	1.83E-01	2.07E-01	2.16E-01
Intermodal Route #3	2.00E-01	2.01E-01	2.27E-01	2.37E-01
Intermodal Route #4	1.83E-01	1.83E-01	2.07E-01	2.16E-01
Intermodal Route #5	1.74E-01	1.74E-01	1.97E-01	2.05E-01

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E.5.0 CONCLUSIONS

E.5.1 Direct Truck and Intermodal Evaluation

Based on the evaluation of direct truck and intermodal shipments of Silos 1 and 2 material in the previous sections, the most conservative route analysis (i.e., analysis of the routes presenting the greatest risk to the public) examine proposed Southern Route #3 for direct truck and proposed Intermodal Route #5 for intermodal. **Figures E.5.1-1** and **E.5.1-2** present maps of proposed Southern Route #3 and proposed Intermodal Route #5, respectively. As a result, these two routes were selected to evaluate whether direct truck and intermodal shipments, respectively, present an acceptable risk to the public under CERCLA. In addition, since the chemical stabilization – other (CHEM2) alternative presented a slightly higher risk during transportation than the other alternatives, it was used for the CERCLA evaluation of the proposed transportation routes.

The risk from exposure to ionizing radiation is measured in latent cancer fatalities (LCF), which is the number of potential cancer fatalities estimated as a result of radiation exposure. An incremental lifetime cancer risk (ILCR) - the increased potential of an individual developing a cancer over a lifetime as a result of exposure - can be determined by comparing the potential number of cancers against the total exposed population. LCFs are calculated by Eq.2.

$$LCF = H_E \bullet CRF \qquad \text{(Eq. 2)}$$

where,

H_E = collective effective dose equivalent for exposed population
LCF = latent cancer fatalities
CRF = cancer risk factor, LCF/person-rem

The cancer risk factor for workers is 4.00E-04 LCFs per person-rem while for the public it's 5.00E-04 per person-rem. These values are used in the RADTRAN5® computer model and are from the latest edition of ICRP-30.

A range of 10^{-4} – 10^{-6} for an additional lifetime cancer risk to the public has been determined to be acceptable under CERCLA. To determine whether the transportation options meet this requirement, the ILCR to the public was determined using Equation 3.

ILCR = LCF/POP (Eq. 3)

where,

LCF = latent cancer fatalities

POP = total population exposed

Based on population density 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. The total population estimated by the RADTRAN5® computer model to be either living along or sharing the proposed Intermodal Route #1 is approximately 619,000 people.

Using the collective dose equivalent of 5,220 person-rem for incident free shipment of the treated waste under the CHEM2 alternative on Southern Route #3 and the exposed population of 1.24 million people, the ILCR is calculated to be 2.10E-06. This equates to 1 additional cancer for approximately every 476,000 people.

Using the collective dose equivalent of 1,640 person-rem for incident free shipment of treated waste from the CHEM2 alternative on Intermodal Route #5 and an exposed population of approximately 746,000 people, the ILCR is calculated to be 1.10E-06. This equates to 1 additional cancer for approximately every 910,000 people.

000069

For evaluating accident scenarios, RADTRAN5® determines the probability of an accident occurring, as well as the collective dose equivalent of the exposed population for each segment of the route. The collective dose equivalent is based on the population density for the segment, evacuation times, the dispersability of the material, deposition rate of the material, and the number of shipments. RADTRAN5® then presents a collective dose equivalent for the entire route which is a sum of the collective dose equivalents for each of the segments along the route. The resulting exposed population is also a summation of the exposed population for each segment of the route.

For the direct truck shipment of treated CHEM2 waste along Southern Route #3, the total estimated collective dose equivalent resulting from evaluation of an accidental release is 0.808 person-rem. The sum of the exposed population for the entire route is approximately 41.9 million people. This results in a calculated ILCR of 9.64E-13, or 1 additional cancer for approximately every 1.04 trillion people.

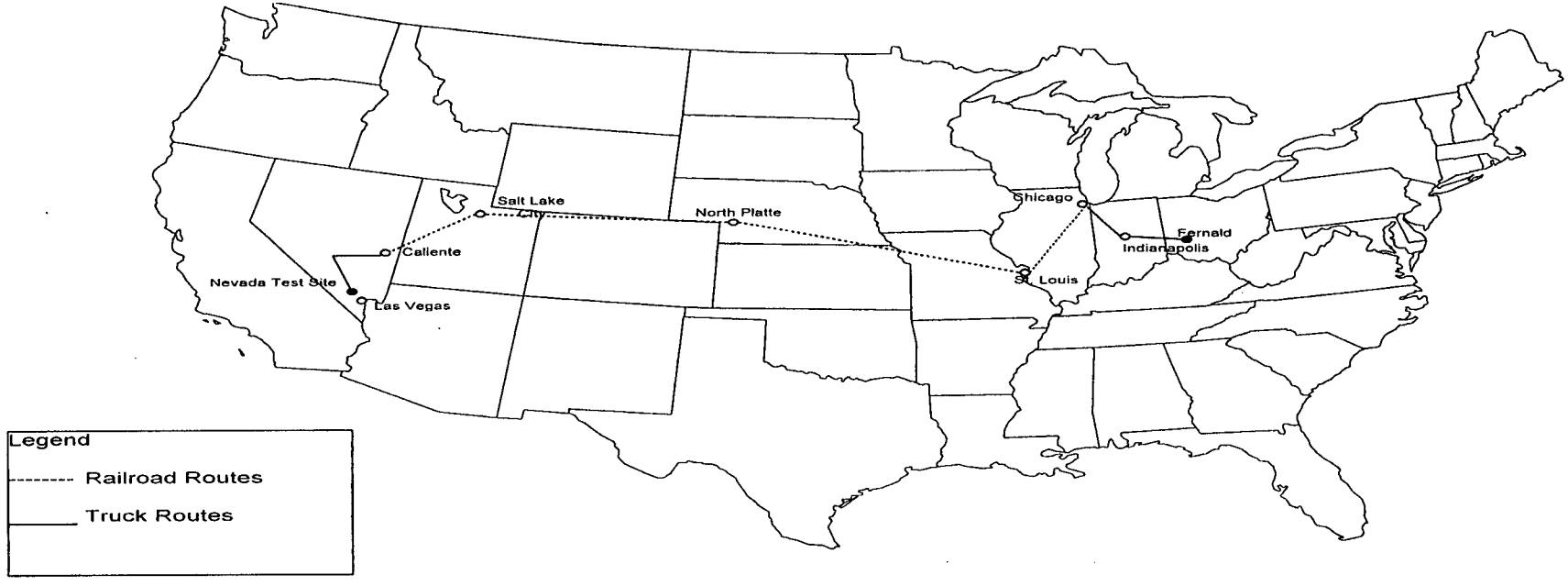
For intermodal shipment of treated CHEM2 waste along Intermodal Route #5, the total estimated collective dose equivalent resulting from evaluation of an accidental release is 0.205 person-rem. The sum of the exposed population for the entire route is approximately 19.7 million people. This results in a calculated ILCR of 5.20E-12, or 1 additional cancer for approximately every 192 billion people.

Both proposed transportation routes meet the acceptable risk range to the public established under CERCLA. In addition, since the two routes evaluated here present the highest risk to the public, it can be determined that both direct truck and intermodal transportation options are acceptable means of shipping Silos 1 and 2 material to the NTS.

000071

FIGURE E. 5.1-1
SOUTHERN ROUTE #3

FIGURE E. 5.1-2
INTERMODAL ROUTE #5



E-8074
000072

For purposes of this revised FS, proposed Southern Route #3 was used as a base case scenario for determining risk and cost data for the treatment technology alternatives being evaluated. However, it is anticipated that actual shipments to the NTS could utilize a combination of both direct truck and intermodal routes throughout the duration of the project.

<END OF SECTION>

F-8074

Appendix F

F-8074

APPENDIX F

OU4 DECISION MAKING PROCESS SUPPLEMENT

=- 8074

TABLE OF CONTENTS

APPENDIX F

Page f-

List of Tables iv
List of Figures v
List of Acronyms & Abbreviations vi
Chemical Elements & Weights and Measures viii

Page F-

F.1.0 INTRODUCTION 1-1

F.1.1 Scope And Role of Remedial Action 1-2
F.1.2 Integration of NEPA into CERCLA 1-4

F.2.0 SUMMARY OF OU4 CHARACTERISTICS 2-1

F.2.1 Investigative Studies 2-1
F.2.2 Summary of Description of Contamination Sources 2-2
F.2.2.1 Description of Operable Unit 4 2-2
F.2.2.2 Operational History for Silos 1 and 2 2-10
F.2.2.3 Silos 1 and 2 Material Characterization 2-21
F.2.3 Nature and Extent of Contamination 2-37
F.2.3.1 Surface Soils 2-38
F.2.3.2 Subsurface Soils 2-39
F.2.3.3 Surface Water and Sediment 2-40
F.2.3.4 Groundwater 2-40
F.2.4 Potential Exposure Pathways for Contaminant Migration 2-43
F.2.4.1 Direct Radiation 2-44
F.2.4.2 Air Emissions 2-44
F.2.4.3 Surface Water Runoff 2-45
F.2.4.4 Groundwater Transport 2-46

F.3.0 BASELINE RISK ASSESSMENT 3-1

F.3.1 Summary of the Baseline Assessment of Risks to Human Health 3-2
F.3.1.1 Constituents of Concern 3-2
F.3.1.2 Exposure Assessment 3-2
F.3.1.3 Toxicity Assessment 3-26
F.3.1.4 Risk Characterization Results 3-27
F.3.1.5 Risk Assessment Uncertainties 3-33
F.3.2 Overview of the Baseline Ecological Risk Assessment 3-35

000075

F.4.0 DESCRIPTION OF REMEDIAL ALTERNATIVES 4-1

F.4.1 No-Action Alternative for Subunits 4-5
F.4.2 Subunit A - Contents of Silos 1 and 2 and the Decant Sump Tank 4-6
F.4.2.1 Alternative 3A.1/Vit - Removal, Vitrification, and Off-Site Disposal at the NTS 4-6
F.4.2.2 Alternative 3A.1/Cem - Removal, Cement Stabilization, and Off-Site Disposal at the NTS 4-10
F.4.3 Subunit B - Contents of Silo 3 4-12
F.4.3.1 Alternative 2B/Vit - Removal, Vitrification, and On-Property Disposal 4-13
F.4.3.2 Alternative 2B/Cem - Removal, Cement Stabilization, and On-Property Disposal 4-16
F.4.3.3 Alternative 3B.1/Vit — Removal, Vitrification, and Off-Site Disposal at the NTS 4-18
F.4.3.4 Alternative 3B.1/Cem — Removal, Cement Stabilization, and Off-Site Disposal at the NTS 4-19
F.4.3.5 Alternative 4B — Removal and On-Property Disposal 4-20
F.4.4 Subunit C - Silos 1, 2, 3, and 4 Structures, Soils, and Debris 4-22
F.4.4.1 Alternative 2C - Demolition, Removal, and On-Property Disposal 4-24
F.4.4.2 Alternative 3C.1 — Demolition, Removal, and Off-Site Disposal at the NTS 4-27
F.4.4.3 Alternative 3C.2 — Demolition, Removal, and Off-Site Disposal (Permitted Commercial Disposal Site) 4-28

F.5.0 SUMMARY OF THE COMPARATIVE ANALYSIS OF ALTERNATIVES 5-1

F.5.1 Evaluation Criteria 5-1
F.5.2 Comparative Analysis of Alternatives 5-2
F.5.2.1 Analysis for Subunit A 5-2
F.5.2.2 Subunit B 5-14
F.5.2.3 Subunit C 5-21

F.6.0 SELECTED REMEDY 6-1

F.6.1 Key Components 6-1
F.6.1.1 Removal of Silos 1, 2 and 3, and Decant Sump Tank Contents 6-2
F.6.1.2 Vitrification of Silos 1, 2 and 3, and Decant Sump Tank Contents 6-3
F.6.1.3 Off-Site Shipment and Disposal of Treated Material 6-3
F.6.1.4 Demolition and Decontamination of Structures 6-6
F.6.1.5 Demolition and Decontamination of Other OU4 Structures 6-6
F.6.1.6 Disposition of Demolished Structures and Debris 6-7
F.6.1.7 Soil Removal 6-11
F.6.1.8 Soil Disposition 6-12
F.6.2 Soil Cleanup Criteria 6-13
F.6.2.1 Land-use and Receptor Description 6-13
F.6.2.2 Preliminary Remediation Levels 6-14
F.6.3 Measures to Control Environmental Impacts 6-21

8074

F.7.0 STATUTORY DETERMINATIONS 7-1

F.7.1 Protection of Human Health and the Environment 7-2
F.7.2 Compliance with Legally Applicable or Relevant and Appropriate Requirements 7-2
F.7.2.1 OU4 ROD ARAR Analysis 7-2
F.7.2.2 Post-OU4 ROD ARAR Analysis 7-4
F.7.3 Cost Effectiveness 7-5
F.7.3.1 Cost 7-6
F.7.4 Utilization of Permanent Solutions and Alternative Treatment Technologies or Resource Recovery Technologies to the Maximum Extent Practicable 7-8
F.7.5 Preference for Treatment as a Principal Element 7-9
F.7.6 Unavoidable Adverse Impacts 7-9
F.7.7 Irreversible and Irretrievable Commitment of Resources 7-13

F.8.0 DOCUMENTATION OF SIGNIFICANT CHANGES 8-1

F.8.1 Repromulgation of 40 CFR Part 191 8-1
F.8.1.1 Background 8-2
F.8.1.2 Impacts of Repromulgation 8-3

F.9.0 BIBLIOGRAPHY 9-1

000077

LIST OF TABLES

Page F-

TABLE F.2.2-1 Summary of Radionuclide Analyses for Silos 1 and 2 Material 2-23
TABLE F.2.2-2 Inventory of K-65 Radiological Constituents 2-25
TABLE F.2.2-3 Summary of Chemical Analyses for Silos 1 and 2 Material 2-28
TABLE F.2.2-4 EP Toxicity Results for Silos 1 and 2 Material 2-33
TABLE F.2.2-5 Summary of TCLP Metals Analyses for Silo 2 Material 1990/1991 2-34
TABLE F.2.2-6 Summary of TCLP Metals Analyses for Silo 1 Material - 1990/1991 2-35
TABLE F.2.2-7 Summary of TCLP Radiological Analyses for Silos 1 and 2 Material 1990/1991 2-36
TABLE F.3.1-1 Constituents of Concern for OU4 3-4
TABLE F.3.1-2 Summary of Land-Use/Receptor/Source Term Scenarios 3-10
TABLE F.3.1-3 Cancer Slope Factors for Carcinogenic Effects of Constituents of Potential Concern in OU4 3-13
TABLE F.3.1-4 Cancer Slope Factors for Operable Unit 4 Radionuclides of Potential of Concern 3-19
TABLE F.3.1-5 Reference Doses for Noncarcinogenic Effects of Constituents of Potential Concern in OU4 3-20
TABLE F.3.1-6 Incremental Lifetime Cancer Risk Summary All Sources/All Pathways 3-29
TABLE F.3.1-7 Hazard Index Summary All Sources/All Pathways 3-30
TABLE F.4.0-1 Summary of Alternatives Considered During Detailed Analysis 4-2
TABLE F.5.2-1 Comparison of Remedial Alternatives 5-4
TABLE F.5.2-2 OU4 Remedial Alternative Cost Summary (Million$) 5-15
TABLE F.6.2-1 Preliminary Remediation Levels in Soils - Radionuclides 6-16
TABLE F.6.2-2 Preliminary Remediation Levels in Soils - Chemicals 6-17
TABLE F.6.2-3 Final Remediation Levels for Soils 6-20
TABLE F.7.3-1 Combined Cost Estimate for Selected Remedy 7-7
TABLE F.7.6-1 Unavoidable Adverse Impacts on Resources 7-10

F-8074

LIST OF FIGURES

Page F-

FIGURE F.2.2-1 Operable Unit 4 2-4
FIGURE F.2.2-2 Silo Dome Configuration 2-5
FIGURE F.2.2-3 Silos 1 and 2 Underdrain/Silo Foundation Detail 2-6
FIGURE F.2.2-4 Silos 1 and 2 Leachate Collection System 2-7
FIGURE F.2.2-5 Hot Raffinate from K-65 Drummed Waste Handling Facility 2-15
FIGURE F.2.2-6 Hot Rafinate Flow to Silo 2 2-20
FIGURE F.3.1-1 OU4 Conceptual Model - Silos Contents 3-11
FIGURE F.3.1-2 OU4 Conceptual Model - Soil and Berm Fill Material 3-12

ACRONYMS & ABBREVIATIONS

A - M

ACA	Amended Consent Agreement
AEA	Atomic Energy Act
ARAR	applicable or relevant and appropriate requirement
AWWT	Advanced Wastewater Treatment
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CI	confidence interval
CIS	Characterization Investigation Study
CMSA	consolidated metropolitan statistical area
COC	constituent of concern
CT	central tendency
DOE	U.S. Department of Energy
DOE-FEMP	U.S. Department of Energy - Fernald Environmental Management Project
DOE-NV	U.S. Department of Energy - Nevada
DOT	U.S. Department of Transportation
EIS	Environmental Impact Statement
EP	extraction procedure
EPA	U.S. Environmental Protection Agency
FEMP	Fernald Environmental Management Project
FMPC	Feed Materials Production Center
FRL	final remediation levels
FS	Feasibility Study
FS/PP-DEIS	Feasibility Study/Proposed Plan - Draft Environmental Impact Statement
HEAST	Health Effects Assessment Summary Table
HEPA	high efficiency particulate air
HI	hazard index
HQ	hazard quotient
HSL	Hazardous Substance List
IARC	International Agency for Research on Cancer
ILCR	incremental lifetime cancer risk
IRIS	Integrated Risk Information System
IRM	interim remedial measures
LOOW	Lake Ontario Ordnance Works
MCL	maximum contaminant level
MCW	Mallinckrodt Chemical Works

000080

8074

ACRONYMS AND ABBREVIATIONS (cont.)

N - Z

NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NEPA	National Environmental Policy Act
NLO	National Lead of Ohio
NOEL	no observed effect levels
NTS	Nevada Test Site
OAC	Ohio Administrative Code
OEPA	Ohio Environmental Protection Agency
O&M	operations and maintenance
OSDF	On-site Disposal Facility
OU	operable unit
PAH	polyaromatic hydrocarbons
PCB	polychlorinated biphenyls
PP	Proposed Plan
ppb	parts per billion
PVC	polyvinyl chloride
RCRA	Resource Conservation and Recovery Act, as amended
RfD	reference dose
RI	Remedial Investigation
RME	reasonable maximum exposure
ROD	Record of Decision
RTS	Radon Treatment System
SQL	sample quantitation limit
TBP	tributyl phosphate
TBC	to be considered
TCLP	Toxicity Characteristic Leaching Procedure
UCL	upper confidence limit
VOC	volatile organic compounds
WAC	waste acceptance criteria

Chemical Elements

actinium (Ac-227)
barium sulfate ($BaSO_4$)
lead (Pb-210)
lime $Ca(OH)_2$
nitric oxide (NO)
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)
thorium-230 (Th-230)
uranium oxide (U_3O_8)
uranium-235 (U-235)
uranium-238 (U-238)

Weights and Measures		Approximate U.S. Equivalent
g	gram	.035 ounce
cm^3	cubic centimeter	.061 cubic inch
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
µg	microgram	

		Approximate Metric Equivalent
gal/min	gallon per minute	3.785 liters per minute
lb	pound	.435 kilogram

mrem/hr	milli-Roentgen equivalent man (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	part per billion
rad	an absorbed dose of 0.01 joule/kilogram
rem	Roentgen equivalent man (rem = rad x quality factor, where quality factor is 1 for gamma radiation)

000082

8074

F.1.0 INTRODUCTION

This appendix summarizes the original decision-making process for the selected remedial actions for the Fernald Environmental Management Project (FEMP) Operable Unit 4 (OU4). The purpose of this appendix is to present sufficient information on the original decision-making process so that the Revised Feasibility Study (FS) for Silos 1 and 2 material can be a stand alone document, to the extent practical, with minimal reference to the original OU4 FS. The goal of the OU4 remedial action is the safe remediation of OU4 components in a safe, timely, and cost-effective manner that complies with applicable or relevant and appropriate requirements (ARARs) and that is protective of human health and the environment.

A Remedial Investigation/Feasibility Study (RI/FS) program was originally conducted for OU4 pursuant to the terms of a Consent Agreement between the Department of Energy (DOE) and the U.S. Environmental Protection Agency (EPA) under Sections 120 and 106(a) of the Comprehensive Environmental Response Compensation, and Liability Act (CERCLA), as amended (EPA 1991). The Ohio Environmental Protection Agency (OEPA) also participated in the RI/FS process at the FEMP through direct involvement in program review meetings and technical review of project documentation. In addition, stakeholders played a fundamental role in the decision-making process for the remediation of OU4 through review and comments on the *Proposed Plan for Remedial Actions at Operable Unit 4* (FEMP 1994a). In December 1994, the EPA approved the *Record of Decision for Operable Unit 4 of the Feed Materials Production Center* (EPA 1994). The selected remedy outlined in the OU4 ROD consists of the removal of the contents of Silos 1, 2 and 3; remediation by vitrification; off-site disposal of the waste at the Nevada Test Site (NTS); and, demolition, removal and final disposition of the contaminated concrete, debris and soils within the OU4 boundary.

As noted in the OU4 ROD, the decision regarding the final disposition of the remaining OU4 contaminated soils and debris was placed in abeyance until completion of the RODs for OU3 (FEMP 1996a) and OU5 (FEMP 1996c) remedial actions. This was done in order to take full advantage of the planned and in-progress waste minimizing treatment processes of these operable units (OUs). Further, this strategy enabled the integration of disposal decisions for contaminated soils and debris on a site-wide basis.

Section F.6 contains supplementary information (post-OU4 ROD) on the final disposition of OU4 contaminated soil and debris. The information is based upon site-wide waste management strategies developed and currently being implemented in accordance with the OU3 and OU5 RODs.

F.1.1 Scope And Role of Remedial Action

To facilitate cleanup, Fernald was divided into five sections OUs based on their locations or the potential for similar technologies to be used in the ultimate cleanup. The OU concept at the FEMP site involves grouping waste areas or related environmental concerns in a manner that permits more expedient completion of the RI/FS process. The five FEMP OUs are broadly defined as:

- Operable Unit 1 (OU1) - Waste Pit Area;
- Operable Unit 2 (OU2) - Other Waste Units;
- Operable Unit 3 (OU3) - Former Production Area;
- Operable Unit 4 (OU4) - Silos 1 through 4; and
- Operable Unit 5 (OU5)- Environmental Media.

Separate RI/FS documentation and RODs have been issued for OUs 1 through 5. The sixth OU, known as the Comprehensive Site-wide Operable Unit, was added as a provision of the Amended Consent Agreement (ACA) (EPA 1991). OU6 is not a specific area; it was created to ensure that ongoing or planned remedial actions identified in the five OU RODs would provide a remedy for the FEMP site that is comprehensive and protective of human health and the environment.

The focus of the remedial action for OU4 was the permanent disposition of inventoried processing materials contained in three concrete silos and an underground sump at the FEMP. The scope also included the disposition of contaminated building materials associated with the concrete silos and ancillary support facilities. The action further involved the disposition of contaminated soils, process wastewater, and perched water encountered within the OU4 study area.

The nature of the material, coupled with the threat of release from their present storage configuration and the potential threat of contaminant migration from the affected soils into the atmosphere and the underlying aquifer system, represents a potential threat to human health and the environment. The purpose of the remedial action was/is to prevent current and future exposure to the inventoried material, remove contaminated soil and debris within OU4, and remove the threat of hazardous substance releases into the environment.

Several removal actions have been completed within the OU4 study area. These removal actions are:

- Installation of a layer of BentoGrout™ clay over the K-65 material in Silos 1 and 2.
- Removal and treatment of water from the K-65 decant sump tank at the FEMP Advanced Wastewater Treatment (AWWT) plant. (Water within the tank is removed whenever the liquid level in the sump reaches 80 percent (%) of the tanks capacity.)
- Removal of a deteriorated dust collector on the dome of Silo 3.
- Installation of a series of drainage control structures, swales, and culverts to direct surface runoff to the existing in-ground sump.

In addition to the removal actions listed above, a polyurethane foam insulation was applied to the exterior of the dome surfaces of Silos 1 and 2 to inhibit wide temperature swings within the silos. These removal actions have been conducted to respond to contaminant releases and to mitigate health and safety threats in accordance with CERCLA. These actions have also been conducted in accordance with the regulations for implementing the provisions of the National Environmental Policy Act (NEPA), set forth by the Council on Environmental Quality (NEPA 1969).

Cleanup decisions for groundwater beneath the OU4 study area, sediment in Paddys Run, and soil and waste source areas outside the OU4 study area are not included within the scope of the OU4 remedial actions. Therefore, separate RI/FS and other remediation documentation has been prepared for these facilities and other FEMP OUs. All remedial documents have been issued consistent with the terms of the ACA (EPA 1991).

F.1.2 Integration of NEPA into CERCLA

DOE chose to complete an integrated CERCLA/NEPA process for OU4. This decision was based on the longstanding interest of local stakeholders to prepare an Environmental Impact Statement (EIS) on the restoration activities at the FEMP and on the recognition that the draft document was issued and public comments received. Therefore, an integrated *Feasibility Study/Proposed Plan - Environmental Impact Statement* (FS/PP-EIS) was completed that evaluated alternatives for the treatment and disposal of radioactive material contained in the storage silos at the FEMP (FEMP 1994b).

In accordance with both CERCLA and NEPA processes, this documentation was made available to the public for comment. The contents of the documents prepared for the remedial actions at the FEMP were not intended to represent a statement on the legal applicability of NEPA to remedial actions conducted under CERCLA (CERCLA 1980).

F.2.0 SUMMARY OF OU4 CHARACTERISTICS

Several investigative studies were conducted to determine the characteristics of the contamination sources and the nature and extent of contamination within OU4. These investigative activities focused on the following facilities and associated environmental media:

- Silos 1 and 2 and their contents (also termed the "K-65 silos");
- Silo 3 and its contents (also termed the "cold metal oxide silo");
- Silo 4;
- K-65 decant sump tank, its contents, and associated piping;
- A radon treatment system (RTS);
- A portion of a concrete pipe trench and other concrete structures;
- An earthen berm surrounding Silos 1 and 2;
- Soils beneath and immediately surrounding Silos 1, 2, 3, and 4; and
- Perched groundwater encountered near the silos while implementing OU4 cleanup activities. (Note: groundwater within the Great Miami Aquifer underlying the silos area is not within the scope of OU4, but it is within the scope of OU5.)

F.2.1 Investigative Studies

The OU4 RI/FS sampling program was the primary source of information for characterizing contamination sources and evaluating the nature and extent of contamination associated with OU4. Other investigative studies that provided characterization data for OU4 include the Waste Pit Area Runoff Control Removal Action (part of Removal Action #2 in the Administrative Record), the FEMP Environmental Monitoring Program, and the *Characterization Investigation Study (CIS)* (Weston 1987).

F.2.2 Summary of Description of Contamination Sources

This section provides a brief physical description of each of the facilities comprising OU4; a summary of the operational history pertinent to Silos 1 and 2; and, pertinent physical, chemical and radiological characterization information relative to the Silos 1 and 2 material. The operational history primarily focuses on the operational activities conducted prior to the initiation of the RI/FS in 1986.

F.2.2.1 Description of Operable Unit 4

OU4 is located on the western side of the FEMP site, south of the OU1 Study Area **(Figure F.2.2-1)**. The geographic area constituting OU4 is bounded by the following Ohio State Plane Coordinates: North 481033, East 1378642, and North 480222, East 1378329. OU4 comprises 2.3 hectares (5.8 acres). Within the boundary of OU4 is a series of FEMP facilities previously defined in the introduction. The following is a summary description of each facility.

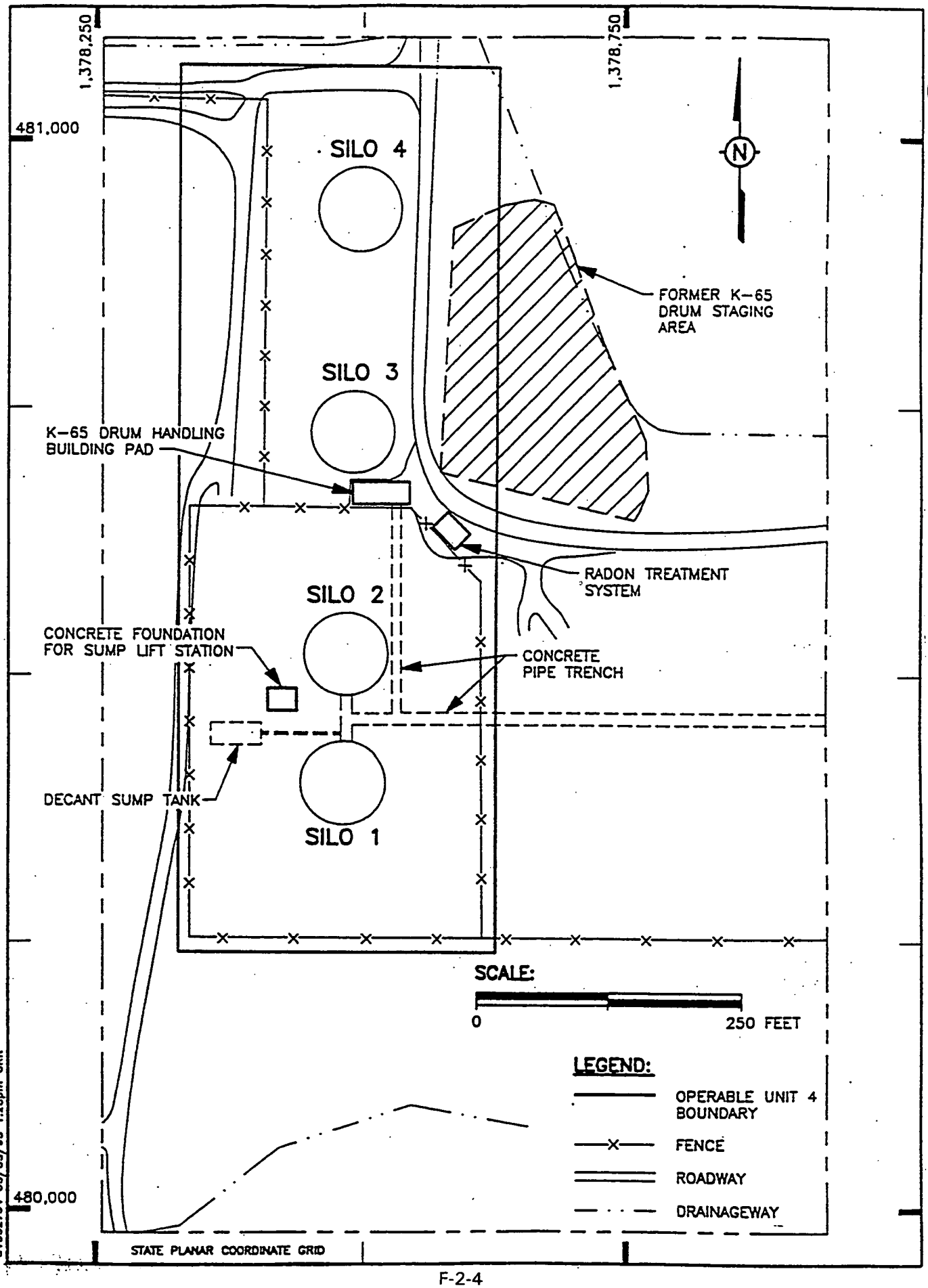
F.2.2.1.1 Silos 1, 2, 3, 4, and the Decant Sump

The waste storage silos were constructed to provide storage for the material resulting from the processing of pitchblende ores and uranium concentrates to extract their uranium content. The silos are large concrete storage structures that were built in 1951 and 1952. Each of the domed silos is 24.38 meters (m) (80 foot [ft]) in diameter, 10.97 m (36 ft) high to the center of the silo dome, and 8.15 m (26.75 ft) tall to the top of the vertical side walls.

The side walls are 20.3-centimeters (cm) (8-inch) thick concrete wrapped with steel post-tensioning wires. The silo sides are covered with a 1.9-cm (0.75-inch) thick layer of gunite. The domed roofs are made of reinforced concrete and taper from 20 cm (8 inches) thick at the silo walls to 10 cm (4 inches) thick at the dome's center (**Figure F.2.2-2**). The floors of Silos 1, 2, 3, and 4 consist of 10 cm (4 inches) of reinforced concrete. Waste materials were originally transferred to Silos 1 and 2 by pumping them as a slurry form. The waste materials eventually settled and formed two layers consisting of settled solids covered by the slurry liquid. To remove the layer of clear liquid following settling, the four silos were equipped with a series of decant ports. However, the structures were not designed to accommodate slurried wastes. These ports were arranged in two vertical lines located on opposite sides of each silo. There were 25 ports in each line, producing 50 total ports per silo. The bottom port on each silo is 30 cm (1 ft) from the silo bottom. The remaining 49 ports are located at 15-cm (6-inch) intervals.

Each decant port for Silos 1 and 2 was, at the time of filling, valved into a single pipe that led to a 9,000-gallon (9,000-gal) carbon steel decant sump tank. The decant sump tank was located between Silos 1 and 2 **(Figure F.2.2-4)** at a level below the base of the silos to allow for gravity drainage. At the base of Silos 1 and 2, at the original ground surface, were skirt drains used to contain any seepage through the walls of the silos or leakage from the decant ports. These skirt drains directed any collected water through a concrete pipe trench to an in-ground concrete-lined sump located on the Drum Handling Building, formerly located between Silos 2 and 3.

An underdrain system exists beneath the floor of Silos 1 and 2. The underdrain system consists of a 5-cm (2-inch) slotted pipe in a 20-cm (8-inch) gravel layer. The gravel layer is underlain by a 5-cm (2-inch)-thick layer of asphaltic concrete followed by a 43-cm (17-inch)-thick layer of compacted clay. A detailed drawing showing the interconnection of the underdrain system and the silo foundation is provided in **Figure F.2.2-3**.



URE F. 2.2-1
OPERABLE UNIT 4

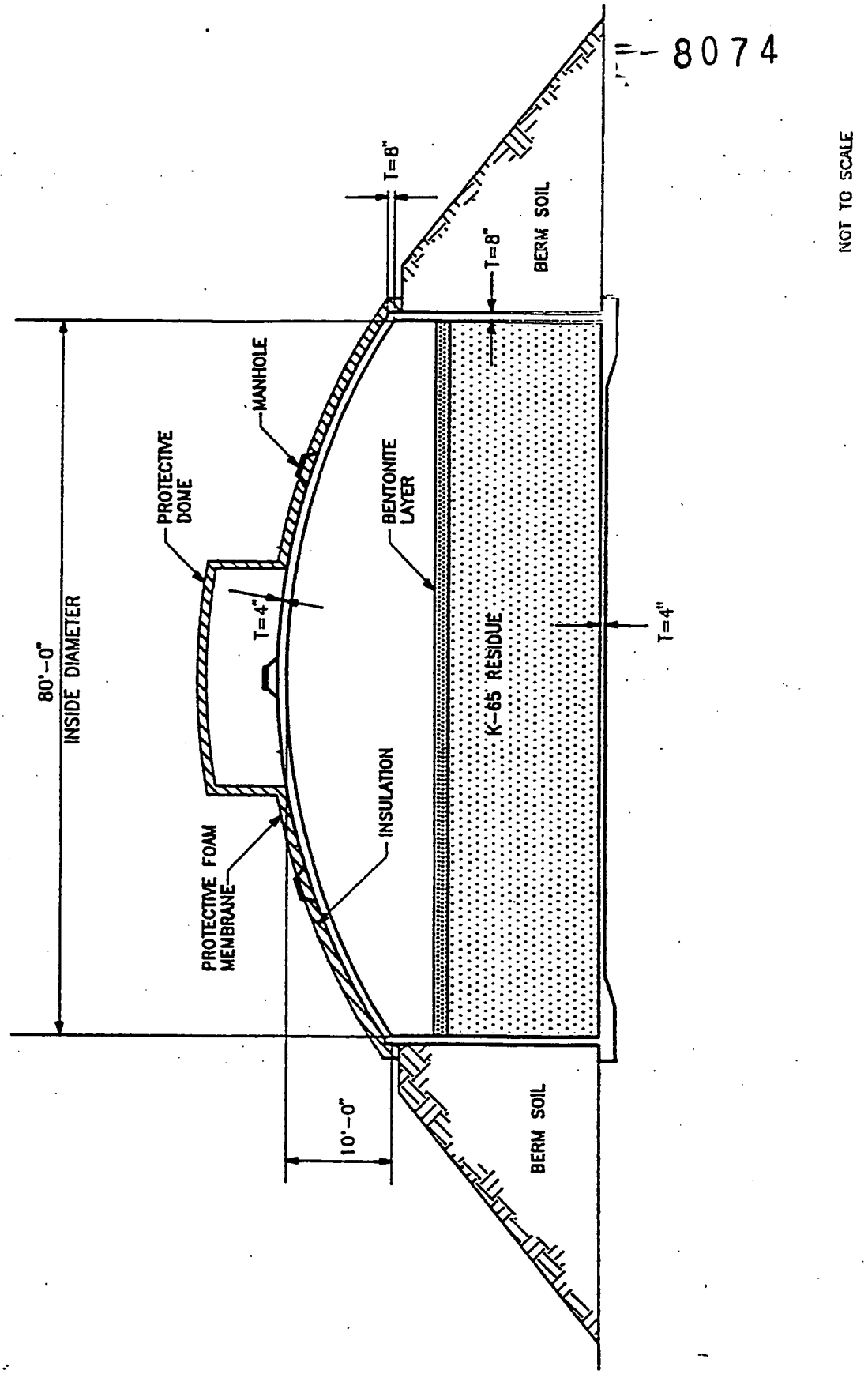


FIGURE F. 2.2-2
SILO DOME CONFIGUATION

408184-A-133 OU4 KNOX
91940133 04/13/93 9:25am CKR

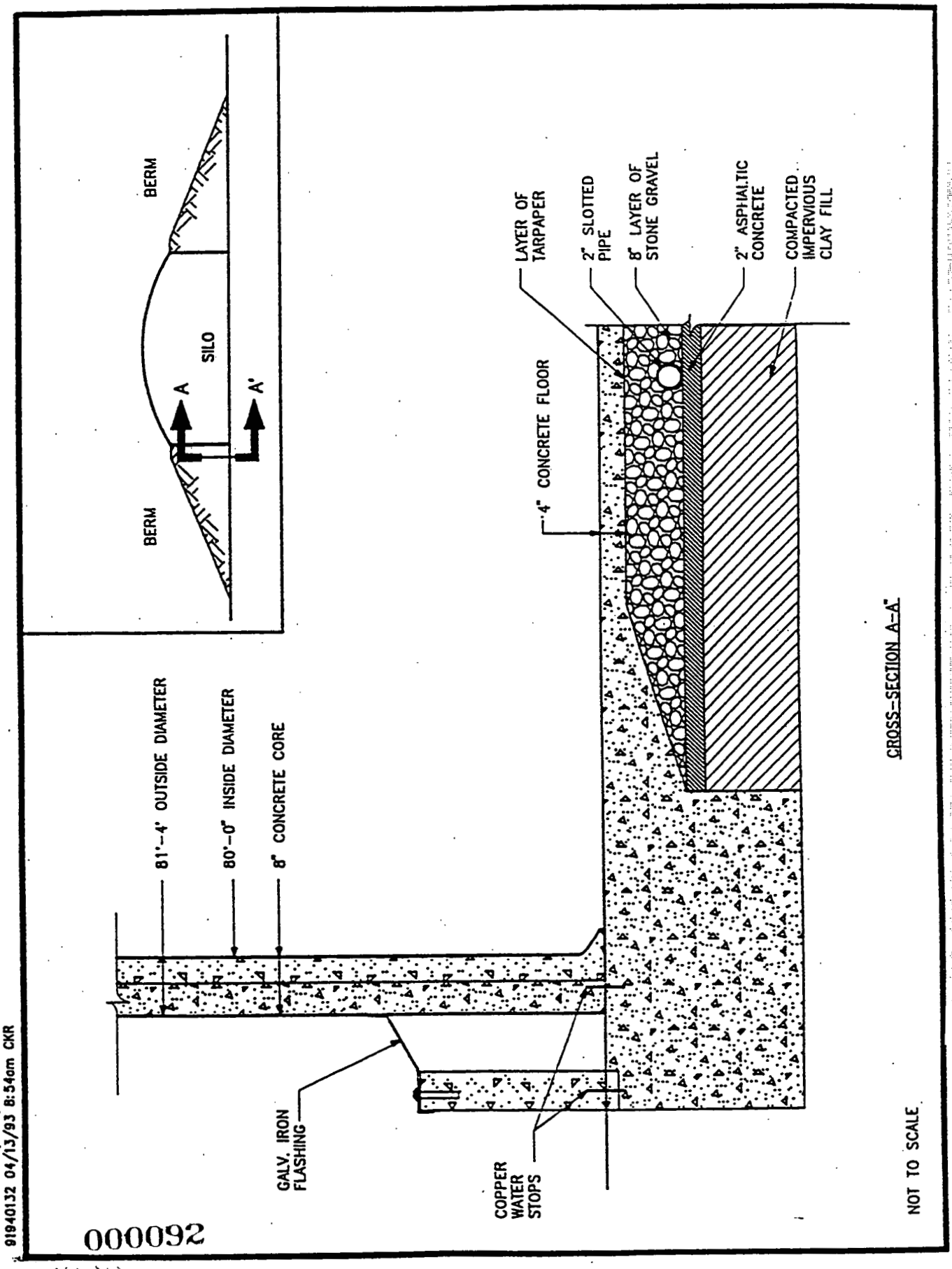


FIGURE F. 2.2-3
SILOS 1 AND 2 - UNDERDRAIN/SILO FOUNDATION DETAIL

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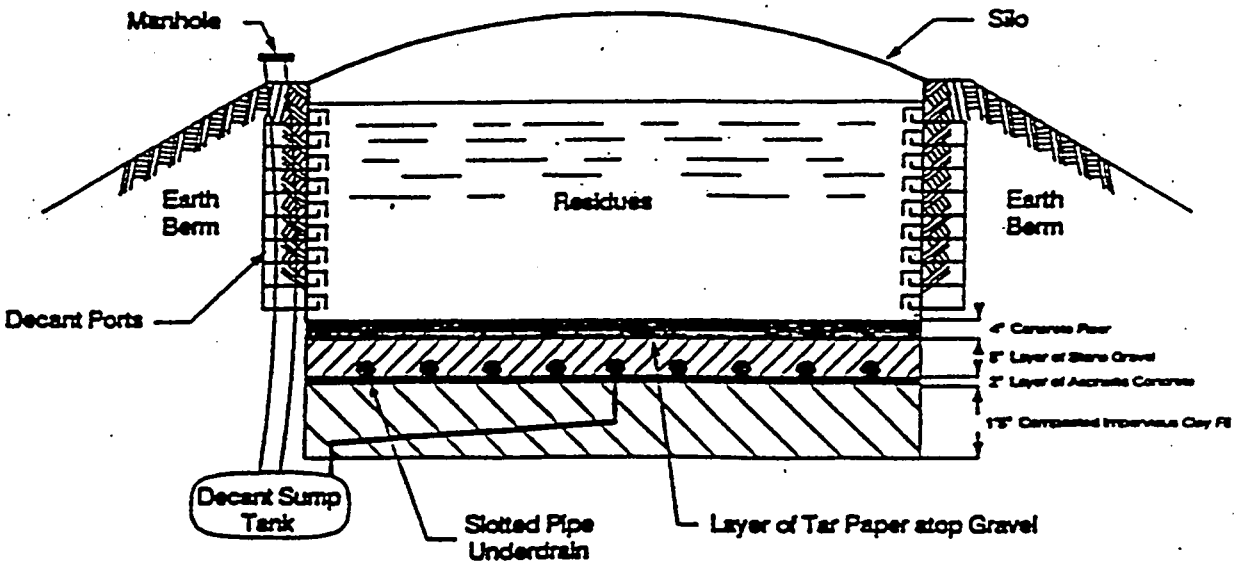
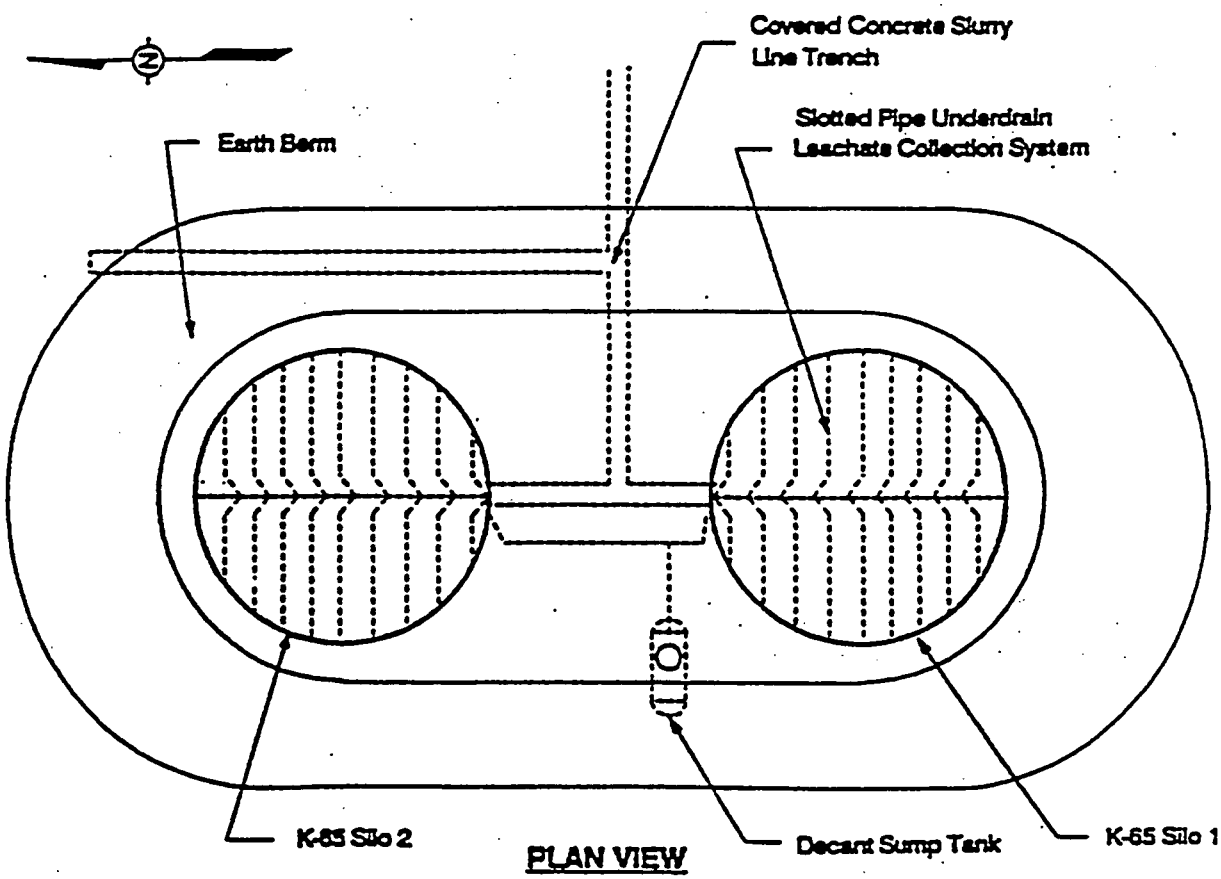


SECTION



PLAN VIEW

Source: PRELOAD ENTERPRISES 7-3-51

(NOT TO SCALE)

FIGURE F. 2.2-4
SILOS 1 AND 2 - LEACHATE COLLECTION SYSTEM

4[illegible]A-87 OU4 KNOX 2/19/93

The underdrain system is connected to the decant sump tank to collect potential leakage through the base of the silos.

Large areas of spalling occurred on the exterior surface coating of Silos 1 and 2, particularly Silo 2, leaving post-tensioning wires corroded and exposed to weather. The exterior surfaces were patched with a 1.9-cm (0.75-inch) thick coat of cement mortar; and, in 1964, a waterproofing membrane was applied.

In January 1986, two load-spreading dome covers 11.9 m (30 ft) in diameter were installed to span a deteriorated portion of the concrete domes of Silos 1 and 2 **(Figure F.2.2-2)**. The covers are self-supporting and sit on a rolled plate-steel skirt. The covers are composed of structural steel members that support thick [1.9-cm (0.75-inch)] plywood sheeting, which is covered with a weatherproof membrane. The dome cover increases the stresses in the existing concrete; however, all stresses are outside the deteriorated area and within acceptable limits (Shanks and Vogel 1988). The dome covers were installed so that the silos contents would remain contained if the center of a silo dome collapsed. The dome covers were not designed to be airtight and, therefore, do not contain the movement of gases such as radon (Rn)-222.

Silo 1 contains 3,280 cubic meters (m^3) (115,900 cubic ft [ft^3]) of material and 360 m^3 (12,600 ft^3) of BentoGrout™ clay. Silo 2 contains 2840 m^3 (100,400 ft^3) of material and 310 m^3 (11,100 ft^3) of BentroGrout™ clay. Silo 3 contains 3,890 m^3 (137,500 ft^3) of material. Silo 4 is empty.

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8074

F.2.2.1.2 Radon Treatment System

The RTS was constructed in 1987 within OU4 to support planned interim remedial measures (IRM), including placement of the dome covers and waterproofing of the domes, for the K-65 silos. The RTS is a pre-engineered aluminum clad building, approximately 65 square meters (m^2) (70 square ft [ft^2]), that contains two calcium drier canisters, eight charcoal adsorption canisters, and two fan units; a 0.8-m (32-inch) thick concrete block wall surrounds the frame of the structure. Also associated with the RTS are multiple lengths of 0.3-m (12-inch)-diameter polyvinyl chloride (PVC) pipe, a 0.15-m (6-inch)-diameter flexible hose, and miscellaneous fittings and valves.

F.2.2.1.3 Concrete Pipe Trench and Other Miscellaneous Concrete Structures

A concrete trench that contained the piping used to transfer waste to Silos 1, 2, and 3 runs 530 m (1,750 ft) from the FEMP refinery (Plant 2/3) to the silo storage area. A portion of the concrete trench, as shown in **Figure F.2.2-3**, resides within the geographical boundaries of OU4. The trench is 0.75 m (2.5 ft) by 0.9 m (3 ft) deep with a steel plate cover that is 0.5-cm (3/16-inch) thick. The piping within the pipe trench was removed before the earthen embankment was placed. Interviews with long-term FEMP employees have not identified any known releases from the concrete pipe trench over the length of its operational life. While no releases are documented, it is reasonable to expect that isolated areas of elevated contamination will exist adjacent to any cracks or construction joints in the concrete trench.

Additionally, within the OU4 boundary are two concrete structures associated with former Silos 1 and 2 operational facilities. A structure called the Drum Handling Building was located between Silos 2 and 3 until it was demolished in 1983. While the above-grade structure was demolished and removed, the concrete slab on grade remains within the boundary of OU4.

Also associated with the operation of the K-65 silos was a concrete lift station used to house the pump for the transfer of decant liquids from the decant sump to a hold tank in the Drum Handling Building **(Figure F.2.2-5)**. The concrete foundation associated with the structure remains within the OU4 boundary.

F.2.2.1.4 Silos 1 and 2 Berms

In 1964, an earthen embankment was built surrounding the top of the walls of Silos 1 and 2 to provide relief from tensile stress that had developed within the walls. The embankment was also constructed to provide weather protection, reduce Rn-222 emissions, and increase shielding from penetrating radiation. The embankment was originally constructed on a slope of 1.5:1. The slope was subsequently modified to 3:1 in 1983 to reduce soil erosion and facilitate grass cutting. Prior to berming the silos in 1964, the decant system was disconnected from the sump tank; but, the underdrain system remained intact. The decant system collected any leakage into the underdrain system. Access was provided to this sump tank by placing a corrugated metal pipe [0.8-cm (30-inch) in diameter] from the tank to above the surface of the soil embankment. This pipe extended upward 10 m (33 ft). The earthen berm was placed around this pipe as the berm was built around the silos.

The soils comprising the earthen berms were surface soils and underlying clays removed from an area directly south of the concrete trench and north of a small drainage ditch running parallel to the trench. The soils comprising the earthen berm constructed in 1983 originated from two on-site areas: from the location of the Biodenitrification Surge Lagoon, and from a borrow area west of Pit 5. No surveys were performed by site personnel to determine the potential presence of radiological contamination of these soils before excavation and placement in the berms.

F.2.2.2 Operational History for Silos 1 and 2

This section provides an abbreviated operational history of the Silos 1 and 2 material. An understanding of the origin and process history of the Silos 1 and 2 material is necessary in order to understand the basis for the regulatory classification of the material and the applicability of the ARARs. The regulatory classification of the Silos 1 and 2 material and the approved ARARs are fundamental drivers for the unique technical and safety requirements for removing, treating, packaging, transporting, and disposing the material.

The Feed Materials Production Center (FMPC) refinery processed two basic classes of materials: (1) mined pitchblende ores from the Shinkolobwe Mine in the Belgian Congo, the Rum Jungle Mine, and the Radium Hill Mine in Australia; and, (2) other uranium concentrates that had already been refined to some degree. The second class of materials included uranium concentrates that had undergone a preliminary refining process at an off-site mill and material recovered at various stages of FMPC operations. The term "K-65" was used to describe the processing of both the Belgian Congo and the Australian ores.

Uranium-bearing ores, as they are mined, contain not only uranium, but also equilibrium (activity) concentrations of uranium progeny [i.e., the isotopes of other elements formed through the sequential, radioactive decay chains that begin with uranium (U)-235 and U-238. These progenies, which include radium, are removed either in a preliminary milling process or in the refining process (if the ores are not preprocessed through a mill). Thus, when the FMPC refinery processed pitchblende ores, the refinery wastes contained a high concentration of the radioactive uranium progeny. These refinery wastes were known as "hot" raffinates. The term "hot" was used to indicate that the materials contained a high concentration of the radionuclide radium and gamma-emitting progenies that result in a significant direct penetrating radiation exposure rate.

The liquid "hot" raffinates were filtered and the filter cake contained most of the radium as insoluble barium-radium sulfate. The filter cake was reslurried, neutralized, and pumped to Silo 2. [The filtrate along with non-pitchblende raffinates from other FMPC production runs was evaporated, calcined, and pneumatically conveyed to Silo 3 as "cold" metal oxides. However, some of the radium remained with the filtrate, and some of the thorium progeny of uranium (i.e., thorium-230) remained within the non-pitchblende uranium concentrates due to the inefficiency of the source mill in removing this metal. Thus, although the materials are called "cold," they are radioactive.]

The material stored in Silo 1 was generated at Mallinckrodt Chemical Works (MCW) in St. Louis, Missouri, as a result of processing to extract uranium from pitchblende ores. The pitchblende ores processed at MCW and the great majority of the pitchblende ores processed at the FMPC site came from one mine, the Shinkolobwe Mine in the Belgian Congo. These ores contained relatively high concentrations of uranium oxides (U_3O_8), in the range of 40 to 50%.

The Shinkolobwe Mine, owned by the African Metals Corporation, began operations for the procurement of radium in 1921. The mine was reopened in 1943 for its uranium. Due to the high value of radium at the time, an agreement was reached between the Atomic Energy Commission (AEC) and the African Metals Corporation that stipulated that the African Metals Corporation would retain ownership of the radium within any processing materials. After the United States had processed the pitchblende to extract uranium, the material would be returned to the African Metals Corporation.

Initially, the materials from the MCW refining operations were sent back to the African Metals Corporation. Beginning in April 1949, the materials were no longer returned to the African Metals Corporation following processing; they were stored at MCW for future disposition. In 1984, ownership of the Silos 1 and 2 material was transferred to the U.S. Department of Energy - Fernald Environmental Management Project (DOE-FEMP).

As production continued, storage became a problem. Therefore, the drummed K-65 materials were sent from MCW to the Lake Ontario Ordnance Works (LOOW) near Niagara Falls, New York, for storage. Some of the drums that were sent to LOOW were emptied into a concrete water tower at that site. Approximately 6,000 drums were shipped from LOOW to the FMPC site for storage. Beginning in 1951, continued production at the MCW resulted in approximately 25,000 drums being sent directly from St. Louis to the FMPC site.

Before construction of the FMPC refinery, MCW operated a refinery for the production of uranium. The MCW refinery used a dual-cycle ether process that was somewhat different from the tributyl phosphate (TBP)-kerosene extraction system used at the FMPC site. Another difference between the FMPC process and the MCW refinery operation was the method used to extract radium and other impurities from the uranium. Unlike the FMPC process, impurities were removed from the K-65 materials at MCW in the ore digestion process before the uranium extraction system.

The removal of uranium from pitchblende at MCW consisted of milling the ores to pass a 100-mesh sieve and, secondly, a 3-hour leach in concentrated nitric acid, which resulted in the radium precipitating as radium sulfate ($RaSO_4$). Barium sulfate ($BaSO_4$) was added during digestion to ensure co-precipitation. If insufficient sulfide was present in the ore, sulfuric acid (H_2SO_4) was added to ensure the precipitation of radium and lead. The precipitated materials were vacuum-filtered, then reslurried and digested with sodium carbonate (Na_2CO_3) and sodium formate ($NaHCO_2$). This second digestion process was to recover approximately 2% of the original uranium, which remained in this waste fraction. The second digestion also led to the precipitation of impurities including ferric, aluminum, and manganese hydroxides. Following the carbonate leach, the slurry was again vacuum-filtered and packaged in drums as K-65 materials. Much of the thorium (most importantly Th-230), as a nitrate, remained soluble and traveled in solution with the uranyl nitrate to the extraction process area. Therefore, Th-230 is not present in secular equilibrium with radium in the K-65 materials.

Approximately 24,000 of the 31,000 drums of pitchblende ore processing materials received at the FMPC site from MCW and LOOW were transferred to Silo 1 for storage. The remaining 7,000 drums of K-65 materials received from MCW and LOOW were transferred to Silo 2. As the drums were received by railroad car at the FMPC site, the drums were temporarily staged in an area to the east of Silos 3 and 4. The drummed material was transferred to Silo 1 from July 1952 until November 1953 by a specially constructed Drum Handling Building.

The K-65 Drum Handling Building received drummed material from MCW and LOOW locations and transferred the material into Silos 1 and 2. A block diagram of this process is presented in **Figure F.2.2-5.**

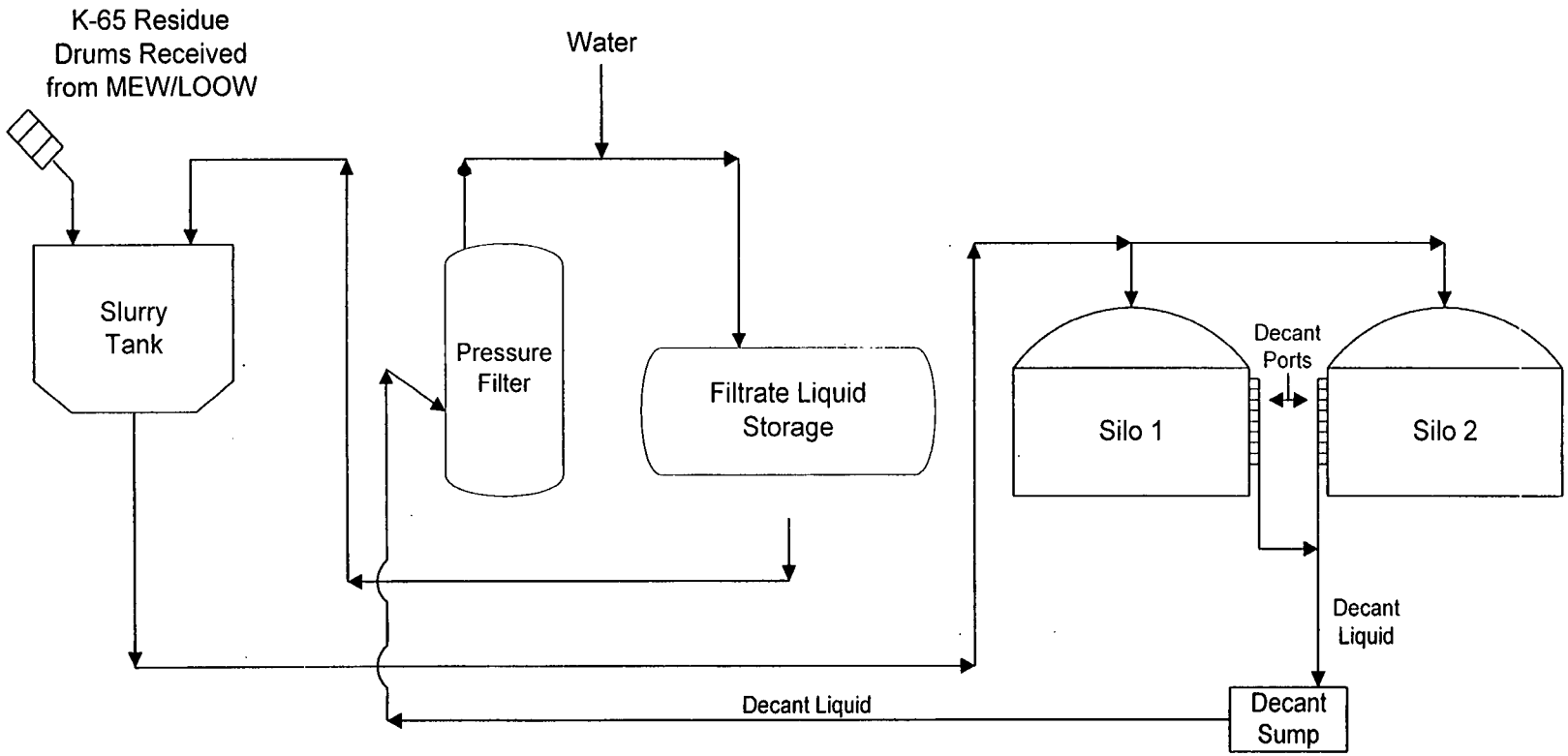
Wet solids were delivered to the K-65 Drum Handling Building in 55-gal drums, each containing approximately 230 kilograms (kg) (500 lb) of material. The material had a bulk density of approximately 1.44 grams/cubic centimeter (g/cm^3) (90 lbs/ft^3) and contained approximately 40% moisture by weight. One drum of material was handled at a time.

Each drum was placed on a slat conveyor and moved inside the building. There it was placed onto a skip hoist and raised to a point above the slurry tank, where it was inverted. The contents of the drum were dumped into the slurry tank by vibration, aided by a high-velocity water jet. The water jet also washed the drum, which was eventually returned to the conveyor and removed from the building. Approximately 280 liters (L) [75 gal] of slurrying liquor, which was fresh water during initial operations, were consumed in removal of the solids from one drum. The resulting slurry, which had a consistency of approximately 4 pounds (lb) of wet solids per gallon of slurry, was continuously agitated in the slurry tank.

When approximately 7,570 L (2,000 gal) of slurry had been produced, the contents of the slurry tank were pumped to storage in Silo 1. This slurry pumping was followed by a 6,250-liter (1,650-gal) clear liquor wash that was passed through the slurry tank, slurry pump, transfer line, and into the storage silo.

The slurries pumped into storage Silo 1 were allowed to settle into two layers. The slurry liquor, which consisted of either water or a metal nitrate solution, formed the top layer over a bed of the settled, wet solids. This layer of liquid was decanted from the silos through the decant ports and into the decant sump tank.

FIGURE F. 2.2-5
HOT RAFFINATE FROM K-65 DRUMMED WASTE HANDLING FACILITY



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From here, the decanted liquid was periodically pumped back to the Drum Handling Building where it passed through a pressure filter and was stored in a filtrate storage tank. The filtrate storage tank was located within the Drum Handling Building on the concrete pad, forming the floor of the structure. The filtered liquid was then used for slurry preparation in the K-65 Drum Handling Building. Excess liquids were transported back to the FMPC Plant 8 for treatment, then to the General Sump for final treatment before being discharged to the Great Miami River. The K-65 Drum Handling Building was demolished in 1983 to allow for installation of the earthen berm.

Although MCW processed the pitchblende ores by batch runs on the incoming ores from the Shinkolobwe Mine, no conscious attempt was made at Fernald to transfer the material to the silos by the original MCW batch or lot number. Therefore, the materials within Silo 1 represent a range of processing runs at MCW, displaying the variations present in the natural ores and the generating production process.

While Silo 1 consists solely of transferred drummed materials from MCW and LOOW, Silo 2 is a mixture of MCW K-65 materials and FMPC-generated K-65 materials. As previously stated, 7,000 drums of K-65 materials transferred from MCW and LOOW to Fernald were emptied into Silo 2. The transfer of the drummed materials received from off-site into Silo 2 occurred between late 1953 and January 1956. The generating process and the methodology to transfer the MCW/LOOW materials into Silo 2 are similar to those used in Silo 1, as discussed in the previous section.

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8074

Additionally, Silo 2 received materials that were generated at the FMPC site (resulting from the processing of pitchblende ores shipped directly from the Shinkolobwe Mine) and a small quantity of Australian ores (from the Rum Jungle Mine and the Radium Hill Mine). The processing completed at the FMPC site was performed to extract the uranium from these very rich pitchblende ores. Belgian Congo ores were processed from May 1954 until August 1958. Australian ores were processed following the Belgian ores from May 1957 until March 1958. The last K-65 slurry was added to Silo 2 in January 1959. The Australian ore residues constitute less than 180,000 kg (200 tons) of the estimated 4.4 million kg (4,900 tons) in Silo 2.

The Fernald-generated material in Silo 2 is a by-product of refinery operations conducted in Plant 2/3 and supporting structures at the facility. Pitchblende ores were received at Plant 1 of the FMPC site where the ores were thawed (if necessary), milled, and assayed for their uranium content. Milling, performed to facilitate the digestion process, took place in a Williams Mill where the ores were ground until they could pass a 100-mesh sieve. The milled ores, following assay, were conveyed to the Plant 1 ore silos for storage until they were processed in the refinery (Plant 2/3).

At the refinery, the milled ores were transferred to digester tanks by batch. Each batch varied from 1,820 to 2,270 kg (4,000 to 5,000 lb) of uranium and 2,270 to 4,550 kg (5,000 to 10,000 lb) of net feed. Nitric acid and water were added to the ores in the digesters to yield a final slurry concentration of 200 grams (g) of uranium per liter and 3 Normal excess nitric acid. Following a typical 3-hour digestion, the digest slurry was transferred to a feed holding tank in the extraction area of the refinery.

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The uranium extraction system at the FMPC site, at the time of K-65 processing, employed a series of three perforated plate pulse columns, including an extraction column, a scrub column, and a reextraction column. The aqueous feed slurry from the hold tank was introduced into the top of the extraction column. An organic extractant, 33.5% by volume TBP in an inert purified kerosene diluent, was introduced into the bottom of the same extraction column. The combined liquid phases were pulsed through the stationary perforated plates, with the aqueous feed slurry passing down and the organic phase moving up through the column. The organic extractant flow rate and the feed stream flow rate were controlled to maintain a constant uranium saturation level in the organic product stream. The uranyl nitrate solution was removed from the aqueous feed slurry by the organic extractant. Extraction of the uranium from the ores was essentially complete when the organic product stream left the top of the extraction column.

The remaining metals and other impurities in the pitchblende ores left the bottom of the extraction column. This by-product stream was known as K-65 raffinates. The K-65 raffinates were freed of the organic phase in a disengagement chamber at the base of the extraction column. Despite this disengagement process, considerable quantities of entrained TBP remained in the raffinate leaving the column. In order to recover these reusable concentrations of TBP, the raffinates were transferred to a single stage mixer settler to be combined with continuously recycled kerosene.

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8074

The TBP extraction system was relatively specific toward uranyl nitrate; other nitrate compounds, such as thorium nitrate, present in the feed slurry were physically entrained in the organic product phase leaving the extraction column. In order to remove these impurities from the feed stream and achieve product quality standards, a second purification step was performed in the scrub column. In the scrub column, the organic product stream from the extraction column entered the bottom while deionized water entered the top of the column. During the continuous flow through the scrub column, essentially all of the remaining metallic impurities were transferred to the aqueous phase, together with a small quantity of uranium. The aqueous phase was directed back to the extraction column to recover the remaining uranyl nitrate. The pure organic phase continued through the final re-extraction column where the TBP-kerosene was separated from the uranyl nitrate. The operation of the re-extraction column is not relevant to the generation of the K-65 materials and is, therefore, not presented. The impurities residing in the aqueous phase from the scrub column were transferred to the K-65 raffinates leaving the extraction column.

The kerosene-washed K-65 raffinates were filtered through a precoated rotary vacuum filter to remove suspended solids (**Figure F.2.2-6**). Most of the gamma-emitting uranium progeny and radium were filtered out in this step. Filtrate was passed on to the cold metal, oxide process for transfer to Silo 3. The filter cake from the rotary filter contained the gamma-emitting uranium progeny; therefore, it was termed "hot raffinate." This filter cake was reslurried and then neutralized with lime [$Ca(OH)_2$]. The resulting slurry had a consistency of about 0.5 kg of wet solids per liter of slurry (4 lb of wet solids/1 gal of slurry). Once each day during refinery operation, the hot raffinate slurry was pumped into Silo 2 through a 7.6-cm (3-inch) Schedule 80 transfer line located in a concrete trench that extended from the refinery to the silos. This slurry transfer was followed by a 4,500- to 5,500-liter (1,200- to 1,500-gal) process water wash to clean the transfer line.

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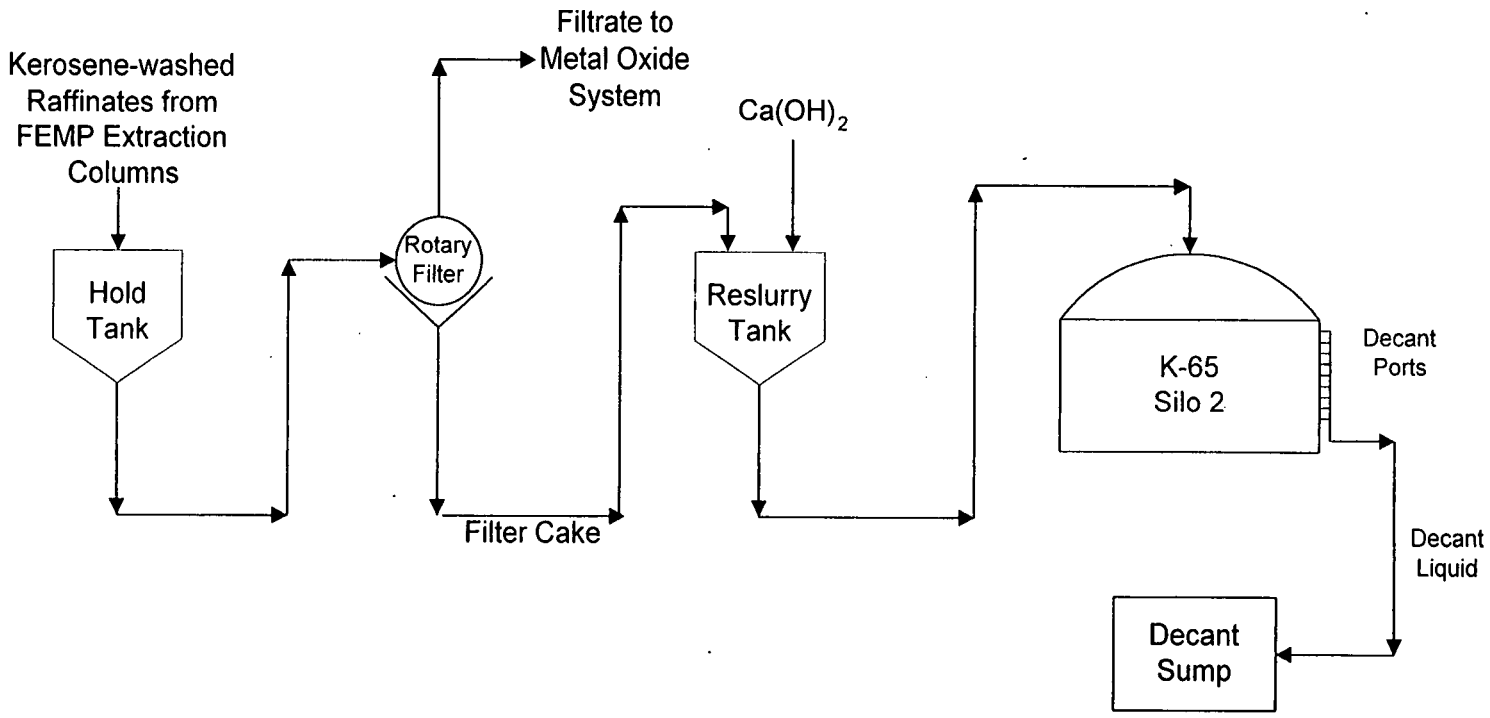
FIGURE F. 2.2-6
HOT RAFFINATE FLOW TO SILO 2



Following completion of K-65 processing operations at the FMPC site, approximately 150 drums of radium-contaminated material, consisting of soils from the MCW/LOOW drum staging area, cleanup materials, and excess K-65 samples, were placed into Silo 2 in June 1960. In response to concerns of the FMPC Operating Contractor [National Lead of Ohio (NLO), Inc.] regarding chronic Rn-222 emissions from the silos, all vents, manways, and other penetrations through the domes of Silos 1 and 2 were sealed in 1979. Material (with the exception of decant liquid and samples) has not been removed from Silos 1 or 2 since the final filling.

F.2.2.3 Silos 1 and 2 Material Characterization

This subsection summarizes the radiological and chemical characterization of the Silos 1 and 2 material.

F.2.2.3.1 Radiological Composition

Silos 1 and 2 were sampled in 1989 and again in 1990/1991 to provide data for the original OU4 RI/FS. Radionuclide analytical results from both sampling efforts are summarized in **Table F.2.2-1**.

Table F.2.2-1 provides a list of the constituents that were detected in Silos 1 and 2 during both sampling efforts. The table shows that the predominant constituents in terms of activity in Silo 1 include: actinium (Ac)-227, lead (Pb)-210, polonium (Po)-210, radium (Ra)-226, and thorium (Th)-230. This information is consistent with process knowledge that the hot raffinates contain primarily U-238 decay products. Though present, Th-230 is not in secular equilibrium with Ra-226, confirming that thorium was not fully precipitated during the refining process that generated the hot raffinates. As expected, other radionuclides out of secular equilibrium are present in relatively low concentrations, including U-234, U-235, and U-238. Members of the Th-232 decay series are also present (Th-232, Th-228, and Ra-228).

The waste in Silo 1 came from MCW and was generated from pitchblende ore containing 40 to 50% U_3O_8. Based on this fact, and assuming that all Ra-226 is precipitated in the hot raffinate, the mass of raffinate into which the radium is concentrated is approximately one-fourth the original mass of the ore. The remaining mass (75%) was classified as cold raffinate and disposed of locally at MCW. The U-238 concentration in Silo 1 suggests an efficiency of greater than 99.8% for the MCW digestion and carbonate treatment process.

Silo 2 sampling results reveal that the predominant constituents include Ac-227, Pb-210, Po-210, Ra-226, and Th-230. This result is consistent with the process knowledge that the hot raffinates contained mostly U-238 decay products. Similar to Silo 1, Th-230 is present in Silo 2 but not in secular equilibrium with Ra-226. The results suggest that only 10 to 25% of the Th-230 was precipitated with the hot raffinate.

As expected, other radionuclides are present from the Th-232 decay chain and the U-235 decay chain. The U-238 concentration suggests an efficiency greater than 99.6% in the extraction process for uranium.

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8074

TABLE F. 2.2-1
SUMMARY OF RADIONUCLIDE ANALYSES FOR SILOS 1 AND 2 MATERIAL[a]

Analyte	Frequency of Detection[b]	Rejected	Arithmetic Mean[c] (pCi/g)[d]	Upper 95% CI on A-Mean[c] (pCi/g)	Range of Detects[c] (pCi/g)
			SILO 1		
Actinium-227	13/20	0	5,960	7,670	4,320 - 17,390
Lead-210	20/20	0	165,000	202,000	48,980 - 381,400
Polonium-210	13/13	0	242,000	281,000	144,000 - 434,000
Radium-226	20/20	0	391,000	477,000	89,280-890,700
Thorium-228	2/20	0	422	2280	835 - 2280
Thorium-230	24/24	0	60,000	68,900	10,569 - 105,372
Thorium-232	8/20	0	424	1110	661 - 1,106
Uranium-234	21/21	0	800	932	326 - 1,548
Uranium-235/236	14/20	0	38	54	19.1 - 105
Uranium-238	20/20	0	642	693	387 - 920
			SILO 2		
Actinium-227	11/14	0	5,100	6,640	2,905 - 10,450
Protactinium-231	1/14	0	2,350	4,040	4,041 - 4,041
Lead-210	14/14	0	145,000	190,000	58,160 - 399,200
Polonium-210	8/8	0	139,000	231,000	55,300 - 241,000
Radium-226	14/14	0	195,000	263,000	657 - 481,000
Thorium-228	5/14	0	645	7,360	411 - 7,360
Thorium-230	15/15	0	48,400	76,200	8,365 - 132,800
Thorium-232	3/14	0	402	985	851 - 985
Uranium-234	13/13	0	961	1,160	121 - 1,465
Uranium-235/236	11/13	0	73	94	35.6 - 172
Uranium-238	14/14	0	912	1,120	46 - 1,925

a Sample data taken from Table 4-2 of the *Remedial Investigation Report for Operable Unit 4* (FEMP 1993a).
b Rejected data not included in total number of samples.
c Values qualified with an "R" (results unusable) are excluded. The mean and upper 95% confidence interval (CI) on mean have been rounded to show three significant figures. The mean is calculated using one-half the sample quantitation limit (SQL) for nondetects.
d Values are expressed in picoCuries per gram (pCi/g).

Summary of Radiological Results

The predominant radiological constituents in Silos 1 and 2 are: Ac-227, Pb-210, Po-210, Ra-226, and Th-230. The 1990/1991 concentrations are, for some radionuclides, at least twice the 1989 concentrations. This variance was probably due to the 1989 sampling event did not collect samples from the bottom half of the silos.

There is a general increase in the concentrations of radiological constituents with depth in all manways. Radiological constituent concentrations are similar horizontally, across the silos and from manway to manway. Although this characteristic is not consistent for all the predominant constituents, there is a discernable trend. This trend probably results from the placement at different times of the material in the silos as layers of slurries.

Table F.2.2-2 is a summary of the inventory of radionuclides in Silos 1 and 2. The inventory is based on the arithmetic mean and the upper confidence limit (UCL) for the radionuclides reported in **Table F.2.2-1**; the estimated waste volume contained in Silos 1 and 2 obtained from the *Waste-Surface Mapping of the Fernald K-65 Silos Using a Structured Light Measurement System* (ORNL 1992); and a dry weight density of 2.050 g/cm^3. The inventory of certain constituents is higher than previously reported, which is probably due to the more efficient collection of waste materials from the deeper portion of the silos.

F.2.2.3.2 Chemical Composition

Chemically, the contents of Silos 1 and 2 are mixtures of hydroxides, carbonates, and sulfates. Carbonates and sulfates compose approximately 20% of the waste. The primary form of uranium contained in the silos material is sodium uranyl carbonate (Dettorre et al. 1981). Other Elements contributing at least 1% to the total are calcium, iron, magnesium, and lead.

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TABLE F. 2.2-2
INVENTORY OF K-65 RADIOLOGICAL CONSTITUENTS

	Silo 1[a]		Silo 2[b]	
Analyte	Mean Inventory[c] (Ci)	UCL Inventory[c] (Ci)	Mean Inventory[c] (Ci)	UCL Inventory[c] (Ci)
Actinium-227	40	52	30	39
Protactinium-231	ND[d]	ND[d]	14	24
Lead-210	1,110	1,360	844	1,110
Polonium-210	1,630	1,890	809	1,340
Radium-226	2,630	3,210	1,140	1,530
Thorium-228	2.8	15.3	3.8	43
Thorium-230	403	463	282	444
Thorium-232	2.9	7.5	2.3	5.7
Uranium-234	5.4	6.3	5.6	6.8
Uranium-235/236	0.26	0.36	0.43	0.55
Uranium-238	4.3	4.7	5.3	6.5
Total Uranium[e]	12.9	14.1	15.9	19.5

a Based on a volume of 3,280 m^3 and a dry mass density of 2.050 g/cm^3.
b Based on a volume of 2,840 m^3 and a dry mass density of 2.050 g/cm^3.
c Values for mean and UCL taken from Table 4-3 of the *Remedial Investigation Report for Operable Unit 4* (FEMP 1993a).
d ND - Analyte was not detected.
e Total uranium mass in metric tons. Calculated from the isotopic distribution of uranium.

Inorganic Constituents

Twenty-seven inorganic metals were detected in Silo 1 during the 1989 and 1990/1991 sampling efforts (**Table F.2.2-3**). The results of the Hazardous Substance List (HSL) analyses show that the predominant inorganic constituents in Silo 1 are barium, calcium, iron, and lead. Other metallic constituents at relatively lower concentrations include aluminum, cobalt, magnesium, molybdenum, nickel, selenium, and silicon. Frequency of detection was high for all constituents.

Predominant inorganic constituents detected through general chemistry analysis include chloride, nitrate, phosphorus, sulfate, and organic carbon. Their concentrations are also shown in **Table F.2.2-3**. The results are consistent with those of previous studies and those expected for uranium ore of the type processed at MCW.

Analytical data from both the 1989 and 1990/1991 sampling of Silo 2 show similar concentrations for the predominant metallic constituents. These constituents include: barium, calcium, iron, and lead. Other metallic constituents detected at lower concentrations than those previously listed include aluminum, arsenic, cobalt, copper, magnesium, nickel, silicon, and sodium. The predominant inorganic constituents detected through general chemistry analysis are the same as those for Silo 1.

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Organic Constituents

The Silo 1 analytical results show detection of 25 organic compounds, which include polychlorinated biphenyls (PCBs) and semivolatile and volatile organics. Aroclor-1248, aroclor-1254, and aroclor-1260 were detected at concentrations up to 10.0, 20.0 and 3.5 milligram per kilogram (mg/kg), respectively. Other constituents detected generally included either common laboratory contaminants or infrequently detected constituents. Tributyl phosphate was detected in Silo 1, which was unexpected because that material was not part of the MCW refinement process. However, the tributyl phosphate was probably introduced by the liquid used to slurry the waste for placement into the silo. The presence of aroclor-1248, aroclor-1254, and aroclor-1260 contaminants are most likely due to PCBs introduced through cleaning and the lubrication of processing and raffinate handling equipment. No PCBs were used directly in the processing of ore.

Silo 2 organic results detected 16 compounds including aroclor-1254, aroclor-1260, and tributyl phosphate. Aroclor-1254 was detected at a mean concentration of 6.6 mg/kg.

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TABLE F. 2.2-3
SUMMARY OF CHEMICAL ANALYSES FOR SILOS 1 AND 2 MATERIAL[a]

Analyte	Frequency of Detection[b]	Rejected	Arithmetic Mean[c] (mg/kg)[d]	Upper 95% CI on A Mean[c] (mg/kg)	Range of Detection (mg/kg)
SILO 1					
General Chemistry					
Ammonia	4/7	0	1.19	8.9	1.1 - 8.9
Chloride	7/7	0	637	1,340	269 - 1,349
Fluoride	2/7	0	1	394	15 - 394
Nitrate	5/5	2	2,930	4,764	2,216 - 4,764
Oil and grease	7/8	0	3,650	27,000	11.7 -27,000
Phosphorus	8/8	0	1,130	3,290	0.4 - 3,290
Sulfate	6/6	1	1,300	3,460	444 - 3,460
Total kjeldahl nitrogen	7/7	0	479	676	51.6 - 782.5
Total organic carbon	8/8	0	19,200	26,200	5,166 - 34,800
Total organic nitrogen	8/8	0	448	623	51.6 - 782
Metals					
Aluminum	13/19	0	1,050	1,320	450 - 2,460
Antimony	11/12	7	21	26	13.3 - 46.2
Arsenic	18/19	0	22	55	3.1 - 68.4
Barium	19/19	0	11,600	14,200	1970 - 22,100
Beryllium	17/19	0	1	1	0.59 - 2.8
Boron	12/12	0	46	50	23.8 - 61.7
Cadmium	11/18	1	2	4	0.56 - 8
Calcium	19/19	0	2,960	3,650	799 - 5,700
Chromium	19/19	0	42	55	19.7 - 165
Cobalt	19/19	0	936	1,100	349 - 1,870
Copper	19/19	0	285	331	122 - 475
Cyanide	19/19	0	2	3	0.52 - 4.4
Iron	19/19	0	14,700	21,100	4,280 - 75,100
Lead	19/19	0	81,700	95,500	17,400 - 33,000
Magnesium	19/19	0	2,880	3,380	1,500 - 6,020
Manganese	19/19	0	72	97	25.6 - 257
Mercury	18/19	0	0.6	0.9	0.15 - 2.8
Molybdenum	12/12	0	4,850	6,290	968 - 8,600

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F-8074

TABLE 2.2-3 (continued)

Analyte	Frequency of Detection[b]	Rejected	Arithmetic Mean[c] (mg/kg)[d]	Upper 95% CI on A Mean[c] (mg/kg)	Range of Detection (mg/kg)
SILO 1 (continued)					
Metals					
Nickel	19/19	0	1,790	2,290	629 - 3,380
Potassium	19/19	0	429	493	158 - 715
Selenium	19/19	0	287	340	58.5 - 2,810
Silicon	12/12	0	723	853	359 - 1,290
Silver	19/19	0	11	13	5 - 23.3
Sodium	19/19	0	8,670	10,700	360 - 16,700
Thallium	8/18	1	0.3	1.4	0.09 - 1.4
Vanadium	19/19	0	136	161	63.1 - 293
Zinc	14/19	0	28	37	7.7 - 212
SILO 2					
General Chemistry					
Chloride	6/6	0	65	141	28 - 141
Nitrate	5/5	1	5,430	8,900	3,490 - 8,900
Oil and grease	4/4	0	301	541	207 - 541
Phosphorus	5/5	0	1,130	1,400	623 - 1,400
Sulfate	6/6	0	8,610	19,300	2,590 - 19,300
Total kjeldahl nitrogen	3/3	0	204	220	176 - 220
Total organic carbon	5/5	0	6,090	24,400	148 - 24,400
Total organic nitrogen	4/4	1	232	289	176 - 289
Metals					
Aluminum	8/14	0	845	1,110	363 - 2,250
Antimony	7/8	6	26	44	14.4 - 77.4
Arsenic	14/14	0	432	1,550	57.5 - 1,960
Barium	14/14	0	6,970	19,900	89.2 - 19,900
Beryllium	14/14	0	2	3	0.59 - 6
Boron	5/8	0	38	51	18.4 - 81.2
Cadmium	13/14	0	5	7	2 - 19.1
Calcium	14/14	0	33,300	301,000	64 - 301,000
Chromium	14/14	0	40	51	0.207 - 83.1
Cobalt	14/14	0	984	2,430	6.2 - 2,430
Copper	13/13	1	531	818	220 - 1,790
Cyanide	13/13	1	3	5	0.9 - 7.1
Iron	13/13	1	16,500	28,900	4,010 - 40,000
Lead	14/14	0	48,200	299,000	153 - 299,000

TABLE 2.2-3 (continued)

Analyte	Frequency of Detection[b]	Rejected	Arithmetic Mean[c] (mg/kg)[d]	Upper 95% CI on A Mean[c] (mg/kg)	Range of Detection (mg/kg)
SILO 2 (continued)					
Metals					
Magnesium	14/14	0	3,800	6,410	805 - 8,740
Manganese	14/14	0	163	259	40.6 - 403
Mercury	13/13	1	0.9	1.2	0.18 - 2.3
Molybdenum	8/8	0	291	440	148 - 479
Nickel	14/14	0	1,380	1,720	14.6 - 2,640
Potassium	14/14	0	217	337	37.8 - 653
Selenium	13/13	1	110	124	49.6 - 155
Silicon	8/8	0	851	1,148	507 - 1,780
Silver	13/13	1	17	22	7.4 - 34.9
Sodium	14/14	0	2,430	3,200	226 - 4,940
Thallium	9/12	1	1	2	0.33 - 5.7
Vanadium	14/14	0	237	298	21.9 - 535
Zinc	14/14	0	54	91	11.2 - 159

a Sample data taken from Table 4-4 of the *Remedial Investigation Report for Operable Unit 4* (FEMP 1993a).
b Rejected data not included in total number of samples.
c Values qualified with an "R" are excluded. The mean and upper 95% CI on mean has been rounded to show three significant figures. The mean is calculated using one-half the SQL for nondetects.
d Values expressed in milligrams per kilogram (mg/kg).

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Tributyl phosphate was present at a mean concentration of 29 mg/kg, which was consistent with process knowledge and demonstrates that the tributyl phosphate recovery system was not totally effective. The concentrations of the other organics in Silo 2 were near detection levels.

HSL volatile organic data from the 1989 sampling of Silos 1 and 2 were rejected during validation due to missed sample holding times. Results for polynuclear aromatic hydrocarbons (PAH) are not seriously effected by extended holding times and can remain basically unchanged for years. Also, aroclors (PCBs) are very persistent and show little tendency toward degradation, either chemically or biologically. Therefore, data for these analytes were retained during validation, while other analyses for semivolatile organic compounds were rejected for missed holding times.

F.2.2.3.3 TCLP Analysis

Samples collected in 1989 were analyzed using the extraction procedure (EP) Tox test, while those collected in 1990/1991 were analyzed using the Toxicity Characteristic Leaching Procedure (TCLP 1993) extraction followed by a full TCLP analysis of the extract. Sample analytical results for these tests are presented in **Tables F.2.2-4** through **F.2.2-7**. Each of these tables also includes a column entitled maximum allowable concentration. The values shown in this column are taken from 40 Code of Federal Regulations (CFR) Part 261.24 and represent those values that characterize a solid waste as exhibiting the toxicity characteristic under the Resource Conservation and Recovery Act (RCRA), as amended (RCRA 1976). The material in Silos 1 and 2, however, is Atomic Energy Act (AEA) 11(e)(2) by-product material and are specifically excluded under RCRA from the definition of solid waste (40 CFR Part 261.4(a)(4). These values are shown in the table only as reference values used by the industry to determine whether waste is hazardous by toxicity characteristics.

The results of the 1989 EP Toxicity tests are summarized in **Table F.2.2-4**. Samples from Silos 1 and 2 yielded leachable lead that exceeded the maximum allowable concentration of 5 mg/L for the toxicity characteristics specified in 40 CFR Part 261.24. The maximum lead concentration from Silo 1 was 904 mg/L, while concentrations from Silo 2 were as high as 714 mg/L.

The results of the 1990/1991 TCLP tests on Silos 1 and 2 samples are summarized in **Tables F.2.2-4 and F.2.2-7**. As with the 1989 samples, lead was detected in the material from both Silos 1 and 2 in concentrations that exceeded the maximum allowable concentration limits of 5 mg/L. The maximum concentrations of lead in the TCLP extract for the 1990/1991 samples were 841 and 1072 mg/L for Silos 1 and 2, respectively. Detections of all the regulated organics were less than the maximum allowable concentration limits.

The TCLP extract was also analyzed for radiological constituents. These results are presented in **Table F.2.2-7**. One sample from each zone was analyzed from Silos 1 and 2. Based on original activity, Pb-210 was constituently more leachable than other radionuclides. This is consistent with the finding of TCLP analyses for elemental lead. A comparison was made between the TCLP radiological results and the results from sampling of the decant sump tank. Actinium-227 was not detected in the decant sump (<91.1 pCi/L) but was present at an average concentration of 4,990 pCi/L in the combined Silos 1 and 2 TCLP results. Lead-210 was present in the TCLP leachate at over 60 times the concentration present in the decant sump. The results for Th-230 in the decant sump tank were rejected during data validation; however, the report values indicated agreement with the TCLP result. Only uranium isotopes showed higher concentrations in the decant sump liquid. Because the tanker from which the decant sump liquid was sampled had been used elsewhere on-site (prior to receiving the liquids), some uncertainty exists in the reported values.

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TABLE F. 2.2-4
EP TOXICITY RESULTS FOR SILOS 1 AND 2 MATERIAL - 1989[a]

	Frequency of Detection	Mean (mg/L)	Standard Deviation (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Maximum Allowable Concentration[b] (mg/L)
			Silo 1			
Arsenic	6/7	0.312	0.144	ND[c]	0.484	5.0
Barium	7/7	4.362	4.399	0.079	14.5	100.0
Cadmium	6/7	0.027	0.031	ND	0.1	1.0
Chromium	7/7	0.333	0.277	0.02	0.964	5.0
Lead	7/7	561	278	0.159	904	5.0
Mercury	0/7	ND	ND	ND	ND	0.2
Selenium	7/7	0.535	0.238	0.217	0.997	1.0
Silver	6/7	0.074	0.040	ND	0.121	5.0
			Silo 2			
Arsenic	6/6	0.389	0.137	0.163	0.592	5.0
Barium	6/6	1.087	0.755	0.095	2.62	100.0
Cadmium	6/6	0.102	0.091	0.017	0.278	1.0
Chromium	4/6	0.380	0.365	ND	1.02	5.0
Lead	6/6	322	266	0.155	714	5.0
Mercury	0/6	ND	ND	ND	ND	0.2
Selenium	6/6	0.705	0.488	0.24	1.56	1.0
Silver	4/6	0.087	0.076	ND	0.213	5.0

a Sample data taken from Table 4-7 of the *Remedial Investigation Report for Operable Unit 4* (FEMP 1993a). The data presented in table have not been validated.
b Data obtained from 40 CFR Part 261.24.
c ND - Not Detected.

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TABLE F. 2.2-5
SUMMARY OF TCLP METALS ANALYSES FOR SILO 2 MATERIAL - 1990/1991[a]

Analyte	Frequency of Detection[b]	Rejected	Mean[c] (mg/L)[d]	Standard Deviation[c] (mg/L)	Range[c] (mg/L)	Maximum Allowable Concentration[e] (mg/L)
Arsenic	8/8	0	0.064	0.110	0.003-0.32	5.0
Barium	8/8	0	2.96	3.30	0.157-8.47	100.0
Cadmium	7/7	1	0.047	0.028	0.010-0.077	1.0
Chromium	8/8	0	0.129	0.036	0.086-0.207	5.0
Lead	7/7	1	516	348	117-1072	5.0
Selenium	8/8	0	0.114	0.184	0.026-0.568	1.0
Silver	8/8	0	0.093	0.032	0.053-0.164	5.0

a Sample data taken from Table 4-10 of the *Remedial Investigation Report for Operable Unit 4* (FEMP 1993a).
b Rejected data not included in total number of samples.
c Values qualified with an "R," "U" (analyte undetected), or "UJ" (analyte undected, quantitation limit may be inaccurate or imprecise) are excluded. The mean and standard deviation have been rounded to show no more than three significant figures. The range has been rounded to the nearest thousandth, unless a fourth decimal place is required to show a value.
d Values expressed in milligram per liter (mg/L).
e Data obtained from 40 CFR Part 261.24.

TABLE F. 2.2-6
SUMMARY OF TCLP METALS ANALYSES FOR SILO 1 MATERIAL - 1990/1991[a]

Analyte	Frequency of Detection[b]	Rejected	Mean[c] (mg/L)[d]	Standard Deviation[c] (mg/L)	Range[c] (mg/L)	Maximum Allowable Concentration[f] (mg/L)
Arsenic	1/11	1	0.002	[e]	[e]	5.0
Barium	12/12	0	0.868	0.402	0.384-1.83	100.0
Cadmium	12/12	0	0.003	0.001	0.002-0.005	1.0
Chromium	12/12	0	0.059	0.012	0.045-0.081	5.0
Lead	8/9	3	614	221	229-841	5.0
Mercury	1/12	0	0.0002	[e]	[e]	0.2
Selenium	11/11	1	0.135	0.088	0.015-0.306	1.0
Silver	12/12	0	0.034	0.008	0.023-0.048	5.0

a Sample data taken from Table 4-8 of the *Remedial Investigation Report for Operable Unit 4* (FEMP 1993a).
b Rejected data not included in total number of samples.
c Values qualified with an "R," "U," or "UJ" are excluded. The mean and standard deviation have been rounded to show no more than three significant figures.
d Values express in milligrams per liter (mg/L).
e Analyte was detected in a single sample.
f Data obtained from 40 CFR Part 261.24.

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F-8074

TABLE F. 2.2-7
SUMMARY OF TCLP RADIOLOGICAL ANALYSES FOR SILOS 1 AND 2 MATERIAL 1990/1991[a]

Analyte	Frequency of Detection[b]	Rejected	Mean[c] (pCi/L)[d]	Standard Deviation[c] (pCi/L)	Range of Detects[c] (pCi/L)
			SILO 1		
Actinium-227	3/3	0	6,550	1090	7,302 - 5,014
Lead-210	3/3	0	1,059,000	476,000	509,000 - 1,670,000
Polonium-210	3/3	0	138,000	55,900	71,200 - 208,000
Radium-226	3/3	0	50,200	11,500	40,150 - 66,370
Thorium-228	3/3	0	34.9	14.7	14.9 - 49.8
Thorium-230	3/3	0	385	61	307 - 455
Thorium-232	3/3	0	7.0	1.1	5.65 - 8.42
Uranium-234	3/3	0	1,010	1040	238 - 2,480
Uranium-235/236	3/3	0	52.3	57.1	9.74 - 133
Uranium-238	3/3	0	976	972	246 - 2,350
			SILO 2		
Actinium-227	3/3	0	3,430	669	2,620 - 4,258
Lead-210	3/3	0	148,000	51,500	104,000-220,000
Polonium-210	3/3	0	24,700	8140	18,100 - 36,200
Radium-226	3/3	0	61,900	26,500	24,410 - 81,840
Radium-228	2/2	1	15.4	4.4	11 - 19.7
Thorium-228	3/3	0	114	73	24.7 - 204
Thorium-230	3/3	0	159	96	72.8 - 293
Thorium-232	1/3	0	1.87	[e]	[e]
Uranium-234	3/3	0	2,200	1,410	417 - 3,860
Uranium-235/236	3/3	0	90.9	56.8	19.2 - 158
Uranium-238	3/3	0	2,270	1,460	421 - 4,000

a Sample data taken from Table 4-12 of the *Remedial Investigation Report for Operable Unit 4* (FEMP 1993a).
b Rejected data not included in total number of samples.
c Values qualified with an "R" or "<" (radionuclide undected) are excluded. The mean and standard deviation have been rounded to show three significant figures.
d Values expressed in picoCuries per liter (pCi/L).
e Analyte was detected in a single sample.

8074

F.2.2.3.4 Summary of Chemical Results

The 1989 and 1990/1991 sampling results from Silos 1 and 2 show similar concentrations in: (1) the predominant *non-radioactive metallic* constituents of barium calcium, iron, and lead, and, (2) the predominant *organic* constituents of aroclor-1254, aroclor-1260, and tributyl phosphate.

F.2.3 Nature and Extent of Contamination

Investigations were performed as part of the original OU4 RI and other site programs to examine the nature and extent of contamination present in environmental media associated with OU4. These investigations included the collection and laboratory analysis of samples and the collection of direct field measurements. The investigations included examination of surface and subsurface soil, surface water and sediment, and groundwater.

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F.2.3.1 Surface Soils

As part of the RI/FS and other site programs, sampling was performed near OU4 that indicated the occurrence of above background concentrations of uranium, and to a lesser degree, other radionuclides in the surface soils within and adjacent to the OU4 study area. Observations, made during the RI, on activity concentrations in the surface soils near OU4 were as much as 20.8 pCi/g for U-238, or 16 times natural background, and 4.8 pCi/g for Th-230, or two times background. These above background concentrations appear to be generally limited to the upper six inches of soil.

Of the inorganic constituents detected in the OU4 surface soils, antimony, beryllium, chromium, copper, magnesium, nickel, silver, and sodium were consistently above background. The only volatile organic compounds detected consisted of common laboratory contaminants. However, there was one exception: a sample collected at a depth of 0.5 to 0.6 m (1.5 to 2.0 ft) contained small concentrations of a number of semivolatile organic compounds, including benzo(a)pyrene. Semivolatile organic compounds were at or only slightly above the contract required quantity limit for the laboratory. Available sample data and process knowledge did not indicate a direct relationship between the surface soil contamination in the OU4 study area and the silos contents. Further, more than 70% of the surface soil samples indicated that the uranium contamination in surface soils is depleted uranium (i.e., the uranium contains depleted percentages of U-235). The silos material consists of natural uranium. Thus, the existence of these activity concentrations in the surface soils is attributed to air deposition resulting from the former production area and past plant production operations and/or waste handling practices in the waste pit area.

Soil samples were collected from the soils contained in the earthen embankment (berm) surrounding Silos 1 and 2. The highest concentrations of radionuclide constituents were detected in a sample taken at a location 9 m (30 ft) below the berm surface, near the base of Silo 1. This sample indicated the occurrence of either some spillage of silos material during filling operations or seepage from the silos onto the original surface soils adjacent to the silos at that location. Analytical results from other berm samples showed the presence of radionuclides at relatively lower concentrations, with the majority of samples showing concentrations near background.

The concentration ranges for those constituents in relatively higher concentrations were: 0.62 to 417 pCi/g for Pb-210; 1.03 to 943 for Po-210; 0.62 to 876 pCi/g for Ra-226; 0.74 to 51.2 pCi/g for Th-230; and 0.75 to 24.7 pCi/g for U-238. Inorganic constituents detected consisted mostly of metals in concentrations close to background concentrations. There were also some organic constituents reported. Most of these constituents are common laboratory contaminants and do not demonstrate any direct linkage to the silos contents.

F.2.3.2 Subsurface Soils

As part of the RI for OU4, samples were collected from the subsurface soils located under and adjacent to the K-65 silos. Analytical results reveal elevated concentrations of radionuclides from the uranium decay series in the soils at the interface between the berm and the original ground level. Elevated concentrations (up to 53 pCi/g for U-238, about 40 times background) were also noted in slant boreholes that passed in close proximity to the silos underdrains. The occurrence of these above background concentrations in soils near the silos underdrains are attributed to vertical migration of leakage from the silos underdrains or decanting system. Elevated readings at the interface between the silos berms and the native soils may be attributed to historical air deposition or past spillage from the silos during filling operations in the 1950s, before installation of the berms.

F.2.3.3 Surface Water and Sediment

Extensive sampling was conducted on the sediment and surface water present in Paddys Run and on key drainage swales leading to Paddys Run, as part of the RI for OU4 and other site programs. Results of the surface water sampling indicate the occurrence of above background concentrations of U-238, up to 1,500 times background, in the drainage swales near Silos 1 through 4. The highest readings were recorded in a drainage ditch that flows from east to west and is located approximately 76 m (250 ft) south of Silo 1. The most probable source of the contamination in Paddys Run and the drainage swales is the resuspension of contaminated particles from surface soils within the OU4 and OU1 study areas into stormwater.

F.2.3.4 Groundwater

Groundwater samples were collected from wells within the OU4 study area during the RI for OU4. Groundwater occurs not only in the Great Miami Aquifer underlying the FEMP site, but also in discrete zones of fine-grained sands located in the glacial overburden. The water contained in these sand pockets in the clay-rich glacial soils is termed "perched water." Samples were collected from the following locales: slant borings placed adjacent to and under Silos 1 and 2; 1000-series wells screened in the glacial overburden; 2000-series wells screened at the water table in the Great Miami Aquifer; and 3000-series wells screened at approximately the central part of the Great Miami Aquifer, just above the clay interbed.

Background concentrations of naturally occurring inorganics and radionuclides in groundwater near the FEMP site were being established under the site-wide RI/FS during the completion of the RI for OU4. In accordance with background data available at the time, a background concentration of total uranium in groundwater of less than 3 micrograms per liter (µg/L) or 3 parts per billion (ppb) was utilized.

Perched Water

Uranium was the major radionuclide contaminant found in the perched water. Elevated concentrations of total uranium were detected in the slant boreholes under and around Silos 1 and 2. Slant Boring 1617, immediately southwest of Silo 1, contained the highest concentration of total uranium (9,240 μg/L). Uranium concentrations were also elevated in samples collected from the 1000-series wells. The highest observed total uranium concentrations obtained from 1000-series wells were in samples collected from Well No. 1032, located 46 m (150 ft) due west of Silo 2. The range of the concentrations was 196 to 276 μg/L. Considering both the slant borings and 1000-series wells, U-238 was found in the range of 1.1 to 1,313 pCi/L.

The major inorganic constituents found in the perched water samples taken from 1000-series wells and the slant borings, included elevated concentrations for major cations (iron, magnesium, manganese, and sodium) and major anions (chloride, nitrate, and sulfate). In particular, the concentrations of sodium, sulfate, and nitrate were significantly above background in slant boring samples. Boring 1615, northwest of Silo 2, had the highest sodium concentration (1,040 mg/L); boring 1618, southeast of Silo 1, had the highest sulfate concentration (2,200 mg/L); and, boring 1617 had the highest nitrate concentration (554 mg/L). Low levels of organic constituents, determined to be contaminants, were detected in some samples. Overall, well measurements and analytical results confirmed that the perched groundwater near OU4 flows from west to east. Further, contaminants within OU4 are contributing to contamination of perched groundwater in this region of the site.

Great Miami Aquifer

The concentration of total uranium in the upper portion of the Great Miami Aquifer, based on analysis of samples from the 2000-series wells, ranged from less than 1 µg/L to 40.3 µg/L. These data do not necessarily suggest that the silos are the source of the observed contamination because both upgradient and downgradient wells contain above background concentrations of total uranium. Well No. 2032, located 46 m (150 ft) west of Silos 1 and 2, exhibited a concentration of total uranium at 39.0 µg/L. Well No. 2033, located 46 m (150 ft) east of Silos 1 and 2, exhibited a concentration of total uranium at 40.3 µg/L. Because groundwater flow in this region of the Great Miami Aquifer is from west to east, these two wells are located upgradient and downgradient of OU4, respectively.

The isotopic ratio of U-234 and U-238 would suggest a natural uranium ratio in these samples. Such a ratio may be expected from OU4, but is not a "fingerprint" for this source. The presence of uranium upgradient in the aquifer from an OU4 source could be explained by leachate travel in the perched groundwater zone of the glacial overburden with emergence to Paddys Run. Here the diluted leachate could enter the aquifer via streambed infiltration or flow at the perched zone/stream channel interface. Evidence is not available to support or preclude this potential route.

The concentration of total uranium measured at deeper levels in the Great Miami Aquifer (3000-series wells) ranged from less than 1 to 4 µg/L, with the exception of 1 sample out of 16, which contained 15 µg/L. Like the 2000-series wells, no conclusion could be drawn that linked this contamination to the silos.

8074

F.2.4 Potential Exposure Pathways for Contaminant Migration

Contaminant transport from OU4 may occur via the following pathways:

- Direct radiation
  - Direct exposure to gamma radiation from radioactive constituents within the silos.
  - Direct exposure to Silo 3 material under the future source term scenario assuming structural collapse of the silo.
  - Direct exposure to gamma radiation from radioactive constituents in surface soil.
- Air emissions
  - Dispersion of radon that escapes from the silos into the atmosphere.
  - Dispersion of volatile organic compounds (VOC) or fugitive dust emissions generated from soil erosion.
  - Dispersion of Silo 3 contents under the future source term scenario assuming structural collapse of the silo.
- Surface water runoff
  - Erosion of contaminated soils into Paddys Run from the vicinity of the silos.
  - Erosion of released Silo 3 contents under the future source term scenario assuming structural collapse of the silo.
- Groundwater transport

  Leaching of contaminants from the silos contents via soils to underlying groundwater.

Each of these potential, contaminant transport pathways is discussed below. The summary of the Baseline Risk Assessment, which is discussed in detail in Section 7.5 of the *Remedial Investigation Report for Operable Unit 4* (FEMP 1993a) and presented in **Section F.3,** provides additional information about the impacts on environmental media or human receptors.

F.2.4.1 Direct Radiation

Gamma radiation from the K-65 material and surface soils are transported as electromagnetic radiation; thus, a transport mechanism is not required. As the distance from the K-65 silos and the surface soil source increases, the magnitude of the radiation's intensity decreases. The soil berms around Silos 1 and 2 provide shielding to potential receptors from the direct gamma radiation associated with the K-65 material. The BentoGrout™ clay layer covering the silos material decreases the diffusion of radon into the silos headspace. Radon progeny are gamma-emitters that contribute significantly to direct radiation exposure. Therefore, as long as the integrity of the berms, the BentoGrout™ clay liner, and the silos is maintained, the direct radiation exposure due to this pathway should not change or increase.

F.2.4.2 Air Emissions

Rn-222 generated by the radioactive decay of Ra-226 in the K-65 and metal oxide residues accumulates in the void headspace inside the silos. At the time of their design, the four silos were not required to be airtight; therefore, air exchanges with the outside environment occur. The air exchange is a result of changes in ambient temperatures that cause expansion and contraction of the air mass inside the silos.

The foam installed on top of Silos 1 and 2 in 1987 has reduced the K-65 silos breathing losses by limiting daily temperature variations inside the silos domes. In addition to direct release to the atmosphere, radon gas can also diffuse through the K-65 silos walls into the surrounding soil berms. Radon has a short half-life (3.82 days) and is expected to decay into its progeny, Pb-210 and Po-210, in the silos walls and in the soil berms surrounding Silos 1 and 2. These are nonvolatile constituents that accumulate in the soil berms. These progeny could be transported via resuspension if the berms erode to a point where this area is exposed. Contaminated soil particulates can also be resuspended into the air from the surface of the K-65 berms and the surrounding OU4 soils and be transported by winds to other locations.

F.2.4.3 Surface Water Runoff

Contaminants in the surface soils can be transported away from OU4 through surface soil erosion caused by surface water runoff. If the existing runoff control structures (i.e., trench drains and curb and gutters) at the perimeter of OU4 were to fail, this would permit stormwater runoff to directly enter Paddys Run. Contaminants contained in near-surface soils that are subject to erosion can be transported to Paddys Run by either dissolving in the runoff surface water or attaching to entrained sediment carried by the water. A portion of these contaminants will partition (i.e., separate) into stream sediment and will not be available for immediate transport to the aquifer. Contaminants in the dissolved phase could be transported to the Great Miami Aquifer by recharge from Paddys Run throughout the length of Paddys Run from OU4 to the Great Miami River.

F.2.4.4 Groundwater Transport

The final potential transport route is via groundwater. Contamination may be transported through the vadose zone into the Great Miami Aquifer near OU4 by traveling through the glacial overburden present beneath the silos. A conceptual model of potential contaminant transport from the bottom of the silos to the Great Miami Aquifer has been developed. This model is based on the current understanding of the OU4 study area and data from past investigations and is listed below:

- Leachate derived from Silos 1 and 2 is formed under the current storage configuration of the silos from liquids used to slurry waste materials into the silos. Additional leachate may be formed based on the assumption that precipitation infiltrates the silos through the silos top and sidewalls and interacts with the wastes within. This leachate may pass through the wastes, exit the bottom of the silos, and enter the glacial overburden.
- Perched groundwater near OU4 flows to the west, toward Paddys Run. Thus, once out of the silos, leachate may migrate through the glacial overburden toward the west, until it reaches Paddys Run, or in a vertical direction until it reaches the Great Miami Aquifer.
- Once in Paddys Run or the Great Miami Aquifer, the contamination can be transported through surface water or groundwater to either on-property or off-site receptors.

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130B

8074

F.3.0 BASELINE RISK ASSESSMENT

Baseline Risk Assessments were performed in 1994 to determine the potential human health effects and ecological risks that could result from exposure to the contaminants present in OU4 (EPA 1989).

The baseline assessment of human health risks quantified the health risks to hypothetical human receptors due to exposure from chemical sources in OU4, under the no-action alternative. The process analyzed the potential, human health consequences under different scenarios if no remedial actions were taken to address identified environmental concerns. This structured, sequential, and analytical process:

- Identified the specific Constituents of Concern (COCs) for OU4.
- Assessed contaminant transport from the sources to potential exposure points.
- Quantified potential exposures to receptors under current and future land-use scenarios.
- Characterized the potential baseline risks associated with OU4 under current and potential, future land-use scenarios.

Appendix D and Section 6.0 of the *RI Report for OU4* (FEMP 1993a) provide detailed information on the baseline assessment of human health risks.

Site-wide baseline ecological risks were evaluated and included in the *Site-wide Characterization Report* (FEMP 1993b). An overview of that discussion is included in **Section F.3.2** of this appendix. The purpose of this evaluation was to conduct a qualitative assessment of the risks posed by FEMP site contaminants to ecological receptors (e.g., plants and animals) if remediation is not implemented, thus, serving as a baseline for future assessments. The ACA between the EPA and DOE stipulates that OU5 was responsible for the preparation of the *Site-wide Ecological Risk Assessment* as part of the RI and FS Reports for OU5 (FEMP 1993b).

130C

F.3.1 Summary of the Baseline Assessment of Risks to Human Health

F.3.1.1 Constituents of Concern

The COCs for human health and their ranges of concentration in effected OU4 media are provided in **Table F.3.1-1**. COCs were detected in Silos 1, 2, and 3, the surrounding surface soil and subsurface soil, and the silos berm soils. Baseline Risk Assessment source term concentrations were determined for the COCs in these media. Fate and transport modeling was then conducted to estimate the exposure point concentrations of contaminants in environmental media (e.g., groundwater, air, and surface water). Contaminants with the potential of posing risk to human health include radionuclides, metals, inorganic anions, PAHs, and pesticides/PCBs. The selection of COCs was based on an evaluation of characterization data on the distribution of contaminants in various media and the potential contribution of these contaminants to the overall human health effects. [Appendix E of the *RI Report for OU4* (FEMP 1993a) provides full details of the process for selecting COCs.]

F.3.1.2 Exposure Assessment

The exposure assessment and Baseline Risk Assessment followed the methodology described in the *Risk Assessment Work Plan Addendum* (FEMP 1992), with the exception of those items identified in Section D of Appendix D of the *RI Report for OU4* (FEMP 1993a). Baseline risks were calculated under a number of contaminant release mechanisms providing exposure to hypothetical receptors under three separate land-use scenarios.

Baseline risks under these land-use scenarios were calculated for a "current source term" and a "future source term." The concentrations of contaminants found in the contents of Silos 1, 2, and 3, the surrounding surface soil, the silos berm soil, and subsurface soil within the OU4 study area were used to determine the source term concentrations for each exposure scenario.

Land-use scenarios that were evaluated included: (1) the "**current land**" use (1994) **without** access controls, (2) the "**current land**" use (1994) **with** access controls, and (3) "**future land**" use **without** access controls. Under the first scenario, the FEMP site was assumed to be managed by an industrial concern other than DOE. Access restrictions provided by DOE were assumed to be discontinued. In addition, it was assumed that remedial actions had not been taken and members of the public had not established residence within the boundaries of OU4. Thus, potential receptors included an off-property resident farmer, a trespassing child, an on-property worker (groundskeeper), and an off-property user of surface water from the Great Miami River.

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130E

TABLE F. 3.1-1
CONSTITUENTS OF CONCERN FOR OU4

	Silos 1 & 2	Silo 3	Surface Soil	Berm Soil
Range of Detection for Chemicals (mg/kg)				
2-Butanone	0.002-0.022		0.002-0.008	0.011[a]
2-Hexanone	0.002-0.017			
2-Nitrophenol		.052[a]		
4,4'-DDE	0.029-0.120			
4,4'-DDT	0.014-0.068			
4-Methyl-2-pentanone	0.002-0.003			
4-Nitrophenol		.045[a]		
Acenaphthylene			1.30[a]	
Acetone	0.033-0.150		0.004-0.079	0.064[a]
Aldrin	0.056[a]			
Ammonia	1.100-8.90			
Anthracene			0.780[a]	
Antimony	13.300-77.4		22.60-32.30	19.100-24.900
Aroclor- 1248	1.700-10.0			
Aroclor- 1254	0.420-20.0			
Aroclor-1260	0.340-3.50			
Arsenic	3.100-1960	532-6380	2.70-9.50	5.000-8.000
Barium	89.20-22100	118.000-332.000	44.7-113.0	47.100-89.400
Benzo(a) anthracene			0.062-4.70	
Benzo(a)pyrene			5.20[a]	
Benzo(b)fluoranthene			0.150-9.70	
Benzo(g,h,i)perylene			5.30[a]	
Benzoic Acid	0.075-.390		0.059[a]	
Beryllium	0.590-6.00	10.000-39.900	0.670-1.00	0.670-0.850
Bis(2-ethylhexyl)phthalate	0.070-6.0		0.075-1.60	
Boron	18.400-81.20			

8074

TABLE F.3.1-1 (continued)

	Silos 1 & 2	Silo 3	Surface Soil	Berm Soil
Range of Detection for Chemicals (mg/kg)				
Cadmium	0.560-19.1	21.500-204.000	4.70-6.20	2.600-4.200
Carbon tetrachloride	.0170[a]			
Chromium	.207-165	139-560	10.20-22.60	16.400-28.400
Chrysene			0.062-3.50	
Cobalt	6.20-2430	1100-3520		
Copper	122-1790	1610-7060	16.200-23.50	19.300-23.800
Cyanide	0.520-7.10		0.120[a]	0.120[a]
Di-n-butyl phthalate	0.046-0.057		0.190[a]	0.048[a]
Di-n-octyl phthalate	0.045-0.970			
Dieldrin	0.093[a]			
Diethyl phthalate	0.410[a]			
Dimethyl phthalate	0.068-0.160			
Endosulfan I			0.011-0.092	
Endosulfan-II	0.082-0.260			
Endrin	0.089[a]			
Fluoranthene	0.064		0.040-6.70	
Fluoride	15.0-394			
Heptachlor epoxide	0.022-0.20			
Indeno(1,2,3-cd)pyrene			4.20[a]	
Lead	153-299000	646-4430		
Manganese		2420-6500		
Mercury	0.150-2.80	0.300-0.690		
Methylene chloride	0.015-0.190		0.025[a]	
Molybdenum	148-8600		3.60-4.90	2.400-13.300
N-nitroso-di-n-propylamine	0.059-0.260			
Nickel	14.60-3380	1760-6170	22.8-38.9	21.700-32.400
Nitrate	2216-8900			
Phenanthrene			2.60[a]	
Phenol	0.40[a]		0.230[a]	0.110[a]
Phosphorus	0.40-3290			
Pyrene	0.047[a]		0.045-8.20	

130G

TABLE F.3.1-1 (continued)

	Silos 1 & 2	Silo 3	Surface Soil	Berm Soil
Range of Detection for Chemicals (mg/kg)				
Selenium	49.60-2810	101.000-349.000		
Silver	5.0-34.9	9.200-23.800	6.60-9.70	5.800-14.400
Tetrachlorethene	0.140[a]			
Thallium	0.090-5.700	4.000-73.900	0.510[a]	0.710[a]
Toluene	0.002-0.190		0.001[a]	0.002-0.200
Total xylenes	0.003[a]			0.069[a]
Tributyl Phosphate	0.200-73.00			
Uranium	137.0-8394.0	738.0-4554.0	4.0-64.0	10.50-12.40
Vanadium	21.90-535.00	418-4550	15.9-27.7	24.600-28.400
Zinc	7.70-212.00	301-672	32.9-65.2	44.200-59.600
Range of Detection for Radionuclides (pCi/g)				
Actinium-227	2905.0-17390	234.0-1363		
Cesium- 137				0.23[a]
Lead-210	48980.0-399200	454.0-6427		0.98-4.45
Polonium-210	55300-43400			1.68-4.70
Protactinium-231	4041[a]	266.0-931		
Radium-224		64.00-453.00		1.020[a]
Radium-226	657.0-890700	467.0-6435	0.6-2.3	1.04-6.68
Radium-228		82.0-559	0.5-1.7	0.8-0.98
Strontium-90			0.8-1.8	
Technetium-99			1.2-3.6	
Thorium-228	411.0-7360	459.0-996	0.9-1.4	1.12-1.52
Thorium-230	8365.0-132800	21010.0-71650	1.4-4.8	1.69-4.78
Thorium-232	661.0-1106	411.0-1451	0.9-1.7	0.86-1.45
Uranium-234	89.0-1548	348.0-1935	2.4-6.9	1.26-3.62
Uranium-235/236	19.1 - 172	42.0-158		
Uranium-238	46.0-1925	320.0-2043	2.4-20.8	1.13 -4.19

[a] only one sample was found to be above the detection limit.

Under the second scenario, the site access restrictions historically provided by DOE were assumed to be maintained, and it was assumed that remedial actions had not been taken. The scenario further assumed that members of the public had not established residence in the OU4 study area, and that DOE was maintaining a site-specific health and safety program to ensure that non-remediation workers and visitors were properly protected. Therefore, the risk assessment addressed workers subjected to a short duration of exposure under controlled conditions. These controls included engineered emission control equipment, personnel protective equipment, and administrative health and safety practices. Potential receptors under this scenario included an off-property resident farmer, a trespassing child, and an off-property user of surface water from the Great Miami River.

The third land-use scenario, "future land" use without access controls, included exposure routes that required development time, such as establishing a home and farm within OU4. Access controls were assumed non-existent and it was assumed that remedial actions had not been taken. In addition, members of the public were assumed to have established a residence within the OU4 boundaries. Hypothetical receptors under this scenario included a reasonable maximum exposure (RME) on-property resident farmer, a central tendency (CT) on-property resident farmer, an on-property resident child, an off-property resident farmer, and an off-property user of surface water from the Great Miami River.

In addition to the three land-use scenarios, two source term scenarios were considered: the "current source term" (1994) scenario and the "future source term" scenario. The current source term scenario considered the silos as they existed in 1994. The future source term scenario considered: (1) complete structural failure of Silo 3, resulting in the spread of its contents to OU4 surface soil; and (2) dome collapses for Silos 1 and 2, consequently exposing their contents to the elements and increasing leaching of the contents through the interception of rainwater.

Under the current land-use scenario without access control and the future land-use scenario, risks were calculated using both the current source term and the future source term. Under the "current land-use with access control scenario," the future source term did not apply. If the site remained under the institutional control of DOE, the assumption was made that measures would be undertaken to maintain the current configuration of the silos and implement mitigative action in the case of silo failure. Thus, under the current land-use with access control scenario, risk was calculated only for the current source term (1994).

The on-property resident farmer receptor was also evaluated using exposure and intake parameters such as exposure duration, which represents the CT of risk. This was performed in response to guidance from the EPA that suggested risk assessments provide an evaluation of the CT of the risk range, using the best information available to describe the average situation (EPA 1992a). This scenario was used to provide an estimate of risk closer to average for the resident adult scenario. This receptor scenario was in the development process by the EPA and required additional review as guidance became available. The CT receptor for this scenario was located at the same location as the RME on-property resident farmer receptor. **Table F.3.1-2** provides a summary of the land-use/source term/receptor scenarios used for the Baseline Risk Assessment.

Exposure pathways quantified in the risk assessment for each scenario are shown in **Figures F.3.1-1 and F.3.1-2** and are discussed in greater detail in Appendix D of the *RI Report for Operable Unit 4* (FEMP 1993a). A summary of exposure pathways having the most impact to site risks is presented in **Section F.3.1.4**. The conceptual model depicted in **Figures F.3.1-1** and **F.3.1-2** indicates which exposure routes were quantitatively evaluated in the risk assessment for each receptor and land-use scenario, and the basis for excluding other exposure routes. Exposures to the RME resident farmer due to the ingestion of groundwater considered two scenarios, which include water obtained from the Great Miami Aquifer and water obtained from perched water beneath and west of Silos 1 and 2.

8074

Section 2.0 and Appendix E of the *RI Report for Operable Unit 4* (FEMP 1993a) address, in detail, fate and transport modeling efforts employed in the determination of exposure point concentrations of the COCs. Appendix D of the RI Report for OU4 discusses the assumptions regarding source term and potential release mechanisms upon which the fate and transport modeling were based.

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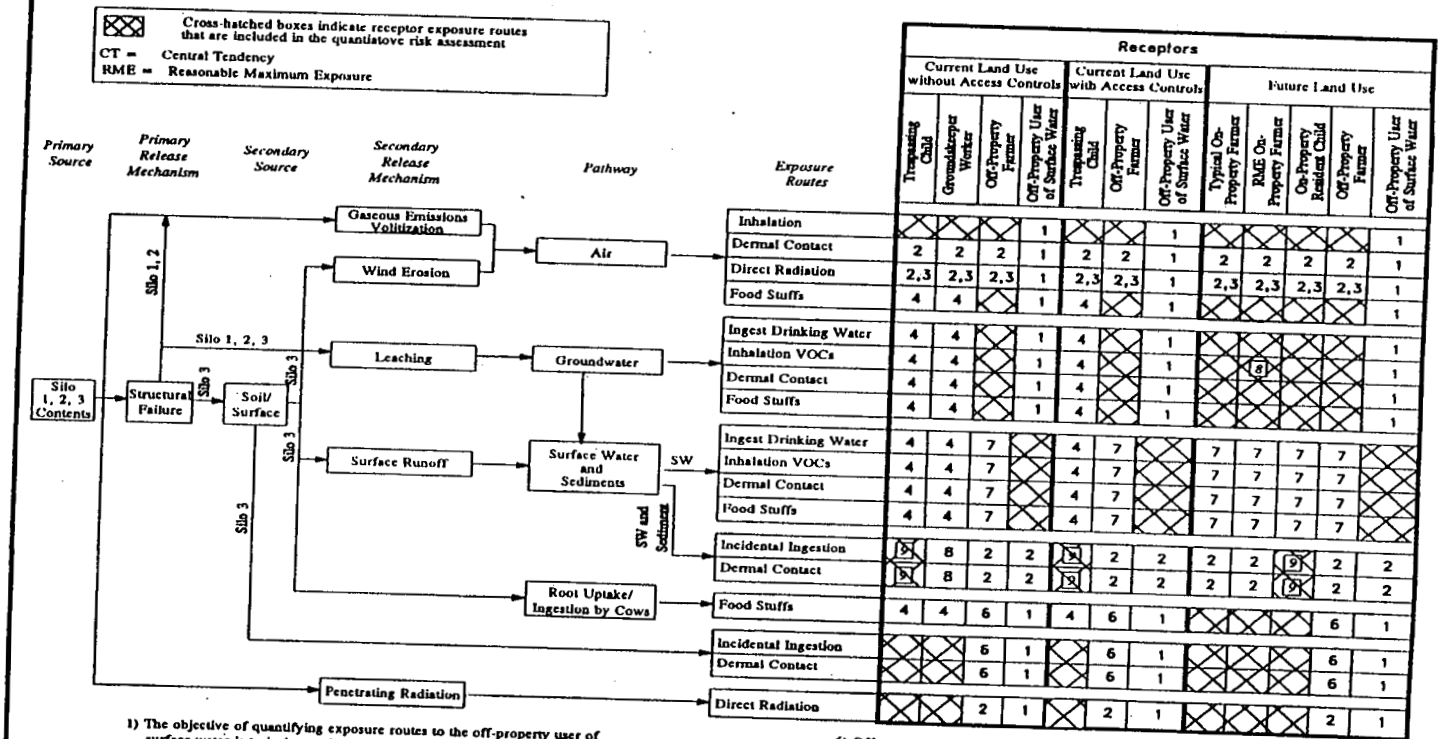
1307

TABLE F.3.1-2
SUMMARY OF LAND-USE/RECEPTOR/SOURCE TERM SCENARIOS

	RECEPTORS	
LAND-USE	**CURRENT SOURCE TEAM**	**FUTURE SOURCE**
Current Land-use Without Access Control	Off-Property Farmer, Trespassing Child, Groundskeeper Worker, Off-Property User of Surface Water from the Great Miami River	Off-Property Farmer, Trespassing Child, Groundskeeper Worker, Off-Property User of Surface Water from the Great Miami River
Current Land-use With Access Control	Off-Property Farmer, Trespassing Child, Off-Property User of Surface Water	N/A
Future Land-use	RME On-Property Resident Farmer, CT On-Property Resident Farmer, On Property Resident Child, Off-Property Farmer, Off-Property User of Surface Water from the Great Miami River	RME On-Property Resident Farmer, CT On-Property Resident Farmer, On Property Resident Child, Off-Property Farmer, Off-Property User of Surface Water from the Great Miami River

Notes: N/A Not Applicable
RME Reasonable Maximum Exposure
CT Central Tendency

FIGURE F. 3.1-1
OU4 CONCEPTUAL MODEL - SILOS CONTENTS



1) The objective of quantifying exposure routes to the off-property user of surface water is to isolate and evaluate the impact of contamination from the Great Miami River through water pathways.
2) Potential impact of exposure route is minor compared to other exposure routes
3) EPA Risk assessment methodology for radionuclides dos not address this exposure route.
4) Exposure route is not applicable to a transient, non-resident receptor.
5) Evaluated using two different exposure point concentrations: modeled aquifer concentration and modeled sand lens concentration.
6) Off-property soils is within the scope of OU5. Impact on food stuff exposure routes from air deposition is included in the air exposure routes.
7) Receptor is assumed to obtain water for all needs from groundwater.
8) Receptor is assumed to restrict activities to work at OU4 and not contact surface water via these exposure routes.
9) Evaluated for sediment ingestion and dermal contact with sediment using modeled concentration impacted by sand lens.

130 M

8074

FIGURE F.3.1-2
OU4 CONCEPTUAL MODEL - SOIL AND BERM FILL MATERIAL

Cross-hatched boxes indicate receptor exposure routes that are included in the quantitative risk assessment

CT = Central Tendency
RME = Reasonable Maximum Exposure

Source: Soil: Surface, Subsurface, Berm Fill

Release Mechanisms → Pathway → Exposure Routes

Release Mechanisms	Pathway	Exposure Routes	Current Land Use without Access Controls: Trespassing Child	Current Land Use without Access Controls: Groundkeeper Worker	Current Land Use without Access Controls: Off-Property Farmer	Current Land Use without Access Controls: Off-Property User of Surface Water	Current Land Use with Access Controls: Trespassing Child	Current Land Use with Access Controls: Off-Property Farmer	Current Land Use with Access Controls: Off-Property User of Surface Water	Future Land Use: Typical On-Property Farmer	Future Land Use: RME On-Property Farmer	Future Land Use: On-Property Resident Child	Future Land Use: Off-Property Farmer	Future Land Use: Off-Property User of Surface Water
Wind Erosion	Air	Inhalation				1			1					1
Wind Erosion	Air	Dermal Contact	2	2	2	1	2	2	1	2	2	2	2	1
Wind Erosion	Air	Direct Radiation	2,3	2,3	2,3	1	2,3	2,3	1	2,3	2,3	2,3	2,3	1
Wind Erosion	Air	Food Stuffs	4	4		1	4		1					1
Leaching	Groundwater	Ingest Drinking Water	4	4	5	1	4	5	1	5	5	5	5	1
Leaching	Groundwater	Inhalation VOCs	4	4	5	1	4	5	1	5	5	5	5	1
Leaching	Groundwater	Dermal Contact	4	4	5	1	4	5	1	5	5	5	5	1
Leaching	Groundwater	Food Stuffs	4	4	5	1	4	5	1	5	5	5	5	1
Surface Runoff	Surface Water and Sediments (SW)	Ingest Drinking Water	4	4	7		4	7		7	7	7	7	
Surface Runoff	Surface Water and Sediments (SW)	Inhalation VOCs	4	4	7		4	7		7	7	7	7	
Surface Runoff	Surface Water and Sediments (SW)	Dermal Contact	4	4	7		4	7		7	7	7	7	
Surface Runoff	Surface Water and Sediments (SW)	Food Stuffs	4	4	7		4	7		7	7	7	7	
Surface Runoff	Surface Water and Sediments (SW and Sediment)	Incidental Ingestion		8	2	2		2	2	2	2		2	2
Surface Runoff	Surface Water and Sediments (SW and Sediment)	Dermal Contact		8	2	2		2	2	2	2		2	2
	Root Uptake/ Ingestion by Cows	Food Stuffs	4	4	6	1	4	6	1				6	1
Direct Contact		Incidental Ingestion			6	1		6	1				6	1
Direct Contact		Dermal Contact			6	1		6	1				6	1
Penetrating Radiation		Direct Radiation			2	1		2	1				2	1

1) The objective of quantifying exposure routes to the off-property user of surface water is to isolate and evaluate the impact of contamination from the Great Miami River through water pathways.
2) Potential impact of exposure route is minor compared to other exposure routes.
3) EPA Risk assessment methodology for radionuclides does not address this exposure route.
4) Exposure route is not applicable to a transient, non-resident receptor.
5) Soil in Operable Unit 4 is not included as a source term to groundwater modeling.
6) Off-property soils is within the scope of OU5. Impact on food stuff exposure routes from air deposition is included in the air exposure routes.
7) Receptor is assumed to obtain water for all needs from groundwater.
8) Receptor is assumed to restrict activities to work at OU4 and not contact surface water via these exposure routes.

130N

TABLE F.3.1-3
CANCER SLOPE FACTORS FOR CARCINOGENIC EFFECTS OF CONSTITUENTS OF CONCERN IN OU4

Chemical	Oral Cancer Slope Factor $(mg/kg/day)^{-1}$	Inhalation Cancer Slope Factor $(mg/kg/day)^{-1}$ [a]	Tumor Site		Cancer Classification [ab]	Reference
			Oral	Inhalation		
Inorganics						
Ammonia	ND[c]	ND	ND	ND	ND	ND
Antimony	ND	ND	ND	ND	D	d
Arsenic	1.75	15	skin	respiratory tract	A	e
Barium	ND	ND	ND	ND	D	d
Beryllium	4.3	8.4	gross tumors	lung	B2	e
Boron	ND	ND	ND	ND	ND	ND
Cadmium (food)	ND	6.3	ND	respiratory tract	B1	e
Cadmium (water)	ND	6.3	ND	respiratory tract	B1	e
Chromium (VI)	ND	42	ND	lung	A	e
Cobalt	ND	ND	ND	ND	ND	ND
Copper	ND	ND	ND	ND	D	e
Cyanide	ND	ND	ND	ND	D	e

130 0

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TABLE F.3.1-3 (continued)

Chemical	Oral Cancer Slope Factor $(mg/kg/day)^{-1}$	Inhalation Cancer Slope Factor $(mg/kg/day)^{-1}$ [a]	Tumor Site		Cancer Classification [ab]	Reference
			Oral	Inhalation		
Inorganics (continued)						
Fluoride	ND	ND	ND	ND	ND	ND
Lead	ND	ND	kidney	ND	B2	e
Manganese	ND	ND	ND	ND	D	e
Mercury	ND	ND	ND	ND	D	e
Molybdenum	ND	ND	ND	ND	D	d
Nickel	ND	0.84	ND	respiratory tract	A	e
Nitrate	ND	ND	ND	ND	ND	ND
Phosphorus	ND	ND	ND	ND	D	e
Selenium	ND	ND	ND	ND	D	e
Silver	ND	ND	ND	ND	D	e
Thallium compounds	ND	ND	ND	ND	ND	e
Uranium	ND	ND	ND	ND	ND	f
Vanadium	ND	ND	ND	ND	ND	d
Zinc	ND	ND	ND	ND	D	e

130P

TABLE F.3.1-3 (continued)

Chemical	Oral Cancer Slope Factor $(mg/kg/day)^{-1}$	Inhalation Cancer Slope Factor $(mg/kg/day)^{-1}$ [a]	Tumor Site		Cancer Classification [ab]	Reference
			Oral	Inhalation		
Volatiles						
2-Butanone	ND	ND	ND	ND	D	e
2-Hexanone	ND	ND	ND	ND	ND	ND
4-Methyl-2-pentanone	ND	ND	ND	ND	ND	ND
Acetone	ND	ND	ND	ND	D	e
Carbon tetrachloride	0.13	0.053	liver	ND	B2	e
Methylene chloride	0.0075	0.0016	liver	lung, liver	B2	e
Tetrachloroethene	0.052	0.002	lung	lung	B2-C	g
Toluene	ND	ND	ND	ND	D	e
Total xylenes	ND	ND	ND	ND	D	e
Semivolatiles						
Acenaphthylene	ND	ND	ND	ND	D	e
Aldrin	17	17	liver	ND	B2	e
Anthracene	ND	ND	ND	ND	D	e
Benzo(a)anthracene	7.3	6.1	ND	ND	B2	h
Benzo(a)pyrene	7.3	6.1	stomach	respiratory tract	B2	e, g
Benzo(b)fluoranthene	7.3	6.1	ND	ND	B2	h
Benzo(g,h,i)perylene	ND	ND	ND	ND	D	e

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TABLE F.3.1-3 (continued)

Chemical	Oral Cancer Slope Factor $(mg/kg/day)^{-1}$	Inhalation Cancer Slope Factor $(mg/kg/day)^{-1}$ [a]	Tumor Site		Cancer Classification [ab]	Reference
			Oral	Inhalation		
Semivolatiles (continued)						
Benzoic acid	ND	ND	ND	ND	D	e
bis(2-Ethylhexyl)phthalate	0.014	ND	liver	ND	B2	e
Chrysene	7.3	6.1	lymphoma, skin	ND	B2	h
Di-n-butylphthalate	ND	ND	ND	ND	D	e
Di-n-octylphthalate	ND	ND	ND	ND	ND	ND
Dibenzo(a,h)anthracene	7.3	6.1	ND	ND	B2	h
Diethyl phthalate	ND	ND	ND	ND	D	e
Dimethyl phthalate	ND	ND	ND	ND	D	e
Fluoranthene	ND	ND	ND	ND	D	e
Indeno(1,2,3-cd)pyrene	7.3	6.1	ND	ND	B2	h
2-Nitrophenol	ND	ND	ND	ND	ND	ND
4-Nitrophenol	ND	ND	ND	ND	ND	ND
N-Nitroso-di-n-propylamine	7	ND	multiple	ND	B2	e

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TABLE F.3.1-3 (continued)

Chemical	Oral Cancer Slope Factor $(mg/kg/day)^{-1}$	Inhalation Cancer Slope Factor $(mg/kg/day)^{-1}$ [a]	Tumor Site		Cancer Classification [ab]	Reference
			Oral	Inhalation		
Semivolatiles (continued)						
Phenanthrene	ND	ND	ND	ND	D	e
Phenol	ND	ND	ND	ND	D	e
Pyrene	ND	ND	ND	ND	D	e
Tributyl phosphate	ND	ND	ND	ND	D	i
Pesticides/PCBs						
Aroclor-1248	7.7	ND	liver	ND	B2	i
Aroclor-1254	7.7	ND	liver	ND	B2	i
Aroclor-1260	7.7	ND	liver	ND	B2	e
4,4'-DDE	0.34	ND	liver	ND	B2	e
4,4'-DDT	0.34	0.34	liver	ND	B2	e
Dieldrin	16	16	liver	ND	B2	e

130S

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TABLE F.3.1-3 (continued)

Chemical	Oral Cancer Slope Factor $(mg/kg/day)^{-1}$	Inhalation Cancer Slope Factor $(mg/kg/day)^{-1}$ [a]	Tumor Site		Cancer Classification [ab]	Reference
			Oral	Inhalation		
Pesticides/PCBs (continued)						
Endosulfan I	ND	ND	ND	ND	ND	ND
Endosulfan II	ND	ND	ND	ND	ND	ND
Endrin	ND	ND	ND	ND	D	d
Heptachlor epoxide	9.1	9.1	liver	ND	B2	e

130T

[a] Derived from inhalations unit risk.

[b] Cancer weight-of-evidence Group A = human carcinogen; Group B1 and B2 = probable human carcinogen; Group C = possible human carcinogen; Group D - not classifiable as to carcinogenicity to humans; Group E = evidence of noncarcinogenicity to humans.

[c] ND - no data

[d] "Drinking Water Regulations and Health Advisories" (EPA 1993a).

[e] Integrated Risk Information System (IRIS), (EPA 1992a).

[f] The carcinogenicity of uranium is attributed to its radioactivity; see Appendix D of the *Remedial Investigation Report for Operable Unit 4* (FEMP `993a).

[g] Health Effects Assessment Summary Table (HEAST)(EPA 1992b).

[h] The oral and inhalation cancer slope factors for benzo(a)pyrene are used for the other polyaromatic hydrocarbons assigned to cancer classification B2 (see the toxicological profile for polyaromatic hydrocarbons of Appendix D of the RI for OU4 for additional information).

[i] Letter J. S. Dollarhede to P. VanLeeuwen (EPA 1993b).

TABLE F.3.1-4
CANCER SLOPE FACTORS FOR OPERABLE UNIT 4 RADIONUCLIDES OF CONCERN[a]

Radionuclide	ICRP Lung Class[b]	Inhalation $(pCi)^{-1}$	GI Absorption Factor (f_1)	Ingestion $(pCi)^{-1}$	Penetrating External Exposure $(pCi \bullet yr/g)^{-1}$
Uranium - 238 Series					
U-238 + 2 dtrs	Y	5.2×10^{-8}	5.0×10^{-2}	2.8×10^{-11}	3.6×10^{-8}
U-234	Y	2.6×10^{-8}	5.0×10^{-2}	1.6×10^{-11}	3.0×10^{-11}
Th-230	Y	2.9×10^{-8}	2.0×10^{-4}	1.3×10^{-11}	5.4×10^{-11}
Ra-226 + 5 dtrs	W	3.0×10^{-9}	2.0×10^{-1}	1.2×10^{-10}	6.0×10^{-6}
Rn-222 + 4 dtrs	Gas	7.7×10^{-12}	1.0×10^{0}	1.7×10^{-12}	5.9×10^{-6}
Pb-210 + 2 dtrs	D	4.0×10^{-9}	2.0×10^{-1}	6.6×10^{-10}	1.6×10^{-10}
Uranium - 235 Series					
U-235 + 1 dtr	Y	2.5×10^{-8}	5.0×10^{-2}	1.6×10^{-11}	2.4×10^{-7}
Pa-231	Y	3.6×10^{-8}	1.0×10^{-3}	9.2×10^{-11}	2.6×10^{-8}
Ac-227 + 7 dtrs	Y	8.8×10^{-8}	1.0×10^{-3}	3.5×10^{-10}	8.5×10^{-7}
Thorium - 232 Series					
Th-232	Y	2.8×10^{-8}	2.0×10^{-4}	1.2×10^{-11}	2.6×10^{-11}
Ra-228 + 1 dtr	W	6.9×10^{-10}	2.0×10^{-1}	1.0×10^{-10}	2.9×10^{-6}
Th-228 + 7 dtrs	Y	7.8×10^{-8}	2.0×10^{-4}	5.5×10^{-11}	5.6×10^{-6}
Fission Products					
Tc-99	W	8.3×10^{-12}	8.0×10^{-1}	1.3×10^{-12}	6.0×10^{-13}
Sr-90 + 1 dtr	D	6.2×10^{-11}	3.0×10^{-1}	3.6×10^{-11}	0.0×10^{0}

[a] Health Effects Assessment Summary Tables, Annual FY 1992 including the July 1992 and November 1992 supplements (EPA 1992b).
[b] Classification recommended by the ICRP for half-time for clearance from the lung. "Y" = years, "W" = weeks, "D" = days

130U

-8074

TABLE F.3.1-5
REFERENCE DOSES FOR NONCARCINOGENIC EFFECTS OF CONSTITUENTS OF POTENTIAL CONCERN IN OU4

Chemical	Oral Reference Dose (mg/kg/day)	Inhalation Reference Dose (mg/kg/day)[a]	Target Organ		Uncertainty Factor	
			Oral	Inhalation	Oral	Inhalation
Inorganics						
Ammonia	ND	0.029[b]	ND	Respiratory system	ND	30
Antimony	0.0004[b]	ND[c]	Liver	ND	1000	ND
Arsenic	0.0003[b]	ND	Skin	ND	3	ND
Barium	0.07[b]	0.00014[d]	Cardiovascular system	Fetus	3	1000
Beryllium	0.005[b]	ND	ND	ND	100	ND
Boron	0.09[b]	0.0057[d]	Testis	Respiratory system	100	100
Cadmium (food)	0.001[b]	ND	Kidney	Cancer	10	ND
Cadmium (water)	0.0005[b]	ND	Kidney	Cancer	10	ND
Chromium (VI)	0.005[b]	ND	ND	ND	500	ND

TABLE F.3.1-5 (continued)

Chemical	Oral Reference Dose (mg/kg/day)	Inhalation Reference Dose (mg/kg/day)[a]	Target Organ		Uncertainty Factor	
			Oral	Inhalation	Oral	Inhalation
Inorganics (continued)						
Cobalt	0.06[e]	0.0000003[f]	Cardiovascular system	Respiratory system	ND	1000
Copper	ND	ND	ND	ND	ND	ND
Cyanide	0.02[b]	ND	Central nervous system	ND	500	ND
Fluoride	0.06[b]	ND	Teeth	ND	1	ND
Lead	ND	ND	Central nervous system	Central nervous system	ND	ND
Manganese	0.14 (food)[b]	0.00011[b]	Central nervous system	Respiratory system	1	300
Manganese	0.005 (water)[b]	0.00011[b]	Central nervous system	Respiratory system	1	300
Mercury	0.0003[d]	0.000086[d]	Kidney	Central nervous system	1000	30
Molybdenum	0.005[b]	ND	Liver	ND	30	ND
Nickel	0.02[b]	ND	ND	Cancer	300	ND
Nitrate	1.6[b]	ND	Blood	ND	1	ND

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TABLE F.3.1-5 (continued)

Chemical	Oral Reference Dose (mg/kg/day)	Inhalation Reference Dose (mg/kg/day)[a]	Target Organ		Uncertainty Factor	
			Oral	Inhalation	Oral	Inhalation
Inorganics (continued)						
Phosphorus	0.00002[b]	ND	Reproductive system	ND	1000	ND
Selenium	0.005[b]	ND	Skin	ND	3	ND
Silver	0.005[b]	ND	ND	ND	3	ND
Thallium	0.00006[b,g]	ND	Central nervous system	ND	3000	ND
Uranium	0.003[b]	ND	Kidney	ND	1000	ND
Vanadium	0.007[d]	ND	ND	ND	100	ND
Zinc	0.3[b]	ND	Blood	ND	3	ND
Volatiles						
2-Butanone	0.05[d]	0.3[b]	ND	Fetus	1000	1000
2-Hexanone	0.04[k]	ND	ND	ND	ND	ND
4-Methyl-2-pentanone	0.05[d]	0.023[d]	Liver	Liver	1000	1000
Acetone	0.1[b]	ND	Liver	ND	1000	ND
Carbon tetrachloride	0.0007[b]	0.00057[h]	Liver	ND	1000	ND
Methylene chloride	0.06[b]	0.86[d]	Liver	Liver	100	100

130 X

TABLE F.3.1-5 (continued)

Chemical	Oral Reference Dose (mg/kg/day)	Inhalation Reference Dose (mg/kg/day)[a]	Target Organ		Uncertainty Factor	
			Oral	Inhalation	Oral	Inhalation
Volatiles (continued)						
Tetrachloroethene	0.01[b]	ND	Liver	ND	1000	ND
Toluene	0.2[b]	0.11[d]	Liver	Central nervous system	1000	300
Total xylenes	2[b]	ND	Central nervous system	ND	100	ND
Semivolatives						
Acenaphthylene	ND	ND	ND	ND	ND	ND
Aldrin	0.00003[b]	ND	Liver	ND	1000	ND
Anthracene	0.3[b]	ND	ND	ND	3000	ND
Benzo(a)anthracene	ND	ND	ND	ND	ND	ND
Benzo(a)pyrene	ND	ND	ND	ND	ND	ND
Benzo(b)fluoranthene	ND	ND	ND	ND	ND	ND
Benzo(g,h,i)perylene	ND	ND	ND	ND	ND	ND
Benzoic acid	4[b]	ND	ND	ND	1	ND
Bis (2-Ethylhexyl)phthalate	0.02[b]	ND	Liver	ND	1000	ND

130Y

F-8074

TABLE F.3.1-5 (continued)

Chemical	Oral Reference Dose (mg/kg/day)	Inhalation Reference Dose (mg/kg/day)[a]	Target Organ		Uncertainty Factor	
			Oral	Inhalation	Oral	Inhalation
Semivolatiles (continued)						
Chrysene	ND	ND	ND	ND	ND	ND
Di-n-butylphthalate	0.1[b]	ND	ND	ND	1000	ND
Di-n-octylphthalate	0.02[d]	ND	Liver	ND	1000	ND
Dibenzo(a,h)anthracene	ND	ND	ND	ND	ND	ND
Diethyl phthalate	0.8[b]	ND	ND	ND	1000	ND
Dimethyl phthalate	10[d]	ND	Kidney	ND	10	ND
Fluoranthene	0.04[b]	ND	Kidney	ND	3000	ND
Indeno(1,2,3-cd)pyrene	ND	ND	ND	ND	ND	ND
2-Nitrophenol	ND	ND	ND	ND	ND	ND
4-Nitrophenol	0.008[h]	ND	ND	ND	ND	ND
N-Nitroso-di-n-propylamine	ND	ND	ND	ND	ND	ND
Phenanthrene	ND	ND	ND	ND	ND	ND
Phenol	0.6[b]	ND	Fetus	ND	100	ND
Pyrene	0.03[b]	ND	Kidney	ND	3000	ND
Tributyl phosphate	0.005[k]	ND	ND	ND	ND	ND

1302

TABLE F.3.1-5 (continued)

Chemical	Oral Reference Dose (mg/kg/day)	Inhalation Reference Dose (mg/kg/day)[a]	Target Organ		Uncertainty Factor	
			Oral	Inhalation	Oral	Inhalation
Pesticides/PCBs						
Aroclor-1248	0.00007[b,i]	ND	Fetus	ND	100	ND
Aroclor-1254	0.00007[b,i]	ND	Fetus	ND	100	ND
Aroclor-1260	0.00007[b,i]	ND	Fetus	ND	100	ND
4,4'-DDE	ND	ND	ND	ND	ND	ND
4,4'-DDT	0.0005[b]	ND	Liver	ND	100	ND
Dieldrin	0.00005[b]	ND	Liver	ND	100	ND
Endosulfan I	0.00005[j]	ND	Kidney	ND	3000	ND
Endosulfan II	0.00005[j]	ND	Kidney	ND	3000	ND
Endrin	0.0003[b]	ND	Liver	ND	100	ND
Heptachlor epoxide	0.000013[b]	ND	Liver	ND	1000	ND

[a] Derived from inhalation RfC (reference concentration).
[b] IRIS (EPA 1992a).
[c] ND - no data.
[d] HEAST (EPA 1992a).
[e] Letter from D. L. Forman regarding cobalt toxicity (EPA 1992c).
[f] Memorandum from Pei-Fung Hurst regarding cobalt toxicity (EPA 1990).
[g] Derived by analogy to thallium sulfate, adjusting for differences in molecular weight.
[h] IRIS (EPA 1992a).
[i] Based on analogy to Aroclor - 1016.
[j] HEAST (EPA 1992a).
[k] EPA, 1993d, Memorandum from J. Dollarhide, ECAO to P. VanLeeuwen, Region V, 7/21/93.

130 AA

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F.3.1.3 Toxicity Assessment

The human health hazards identified in the toxicity assessment were cancer induction and chemical toxicity. Chemical toxicity included numerous health effects such as kidney damage, liver disease, or eye irritation. For both types of health hazards, dose-response data from human and animal studies were used to determine the potency of the individual radionuclides and chemicals.

Intakes calculated in the exposure assessment were used in conjunction with the cancer slope factor from the dose-response data to determine the incremental lifetime cancer risk (ILCR). Toxicity data for the OU4 risk assessment were taken from the *Integrated Risk Information System* (IRIS) (EPA 1992a) and the updated *Health Effects Assessment Summary Table* (HEAST) (EPA 1992b). Cancer slope factors have been developed by the EPA for estimating ILCRs associated with exposure to carcinogenic chemicals. The slope factors, which are expressed in units of milligrams per kilograms-day (mg/kg-day), are multiplied by the estimated intake of a carcinogen, in mg/kg-day, to provide an upper-bound estimate of the ILCR associated with exposure at that intake level. The term "upper-bound" reflects the conservative estimate of the risks calculated from the slope factor. Use of this approach makes underestimation of the actual cancer risk highly unlikely. Cancer slope factors are derived from the results of human epidemiological studies or chronic animal bioassays to which animal-to-human extrapolation and uncertainty factors have been applied. **Tables F.3.1-3** and **F.3.1-4** provide the cancer slope factors for OU4 chemical COCs and radiological COCs, respectively.

For cancer induction, it was assumed that a dose threshold does not exist. Therefore, for any dose of a carcinogen, there exists a possibility, however small, of contracting cancer. ILCRs are expressed in terms of the probability that a given receptor (person) will contract cancer due to the calculated exposures. For example, if the receptor has an additional 1 chance in 10,000 of contracting cancer due to the calculated exposures, the probability of developing cancer is expressed as a 10^{-4} (1 in 10,000) risk. However, these risk factors should only be used to make a qualitative estimate of individual receptor impact because the risk coefficients are intended for predicting cancer in a large population.

For chemical toxicants, the data suggests a dose threshold or reference dose (RfD) exists below which a toxic effect is not observed. RfDs have been developed by the EPA for indicating the potential for adverse health effects from exposure to chemicals exhibiting non-carcinogenic effects. RfDs, which are expressed in units of mg/kg-day, are estimates of lifetime daily exposure levels for humans, including sensitive individuals. Estimated intakes of chemicals from environmental media (e.g., the amount of a chemical ingested from contaminated drinking water) can be compared to the RfD. RfDs are derived from human epidemiological studies or animal studies to which uncertainty factors have been applied (e.g., to account for the use of animal data to predict effects on humans). These uncertainty factors help to ensure that the RfDs will not underestimate the potential for adverse non-carcinogenic effects to occur. **Table F.3.1-5** provides the RfDs for OU4 COCs.

To determine whether the exposure levels of OU4 constituents may cause adverse health effects, the estimated intake of a particular constituent (calculated from the exposure assessment) is compared to the RfD, which defines the acceptable intake. If the ratio of estimated intake to the acceptable intake is greater than one, the site-related intake may cause toxic effects. This ratio is called the hazard quotient (HQ). When HQs for multiple COCs are summed, the resultant value is the hazard index (HI).

F.3.1.4 Risk Characterization Results

Excess lifetime cancer risks are determined by multiplying the intake level with the cancer potency factor. These risks are probabilities that are generally expressed in scientific notation (e.g. 1×10^{-6} or 1E-6). An excess lifetime cancer risk of 1×10^{-6} indicates that, as a plausible upper bound, an individual had a one in one million chance of developing cancer as result of site-related exposure to a carcinogen over a 70-year lifetime under the specific exposure conditions at a site.

130CC

Potential concern for noncarcinogenic effects of a single contaminant in a single medium is expressed as the HQ (or the ratio of the estimated intake derived from the contaminant concentration in a given medium to the contaminant's reference dose). By adding the HQs for all contaminants within a medium or across all media to which a given population may reasonably be exposed, the HI can be generated. The HI provides a useful reference point for gauging the potential significance of multiple contaminant exposures within a single medium or across media.

Tables F.3.1-6 and **F.3.1-7** shows the baseline risks and HIs for each hypothetical receptor by land-use and source term scenario. Risk values in **Table F.3.1-6** are reported in units of ILCR for radiological, chemical, and total risk. The chemical HI, which has no units, is presented in **Table F.3.1-7.**

F.3.1.4.1 urrent Land-use Without Access Control/Current Source Term Scenario

The receptor with the greatest total radiological risk is the trespassing child (**Table F.3.1-6**). The greatest contributor under this scenario is from exposure to external radiation while the receptor is on top of the Silos 1 or 2 dome (5×10^{-3}). In addition, the receptor is exposed to air, soil, and surface water pathways resulting in a radiological risk of 3×10^{-5}. The total radiological risk to the trespassing child is 5×10^{-3} (external radiation) plus 3×10^{-5} (nuclide-specific radiation) totaling 5×10^{-3}. The receptor with the greatest total chemical risk (1×10^{-4}) is the off-property resident farmer (**Table F.3.1-6**). The greatest contribution under this scenario is from exposure to air pathways (1×10^{-4}). The receptor with the greatest total radiological plus chemical risk under this scenario (5×10^{-3}, **Table F.3.1-7**) is the trespassing child. The greatest HI is 0.3 to the trespassing child (**Table F.3.1-7**). The greatest contribution, under this scenario is from soil exposure pathways (0.2).

TABLE F.3.1-6

INCREMENTAL LIFETIME CANCER RISK SUMMARY ALL SOURCES/ALL PATHWAYS

Land Use/ Source Term Scenario	Type of Risk	Trespassing Child	Grounds Keeper	Off-Property Resident Farmer	Off-Property User of Surface Water	CT On-Property Resident Farmer	RME On-Property Resident Farmer[a]	On-Property Resident Child
Current Land Use without Access Control/Current Source Term Scenario	Radiological-Nuclide Specific[b]	3.0×10^{-3}	8.0×10^{-3}	1.0×10^{-3}	1.0×10^{-7}	NA[c]	NA	NA
	Radiological-External[d]	5×10^{-3}	1×10^{-4}	NA	NA	NA	NA	NA
	Chemical Risk	1.0×10^{-3}	2.0×10^{-3}	1.0×10^{-4}	1.0×10^{-7}	NA	NA	NA
	Total Risk	5.0×10^{-3}	2.0×10^{-4}	1.0×10^{-4}	2.0×10^{-7}	NA	NA	NA
Current Land Use without Access Control/Future Source Term Scenario	Radiological-Nuclide Specific	1.0×10^{-2}	3.0×10^{-3}	2.0×10^{-3}	1.0×10^{-6}	NA	NA	NA
	Chemical Risk	4.0×10^{-4}	6.0×10^{-4}	2.0×10^{-4}	7.0×10^{-7}	NA	NA	NA
	Total Risk	1.0×10^{-2}	3.0×10^{-3}	2.0×10^{-3}	2.0×10^{-6}	NA	NA	NA
Current Land Use with Access Control/Current Source Term Scenario	Radiological-Nuclide Specific	3.0×10^{-3}	NA	1.0×10^{-3}	1.0×10^{-7}	NA	NA	NA
	Radiological-External	5.0×10^{-3}	NA	NA	NA	NA	NA	NA
	Chemical Risk	1.0×10^{-3}	NA	1.0×10^{-4}	1.0×10^{-7}	NA	NA	NA
	Total Risk	5.0×10^{-3}	NA	1.0×10^{-4}	2.0×10^{-7}	NA	NA	NA
Future Land Use/Current Source Term Scenario	Radiological-Nuclide Specific	NA	NA	1.0×10^{-3}	1.0×10^{-7}	2.0×10^{-4}	3.0×10^{-3}	3.0×10^{-4}
	Radiological-External	NA	NA	NA	NA	2.0×10^{-4}	2.0×10^{-3}	9.0×10^{-3}
	Chemical Risk	NA	NA	1.0×10^{-4}	1.0×10^{-7}	5.0×10^{-3}	8.0×10^{-3}	5.0×10^{-4}
	Total Risk	NA	NA	1.0×10^{-4}	2.0×10^{-7}	5.0×10^{-3}	9.0×10^{-3}	6.0×10^{-3}
Future Land Use/ Future Source Term Scenario	Radiological-Nuclide Specific	NA	NA	2.0×10^{-3}	1.0×10^{-6}	1.0×10^{-1}	1.0×10^{0}	1.0×10^{-1}
	Chemical Risk	NA	NA	2.0×10^{-4}	7.0×10^{-7}	1.0×10^{-2}	2.0×10^{-1}	9.0×10^{-2}
	Total Risk	NA	NA	2.0×10^{-3}	2.0×10^{-6}	1.0×10^{-1}	>1.0	2.0×10^{-1}

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[a] The ILCR values were identical for the future land-use/future source term scenario evaluated for either the Great Miami Aquifer or for perched water.
[b] The ILCR result from exposure to radionuclides from air, water (ground and surface), soil and sediment.
[c] NA signifies "not applicable."
[d] This risk results from exposure to direct external radiation from large sources (Silos 1, 2, and 3). It does not include exposure to external radiation emanating from radionuclides in surface soils. These later risks are accounted for in the nuclide-specific ILCR.

130 of 1

TABLE F.3.1-7
HAZARD INDEX SUMMARY ALL SOURCES/ALL PATHWAYS

Land-use/ Source Term Scenario	Type of Risk	Trespassing Child	Grounds Keeper	Off-Property Resident Farmer	Off-Property User of Surface Water	CT On-Property Resident Farmer	RME On-Property Resident Farmera	On-Property Resident Child
Current Land-use without Access Control/Current Source Term Scenario	Chemical Hazard Index	0.3	0.1	0.05	0.0004	NAb	NA	NA
Current Land-use without Access Control/Future Source Term Scenario	Chemical Hazard Index	20	20.0	5.0	0.002	NA	NA	NA
Current Land-use with Access Control/Current Source Term Scenario	Chemical Hazard Index	0.3	NA	0.05	0.0004	NA	NA	NA
Future Land Use/Current Source Term Scenario	Chemical Hazard Index	NA	NA	0.05	0.0004	8	20	100
Future Land Use/Future Source Term Scenario	Chemical Hazard Index	NA	NA	5.0	0.002	300	500	2000

a The HI (500) was identical for the future land-use/future source-term scenario.
b NA signifies "not applicable."

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F.3.1.4.2 Current Land-use Without Access Control/Future Source Term Scenario

The receptor with the greatest total *radiological* risk was the groundskeeper (**Table F.3.1-6**). The greatest contribution under this scenario was from exposure to soil pathways (2×10^{-2}). The total radiological risk to the groundskeeper under this scenario was 3×10^{-2} (**Table F.3.1-6**). The receptor with the greatest total *chemical* risk was also the groundskeeper (**Table F.3.1-6**). The greatest contribution was from exposure to soil pathways (5×10^{-4}). The total chemical risk to the groundskeeper under this scenario was 6×10^{-4}. The total radiological plus chemical risk to the groundskeeper under this scenario was 3×10^{-2} (**Table 3.1-6**). The greatest HI was 20 to the groundskeeper (**Table F.3.1-7**) and to the trespassing child (**Table F.3.1-6**). The greatest contribution to both receptors under this scenario was from exposure to air pathways.

F.3.1.4.3 Current Land-use With Access Control/Current Source Term Scenario

This scenario most closely approximates the conditions at the FEMP site. However, the risk and HI results for this scenario were numerically the same as the results for the current land-use scenario without access controls, assuming the current source term (**Section F.3.1.4.1**). This is because the presence or absence of access controls did not change the numerical values of exposure parameter values for receptors. The trespassing child's exposure parameter values reflected the standard scenario specified by the EPA. Also, the off-property resident farmer, and surface water user exposures were not impacted by the status of access controls.

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F.3.1.4.4 Future Land-use/Current Source Term Scenario

The receptor with the greatest total radiological risk was the on-property resident child (**Table F.3.1-6**). The greatest contribution under this scenario was from exposure to external radiation while the receptor was on top of the Silos 1 or 2 dome (9×10^{-3}). In addition, the receptor was exposed to air, soil, and surface water pathways resulting in a radiological risk of 3×10^{-4}, primarily from the soil pathway (2×10^{-4}). The total radiological risk to the on-property resident child was 9×10^{-3} plus 3×10^{-4}, totaling 9×10^{-3}. The receptor with the greatest total chemical risk (8×10^{-2}) was the RME on-property resident farmer (**Table F.3.1-6**). The greatest contribution under this scenario was from exposure to soil pathways (8×10^{-2}). The receptor with the greatest total radiological plus chemical risk under this scenario (9×10^{-2}, **Table F.3.1-6**) was the RME on-property resident farmer. The greatest HI was 100 to the on-property resident child (**Table F.3.1-7**). The greatest contribution to chemical hazard under this scenario was from soil exposure pathways (100).

F.3.1.4.5 Future Land-use/Future Source Term Scenario

This represents the most conservative scenario considered under the Baseline Risk Assessment. Within this scenario, a family was assumed to have established a residence within the OU4 boundaries. Additionally, the domes of Silos 1 and 2 were assumed to have failed and Silo 3 was assumed to have suffered total structural failure, spreading its contents to the surface of OU4. As described in Section D.3 of the *RI Report for Operable Unit 4* (FEMP 1993a), the structural failure of Silo 3 and the assumed distribution of its contents onto the surrounding surface made it more appropriate to evaluate direct external exposure in a nuclide-specific manner rather than as a large source. With the failure of the domes of Silos 1 and 2, it was no longer appropriate to evaluate direct external radiation exposure at these locations. Therefore, the separate entry in **Table F.3.1-6** for external radiation does not appear for the future source term scenario.

The receptor with the greatest total radiological risk was the RME on-property resident farmer (**Table F.3.1-6**). The greatest contribution under this scenario was from exposure to soil pathways (approaching unity risk). The total radiological risk to the RME on-property resident farmer under this scenario also approached unity (1) risk. The receptor with the greatest total chemical risk was also the RME on-property resident farmer (**Table F.3.1-6**). The greatest contribution was from exposure to soil pathways (2×10^{-1}). The total chemical risk to the RME on-property resident farmer under this scenario was 2×10^{-1}. The total radiological plus chemical risk to the RME on-property resident farmer under this scenario exceeded unity (**Table F.3.1-6**). The greatest HI was 2,000 to the on-property resident child (**Table F.3.1-7**). The greatest contribution to this receptor under this scenario was from exposure to soil pathways.

F.3.1.5 Risk Assessment Uncertainties

The uncertainties inherent in the risk assessment process are presented in detail in Section D.6.0 of Appendix D of the *Remedial Investigation Report for Operable Unit 4* (FEMP 1993a). These uncertainties are summarized below to enable a better understanding of their impacts on the foregoing risk assessment.

Uncertainty is a factor in each step of the exposure and toxicity assessment process. Such uncertainty can involve variations in sample analytical results, the values of variables used as input to a given model, the accuracy with which the model itself represents actual environmental or biological processes, the manner in which the exposure scenario is developed, and the high-to-low dose and interspecies extrapolations for dose-response relationships.

Generally, risk assessments carry two types of uncertainty. First, measurement uncertainty refers to the usual variance that accompanies scientific measurements (such as the range of an exposure estimate) and reflects the accumulated variances of the individually measured values used to develop the estimate. The second form of uncertainty is due to the absence of information needed to complete the database for the assessment. In some instances, the impact is significant, such as the absence of information on the adverse effects or the biological mechanism of action of a chemical agent.

F.3.1.5.1 Sources of Uncertainty

As noted previously, uncertainties are associated with the information and data used in each phase of the OU4 Baseline Risk Assessment. The first source of uncertainty arises from data gaps or limitations in the data. For example, the data set for soil is limited, and virtually nothing is known regarding contaminants in the area of the former Drum Handling Building. These limitations could result in failure to identify some COCs, possibly resulting in underestimation of risk. [This data limitation and its expected impact on the Baseline Risk Assessment is discussed in detail in Section 7.5 of the *Remedial Investigation Report for Operable Unit 4* (FEMP 1993a)].

Other sources of uncertainty include the conservative bias of parameters, parameter variability (random errors or natural variations), and the necessity of using computer models to predict complex environmental interactions. Uncertainties also arise from the use of animal data to predict the toxic effects and the toxic potency in humans. Uncertainties associated with information and data are evaluated below to provide the spectrum of information regarding the overall quality of the risk assessment results. The uncertainties are associated with exposure route selection, selection of COCs, exposure point concentrations, and exposure factors.

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F.3.1.5.2 Toxicity Assessment

Considerable uncertainty is associated with the qualitative (hazard assessment) and quantitative (dose-response) evaluations of a Superfund Risk Assessment. A hazard assessment deals with characterizing the nature and strength of the evidence of causation, or the likelihood that a chemical that induces adverse effects in animals will induce adverse effects in humans. Hazard assessment of carcinogenicity is evaluated as a weight-of-evidence determination, using schemes of either the International Agency for Research on Cancer (IARC 1987) or the EPA (EPA 1986). Positive cancer test data in experimental animals suggest that a human exposed to the same agent may suffer adverse effects. However, animal data may not accurately predict the same response or the same target organ tissue for cancer in humans. Also, biochemical repair mechanisms present in humans may inhibit or preclude an identical response. Accordingly, the uncertainty of possible effects is significant. In assessing noncancer effects, however, positive experimental animal data from well-designed studies in appropriate models suggest both the target tissues and type of effects that may be anticipated in humans (EPA 1989).

F.3.2 Overview of the Baseline Ecological Risk Assessment

The purpose of the ecological risk assessment, which was completed as a companion to the preliminary site-wide Baseline Risk Assessment in the *Site-wide Characterization Report* (FEMP 1993b), was to estimate the potential and future baseline risks of FEMP contaminants to ecological receptors.

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The EPA and DOE agreed in the September 1991 ACA that the Site-wide Ecological Risk Assessment would be performed as part of the *Remedial Investigation Report for Operable Unit 5* (FEMP 1994c). The Site-wide Ecological Risk Assessment in the RI for OU5 quantifies and assesses the possible risks from current concentrations of site contaminants to ecological receptors inhabiting on-property and off-site areas not presently targeted for remediation based on human-health concerns. More discussion on the Risk Assessment and Ecological Risk issues specific to OU4 can be found in the *Proposed Plan for Remedial Actions at Operable Unit 4* (FEMP 1994a).

The ecological receptors potentially exposed to FEMP contaminants included all organisms, exclusive of humans and domestic animals. The ecological risk assessment focused on a group of indicator species selected to represent a variety of exposure pathways and trophic positions. Terrestrial vegetation was represented by a generic plant species. Terrestrial wildlife species to be evaluated were selected based on species abundance on the FEMP site, trophie level position, and habitat requirements. The species evaluated were the white-tailed deer *(Odocoileus virginianus),* white-footed mouse *(Peromyscus leucopus),* raccoon *(Procyon lotor),* red fox *(Vulpes fulva),* muskrat *(Ondatra zibethica),* American robin *(Turdus migratorius),* and red-tailed hawk *(Buesto jamaicensis).*

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The assessment examined risks to terrestrial organisms associated with contaminants in two environmental media: surface soils, summarized for the entire site, and surface water in Paddys Run from the northern boundary of the FEMP site to the confluence with the storm sewer outfall ditch. Risks to aquatic organisms were evaluated for exposure to contaminants in Paddys Run, the Great Miami River, and in runoff into the storm sewer outfall ditch. All nonradioactive and radioactive constituents of greatest human health risk were considered to be of concern for the ecological risk assessment. Estimated ecological risks associated with exposure to FEMP site COCs are primarily due to nonradioactive inorganic chemicals in soils, rather than to organic chemicals or radionuclides. This is true for both terrestrial and aquatic organisms and for plants as well as wildlife. In particular, estimated intakes of arsenic, cobalt, lead, and silver from FEMP soils were all higher than the estimated "No Observed Effect Levels" (NOELs) for at least six of the seven indicator species selected for this assessment. The relative hazards to individual species varied, but the white-footed mouse consistently had the highest indices of these chemicals. This can be attributed to the assumed intake by the mouse of insects (using earthworms as surrogates), which in turn were assumed to assimilate chemicals from soil with a transfer coefficient of 1.0.

Estimated hazards to terrestrial organisms of exposure to COCs in FEMP surface waters were relatively low, with HIs greater than one only for arsenic, lead, molybdenum, and silver. These chemicals presented hazards of two, five, four and three to species, respectively; and, the highest HI estimated was for lead intake by the mouse.

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Estimated doses to terrestrial organisms at the FEMP site, originating from soil uptake by plants and earthworms, were below levels expected to cause detectable effects. However, as with inorganic chemicals, this conclusion is sensitive to assumptions about muscle-to-muscle transfer of radionuclides. If perfect transfer or biomagnification of uranium occurs (i.e., transfer factor equals 1.0), it could expose terrestrial wildlife at the FEMP to potentially harmful radiation levels. However, if the more realistic muscle-to-muscle transfer coefficient were assumed (i.e., 0. 1), the estimated radiation doses would fall below the range likely to result in harmful effects. Radiation doses due to water intake were insignificant.

Exposure to radiological contaminants does not appear to pose a significant risk to aquatic organisms at the measured concentrations in the surface waters and sediments impacted by the FEMP site. However, modeled concentrations of radionuclides in runoff from the FEMP site into surface water would cause estimated exposures to exceed the upper limit of 1 rad (an absorbed dose of 0.01 joule/kilogram) per day. A chronic dose rate of 1 rad/day or 3.65×10^5 mrad/year or less to the maximally exposed member of a population of aquatic organisms would ensure that there were not any deleterious effects from radiation on the population.

The most affected organisms would be aquatic plants, receiving a total dose from internal and external exposure of about 140 rad/day. The total dose to fish is minimally over the limit, at 1.6 rad/day, and the total dose to benthic macroinvertebrates is about 14 rad/day. The maximum concentrations calculated in the storm sewer outfall ditch were used in source runoff calculations. Doses to aquatic organisms in the storm sewer outfall ditch may exceed the limit of 1 rad/day. Doses in Paddys Run and the Great Miami River would be lower than that indicated in the storm sewer outfall ditch and would be well below 1 rad/day. The measured concentrations of cadmium in Paddys Run and the Great Miami River; copper in the Great Miami River; mercury in Paddys Run, the Great Miami River, and the storm sewer outfall ditch; and silver in Paddys Run water exceeded chronic toxicity criteria for the protection of freshwater organisms.

Field studies on the impact of the FEMP site on terrestrial and aquatic communities do not indicate any effects consistent with contaminant impacts except for above-background levels of arsenic and mercury recorded in RI/FS plant samples. In addition, although potential impacts at the individual level were predicted for wildlife species, detrimental or adverse impacts have not been observed in the field. This suggests that the potential exposures predicted by modeling may not occur in the field or that the resulting potential effects from exposures may not occur. A comparison of the concentrations of inorganic chemical concentrations in FEMP soils to regional background values indicate that the mean FEMP concentrations may be similar to the upper 95% confidence levels of background values. This indication suggests that ecological risks estimated using background values of inorganics would be comparable to those estimated for the FEMP site, and emphasizes the conservative nature of the method used.

In summary, although radionuclides are the most ubiquitous contaminants at the FEMP, estimated ecological risks to both terrestrial and aquatic organisms are primarily associated with nonradioactive inorganic chemicals. Although estimated risks are substantial in some instances, they are based on soil inorganic chemical concentrations comparable to background levels, and deleterious effects have not been observed in the field. This suggests that FEMP site-specific ecological risks are low. However, remedial actions are appropriate to address contaminants that have potential to cause harm in the future.

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F.4.0 DESCRIPTION OF REMEDIAL ALTERNATIVES

As previously discussed in **Section F.2.0** of this Appendix, the waste materials within OU4 exhibit a wide range of properties. Most notable would be the elevated direct radiation associated with the moist to wet Silos 1 and 2 material versus the much lower direct radiation associated with the dry, powdery cold metal oxides in Silo 3. Even more significant would be the much lower levels of contamination associated with the soils and building materials, like concrete, within the OU4 study area. To account for these differences and for the varied cleanup alternatives applicable to each type of waste, OU4 was segmented into three subunits. These subunits, which are listed below, were used through the detailed evaluation of alternatives and the identification of the preferred alternative.

Subunit A: Silos 1 and 2 (K-65 material and BentoGrout™ clay) and the sludge in the decant sump tank.

Subunit B: Silo 3 (cold metal oxides).

Subunit C: Silos 1, 2, 3, and 4 structures; contaminated soils within the OU4 boundary, including surface and subsurface soils and the earthen berm around Silos 1 and 2; the decant sump tank; the radon treatment system; the concrete pipe trench and the miscellaneous concrete structures within OU4; any debris (i.e., concrete, piping, etc.,) generated during for Subunits A and B; and, any perched groundwater encountered during remediation.

Table F.4.0-1 presents a summary of the alternatives considered during the detailed analysis in the original OU4 FS.

With the exception of Alternatives 2A/Vit and 2A/Cem (see **Section F.8.0** for details), the remedial alternatives, which went through detailed analysis during the FS for OU4, are summarized below. The discussions presented here are based on the information used for detailed analysis of alternatives during the OU4 FS. Actual methods used during the implementation of the selected alternative(s) will be determined during detail engineering design described in the remedial design and may differ from the descriptions provided below.

TABLE F.4.0-1
SUMMARY OF ALTERNATIVES CONSIDERED DURING DETAILED ANALYSIS

Original OU4 FS Alternative Designation	Alternative Description
SUBUNIT A	
2A/VIT	Removal, vitrification, and on-property disposal of Silos 1 and 2 material.
2A/CEM	Removal, cement stabilization, and on-property disposal of Silos 1 and 2 material.
3A.1/VIT	Removal, vitrification, and off-site disposal at the NTS of Silos 1 and 2 material.
3A.1/CEM	Removal, cement stabilization, and off-site disposal at the NTS of Silos 1 and 2 material.
SUBUNIT B	
2B/VIT	Removal, vitrification, and on-property disposal of Silo 3 material.
2B/CEM	Removal, cement stabilization, and on-property disposal of Silos 3 material.
3B.1/VIT	Removal, vitrification, and off-site disposal at the NTS of Silos 3 material.
3B.1/CEM	Removal, cement stabilization, and off-site disposal at the NTS of Silo 3 material.
4B	Removal and on-property disposal of Silo 3 material.
SUBUNIT C	
2C	Demolition, removal, and on-property disposal of Silos 1, 2, 3, and 4 structures, earthen berm, decant sump tank, process piping and trenches.
3C.1	Demolition, removal, and off-site disposal at the NTS of Silos 1, 2, 3, and 4 structures, earthen berm, decant sump tank, process piping and trenches.
3C.2	Demolition, removal, and off-site disposal (permitted commercial disposal site) of Silos 1, 2, 3, and 4 structures, earthen berm, decant sump tank, process piping and trenches.

130RR

Section 121 of CERCLA requires that remedial actions be protective of human health and the environment, and a level or standard of control that is consistent with federal or state environmental laws or state facility siting regulations (ARARs). ARARs pertain to all aspects of a remedial action, including the establishment of cleanup levels, the operation and performance of treatment systems, and the design of disposal facilities.

The Baseline Risk Assessment, performed as part of the *Remedial Investigation Report for Operable Unit 4* (FEMP 1993a), quantified the health risks to hypothetical human receptors due to exposure from chemical and radiological sources in OU4 under the no-action alternative. A summary of the risk assessment and results is presented in **Section F.3.0**. Essentially, the results emphasize the need to effectively complete the selected remedial actions at OU4 in order to ensure overall protection of human health and the environment.

Potential remedial alternatives were developed and evaluated in the FS Report for OU4 (FEMP 1994d) as to how these risks would be eliminated, reduced, or controlled through treatment, engineering controls, or institutional controls. Both long-term and short-term risks associated with implementing an alternative were considered in determining whether a given alternative was protective. Each alternative evaluated provides a description of its overall effectiveness in reducing risks to human health and the environment.

ARARs consist of two sets of requirements, those that are applicable and those that are relevant and appropriate. Applicable requirements are those substantive standards that specifically address a situation at a CERCLA site. Relevant and appropriate requirements are standards that address problems similar enough to the situation at a CERCLA site that their use is well suited to the site. In certain eases, standards may not exist in the promulgated regulation that address the proposed action or the COCs. In these cases, non-promulgated advisories, criteria, or guidance that were developed by the EPA, other federal agencies, or states are to be considered (TBC) in establishing remedial action objectives that are protective of human health and the environment.

A detailed discussion of all ARARs and TBC criteria associated with the remedial alternatives being evaluated is presented in **Appendix A** of this revised FS. From detailed lists of ARARs and TBC criteria, certain major ARARs and TBCs were selected based on their importance in protecting human health and the environment. These included those associated with the protection of drinking water sources, the control of radionuclide emissions, the design and siting of a solid waste disposal facility, the management of RCRA hazardous waste, and compliance with NEPA.

The major ARARs associated with remedial alternatives are segregated into three types:

(a) Chemical-specific ARARs are usually health- or risk-derived numerical values or methodologies that establish an acceptable level or concentration of chemical or radionuclide that may remain in specific environmental media after remediation is complete. These levels are deemed to be protective of human health and are used to help establish remedial cleanup goals.

(b) Location-specific ARARs generally restrict certain activities or dictate where certain activities may be conducted, solely because of geographical, hydrologic, hydrogeologic, or land-use concerns.

(c) Action-specific ARARs are usually technology or activity based requirements or restrictions on the conduct of certain activities or the operation of certain technologies at the site.

Appendix A identifies the remedial alternatives evaluated along with their major regulatory requirements, the rationale for designation of each regulatory requirement as an ARAR/TBC, and the mechanism by which the remedial alternative complies with the requirement.

130TT

F.4.1 No-Action Alternative for Subunits

The No-Action Alternative for Subunits A, B, and C was presented to provide a baseline for comparison with the other alternatives per the President's Council on Environmental Quality and 40 CFR Part 300, the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) regulations. Under the No-Action Alternatives, designated as 0A, 0B, and 0C for each of the three subunits, the contaminated and/or uncontaminated materials within each subunit remained unchanged without any further waste removal, treatment, or containment activities.

Alternatives 0A, 0B, and 0C did not provide for the monitoring of soil, groundwater, or radon emissions from the OU4 facilities or soils, nor did it provide for access controls (e.g., physical barriers and deed restrictions) to reduce the potential for exposure to any human or ecological receptors. The No-Action Alternatives did not decrease the toxicity, mobility, or volume of contaminants or reduce public health or environmental risks. Also, goals for protecting the underlying groundwater aquifer were not met. No costs were associated with the No-Action Alternative.

<u>ARAR Compliance for No-Action Alternatives</u>

Alternatives 0A, 0B, and 0C did not comply with a number of chemical-specific, location-specific, or action-specific ARARs. Under the no-action alternatives, Silos 1, 2, and 3 would eventually fail, resulting in the release of silos contents to the air, soil, groundwater, and surface water. Fate and transport modeling indicates that uranium and gross alpha and beta radiation would exceed safe drinking water limits under 40 CFR Part 141. In addition, localized "hot spots" could exceed the limits established in 40 CFR Part 192.12.

F.4.2 Subunit A - Contents of Silos 1 and 2 and the Decant Sump Tank

With the exception of Alternatives 2A/Vit and 2A/Cem (see **Section F.8.0** for details) this section presents the alternatives that were evaluated for Subunit A during the detailed analysis of alternatives phase of the OU4 FS. These alternatives focused on the remediation of the K-65 material contained in Silos 1 and 2 material and the sludges in the decant sump tank.

All of the alternatives provided overall protection of human health (assuming continued federal government control) and the environment by eliminating, reducing, or controlling risk through treatment, engineering controls, or institutional controls. The selected remedy (3A.1/Vit) provided greater certainty for overall protection than other alternatives because the Subunit A material was to be vitrified and removed to the NTS to reduce the potential for contaminant migration to human and ecological receptors. The source of unacceptable risks to the OU4 expanded trespasser and off-site farmer were to be eliminated and, in the event that the government lost control of the FEMP site, there would not be any risk from Subunit A material to an on-property farmer.

Overall protection at the NTS was to be maintained because the vitrified material resists leaching and the NTS is located in a climatic, demographic, and hydrogeologic setting that favors minimization of contaminant migration to both human and environmental receptors.

F.4.2.1 Alternative 3A.1/Vit - Removal, Vitrification, and Off-Site Disposal at the NTS

Capital Cost:	$38.3 Million (M)
Operations and Maintenance (O&M) Costs:	
During Remediation:	$11.7 M
Post-Remediation:	$0
Present Worth:	$43.7 M
Years to Implement:	6

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This alternative involved the removal, vitrification, and off-site disposal of the treated Silos 1 and 2 material and decant sump tank sludge. Treated material was to be transported by rail, then truck, to the NTS. Under Alternative 3A.1Vit, approximately 6,796 m^3 (8,890 yd^3) of untreated material was to be removed from Silos 1 and 2 and combined with approximately 3,785 L (1,000 gallons) of sludge from the decant sump tank and treated. Approximately 2,770 m^3 (3,623 yd^3) of vitrified material was to be packaged in containers and transported to the NTS for disposal. Disposal of contaminated materials from the berms, Silos 1 and 2 structures, the material removal equipment, and the vitrification system was to be managed under the selected alternative for Subunit C. No five-year CERCLA reviews were required under this alternative since no Subunit A material would remain at the FEMP. The components of this alternative that were not previously described are discussed next.

Material Removal

Silos 1 and 2 material and decant sump tank sludge were to be slurried and pumped to the vitrification plant for processing. During the material removal phase, Silos 1 and 2 and the decant sump tank would have been equipped with an off-gas handling system to treat radon and other potential airborne contaminants. This off-gas handling system would have operated during material removal and before personnel entered the area above the silos domes to reposition material removal equipment and conduct repairs or maintenance. The off-gas handling system and operating procedures would have been designed as necessary to minimize exposure to personnel located over the work areas and to prevent the escape of radon and radioactive particulates from the silos and the decant sump tank to the atmosphere.

Material Remediation

Silos 1 and 2 material and decant sump tank sludge were to be combined with glass forming agents, processed in a high temperature furnace, and converted into a stable vitrified glass form exhibiting excellent durability and constituent leaching characteristics. It should be noted that this plan focused upon pouring the molten glass directly into containers capable of withstanding the high temperature of the vitrified wasteform. The final wasteform was to be continually optimized and a final decision regarding the final wasteform reached during the pilot plant treatability studies. Process tanks/vessels and piping containing slurried K-65 material were to minimize potential radon and particulate emissions to the atmosphere during treatment. The direct radiation associated with the treated material would remain relatively unchanged from the untreated form of the K-65 material.

Interim Storage

The containerized vitrified product would have required interim storage at the FEMP prior to its transportation to the NTS for disposal. The purpose of this interim storage was two-fold. First, the vitrified product would require verification sampling in order to certify that each production lot had met specific performance and waste disposal criteria. Second, interim storage would provide the Fernald waste shipping program a buffer staging area where the material could be safely managed prior to its shipment to the NTS to ensure compliance with DOE ALARA principles and ARARs identified and included in the OU4 ROD, as well as protection of human health and the environment. It was anticipated that the interim storage area would accommodate the interim handling of approximately 90 days of vitrification production.

130 XX

Disposal of Treated Material

Off-site disposal for this alternative involved the packaging, loading, and shipping of the treated material, in accordance with the required United States Department of Transportation (DOT) specification regulations, to the low-level radioactive waste disposal site at the NTS. Shipment of the treated material to the NTS would have been performed by rail and/or truck transportation from the FEMP site. Currently, there are not any direct rail lines into the NTS. The treated material would have been transported by rail to either a point near Las Vegas, Nevada, or one of the areas north of Las Vegas. From either location, the containers carrying the treated material would have been transferred to trucks for transportation over roads to the NTS.

The NTS is located approximately 3,219 kilometers (km) [2,000 miles (mi)] from the FEMP site. Because the vitrified material resists leaching and the NTS is located in a sparsely populated, arid region where depths to groundwater are at least 235 m (771 ft) below the surface, disposal at the NTS would have been very effective at precluding human contact with and contaminant migration from the treated material from Subunit A.

The FEMP site has an approved NTS waste shipment and certification program that is periodically audited by the NTS. All the NTS waste acceptance requirements need to be satisfied before shipping OU4 treated material to the NTS.

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Implementation Time and Costs

Completion time for remedial action activities under Alternative 3A.1/Vit was estimated at six years. Approximately three years were projected for completion of site preparation, facilities construction, and equipment installation. Material removal and treatment activities would have required an additional three years. Transportation and off-site disposal would have concluded shortly after the completion of material processing. Capital costs for Alternative 3A.1/Vit were estimated to be 38.3 million dollars. O&M costs during remediation were estimated at 11.7 million dollars over a three-year period. Due to the off-site disposal option, there were not any post-remediation O&M costs associated with this alternative. The 1994 net present value cost for this alternative was estimated at 43.7 million dollars.

F.4.2.2 Alternative 3A.1/Cem - Removal, Cement Stabilization, and Off-Site Disposal at the NTS

Capital Cost:	$71.8 M
O&M Costs:	
During Remediation:	$11.7 M
Post-Remediation	$0
Present Worth:	$73.1 M
Years to Implement:	6

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This alternative was identical to Alternative 3A.1/Vit except that the vitrification of the Silos 1 and 2 material and decant sump tank sludge were replaced by cement stabilization. Treated material and debris would have been transported by rail, then trucked to the NTS. Under Alternative 3A.1/Cem, approximately 6,796 m^3 (8,890 yd^3) of untreated materials would have been removed from Silos 1 and 2, combined with approximately 3,785 L (1,000 gallons) of sludge from the decant sump tank, and treated. Approximately 18,166 m^3 (23,760 yd^3) of cement stabilized product would have been packaged in containers and transported to the NTS for disposal. Disposal of contaminated materials from the berms, Silos 1 and 2 structures, the material removal equipment, and the cement stabilization system would have been managed under the selected alternative for Subunit C. Five-year CERCLA reviews would not have been required since all Subunit A materials would have been removed from the site. The components of this alternative that were not previously described under alternative 3A.1/Vit are discussed next.

Material Remediation

Silos 1 and 2 material and the decant sump tank sludge would have been combined with cement and other additives necessary for stabilizing the materials into a cement form. Similar to Alternative 3A.1/Vit, process tanks/vessels and piping containing slurried K-65 material would have been designed to minimize potential radon and radionuclide particulate emissions to the atmosphere during treatment. Studies conducted on a small scale in a laboratory, as part of the OU4 RI/FS, indicated that an estimated 150% increase could be expected in the volume of waste requiring disposal following remediation. This increase is a result of the large volume of additives needed to effectively stabilize the silos material and decant sump tank sludge in cement. These studies also concluded that the cement stabilization of the wastes would not effectively reduce the radon emanation rate from the waste and the tendency of the waste to leach contaminants into groundwater. The direct radiation associated with the untreated material would have been slightly reduced due to the effects of mixing the additives with the material. The solidified materials would have been packaged in containers for disposal.

Implementation Time and Costs

Completion time for remedial action activities under Alternative 3A.1/Cem was estimated at six years. Approximately three years were projected for completion of site preparation, facilities construction, and equipment installation. Material removal and treatment activities would have required an additional three years. Transportation and off-site disposal would have concluded shortly after the completion of material processing. Capital costs for Alternative 3A.1/Cem were estimated to be 71.8 million dollars. O&M costs during remediation were estimated at 11.7 million dollars over three years. Due to the off-site disposal option, there were not any post-remediation O&M costs associated with this alternative. The 1994 net present value cost of this alternative was estimated at 73.1 million dollars.

F.4.3 Subunit B - Contents of Silo 3

This section presents alternatives that were evaluated for Subunit B during the detailed analysis of alternatives phase of the OU4 FS. These alternatives focused on the remediation of the cold metal oxides contained in Silo 3.

As discussed in **Section F.3.0**, this evaluation assumed that the federal government would continue to own the FEMP site. For a cleanup remedy to be considered protective, it should not result in any unacceptable risks to an OU4 expanded trespasser or an off-site farmer.

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All alternatives would have provided overall protection of human health and the environment. These alternatives would have eliminated, reduced, or controlled the health or environmental risks resulting from constituents in Subunit B materials. All of the action alternatives, except Alternative 4B, would have limited exposure to contaminants by removing the material, treating the material by either vitrification or cement stabilization, and then disposing the treated material in an on-property above-grade disposal vault (Alternative 2B) or off-site at the NTS (Alternative 3B.1). Alternative 4B's protection was based on removal and disposal of treated material in an on-property above-grade vault, and the use of institutional controls. Long-term effectiveness would have been attained for each of these alternatives.

In summary, the preferred alternative (3B-1/Vit) would have provided for overall protection because the Subunit B material would have been vitrified and removed to the NTS, reducing the potential for contaminant migration to human and ecological receptors.

F.4.3.1 Alternative 2B/Vit - Removal, Vitrification, and On-Property Disposal

Capital Cost:	$25.2 M
O&M Costs:	
During Remediation:	$4.9 M
Post-Remediation:	$3.2 M
Present Worth:	$28.0 M
Years to Implement:	4

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This alternative required the removal, vitrification, and on-property disposal of the Silo 3 contents. Under Alternative 2B/Vit, approximately 3,890 m^3 (5,088 yd^3) of untreated material would have been removed from Silo 3 and stabilized in a vitrified glass form. Following treatment, approximately 1,471 m^3 (1,924 yd^3) of vitrified material would have been packaged in containers and placed in an on-property, above-grade reinforced concrete disposal vault. The Silo 3 structural material, associated soils, the material removal system, and the vitrification system would have been managed under the selected alternative for Subunit C. In accordance with CERCLA 121(c) requirements, after commencement of remedial activities, a review would have been performed every five years by the EPA to ensure the continued protection of human health and the environment.

Material Removal

Due to the powder-like characteristics of Silo 3 cold metal oxide material, Alternative 2B/Vit utilized a pneumatic removal process to transport Silo 3 contents to the material processing facility. The pneumatic removal system consisted of a compressed air-driven pump that displaced and removed the dry wastes. Air entrained in the cold metal oxides, suctioned from Silo 3, would have been separated using filter/receiver systems allowing the cold metal oxides to be pneumatically "pushed" to the vitrification facility. A glove box system would have been used at the interface of the pneumatic removal system and the silo dome to function as secondary containment. This arrangement, along with appropriate operations procedures, would have been designed to prevent releases to the atmosphere during operations.

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Material Remediation

The vitrification process is identical to that described in **Section F.4.2.1** for Alternative 3A.1/Vit. Bench-scale studies conducted in a laboratory as part of the RI/FS for OU4 indicate that vitrification can effectively reduce the tendency of the Silo 3 material to leach inorganics and radionuclides to groundwater. This testing also demonstrated that a reduction greater than 50% in the volume of material requiring disposal could be achieved through the application of vitrification technology to the Silo 3 material. The vitrified material would have been packaged in containers for disposal.

Disposal of Treated Material

Studies completed on a bench-scale as part of the RI/FS project concluded that the volume of material requiring disposal could be reduced by over 50% through the vitrification process. The vitrified material would have been containerized and disposed in an above-grade, reinforced concrete disposal vault located on property. The vault would have been constructed on a reinforced concrete mat and equipped with a leachate collection/detection system to facilitate the collection of any contaminated leachate after final closure. The capping system would have been composed of alternating composite soil liners and drainage layers to minimize the potential release of contaminated leachate to the underlying Great Miami Aquifer. The proposed disposal facility would have been located at a suitable location of the FEMP site.

Final closure would have been completed by the construction of a multimedia cap over the vault. This cap would have included a clay cover to eliminate radon emanation from the disposed materials to the atmosphere and a barrier to preclude intrusion by burrowing animals and hypothetical future residents of the area. Upon completion of the multimedia cap, security controls such as fencing would have been installed. Monitoring wells would have been appropriately located to evaluate the effectiveness of the above-grade disposal vault in ensuring long-term protection of human health and the environment.

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To provide added assurance against any future activities by humans to intrude into the disposal vault, permanent markers would have been installed to identify the vault, and restrictions would have been placed on the site. Additionally, in order to ensure long-term protectiveness for this alternative, it was assumed that the effected disposal areas at the FEMP would require the continued ownership by the federal government. While the disposal vault would not have required any continued active operations or maintenance, long-term ownership would have permitted the government to continue exercising its right to preclude any development or drilling in areas where contaminated materials were disposed.

All facilities and equipment installed and used by this alternative would have been disassembled and decontaminated during the post-remediation phase. Contaminated materials would have been disposed in accordance with the selected remedy for Subunit C.

Implementation Time and Costs

Completion time for remedial action activities under Alternative 2B/Vit was estimated at four years. Site preparation and construction activities would have taken approximately three years. Removal and material processing activities would have required an additional year. Capital costs for Alternative 2B/Vit were estimated to be 25.2 million dollars. O&M costs during remediation were estimated at 4.9 million dollars over a one-year period, while post-remediation O&M costs were estimated at 3.2 million dollars over a thirty-year period. The 1994 net present value cost for this alternative was estimated at 28.0 million dollars.

F.4.3.2 Alternative 2B/Cem - Removal, Cement Stabilization, and On-Property Disposal

Capital Cost:	$35.9 M
O&M Costs:	
During Remediation:	$4.9 M
Post-Remediation:	$3.2 M
Present Worth:	$37.4 M
Years to Implement:	4

This alternative would have used the material removal methodology presented in Alternative 2B/Vit, followed by treatment of the Silo 3 contents by cement stabilization and on-property disposal of the stabilized material. Under Alternative 2B/Cem, approximately 3,890 m^3 (5,088 yd^3) of untreated materials would have been removed from Silo 3 and stabilized in a cement form. Approximately 5,999 m^3 (7,846 yd^3) of stabilized material would have been packaged in containers and placed in an on-property, above-grade reinforced concrete disposal vault. The Silo 3 structural materials, the material removal system, and the cement stabilization system and associated soils would have been remediated with the selected alternative for Subunit C. In accordance with CERCLA 121(c) requirements, after commencement of remedial activities, a review would have been performed every five years by the EPA to ensure the continued protection of human health and the environment. The components of this alternative that were not previously described are discussed next.

Material Remediation

The cement stabilization process was identical to that described in **Section F.4.2.2** for Alternative 3A.1/Cem with the exception of differences in the cement formulations required to accommodate physical and chemical differences between the K-65 material and Silo 3 cold metal oxides. The *Feasibility Study for Operable Unit 4* (FEMP 1994d), Appendix C, discusses the results of bench-scale treatability studies, which indicated that cementation of the Silo 3 metal oxides would have resulted in an approximate 50% increase in the volume of treated material requiring disposal.

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Implementation Time and Costs

Completion time for remedial action activities under Alternative 2B/Cem were estimated at four years. Site preparation and construction activities would take approximately three years. Removal and material processing activities would require about one year. Capital costs for Alternative 2B/Cem are estimated to be 35.9 million dollars. O&M costs during remediation are estimated at 4.9 million dollars over one year, while post-remediation O&M costs are estimated at 3.2 million dollars over a 30-year period. The 1994 net present value cost of this alternative was estimated at 37.4 million dollars.

F.4.3.3 Alternative 3B.1/Vit — Removal, Vitrification, and Off-Site Disposal at the NTS

Capital Cost:	$26.8 M
O&M Costs:	
During Remediation:	$4.9 M
Post-Remediation:	$0
Present Worth:	$28 M
Years to Implement:	4

This alternative involved the removal, remediation, and off-site disposal of the Silo 3 contents. This alternative was identical to Alternative 2B/Vit, except the on-property disposal, monitoring, and institutional controls were replaced by the transportation of the treated material by rail and/or truck to the NTS for disposal. Under Alternative 3B.1/Vit, approximately 3,890 m^3 (5,088 yd^3) of untreated materials would have been removed from the silos. Approximately 1,471 m^3 (1,923 yd^3) of vitrified material would have been packaged in containers and transported to the NTS for disposal. Off-site requirements applicable to Alternative 3B. I/Vit would have included the NTS material acceptance criteria and DOT regulations pertaining to the transport of hazardous and radioactive materials. Five-year reviews would not have been required since Subunit B wastes would have been removed from the site under this alternative.

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Implementation Time and Costs

Completion time for remedial action activities under Alternative 3B.1/Vit were estimated at four years. Site preparation and construction activities would have taken approximately three years. Removal activities would have required about one year. Transportation and off-site disposal would have concluded shortly after the completion of material processing. Capital costs for Alternative 3B.1/Vit were estimated at 26.8 million dollars. O&M costs during remediation were estimated at 4.9 million dollars over one year. Due to the off-site disposal option, there were not any post-remediation O&M costs associated with this alternative. The 1994 net present value cost of this alternative was estimated at 28 million dollars.

F.4.3.4 Alternative 3B.1/Cem — Removal, Cement Stabilization, and Off-Site Disposal at the NTS

Capital Cost:	$36.8 M
O&M Costs:	
During Remediation:	$4.1 M
Post-Remediation:	$0
Present Worth:	$36 M
Years to Implement:	4

This alternative is identical to Alternative 3B.1/Vit (**Section F.4.3.3**), except that Silo 3 contents were to be stabilized in cement prior to off-site disposal at the NTS as described for Alternative 2B/Cem (**Section F.4.3.2**). Under Alternative 3B.1/Cem, approximately 3,890 m^3 (5,088 yd^3) of contaminated materials would have been removed from Silo 3. Approximately 5,999 m^3 (7,846 yd^3) of stabilized material would have been transported to the NTS for disposal. Five-year reviews would not have been required since all Subunit B wastes would have been removed from the site under this alternative.

Implementation Time and Costs

Completion time for remedial action activities under Alternative 3B.1/Cem was estimated at four years. Site preparation and construction activities would have taken approximately three years. Removal activities would have required about one year. Transportation and off-site disposal would have concluded shortly after the completion of material processing. Capital costs for Alternative 3B.1/Cem were estimated to be 36.8 million dollars. O&M costs during remediation were estimated at 4.1 million dollars over one year. Due to the off-site disposal option, there were not any post-remediation O&M costs associated with this alternative. The 1994 net present value cost of this alternative was estimated at 36 million dollars.

F.4.3.5 Alternative 4B — Removal and On-Property Disposal

Capital Cost:	$21.8 M
O&M Costs:	
During Remediation:	$1.1 M
Post-Remediation:	$3.2 M
Present Worth:	$22.0 M
Years to Implement:	2

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This alternative required the removal of the Silo 3 contents, packaging, and on-property disposal of the untreated material. This alternative is identical to Alternative 2B, with the exception that it did not include treatment. Under Alternative 4B, approximately 3,890 m^3 (5,088 yd^3) of contaminated materials would have been removed from Silo 3 and packaged in containers for disposal in an on-property, above-grade reinforced concrete disposal vault. The Silo 3 structural materials, associated soils, and removal system would have been managed under the Subunit C alternative. In accordance with CERCLA 121(c) requirements, after commencement of remedial activities, a review would have been performed every five years by the EPA to ensure the continued protection of human health and the environment.

Implementation Time and Costs

Completion time for remedial action activities under Alternative 4B was estimated at two years. Site preparation and construction activities would have taken approximately one year. Removal and packaging activities would have required about one year. Capital costs for Alternative 4B were estimated to be 21.8 million dollars, O&M costs during remediation were estimated at 1.1 million dollars over one year. Post-remediation O&M costs were estimated at 3.2 million dollars. The 1994 net present value cost of this alternative was estimated at 22 million dollars.

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F.4.4 Subunit C - Silos 1, 2, 3, and 4 Structures, Soils, and Debris

This section presents alternatives that were evaluated for Subunit C during the detailed analysis of alternatives phase of the FS for OU4. These alternatives focus on the remediation of: Silos 1, 2, 3, and 4 structures; contaminated soils within the OU4 boundary, including surface and subsurface soils and the earthen berms around Silos 1 and 2; the existing RTS; the K-65 Drum Handling Building pad; standing water within Silo 4 (if any); the decant sump tank; the process piping and trenches; and, any rubble or debris (i.e., decontamination and decommissioning of the treatment facility) generated consequential to the implementation of remedial actions for OU4 subunits. The volumes of soil, rubble, and debris to be generated under Subunit C were small in comparison to the volume of similar materials generated by other FEMP OUs. The Subunit C alternatives evaluated through detailed analysis considered integration of disposal activities with OU3 and OU5. These integration efforts would allow waste minimization initiatives developed for OU3 and OU5 to be integrated into the final remedy chosen for Subunit C materials.

As discussed in **Section F.3.0**, evaluations were conducted for future land-uses with and without continued federal ownership. For a cleanup remedy to be considered protective, it could not result in any unacceptable risks to an OU4 expanded trespasser or an off-site farmer under the future land-use with continued federal ownership scenario.

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All of the evaluated alternatives would have limited exposure to constituents by decontaminating, demolishing, and removing the material to either an on-property, above-grade disposal facility or off-site disposal facility, and then excavating contaminated soils and placing clean fill over residual contaminated subsurface soils. The placement of the clean fill was not to be used as a measure to limit exposures but rather to restore the natural drainage patterns and promote revegetation. **Table F.6.2-2** summarizes the proposed remedial levels for soils, all of which would have been protective to the OU4 expanded trespasser, trespassing child, and off-site resident over the long-term. Short-term risks would have been higher for off-site disposal due to the increased risk of transportation accidents. These action alternatives would have been protective of all anticipated receptors assuming continued federal government ownership and control of the area; this includes the off-site farmer and the OU4 expanded trespasser receptors.

The basic difference among the action alternatives was the disposal option. On-property disposal (Alternative 2C) would have been in an above-grade disposal facility. Off-site disposal options included the NTS (Alternative 3C.1) and a permitted commercial disposal site (Alternative 3C.2).

The on-property, above-grade disposal facility would have been designed for a 1,000 year life without active maintenance. Fate and transport modeling using conservative assumptions concluded that protectiveness would have been maintained over the long-term.

The NTS and the permitted commercial disposal facility would have incorporated engineering controls to ensure protectiveness. Both are located in a climatic, demographic, and hydrogeologic setting which favors minimization of constituent migration to human or environmental receptors. Short-term risks to the public and workers are slightly greater for off-site disposal options due to the increased risks of transportation accidents resulting in injuries or radiation exposure.

For all of the Subunit C alternatives, hazardous substances (i.e., contaminated soil or debris) would have remained on-site at levels that precluded unlimited use or unrestricted exposure. Therefore, in accordance with the requirements of CERCLA 121(c), all the Subunit C alternatives would have required that a review be conducted every five years, after commencement of remediation to ensure that the alternative continued to provide adequate protection of human health and the environment.

F.4.4.1 Alternative 2C - Demolition, Removal, and On-Property Disposal

Capital Cost:	$36.3
O&M Costs:	
During Remediation:	$0
Post-Remediation:	$3.6 M
Present Worth:	$34.3 M
Years to Implement:	2

Alternative 2C involved the demolition of the Silos 1, 2, 3, and 4 structures and disposal of the materials from the removal of the earthen berm, decant sump tank, process piping, and trenches. Alternative 2C further addressed the excavation of contaminated subsurface soils within the OU boundary and disposal of the debris generated as a result of implementing remedial actions for Subunits A and B. Contaminated material would have been placed in an above-grade disposal vault at the FEMP site. Under Alternative 2C, approximately 34,956 m^3 (45,748 yd^3) of material would have been placed in an on-property, above-grade disposal vault.

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Demolition and Decontamination of the Silos Structures

Before Silos 1, 2, 3, and 4 were demolished, loose interior materials and concrete would have been removed from the silos surfaces. Concrete exhibiting highly elevated direct radiation levels would have been segregated from other Subunit C waste and dispositioned as part of the selected remedy for Subunit A. Silos demolition would have consisted of the systematic decontamination, removal, dismantling, and disposal of the Silos 1, 2, 3, and 4 domes, walls, floor slabs and footers. Removal would have involved cutting each of the silos structures into manageable pieces after appropriate bracing had been installed. The demolition would have begun with the dismantling of Silo 4, since this silo has never been used, making it an ideal full-scale model to test and confirm demolition methodologies with minimal risk of radiological release to the environment. Based on experience obtained through the dismantling of Silo 4, demolition of Silos 1, 2, and 3 would have proceeded according to the sequencing and procedures established during the remedial design and remedial action phases.

Demolition and Decontamination of Other OU4 Structures

The existing RTS, Drum Handling Building pad, sump lift station foundation, concrete pipe trench, and the decant sump tank would also have been removed and decontaminated. An estimated 790 m (2,600 ft) of process piping in the process piping trenches would have been cut into manageable sections and disposed. An estimated 280 m^3 (365 yd^3) of concrete from the trench, decant sump tank process piping, and existing RTS would have been disposed. Additionally, all facilities constructed and equipment installed and used to implement the selected alternatives for Subunits A and B would have been disassembled, decontaminated (if necessary), and either recycled, reused, or disposed.

Non-porous materials, such as steel fencing and structural steel, that attained the unrestricted use, free release criteria defined in DOE Order 5400.5 would have been released from the site as uncontaminated. Materials not attaining these levels would have been retained for disposal as contaminated waste consistent with the approved *Operable Unit 3 Record of Decision* (1996a).

Remediation of Soil

After the silos were demolished, the contaminated surface soils within the boundary of OU4 would have been excavated to attain proposed remediation levels for each of the COCs. After the silos were demolished, the contaminated surface soils within the boundary of OU4 would have been excavated to attain proposed remediation levels, as described in **Section F.6.2.2**, for each of the contaminants of concern. Attainment of these levels would have been demonstrated applying regulatory guidance available at the time. The cleanup levels were considered protective of the hypothetical expanded trespasser receptor. To attain these goals, a minimum of 15 centimeters (cm) [6 inches (in)] of soils across the entire OU area would have been excavated. Additional soils beneath the silos, decant sump tank, concrete pipe trench, or other locations below this depth would have been removed as necessary to attain these cleanup goals.

Soils exhibiting highly elevated direct radiation levels (i.e., potentially contaminated soils beneath Silos 1 and 2) would have been segregated from other Subunit C wastes and dispositioned as part of the selected remedy for Subunit A. Following excavation, the affected areas would have been returned to original grade with the placement of clean backfill and then seeded. Additionally, the area would have been fenced and appropriate signs placed to indicate that trespassing and hunting was not permitted. Continued federal ownership with appropriate deed restrictions would have been implemented to ensure that any future transfer of property would be consistent with CERCLA 120(h).

Water Treatment

Wastewater generated as a result of this remedial action, along with water removed from the decant sump tank, Silo 4 (if any), and any perched groundwater encountered during remedial activities would have been collected, pretreated if necessary, and sent to the FEMP AWWT facility for treatment prior to discharge to the Great Miami River. In accordance with the ACA, groundwater remediation would have been handled by OU5. OU4 would only have handled the cleanup of perched water encountered during remedial action activities.

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Disposal of Soil, Debris, and Rubble

Final disposition of contaminated soil and debris generated from the selected remedy for OU4 was to be conducted in accordance with the RODs for OU3 and OU5 to allow for an integrated site-wide approach for soil and debris disposition. In addition, OU4 would be able to take advantage of any applicable waste minimization initiatives developed for soil and debris by OU5 and OU3, respectively.

The volume of contaminated soil, rubble, and debris to be addressed under OU4 represents a small fraction (less than 1%) of the total volume of similar wastes to be addressed under OU5 and OU3. OU3 conducted a RI/FS (FEMP 1996b) that provided additional insight into the effectiveness of various decontamination technologies on building materials. In addition, the OU3 RI/FS evaluated the appropriate type and location of disposal for contaminated rubble and debris. The OU3 ROD has identified certain debris that could be disposed in the on-site disposal facility (OSDF) contingent upon meeting the OSDF WAC.

Implementation Time and Costs

Approximately three months would have been required for site preparation; 15 months would have been required to demolish and decontaminate the silos structures as well as the surface soil, berm soils, subsurface soils, process piping, and decant sump tank. Demobilization activities would have extended the duration of the alternative to two years. During this timeframe, the above-grade disposal facility would also have been constructed and capped. Capital costs for Alternative 2C were estimated at 36.3 million dollars. Post-remediation O&M costs were estimated at 3.6 million dollars. The 1994 net present value cost of this alternative was estimated at 34.3 million dollars.

F.4.4.2 Alternative 3C.1 — Demolition, Removal, and Off-Site Disposal at the NTS

Capital Cost:	$83.6 M
O&M Costs:	$0
Present Worth:	$75.5 M
Years to Implement:	2

This alternative was identical to Alternative 2C, except that the on-property disposal, monitoring, and institutional controls were replaced by packaging and off-site transportation of the material by rail or truck to the NTS for disposal. The off-site disposal option for Alternative 3C.1 involved the packaging, loading, and shipping of the material generated by this alternative to the NTS.

Implementation Time and Costs

Remedial actions for Alternative 3C.1 would have required about two years to complete, including the transportation of the packaged materials to the NTS. Capital costs for Alternative 3C.1 were estimated to be 83.6 million dollars. Due to the off-site disposal aspect of this alternative, O&M costs were not anticipated. The 1994 net present value cost of this alternative was estimated at 75.5 million dollars.

F.4.4.3 Alternative 3C.2 — Demolition, Removal, and Off-Site Disposal (Permitted Commercial Disposal Site)

Capital Cost:	$48.6 M
O&M Costs:	$0
Present Worth:	$44.0 M
Years to Implement:	2

This alternative was identical to Alternative 3C.1, except that the off-site disposal at the NTS was replaced by off-site disposal at a permitted commercial disposal site and the waste would have been shipped in bulk instead of being packaged. One such site is located near Clive, Utah, approximately 3,058 km (1,900 mi) from the FEMP site. The facility has been permitted by the State of Utah to accept low-level radioactive waste, mixed hazardous waste, and naturally occurring by-product materials such as those in Subunit C.

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Disposal

Due to its relatively long distance from the FEMP site, coordination with several states for transportation of Subunit C wastes would have been required. Additionally, an exemption from DOE Order 5280.2A prohibiting disposal of DOE wastes at a commercial facility would have been necessary for the OU4 waste before it could have been transported to the disposal site.

Implementation Time and Costs

Remedial actions for Alternative 3C.2 would have required approximately two years to complete; this includes the transportation of the materials to a permitted commercial disposal site. Capital costs were estimated at 48.6 million dollars. Due to the off-site disposal option, O&M costs were not anticipated for Alternative 3C.2. The 1994 net present value cost of this alternative was estimated at 44.0 million dollars.

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F.5.0 SUMMARY OF THE COMPARATIVE ANALYSIS OF ALTERNATIVES

F.5.1 Evaluation Criteria

Specific legal requirements for remedial actions are specified under CERCLA Section 121. These requirements include protection of human health and the environment, compliance with ARARs (unless a waiver is obtained), a preference for permanent solutions that use treatment as a principal element (to the maximum extent possible), and cost-effectiveness. To determine whether alternatives meet the requirements, the EPA has identified nine criteria in the NCP that must be evaluated for each alternative selected for detailed analysis. These criteria are listed below.

1. **Overall protection of human health and the environment**: Examines whether a remedy provides adequate overall protection to human health and the environment in the short- and long-term. Evaluates how risks are eliminated, reduced, or controlled through treatment and engineering or institutional controls included in the alternative.

2. **Compliance with ARARs**: Addresses whether the alternative attains compliance with federal and state environmental laws and requirements, unless a waiver of an ARAR applies.

3. **Long-term effectiveness and permanence**: Evaluates the permanence of the remedy, long-term effectiveness and likelihood that the remedy will be successful.

4. **Reduction of toxicity, mobility, or volume through treatment**: Reviews the anticipated treatment technologies to reduce the hazards of, prevent the movement of, or reduce the quantity of waste materials.

5. **Short-term effectiveness**: Evaluates the ability of a remedy to achieve protection of workers, the public, and the environment during construction and implementation of the remedial action.

6. **Implementability**: Examines the practicality of carrying out a remedy, including the availability of materials and services needed during implementation of the remedial action.

7. **Cost:** Reviews the estimated capital, operation, and maintenance costs of the remedy. Costs are presented as present worth costs. "Present worth" is defined as the amount of money that, if invested in the first year of implementing a remedy and paid out as needed, would be sufficient to cover all costs associated with the remedy over its planned life. Present worth costs allow remedies that would occur over different periods to be compared on an even basis.

8. **State Acceptance:** Evaluates the technical and administrative issues and concerns that the State of Ohio may have regarding each of the alternatives, and the State comments on ARARs or proposed use of waivers.

9. **Community Acceptance:** Evaluates the issues and concerns the public may have regarding each of the alternatives, including which parts of the alternatives are supported or opposed.

The first two criteria are considered *threshold criteria* and must be met by the final remedial action alternatives for OU4 (unless a specific ARAR is waived). The next five criteria are considered *primary balancing criteria* and are considered together to identify significant tradeoffs that must be addressed. The last two are considered *modifying criteria* that are considered in final remedy selection. The alternatives comparison for each subunit is summarized in **Table F.5.2-1**.

F.5.2 Comparative Analysis of Alternatives

The following sections summarize the information presented in Section 5.0 of the *Feasibility Study for Operable Unit 4* (FEMP 1994d) and rely upon the detailed analysis of alternatives presented in Section 4.0 of the same report.

F.5.2.1 Analysis for Subunit A

F.5.2.1.1 Threshold Criteria

The analysis of the Subunit A alternatives against the threshold criteria of overall protection of human health and the environment, and compliance with ARARs is summarized below.

Overall Protection of Human Health and the Environment

As part of the original OU4 FS, two potential future land-uses of the FEMP were evaluated to assess the ability of the individual alternative to adequately protect human health and the environment. These land-uses consider potential exposures to contaminants released during or following the implementation of the alternatives and were evaluated for a range of viable receptors. These scenarios included future land-use with and without the assumption of continued federal ownership. With continued government ownership, the FEMP land would not have been available for residential or farming use; and, access to the site would have been limited by fencing and physical markers. It would be reasonable to assume that an OU4 expanded trespasser would have visited the site occasionally.

It was also assumed that the land surrounding the FEMP site would have continued to be used for family farms. For a cleanup remedy to be considered protective, it should not result in any unacceptable risks to an expanded trespasser or an off-site farmer. The evaluation also considered the future possibility that the federal government might not have control of the FEMP site. In that case, a farm might be established on the FEMP property. The remedial alternatives were evaluated as to what risks might exist for a hypothetical on-property farmer if government control is no longer present. A summary of these evaluations is presented in **Section F.3.0** of this Appendix.

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000146

TABLE F. 5.2-1
COMPARISON OF REMEDIAL ALTERNATIVES

SUBUNIT A - SILOS 1 AND 2 CONTENTS

Alternative	Overall Protection of Human Health and Environment	Compliance with ARARs	Long-Term Effectiveness and Permanence	Reduction of Toxicity, Mobility or Volume through treatment	Short-Term Effectiveness	Implementability	Total Present Worth Cost
0A - No Action	Not protective	Does not comply with all ARARs	Not effective or permanent	No treatment; therefore, no reduction	High	Easy	-0-
3A.1/Vit - Removal, Vitrification, Off-Site Disposal - Nevada Test Site	**Protective**	**Complies with all ARARs**	**Effective and most reliable**	**Reduces toxicity, mobility, and volume**	**Medium**	**Innovative technology, Difficult**	**$43.7M**
3A.1/Cem - Removal, Cement Stabilization, Off-Site Disposal - Nevada Test Site	Protective	Complies with all ARARs	Effective and most reliable	Reduces mobility	Medium	Reliable technology, Difficult	$73.1M

[1] Assessment of protectiveness adopts the use of continued federal goverment ownership and evaluates risk to expanded trespassers and the off-property farmer.
[2] Assumes substantive technical requirements for Ohio disposal facility siting are met.
Bold -- Preferred Remedial Action Alternative.
Shaded areas -- Did not meet threshold criteria (Overall Protection or Compliance with ARARs), therefore, not compared.
Protective -- Risk is within the one in ten thousand to one in a million (10^{4} to 10^{6}) EPA target risk range.

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TABLE F. 5.2-1 (continued)

SUBUNIT B - SILO 3 CONTENTS

Alternative	Overall Protection of Human Health and Environment	Compliance with ARARs	Long-Term Effectiveness and Permanence	Reduction of Toxicity, Mobility or Volume through treatment	Short-Term Effectiveness	Implementability	Total Present Worth Cost
0B - No-Action	Not protective	Does not comply with all ARARs	Not effective or permanent	No treatment; therefore, no reduction	High	Easy	-0-
2B/Vit - Removal, Vitrification, On-Property Disposal	Protective[1]	Complies with all ARARs[2]	Effective and reliable	Reduces mobility and volume	Medium	Innovative technology, Moderately Difficult	$28M
2B/Cem - Removal, Cement Stabilization, On-Property Disposal	Protective[1]	Complies with all ARARs[2]	Effective and reliable	Reduces mobility	Medium	Reliable technology, Easy	$37.4M
3B.1/Vit - Removal, Vitrification, Off-Site Disposal - NTS	**Protective**	**Complies with all ARARs**	**Effective and most reliable**	**Reduces mobility and volume**	**Medium**	**Innovative technology, Difficult**	**$28M**
3B.1/Cem - Removal, Cement Stabilization, Off-Site Disposal - NTS	Protective	Complies with all ARARs	Effective and most reliable	Reduces mobility	Medium	Reliable technology, Difficult	$36M
4B - Removal and On-Property Disposal	Protective[1]	Complies with all ARARs[2]	Effective and reliable	No treatment; therefore, no reduction	High	Reliable technology, Easy	$22M

[1] -- Assessment of protectiveness adopts the use of continued federal goverment ownership and evaluates risk to expanded trespassers and the off-property farmer
[2] -- Assumes substantive technical requirements for Ohio disposal facility siting are met.
Bold -- Preferred Remedial Action Alternative
Shaded areas -- Did not meet threshold criteria (Overall Protection or Compliance with ARARs), therefore, not compared.
Protective -- Risk is within the one in ten thousand to one in a million USEPA target risk range

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TABLE F. 5.2-1 (continued)

SUBUNIT C - SILOS 1, 2, 3, AND 4 STRUCTURES, SOILS, AND DEBRIS

Alternative	Overall Protection of Human Health and Environment	Compliance	Long-Term Effectiveness and Permanence	Reduction of Toxicity, Mobility or Volume through treatment	Short-Term Effectiveness	Implementability	Total Present Worth Cost
0C - No-Action	Not protective	Does not comply with all ARARs	Not effective or permanent	No treatment; therefore, no reduction	High	Easy	-0-
2C - Demolition, Removal, On-Property Disposal	**Protective[1]**	**Complies with all ARARs[2]**	**Effective and reliable**	**No treatment; therefore, no reduction**	**Medium**	**Reliable technology, Easy**	**$34.3M**
3C.1 - Demolition, Removal, Off-Site Disposal - Nevada Test Site	Protective	Complies with all ARARs	Effective and most reliable	No treatment; therefore, no reduction	Medium	Reliable technology, Moderately difficult	$75.5M
3C.2 - Demolition, Removal, Off-Site Disposal - Permitted Commercial Facility	Protective	Complies with all ARARs	Effective and most reliable	No treatment; therefore, no reduction	Medium	Reliable technology, Moderately difficult	$44M

[1] -- Assessment of protectiveness adopts the use of continued federal goverment ownership and evaluates risk to expanded trespassers and the off-property farmer.
[2] -- Assumes substantive technical requirements for Ohio disposal facility siting are met.
Bold -- Preferred Remedial Action Alternative
Shaded areas -- Did not meet threshold criteria (Overall Protection or Compliance with ARARs), therefore, not compared.
Protective -- Risk is within the one in ten thousand to one in a million USEPA target risk range

All of the alternatives would have provided protection of human health and the environment by eliminating, reducing, or controlling risk through treatment, engineering controls, or institutional controls. The preferred alternative (3A.1/Vit) would have provided for overall protection because the Subunit A material was to be treated and removed to the NTS. The source of risks to the OU4 expanded trespasser and off-site farmer would have been eliminated; and, in the event that the government lost control of the FEMP site, there would not have been any risk from Subunit A material to an on-property farmer. Overall protection at the NTS would have been maintained because the vitrified material resists leaching and the NTS is located in a sparsely populated, arid region, where depths to groundwater are at least 235 m (771 ft) below the surface.

Compliance with ARARs.

CERCLA requires that remedial actions achieve a standard or level of control that is consistent with federal and state environmental laws or state siting regulations (ARARs). ARARs apply to all aspects of remedial action, including the establishment of cleanup levels, the operation and performance of treatment systems, and the design of disposal facilities. In addition to meeting ARARs, operations at DOE-owned facilities must be conducted according to DOE Orders. Although DOE Orders are not promulgated standards, their technical requirements may be adapted if they cover areas not addressed by other laws, or if they improve protection of human health and the environment because they are more stringent than existing laws. A detailed discussion of compliance with ARARs is provided in **Appendix A** of this revised FS.

With the exception of Alternatives 2A/Vit, 2A/Cem (see **Section F.8.0** for details) and the no action alternative, all of the Subunit A alternatives would have met ARARs. Since the preferred alternative (Alternative 3A.1/Vit) included off-site disposal at the NTS, there would not have been any long-term compliance issues associated with the FEMP site. For example, off-site disposal would have eliminated the need to demonstrate that drinking water maximum contaminant levels (MCLs) were attained for Subunit A material. In the short-term, the on-property remediation activities during removal and treatment would have addressed the operational requirements for airborne emissions, soil pathways, and penetrating radiation by engineered controls.

For Alternative 3A.1/Vit, the packaging and transportation of the treated material would have complied with the requirements for the protection of worker and public safety from radiological hazards (49 CFR Parts 171-177). This alternative would also have complied with other off-site requirements, such as the WAC specified by the NTS, to meet their disposal requirements. The probability of an inadvertent intruder coming in contact with the Subunit A material at the NTS is less than that for the FEMP site, based on the demographic characteristics of both locations.

F.5.2.1.2 Primary Balancing Criteria

Those alternatives that satisfy the threshold criteria comparative analysis were carried forward to the primary balancing criteria for further comparative analysis. Because Alternative 0A (No Action) did not satisfy either of the threshold criteria, and Alternatives 2A/Vit and 2A/Cem (see **Section F.8.0** for details) did not satisfy compliance with specific ARARs, these alternatives were not considered further in this analysis.

F-8074

Long-Term Effectiveness and Permanence

Alternatives 3A.1/Vit and 3A.1/Cem would have ensured long-term protectiveness to human health and the environment because residual risks to viable receptors (off-site farmer and expanded trespasser) would have been less than a 10^{-6} ILCR, and no non-carcinogenic effects (hazard index less than 0.2) would have been indicated for either receptor.

All alternatives involved the removal and treatment of Subunit A material by either vitrification or cement stabilization. The preferred alternative would have been most effective based on the results of bench-scale treatability studies conducted during the RI/FS [*Feasibility Study Report for Operable Unit 4*, Appendix C (FEMP 1994d)] on the Subunit A materials, which demonstrated that vitrification would effectively reduce radon emanation and minimize the leaching of constituents. Tests using cement stabilization demonstrated that this process is effective in preventing the movement of constituents from the stabilized form; however, there was little or no reduction in radon emanation rates. The vitrified material is expected to have greater durability over the long-term.

Over the long-term, the characteristics (i.e., demographics, climate, geology, groundwater level) of the NTS would provide for greater certainty than FEMP on-property disposal that the treated material would not affect human health and the environment.

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Reduction of Toxicity, Mobility, or Volume through Treatment.

Alternative 3A.1/Vit would have used vitrification to treat the Subunit A material. This technology chemically binds the contaminants in a glass-like matrix that significantly reduces contaminant mobility and material volume. Mobility would have been reduced because the contaminants would have been bound in the matrix and the volume of the treated material would have been less than 50% of the untreated material volume. Vitrification would also have destroyed organic contaminants in the treated material. Although most contaminants in the treated material would have been incorporated into the vitrified product to reduce mobility over the long-term, some contaminants would have been released during the vitrification process and required treatment through an off-gas treatment system. The material generated through the off-gas treatment system may have required remediation to limit subsequent contaminant mobility.

Alternative 3A.1/Cem would have used the cement stabilization process to treat contaminated material. This technology physically and chemically binds the constituents in a cement-like matrix, so the mobility of constituents via leaching from this treated material would have been greatly reduced. However, organic constituents would not have been destroyed. The total volume of material would have increased by approximately 150% as a result of adding the cement stabilizing and setting agents.

Alternative 3A.1/Vit was favored over Alternative 3A.1/Cem because it would have: reduced the toxicity of organic contaminants, more effectively reduced the radon emanation from the treated material, generated a treated form with good resistance to leaching, and significantly reduced the volume of Subunit A material.

8074

Short-Term Effectiveness

The various removal, treatment, and disposal activities of alternatives 3A.1/Vit and 3A.1/Cem would have resulted in increased short-term risks for exposures (compared to no action). The short-term effectiveness of the material removal operations was expected to be the same among all alternatives for Subunit A. There was some uncertainty associated with controlling and treating the off-gases generated by the vitrification process. The on-property risks for 3A.1/Cem from transportation would have been higher than with 3A.1/Vit because the increased volume of the treated material would have increased the number of potential transportation accidents. Short-term impacts at the NTS associated with the transportation and off-loading of the treated material would have been indistinguishable from normal operations.

In summary, Alternative 3A.1/Cem was favored over Alternative 3A.1/Vit because of the uncertainty associated with off-gas control and treatment for the vitrification process.

Implementability

The removal and treatment activities in Alternative 3A.1/Cem would have been implemented using standard equipment, procedures, and readily available resources. Hydraulic removal is a standard mining technology that is normally reliable and uses readily available equipment. The cement stabilization technology has been applied successfully at a number of remedial sites. EPA considers cement stabilization a demonstrated treatment technology and has approved its use in the final remedy for many NPL sites. This technology has also been applied at other sites that have radioactively contaminated waste. The cement stabilization process would have required large quantities of cement, flyash, and blast furnace slag, which are available elements.

Although removal and disposal are the same for Alternative 3A.1/Vit as for Alternative 3A.1/Cem, the vitrification process would have been more difficult to implement than the cement stabilization process. The vitrification process would have required fewer chemical reagents than the cement stabilization process, but larger amounts of energy (electricity). Vitrification would have allowed the re-processing of off-specification treated materials, unlike cement stabilization. However, the vitrification process equipment would have been more complex to construct and operate than that of the cement stabilization process. There is limited experience available for the types and quantities of the material from the silos and decant sump tank on which to base an assessment of the likely performance of the vitrification technology. The vitrification technology is not as widely available as the cement stabilization technology. Off-gas treatment is also an additional complexity with vitrification where delays could occur. However, operational experience has been gained as part of the structured RI/FS treatability studies (PNL and FEMP 1993) and vitrification pilot studies.

Alternatives 3A.1/Vit and 3A.1/Cem involved off-site transportation and disposal at the NTS. While technically straightforward, off-site transportation requires coordination efforts with a number of states located along the transportation route, as well as the State of Nevada. Demonstrated compliance with the NTS WAC would be required before shipping the Subunit A materials. The transportation of this material would also comply with the off-site acceptability amendment to CERCLA's implementing regulations, the NCP [58 FR 49200 (September 22, 1993)].

In summary, Alternative 3A.1/Cem would have been favored over Alternative 3A.1/Vit, based on relative overall implementation.

8074

Cost

The 1994 estimated, net present value costs for the Subunit A alternatives are provided in **Table F.5.2-2** and include a breakdown of capital and O&M costs. The 1994 net present value cost of Alternative 3A.1/Cem was approximately 67% more expensive than Alternative 3A.1/Vit, primarily due to the additional packaging, transportation, and disposal for the larger volume of cement-stabilized material.

F.5.2.1.3 Modifying Criteria

State Acceptance

The State of Ohio reviewed the preferred remedial alternative for Subunit A that was provided in the PP, and concurred with the selection of Alternative 3A.1/Vit. A letter from the OEPA conditionally approving the FS and PP for OU4 can be found in Appendix E of the OU4 ROD (EPA 1994).

Community Acceptance

DOE solicited input from the community on the preferred remedial alternative for Subunit A that was provided in the PP. Verbal comments received during the public meeting indicated support of the chosen remedial alternative. Written comments received during the public comment period were addressed in the responsiveness summary in Appendix C of the OU4 ROD (EPA 1994).

F.5.2.1.4 Subunit A Comparative Analysis Summary

Alternative 3A.1/Vit was identified as the preferred alternative because it would result in the permanent treatment and volume reduction of Subunit A material and it was cost-effective. It would have provided overall protection of human health and the environment with fewer uncertainties over the long-term.

F.5.2.2 Subunit B

F.5.2.2.1 Threshold Criteria

Subunit B alternatives would have employed the same removal, treatment, and disposal options as those for Subunit A materials. Many of the factors considered and discussed under the Subunit A analysis were identical for Subunit B. Therefore, this discussion makes frequent references to the information presented previously in **Section F.5.2.1**. Only those factors unique to remediation of the Subunit B material are emphasized. This approach is applied to the discussions under the primary balancing criteria as well.

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TABLE F. 5.2-2

OU4 REMEDIAL ALTERNATIVE COST SUMMARY (MILLION$)

ALTERNATIVE	CAPITAL	OPERATING & MAINTENANCE		TOTAL PRESENT WORTH COST
		SHORT-TERM (During Remediation)	LONG-TERM (Post Remediation)	
Subunit A - Silos 1 and 2 Contents				
OA - No Action	0	0	0	0
3A.1/Vit - Removal, Vitrification, Off-Site Disposal - Nevada Test Site	38.3	11.7	0	43.7
3A.1/Cem - Removal, Cement Stabilization, Off-Site Disposal - Nevada Test Site	71.8	11.7	0	73.1
Subunit B - Silo 3 Contents				
OB - No Action	0	0	0	0
2B/Vit - Removal, Vitrification, On-Property Disposal	25.2	4.9	3.2	28
2B/Cem - Removal, Cement Stabilization, On-Property Disposal	35.9	4.9	3.2	37.4
3B.1/Vit - Removal, Vitrification, Off-Site Disposal - Nevada Test Site	26.8	4.9	0	28
3B.1/Cem - Removal, Cement Stabilization, Off-Site Disposal - Nevada Test Site	36.8	4.1	0	36
4B - Removal, On-Property Disposal	21.8	1.1	3.2	22
Subunit C - Silos 1, 2, 3, and 4 Structures, Soils, and Debris				
0C - No Action	0	0	0	0
2C - Demolition, Removal, On-Property Disposal	36.3	0	3.6	34.3
3C.1 - Demolition, Removal, Off-Site Disposal - Nevada Test Site	83.6	0	0	75.5
3C.2 - Demolition, Removal, Off-Site Disposal - Permitted Commercial Facility	48.7	0	0	44

NOTES:
The accuracy of the cost estimates are between +50% and -30%.
Estimates of capital and operations and maintenance costs are expressed in terms of total costs. The total present worth costs are calculated from the total cost figures applying a discount rate of 7 percent and an operating and maintenance period of 30 years.

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The comparison of the Subunit B alternatives against the threshold criteria of overall protection of human health and the environment and compliance with ARARs is summarized below.

Overall Protection of Human Health and the Environment

As discussed in **Section F.5.2.1.1**, this evaluation assumed that the federal government would have continued to own the FEMP site. For a cleanup remedy to be considered protective, it should not result in any unacceptable risks to an expanded trespasser or an off-site farmer.

All alternatives, with the exception of the no-action alternative (0B), would have provided overall protection of human health and the environment. These alternatives would have eliminated, reduced, or controlled the health or environmental risks resulting from constituents in Subunit B materials. Except for Alternative 4B, the alternatives would have limited exposure to contaminants by removing the material and treating it through vitrification or cement stabilization. The treated material would have been disposed in an on-property, above-grade disposal vault for Alternative 2B or off-site at the NTS for Alternative 3B.1. Alternative 4B's protection was based on removal and disposal in an on-property, above-grade vault and institutional controls. All alternatives would have attained long-term effectiveness.

In summary, Alternatives 3B.1/Vit and 3B.1/Cem would have provided overall protection to the expanded trespasser and off-site farmer because they would have removed the Subunit B material from the FEMP site.

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Compliance with ARARs

With the exception of the no-action alternative, Subunit B alternatives would have complied with all pertinent ARARs. Under the no-action alternative, Silo 3 would have eventually failed, resulting in the release of cold metal oxides to the environment. This scenario would most likely have resulted in radiological releases to the air, soil, groundwater, and surface water (via stormwater runoff). For example, fate and transport modeling for this scenario indicated that the safe drinking water limits (MCLs in 40 CFR Part 141) would have been exceeded for uranium, and gross alpha and beta radiation.

For those alternatives that included on-property disposal, Alternative 4B was the least favorable on-property alternative because the material would not be treated.

In summary, Alternatives 2B/Vit, 2B/Cem, 3B.1/VIT, 3B.1/Cem, and 4B would have met all pertinent ARARs. Because of the uncertainty associated with demonstrating that the FEMP on-property disposal vault would have provided for the long-term protection of inadvertent intruders, Alternatives 3B.1/Vit and 3B.1/Cem were favored over 2B/Vit, 2B/Cem, and 4B.

F.5.2.2.2 Primary Balancing Criteria

Those alternatives that satisfied the threshold criteria comparative analysis were carried forward to the primary balancing criteria comparative analysis. Because Alternative 0B (No Action) did not satisfy either of the threshold criteria, it was not considered further in the analysis.

Long-Term Effectiveness and Permanence

All Subunit B alternatives would have ensured long-term protectiveness to human health and the environment. For all alternatives, projected FEMP site residual risks to viable receptors (off-site farmer and expanded trespasser) would have been less than 10^{-6} ILCR, and no non-carcinogenic effects (hazard index less than 0.2) would have been indicated for either receptor.

The characteristics of the treated material form (vitrification or cement stabilization) and the disposal options (on-property or off-site at the NTS) were similar to those discussed under long-term effectiveness for Subunit A material. Long-term environmental impacts were also the same as those considered for Subunit A.

In summary, Alternatives 3B.1/Vit and 3B.1/Cem provided a greater degree of long-term effectiveness than Alternatives 2B/Vit, 2B/Cem, and 4B.

Reduction of Toxicity, Mobility, or Volume through Treatment

Alternatives 2B/Vit and 3B.1/Vit would have used vitrification to treat the Subunit B material. This technology would have chemically bound the contaminants in a glass-like matrix, which would have significantly reduced contaminant mobility and material volume. Mobility would have been reduced since the contaminants would have been bound in the matrix and the volume of the treated material would have been approximately 62% of the untreated material volume.

Alternatives 2B/Cem and 3B.1/Cem would have used the cement stabilization process to treat the Subunit B material. This technology would have physically and chemically bound the constituents in a cement-like matrix, so the mobility of constituents (via leaching from) in this treated material would have been greatly reduced. However, the total volume of material would have increased by 55% as a result of adding the cement stabilizing and setting agents.

Alternative 4B would not have reduced toxicity, mobility, or volume because it did not include treatment. In summary, Alternatives 2B/Vit and 3B.1/Vit were favored over Alternatives 2B/Cem, 3B.1/Cem, and 4B because they would have generated a treated form with good resistance to leaching, and significantly reduced the volume of the Subunit B materials.

8074

Short-Term Effectiveness

For the Subunit B action alternatives, the various removal, treatment, and disposal activities would have resulted in increased short-term risks (compared to no action). The short-term effectiveness of removal operations was expected to be the same among all alternatives for Subunit B. There was some degree of uncertainty associated with controlling and treating the off-gases generated by the vitrification process.

The increased risks due to off-site transportation of the treated material to the NTS and the short-term environmental impacts associated with removal, treatment, and disposal were similar to those described in **Section F.5.2.1.2**. Alternative 4B provided the highest short-term effectiveness because no treatment was provided.

In summary, Alternative 4B was the favored alternative, and Alternatives 2B/Cem and 3B.1/Cem were favored over Alternatives 2B/Vit and 3B.1/Vit because of the uncertainty associated with off-gas control and treatment for the vitrification process.

Implementability

The removal and treatment activities for all Subunit B action alternatives could have been implemented with standard equipment, procedures, and readily available resources. Pneumatic removal would have been employed for the Subunit B materials and it is a standard technology that is typically reliable and uses readily available equipment. All other aspects of implementing the action alternatives for Subunit B were identical to those discussed for Subunit A under the implementability criterion in **Section F.5.2.1.2**.

In summary, Alternative 4B would have been favored and Alternatives 2B/Vit and 3B.1/Vit would have been the least favored, based on relative overall implementability.

Cost

The 1994 net present value costs for Subunit B Alternatives are provided in **Table F.5.2-2** and include a breakdown of capital and O&M costs.

Alternative 4B was the least expensive action alternative. The 1994 net present value costs of Alternatives 2B/Vit and 3B.1/Vit were approximately the same, and were about 6 million dollars higher than that of Alternative 4B. This was due to the treatment component of those alternatives not included in Alternative 4B. Alternatives 3B.1/Cem and 2B/Cem were approximately 30% and 34% more expensive, respectively, than Alternatives 3B.1/Vit and 2B/Vit, respectively. Alternative 3B.1/Cem was more expensive than Alternative 3B.1/Vit primarily due to the additional packaging, transportation, and disposal of the larger volume of cement-stabilized material.

F.5.2.2.3 Modifying Criteria

State Acceptance

The State of Ohio reviewed the preferred remedial alternative for Subunit B that was provided in the PP, and concurred with the selection of alternative 3B.1/Vit. A letter from the OEPA conditionally approving the FS and PP for OU4 can be found in Appendix E of the OU4 ROD (EPA 1994).

Community Acceptance

DOE solicited input from the community on the preferred remedial alternative for Subunit B that was provided in the PP. Verbal comments received during the public meeting indicated support of the chosen remedial alternative. Written comments received during the public comment period were addressed in the responsiveness summary in Appendix C of the OU4 ROD (EPA 1994).

F.5.2.2.4 Subunit B Comparative Analysis Summary

Alternative 3B.1/Vit was the preferred alternative because it was cost-effective and would have resulted in the permanent treatment and volume reduction of Subunit B materials. Alternative 3B.1/Vit would have provided overall protection of human health and the environment with fewer uncertainties over the long-term.

8074

F.5.2.3 Subunit C

F.5.2.3.1 Threshold Criteria

The analysis of the Subunit C alternatives against the threshold criteria of overall protection of human health and the environment, and compliance with ARARs is summarized below.

Overall Protection of Human Health and the Environment

Alternative 0C would not have provided adequate protection of human health and the environment. As discussed in **Section F.5.2.1.1**, evaluations were conducted for future land-uses with and without continued federal ownership. For a cleanup remedy to be considered protective, it could not result in any unacceptable risks to an expanded trespasser or an off-site farmer under the future land-use with continued federal ownership scenario, or an on-property farmer under the future land-use without continued federal ownership.

All of the action alternatives (Alternatives 2C, 3C.1, and 3C.2) would have limited exposure to constituents by decontaminating, demolishing, and removing the material to either an on-property, above-grade disposal facility or an off-site disposal facility, followed by excavation of the contaminated soils and placement of clean fill over residual contaminated subsurface soils. **Section F.6.2** presents and discusses the soil cleanup levels, all of which would have been protective to the expanded trespasser and off-site resident over the long-term. Short-term risks would have been higher for off-site disposal due to the increased risk of transportation accidents.

The basic difference among the action alternatives was the disposal option. On-property disposal (Alternative 2C) would have been in an above-grade disposal facility. Off-site disposal options included the NTS (Alternative 3C.1) and a permitted commercial disposal site (Alternative 3C.2).

The on-property, above-grade disposal facility would have been designed for a 1,000-year life with no active maintenance. Fate and transport modeling using conservative assumptions concluded that protectiveness would have been maintained over the long-term.

The NTS and the permitted commercial disposal facility would have incorporated engineering controls to ensure protectiveness. Both facilities are located in a climatic, demographic, and hydrogeologic setting that favors minimization of constituent migration to human or environmental receptors.

In summary, Alternatives 3C.1 and 3C.2 would have provided overall protectiveness because they would have removed the Subunit C excavated soils and debris from the FEMP site.

Compliance with ARARs

All alternatives, other than Alternative 0C (No Action) would have met all pertinent ARARs. Under the no-action alternative, constituents would most likely have continued to be released into the air, groundwater, and surface water. There would also have been a risk for direct contact with contaminated soil and exposure to direct radiation.

For Alternative 2C, an exemption to Ohio Administrative Code (OAC) rule 3745-27-07(B)(5) may have been granted on the basis of meeting certain technical requirements. Supporting technical data for the proposed location of the disposal facility on the FEMP site would need to have been developed to satisfy the requirements of OAC rule 3745-27-07(B)(5).

In summary, Alternatives 3C.1, and 3C.2 would have met all pertinent ARARs. Alternative 2C would have required a waiver of OAC rule 3745-27-07(B)(5) based on demonstration that it met certain technical requirements.

F.5.2.3.2 Primary Balancing Criteria

Those alternatives that satisfied the threshold criteria of compliance with ARARs and overall protection of human health and environment were carried forward to the primary balancing criteria comparative analysis. Because Alternative 0C (No Action) did not satisfy either of the threshold criteria, it was the only alternative not considered further in this analysis.

Long-Term Effectiveness and Permanence

All Subunit C alternatives would have ensured long-term protectiveness to human health and the environment. For all alternatives, projected FEMP site residual risks to viable receptors (off-site farmer and expanded trespasser) would have been less than 10^{-6} ILCR and no non-carcinogenic effects (hazard index less than 0.2) would have been indicated for either receptor. Although residual contamination would have remained in the OU4 study area, the level of risk from the contaminated soil would have been controlled by excavating soil that exceeded proposed cleanup levels, by placing clean soil over the excavated areas, and by providing appropriate access controls and deed restrictions.

Alternative 2C would have employed an on-property disposal facility designed to minimize leachate generation from water infiltration and contact with contaminated soil and debris. Fate and transport modeling using conservative assumptions demonstrated that both risk- and ARAR-based protective levels would have been maintained for the Great Miami Aquifer over the long-term.

Alternatives 3C.1 (NTS) and 3C.2 (permitted commercial disposal facility) would have provided long-term protectiveness because the residual soils and debris would have been removed from the FEMP site.

Following completion of remedial operations, impacted areas would have been restored; long-term environmental impacts were expected to be minor. Alternative 2C would have permanently committed approximately 4.7 hectares (11.6 acres) of land for the disposal facility.

In summary, Alternatives 3C.1 and 3C.2 would have provided a greater degree of long-term effectiveness than Alternative 2C.

Reduction of Toxicity, Mobility, or Volume through Treatment

Alternatives 2C, 3C.1, and 3C.2 would have isolated the material from the environment by containment. Treatment of the contaminated silos structures, berm material, or soils was not included in any of the alternatives, so no reduction in toxicity, mobility, or volume would have been achieved.

Short-Term Effectiveness

For all alternatives, the various demolition and removal activities would have resulted in increased short-term exposures compared to no action. Alternatives 3C.1 and 3C.2 would have posed additional risks to the public and workers associated with off-site shipment to the NTS or the permitted commercial disposal facility.

During the implementation of any of the action alternatives, the general public should not have been exposed to contaminants because of the distance from the work area, the very low levels of contamination, and the methods proposed to control emission dust during demolition and excavation. Potential short-term environmental impacts resulting from the implementation of Alternatives 2C, 3C.1, and 3C.2 included generation of fugitive dust, increased sediment in surface runoff, and disturbance and/or displacement of wildlife as a result of noise, dust, or human activity. Engineering controls would have been used to minimize these potential short-term impacts.

In summary, Alternative 2C was favored over Alternatives 3C.1 and 3C.2. The short-term risks to the public and workers for constructing the on-property disposal facility would have offset the increased risks to the public and workers associated with off-site transportation of the contaminated soils and debris.

8074

Implementability

Alternatives 2C, 3C.1, and 3C.2 would have employed the same decontamination, demolition, and excavation operations. With the exception of the remotely controlled operations proposed for decontaminating Silos 1, 2, and 3, all operations were standard construction activities that would have been easily implemented. The remote silos decontamination operations would have been used on the uncontaminated Silo 4 first in order to familiarize workers with the operation processes and identify any potential operational difficulties.

Alternative 2C involved on-property disposal facility construction, which would have employed standard construction services and materials. The off-site disposal alternatives (3C.1 and 3C.2) would have involved standard transportation practices for radioactive materials. Alternatives 3C.1 and 3C.2 would have been more administratively difficult to implement than Alternative 2C due to the coordination required with those states through which shipment would have passed to the off-site locations. Additional efforts would have been required to ensure that the Subunit C materials complied with criteria established by either the NTS or the permitted commercial disposal facility. Alternative 2C would have required coordination with the State of Ohio to ensure that all technical requirements for the on-property disposal facility were met.

In summary, Alternative 2C was favored over Alternatives 3C.1 and 3C.2 based on relative overall implementability.

Cost

The estimated 1994 net present value costs for Subunit C alternatives are provided in **Table F.5.2-1**, and include a breakdown of capital and O&M cost.

Alternative 2C, which includes on-property disposal, was the least expensive action alternative. Transportation to the NTS (Alternative 3C.1) or to a permitted commercial disposal facility (Alternative 3C.2) were both more expensive than constructing an on-property vault. However, the overall cost of disposal at a permitted commercial disposal facility was anticipated to be approximately 60% lower than the cost of disposal at a DOE-owned facility. This is primarily due to the packaging requirements of the DOE-owned facility. The commercial disposal facility accepts bulk shipment of material.

F.5.2.3.3 Modifying Criteria

State Acceptance

The State of Ohio reviewed the preferred remedial alternative for Subunit C that was provided in the PP, and concurred with the decision that the final disposition of the Subunit C contaminated soil and debris would be placed in abeyance to take full advantage of planned and in-progress waste minimization treatment processes. The contaminated soil and debris would have either been processed through the selected OU5 and OU3 remedies identified by the respective OU5 and OU3 RODs (FEMP 1996c, a) or placed in interim storage to await the finalization of the disposal decisions for soils and debris under OU5 and OU3. For the sole purpose of evaluating the performance of an overall preferred remedial alternative for OU4, the State of Ohio concurred with the identification of Alternative 2C as the preferred alternative for Subunit C.

Community Acceptance

DOE solicited input from the community on the preferred remedial alternative for Subunit C that was provided in the PP. Verbal comments received during the public meeting indicated support of the chosen remedial alternative. Written comments received during the public comment period were addressed in the responsiveness summary in Appendix C of the OU4 ROD (EPA 1994).

8074

F.5.2.3.4 Subunit C Comparative Analysis Summary

Alternatives 2C and 3C.2 were relatively equal, as both would have been cost-effective, and would have provided overall protection of human health and the environment both in the short-term and the long-term. For evaluation purposes only, Alternative 2C was identified as the preferred alternative for Subunit C. The decision regarding the final disposition of the OU4 Subunit C contaminated soil and debris was placed in abeyance in order to take full advantage of planned and in-progress waste minimization treatment processes. The contaminated soil and debris would have either been processed through the selected OU5 and OU3 remedies identified by the respective OU5 and OU3 RODs (FEMP 1996 c,a) or placed in interim storage to await the finalization of the disposal decisions for soils and debris under OU5 and OU3.

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F.6.0 SELECTED REMEDY

On the basis of the evaluation of final alternatives, the selected remedy to be used at OU4 at the FEMP was a compilation of the selected alternatives from each subunit; i.e., Alternatives 3A.1/Vit - Removal, Vitrification, and Off-site Disposal at the NTS; 3B.1/Vit - Removal, Vitrification, and Off-site Disposal at the NTS; and 2C - Demolition, Removal and On-Property Disposal. The selected remedy would have satisfied the requirements of both CERCLA and NEPA for the protection of human health and the environment; complied with all regulatory requirements; remained cost-effective; utilized permanent solutions to the maximum extent practicable; and utilized treatment as a principal element of the response. The discussions presented here are based on the information used for detailed analysis of alternatives during the FS for OU4 (FEMP 1994d). Actual methods used during the implementation of the remedy were determined during detailed engineering design described in the remedial design and may differ from the descriptions provided below.

F.6.1 Key Components

The major components of the selected remedy consisted of the following:

- Removal of the contents of Silos 1, 2, and 3 (K-65 material and cold metal oxides) and the decant sump tank sludge.
- Vitrification (glassification) to stabilize the material and sludges removed from the silos and decant sump tank.
- Off-site shipment for disposal at the NTS of the vitrified contents of Silos 1, 2, 3, and the decant sump tank.
- Demolition of Silos 1-4 and decontamination of the gross and loose contamination, to the extent practicable, of the concrete rubble, piping, and other generated construction debris.
- Removal of the earthen berms and excavation of contaminated soils within the boundary of OU4, to achieve proposed remediation levels. Placement of clean backfill following excavation (i.e. structure, foundations or large excavations which affect local topography).

- Segregation of non-contaminated soils and demolition of the vitrification treatment unit and associated facilities after use. Decontamination or recycling of debris prior to disposition.

- On-property interim storage of excavated contaminated soils and remaining contaminated debris in a manner consistent with the approved *Work Plan for FEMP Removal Action No. 17 - Improved Storage of Soil and Debris* (DOE 1996).

- Continued access controls and maintenance, and monitoring of the stored wastes inventories.

- Institutional controls of the OU4 area such as deed and land-use restrictions.

- Potential additional treatment of stored OU4 soil and debris using OU3 and OU5 waste treatment systems.

- Pumping and treatment of any contaminated perched groundwater encountered during remedial activities.

- Disposal of remaining OU4 contaminated soils and debris consistent with the selected remedies for OU5 and OU3, respectively.

F.6.1.1 Removal of Silos 1, 2 and 3, and Decant Sump Tank Contents

The K-65 material in Silos 1 and 2, the cold metal oxides in Silo 3, and the sludge in the decant sump tank were to be removed. Approximately 6,796 m^3 (8,890 yd^3) of K-65 material from Silos 1 and 2, along with 3,785 L (1,000 gallons) of sludge from the decant sump, and 3,890 m^3 (5,088 yd^3) of cold metal oxides from Silo 3 were to be removed. The silos and the decant sump were to be equipped with an off-gas treatment system(s) designed to handle radon emissions generated during removal.

F.6.1.2 Vitrification of Silos 1, 2 and 3, and Decant Sump Tank Contents

The major treatment component of the selected remedy consisted of a vitrification system to remediate the materials from Silos 1, 2, and 3 and the decant sump tank. The material removed from the silos and the decant sump would have been transferred to a vitrification processing facility constructed on-site. The material would have been thickened as necessary for vitrification and then mixed with glass forming agents and placed into a vitrification melter. The vitrification process converts the contents of the silos and the decant sump into a very durable glass form that is extremely resistant to the effects of time and weather. The process destroys organic contaminants and the vitrified wasteform significantly reduces both the tendency of the material to leach contaminants into the environment and the emanation rate of radon gas. The direct radiation associated with the treated material remains relatively unchanged from the untreated form of the material. Off-gases produced as a result of the high operating temperatures of the vitrification melter would be routed through an off-gas treatment system designed to remove solid particles and treat gaseous emissions such as radon. Treatability studies, conducted on a small scale as part of the RI/FS, indicated that the volume of vitrified material requiring disposal could be reduced by as much as 50% of the volume of untreated material removed from the silos and the decant sump (PNL and FEMP 1993).

F.6.1.3 Off-Site Shipment and Disposal of Treated Material

Approximately 2,770 m^3 (3,623 yd^3) of vitrified material from Silos 1 and 2 and the decant sump, along with approximately 1,471 m^3 (1,923 yd^3) of vitrified material from Silo 3, would have been packaged and transported to the NTS for disposal.

The NTS is a DOE owned and operated disposal site located near Las Vegas, Nevada. The treated material was to be either transported by rail to a destination near to or north of Las Vegas, Nevada or directly to the NTS by truck. If by rail, it would have been necessary to transfer the disposal containers carrying the treated material to trucks for transportation over roads to the NTS.

The NTS is located approximately 3,219 kilometers (km) [2,000 miles (mi)] from the FEMP. The FEMP has an approved NTS waste shipment and certification program, for low-level radioactive wastes, that is periodically audited by the NTS. Technical oversight of the waste management activities at the NTS is provided by the State of Nevada. This existing waste shipment disposal program was to be modified and amended to include the shipment and disposal of treated OU4 wastes.

All off-site shipments must comply with the DOT regulations found in 49 CFR Parts 171 - 178 pertaining to transportation of hazardous and radioactive materials. Additionally, all the NTS waste acceptance requirements must be satisfied. The off-site transport of materials also needs to comply with the off-site acceptability requirement under CERCLA.

The remedy specified off-site disposal of vitrified contents of Silos 1, 2 and 3 at the NTS. At the time of the signing of the ROD, the U.S. Department of Energy - Nevada Operations Office (DOE-NV) was in the process of preparing a site-wide EIS under NEPA for the NTS (DOE 1996). Shipments of waste generated from the cleanup of OU4 were not proposed to begin until after the expected completion of the NTS site-wide EIS.

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The *Final Environmental Impact Statement for the Nevada Test Site and Off-site Locations in the State of Nevada* was completed by DOE-NV in August 1996. As part of the EIS, a NEPA ROD was developed to specify which alternatives were considered environmentally preferable. The NEPA ROD associated with the NTS site-wide EIS recommended that a combination of three alternatives be implemented: Alternative 1 - Continue Current Operations (no action); Alternative 2 - Expanded Use; and, Alternative 3 - Alternative Use of Withdrawn Lands. These preferred alternatives represent a continuation of the multipurpose, multi-program use of the NTS site and further represents a continuation and diversification of the DOE-NV and interagency programs and operations at the NTS. It includes support for ongoing DOE-NV programs such as waste management and environmental restoration activities. This alternative would also make the NTS more available to both public and private institutions for demonstrating new technologies, and would include establishing educational tour routes on the NTS and promoting the concept of creating a nuclear era museum.

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F.6.1.4 Demolition and Decontamination of Structures

Demolition of the silos structures was to proceed with the systematic removal and dismantling of the Silos 1, 2, 3, and 4 domes, walls, floor slabs and footers. After removal of the silos contents and before Silos 1, 2, 3, and 4 were demolished, loose interior material and loose concrete would have been removed from the surfaces of the silos and transferred to the vitrification facility to be vitrified. Also, contaminated concrete from Silos 1 and 2, which exhibited highly elevated direct radiation fields, would have been separated from the other OU4 concrete and construction debris and prepared for processing in the vitrification facility. Contaminated piping, steel fencing, and other non-porous materials would have been decontaminated to facilitate segregation for possible unrestricted release or disposal in a permitted commercial landfill. Only non-porous materials attaining the unrestricted use, free release criteria defined in DOE Order 5400.5 or any subsequent DOE order or amendment or final promulgated regulation addressing free release, were to be released from the site as uncontaminated.

F.6.1.5 Demolition and Decontamination of Other OU4 Structures

The existing RTS, Drum Handling Building pad, sump lift station foundation, concrete pipe trench, and decant sump tank were to be removed and decontaminated. Additionally, all vitrification facilities constructed and equipment installed and used for the implementation of this remedy were to be disassembled, decontaminated (if necessary), and dispositioned. Conventional decontamination and decommission techniques and equipment would have been employed for these facilities. Uncontaminated materials attaining the unrestricted use, free release criteria defined in DOE Order 5400.5 were to be released from the site for unrestricted use or for disposal in a commercial landfill.

F.6.1.6 Disposition of Demolished Structures and Debris

F-8074

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

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 WAC for debris were established in the OU3 ROD. The 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.

Consistent with the OU4 ROD (EPA 1994), Section 2.5.2 of the WAC Attainment Plan specifically excludes "contaminated concrete from Silos 1 and 2 that exhibits a highly elevated direct radiation field" from disposal in the OSDF. Although OU4 debris was not specifically included in the OU3 WAC calculations, the WAC Attainment Plan indicates that the remainder of the debris from OU4 is acceptable for disposal in the OSDF provided that it meets the appropriate physical and radiological WAC.

F.6.1.6.3 Development of OU3 WAC for Debris

The WAC for OU3 debris were developed through screening and subsequent modeling of COCs in the OU3 RI/FS (FEMP 1996b). The first step, travel time screening, involved estimation of the time required for a potential constituent of concern (COC) to migrate through the OSDF and reach the aquifer. This calculation, originally conducted for the OU5 FS, is independent of the source term, or concentration, of a particular COC in the debris. Potential COCs estimated not to reach the aquifer within either 1000 years or 30 half-lives were screened out and not carried forward for transport modeling. Those COCs not screened out were modeled to determine WAC limits. Based upon the transport modeling, limits were developed for technetium-99 and uranium.

The OU3 RI/FS modeling concluded that "because source-term estimates are significantly lower (approximately 15 times) than the allowable mass for these materials, and because of the inherent conservatism in the calculations, no material-specific uranium WAC need to be established as a performance mechanism" (OU3 RI/FS, Section G.4.5.1). Based upon this analysis, the OU3 ROD concluded that all uranium-contaminated debris, with the exception of those with visually-discernable process materials, can be safely disposed in the OSDF. A visual inspection process was, therefore, adopted as the WAC attainment mechanism for uranium-contaminated debris.

000178

OU3 RI/FS modeling resulted in a technetium mass limit of 105 grams as the total amount of technetium to be contained in contaminated debris disposed in the OSDF. The OU3 ROD (FEMP 1996a) specifies that selected technetium-contaminated materials (acid brick, process residues, product and special materials) are excluded from OSDF disposal, and specifies that concrete from selected process-area locations must be scabbled to prescribed depths. Calculations indicate that these measures will reduce the amount of technetium-99 going to the OSDF from OU3 debris to 59 grams (56% of the 105-gram limit).

While technetium-99 is the primary radiological COC in determining disposal of OU3 debris, the predominant COCs in Silos 1 and 2 debris are Pb-210, Ac-227, and Ra-226. These radionuclides are present in the Silos 1 and 2 material at significantly higher levels than in the OU3 material evaluated in determining the OSDF WAC. Due to the high radium content of the Silos 1 and 2 material, radon flux from the debris is also a concern.

Lead-210 and Ra-226 were evaluated, and screened out, in the OU5 travel-time screening presented in Table G-3 of the OU3 RI/FS. Actinium-227 was not specifically evaluated in the travel-time screening. Comparison of the properties of actinium (solubility, half-life) with those of the radionuclides evaluated in the travel-time screening indicates, however, that the travel time for actinium would be greater than the 1,000-year threshold.

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Although the source term resulting from disposal of debris from the silos was not specifically evaluated during development of the OU3 debris WAC, the OU5 travel-time screening indicates that WAC limits are not required for the predominant radiological COCs present in Silos 1, 2, and 3 materials. Further, as documented in the WAC Attainment Plan, the OU4 debris is not a potential source of technetium-99 and would not, therefore, cause a significant erosion of the 46 gram "buffer" between the estimated OU3 technetium source term and the 105-gram limit. Therefore, the analysis documented in the OU3 RI/FS and ROD, as well as the evaluation of the OSDF design, supports the application of the OU3 criteria to disposal of the silos debris. In addition, examination of the cover system specified in the OSDF design indicates that sufficient radon attenuation would be provided so that radon flux from silos debris disposed in the OSDF would meet regulatory requirements.

As stated previously, the OSDF WAC Attainment Plan specifies that concrete from Silos 1 and 2 which exhibits a "highly elevated direct radiation field" may not be disposed in the OSDF. Application of this criterion requires a definitive threshold criterion capable of being implemented in the field using typical radiological survey techniques.

F.6.1.6.4 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.

000180

Demolition and removal of OU4 structures and facilities will proceed as described above. OU4 rubble and debris will be dispositioned according to the selected remedy identified in the OU3 ROD.

F.6.1.7 Soil Removal

After demolition of the silos, the surface and subsurface soils within the boundary of OU4 were to be excavated to attain required remediation levels for each of the COCs. These soil remediation levels were considered preliminary until final soil remediation levels could be established through the OU5 ROD (FEMP 1996c). As indicated earlier, OU5 has site-wide responsibility for soil cleanup. Also, the anticipated volume of soil to be removed from OU4 will be less than 1% of the anticipated volume of soil to be remediated for the entire site. The surface and subsurface soils within OU4 were to be excavated to achieve the preliminary remediation levels presented and discussed in **Section F.6.2**. These OU4 soil remedial levels were based upon information available at the time of preparation of the 1994 ROD, from the OU5 RI/FS. In the event that the Operable Unit 5 ROD (FEMP 1996c) determined that lower soil remediation levels were required, further remedial action was to be conducted on the OU4 residual soils to achieve the lower remediation levels for those COCs affected.

Soils exhibiting elevated direct radiation levels (i.e., potentially contaminated soils beneath Silos 1 and 2) were to be segregated from other soils and transported to the vitrification facility for processing. Following excavation, the affected areas were to be returned to original grade with the placement of clean backfill and revegetated to control erosion.

F.6.1.8 Soil Disposition

The selected remedy as defined under Alternative 2C specified on-property disposal for OU4 contaminated soils. However, this final action was held in abeyance until a site-wide decision was reached in the OU5 ROD (FEMP 1996c) for the final disposal of contaminated soils. The final decision on disposal of contaminated soils generated from OU4 was to be determined as part of the ROD for OU5. The OU4 soils were to be managed consistent with the disposal remedy put forth in the OU5 ROD for contaminated soils. In the event that unforeseen circumstances precluded the integration of OU4 contaminated soils into the OU5 disposal decision, the final disposal decision for OU4 contaminated soils was to 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 final disposal option for OU4 contaminated soils. A ROD amendment to the OU4 ROD (EPA 1994) would not be necessary in the event that the OU5 remedy for contaminated soils could be feasibly implemented by OU4.

Holding the OU4 final disposal decision in abeyance fostered an integrated site-wide disposal approach for contaminated soils. The largest volume of contaminated soils from the site would be generated within OU5, making it more appropriate to fully develop the final disposal option for contaminated soil through the OU5 ROD. Additionally, OU4 would be able to take advantage of any applicable waste minimization initiatives developed for contaminated soils under the OU5 ROD.

Excavation and removal of OU4 contaminated soils would have proceeded as described above. OU4 contaminated soils would have been disposed in accordance with the selected remedy identified in the OU5 ROD for soils. Contaminated soils generated before finalization of the OU5 ROD were to be placed in interim storage to await finalization of the disposal decision for contaminated soils under OU5. The management of OU4 contaminated soils would have included measures to ensure future identification and retrieval of these wastes for final disposition.

000182

8074

Water Treatment

Wastewater generated as a result of this selected remedy along with water removed from the decant sump tank, Silo 4 (if any), and any contaminated perched water encountered during remediation would have been treated at the FEMP AWWT prior to discharge. In accordance with the ACA, groundwater cleanup would be handled by OU5. OU4 would only have handled the cleanup of perched water encountered during implementation of the selected remedy.

F.6.2 Soil Cleanup Criteria

After demolition of the silos, the surface and subsurface soils within the OU4 boundary were to be excavated to attain required remediation levels for each of the COCs. These soil remediation levels were preliminary until final soil remediation levels could be established through the OU5 ROD. In the event that the OU5 ROD determined that lower soil remediation levels were required, further remedial action would be conducted on the OU4 residual soils to achieve the lower remediation levels for those COCs affected.

F.6.2.1 Land-use and Receptor Description

Preliminary remediation levels for soil cleanup were developed for an expanded trespasser receptor under a future land-use with continued federal ownership to represent post remediation conditions at OU4 and, therefore, provide the basis for establishing cleanup levels.

The future land-use with continued federal ownership scenario represented a government reserve that would remain under U. S. government control with no future development intended. Active access controls currently in place at the FEMP site (i.e. fencing, security, access control, signs, etc.) would have been discontinued, but the federal government would maintain the right to preclude site development through deed restrictions. This land-use scenario was not included in the Baseline Risk Assessment. It was developed in a part of the FS for OU4 to facilitate evaluation of long-term risks with continued land-use restrictions. In addition to deed and land development restrictions, fences would be erected and equipped with signs posted to prohibit trespassing.

The expanded trespasser receptor was developed to represent an adult and/or child that visits the site despite restrictions imposed under continued federal ownership. The possible activities of this receptor included hiking, roaming, bird watching, and other similar activities. An expanded trespasser may be exposed to OU4 residual contaminants through the following pathways:

- Inhalation of fugitive dust, volatile organic compounds, and radon;
- Incidental ingestion of soil;
- Dermal contact with contaminants in soil; and
- External radiation exposure from radionuclides in soil.

F.6.2.2 Preliminary Remediation Levels

Tables F.6.2-2 and **F.6.2-3** provide remediation levels for soil cleanup and the estimated risk to affected receptors from the residual contaminants left in the soils. Specific details on the development of these preliminary remediation levels are provided in the FS Report for OU4 (FEMP 1994d).

000184

As mentioned earlier, the future land-use scenario for OU4 was as a government reserve with continued federal ownership. The on-property receptor of concern under this scenario was an expanded trespasser. Cancer risks and chemical hazard to the expanded trespasser, from residual contaminants, are presented in **Tables F.6.2-2** and **F.6.2-3**. For comparison, cancer risks and chemical hazard to an on-property farmer under a future land-use scenario without federal ownership are also presented. Proposed remediation goals based on an ILCR of 10^{-6} and an HI of 0.2 were developed in the FS. These goals, presented in **Tables F.6.2-2** and **F.6.2-3** for the expanded trespasser, represented allowable incremental concentrations above background for these COCs based on targets of a 10^{-6} incremental risk and a hazard index of 0.2.

For radionuclide COCs, the proposed remediation goal was added to the background concentration to derive the preliminary remediation level. Based on the contaminant concentrations found in OU4 soils, preliminary remediation levels were not required for non-radionuclide contaminants as indicated in **Table F.6.2-3**.

<END OF PAGE>

000186

TABLE F.6.2-1
PRELIMINARY REMEDIATION LEVELS IN SOILS - RADIONUCLIDES

Constituent of Concern	Expanded Trespasser 10^{-6} ILCR PRG pCi/g	Background (95th percentile) pCi/g	ARAR Target pCi/g	Max. Detected Soil Concentration, pCi/g		Proposed Remediation Level[a] pCi/g	ILCR above background to an Expanded Trespasser from Proposed Remediation Level[b]
				Surface	Subsurface		
Pb-210 +2 progeny	77	1.33	NA	4.5	101	78	1.0×10^{-6}
Ra-226 +5 progeny	0.37	1.45	5 (top 6" soil) 15 (max. below 6")	88	206	2	1.0×10^{-6}
Ra-228 +1 progeny	0.77	1.19	NA	0.48	1.24	2	1.0×10^{-6}
Sr-90 +1 progeny	1420	ND	NA	1.8	0.8	NR	$< 1 \times 10^{-6}$
Tc-99	38700	ND	NA	3.6	3.6	NR	$< 1 \times 10^{-6}$
Th-228	0.4	1.43	NA	2.9	1.3	2	1.0×10^{-6}
U-238 +2 progeny	59	1.22	NA	37	53	60	1.0×10^{-6}

Notes:
a) Sum of backround and PRG.
b) Includes the direct radiation, soil ingestion, and inhalation pathways.
NA Not Available
NR No Remediation Required

TABLE F.6.2-2
PRELIMINARY REMEDIATION LEVELS IN SOILS - CHEMICALS

Constituent of Concern	Expanded Trespasser HI = 0.2 PRG mg/kg	Expanded Trespasser 10^{-6} ILCR PRG mg/kg	Background (95th percentile) mg/kg	ARAR Target mg/kg	Max. Detected Soil Concentration, mg/kg		Proposed Remediation Levels mg/kg	HI to an Expanded Trespasser from Proposed Remediation Levels	Risk to an Expanded Trespasser from Proposed Remediation Level*
					Surface	Sub surface			
Antimony	31	N/A	7.7	NA	32	32	NR	0.2	N/A
Arsenic	510	23	8.45	NA	10	12	NR	N/A	$< 1x10^{-6}$
Barium	>10000	N/A	91.3	NA	112	142	NR	<.1	N/A
Cadmium	26	N/A	0.82	NA	6	7	NR	<.1	N/A
Chromium(III)	NA	N/A	15.5	NA	23	25	NR	<.1	N/A
Molybdenum	930	N/A	2.6	NA	25	30	NR	<.1	N/A
Nickel	8300	N/A	20.9	NA	39	39	NR	<.1	N/A
Silver	130	N/A	2.6	NA	10	18	NR	<.1	N/A
Thallium	31	N/A	0.58	NA	0.5	0.5	NR	<.1	N/A
Vanadium	1700	N/A	30.4	NA	28	33	NR	<.1	N/A
Zinc	>10000	N/A	62.2	NA	65	67	NR	<.1	N/A

F-8074
000187

000188

TABLE F.6.2-3 (continued)

Constituent of Concern	Expanded Trespasser HI = 0.2 PRG mg/kg	Expanded Trespasser 10^{-6} ILCR PRG mg/kg	Background (95th percentile) mg/kg	ARAR Target mg/kg	Max. Detected Soil Concentration, mg/kg		Proposed Remediation Levels mg/kg	HI to an Expanded Trespasser from Proposed Remediation Levels	Risk to an Expanded Trespasser from Proposed Remediation Level[a]
					Surface	Sub surface			
Benzo(a)anthracene	NA	61	ND	NA	4.7	ND	NR	N/A	$<1x10^{-6}$
Benzo(a)pyrene	NA	8.8	ND	NA	5.2	ND	NR	N/A	$<1x10^{-6}$
Benzo(b)fluoranthene	NA	72	ND	NA	9.7	ND	NR	N/A	$<1x10^{-6}$
Chrysene	NA	2000	ND	NA	3.5	ND	NR	N/A	$<1x10^{-6}$
Dibenzo(a,h)anthracene	NA	7.9	ND	NA	0.9	ND	NR	N/A	$<1x10^{-6}$
Indeno(1,2,3-cd)pyrene	NA	32	ND	NA	4.2	ND	NR	N/A	$<1x10^{-6}$

[a]Includes the direct radiation, soil ingestion, and inhalation pathways.
NA = Not Available.
N/A = Not Applicable.
ND = Not Detected.
NR = No Remediation Required.

The clean-up levels presented in **Tables F.6.2-2** and **F.6.2-3** were preliminary. The development of final soil clean-up levels for OU4 was addressed in the OU5 ROD (FEMP 1996c). These final clean-up levels would be consistent with the overall site approach for the development of soil clean-up levels as approved by the EPA.

In those cases where a target concentration level specified by an ARAR was less than the proposed remedial level, the ARAR level was adopted as the remediation level. Remediation would be required for COCs present in the surface and subsurface soil at higher concentrations than the preliminary remediation level..

Based on the preliminary remediation levels, the COCs driving soil cleanup were Pb-210 and Ra-226. Soil remediation targeted at achieving the preliminary remediation levels for Pb-210 and Ra-226 would generate the largest volume of excavated soils.

As stated previously, the remediation levels presented in the OU4 ROD were preliminary pending finalization of soil clean-up levels in the OU5 ROD. The OU5 ROD was finalized in December 1995 with the final remediation levels for COCs associated with the site's contaminated soil. The final remediation levels for COCs associated with contaminated soil in the area of the silos is presented in **Table F.6.2-4**.

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TABLE F.6.2-3
FINAL REMEDIATION LEVELS FOR SOILS[A]

Constituent	On-Property Final Remediation Level
Radionuclides (pCi/g)	
Lead-210 + 2d	38
Radium-226 + 8d	1.7
Radium-228 + 1d	1.8
Strontium-90 + 1d	14
Technetium-99	30
Thorium-228 + 7d	1.7
Uranium, total (K_1 = 325 L/Kg[b])(ppm)	82
Uranium, total (K_1 = 15 L/Kg)(ppm)	20
Chemicals (mg/Kg)	
Antimony	96
Arsenic	12
Barium	68,000
Benzo(a)anthracene	20
Benzo(a)pyrene	2
Benzo(b)fluoranthene	20
Cadmium	82
Chromium (III)	NR[c]
Chromium (VI)	300
Chrysene	2,000
Dibenzo(a,b)anthracene	20
Indeno(1,2,3-cd)pyrene	20
Molybdenum	2,900
Nickel	15,000
Silver	29,000
Thallium	91
Vanadium	5,100
Zinc	120,000

[a] Information referenced from Table 9-3 of the OU5 ROD, December 15, 1995.
[b] K_1 = leaching coefficient.
[c] No remediation required.

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Based on the final remediation levels, Pb-210 and Ra-226 are still the COCs driving soil cleanup in the area of the silos. The final remediation levels for uranium are presented in both leachable (K_1 = 15 L/Kg) and relatively nonleachable (K_1 = 325 L/Kg) forms. For soil exhibiting less leachable forms of uranium, the final remediation level is 82 ppm of uranium. However, an ALARA goal of 50 ppm of uranium in soil has been established for the less leachable form of uranium. The FEMP will apply available hand-held instruments to help guide excavation and assist in identifying any isolated areas of higher contamination to help within this ALARA goal.

F.6.3 Measures to Control Environmental Impacts

All practical measures were to be employed at the FEMP site to minimize environmental impacts during the implementation of the OU4 Remedial Action. In accordance with DOE regulations for implementing the NEPA (10 CFR Part 1021), DOE factored environmental impacts into the decision making process for the OU4 Remedial Action.

Measures to control environmental impacts were identified in the *Operable Unit 4 Feasibility Study/Proposed Plan - Draft Environmental Impact Statement (FS/PP - DEIS)* (FEMP 1993c) and implemented during remedial design and remedial action to minimize impacts to on-property natural resources (e.g., wildlife and wildlife habitat, cultural resources, wetlands, surface water, groundwater). OU4 remedial activities would not have impacted floodplain areas at the FEMP. The 100- and 500-year floodplain of Paddys Run is located near the silos and associated support facilities. Direct physical impact to the floodplain would not have occurred; however, engineering controls were implemented to eliminate any indirect impact such as runoff and sediment deposition to the floodplain. Changes in flood elevation would not occur. The following provides a discussion of the measures to have been taken to minimize impacts to the environment on and adjacent to the FEMP Site.

Excavation activities and the construction and operation of the various support facilities (e.g., waste processing facility and storage facility) would have resulted in the disturbance of 1.0 hectare (ha) (2.5 acres) of terrestrial and managed field habitat and potential increased erosion and sediment loads to surface water; i.e., Paddys Run. However, appropriate engineering controls such as silt fences, vegetative cover, and runoff control systems were to be utilized to minimize runoff to Paddys Run and its associated aquatic habitat, including the state-threatened Sloan's crayfish (*orconectes sloanii*). In addition, appropriate high efficiency particulate air (HEPA) filtration systems were to be utilized during operation of the vitrification facility to minimize the potential for increased emissions to the ambient air and potential impacts to surrounding riparian habitat.

Groundwater, surface water, and air monitoring were to be performed before, during, and after remedial activities. If adverse effects were detected in any of these environmental media, work was to be immediately stopped until the effects were controlled and/or the appropriate response actions executed.

The selected remedy for OU4 included the removal of the contaminated surface soil from the entire OU4 area and replacement with clean fill material. OU4 soils will be remediated in accordance with the final remediation levels (FRLs) approved in the OU5 ROD (FEMP 1996c). Because the contact of ecological receptors was limited (near background levels) to surface soil and surface waters, residual ecological risks associated with the OU4 preferred alternative would have been indistinguishable from those risks posed by background levels in the soil.

<END OF SECTION>

F.7.0 STATUTORY DETERMINATIONS

In accordance with the statutory requirements of Section 121 of CERCLA, as amended, remedial actions taken pursuant to Sections 104 and 106 must satisfy the following:

- Be protective of human health and the environment.
- Comply with all ARARs established under federal and state environmental laws (or justify a waiver).
- Be cost-effective.
- Utilize permanent solutions and alternative technologies or recovery technologies to the maximum extent practicable.
- Satisfy the statutory preference for remedies that utilize treatment and also significantly reduce the toxicity, mobility, and volume of the hazardous substances, pollutants, or contaminants.

In addition, CERCLA requires five-year reviews to determine if adequate protection of human health and the environment is being maintained where remedial actions result in hazardous substances remaining on-site above health-based levels. A discussion is provided below on how the selected response actions for OU4 satisfied these statutory requirements.

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F.7.1 Protection of Human Health and the Environment

The selected remedy achieved the requirement of being protective of human health and the environment by: (1) removing the sources of contamination, (2) treating and stabilizing the materials giving rise to the principal threats from OU4, (3) disposing of treated materials at an off-site location which provided the appropriate level of protectiveness, and (4) remediating contaminated soils and debris to protective levels. The contents of Silos 1, 2, and 3 and the Decant Sump Tank were to be removed and treated through a vitrification process and disposed at the NTS. Vitrification would stabilize these materials and inhibit leaching of contaminants to the environment upon disposal. All silos structures and other facilities would be removed from OU4 and disposed of in a manner consistent with the ROD for OU3 (FEMP 1996a). Contaminated soil would also have been removed and disposed in a manner consistent with the OU5 ROD (FEMP 1996c).

Baseline cancer risks from 1994 conditions exceeded the 10^{-4} to 10^{-6} acceptable risk range. Under 1994 conditions, the dominant risk was 5×10^{-3} to the trespassing child. Under the future land-use scenario of continued federal ownership and the expanded trespasser receptor, the residual cancer risk from OU4 would have been reduced to less than 1×10^{-6}. There were no short-term threats associated with the selected remedy that could not be readily controlled. In addition, no adverse cross-media impacts were expected from the remedy.

F.7.2 Compliance with Legally Applicable or Relevant and Appropriate Requirements

F.7.2.1 OU4 ROD ARAR Analysis

In accordance with Section 121 of CERCLA, the selected remedy would achieve a standard or level of control consistent with all federal and State of Ohio ARARs and TBCs. The selected remedy would also have been performed in accordance with all pertinent DOE Orders as well as other requirements. Appendix B of the OU4 ROD (EPA 1994) provides a listing of the chemical-, action-, and location-specific ARARs and TBCs that are invoked by this remedy.

Removal, treatment by vitrification, and shipment for off-site disposal of silos material would be conducted in accordance with the ARARs identified in the OU4 ROD. Disposition of rubble and debris from OU4 would be determined by the ROD for OU3 (FEMP 1996a), and conducted in accordance with the ARARs identified in that ROD; similarly, disposition of soils from OU4 would be determined by the ROD for OU5 (FEMP 1996c) and conducted in accordance with ARARs established in that ROD. Any interim storage of rubble and debris or soils, prior to final disposition under the RODs for OU3 and OU5, respectively, would be in accordance with ARARs identified in the OU4 ROD, pertinent DOE orders, and applicable site procedures.

Although RCRA is cited as an ARAR for remediation of OU4, the silos material destined for remediation are by-product material as defined under Section 11 (e)(2) of the AEA of 1954, and as such, are excluded from RCRA regulation [40 CFR Part 261.4(a)(4)]. By-product material, as defined by the AEA, includes tailings or wastes produced by the extraction or concentration of uranium and thorium from any ore processed primarily for its source material content (42 U.S.C. 2014).

Since the silos material is excluded from regulation as solid or hazardous waste, the requirements under RCRA are not applicable to OU4 remedial actions. However, analytical data from Silos 1, 2, and 3 material exceed toxicity characteristic levels for various toxicity characteristic metals under RCRA. Because the material is sufficiently similar to hazardous waste regulated by RCRA and some RCRA requirements are appropriate for the circumstances of its release or potential release, certain substantive requirements of RCRA are relevant and appropriate for management of the material, and are included in the table of ARARs.

The NCP only requires attainment or waiver of ARARs that become effective after a ROD is signed when it is determined to be "necessary to ensure that the remedy is protective of human health and the environment" [40 CFR Part 300.430(f)(1)(ii)(B)(1)].

F.7.2.2 Post-OU4 ROD ARAR Analysis

In cases where a ROD Amendment adds a new component of the remedy not described in the original ROD, the new component of the remedy must attain or waive any ARAR promulgated at the time the ROD Amendment, which added the new component to the remedy, was signed [40 CFR Part 300.430(f)(1)(ii)(B)(2)].

This revised Silos 1 and 2 FS, and subsequent PP and ROD Amendment, are being prepared in order to evaluate alternatives for implementing the remedial component of the selected remedy for Silos 1 and 2. The rationale driving this reevaluation is projected cost increases for implementation of the original remediation method. The revised FS/PP and ROD Amendment will not add a new component to the remedy evaluated in the original ROD.

The change in remedy being evaluated in this revised FS is limited to reexamination, from a technical and cost standpoint, of the most effective means of implementing the remediation component for the original remedy proposed by the OU4 FS (FEMP 1994d) and approved in the OU4 ROD (EPA 1994). Neither the general response action (remediation and off-site disposal), nor the RAOs, are being reevaluated.

As required by the NCP, this revised FS will evaluate remediation alternatives in detail against the nine NCP criteria, including the threshold criteria of compliance with ARARs and overall protectiveness [40 CFR Part 300.430(e)(9)(iii)]. The PP will demonstrate, based upon the results of this revised FS, that the proposed remedial remedy will be protective of human health and the environment if successfully implemented in accordance with current OU4 ARARs. The revised FS/PP will demonstrate, therefore, that attainment of ARARs promulgated after signature of the existing OU4 ROD is not necessary to ensure that the remedy will be protective of human health and the environment. The change in remediation technology, evaluated in the revised Silos 1 and 2 FS/PP and to be documented in the ROD Amendment, does not meet the criteria specified by the NCP [40 CFR Part 300.430(f)(1)(ii)(B)] that requires modification of ARARs.

The ARARs identified in the OU4 ROD for vitrification of the Silos 1 and 2 material also pertain to chemical stabilization of the Silos 1 and 2 material. Therefore, modifications to the ARARs and TBCs are not expected as a result of changing the preferred alternative for the Silos 1 and 2 material from vitrification to chemical stabilization (followed by transport for final disposition at the NTS). In addition, FDF has conducted a thorough evaluation of requirements promulgated since December 1994, and concluded that new requirements impacting selection of the Silos 1 and 2 material remedy have not been promulgated. A detailed discussion of the ARARs identified for remediation of Silos 1 and 2 material is presented in **Appendix A** of this revised FS.

F.7.3 Cost Effectiveness

The selected remedial alternatives for each subunit have been determined to be protective of human health and the environment, and to be cost effective. The 1994 net present value cost for this remedy was 91.7 million dollars.

The off-site alternatives selected for the contents of Silos 1, 2, and 3 had a lower cost than the on-property disposal alternative for these materials. This was due to the fact that costs associated with construction of a facility that would provide the needed level of protection to human health and the environment from the silos contents would be greater due to the increased intruder protection requirements in the event of a trespasser. Also, the packaging and transportation costs associated with the vitrified material were lower than those for the cement stabilized material. Vitrification was more cost effective than cementation because the reduction in volume of vitrified product minimized the amount of waste requiring handling, resulting in reduced transportation and disposal costs.

Conversely, transportation and disposal costs associated with disposing OU4 soils and debris at the NTS or a commercial facility are higher than the costs associated with construction of an engineered facility designed to manage the material on-property. Also, integration of the OU4 disposal remedy for soils and debris with OU5 and OU3, respectively, would have allowed for economies of scale through treatment by processes developed for larger volumes of soil and debris.

F.7.3.1 Cost

The estimated, 1994 net present value cost for the selected remedy was 91.7 million dollars. **Table F.6.2-1** summarizes the capital and the O&M costs. This estimated, net present value cost was less than the sum of the total costs of the preferred alternatives for Subunits A, B, and C. This was because Subunits A and B would share common costs for site preparation, construction of the silos contents removal work platform and processing facilities, and packaging and transportation.

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TABLE F. 7.3-1
COMBINED COST ESTIMATE FOR SELECTED REMEDY

DESCRIPTION	DIRECT COST	INDIRECT COST	TOTAL COST
Capital Costs			
Site Preparation	$768,600	$660,000	$1,428,600
Waste Processing	$1,695,800	$1,427,700	$3,123,500
Vitrification Equipment	$2,935,500	$1,703,600	$4,639,100
Hydraulic/Pneumatic Removal System	$6,655,400	$14,068,800	$20,724,200
Demolition & Removal	$3,980,400	$5,977,000	$9,957,400
Transportation	$1,915,000		$1,915,000
Disposal	$2,360,200		$2,360,200
Packaging (3,694 pkgs. @ $955/pkg.)	$975,200	$2,552,600	$3,527,800
Disposal Vault	$6,410,200	$10,914,800	$17,325,000
Total Capital	$27,696,300	$37,304,500	$65,000,800
Risk Budget	$3,046,600	$4,103,500	$7,150,100
Subtotal	$30,742,900	$41,408,000	$72,150,900
Contingency (20.0%)	$6,148,600	$8,281,600	$14,430,200
Total Estimated Installed Cost	$36,891,500	$49,689,600	$86,581,100
Operation and Maintenance (O&M) Costs			
During Construction			$16,615,500
Post - Remediation			$3,567,000
Total Present Worth Costs (Capital and O&M @ 7%)			$91,738,000

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F-8074

F.7.4 Utilization of Permanent Solutions and Alternative Treatment Technologies or Resource Recovery Technologies to the Maximum Extent Practicable

The EPA and the State of Ohio determined that the selected remedy for OU4 represented the maximum extent to which permanent solutions and treatment technologies could be utilized in a cost-effective manner. Of the alternatives that were protective of human health and the environment and complied with ARARs, the EPA and the State of Ohio determined that the selected remedy provided the best balance of tradeoffs among the alternatives in terms of long-term effectiveness and permanence, reduction in toxicity, mobility, and volume through treatment, short-term effectiveness, implementability, and cost. The selected remedies also met the statutory preference for treatment as a principal element, and state and community acceptance.

Vitrification and off-site disposal would provide permanent treatment and volume reduction for the silos contents. By physically binding the contaminants into a glass-like matrix, the mobility of the contaminants and the emanation of radon gas would be greatly reduced. Vitrification would also significantly reduce the leachability of metal contaminants of concern to levels below RCRA regulatory thresholds. Vitrification would destroy any organic contaminants in the waste material due to the operating temperature of the treatment process. In addition, the treated material would be less than 50% of its original volume. As a result, the selected remedy would have met the CERCLA requirement for permanent solutions that reduce the toxicity, mobility, or volume through treatment.

Part of the remedy selected for contaminated soils and debris may have also involved treatment of the waste material prior to disposal. The soil and debris would have been placed into interim storage pending finalization of the disposal decision for these wastes through the RODs for OU3 and OU5. This allowed for the implementation of any applicable resource recovery technologies for these wastes, which were developed and included in the RODs for the OUs.

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F.7.5 Preference for Treatment as a Principal Element

By treating the contents of Silos 1, 2, and 3 in a vitrification process, and providing for treatment of contaminated debris and soils should treatment become the selected remedy for these wastes in the OU3 and OU5 RODs, the selected remedy would have mitigated the principal threats posed by OU4 through the use of treatment technologies. Therefore, the statutory preference for remedies that employ treatment as a principal element was satisfied.

F.7.6 Unavoidable Adverse Impacts

A number of unavoidable adverse impacts (**Table F.7.6-1**) would have occurred when any one of the remedial action alternatives were implemented. As stated in the alternatives and in **Table F.7.6-1**, many of these impacts would only have been temporary. In addition, it should be noted that these impacts are presented for those remedial actions that would have been implemented under the selected remedy. Those impacts associated with the final disposition of Subunit C material (soil and debris) were identified and evaluated as part of the RODs for OU3 and OU5.

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TABLE F.7.6-1
UNAVOIDABLE ADVERSE IMPACTS ON RESOURCES

Affected Resource	Impact Type
Soil and Geology	Soil and Geology
	Soil at the FEMP site and the NTS would be disrupted by construction and excavation activities. Many impacts would be temporary, pending completion of remedial activities and restoration programs. The implementation of the selected remedy would temporarily disturb approximately 1.0 ha (2.5 acres) at the FEMP (e.g., excavation and construction). A permanent disruption of approximately 8 ha (20 acres) at the NTS would occur. All areas disturbed at the FEMP site would be regraded and revegetated. The regional geology of the FEMP site and surrounding area would not be affected by the selected remedy. Implementation of off-site disposal would not affect the regional geology of the NTS or surrounding areas.
Water Quality and Hydrology	Potential short-term impacts (e.g., release of sediment and fugitive dust) on water quality and hydrology would be minimal. Regrading and revegetation around the silos would minimize potential water quality impacts. Assuming monitoring and maintenance activities continue at the NTS, long-term impacts would not be expected from waste disposal at the NTS.
Air Quality	Some temporary impacts to air quality at the FEMP site would result from fugitive dust emissions associated with construction and excavation activities (e.g., grading, compacting, loading). Lesser impacts would also be incurred from vehicle and equipment exhausts. These impacts are not expected to affect human health or the environment. Long-term impacts on air quality would not be expected from activities associated with the selected remedy. Disturbed areas would be restored (e.g., regraded and revegetated) after completion of the remedial activities, thus minimizing the potential for the fugitive dust release. The off-site waste disposal facility would be designed to prohibit emission from stored waste. Only in the case of an accident during remedial actions would appreciable air quality impacts occur.

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TABLE F.7.6-1 (continued)

Affected Resource	Impact Type Soil and Geology
Biotic/Ecological Resources	Short-term disturbance of terrestrial, managed field, riparian and aquatic habitat would be expected. Approximately 1.0 ha (2.5 acres) of habitat at the FEMP site would be disturbed during excavation and construction activities. Habitat at the NTS is limited and it is believed that little displacement of native species would occur.
Wetlands and Floodplains	Alternative 2C would not impact wetlands. Direct floodplain impacts resulting in a change of flood elevations would also not occur. Engineering controls would be implemented to minimize or eliminate indirect floodplain impacts. Neither wetlands nor floodplains are present at the NTS.
Socioeconomics and Land-use	Minimal short-term impacts (e.g., increased traffic noise) to the socioeconomics and land-use would occur. The long-term socioeconomic and land-use impacts for the FEMP site would be positive because the waste would be isolated and controlled, thus no changes from current land-use would be expected. Removing waste from the site would help to eliminate impacts on future populations and economic growth at the FEMP site. Disposal of this waste at the NTS would not be expected to impact socioeconomics or land-use. Total present worth costs of the selected remedy is $91.7M. For this analysis, it is assumed that all resources required for remedial activities can be found within the thirteen county Consolidated Metropolitan Statistical Area (CMSA). The cumulative operating budget for the CMSA was approximately $805,000,000.00. The collectible revenue for the CMSA would increase up to approximately 11.4%.

TABLE F.7.6-1 (continued)

Affected Resource	Impact Type Soil and Geology
Visual Resources	Construction and excavation activities would result in some minor incremental increases over the current visual and aesthetic impacts of the FEMP site. Short-term impacts would also be incurred at the NTS during construction, excavation, and transportation activities. The majority of impacts would be temporary and would cease following completion of remedial action activities and site restoration; however, aesthetic impacts would occur from the implementation of waste disposal facilities.
Noise	Ambient noise levels would temporarily increase as a result of construction, excavation, and transportation activities. All noise impacts would be temporary and would cease following completion of remedial activities.

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F.7.7 Irreversible and Irretrievable Commitment of Resources

Implementing the selected remedy would have resulted in permanent commitment of on-property land and associated natural resource services for material disposal at the FEMP site and off-site land at the NTS.

Soil at the FEMP site and the NTS would have been disturbed by construction and excavation activities. Many impacts would have been temporary, pending completion of remedial activities and restoration programs. The implementation of the selected remedy would have temporarily disturbed approximately 1.0 ha (2.5 acres) at the FEMP site. Furthermore, implementation of this remedy would have permanently committed 8 ha (20 acres) at the NTS. All areas disturbed at the FEMP site were to be regraded and revegetated.

Approximately 1.0 ha (2.5 acres) of habitat at the FEMP site would have been disturbed during excavation and construction activities. Approximately 89 ha (220 acres) were expected to be permanently committed on a site-wide basis, with another twenty to thirty acres subject to temporary disturbances. It was assumed that processes such as revegetation and regrading are successful; however, the loss of habitat would have resulted in a permanent displacement or loss of wildlife and associated services. Terrestrial habitat at the off-site disposal areas is limited, and little displacement of species was expected to occur.

Wetlands and associated natural resource services would not have been injured by the selected remedy. Long-term direct impacts to the floodplain resulting in changes of flood elevations would not have occurred. Engineering controls would have been implemented to minimize or eliminate any indirect impacts. There would not have been any impacts to wetlands or floodplains with disposal at the off-site disposal areas.

Consumptive use of geological resources (e.g., quarried rock, sand, and gravel) and petroleum products (e.g., diesel fuel and gasoline) would have been required for removal, construction, and disposal activities of the selected remedy. Supplies of these materials were to be provided by the construction contractor. Additional fuel use would have resulted from off-site transport of the materials. However, adequate supplies were available without having affected local requirements for these products.

The treatment processes for the selected remedy would have required the consumptive use of materials and energy. The vitrification process is energy-intensive and requires commitment of a considerable supply of electricity. Electricity can be obtained from the local utility.

Maintenance activities were to be performed as necessary. Long-term environmental impacts were not expected to occur from the OU4 selected remedy. Monitoring and periodic site inspections were to be performed to ensure long-term protection of human health and the environment.

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F.8.0 DOCUMENTATION OF SIGNIFICANT CHANGES

The Feasibility Study/Proposed Plan - Draft Environmental Impact Statement (FS/PP-DEIS) for OU4 was released for public comment in March 1994 (FEMP 1993c). The DOE reviewed the written and oral comments submitted during the public comment period. Upon review of these comments, it was determined that no significant changes to the remedy, as was originally identified in the FS/PP-DEIS, were necessary. However, it should be noted that the repromulgation of 40 CFR Part 191 by the EPA did result in minor changes in the comparative analysis of alternatives presented in the FS/PP-DEIS. The following discussion addresses the nature and extent of the changes.

F.8.1 Repromulgation of 40 CFR Part 191

Repromulgation of the 40 CFR Part 191 requirements for Management and Disposal of Spent Nuclear Fuel, High-Level, and Transuranic Wastes caused changes to be made to the ARARs as described in the Draft Final FS/PP-DEIS, which was conditionally approved by the EPA on February 9, 1994. DOE chose not to submit revision pages to the FS/PP-DEIS; all changes to the ARARs for that document and any impacts from the repromulgation were discussed in Section 11.0 of the OU4 ROD (EPA 1994). Since the repromulgation resulted in relevant and appropriate, rather than applicable requirements, the repromulgation of 40 CFR Part 191 did not impact the proposed off-site alternative for disposition of the K-65 material. However, the on-property disposal alternatives (Alternatives 2A/Vit and 2A/Cem) that were previously retained, having passed the threshold criteria of the detailed analysis, were no longer able to meet the threshold criteria of compliance with ARARs, and were consequently dropped from further consideration. Subsequently, references to Alternative 2A were deleted from reference in the text of the OU4 ROD, and in Appendix A of the OU4 ROD.

The only relevant and appropriate requirement from 40 CFR Part191 that was retained as an ARAR in the OU4 ROD (Appendices A and B) for the proposed alternative was 40 CFR Part 191.03(b), which establishes dose limits for management and storage of the K-65 material. However, since this ARAR was relevant and appropriate, rather than applicable, it pertained only to the on-property portions of the remedial activities conducted under this action.

F.8.1.1 Background

The DOE-FEMP received conditional approval of the Draft Final FS/PP-DEIS (FEMP 1993c) for OU4 from the EPA on February 9, 1994. Included in the FS/PP-DEIS ARARs was a reference to 40 CFR Part 191, "Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level, and Transuranic Wastes." This reference to 40 CFR Part 191 was modified in the OU4 FS/PP-DEIS, submitted in February 1994 in response to the conditional approval letter, to reflect the changes to the regulation that occurred upon its repromulgation on December 20, 1993. It still accommodated the specific direction previously provided by the EPA regarding incorporation of the 40 CFR Part 191 requirements as ARAR/TBC (EPA 1990).

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The final rule became effective on January 19, 1994, during final revision of the OU4 FS/PP-DEIS, and agency comments did not address the repromulgation of the rule. This fact was discussed with the EPA, and a DOE position paper on the incorporation of 40 CFR Part 191 as an ARAR for OU4 remediation was submitted to the EPA for concurrence. The EPA disagreed with the draft position proposed by DOE, and responded with a directive to incorporate the substantive elements of the repromulgated rule into the ROD with an option to resubmit change pages to the FS/PP-DEIS. DOE elected not to revise the FS/PP-DEIS, but rather to describe in Section 11.0 of the OU4 ROD changes to the table of ARARs and associated impacts on selection or implementation of remedial alternatives that occurred between the time the Draft Final FS/PP-DEIS was conditionally approved, and the submittal of the ROD to the EPA and OEPA. The list of ARARs in the ROD and the proposed approach to compliance with the substantive elements thereof - once approved by the EPA - became the final approved list of ARARs for final remediation of OU4.

F.8.1.2 Impacts of Repromulgation

Since 40 CFR Part 191 could not be considered a legally "applicable" class of ARARs for this CERCLA remediation, Part 191 was not applicable to any OU4 waste streams. Since compliance with only applicable requirements is required to be demonstrated for off-site remedial alternatives proposed under CERCLA, these requirements would not have impacted the proposed off-site alternative for disposal of the treated K-65 material at the NTS.

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DOE had previously included 40 CFR Part 191 Subpart A as a relevant and appropriate requirement, and Subpart B as a TBC criteria for management of K-65 material in accordance with guidance received from the EPA. Subpart A of Part 191, entitled "Environmental Standards for Management and Storage" includes public dose rate standards for protection of the public from radiation hazards posed by spent nuclear fuel, high-level, or transuranic waste material. The repromulgation of the Final Rule did not materially affect the sections of Subpart A referenced in the OU4 FS/PP-DEIS; the Subpart A requirement referenced in the OU4 FS/PP-DEIS remained unchanged in the table of ARARs as a relevant and appropriate requirement for the on-property portion of the remedial activities to be conducted on the K-65 material.

Prior to repromulgation, Subpart B requirements were in remand, and were therefore considered TBCs in the FS/PP-DEIS submitted to the agencies. Since Subpart B of Part 191, entitled "Environmental Standards for Disposal," had been repromulgated, the EPA directed that sections must be considered as relevant and appropriate requirements for any on-property disposal alternatives. Since it could not be demonstrated that the on-property disposal of treated K-65 material would comply with specific requirements of this Subpart, those alternatives involving on-property disposal (Alternatives 2A/Vit and 2A/Cem) no longer met the threshold criteria of compliance with these ARARs, and were consequently dropped from further consideration. All descriptions to Alternative 2A were therefore deleted from reference in the text of the OU4 ROD, and in Appendix A of the OU4 ROD.

A new Subpart C of Part 191 "Environmental Standards for Groundwater Protection," was created by the repromulgated rule. As with Subpart B, this new Subpart pertains only to disposal systems. The elements of this Subpart had to be considered as relevant and appropriate requirements; however, since the on-property disposal alternatives to which this Subpart pertains were dropped from further consideration on the basis of non-compliance with Subpart B requirements, and since Subpart C would not pertain to any off-site disposal alternatives, these requirements were not included in Appendix A or B tables of ARARs in the OU4 ROD. Therefore, Subpart C did not effect the selected alternative, which included off-site disposal.

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F-8074

Appendix G

--8074

APPENDIX G

DESIGN BASIS AND DESCRIPTION

F-8074

Table of Contents

8074

TABLE OF CONTENTS
APPENDIX G

List of Tables . . . . . g-x

List of Figures . . . . . g-xi

List of Attachments . . . . . g-xii

List of Acronyms & Abbreviations . . . . . g-xiii

G.1.0 INTRODUCTION AND TECHNOLOGIES SUMMARIES G.1-1

G.1.1 Introduction G.1-1
G.1.1.1 Silos Background G.1-1
G.1.1.2 Purpose G.1-2
G.1.1.3 Structure of this Document and Presentation of the Technologies G.1-2
G.1.2 Temporary Storage of the Silos 1 and 2 Material G.1-3
G.1.3 Technology Summaries G.1-5
G.1.3.1 Vitrification — Joule-heated G.1-8
G.1.3.2 Vitrification — Other G.1-13
G.1.3.3 Chemical Stabilization — Cement-based G.1-18
G.1.3.4 Chemical Stabilization — Other G.1-23

G.2.0 GENERAL DESIGN CRITERIA G.2-1

G.2.1 Silos 1 and 2 Material G.2-1
G.2.1.1 Quantities G.2-1
G.2.1.2 Characteristics G.2-3
G.2.2 Contractor - FDF Interface G.2-8
G.2.3 Process and Facility Constraints G.2-10
G.2.4 Slurry Feed from the Transfer Tank Area G.2-10
G.2.5 Treated Silos 1 and 2 Material Acceptance Requirements G.2-11
G.2.6 Treatment Factors G.2-14
G.2.6.1 Waste Loading G.2-14
G.2.6.2 Bulking Factor G.2-14
G.2.6.3 Incremental Bulking and Overall Bulking Factor G.2-15
G.2.7 Treated Silos 1 and 2 Material Sampling and Analysis G.2-15
G.2.8 Rework and Recycle Water G.2-16
G.2.8.1 Rework G.2-16
G.2.8.2 Recycle Water G.2-17
G.2.9 Containers and Product Handling Requirements G.2-17

000218

G.2.9.1 Physical Criteria G.2-18
G.2.9.2 Product Handling G.2-19
G.2.10 Container Staging G.2-19
G.2.11 Treated Silos 1 and 2 Material Shipping G.2-21
G.2.12 Disposal G.2-21
G.2.12.1 Treated Silos 1 and 2 Material Disposal G.2-22
G.2.12.2 Secondary and D&D Wastes G.2-22
G.2.13 Secondary Waste G.2-22
G.2.13.1 Secondary Liquid Waste Treatment G.2-23
G.2.13.2 Secondary Solid Waste Treatment G.2-26
G.2.13.3 Gaseous Effluents G.2-26
G.2.14 Radon Handling and Control G.2-27
G.2.15 Facility Design G.2-28
G.2.15.1 Operability/Maintainability G.2-29
G.2.15.2 Piping G.2-31
G.2.15.3 Mechanical Equipment G.2-31
G.2.16 HVAC G.2-32
G.2.16.1 General G.2-32
G.2.16.2 Analytical laboratory G.2-36
G.2.16.3 Warehouse G.2-36
G.2.16.4 Mechanical/Electrical Building G.2-36
G.2.16.5 Staging Area G.2-36
G.2.17 Support Systems G.2-36
G.2.17.1 Analytical Support Laboratory/Services G.2-36
G.2.17.2 Mechanical/Electrical Building G.2-37
G.2.17.3 Interim Container Staging G.2-38
G.2.17.4 Control Room Trailer G.2-39
G.2.17.5 Office Trailers G.2-39
G.2.17.6 PPE Change Trailer G.2-40
G.2.17.7 Change Trailer G.2-40
G.2.17.8 Parking G.2-40
G.2.18 Utilities G.2-41
G.2.18.1 Electrical G.2-41
G.2.18.2 Emergency Power G.2-41
G.2.18.3 Communications G.2-42
G.2.18.4 Water G.2-42
G.2.18.5 Steam G.2-42
G.2.18.6 Compressed Air G.2-42
G.2.18.7 Breathing Air Lines G.2-42
G.2.18.8 Sanitary Sewer G.2-42
G.2.18.9 Stormwater G.2-43
G.2.18.10 Natural Gas G.2-43
G.2.19 Health and Safety G.2-44
G.2.19.1 Personal Protective Equipment G.2-44
G.2.19.2 Radiological Considerations G.2-44
G.2.19.3 Radiation Area Definitions G.2-46

000219

F-8074

G.2.19.4 Surface Contamination Control G.2-51
G.2.19.5 Airborne Radioactivity Control G.2-52
G.2.20 Environmental Considerations G.2-53
G.2.20.1 Environmental ALARA in Design G.2-54
G.2.20.2 Air Emission/Off-gas Control G.2-55
G.2.20.3 Liquid Waste Control G.2-55
G.2.21 Project Schedule G.2-56
G.2.21.1 Proof of Principle Testing G.2-56
G.2.21.2 Regulatory Documentation Process G.2-57
G.2.21.3 Procurement Process G.2-57
G.2.21.4 Design and Documentation G.2-58
G.2.21.5 Construction and Construction Acceptance Testing G.2-61
G.2.21.6 Systems Operability Testing G.2-63
G.2.21.7 Operational Readiness Review G.2-63
G.2.21.8 Proof of Process Testing G.2-64
G.2.21.9 Remediation Operations G.2-64
G.2.21.10 Safe Shutdown and D&D of Facilities G.2-64
G.2.22 Process Systems and Equipment Numbering G.2-64

G.3.0 POP GENERATED CRITERIA G.3-1

G.3.1 Waste Loading Criteria G.3-1
G.3.1.1 Vitrification — Joule-heated G.3-2
G.3.1.2 Vitrification — Other G.3-3
G.3.1.3 Chemical Stabilization — Cement-based G.3-3
G.3.1.4 Chemical Stabilization — Other G.3-6
G.3.2 Process Control G.3-8
G.3.2.1 Vitrification Technologies G.3-8
G.3.2.2 Chemical Stabilization Technologies G.3-9
G.3.3 Robustness G.3-9
G.3.3.1 Operational Envelope and Robustness Diagrams for the Vitrification Technologies G.3-12
G.3.3.2 Operational Envelope and Robustness Diagrams for the Chemical Stabilization Technologies G.3-16

G.4.0 VITRIFICATION — JOULE-HEATED G.4-1

G.4.1 Summary G.4-1
G.4.1.1 Functional Analysis G.4-1
G.4.1.2 System Model G.4-10
G.4.1.3 Treatment Recipe G.4-12
G.4.1.4 Mass and Energy Balance Overview G.4-12
G.4.1.5 Availability and Work Schedule G.4-12
G.4.2 Feed and Additives Preparation (Systems 15, 16, and 44) G.4-12
G.4.2.1 System Description G.4-13
G.4.2.2 Assumptions G.4-14

000220

G.4.2.3 Key Equipment Descriptions G.4-15
G.4.2.4 System Interfaces G.4-15
G.4.2.5 Recycle Back to the TTA G.4-16
G.4.3 Treatment (System 17) G.4-16
G.4.3.1 System Description G.4-16
G.4.3.2 Assumptions G.4-17
G.4.3.3 Key Equipment Descriptions G.4-18
G.4.3.4 System Interfaces G.4-18
G.4.4 Product Handling (Systems 23,24, 25 and 82) G.4-19
G.4.4.1 System Description G.4-19
G.4.4.2 Assumptions G.4-21
G.4.4.3 Key Equipment Descriptions G.4-21
G.4.4.4 System Interfaces G.4-23
G.4.5 Gaseous Emission Control (Systems 18 and 20) G.4-24
G.4.5.1 System Description G.4-25
G.4.5.2 Assumptions G.4-26
G.4.5.3 Key Equipment Descriptions G.4-27
G.4.5.4 System Interfaces G.4-28
G.4.5.5 Emergency Off-gas System G.4-28
G.4.6 Secondary Liquid Waste Treatment G.4-29
G.4.7 Secondary Solid Waste Treatment G.4-30
G.4.8 Shipping Container Operations (System 25) G.4-30
G.4.8.1 System Description G.4-30
G.4.8.2 Assumptions G.4-31
G.4.8.3 Key Equipment Descriptions G.4-31
G.4.8.4 System Interfaces G.4-31
G.4.9 Product Rework (System 26) G.4-31
G.4.9.1 System Description G.4-32
G.4.9.2 Assumptions G.4-33
G.4.9.3 Key Equipment Descriptions G.4-33
G.4.9.4 System Interfaces G.4-34
G.4.10 Facility Design G.4-35
G.4.10.1 Bulk Additive Building G.4-35
G.4.10.2 Feed Preparation System G.4-35
G.4.10.3 Melter Room G.4-37
G.4.10.4 MTC Load-In Area G.4-38
G.4.10.5 Fill Station G.4-38
G.4.10.6 Off-Gas G.4-39
G.4.10.7 Monolith Cooling Room G.4-39
G.4.10.8 Shipping Container Area G.4-40
G.4.10.9 Rework Room G.4-40
G.4.10.10 Load-In Areas G.4-41
G.4.10.11 Facility Entrance G.4-41
G.4.11 HVAC (Systems 73, 75, 76, and 77) G.4-42
G.4.11.1 Zone 3 . . . . . G.4-42
G.4.11.2 Zone 2 . . . . . G.4-43

000221

G.4.11.3 Zones 1 and 2 . . . . . G.4-44
G.4.11.4 HVAC Stack G.4-44
G.4.12 Support (Systems 53 and 94) G.4-45
G.4.12.1 Analytical Support Laboratory/Services G.4-45
G.4.12.2 Special Support Systems - Cooling Water G.4-45
G.4.13 Utilities (Systems 30, 31, 32, 33, 40, 51, 52, 60, 90, and 94) G.4-46
G.4.14 Special Health and Safety Considerations G.4-50
G.4.15 Special Environmental Considerations G.4-51

G.5.0 VITRIFICATION — OTHER G.5-1
G.5.1 Summary G.5-1
G.5.1.1 Functional Analysis G.5-1
G.5.1.2 System Model G.5-11
G.5.1.3 Treatment Recipe G.5-13
G.5.1.4 Mass and Energy Balance Overview G.5-13
G.5.1.5 Availability and Work Schedule G.5-13
G.5.2 Feed and Additives Preparation (Systems 15, 16, and 44) G.5-13
G.5.2.1 System Description G.5-13
G.5.2.2 Assumptions G.5-16
G.5.2.3 Key Equipment Descriptions G.5-17
G.5.2.4 System Interfaces G.5-20
G.5.2.5 Recycle Back to the TTA G.5-20
G.5.3 Treatment (System 17) G.5-20
G.5.3.1 System Description G.5-20
G.5.3.2 Assumptions G.5-21
G.5.3.3 Key Equipment Descriptions G.5-22
G.5.3.4 System Interfaces G.5-23
G.5.4 Product Handling (Systems 23,24, and 25) G.5-23
G.5.4.1 System Description G.5-24
G.5.4.2 Assumptions G.5-25
G.5.4.3 Key Equipment Descriptions G.5-25
G.5.4.4 System Interfaces G.5-26
G.5.5 Gaseous Emission Control (Systems 18 and 20) G.5-26
G.5.5.1 System Description G.5-27
G.5.5.2 Assumptions G.5-28
G.5.5.3 Key Equipment Descriptions G.5-29
G.5.5.4 System Interfaces G.5-30
G.5.5.5 Emergency Off-gas System G.5-31
G.5.6 Secondary Liquid Waste Treatment G.5-31
G.5.6.1 System Description G.5-31
G.5.6.2 Recycle G.5-32
G.5.6.3 Discharge to FEMP AWWT G.5-32
G.5.7 Secondary Solid Waste Treatment G.5-32
G.5.7.1 System Description G.5-33
G.5.7.2 Recycle G.5-33
G.5.7.3 Key Equipment Descriptions G.5-33

G.5.8 Shipping Container Operations (System 25) G.5-33
G.5.8.1 System Description G.5-33
G.5.8.2 Assumptions G.5-34
G.5.8.3 Key Equipment Descriptions G.5-34
G.5.8.4 System Interfaces G.5-35
G.5.9 Product Rework (System 26) G.5-35
G.5.9.1 System Description G.5-35
G.5.9.2 Assumptions G.5-36
G.5.9.3 Key Equipment Descriptions G.5-36
G.5.9.4 System Interfaces G.5-37
G.5.10 Facility Design G.5-37
G.5.10.1 Bulk Additives G.5-37
G.5.10.2 Feed Preparation System G.5-38
G.5.10.3 Melter Feed System G.5-40
G.5.10.4 Load-In Areas G.5-41
G.5.10.5 Fill Station G.5-41
G.5.10.6 Off-gas G.5-42
G.5.10.7 Rework Room G.5-43
G.5.10.8 Facility Entrance G.5-44
G.5.11 HVAC (Systems 73, 75, 76, and 77) G.5-44
G.5.11.1 Zone 3 . . . . . G.5-44
G.5.11.2 Zones 1 and 2 . . . . . G.5-46
G.5.11.3 HVAC Stack G.5-47
G.5.12 Support Systems G.5-47
G.5.12.1 Analytical Support Laboratory/Services G.5-47
G.5.12.2 Special Support Systems G.5-48
G.5.13 Utilities (Systems 30, 31, 32, 33, 40, 51, 52, 60, 90, and 94) G.5-49
G.5.13.1 Natural Gas G.5-49
G.5.13.2 Compressed Air G.5-49
G.5.13.3 Electrical G.5-49
G.5.13.4 Control Systems G.5-51
G.5.14 Special Health and Safety Considerations G.5-52
G.5.15 Special Environmental Considerations G.5-53

G.6.0 CHEMICAL STABILIZATION — CEMENT-BASED G.6-1

G.6.1 Summary G.6-1
G.6.1.1 Functional Analysis G.6-1
G.6.1.2 System Model G.6-9
G.6.1.3 Treatment Recipe G.6-11
G.6.1.4 Mass and Energy Balance Overview G.6-11
G.6.1.5 Availability and Work Schedule G.6-12
G.6.2 Feed Preparation (Systems 15, 43 and 44) G.6-12
G.6.2.1 System Description G.6-13
G.6.2.2 Assumptions G.6-16
G.6.2.3 Key Equipment Descriptions G.6-18
G.6.2.4 System Interfaces G.6-20

000223

G.6.2.5 Recycle back to the TTA G.6-20
G.6.3 Treatment (System 17) G.6-21
G.6.3.1 System Description G.6-21
G.6.3.2 Assumptions G.6-22
G.6.3.3 Key Equipment Descriptions G.6-23
G.6.3.4 System Interfaces G.6-24
G.6.4 Product Handling (Systems 25, 26 and 82) G.6-24
G.6.4.1 System Description G.6-24
G.6.4.2 Assumptions G.6-27
G.6.4.3 Key Equipment Descriptions G.6-27
G.6.4.4 System Interfaces G.6-30
G.6.5 Gaseous Emission Control G.6-31
G.6.5.1 System Description G.6-31
G.6.5.2 Assumptions G.6-32
G.6.5.3 Key Equipment Descriptions G.6-32
G.6.5.4 System Interfaces G.6-33
G.6.6 Secondary Liquid Waste Treatment (System 62) G.6-33
G.6.6.1 System Description G.6-33
G.6.6.2 Assumptions G.6-34
G.6.6.3 Discharge to AWWT G.6-34
G.6.6.4 Key Equipment Descriptions G.6-35
G.6.6.5 Recycle G.6-36
G.6.6.6 Secondary Solid Waste Treatment G.6-36
G.6.7 Container Operations G.6-37
G.6.7.1 System Description G.6-37
G.6.7.2 Assumptions G.6-37
G.6.7.3 Key Equipment Descriptions G.6-38
G.6.7.4 System Interfaces G.6-38
G.6.8 Product Rework (System 26) G.6-39
G.6.8.1 System Description G.6-39
G.6.8.2 Assumptions G.6-40
G.6.8.3 Key Equipment Descriptions G.6-41
G.6.8.4 System Interfaces G.6-43
G.6.9 Facility Design G.6-43
G.6.9.1 Unique Features G.6-53
G.6.10 HVAC (Systems 73, 75, 76 and 77) G.6-53
G.6.10.1 Zone 3 . . . . . G.6-54
G.6.10.2 Zone 2 . . . . . G.6-55
G.6.10.3 Zones 1 and 2 . . . . . G.6-56
G.6.10.4 HVAC Stacks G.6-57
G.6.11 Support Systems G.6-57
G.6.11.1 Analytical Support Laboratory/Services G.6-57
G.6.12 Utilities G.6-58
G.6.13 Special Health and Safety Considerations G.6-62
G.6.14 Special Environmental Considerations G.6-62

G.7.0 CHEMICAL STABILIZATION — OTHER G.7-1

G.7.1 Summary G.7-1
G.7.1.1 Functional Analysis G.7-1
G.7.1.2 System Model G.7-9
G.7.1.3 Treatment Recipe G.7-11
G.7.1.4 Mass and Energy Balance Overview G.7-11
G.7.1.5 Availability and Work Schedule G.7-12
G.7.2 Feed Preparation (Systems 15, 16 and 44) G.7-12
G.7.2.1 System Description G.7-12
G.7.2.2 Assumptions G.7-15
G.7.2.3 Key Equipment Descriptions G.7-17
G.7.2.4 System Interfaces G.7-18
G.7.2.5 Recycle back to the TTA G.7-19
G.7.3 Treatment System (System 82) G.7-19
G.7.3.1 System Description G.7-19
G.7.3.2 Assumptions G.7-20
G.7.3.3 Key Equipment Descriptions G.7-21
G.7.3.4 System Interfaces G.7-21
G.7.4 Product Handling G.7-22
G.7.4.1 System Description G.7-22
G.7.4.2 Assumptions G.7-25
G.7.4.3 Key Equipment Descriptions G.7-26
G.7.4.4 System Interfaces G.7-29
G.7.5 Gaseous Emission Control G.7-30
G.7.5.1 System Description G.7-30
G.7.5.2 Assumptions G.7-31
G.7.5.3 Key Equipment Descriptions G.7-31
G.7.5.4 System Interfaces G.7-32
G.7.6 Secondary Liquid Waste Treatment G.7-32
G.7.6.1 System Description G.7-32
G.7.6.2 Assumptions G.7-32
G.7.6.3 Key Equipment Descriptions G.7-33
G.7.6.4 System Interfaces G.7-33
G.7.6.5 Recycle G.7-33
G.7.6.6 Discharge to AWWT G.7-33
G.7.7 Secondary Solid Waste Treatment G.7-33
G.7.8 Container/Mixer Operations G.7-34
G.7.8.1 System Description G.7-34
G.7.8.2 Assumptions G.7-34
G.7.8.3 Key Equipment Descriptions G.7-35
G.7.8.4 System Interfaces G.7-35
G.7.9 Product Rework (System 26 . . . . . G.7-36
G.7.9.1 System Description G.7-36
G.7.9.2 Assumptions G.7-38
G.7.9.3 Key Equipment Descriptions G.7-38
G.7.9.4 System Interfaces G.7-40

G.7.10 Facility Design G.7-41
G.7.10.1 Unique Features G.7-47
G.7.11 HVAC (Systems 73, 75, 76 and 77) G.7-47
G.7.11.1 Zone 3 . . . . . G.7-48
G.7.11.2 Zone 2 . . . . . G.7-50
G.7.11.3 Zones 1 and 2 . . . . . G.7-50
G.7.11.4 HVAC stack G.7-51
G.7.12 Support Systems G.7-52
G.7.12.1 Analytical Support Laboratory/Services G.7-52
G.7.13 Utilities G.7-53
G.7.14 Special Health and Safety Considerations G.7-55
G.7.15 Special Environmental Considerations G.7-56

LIST OF TABLES

G.1.3-1 Estimated Quantities Treated Materials and Containers produced by the Technologies G.1-6
G.2.1-1 Silos 1 and 2 Material Quantities G.2-2
G.2.1-2 Major Radionuclides in the K-65 Silos 1 and 2 Material G.2-2
G.2.1-3 Silos 1 and 2 Elemental Compositions According to PNL Analysis and FDF Analysis for SO_3 . . . . . G.2-5
G.2.1-4 Variability in K-65 Samples G.2-7
G.2.1-5 Average BentoGrout™ Composition G.2-8
G.2.5-1 RCRA TCLP Limits G.2-13
G.2.8-1 TTA Recycle Silos 1 and 2 Material G.2-17
G.2.13-1 Wastewater Discharge Limits G.2-25
G.2.19-1 RAZ Chart G.2-48
G.2.21-1 Summary of Silos 1 and 2 Regulatory Milestones G.2-57
G.2.22-1 Silos 1 & 2 Project System Numbering Scheme G.2-65
G.3.1-1 Waste Loading by Technology G.3-2
G.4.1-1 Functional Block Descriptions Vitrification — Joule-heated G.4-3
G.5.1-1 Functional Block Descriptions Vitrification — Other G.5-3
G.6.1-1 Functional Block Descriptions Chemical Stabilization — Cement-based G.6-3
G.6.11-1 Laboratory Analyses and Required Equipment G.6-58
G.7.1-1 Functional Block Descriptions Chemical Stabilization — Other G.7-3
G.7.12-1 Laboratory Analyses and Required Equipment G.7-53

000227

LIST OF FIGURES

G.1.3-1 Transfer to TTA – Common to All Technologies G.1-7
G.1.3-2 Simplified Process Diagram Vitrification — Joule-heated G.1-10
G.1.3-3 Bulking Factor Pictorial Vitrification — Joule-heated G.1-11
G.1.3-4 Shipping and Disposal Container Vitrification — Joule-heated G.1-12
G.1.3-5 Simplified Process Diagram Vitrification — Other G.1-15
G.1.3-6 Bulking Factor Pictorial Vitrification — Other G.1-16
G.1.3-7 Shipping and Disposal Container Vitrification — Other G.1-17
G.1.3-8 Simplified Process Diagram Chemical Stabilization — Cement-based G.1-20
G.1.3-9 Bulking Factor Pictorial Chemical Stabilization — Cement-based G.1-21
G.1.3-10 Shipping and Disposal Container Chemical Stabilization — Cement-based G.1-22
G.1.3-11 Simplified Process Diagram Chemical Stabilization — Other G.1-25
G.1.3-12 Bulking Factor Pictorial Chemical Stabilization — Other G.1-26
G.1.3-13 Shipping and Disposal Container Chemical Stabilization — Other G.1-27
G.2.2-1 Contractor-FDF Interface Diagram G.2-9
G.2.21-1 Baseline Schedule G.2-59
G.2.21-2 Silos 1 and 2 Project Block Flow Diagram G.2-62
G.3.3-1 Operating Envelope Diagram Vitrification — Joule-heated G.3-13
G.3.3-2 Operating Envelope Diagram Vitrification — Other G.3-14
G.3.3-3 Operating Window Determination Chemical Stabilization — Cement-based G.3-19
G.3.3-4 Operating Envelope Diagram Chemical Stabilization — Cement-based . . G.3-20
G.3.3-5 Operating Envelope Diagram Chemical Stabilization — Other G.3-21
G.4.1-1 Functional Analysis Block Flow Diagram Vitrification — Joule-heated . . . G.4-2
G.4.1-2 System Block Flow Diagram Vitrification — Joule-heated G.4-11
G.5.1-1 Functional Analysis Block Diagram Vitrification — Other G.5-2
G.5.1-2 System Block Flow Diagram Vitrification — Other G.5-12
G.6.1-1 Functional Analysis Block Diagram Chemical Stabilization — Cement-based G.6-2
G.6.1-2 System Block Flow Diagram Chemical Stabilization — Cement-based . . . G.6-10
G.7.1-1 Functional Analysis Block Diagram Chemical Stabilization — Other G.7-2
G.7.1-2 System Block Flow Diagram Chemical Stabilization — Other G.7-10

LIST OF ATTACHMENTS

1. Treatment Quantity Calculations for the Technologies Presented in the Revised Feasibility Study for Silos 1 and 2 . . . . . G.A-1

2. Chemical Stabilization Treatment and TCLP Correlations with the Fernald OU4 Silos 1 and 2 Material, dated August 16, 1999 . . . . . G.A-2

000229

ACRONYMS & ABBREVIATIONS

ALARA	as low as reasonablely achievable
ANL	Argonne National Laboratory
ANTI-C	Anti-Contamination Clothing
ARAR	applicable or relevant and appropriate requirements
ASTM	American Society for Testing and Materials
AWR	Accelerated Waste Retrieval
AWWT	Advanced Wastewater Treatment
BAT	best available technology
BMP	best management practices
CCTV	closed circuit television
CEDE	committed effective dose equivalent
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act, as amended
CFR	Code of Federal Regulations
CINERGY	Cincinnati Gas & Electric Company
CMAA	Crane Manufacturers of America Association
CRV	counter-rotating vortex
DCS	Distributed Control System
DAC	derived air concentration
D&D	decontamination and demolition
DOE	U.S. Department of Energy
DOP	dioctyl phthalate
DOT	U.S. Department of Transportation
DS	demonstration surrogate
EDE	effective dose equivalent
EPA	U.S. Environmental Protection Agency
EOG	emergency off-gas
FDF	Fluor Daniel Fernald
FEMP	Fernald Environmental Management Project
FS	Feasibility Study
HEPA	high efficiency particulate air
HOA	hand/off/auto
HVAC	heating, ventilation, and air conditioning

ACRONYMS & ABBREVIATIONS (cont.)

IEEE	Institute of Electrical and Electronics Engineers
IES	Illuminating Engineering Society
I/O	input/output
IP-2	Industrial Package - Type 2
IT	International Technology Corporation
MCC	motor control center
MCR	monolith cooling room
MTC	monolith transfer container
NFPA	National Fire Protection Agency
NTS	Nevada Test Site
LAN	Local Area Network
ODOT	Ohio Department of Transportation
OEPA	Ohio Environmental Protection Agency
ORR	operational readiness review
OSDF	On-Site Disposal Facility
OU4	Operable Unit 4
PA	Public Announcement System
PAS	personal air sampling
PFD	process flow diagram
PNL	Batelle-Pacific Northwest Laboratories
POP	Proof of Principle
PPE	personal protective equipment
PVS	Process Vent System
PVV	process vessel vent
RAD	radiation
RAZ	Radiation Access Zone
RCRA	Resource Conservation and Recovery Act, as amended
RCS	Radon Control System
RFP	request for proposal
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
RWP	Radiological Work Permit

ACRONYMS & ABBREVIATIONS (cont.)

SBT	slurry batch tank
SEG	Scientific Ecology Group
SOT	Systems Operability Testing
SRPD	self-reading pocket dosimeter
SSC	structures, systems, or components
TBC	to be considered
TCLP	Toxicity Characteristic Leaching Procedure
TDS	total dissolved solids
TEDE	total effective dose equivalent
TRD	technical requirements document
TSP	triple super phosphate (for Chemical Stabilization — Cement-based) tri-sodium phosphate (for Chemical Stabilization — Other)
TTA	Transfer Tank Area
TWW	treated waste weight
UCS	unconfined compressive strength
UL	Underwriters' Laboratory
UPS	uninterruptable power supply
UTS	Universal Treatment Standards
VITPP	Vitrification Pilot Plant
WAC	waste acceptance criteria
WDW	waste dry weight
WESP	wet electrostatic precipitator
WL	working level
WWT	wastewater treatment
XRF	X-Ray Fluorescence

WEIGHTS, MEASURES, & EQUATION SYMBOLS

BDL	below detectable limits
BF	bulking factor
Btu	British thermal unit
cfm	cubic feet per minute
Ci	Curies
cm	centimeter
cm^2	square centimeters
dpm	disintegrations per minute
ft	foot
ft^3	cubic feet
ft^3/min	cubic feet per minute
gal	gallon
gpm	gallons per minute
HP	horse power
hr	hour
kV	kilovolt
kVa	kilovoltampere
kWh	kiloWatt hours
lb	pound
lb/ft^3	pounds per cubic foot
lb/hr	pounds per hour
m	meter
mm	millimeter
manRem	(summation of radiation exposure to a group)
mrem/hr	milli-Roentgen equivalent man (10^{-3} rem) per hour
MW	megawatts
pCi/g	picoCuries per gram
pCi/L	picoCuries per liter
ppm	parts per million
rem	Roentgen equivalent man
scfm	standard cubic feet per minute
Vf	final treatment volume
Vi	original (in situ) volume
wt%	weight percent
yr	year

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Section G.1

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G.1.0 INTRODUCTION AND TECHNOLOGIES SUMMARIES

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.

Section G.2 General Design Criteria

This section defines the quantities and types of materials needing processing. It presents the criteria to which a full-scale treatment facility is to be designed and gives constraints placed on the design.

Section G.3 POP Generated Criteria

This section takes results from the Proof of Principle (POP) Testing Project's extrapolate expected values (e.g., capabilities, production rates, etc.) for the full-scale treatment facility. These values are used as the basis and criteria for designing the full-scale facilities.

Sections G.4 through G.7

These sections contain the conceptual designs for the four technologies. Detailed design descriptions and specific design criteria for each technology are given in these sections. Detailed mass and energy balances and conceptual drawings for each technology are included at the end of each section (i.e., **Section 4**). The sections are:

G.4 Vitrification — Joule-heated

G.5 Vitrification — Other

G.6 Chemical Stabilization — Cement-based

G.7 Chemical Stabilization — Other

G.1.2 Temporary Storage of the Silos 1 and 2 Material

By the time the full-scale treatment facility is constructed, the Silos 1 and 2 material will no longer be contained in the silos; but rather, the Silos 1 and 2 material will be placed in temporary storage tanks in the Transfer Tank Area (TTA). To gain a better understanding of the condition of the materials to be treated, a brief discussion of the temporary storage of the Silos 1 and 2 material follows.

Silos 1 and 2 contain approximately 8,012 yd^3 of material and 878 yd^3 of BentoGrout™. The inside dimensions of the silos measure 80 feet (ft) in diameter by 26 ft high. To de-couple the tasks and associated challenges of retrieval and treatment, the silos material will be moved to temporary storage tanks in the TTA before being treated in the full-scale treatment facility. The volume of material stored in the TTA is expected to be more than in situ volume. The Silos 1 and 2 material is at 70 weight percent (wt%) solids in the silos. During retrieval operations, the BentoGrout™is mixed with the K-65 and is expected for prevent the K-65 from settling to more than 50 wt% solids. This decrease in solids content causes an overall volume content increase of the Silos 1 and 2 material.

The average measured dry density of the Silos 1 and 2 material is 90 pounds per cubic foot (lb/ft^3). Using this density, the calculated amount of material (dry) requiring treatment is approximately 20 million pounds (lb) (10,000 tons). Samples collected at different locations in Silos 1 and 2 indicate that the average moisture content of the Silos 1 and 2 material is approximately 30 wt%. The BentoGrout™ was placed in the silos at an average moisture content of 75 wt%. These percentages equate to 14,800 tons of silos material in a volume of 8,890 yd^3.

The Silos 1 and 2 material will be slurried with water and then pumped into the temporary tanks. Solids in the slurry will be allowed to settle in the TTA and the water will be returned to the silos to retrieve more Silos 1 and 2 material. Settling tests, performed at a FEMP laboratory, indicate that BentoGrout™ may interfere with the settling of the solids from the slurry in the temporary tanks. A slurry consisting of actual Silos 1 and 2 material and BentoGrout™ settled to approximately 50 wt% solids, which is significantly less than the existing 70 wt% in the silos. This information was used in the calculations to determine the expected quantities in the temporary tanks. The calculations are presented in **Attachment G.1**. **Figure G.1.3-1** summarizes the results of these calculations.

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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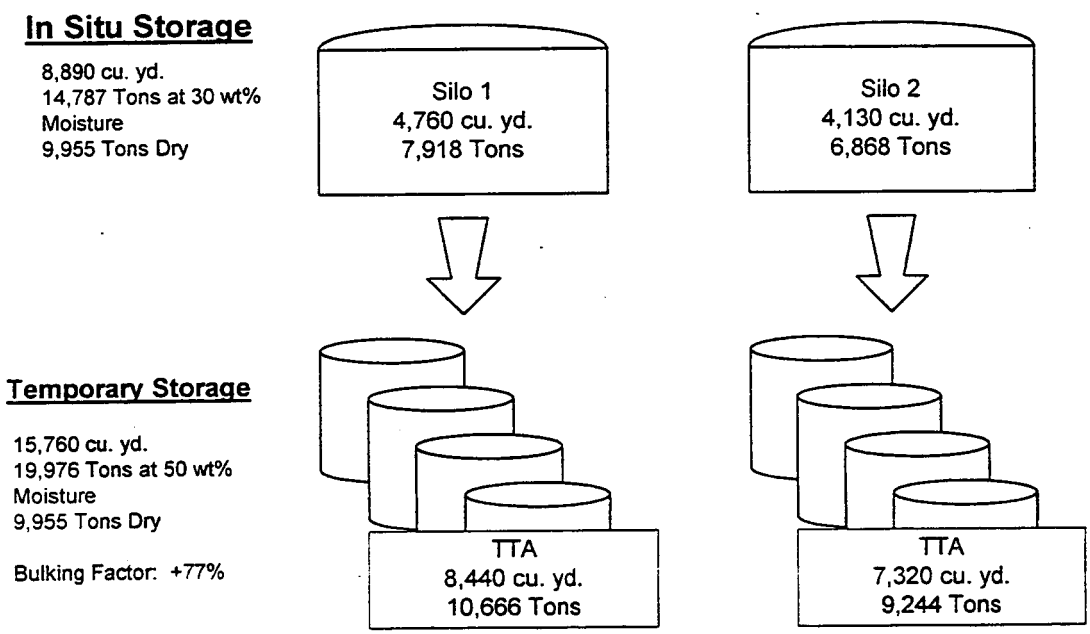
000239

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 (w/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	8,689	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

[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.1.3-1
TRANSFER TO TTA – COMMON TO ALL TECHNOLOGIES



"Overall Bulking Factor" represents the percentage of increased volume of treated material compared to the raw (i.e., original) material volume. A higher value is generally desirable for Waste Loading because it represents a higher percentage of Silos 1 and 2 material per unit weight; and, a lower value is desirable for Overall Bulking Factor because it represents less total volume of waste to dispose of at the Nevada Test Site (NTS). Definitions for these factors and how they are calculated are given in **Section G.2.6 - *Treatment Factors***.

G.1.3.1 Vitrification — Joule-heated

The Vitrification — Joule-heated technology uses heat and additives, as necessary, to incorporate the Silos 1 and 2 materials into a vitrified form (i.e., glass). The passing of electrical current through the molten glass generates most of the heat in the joule-heating process. The process is contained with the off-gas collected and treated for release to the 500 standard cubic feet per minute (scfm) Radon Control System (RCS). The molten glass is collected, cast into monoliths, cooled, and placed in shielded containers for shipment and disposal.

The process and facility for this technology were developed based on input from the contractor's POP report. **Appendix H, Attachment H1** contains the contractor's summary report; and **Appendix H, Section H.3** contains the list of changes from the contractor's design and the reasons for the changes.

The contractor representing this technology chose a melter with molybdenum electrodes to supply the joule-heating. After joule-heating transforms the wasteform into glass, it is poured into steel molds to form monoliths. The monoliths are cooled and then placed into shielded concrete containers for shipment and disposal. The melter has the capability to remove a molten sulfate layer if it forms on the surface of the molten glass pool. However, the contractor plans (as demonstrated at the POP demonstration run) to size and operate the melter at rates such that the sulfates have enough time to be reduced to sulfurous oxide gases by the heat. The sulfurous oxide gases are captured in the off-gas scrubber system. The melter also has the capability to drain molten metal as it forms in the glass bath. Some lead metal production is expected with molybdenum electrodes. However, the amount was demonstrated to be small during the POP

demonstration. Other electrode materials and/or methods may not produce molten lead. For example, Inconnel™and tinoxide are materials that are used as electrodes that would not chemically react with the molten glass.

A simplified flow diagram of the process is shown in **Figure G.1.3-2.** A pictorial that presents the expected amount of glass produced, the number of containers, and their disposal volume is provided in **Figure G.1.3-3.** Supporting calculations are given in **Attachment G-1.** A sketch of a plausible shipping and disposal container is shown in **Figure G.1.3-4.**

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FIGURE G.1.3-2
SIMPLIFIED PROCESS DIAGRAM
VITRIFICATION — JOULE-HEATED

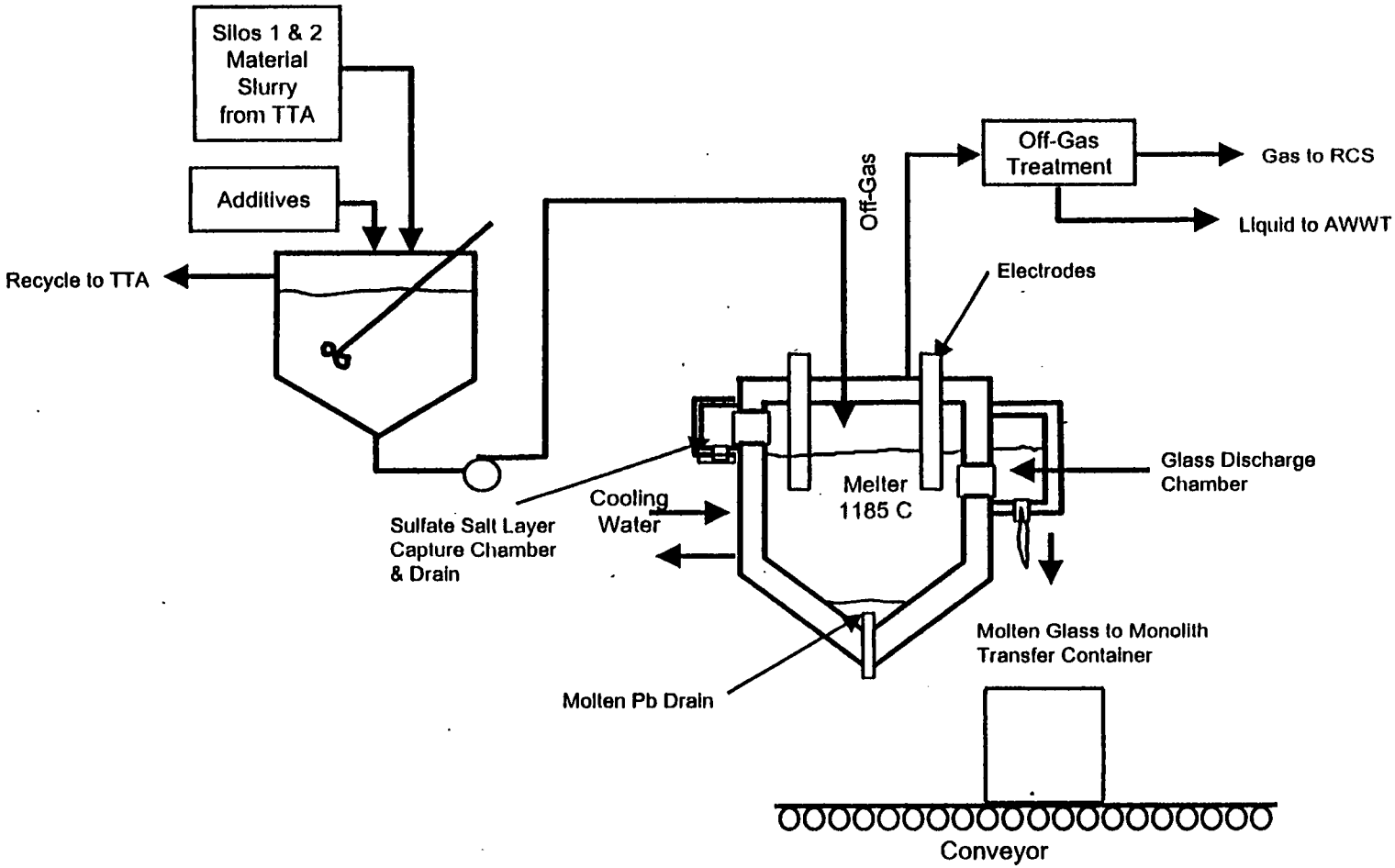

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FIGURE G.1.3-3
BULKING FACTOR PICTORIAL
VITRIFICATION — JOULE-HEATED

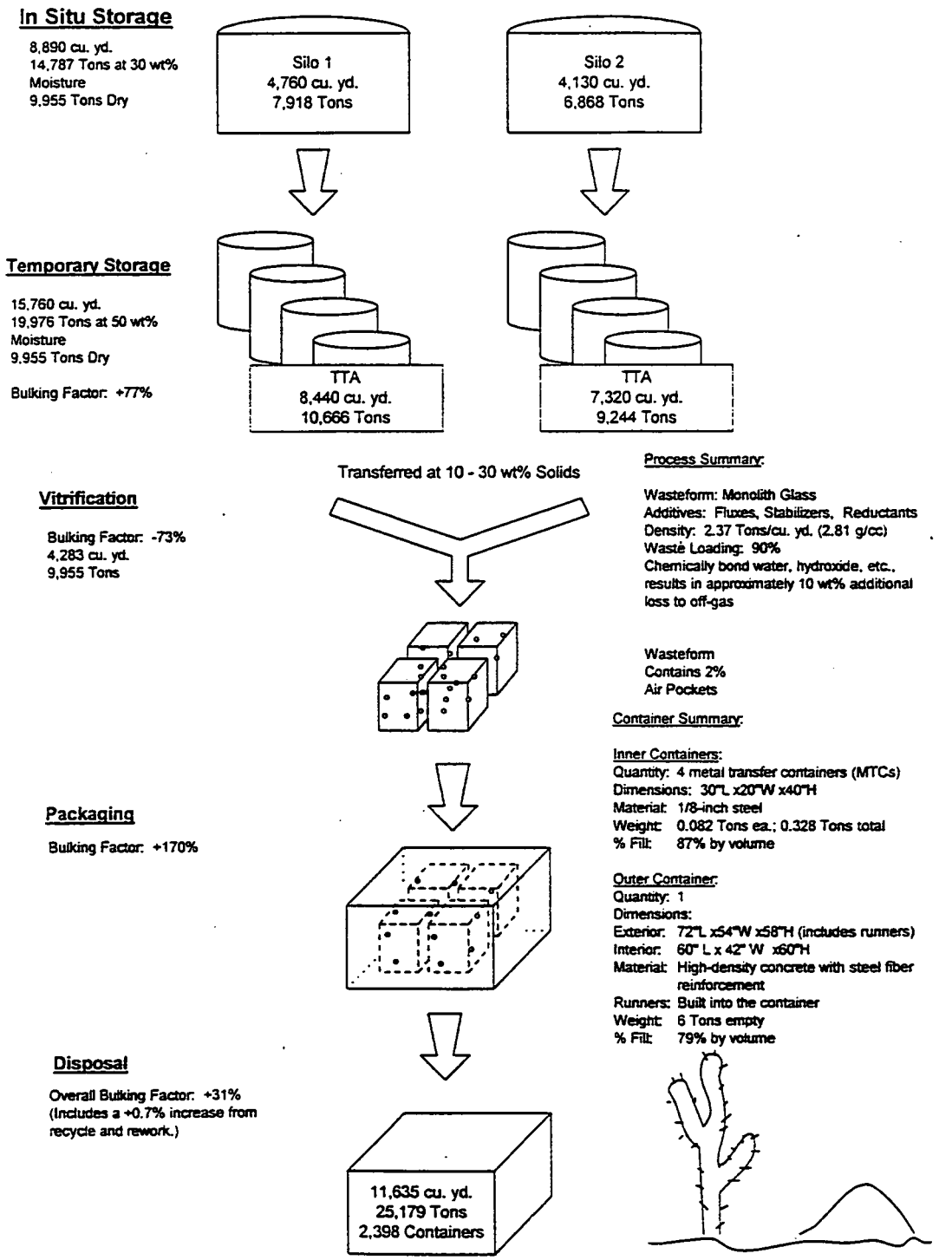
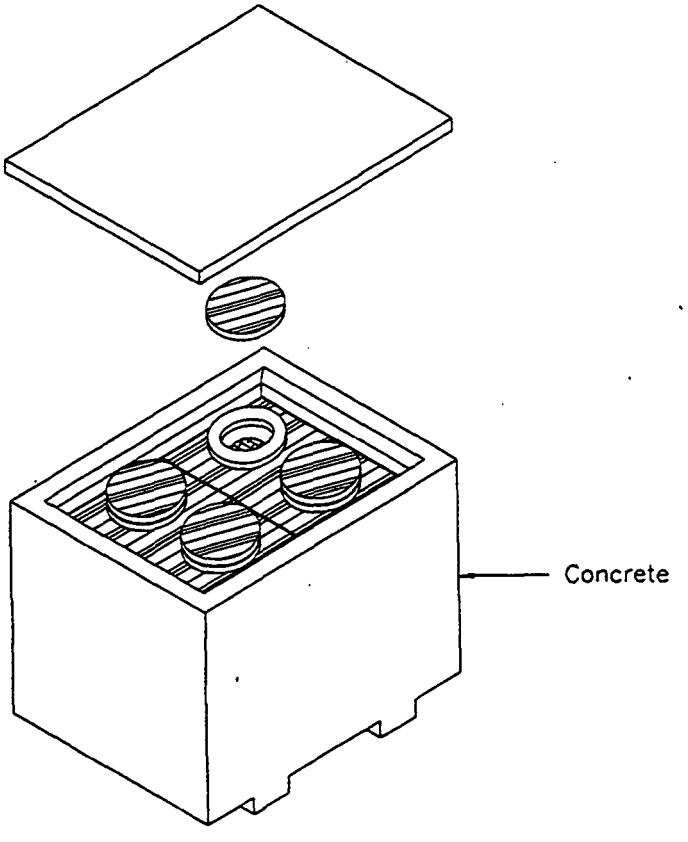


FIGURE G.1.3-4
SHIPPING AND DISPOSAL CONTAINER
VITRIFICATION — JOULE-HEATED



Outside Dimensions: 72" L x 54" W x 58" H x 6" wall

Vitrification – Joule Heated (monolith)

4 Monolith Blocks per Container
Weight of Waste per Container: 8,344 lbs
External Volume of Container: 130.5 cu. ft.
2,398 Concrete Containers

000245

FILENAME: SHIP_BOXES

INITIALS: RWR DATE: 11/9/89

G.1.3.2 Vitrification — Other

The Vitrification— Other technology uses heat and additives, as necessary, to transform the Silos 1 and 2 material into a vitrified form (i.e., glass). Most of the heat comes from a non-joule heating source, such as combustion or plasma arc. Combustion is the method chosen by the contractor to represent this technology. The process is contained with the off-gas collected and treated for release to the radon treatment systems (500 scfm capacity existing from the RCS and 300 scfm additional capacity provided by a Radon Treatment System designed by the contractor)[5]. The molten glass is quenched, producing frit, and placed in shielded containers for shipment and disposal.

The process and facility for this technology were developed based on input from the contractor's POP report. **Appendix H, Attachment H2** contains the contractor's summary report and **Appendix H, Section H.3** contains the list of changes from the contractor's design and the reasons for the changes.

The contractor representing this technology demonstrated a cyclone melter that uses natural gas as its heat source. In the full-scale design, the contractor chose to dry the feed slurry to reduce fuel consumption and off-gas volume. The dry Silos 1 and 2 material is then blended with glass additives and injected at the top of the melter. The solids react and absorb heat from the burning gases while falling and being conveyed downward by the products of combustion through the vertical chamber of the melter. The melting solids then collect and form a molten pool in the refining section at the bottom of the melter. The molten glass then flows over a weir and exits the melter into a pool of water to form frit (granular glass). The frit is mechanically conveyed by water into a shielded concrete container for shipment and disposal. Heat remaining in the glass dries the glass as it is conveyed. Sulfates are reduced

[5] In most plasma arc technologies, the heat to produce glass comes from an electrical arc. The off-gas is minimal, and therefore, a slurry can be easily accommodated. The only off-gas is water vapor, gases of decomposition, and enough air flow through the melter to maintain negative pressure. The volume off-gas system for the plasma arc system would be less since combustion air is not required. Additionally, radon treatment capacity is not an issue with plasma arc systems due to the relatively low flow of off-gas from the melter.

to sulfurous oxide gases by the heat in the melter. The sulfurous oxide gases are captured in the off-gas scrubber system. Lead volatilized from the melter is captured in the off-gas system and recycled back to the melter. A simplified flow diagram of the process is shown in **Figure G.1.3-5.** A pictorial that presents the expected amount of glass produced and number of containers and their disposal volume is given in **Figure G.1.3-6.** Supporting calculations are in **Attachment G-1**. A sketch of a plausible shipping and disposal container is shown in **Figure G.1.3-7.**

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FIGURE G.1.3-5
SIMPLIFIED PROCESS DIAGRAM
VITRIFICATION — OTHER

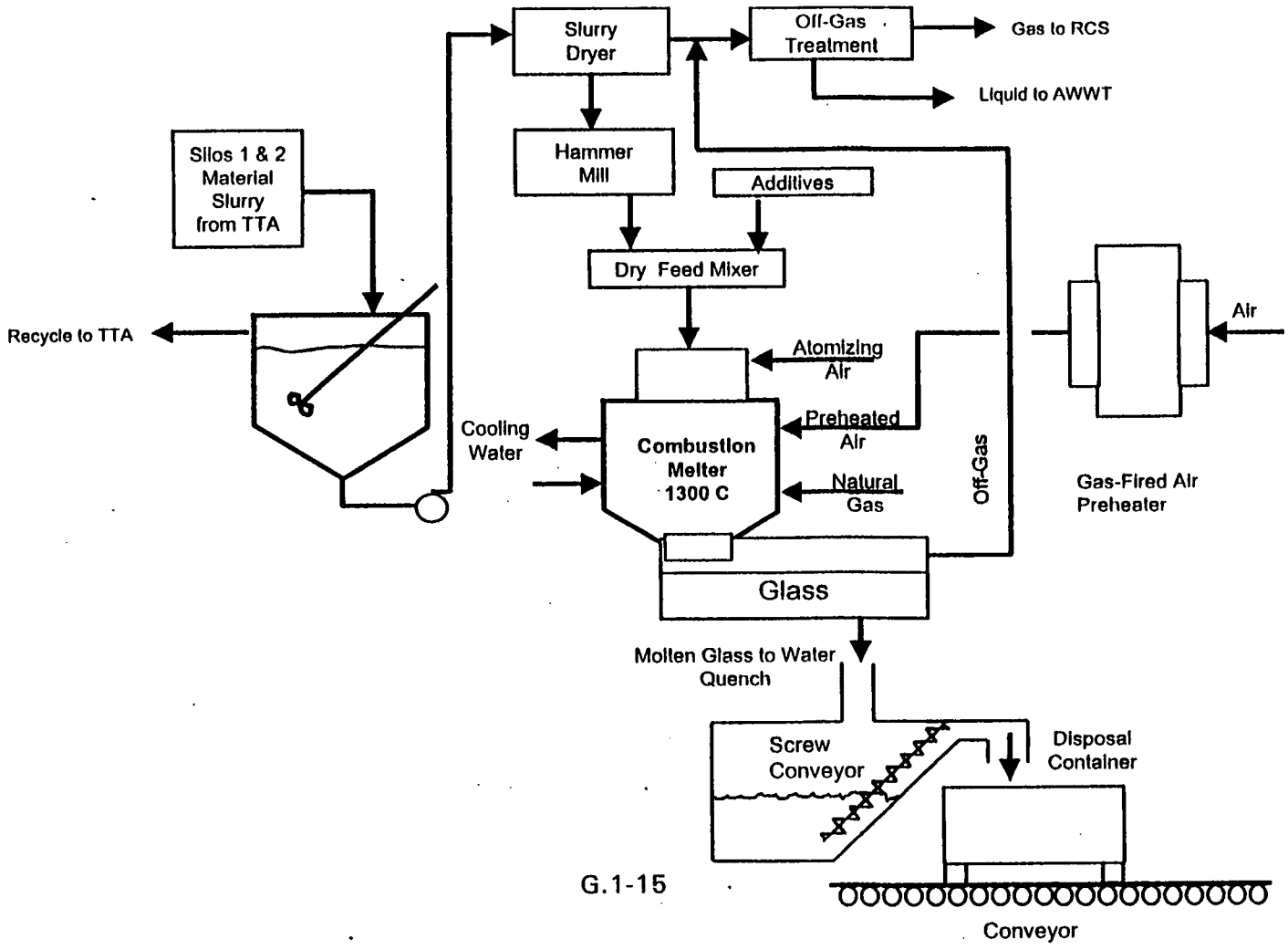

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FIGURE G.1.3-6
BULKING FACTOR PICTORIAL
VITRIFICATION — OTHER

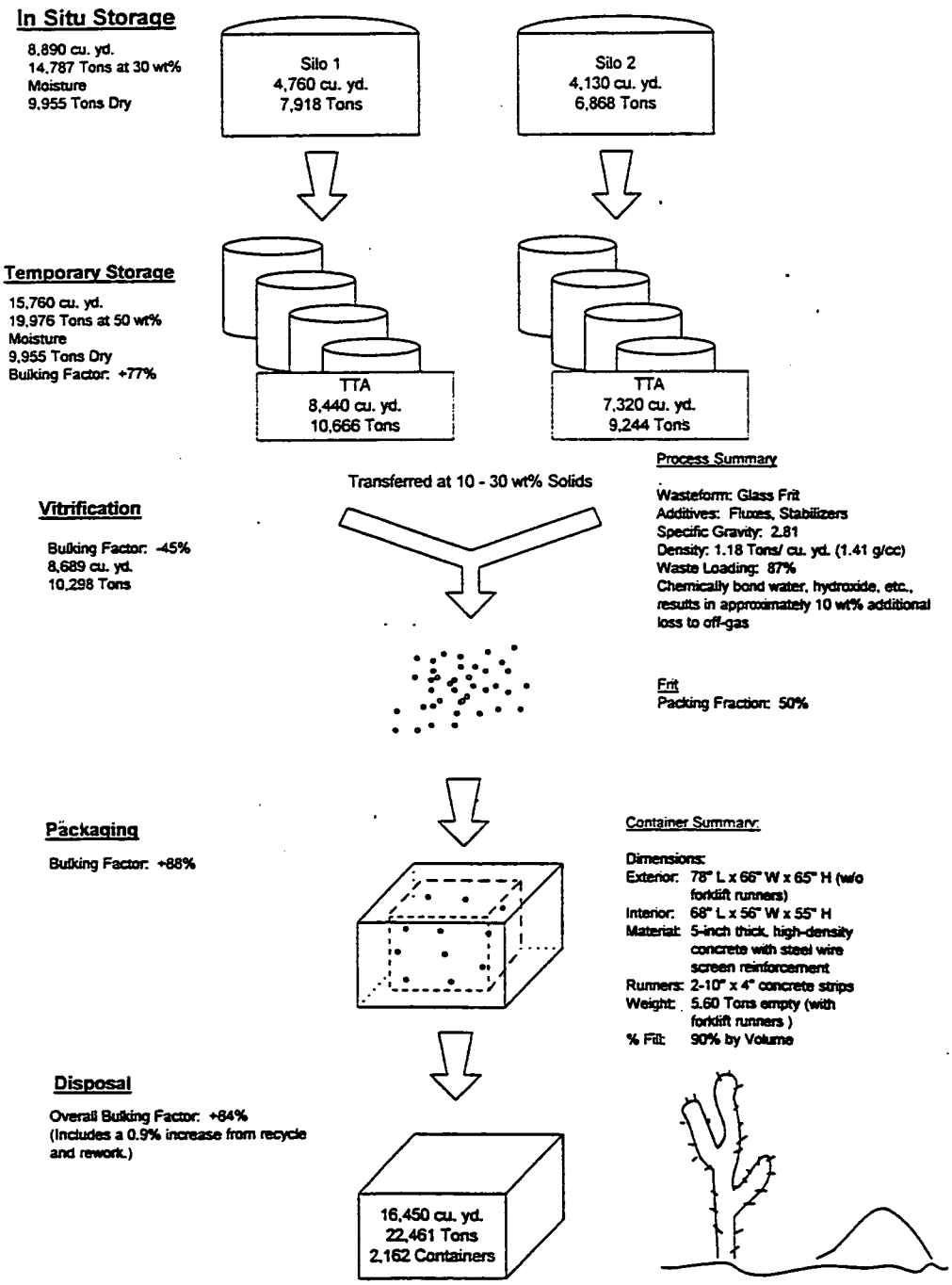

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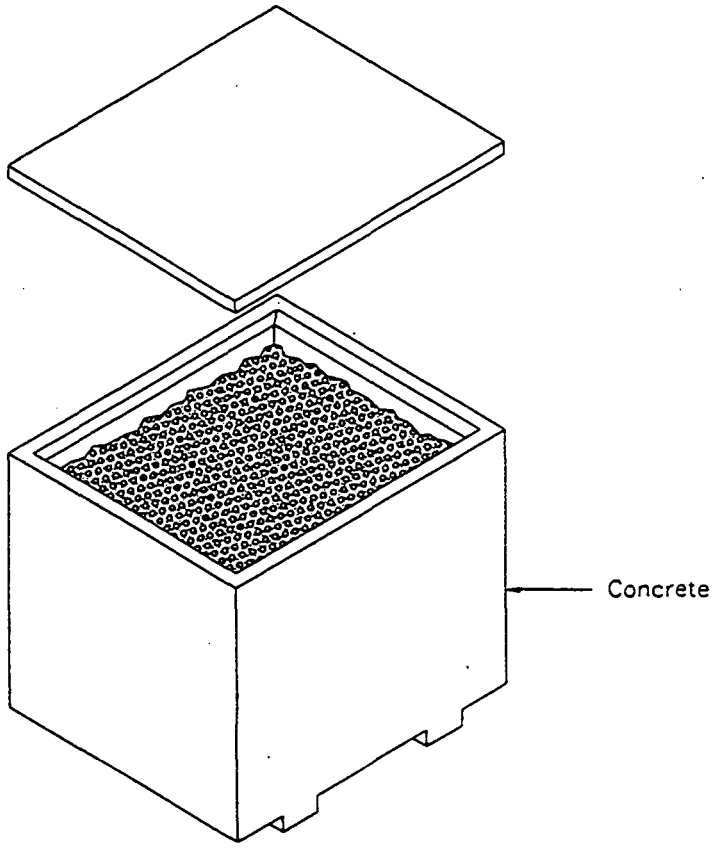
FIGURE G.1.3-7
SHIPPING AND DISPOSAL CONTAINER
VITRIFICATION — OTHER



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

DATE: 11/9/95

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. (PROD Index No. 4-202.1)

the filter cake in the mixer. The contractor also chose triple super phosphate (TSP[7]) as an additive to help control the leaching of lead. Results of using phosphates are discussed in **Section G.3**.

A simplified flow diagram of the process is shown in **Figure G.1.3-8**. A pictorial that presents the expected amount of grout produced and number of containers and their disposal volume is provided in **Figure G.1.3-9**. Supporting calculations are given in **Attachment G-1**. A sketch of a plausible shipping and disposal container is shown in **Figure G.1.3-10**.

<END OF PAGE>

[7] Notice that each chemical stabilization technology uses a "TSP" chemical in the treatment process, but there are two types of TSP. For Chemical Stabilization — Cement-based, TSP stands for *triple super phosphate*, which is a mixture of calcium, magnesium, and hydrogen phosphates. For Chemical Stabilization — Other, TSP stands for *trisodium phosphate.*

FIGURE G.1.3-8
SIMPLIFIED PROCESS DIAGRAM
CHEMICAL STABILIZATION — CEMENT-BASED

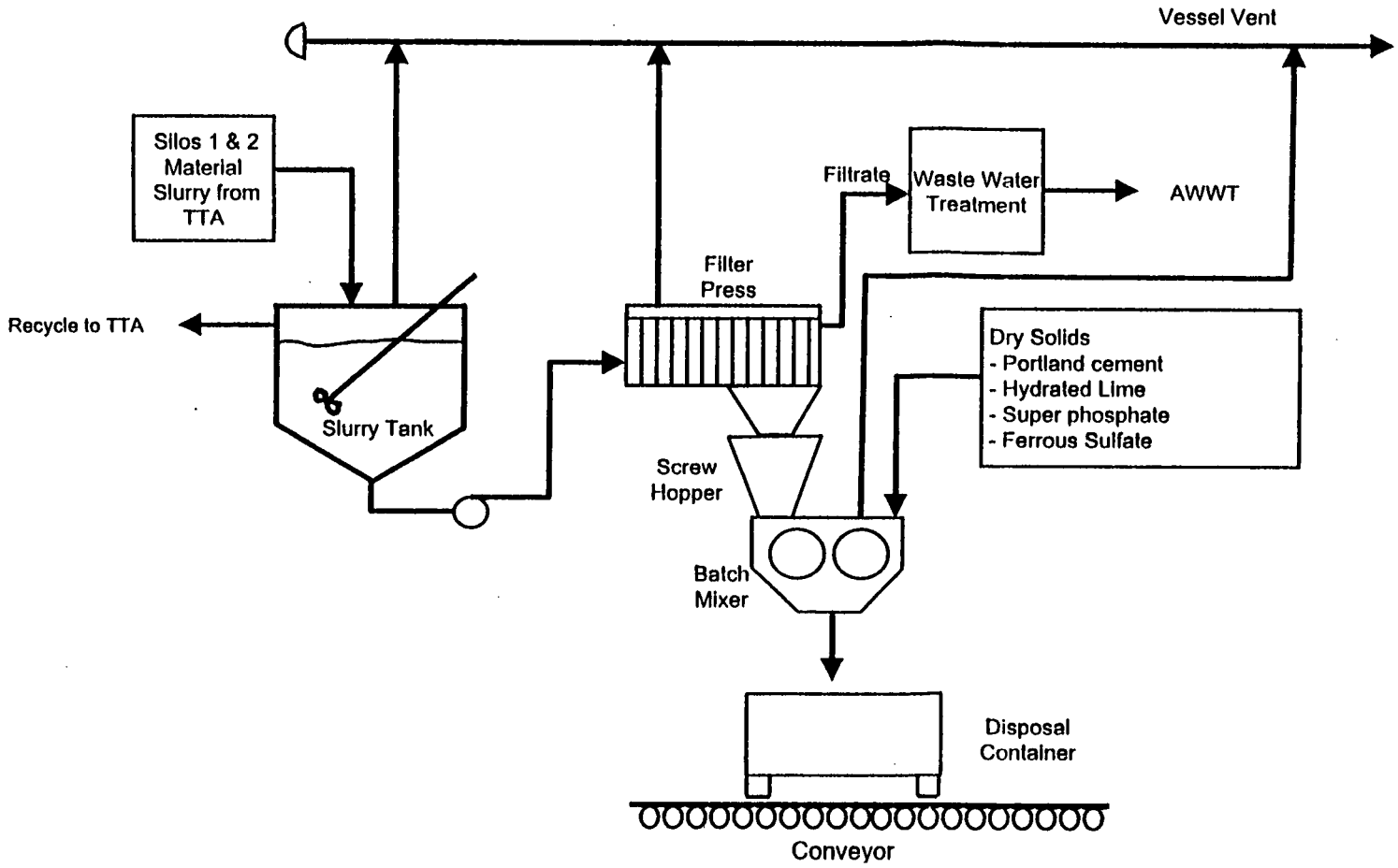

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FIGURE G.1.3-9
BULKING FACTOR PICTORIAL
CHEMICAL STABILIZATION — CEMENT-BASED

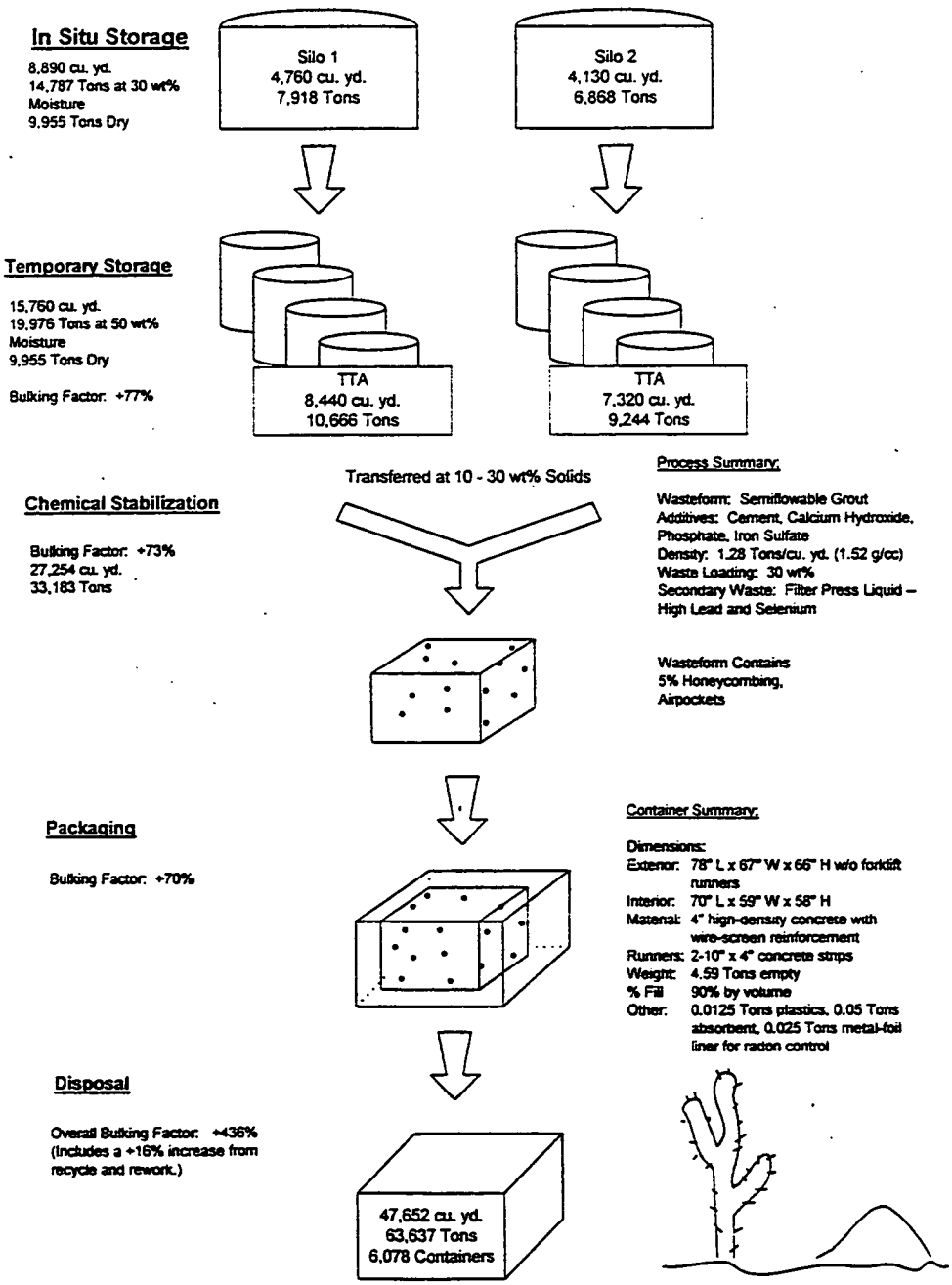
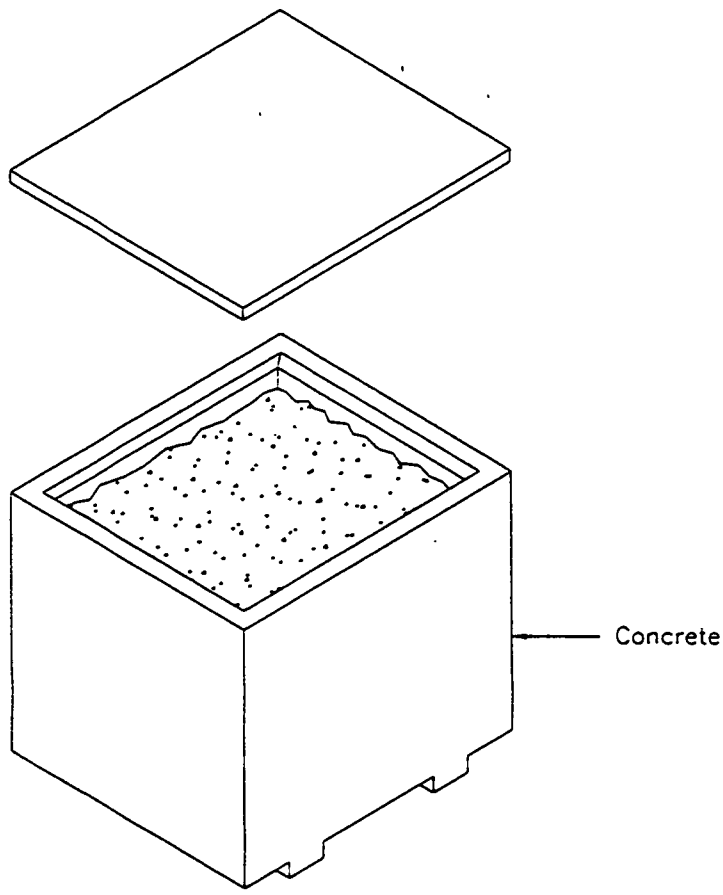


FIGURE G.1.3-10
SHIPPING AND DISPOSAL CONTAINER
CHEMICAL STABILIZATION — CEMENT-BASED



Outside Dimensions: 78" L x 67" W x 70" H x 4" wall

Chemical Stabilization – Cement

Weight of Waste per Container: 11,247 lbs
External Volume of Container: 211.7 cu. ft.
6,078 Concrete Containers

000255

FILENAME: SHIP_BOXES

INITIALS RWR DATE: 11/9/99

G.1.3.4 Chemical Stabilization — Other

The Chemical Stabilization — Other technology involves using inorganic chemicals to provide both stabilization and solidification. This technology uses a hydraulic binder that reacts with water to form a solid product. The original intent of this technology was to be an alternative to using Portland cement or silicates as the main binder, such as using sulfates and phosphates. However, it became apparent during the POP bidding process that few companies have used a non-Portland cement or a non-silicate binder in a large full-scale remediation effort. Therefore, the use of Portland cement or a non-silicate was accepted; and, the selection of the POP contractor focused on chemical additives, in addition to the binder, that imparted desired qualities to the treated Silos 1 and 2 material. The selected contractor stated that additives such as phosphates and sulfides would be investigated as necessary to obtain the desired treated wasteform. The contractor finally selected trisodium phosphate (TSP[8]) as the additive of choice. The phosphate appeared to be useful in preventing premature hardening of the grout in the mixer; however, it did not appear to have significant impact on the leaching of lead. Results of using phosphates are discussed in **Section G.3**. The process and facility for this technology were developed based on input from the contractor's POP report. **Appendix H, Attachment H4** contains the contractor's summary report and **Appendix H, Section H.3** contains the list of changes from the contractor's design and why the changes were made.

The contractor representing this technology chose to mix the grout in the shipping and disposal container itself. This will be referred to as "in-container" mixing. External mixing is also adaptable to this technology. The container has a ¾-inch steel wall for radiation shielding purposes. The container has an internal mixing assembly that is disposed with the container.

A dewatering step is required to increase waste loading of the final product. The contractor's original plan to meet this requirement was to place disposable filters in the container and draw

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8 Notice that each contractor uses the term TSP, but there are two types. For Chemical Stabilization — Cement-based, TSP stands for Triple Super Phosphate. For Chemical Stabilization — Other, TSP stands for trisodium phosphate.

excess water through the filters. However, the filters plugged from the fines in the slurry. The contractor met this requirement by allowing the solids to settle in the slurry holding tank and then decanting off the excess water.

A simplified flow diagram of the process is shown in **Figure G.1.3-11**. A pictorial that presents the expected amount of grout produced and number of containers and their disposal volume is provided in **Figure G.1.3-12.** Supporting calculations are given in **Attachment G-1**. A sketch of a plausible shipping and disposal container is shown in **Figure G.1.3-13**.

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FIGURE G.1.3-11
SIMPLIFIED PROCESS DIAGRAM
CHEMICAL STABILIZATION — OTHER

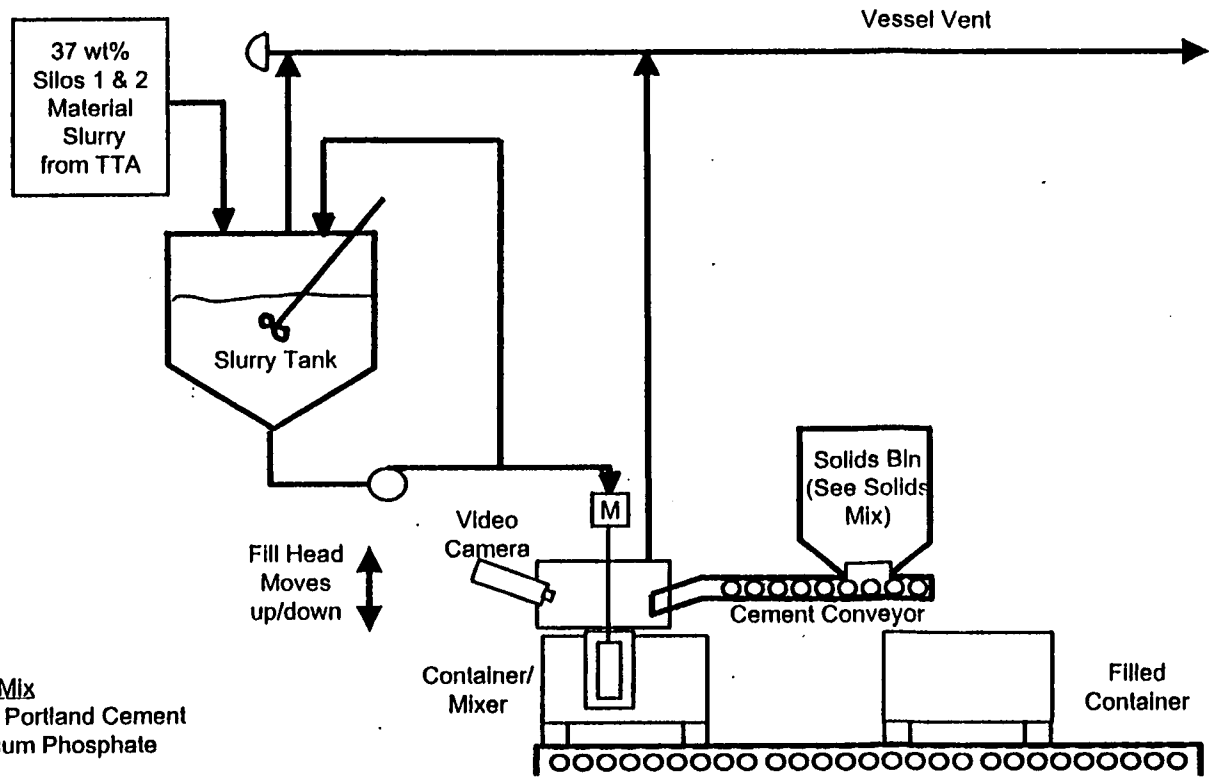

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FIGURE G.1.3-12
BULKING FACTOR PICTORIAL
CHEMICAL STABILIZATION — OTHER

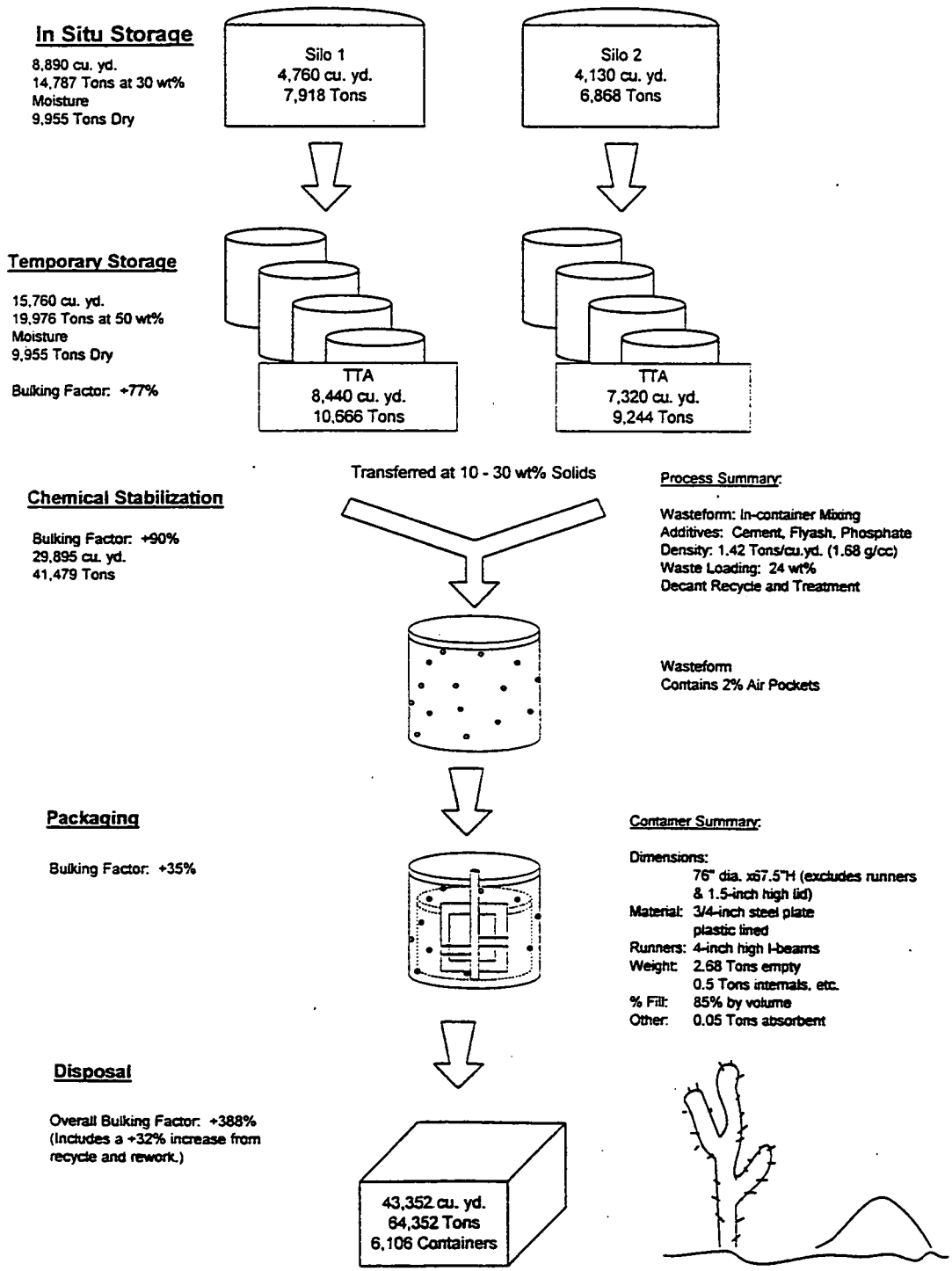

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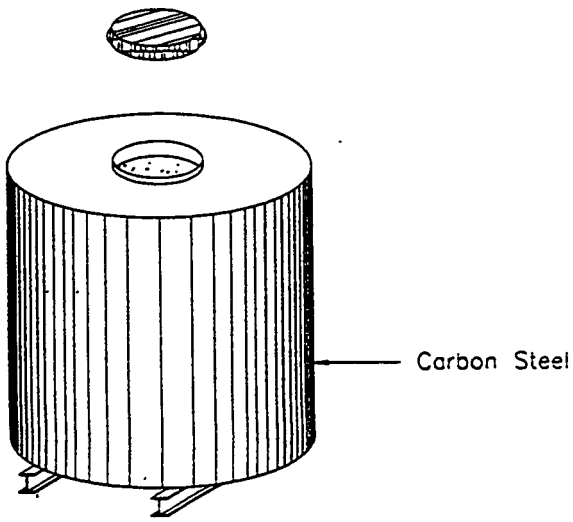
FIGURE G.1.3-13
SHIPPING AND DISPOSAL CONTAINER
CHEMICAL STABILIZATION — OTHER



Outside Dimensions: 76" D x 73" H x 3/4" wall

Chemical Stabilization – Other

Weight of Waste per Container: 14,536 lbs
External Volume of Container: 191.6 cu. ft.
6,106 Carbon Steel Containers

FILENAME: SHIP_BOXES

DATE: 11/9/89

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Section G.2

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).

<END OF PAGE>

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 *Units Waste Information Manual*, Oct. 1995. 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 Phase I Interim Treatability Study Report, FDF Report No. 40110-WP-0002, Revision1*. Prepared under contract for the U.S. Department of Energy: Fernald Field Office, Fernald, OH. (PROD Index No. 4-401.9)

TABLE G.2.1-3
SILOS 1 AND 2 ELEMENTAL COMPOSITIONS ACCORDING TO PNL ANALYSIS AND FDF ANALYSIS FOR SO_3
(Elemental makeup expressed in wt% as oxides)

Rank	Silo 1 w/o BentoGrout™			Silo 2 w/o BentoGrout™		
	Component*1	Measured*2	Normalized*3	Component*1	Measured*2	Normalized*3
1	SiO_2	50.00	57.00	SiO_2	51.00	58.99
2	PbO	12.00	13.68	PbO	6.20	7.17
3	BaO	6.30	7.18	Fe_2O_3	6.10	7.06
4	SO_3	3.40	3.88	SO_3	3.50	4.05
5	CO_2	3.20	3.65	Al_2O_3	3.40	3.93
6	Al_2O_3	2.60	2.96	CO_2	3.40	3.93
7	Fe_2O_3	2.50	2.85	BaO	3.00	3.47
8	Na_2O	1.80	2.05	CaO	2.50	2.89
9	MgO	1.20	1.37	MgO	1.70	1.97
10	K_2O	0.68	0.78	Na_2O	0.88	1.02
11	P_2O_5	0.62	0.71	K_2O	0.68	0.79
12	MoO_2	0.43	0.49	P_2O_5	0.68	0.79
13	La_2O_3	0.42	0.48	N_2O_5	0.62	0.72
14	NiO	0.42	0.48	UO_2	0.47	0.54
15	Ce_2O_3	0.41	0.47	NiO	0.36	0.42
16	CaO	0.37	0.42	Ce_2O_3	0.33	0.38
17	N_2O_5	0.29	0.33	TiO_2	0.33	0.38
18	TiO_2	0.28	0.32	La_2O_3	0.29	0.34
19	CoO	0.19	0.22	CoO	0.21	0.24
20	Nd_2O_3	0.19	0.22	Nd_2O_3	0.16	0.19
21	SrO	0.08	0.09	ZrO_2	0.14	0.16
22	Cl	0.08	0.09	CuO	0.08	0.09
23	V_2O_3	0.06	0.07	Cr_2O_3	0.08	0.09
24	CuO	0.06	0.07	V_2O_3	0.08	0.09
25	ZrO_2	0.05	0.06	MoO_2	0.08	0.09
26	SeO_2	0.05	0.06	SrO	0.06	0.07
27	Cr_2O_3	0.02	0.02	As_2O_3	0.05	0.06
28	MnO_2	0.01	0.01	SeO_2	0.04	0.05
29	BeO	0.01	0.01	MnO_2	0.03	0.03
30	F	0.00	0.00	ZnO	0.01	0.01
31	As_2O_3	<0.01	-	Cl	0.00	0.01
32	CdO	<0.01	-	F	0.00	0.01
33	Li_2O	<0.01	-	BeO	<0.01	-
34	ThO_2	<0.01	-	CdO	<0.01	-
35	UO_2	<0.01	-	Li_2O	<0.01	-
36	Y_2O_5	<0.01	-	ThO_2	<0.01	-
37	ZnO	<0.01	-	Y_2O_5	<0.01	-
Totals		87.72	100.00		86.46	100.00

*1 These Silos 1 and 2 material are shown as oxides, which is a convention frequently used, especially in the ceramic and soil fields. However, the in situ compounds are not necessarily oxides. For example, Feldspar minerals are known to compose part of the mix. The gases CO_2, SO_3, and N_2O_5 would most likely be combined with the oxide to form carbonates, sulfates, and nitrates. For example, $BaO + SO_3 - BaSO_4$.

*2 Many of these metal oxides (listed above) form hydroxides and hydrates, which are not decomposed by low-temperature drying (105 °C) and are not normally detected by most analytical methods. This factor could account for most of the variability; some could be sampling and analytical error.

*3 Normalized means that measured wt% values have been proportioned so that their sum total is 100%. The normalized basic values should more closely represent the expected composition of the Silos 1 and 2 materials if it were dried at a higher temperature and the hydroxides and hydrates decomposed.

<END OF PAGE>

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.

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

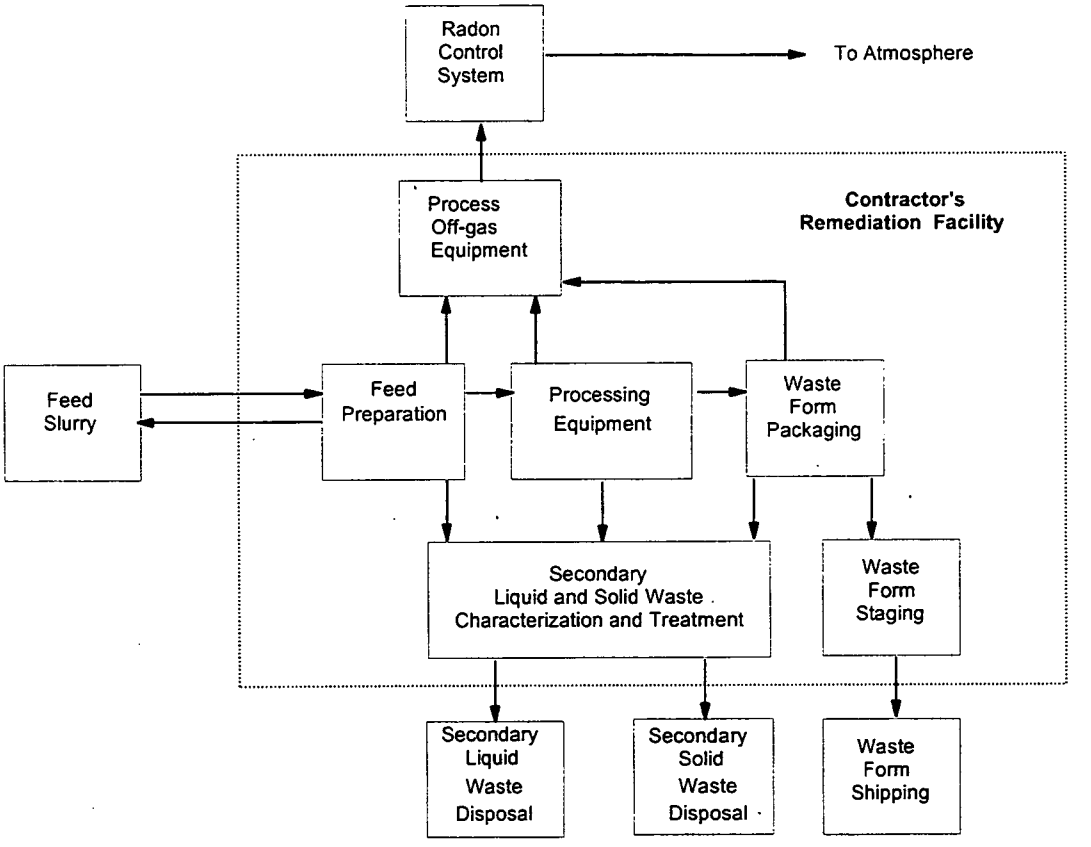
G.2.2 Contractor – FDF Interface

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%.

FIGURE G.2.2-1
CONTRACTOR-FDF INTERFACE DIAGRAM



G.2.3 Process and Facility Constraints

The process and facility are to be sized for the following constraints:

E. The Silos 1 and 2 material (and generated secondary wastes) are processed during a 3-year period.

F. The remediation facilities are designed and sized to process the Silos 1 and 2 material with 70% availability. Therefore, the facility must process at a higher production rate when operating to compensate for lost production time when the plant has planned and unplanned downtime.

G.2.4 Slurry Feed from the Transfer Tank Area

The Silos 1 and 2 material is retrieved from the TTA using an existing slurry pumping system. The final remediation contractor must install transfer lines from the TTA to the process facility to transport the slurry. A 4-inch, 150-lb raised-face flange interface at the TTA will be available for connection. Applicable requirements are listed below.

Assumption: The solids content of the delivery slurry is expected to vary. However, the solids content is expected to be in the range of 10 to 30 wt% solids. Process equipment is installed and sized for 10 wt% solids. Process equipment is installed to concentrate and maintain a constant solids content for feed to the remediation systems.

Basis: Experience with the FEMP Vitrification Pilot Plant (VITPP) and transfer of similar Silos 1 and 2 material at Niagra Falls.

A. The maximum delivery flow rate of the slurry is 5,900 pounds per hour (lb/hr) on a dry weight basis.

B. The process technology dictates when the slurry is delivered. However, for the design estimate, a routine schedule is stated for each technology. Such a schedule, at the maximum flow rate of 5,900 lb/hr solids, could be 5 hr/day, 5 days/week. A technology requiring delivery in excess of 12 hr/day needs to use

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. (PROD Index No. 4-302.3 – 4); 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>

TABLE G.2.5-1
RCRA TCLP LIMITS

Constituent	TCLP Limit ppm
Arsenic (As)	5.0
Barium (Ba)	100.0
Cadmium (Cd)	1.0
Chromium (Cr)	5.0
Lead (Pb)	5.0
Mercury (Hg)	0.20
Selenium (Se)	1.0
Silver (Ag)	5.0

E. Dusting/Particulate. Fine particles of Silos 1 and 2 material (and secondary wastes, etc.) are immobilized so that the treated material does not contain more than 1 wt% of loose, less-than-10 micrometer, diameter particles, or 15 wt% of loose, less than 200-micrometer, diameter particles.

F. RCRA Characteristics. The treated wasteform shall not exhibit a characteristic of a hazardous waste as defined by 40 Code of Federal Regulations (CFR) 261 Subpart C - Characteristics of Hazardous Waste (261.20 through 261.24 and OAC 3745-51-20 through OAC 3745-51-24). Also, the waste must not contain any listed waste as identified in 40 CFR Part 261.30 through 40 CFR Part 261.33, and OAC 3745-51-30 through OAC 3745-51-33.

G.2.6 Treatment Factors

The conventions to estimate how the Silos 1 and 2 material respond quantitatively to treatment are "Waste Loading" when the issue is weight, and "Bulking Factor" when the issue is volume. The equations for calculating Waste Loading and Bulking Factor are presented next.

G.2.6.1 Waste Loading

Waste loading of the treated Silos 1 and 2 material is calculated and expressed as:

$$\text{Waste loading (wl)} = \frac{\text{Dry weight of Silos 1 and 2 material (w/BentoGrout™) x 100 wt\%}}{\text{Weight of the treated Silos 1 and 2 material}}$$

(Equation 1)

Dry weight is defined as the resulting weight of the Silos 1 and 2 material dried at 105 °C.

G.2.6.2 Bulking Factor

The bulking factor is determined by the resulting treated volume divided by the original (or 'in situ') volume of the Silos 1 and 2 material in the silos (**Table G.2.1-1**), expressed as:

$$BF = (V_f \div V_i) \times 100\% \qquad \text{(Equation 2)}$$

Where:

BF = Bulking Factor

V_i = Volume of Silos 1 and 2 material in the silos.

V_f = Volume of treated Silos 1 and 2 material w/BentoGrout™.

The bulking factor references the "bulk volume" of treated Silos 1 and 2 material. It does not include the volume of the shipping container or excess air (i.e., air pockets) that may become entrained during the processing and handling of the material. This is accounted for separately in volume determinations.

G.2.6.3 Incremental Bulking and Overall Bulking Factor

These bulking factors are used when describing steps in a process. The bulking factors describe how the effected volume of the Silos 1 and 2 material has increased or decreased from the previous step. These bulking factors include the volume of the containers, etc., that affect disposal cost.

The overall bulking factor represents how a technology will increase the volume of the in situ Silos 1 and 2 material from inside the silos to final disposal in the ground.

Incremental bulking factors are designated with a "+" or "-" sign placed in front of the percentage amount to indicate an increase or decrease, respectively, in bulking. The incremental and overall bulking factors are calculated as follows:

$$\Delta BF = (V_a \div V_b)/V_b \times 100\% \qquad \text{(Equation 3)}$$

Where:

ΔBF = Bulking Factor

V_b = Volume of Silos 1 and 2 material (plus container, if applicable) before a process step.

V_a = Volume of treated material after a process step.

G.2.7 Treated Silos 1 and 2 Material Sampling and Analysis

Each technology has a sampling and analysis program. The following items are included in the program.

A. Documentation of approach to sampling and analysis with rationale supporting approach.

B. Procedures for the specified analytical tests.

C. Duplicate samples of the treated Silos 1 and 2 material are collected from (1) each chemical stabilization process batch and cured under conditions (e.g., temperature and humidity) similar to that of the treated Silos 1 and 2 material in containers, or (2) each vitrification process shift. One sample is archived and the other is

prepared for analysis.

D. Proposed sampling frequency: A minimum of one sample of the treated Silos 1 and 2 material per shift shall be analyzed by the TCLP. For the chemical stabilization technology, unconfined compressive strength shall also be measured.

E. Archived samples are stored until remediation of the site is complete. The facility design shall provide for storage of the archive samples.

F. Process sampling systems provide for process control, accountability, diagnosis, and documentation of compliance with treated Silos 1 and 2 material acceptance requirements.

G.2.8 Rework and Recycle Water

G.2.8.1 Rework

To ensure that facilities are designed for the handling of rejected treated Silos 1 and 2 material, it is assumed that 1% of the treated material will fail minimum shipment and/or disposal requirements, and require reprocessing. The design basis assumptions for rework are described below.

A. **Assumption:** The vitrification technologies ultimately produce only 1.5 new shipping containers of processed material for each failed, full shipping container. This is because glass can be melted; thus the failed processed material is size-reduced, as necessary, and fed back into the melter.

B. **Assumption:** The chemical stabilization technologies produce 3 new shipping containers of processed material for each failed, full container of processed material because the failed grout is size-reduced and reintroduced into the solidification process as aggregate.

C. **Assumption:** The reworked shipping containers are considered secondary waste, even though they may be reusable and/or have small (minor) amounts of residue in them.

D. **Assumption:** Full shipping containers requiring rework are scheduled during the

000277

processing window (e.g., rework occurs in parallel with remediation operations).

E. **Assumption:** The rework station is designated as a radiologically contaminated area due to the invasive nature of the size-reducing process.

G.2.8.2 Recycle Water

Settling tests indicate that approximately one-half of the BentoGrout™ settles. It is assumed that some recycle water from the remediation process remains at the end of processing. This wastewater is used for the final flushing and cleaning of the TTA tanks in preparation for decontamination and demolition (D&D). This newly generated wastestream is treated by the remediation process and packaged for disposal. Assume that half of the suspended BentoGrout™ solids will find their way into the process. This equates to 25 wt% or 55 tons (dry) of the BentoGrout™ remaining in wastewater. Some Silos 1 and 2 material fines will also remain suspended and are shown in **Table G.2.8-1** - ***TTA Recycle Silos 1 and 2 Material***, which equates to 1 wt% of the total Silos 1 and 2 material and BentoGrout™.[17]

TABLE G.2.8-1
TTA RECYCLE SILOS 1 AND 2 MATERIAL

Silos 1 and 2 Material	49 tons (dry)
BentoGrout™	55 tons (dry)
Total Solids	104 tons (dry)

G.2.9 Containers and Product Handling Requirements

Since the Silos 1 and 2 material is radioactive and contains radon, special requirements are placed on the containers for handling, shipment, and disposal.

[17] This is the assumption that the facilities and estimates are based. However, recent settling tests being performed at the FEMP laboratories appear to indicate that the BentoGrout™ reacts with Silos 1 and 2 material (or vice versa) and prevents complete settling. This can increase the amount dilute Silos 1 and 2 material the technologies need to process at the end of the project. This can have a significant impact on decanting operations, especially the decanting process used in the Chemical Stabilization — Other technology. See **Section 3.1** - ***Waste Loading Criteria***.

G.2.9.1 Physical Criteria

A. The container must, at a minimum, meet the design requirements for an Industrial Package - Type 2 (IP-2) container (49 CFR Part 173.411).

B. Containers remain watertight under expected inclement (hot, cold, rainy, icy, etc.) weather conditions at the FEMP, in transport, and until disposal at the NTS.

C. The maximum weight of each container (including contents) is 21,000 lb.

Basis: DOE-FEMP experience indicates that 42,000 lb is the maximum weight that can be routinely placed on a truck (for the expected type of trucks to be used for shipment) with the guarantee of meeting U.S. Department of Transportation (DOT) axle weight limits on highways. Two smaller containers (rather than one large container) are used to assist handling and loading at the FEMP, as well as material handling capabilities at the NTS.

D. The disposal container is stackable and can withstand a compression test at 3,375 lb/ft^2 to prevent collapse of the container after disposal.

Basis: NTS Waste Acceptance Criteria.

E. The surface of the filled container does not exceed a radiation exposure level of 70 milli-Roentgen equivalent man per hour (70 mrem/hr).

Basis: The DOT requirement for surface radiation levels is 200 mrem/hr. However, in order to meet the DOT requirement for "exclusive use shipments" of radiation levels of 10 mrem/hr at 2 meters (m) from the transport vehicle, the results of Microshield® modeling suggest an administrative limit for surface radiation levels of 70 mrem/hr be met.

F. If the treated wasteform is porous or does not significantly reduce radon emanation, then the container must have a liner and liner seal (in addition to being water tight and airtight) to stop emanation. This means that, at a minimum, a thin-metal liner (or equivalent) is installed with the grout

wasteforms. Glass is assumed to be essentially non-porous (can contain the radon) and, thus, does not warrant the need for a liner.

G.2.9.2 Product Handling

A. Container handling is a primary consideration for the layout of the facility. The in-and-out flow of the containers is addressed, and space is allotted for shielding, maintenance, and housekeeping.

B. Containers are moved by conveyor whenever possible to make the operations safer, more efficient, and to minimize operator exposure.

C. Filled containers are handled remotely. Remotely operated conveyors and cranes are used for all routine handling of filled containers. Specialty equipment for container lid handling, placement, and fastening are supplied for remote operation to provide high reliability, recovery from failure, and operating efficiency.

D. Filled shipping containers are stored in the interim staging facility before off-site shipment to the approved disposal facility. The lifting and placement of shipping containers are performed remotely. However, workforce contact with the filled shipping containers is necessary to secure and prepare shipments in accordance with FEMP procedures before departure from the site.

Note: The external surfaces of the shipping containers are anticipated to be essentially free of loose surface radioactivity. However, radiological surveys will be performed and documented before shipment in accordance with FEMP procedures and DOT regulations.

E. The shipping container is grappled in the interim staging facility by a remotely operated bridge crane and placed in an inspection area. Once a container has been certified, it is loaded onto a truck, secured, and prepared for off-site shipment.

Note: The generation and buildup of radon is not anticipated to be a concern in the interim staging facility, since the shipping containers are sealed before staging; therefore, the facility will not require special ventilation.

G.2.10 Container Staging

Facilities to stage the containers of failed material and to reprocess the failed materials are included in the overall process/plant design and included in the overall schedule.

Filled containers are staged at the FEMP before being transported to the disposal site. Management of the containers includes inspection, handling, certifying, staging, and shipment. Containers are stored at the contractor's facilities for 45 calendar days after the contractor has (1) packaged the treated material in compliance with the ***Container and Product Handling Requirements, Section G.2.9***, and (2) has verified that the treated material complies with the ***Treated Silos 1 and 2 Material Acceptance Requirements***, **Section G.2.5.** For the chemical stabilization technologies, it is assumed that the grout reaches minimum strength in six days and the TCLP analysis is performed on the grout samples on the seventh day. For vitrification technologies, the TCLP analysis can be performed immediately and the containers can be staged after they have cooled. The contractor is responsible for the containers until they are properly turned over to FDF for shipment (for a period not to exceed 45 days).

<u>Physical Criteria</u>

A. Filled containers are stacked in the interim storage area no more than two high; stacking is not allowed if the containers' lids are not bolted or firmly attached.

B. For chemical stabilization technologies, the containers are stored in a controlled environment for seven days (six days cure time plus 1 day to perform the TCLP).

   Basis: The POP testing demonstrated that the remediation technologies could achieve minimum compressive strength within six days, see **Section G.3.1.3** for additional information.

C. One month inventory of empty shipping and disposal containers are maintained to support continuous operations.

G.2.11 Treated Silos 1 and 2 Material Shipping

A. Maximum payload of 42,000 lb (including the containers and their contents) may be shipped per truck.

B. An absorbent mat is placed onto cured, chemically stabilized waste to eliminate free standing water from forming within the stabilized waste containers.

Basis: Based on documented U.S. Department of Energy (DOE) cement/grout failures, transportation (DOT) incidents, and disposal site rejects have occurred either because of free standing water separating from the grout for various reasons, or from water condensation in the container from water-saturated grout. Although the treated wasteform can contain in excess of 50 wt% water, some proposed treatment recipes contain only 10 wt% cement, which chemically treats less than 5 wt% (absolute) of the water. This leaves the remaining water loosely bound or in the pores of the grout. Temperature gradients, continual evaporation, and condensation of the loosely-bound water could result in sweating and puddling of water inside the container; or, continual vibration during shipment could result in separation of the loosely-bound water.

G.2.12 Disposal

This revised FS assumes that the treated Silos 1 and 2 material will be disposed at the NTS. Disposal costs for the cost estimate shall be those required for disposal at the NTS. The present schedule indicates that the On-Site Disposal Facility (OSDF) will be closed by the time the Silos 1 and 2 material is remediated. Therefore, all treated Silos 1 and 2 material, secondary wastes, and D&D materials shall be assumed to be properly size reduced, containerized, and shipped to NTS for disposal.

G.2.12.1 Treated Silos 1 and 2 Material Disposal

See **Section G.2.9** - ***Containers and Product Handling Requirements,*** and **Section G.2.5** — ***Treated Silos 1 and 2 Material Acceptance Requirements,*** for details on the disposal requirements for the Silos 1 and 2 material.

G.2.12.2 Secondary and D&D Wastes

Requirements for secondary and D&D waste include:

A. Solid waste is size-reduced, packaged in 4 ft. x 4 ft. x 7 ft. or 4 ft. x 2 ft. x 7 ft. (width x height x length) standard issue boxes. The gross weight limit is 9,000 lb per box.

B. The interior volume of waste packages is loaded as efficiently and compactly as practical in order to minimize shipping and disposal costs.

C. Scavenged disposal containers with contamination or debris are assumed to be disposed at the NTS.

G.2.13 Secondary Waste

Design of the remediation process minimizes the generation of secondary waste and allows waste recycling back into the remediation process, to the extent practical. Secondary wastes include wastewater, solid waste, spent filters, air emissions/gaseous effluents, etc. Secondary waste generated by remediation alternatives is collected, treated, and dispositioned in accordance with the applicable or relevant and appropriate requirements (ARARs) and existing site procedures. Solid waste may be generated during construction, operation, and D&D of the facility.

Recycling and reuse of secondary waste and excess materials is an integral part of the project philosophy to meet environmental "as low as reasonablely achievable" (ALARA) goals. For example, off-gas sludges from the wet electrostatic precipitator (WESP) are collected and recycled into the melter feed. Designs include facilities for characterization, staging, segregation, containment, and treatment (if necessary) before disposal. Designs shall also include tanks and tank systems appropriate for the management of material characterized under RCRA. Facilities to accommodate survey and packaging of secondary waste for on-site or off-site disposal in containers appropriate for the materials' classifications would also be included. Treatment and disposal of secondary wastes shall be included in the alternative's cost estimate. Mixing or blending to dilute characteristically hazardous waste to render it non-hazardous is prohibited.

G.2.13.1 Secondary Liquid Waste Treatment

All water or liquid streams potentially contaminated with hazardous or radioactive constituents, whether particulate or dissolved, are collected and treated for safe release to the environment. The handling of liquid effluent is considered in the design and cost estimates. If further consideration indicates that a hazardous constituent (e.g., lead) will exceed the limits (listed below), then treatment (e.g., ion exchange) must be included in the final design. Water (liquid) effluents are sent to the present on-site Advanced Wastewater Treatment (AWWT) facility for final disposition. Water effluent is collected, sampled, and analyzed for **Table G.2.13-1 - *Wastewater Discharge Limits***, constituents before being released to the AWWT. The water effluent must meet, at a minimum, the following requirements prior to being discharged to the AWWT:

- 10 gallons per minute (gpm) maximum flow rate (assuming no other silos function is operating at this time, as 10 gpm is the limit for OU4 in its entirety);
- 1,000 ppm total suspended solids; and
- Metals and radionuclides concentrations and quantities equal to or less than the discharge limits given in **Table G.2.13-1 - *Wastewater Discharge Limits***.

The FEMP AWWT has not established total dissolved solids (TDS) limits on the 10 gpm liquid effluent discharged from the OU4 remediation facilities. TDS is not a concern because the 10 gpm wastewater stream will be significantly diluted by the much larger wastewater streams at the AWWT.

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TABLE G.2.13-1
WASTEWATER DISCHARGE LIMITS[18]

Metals	Discharge Limit (mg/L)	Radionuclides	Discharge Limit (pCi/L)
Arsenic (As)	5.0	Actinium-227	10
Barium (Ba)	100.0	Lead-210	30
Cadmium (Cd)	1.0 or 0.012 kg/day	Polonium-210	80
Chromium (Cr)	5.0	Protactinium-231	10
Lead (Pb)	5.0 or 0.06 kg/day	Radium-226	100
Mercury (Hg)	BDL[19]	Radium-228	100
Selenium (Se)	1.0	Thorium-228	400
Silver (Ag)	5.0 or 0.003 kg/day	Thorium-230	300
Iron (Fe)	0.055 kg/day[20]	Thorium-232	50
		Uranium-234	5 ppm total U
		Uranium-235/236	
		Uranium-238	

18 Limits are set by the FEMP AWWT facility wastewater acceptance criteria. These limits are valid for discharges up to 10 gpm.

19 Below detectable limits (BDL).

20 Iron does not have a concentration limit.

G.2.13.2 Secondary Solid Waste Treatment

All solid streams, potentially contaminated with hazardous or radioactive constituents, are collected and treated for safe release to the environment. Secondary solid waste is size reduced as follows:

- Metal – 7 ft long by 4 ft wide by 1.5 ft high maximum
- Concrete – 6 ft long by 4 ft wide by 1.5 ft high maximum
- Other Materials – 7 ft long by 4 ft wide by 1.5 ft high maximum

G.2.13.3 Gaseous Effluents

Environmental limits are placed on air emissions of radioactive particulate and radon during storage and treatment of a source material. Process off-gas is generated only by the treatment processes for the vitrification alternatives; but, radon and particulates are produced by all remedial alternatives. Vitrification off-gas is controlled by a system specifically designed to mitigate acid gases and particulate emissions using best available technology. Acid gases are controlled by scrubbers and NO_x removal systems. Particulate is controlled by electrostatic precipitation and high efficiency particulate air (HEPA) filtration and prefilters downstream from off-gas control equipment. Iso-kinetic monitoring for particulate material and radioactivity in the off-gas is provided at the discharge stack. The stack design accommodates stack test monitoring equipment for sampling and analysis of the off-gas to ensure environmental limits are not exceeded.

All air or gas streams, potentially contaminated with hazardous or radioactive gases or air borne particulates, are collected and treated for safe release to the environment. However, those streams that are expected to contain radon must meet the special requirements of **Section G.2.14 - *Radon Handling and Control.*** Equipment selection/design of the full-scale treatment facility include enclosed systems and other controls that preclude or limit the release of gaseous and particulate radionuclides, and other air contaminants to the environment. Point source off-gas control systems used in remediation shall use best available technology (BAT).

A. All process equipment and enclosures venting to the RCS are as airtight as practical to reduce air inleakage, and thus, reduce the ventilation load going to the RCS.

B. Ventilation air from indoor storage areas that does not contain significant radon is treated for particulate control using HEPA filtration and released through a separate non-process stack. All HEPA filtration systems are designed for dioctyl phthalate (DOP) testing, and differential pressure (DP) monitoring and alarms.

G.2.14 Radon Handling and Control

There will be an existing control system for radon provided at the site at the time of remediation operations. The existing RCS will be built for the Accelerated Waste Retrieval (AWR) Project and be capable of handling 1,000 cubic feet per minute (ft^3/min), with 500 ft^3/min available for the full-scale treatment facility. The preconceptual full-scale design must include additional facilities for the treatment of radon-laden streams that exceed 500 ft^3/min. (For cost estimating purposes over the 500 ft^3/min, cost will be extrapolated from the present RCS design.) A 10-inch, 150-lb raised face flange interface at the AWR RCS facility is used for connection to the RCS.

Radon in the off-gas is controlled by use of engineering process control features including carbon beds for adsorption of radon. Radon in ventilation air from process equipment, and areas that contain exposed Silos 1 and 2 material, is controlled in a similar manner by ventilation to the RCS. Other significant point sources of radon such as open containers of chemically stabilized Silos 1 and 2 material are controlled with engineered ventilation hoods and treatment in the RCS. Radon control is monitored at the RCS point source discharge stack to ensure that fence-line concentration limits are not exceeded.

To minimize the need for radon control facilities, the following is observed in the process and facility designs:

A. Process equipment, rooms, cells, and structures that contain exposed Silos 1 and 2 material are ventilated to the RCS. Also, air exposed to open containers of grout (chemically stabilized Silos 1 and 2 material) are captured with engineered,

ventilation hoods and sent to the RCS, or all air discharge/ventilation is sent to the RCS.

B. Airlocks are used for the entry and exit points of cells. A "cell" is defined as an enclosed, air-controlled room housing process equipment or operations.

Discharge limits to RCS

The process design for each technology ensures that the off-gas and/or ventilation air going to the RCS has the following quality:

- 90° F and 0.022 lb water/lb dry air, maximum;
- 20 ppm (vol) SO_x, maximum;
- 20 ppm (vol) NO_x, maximum;
- 15% (vol) CO_2, maximum;
- 40 ppm organics, maximum; and
- Filtered or scrubbed for particulates.

G.2.15 Facility Design

The facility layout for each alternative minimizes space consumption and impacts to the site. The preconceptual design is functional in form and able to meet the requirements of the facility mission in the most prudent, cost effective, and sensible means.

The layout for the facility is governed by a number of specific issues and factors. It must be operable, maintainable, and protected from safety (health hazards) and radiological (radiological hazards) concerns. Provided within the concept, must be the application of ALARA principles and methods for exposure and contamination control.

Finally, each of the concepts is flexible and robust to allow for potential process and/or operational upsets and contingencies.

000289

G.2.15.1 Operability/Maintainability

The facility layout and design for the full-scale treatment facility processes and packages the Silos 1 and 2 material in a safe and efficient manner. In doing so, the layout shows that the involved facilities are operable and maintainable. This includes a compact design that minimizes space consumption. Design flexibility is considered as each of the processes, systems, and structures are conceptually described by the POP contractors. Design modifications and alterations to many of the systems are expected in the actual design of the facility.

The facility layout considers the requirements of the process and the FEMP as a whole to perform its mission. Operability is a qualitative assessment of those requirements. Like operability, maintainability requirements are considered in the facility design and layout. Maintainability is assessed by evaluating the complexity, reliability, and the repairability of associated equipment and systems. Repairability is influenced by factors such as:

- Available work space;
- Location of equipment;
- Controlled or uncontrolled areas;
- Method – replacement or repair;
- Number, type, and availability of maintenance personnel;
- Pre-maintenance preparation requirements; and
- And post maintenance clean-up.

In developing the facility layout, consideration is given to practicality. Practicality refers to whether the equipment, layout, or design is "fit for its intended purpose." Does it perform its intended function efficiently and effectively? Do the layout and equipment perform efficiently as required? The complexity of the design and equipment is a liability in the facility's layout because it can indirectly increase personnel exposure to health hazards. Simplification is the

key to reduce maintenance and operational requirements. Overall facility performance should benefit from the reduction in complex requirements.

The facility layout provides space for equipment and for access to equipment and supporting systems. Aisles within work areas are wide enough not only to facilitate operation and maintenance but to provide for equipment removal. The design of the facility weighs these requirements against safety and cost. Excessive additional space is also considered. Space requirements minimize and, at the same time, provide flexibility to perform operational and maintenance tasks safely and efficiently.

Radiological or potentially contaminated areas are controlled and segregated from radiologically uncontrolled "clean" areas. Maintenance and Operations personnel have access to the equipment within the facility's radiological working areas. Areas to don and doff protective clothing as well as radiological survey equipment are provided. Additional access space is provided in controlled areas where maintenance personnel may be required to perform awkward tasks in bulky personal protective equipment (PPE) clothing.

Facility systems are comfortable and natural for personnel to operate, use, and maintain (human factors requirements). Deviations are allowable if compliance is not cost-effective or compromises safety, providing the deviations do not jeopardize the operability and maintainability of the system or facility.

Exterior areas around the facility provide space for support services and general equipment. The production facility has the capability and means to receive and store all chemicals, consumables, and materials necessary to operate and maintain the plant. Space is provided to decon, package, and store failed radioactive contaminated equipment before removal from the facility. This space is sufficient to minimize adverse impact to facility operations.

The facility is located to permit convenient tie-in into the existing infrastructure (i.e., roadways and utilities). Buildings and structures are located to minimize interference with existing

underground and above ground utilities. The facility's location does not hinder the operation of other facilities co-located within the site boundaries, the ability to make mechanical alterations and refinements, or the final requirements for demolition of the facility.

G.2.15.2 Piping

Piping systems, components, and equipment exposed to freezing temperatures are insulated and heat traced where appropriate. Radioactive or hazardous materials conveyed by piping systems or held in vessels have secondary confinement. Leak monitoring is provided to detect leakage into the closed interstitial space.

G.2.15.3 Mechanical Equipment

Equipment is selected for practicality of design as referred to a "fit for purpose" selection or having a configuration that efficiently performs its intended function. Other factors considered include: reliability; maintainability; practicality; cost effectiveness; and use of a demonstrated technology that is readily supplied, and preferably, commercially available off the shelf.

Modular and skid mounted equipment are used wherever practicable. Modularization of equipment systems can lead to simplifying construction activities and have an overall cost benefit for the facility. Mechanical systems maximize the use of interchangeable equipment to minimize spare parts inventories, operations, and maintenance training requirements. Redundant equipment is used within the facility to ensure reliability and to reduce worker exposure in controlled radiological areas. Similar types of equipment, which require operator monitoring, are located in close proximity to each other. Space is provided and identified for maintenance, preventative servicing, and/or repairing. Complex structures, systems, or components (SSCs), including electronic devices, or SSCs having a high probability of failure are located for easy access and maintenance. Complex operator interactive equipment, requiring operator interaction to make constant interpretive judgements for operations, is minimized. The structural design of the facility includes loads due to mechanical equipment

imposed on the floor and on the superstructure. The facility design includes the means to recover from postulated equipment failures and operator errors.

G.2.16 HVAC

G.2.16.1 General

This section discusses the general design criteria for the treatment facility's heating, ventilation, and air conditioning (HVAC) systems.

A. The HVAC systems for the remediation facilities are designed to maintain temperatures in the recommended range for the operation and optimum service life of plant equipment, and for comfort of workers in normally occupied areas. Electric resistance heating is used.

B. The HVAC Air Supply Systems are sized and matched with the corresponding exhaust system.

C. HVAC Systems are sized in accordance with the following criteria:

1. <u>Inside design temperature</u>

Cooling by Ventilation:	Outdoor air temperature + 10 °F rise
Cooling by Refrigeration:	75 °F
Heating (Electric):	Minimum 55 °F for equipment rooms and unoccupied areas. Minimum 65 °F for corridors and operating areas.
Humidity:	No Controls.

2. <u>Outside design temperature for Zone 1, Zone 2 and Zone 3</u>

Summer-Maximum:	95 °F
Winter-Minimum:	-20°F

These criteria are also applicable for the analytical laboratory, warehouse,

000293

mechanical/electrical building and staging areas.

D. Areas within the remediation facilities are designated as Zone 1, Zone 2, and Zone 3 according to air pressure and the number of air changes. The basis for the number of air changes is to provide comfort for plant personnel.

Zone 1: Expected to be "clean" areas and are maintained at - 0.25 inch wg with a minimum of six air changes per hour.

Zone 2: Expected to be potentially contaminated areas and are maintained at -0.50 inch wg with a minimum of seven air changes per hour.

Zone 3: Expected to be contaminated areas and are maintained at - 1.0 inch wg with a minimum of five air changes per hour. Plant personnel are expected to spend the least amount of time in Zone 3 (compared to Zones 1 and 2).

E. The process facility has three separate HVAC systems (except for Vitrification — Other, which has two). One system is exclusively for Zone 3, one is for the curing room (in the chemical stabilization process) or cooling room (in the joule-heated vitrification process) for Zone 2, and one is used for both the remainder of Zone 2 and all of Zone 1.

- Vitrification — Other has only two separate HVAC Systems: one dedicated to Zone 3 and the second for combined Zones 1 and 2.

- The air potentially contaminated with radon from specified areas in Zone 3 are exhausted to the RCS for treatment. The maximum flow rate discharged to the RCS shall not to exceed the RCS design capacity.

F. The following are the design criteria for sizing the HVAC equipment:

<u>Air handlers</u>

The heating and cooling requirements for the treatment facility are met by independent air handlers. The air handlers are to include a supply fan, inlet filters, and electric heating as applicable. Inlet filters are to include a pre-filter and a high efficiency filter. For the Vitrification — Joule-heated process, air conditioning is included with the air handler to cool the cooling room.

The air handlers designated exclusively for Zone 3 and Zone 2 (curing room / cooling room) are designed for 100% capacity, with 100% backup. The air handlers designated for the combined Zones 1 and 2 are designed for 100% capacity and do not have back up systems.

Exhaust fans

The exhaust fans designated exclusively for Zone 3 and Zone 2 (curing room / cooling room) are designed for 100% capacity, with 100% backup. Combined Zones 1 and 2 have two exhaust fans with 50% capacity, without any backup.

Exhaust filters

Exhaust filter units have a pre-filter and two stage HEPA filters. The exhaust air discharged from all zones passes through a HEPA filtration system to remove particulate from the air stream. After the exhaust air passes through the HEPA filters, it is discharged through a stack. Exiting air is isokinetically monitored for airborne radioactivity.

The Exhaust Filter System for Zone 3 and exclusive Zone 2 (curing room / cooling room) has three filters with 50% capacity (two are required for normal operation). Combined Zones 1 and 2 have two-filter systems with 50% capacity, without any backup.

Filter efficiency

- Pre filter — 36% efficiency on 20 micron and larger
- HEF — 90% efficiency on atmospheric dust
- HEPA filter — 99.97 % efficiency on 0.3 micron particles

000295

Electric heating

Electric heating is included with the air handlers dedicated for Zone 3 and Zone 2 (curing room / cooling room) only. The combined Zones 1 and 2 area has individual electric heaters dedicated to each room.

HVAC stacks

Two facility stacks are provided: one stack handles the exhaust air discharged from areas expected to be contaminated areas (designated as Zone 3) and the other stack handles all other exhaust air from areas expected to be clean zones (designated as Zone 1) and potentially contaminated areas (Zone 2).

G. The lowest pressures are maintained in zones that have the greatest potential to release radon gas.

H. Backup power are provided for all HVAC systems. Air conditioners and electric heaters do not have backup power.

I. Central heating/air-conditioning units are provided, as required, to maintain temperature controls as previously identified. Air conditioning is direct expansion refrigeration. Supplemental heating is provided by means of electric unit heaters in areas with minimal ventilation requirements.

J. Design criteria for duct work construction:

Zone 3

- All exhaust duct work consists of galvanized steel construction, 16 ga minimum thickness, with welded construction.
- Supply fan isolation dampers and duct work inside Zone 3 areas consist of galvanized steel construction, 16 ga minimum thickness, with welded construction.

Zone 1 and 2

- The same as above with flanged connections.

G.2.16.2 Analytical laboratory

The analytical laboratory has two zones as follows:

- Zone 1 consists of the office area, which is clean without a filtered exhaust system. It has a standard wall-mounted heating/cooling unit typical of a modular building.

- Zone 2 consists of the areas where hazardous materials are handled and is provided with a 2-stage HEPA filtered exhaust system with redundancy. It has an air handler to heat and cool with 100% make up air without any recirculating.

G.2.16.3 Warehouse

The warehouse has a small office. The office has a standard wall-mounted heating/cooling unit. The other areas have electric heaters to provide heat during cooler months. Ventilation is not provided.

G.2.16.4 Mechanical/Electrical Building

Heating and cooling functions are provided by electric heaters and ventilation, respectively.

G.2.16.5 Staging Area

The staging area includes a small office. The office has a standard wall-mounted heating/cooling unit. The area has a ventilation system; but, heat is not provided.

G.2.17 Support Systems

G.2.17.1 Analytical Support Laboratory/Services

The process facility uses an on-site dedicated laboratory staffed by site personnel to analyze process samples and provide for any additional requirements as space and equipment allow. The laboratory is composed of a trailer complex modified to provide the working space and conditions for the laboratory facility.

The trailer HVAC and Drain Systems are designed to control the spread of contamination. There are two separate HVAC Systems. One system is for the laboratory hoods. The other system is for environmental spaces. Two separate drain systems, potentially radioactive and non-radioactive, are provided for the laboratory spaces. Individual catch tanks are provided for each system; they are located in a covered concrete vault adjacent to the trailer complex.

The laboratory space is considered to be a Radiation Access Zone (RAZ) 4 because of the number of process and TCLP samples being handled on a daily basis within the laboratory and the resulting potential for radioactive contamination. The office space within the complex is considered to be uncontrolled access. The complex is divided into a non-radioactive area for office work space and a potentially-radioactive laboratory space. To check the spread of contamination, a survey/monitoring room is provided to control entrance and egress of the laboratory space.

G.2.17.2 Mechanical/Electrical Building

The Mechanical/Electrical Building provides space for the treatment facility's general utilities. The building is a pre-engineered metal building with a concrete floor. The structure has large roll-up doors to allow for access and possible replacement for all of the utility equipment.

The building is divided into three sections: Maintenance Shop, Electrical Room and the Utility Equipment Room. The Maintenance Shop is designed for general servicing and repairing of mechanical equipment. The shop contains general equipment common to machine shops (i.e., drill press, lathe, etc.). It has a fenced-in area for a tool crib and a welding area equipped with a ventilation hood. Floor and table space is provided for equipment disassembly. The Maintenance Shop has a roll-up door to allow forklift and truck access. A monorail near the entrance allows for off-loading of equipment or components from vehicles. The room has temperature activated fans to dissipate equipment generated heat loads.

The Utility Electrical Room furnishes space for the facility's electrical requirements. Electrical power is routed from the site distribution power poles outside into the room. The equipment

in the Electrical Room distributes the power to the facility. Space is provided within the room for the electrical switchgear, motor control center (MCC) cabinets, uninterruptable power supply (UPS) source, and other electrical equipment. The room is fire rated for two hours and has a unit heater and a ventilation fan to provide environmental temperature control.

The Utility Equipment Room contains the mechanical equipment, such as the air compressors, that provides utilities for the facility. It also contains the diesel generator for back-up power. The generator and support equipment are contained within a curbed area. An overhead pipeway supports the distribution of the utilities. The room has heating units to provide for temperature control.

The Mechanical/Electrical Building and surrounding area is an uncontrolled radiation access zone. It is expected that neither radioactive nor contaminated materials will be contained within this structure or the general area.

G.2.17.3 Interim Container Staging

The Interim Container Staging area provides for temporary staging of filled containers until they can be released for shipment to the NTS. The containers in the area can be double stacked. The size of the facility varies upon the production capacity of the process; but, up to 45 days worth of production can be staged within the area.

The staging area is enclosed in a field-erected, temporary structure. Within the structure is a modular, concrete shield wall approximately 2 ft-thick, with a remotely operated overhead crane. The structure has an engineered steel framework with a PVC coated polyester fabric stretched over it. A small shelter building is provided within the structure, but outside of the shielded area for the crane operator. It has a heater and AC unit for temperature control. For cement type stabilization, the prefabricated type structure is heated during freezing conditions to prevent freezing of the grout or hampering of the curing process. The ground adjacent to the structure is sloped away from each side to allow for the rain to runoff into the local controlled drainage system.

A motorized roller conveyor moves filled containers from the processing plant to the Interim Staging area. The container is lifted by an overhead bridge crane and moved into the interim storage. For shipment, a tractor-trailer enters the structure through a roll-up door. A container is removed from the storage area and moved to the load-out area. The bridge crane then places the container onto the trailer.

The area inside the shielded portion of the Interim Container Staging Area is considered to be a RAZ 5. The area is a controlled area because of the high radiation exposure rate from the processed material stagged in the area. In keeping with ALARA principles, regular personnel access is not allowed in the high radiation area. However, on an emergency basis, access can be made by a manned fork lift. The Loadout Area is considered to be a RAZ 4 during container loading operations, and a RAZ 1 otherwise. Personnel access into a Loadout Area is controlled during loading of containers onto trailers.

G.2.17.4 Control Room Trailer

The Control Room Trailer provides the space to control and supervise the process functions and supporting activities. It contains all necessary equipment to perform those functions.

The control room is composed of a trailer duplex that borders the treatment facility. The space is divided into a shift supervisor's office, ready room, and control room. The duplex has it own dedicated HVAC system for heating and cooling.

The Control Room Trailer is not in a radiological area. Access to the trailer is not controlled except for movement through the control room to limit unwanted noise and distractions.

G.2.17.5 Office Trailers

Facility support personnel not directly associated with the day-to-day operation or maintenance of the facility are housed in existing on-site trailers (i.e., T-117, T-118). As needed, additional site trailers can be relocated and modified for office use. The trailers are located in and around

T-117 and T-118. Additional space may be made available adjacent to T-92 or north of the High Nitrate Tank.

G.2.17.6 PPE Change Trailer

A PPE Change Trailer is located adjacent to the production facility. It services the radiological protection requirements of personnel entering the facility. The trailer is an on-site surplus trailer used for storage and donning of PPE. Facility personnel can suit-up in PPE clothing and enter the adjacent facility to perform their assigned tasks. Next to the radiological working areas of the facility, space is provided for temporary step-off pads and survey equipment so that Maintenance and Operations personnel can doff their PPE.

G.2.17.7 Change Trailer

It is assumed that the existing trailer complex T-89, 90, 91, and 92 will be available for clothing change, showering, and access control. If necessary, to better control site access, the trailer complex could be relocated.

G.2.17.8 Parking

The existing parking lot East of the Haul Road can be used for facility workers to park their personal vehicles. Personal vehicles will not be allowed within the facility or surrounding area.

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G.2.18 Utilities

G.2.18.1 Electrical

Each remediation option is supplied electrical power in a similar manner. Normal electrical power is supplied by the local utility company, Cincinnati Gas & Electric Company (Cinergy). Power at 13.2 kilovolt (kV) is supplied via the site distribution system to a new oil-filled, pad-mounted transformer located adjacent to the treatment facility. A transformer steps down 13,200 volts to 480 volts. The rating of the transformer varies with each option; a 480-volt switchgear is supplied as needed by each option.

Electrical design considers energy conservation, ease of maintainability, and "off the shelf" equipment.

Space is provided within the facility for the MCC cabinet, UPS source, and other electrical equipment. The space is fire-rated for two hours and has ventilation and heating units to provide for environmental temperature control.

Interior and exterior lighting meet or exceed the Illuminating Engineering Society (IES) and Institute of Electrical and Electronics Engineers (IEEE) recommendations for the type of work being performed within those areas. Grounding electrodes are used in accordance with IEEE Standard 142-1991, *Practice for Grounding for Industrial and Commercial Power Systems*, (ANSI/IEEE 1991).

G.2.18.2 Emergency Power

Emergency power is supplied for critical items in order to prevent a release of contamination or equipment failure. Typical loads to be considered are: breathing air, additional RCS needs, instrumentation and controls (including stack monitoring), agitators, cement mixing and pouring operations, melter room cooling, glass cooling, and facility HVAC.

G.2.18.3 Communications

The treatment facility complex is connected to a Public Announcement System (PA) for emergency messages. Local Area Network (LAN) Computer hookups are included in the control room.

G.2.18.4 Water

Site utility water services supplied to the facility and process are isolated from the potential of becoming contaminated. Back-flow prevention equipment and engineering methods and controls ensure that the water supply systems do not become contaminated.

G.2.18.5 Steam

No Requirements.

G.2.18.6 Compressed Air

Air compressors, dryers, and accumulator tanks are used to satisfy the requirements for plant operations and instrument systems.

G.2.18.7 Breathing Air Lines

A breathing air line provides for performing hands-on maintenance activities in areas where radon exposure is a potential. The air intake is located far enough away to provide a clean air supply during credible airborne release emergencies.

G.2.18.8 Sanitary Sewer

A sanitary line is not available. However, existing restroom trailers in the area will be relocated. See **Section G.2.17.7 — *Change Trailer*.**

G.2.18.9 Stormwater

Protection of surface waters are ensured by segregation of contaminated from uncontaminated runoff, and by control of runoff from all areas of the project. Contaminated runoff is held for characterization and pre-treated (if necessary) before being released to the site AWWT facility. Restrictions on uncontrolled discharges to surface water bodies are met through engineering controls, and best management practices (BMPs). All storm drainage is designed in accordance with the Ohio Department of Transportation (ODOT) Location and Design Manual, using a 25-yr, 24-hr storm event for Hamilton County for sizing drainage systems for potentially contaminated areas and structures. The existing drainage pattern in the vicinity of the plant is maintained, and area drainage uses existing features such as culverts and catch basins wherever possible. Clean runoff, including building roof drains and runoff from areas of fixed contamination, are discharged either into the stormwater collection basin, or routed to adjacent drainage systems. Areas used for processing of material are protected from precipitation and stormwater run on and run-off. Clean and contaminated runoff waters are not combined.

Stormwater systems provide for drainage away from the facility, collection, and segregation of contaminated stormwater from uncontaminated. Paving, catch basins, curbs, and retention basins are used in conjunction with open drainage systems (e.g., culverts, ditches, and gutters) to provide for efficient and complete drainage around the work site. The existing drainage pattern in the vicinity of the plant shall be maintained. Area drainage patterns shall make use of existing drainage systems such as culverts and catch basins whenever possible.

G.2.18.10 Natural Gas

Natural gas is presently available on-site, although not in the OU4 area, and will be available during operation of the remedial facility.

G.2.19 Health and Safety

Mission and property protection are included with the safety criterion because accidents are assumed to be a major interruption of the mission and could potentially be damaging or costly to the equipment. Failure to consider, within the design, health and safety threats to the public or site personnel foreshadows potential capital property loss and possible failure to complete the facility's mission.

Standard industrial health and safety practices, regulations, and guidelines are followed. However, radiological protection is unique to this type of project/process. Therefore, the safety concepts, requirements, and basis for design, as elaborated here, are addressed separately because of their potential to be discriminating or key factors in determining layout requirements.

G.2.19.1 Personal Protective Equipment

Radiological or potentially-contaminated areas are controlled and segregated from "clean" areas. Maintenance and Operations personnel need access to the equipment within the facility's radiological working areas. The design includes provisions for the removal of PPE, disposal of contaminated materials, and personnel/equipment monitoring before exiting the area.

Additional access space is provided in controlled areas where maintenance personnel are required to perform awkward tasks in bulky PPE clothing.

G.2.19.2 Radiological Considerations

Radiological requirements accentuate the complexity of operations and maintenance activities. All functions and activities are directed to maintain worker exposure to ionizing radiation ALARA. The ALARA philosophy states that any exposures to ionizing radiation by general employees, the public, or the environment is to be minimized to the extent that social, technical, economic, practical and public policy considerations allow.

Remote handling and maintenance areas provide for appropriate decontamination equipment, safety showers, and eyewash stations to accommodate contact maintenance requirements. The facility incorporates strategies to avoid the spread of contamination and to simplify methods of operations and maintenance in radiologically controlled areas. Health Physics monitors are provided within the facility to ensure personnel safety.

Project management shall be committed to keeping exposure ALARA through engineering (design), management (administrative controls), and supervision (procedures). This principle is affected by six key elements that must be considered in the design:

- Reduction of the time spent within radiological areas;
- Reduction of the source(s) of radioactivity;
- Increased distance from sources of radioactivity;
- Provision for containment of, and shielding from, sources of radioactivity;
- Minimized internal exposure through the use of confinement and ventilation; and
- Reduction of the labor requirements for operations.

The criteria for new facility design in regard to reducing external exposures to ionizing radiation shall be in accordance with the requirements of 10 CFR 835, *Occupational Radiation Protection* §835.1002(b) *Facility Design and Modifications*. Specifically, personnel exposures shall not exceed a total effective dose equivalent (TEDE) of 1 rem/yr. Through the proper use of confinement and ventilation, the average internal exposure is not expected to contribute greater than 200 mrem/yr, or 20% of the TEDE limit. Therefore, the continuous occupancy design limit for external dose rate is established at 0.4 mrem/hr. In addition, the design objective for any area of continuous occupancy (2,000 hr/yr) shall be to maintain exposure levels below an average of 0.5 mrem per hour and as far below this limit as reasonably achievable.

Since the TEDE is the sum of the committed effective dose equivalent (CEDE) for internal exposures and the effective dose equivalent (EDE) for external exposures, the dose

contribution resulting from potential airborne sources must be considered when developing a design control limit for external exposures.

A value of $52,000/manRem shall be used to determine whether a function shall be completed "hands on" or engineered facilities installed in order to reduce radiation exposure. This means that engineered systems – e.g., remote handling, automation, extra shielding, etc. – shall be installed to reduce occupational radiation exposure if it can be done for $52,000/manRem over the life of the project.

G.2.19.3 Radiation Area Definitions

Using the radiation modeling data, the proposed layout for remediation was evaluated to establish preliminary RAZs. Access control was determined by delineating equipment and areas that must be segregated or isolated based on risks of external exposure. These areas were categorized with respect to exposure rate and assigned a maximum occupancy factor based on limiting personnel external exposures to less than 800 mrem/yr. The assignment of occupancy factors was based on detailed studies of the specific equipment design, a material balance study for the output of the system, and an ALARA analysis.

Table G.2.19-1 - ***RAZ Chart*** is an application of the ALARA philosophy. The chart administratively defines the radiological requirements within each zone and provides guidelines to operations and maintenance for maximum durations in those areas.

An **uncontrolled area** does not require any occupancy restrictions or other personal protection requirements. Personnel can perform operations or maintenance tasks whenever required without radiological limitations. Individuals who enter only the uncontrolled area are not expected to receive a deep dose equivalent of more than 50 mrem/yr, or a CEDE of more than 50 mrem/yr.

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A **controlled area** is any area to which access is managed to protect individuals from exposure to radiation and/or radioactive material. Individuals who enter only the controlled area without entering radiological areas are not expected to receive a total effective dose equivalent (TEDE) of more than 100 mrem/yr from sources other than occupational exposure to radon or thoron and their progenies. Individuals who enter only the controlled area without entering radiological areas are not expected to receive a CEDE of more than 500 mrem/yr from exposure to radon or thoron and their progenies.

A **contamination area** is an area where removable alpha contamination levels are greater than 20 disintegrations per minute per 100 square centimeters (20 dpm/100 cm^2) but less than or equal to 2,000 dpm/100 cm^2, or beta/gamma contamination levels are greater than 1,000 dpm/100 cm^2 but less than or equal to 100,000 dpm/100 cm^2.

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TABLE G.2.19-1
RAZ CHART

RADIATION ACCESS ZONES				OCCUPANCY GUIDELINES	RADIATION LEVEL
Uncontrolled Areas				Full-time	0.025 mrem/hr in habitable structures, 0.050 mrem/hr all other areas.
CONTROLLED AREA	1			40 hours per week	0.050 mrem/hr < x ≤ 0.40 mrem/hr
	2			8 hours per week	0.40 mrem/hr < x ≤ 2.0 mrem/hr
	3			3 hours per week	2.0 mrem/hr < x ≤ 5.0 mrem/hr
	RADIOLOGICAL AREA	Radiation Area	4	Access requires a self reading pocket dosimeter (SRPD) and controls by a Radiological Work Permit (RWP).	5.0 mrem/hr <x ≤100 mrem/hr
		HIGH RAD AREA	5	No normal access.	100 mrem/hr ≤ x < 1 RAD/hr
			6	Additional engineering controls are required.	1 RAD/hr ≤ x <500 Rads in 1 hour (hr) at 1 meter (m) from the source.

A **high contamination area** is an area where removable radioactive contamination levels are greater than 100 times the limits specified for a contamination area. High contamination areas are required to be posted with the words "Danger, High Contamination Area" and shall require, at a minimum, Class A or Class B PPE for entry. For areas requiring routine access, sufficient engineering controls are used to preclude controlling the area as a high contamination area. In the case of system maintenance or any other activity resulting in a loss of containment, access to the area is restricted and it is posted as a high contamination area.

A **radiological area** is an area, within a controlled area, that must be posted as a "Radiation Area," "High Radiation Area," "Contamination Area," "High Contamination Area," or "Airborne Radioactivity Area" according to § 10 CFR 835.603. RAZ 4 and RAZ 5 are radiological areas.

RAZ 1 is any area accessible to individuals in which radiation levels could result in an individual receiving a deep dose equivalent exceeding 0.05 mrem/hr and up to 0.4 mrem/hr at 30 centimeters from the source or from any surface that the radiation penetrates. Individuals who enter only RAZ 1 areas are not expected to receive a TEDE of more than 1 rem/yr assuming an occupancy of 40 hr/week. For design efforts, RAZ 1 is designated for "continuous occupancy."

RAZ 2 is any area accessible to individuals in which radiation levels are greater than RAZ 1 criteria and could result in an individual receiving a deep dose equivalent of up to 2 mrem/hr at 30 centimeter (cm) from the source or from any surface that the radiation penetrates. Individuals who enter to perform routine duties (e.g., log keeping, sampling, inspections, etc.) are not expected to receive a TEDE of more than 1 rem/yr, assuming an occupancy of 8 hr/week.

RAZ 3 is any area accessible to individuals in which radiation levels are greater than RAZ 2 criteria and could result in an individual receiving a deep dose equivalent of up to 5 mrem/hr at 30 cm from the source or from any surface that the radiation penetrates. Individuals who

enter to perform routine duties (e.g., log keeping, sampling, inspections, etc.) are not expected to receive a TEDE of more than 1 rem/yr, assuming an occupancy of 3 hr/week.

RAZ 4 is any area accessible to individuals in which radiation levels could result in an individual receiving a deep dose equivalent of more than 5 mrem/hr at 30 cm from the source or from any surface that the radiation penetrates. These areas shall be posted with the words "Caution Radiation Area." Access requirements for RAZ 4 areas shall be delineated by a RWP. Individuals who enter to perform routine duties (e.g., log keeping, sampling, inspections, etc.) shall be issued direct reading dosimetry, and an individual's dose shall be routinely monitored and maintained ALARA.

RAZ 5 is a high radiation area, or any area accessible to individuals in which radiation levels could result in an individual receiving a deep dose equivalent of more than 100 mrem in 1 hr at 30 cm from the source or from any surface that the radiation penetrates. These areas shall be posted with the words "Danger, High Radiation Area." During periods when access is required, positive control over each entry shall be maintained by RWP and continuous radiological control coverage. Direct reading dosimetry shall be required for entry, and worker dosage shall be maintained ALARA. For design purposes, routine access shall not be acceptable.

RAZ 6 is a high radiation area in which radiation levels exist such that an individual could exceed a deep dose equivalent to the whole body of 1 Roentgen equivalent man (rem) in any hour at 30 cm from the source or from any surface that the radiation penetrates. In addition to the requirements of RAZ 5 above, at least one of the following shall be used to control entry:

(1) A control device that prevents entry to the area when high radiation levels exists or upon entry causes the radiation level to be reduced below the level defining a high radiation area.

(2) A device that functions automatically to prevent use or operation of the radiation source or field while personnel are in the area.

(3) A control device that energizes a conspicuous visible or audible alarm signal so that the individual entering the high radiation area and the supervisor of the activity are made aware of the entry.

(4) A locked entryway. During periods when access to the area is required, positive control over each entry is maintained.

(5) Continuous direct or electronic surveillance that is capable of preventing unauthorized entry.

(6) A control device that shall automatically generate audible and visible alarm signals to alert personnel in the area before use or operation of the radiation source, and in sufficient time to permit evacuation of the area or activation of a secondary control device that shall prevent use or operation of the source.

An **airborne radioactivity area** is any area where the measured concentration of airborne radioactivity, above natural background, exceeds or is likely to exceed 10% of the derived air concentration (DAC) values listed in Appendix A or Appendix C of 10 CFR 835. The airborne radionuclides of concern include Thorium-230, Radon-226, Radon-222 and its progeny. Participation in a personal air sampling (PAS) program and bioassay monitoring consisting of a routine urinalysis program is required. Radon and working level (WL) measurements are performed during operations; posting and controls shall be commensurate with the hazards as determined by these measurements.

G.2.19.4 Surface Contamination Control

The treatment facility shall incorporate features to prevent the buildup and spread of contamination. Surfaces from which material could be resuspended (e.g., scaffolding, open rafters, hanging light fixtures, cable runs, etc.) shall be kept to a minimum. The design of the facility ventilation system is particularly important for controlling contamination and ensuring adequate diffusion of air so that resuspension is minimized. The surface finish of process tanks and other similar equipment will be adequate to minimize the deposition of radioactive material, thus reducing the difficulties associated with future decontamination efforts.

The Silos 1 and 2 material radionuclide inventory consists of naturally occurring alpha and beta-gamma emitting isotopes resulting from the uranium and thorium decay series. The primary (most limiting) radionuclides within Silos 1 and 2 material are Thorium-230 and Radium-226, both of which are alpha-emitters. The limits for fixed and/or removable contamination are found in Appendix D of 10 CFR 835. Where surface contamination by both alpha and beta gamma-emitting nuclides exists, the limits established for alpha and beta gamma-emitting nuclides shall apply independently.

Due to the restrictive limits assigned to alpha emitters, operations and maintenance activities shall most likely be assigned to areas that shall be posted and controlled as contamination areas. These areas are designed and controlled to keep contamination levels ALARA. The minimum requirements for working within a contamination area are:

- Radiological controls established by a RWP;
- Appropriate PPE;
- Radiological Worker II training; and
- Personnel and material contamination monitoring upon exiting.

G.2.19.5 Airborne Radioactivity Control

The following criteria are used to design controls for limiting exposures to airborne radioactive materials:

- Areas with significant concentrations of airborne radioactive materials are provided with physical barriers to prevent the entry of persons not wearing respiratory protection.

- HVAC systems are designed for 100% outside air, without recirculation.

- Air sampling and monitoring are provided for the detection and measurements of airborne materials.

- The <u>annual average</u> concentration of airborne radioactive materials at all

locations routinely accessed by personnel are kept ALARA and do not result in a CEDE in excess of 100 mrem from sources other than radon or thoron and their progenies, or 500 mrem from radon or thoron and their progenies, in a year.

- The maximum allowable average (chronic) airborne radon concentration in a normally occupied work area is 4 picoCuries per liter (pCi/L) with a maximum of 30 pCi/L instantaneous (acute) radon concentration.

- Releases from all silos activities (of which those described in this text are only a part) do not add any more than 0.5 pCi/L radon concentrations to the fence-line.

  Basis: The current limit is 3.0 pCi/L above background on an annual average. The latest proposed revised 10 CFR Part 834 limit (not identified as an ARAR) is 0.5 pCi/L above background annual average. This concentration limit is being applied elsewhere (i.e., Silo 3, AWR, etc.). Radon emissions from Silos 1 and 2 remediation must be limited such that they result in a contribution (annual average) of no more than 0.5 (pCi/L) to the fence-line concentrations. Excerpt from the waste pit remediation contract reads: "Radon emission from the point sources shall meet a stack limit based on a maximum off-site impact of 0.5 pCi/L annual average."

G.2.20 Environmental Considerations

The design basis must ensure protection of human health and the environment during the remediation of the Silos 1 and 2 material. Protection of human health and the environment is a key criterion for the selected remedy of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended, and the NCP. Environmental requirements for the design and operation of the remediation project to ensure protection of off-site public and the environment are identified in the ARARs and to be considered (TBC) criteria. The ARARs and TBCs include various federal and state regulations under the Clean Air Act, Clean Water Act, RCRA, etc., as well as environmental requirements embodied in the

various DOE Orders. These CERCLA threshold requirements will be identified in the Record of Decision (ROD), as amended, and are discussed for each alternative in this revised FS. Protection of human health and the environment is ensured by incorporation of the environmental regulatory requirements as engineering controls, or in the system design, using the principles of environmental ALARA.

Environmental pathways to the off-site receptors for the remedial alternatives include discharges to air, water, and through management of solid waste. Compliance is achieved primarily by isolating and removing the source term, or by altering or neutralizing the sources of environmental contamination. All air or gas streams, potentially contaminated with hazardous or radioactive gases or airborne particulates, are collected and treated before being released to the environment. In addition, during operations and D&D potentially contaminated water or liquid streams, and solid wastestreams are collected and treated before being released in order to protect human health and the environment.

G.2.20.1 Environmental ALARA in Design

Environmental ALARA seeks primarily to prevent, and secondly to minimize, releases of contaminants to the environment. Prevention of release is achieved during design by containment for all sources. All tanks and lines with radon source material are totally enclosed, and vented to the RCS using backup redundancy for key critical equipment. All particulate sources such as dry feed or additive bins are controlled by appropriate filtration. RCRA requirements for management of Silos 1 and 2 material, or wastestreams from processing Silos 1 and 2 material, dictate containment in tanks and appurtenant transfer lines. All tank systems containing source material with free liquids are designed with secondary containment and leak detection to prevent spills or releases to the environment. Secondary containment and leak detection systems include: tanks, containment systems, mixers, and melters associated with material thickening, slurry transfer and batching, recycle water, feed preparation, drying, and filtration. In addition, tanks for uncharacterized liquids from the

off-gas system, wastewater, and solid waste systems would also fall under this design requirement.

Minimization of releases is achieved by process design, which includes provisions for recycling of wastestreams as much as practicable. For example, water removed during dewatering in the feed preparation process is recycled into the Silos 1 and 2 material retrieval process, and filter solids are processed by reintroducing them with the silo feed material for treatment. Minimization of solid waste also includes use of sealed, painted, or otherwise easily decontaminated surfaces to facilitate D&D.

G.2.20.2 Air Emission/Off-gas Control

This information has been included in **Section G.2.13.3 - *Gaseous Effluents***.

G.2.20.3 Liquid Waste Control

This information has been included with **Section G.2.13.1 - *Secondary Liquid Waste Treatment*** for general wastewater management and **Section G.2.18.9 - *Stormwater*** for criteria on surface wastewater management.

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G.2.21 Project Schedule

A project schedule graphically depicts the plan for implementing the required activities for a given alternative to successfully complete a task. The schedule presents the logical relationships between activities, and indicates the anticipated duration and sequence of each operation. For this revised FS, the schedule for each alternative in **Section 3** presents the activities required to complete the remediation of the Silos 1 and 2 material. **Figure G.2.21-1** presents a generic baseline schedule of Silos 1 and 2 remediation activities, which serves as a template from which the four alternatives' schedules are derived in this FS. Many of the activities have been taken directly from the Silos Division Project technical baseline. However, each of the four alternatives' schedules discussed in the evaluations have been customized to be technology-specific using durations provided by each contractor based upon the proposed process in the four *POP Final Reports* **(Appendix H)**. The following narrative provides a brief description of each activity in the project schedule.

G.2.21.1 Proof of Principle Testing

As stated previously, POP testing involved the pilot-scale testing of commercially available remediation technologies under four separate contracts. The testing involved the use of nonradioactive surrogates that simulated selected chemical and physical characteristics of the Silos 1 and 2 material. The results were published in final test reports (**Appendix H**). The POP testing provided technology-specific information on safety, implementability, reliability, cost, and schedule on a full-scale basis for treating the Silos 1 and 2 material. The data has been integrated into the detailed analysis of the four alternatives in this section. The duration of this activity in **Figure G.2.21-1** reflects the actual contractual period of performance of the POP testing contracts.

G.2.21.2 Regulatory Documentation Process

Data from the POP testing supports the evaluation of alternatives in this revised FS, and will support subsequent development of the PP and ROD Amendment. The preparation, stakeholder review, agency review and approval of these documents constitute the "regulatory documentation process." The duration of this activity supports the EPA enforceable milestones established for the revised FS, PP, and ROD Amendment documents. **Table G.2.21-1** summarizes the Silos 1 and 2 regulatory milestones as follows:

TABLE G.2.21-1
SUMMARY OF SILOS 1 AND 2 REGULATORY MILESTONES

Milestone	Date
Submit Draft Revised FS/PP to the EPA	2/01/00
Submit Draft ROD Amendment for Silos 1 and 2 to the EPA	12/29/00

G.2.21.3 Procurement Process

This activity summarizes the procurement activities necessary to prosecute a firm-fixed price/firm-fixed unit price, service contract for the remediation of the Silos 1 and 2 material. The procurement process begins with the development, review and approval of the technical requirements document (TRD) and the request for proposal (RFP). The TRD is a key component of the RFP. The TRD identifies the minimum requirements for the remediation contractor in the areas of project management, design and documentation. The procurement process also consists of proposal preparation, proposal evaluation, a best and final offer cycle, consent package preparation review, and approval cycles. The duration of all these activities is based upon recent OU4 (Silos Project) procurement actions involving a similar procurement process for the placement of service contracts for the Silo 3 Project and the AWR Project. The procurement process is expected to start immediately following the completion of the regulatory documentation process.

G.2.21.4 Design and Documentation

Due to radiological issues and DOE concerns, this project requires readiness reviews in accordance with DOE Order 425.1 and the FDF Pre-Operational Assessment Program. To comply with readiness requirements for this project, comprehensive documentation, evaluations, planning, and training are required.

In accordance with the Silos 1 and 2 remediation contract, the successful contractor is required to develop, obtain the appropriate reviews and/or approvals, issue, and implement documents in accordance with the project submittal register. The documentation is then appropriately reviewed and approved by DOE, EPA, and the Ohio Environmental Protection Agency (OEPA); and, inspected by stakeholders. This activity consists of specified review cycles for regulatory submittals in accordance with the Amended Consent Agreement.

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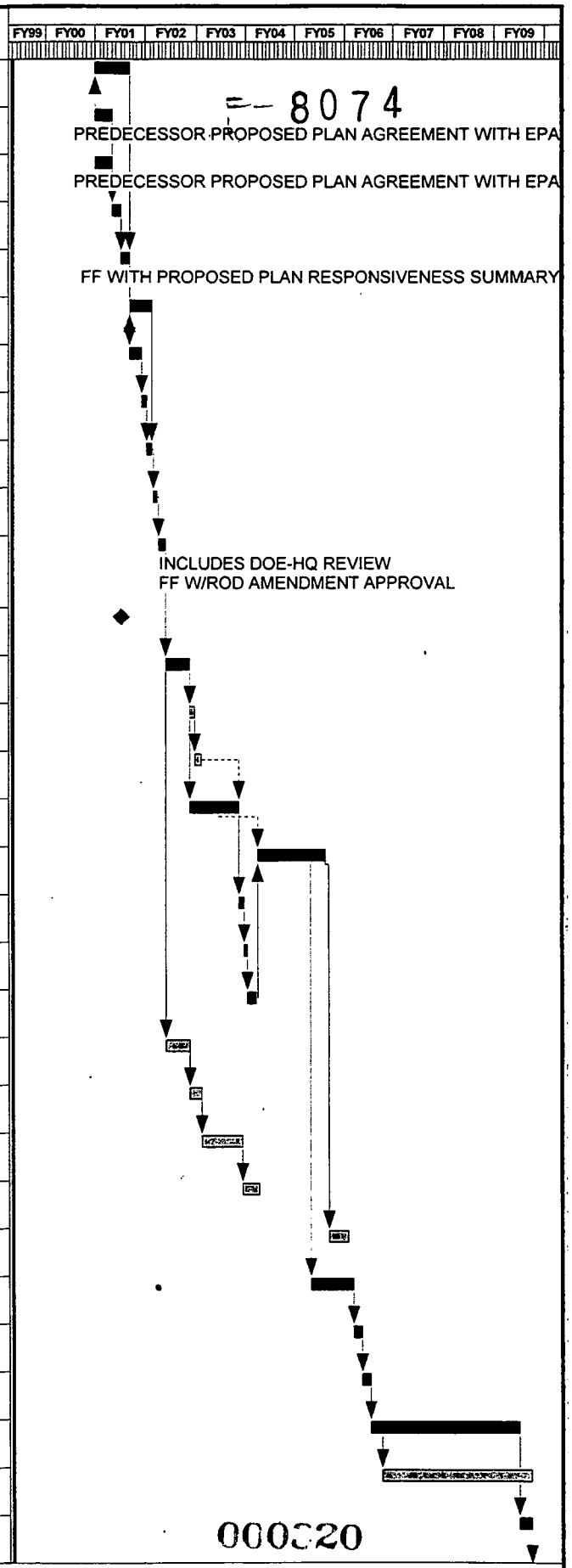
Activity ID	Activity Description	Orig Dur	Rem Dur	Early start	Early finish
0100	DEVELOP FINAL REMEDIATION RFP	166*	166*	02OCT00	01JUN01
0400	TRD DEVELOPMENT	79	79	02OCT00*	26JAN01
[illegible]00	DRAFT RFP	79	79	02OCT00*	26JAN01
1000	STORYBOARD RFP	44	44	29JAN01	30MAR01
1300	REVIEW/FINALIZE RFP	43	43	02APR01	01JUN01
1600	RFP BID CYCLE	120*	120*	04JUN01	21NOV01
1900	BID PERIOD	64	64	04JUN01	31AUG01
2200	BID EVALUATION	29	29	04SEP01	12OCT01
2500	BAFO	27	27	15OCT01	21NOV01
2800	CONSENT PKG PREP/REVIEW	23	23	26NOV01	28DEC01
3100	DOE CONSENT PKG REVIEW/APPROVAL	42	42	31DEC01	28FEB02
3200	NOA ISSUED FOR ROD	0	0	10APR01*	
3400	PRELIMINARY DESIGN	120	120	01MAR02	20AUG02
3700	FDF REVIEW PRELIMINARY DESIGN	20	20	21AUG02	18SEP02
4000	FINALIZE/APPROVE PRELIMINARY DESIGN	40	40	19SEP02	14NOV02
4300	FINAL DESIGN	250	250	21AUG02	20AUG03
[illegible]500	CONSTRUCTION	350	350	26DEC03	18MAY05
4900	FDF REVIEW FINAL DESIGN	20	20	21AUG03	18SEP03
5200	FINALIZE FINAL DESIGN	20	20	19SEP03	16OCT03
5500	EPA REVIEW/APPROVE FINAL DESIGN	45	45	17OCT03	23DEC03
5800	PHAR DEVELOPMENT	120	120	01MAR02	20AUG02
6100	PHAR REVIEW/APPROVAL	60	60	21AUG02	14NOV02
6400	FHAR DEVELOPMENT	200	200	15NOV02	04SEP03
6700	FHAR REVIEW/APPROVAL	90	90	05SEP03	16JAN04
7000	SYSTEM OPERABILITY TEST	100	100	07JUN05	26OCT05
7300	READINESS PREPARATION	213	213	26JAN05	30NOV05
7600	ORR	40	40	01DEC05	30JAN06
7900	PROOF OF PROCESS TEST	40	40	31JAN06	28MAR06
8200	OPERATION	750	750	29MAR06	27MAR09
8500	WASTE DISPOSITION	750	750	28JUN06	26JUN09
[illegible]800	SAFE SHUTDOWN	60	60	30MAR09	23JUN09



Project Start	01OCT95	Early Bar	
Project Finish	15DEC09	Progress Bar	
Data Date	01FEB99	Critical Activity	
Run Date	06DEC99		

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MV04

Sheet 1 of 2

SILOS 1 & 2 PROJECT

TEMPLATE BASELINE SCHEDULE

FIGURE G.2.21-1

Activity ID	Activity Description	Orig Dur	Rem Dur	Early start	Early finish
8900	FACILITY D&D AND DISPOSAL @NTS	120	120	24JUN09	15DEC09

FY99 | FY00 | FY01 | FY02 | FY03 | FY04 | FY05 | FY06 | FY07 | FY08 | FY09

000321

Project Start 01OCT95 Project Finish 15DEC09 Data Date 01FEB99 Run Date 06DEC99 © Primavera Systems, Inc.	Early Bar Progress Bar Critical Activity	MV04 SILOS 1 & 2 PROJECT TEMPLATE BASELINE SCHEDULE FIGURE G.2.21-1	Sheet 2 of 2 G.2-60

Figure G.2.21-2 presents a block flow diagram presenting various documentation and information required to be developed and submitted to support the execution of the remediation of the Silos 1 and 2 material. The block flow diagram depicts the logical relationship of the documents relative to their support of the project activities. The block flow diagram distinguishes between documents that would be the responsibility of the contractor and documents that would be the responsibility of the contracting organization. The information presented in the block flow diagram has been factored into the remediation schedule and serves as a basis for estimates of costs associated with contract documentation development, project management, and administrative support **(Appendix C)**.

G.2.21.5 Construction and Construction Acceptance Testing

This activity involves the construction of the remedial facilities necessary for the remediation of the Silos 1 and 2 material and the staging of the packaged treated material before shipment to the NTS for disposal. This activity assumes that the infrastructure project (e.g., roads, utilities) is complete in the Silos 1 and 2 area and the Silos 1 and 2 material has been retrieved and stored in the AWR TTA. This activity includes the testing of the facilities and equipment to verify that utilities have been properly connected, installations have been done according to design, and that equipment purchases under the construction contract meet specification.

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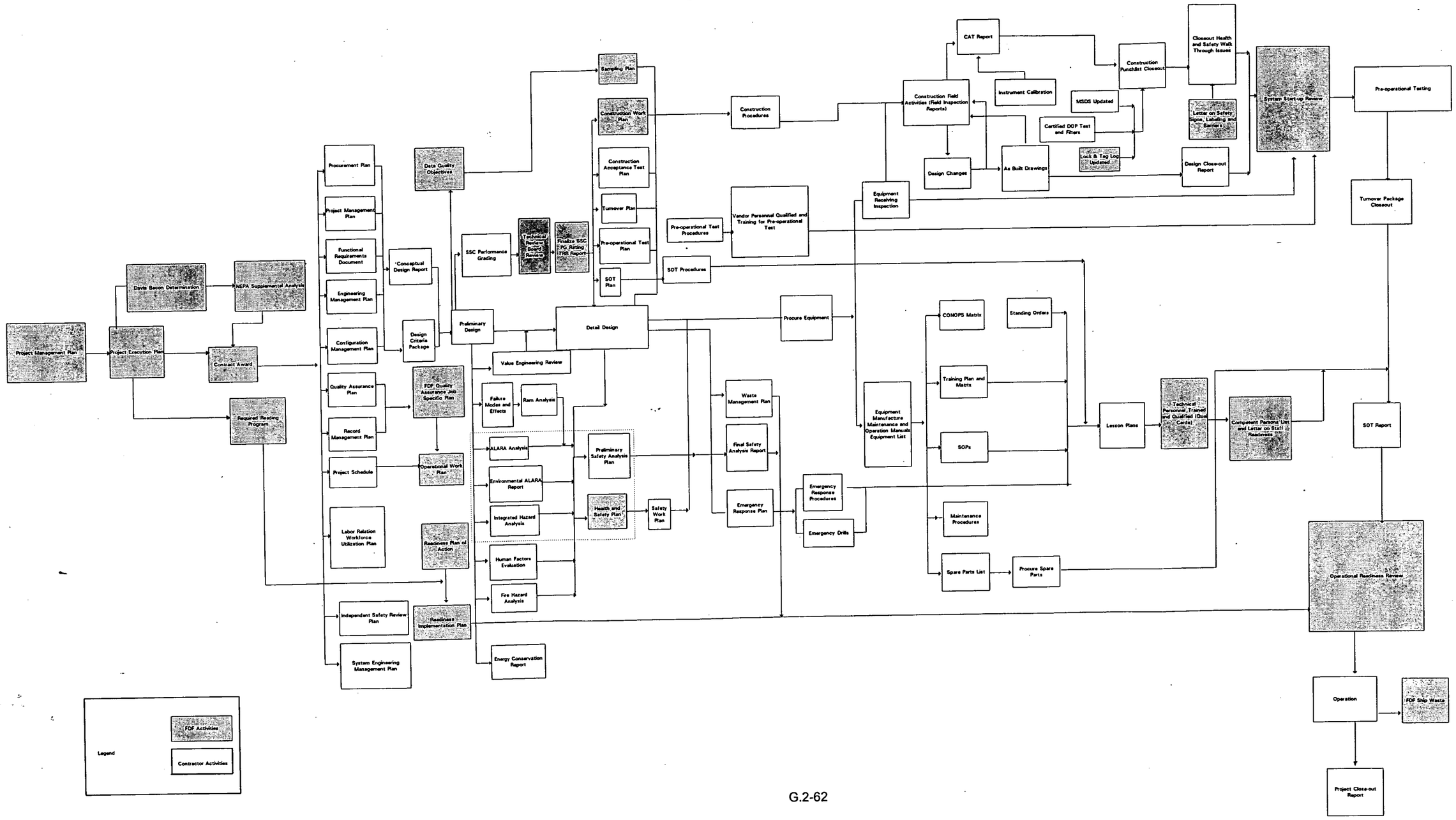
Draft
Silos 1 and 2 Project
Block Flow Diagram
Figure G.2.21-2



G.2.21.6 Systems Operability Testing

Systems Operability Testing (SOT) would be conducted to ensure that the following activities are completed as minimum requirements:

A. Performance of integrated systems in meeting design and performance requirements;

B. Optimum operating performance of the integrated systems; and

C. Identification and implementation of corrective actions for any problems that may adversely affect operational reliability of the system.

Systems passing SOT would be reviewed for readiness in accordance with the operational readiness review (ORR) program.

G.2.21.7 Operational Readiness Review

The primary management tool used by DOE to determine a contractor's readiness to operate a facility is the preoperational assessment process outlined in DOE Order 425.1. Based upon the anticipated inventory of Silos 1 and 2 material being processed under static conditions and the hazards associated with the process, the criteria of an ORR, in accordance with DOE Order 425.1, will need to be met. It is assumed that the following remedial activities, at a minimum, will be reviewed under an ORR, and subsequent start-up approval from DOE required before the contractor and FDF can begin remediation operations:

A. Retrieval and transfer of the Silos 1 and 2 material from the AWR TTA;

B. Operation of the treatment facility and support systems;

C. Sampling and analysis systems and process;

D. Loading of treated material into containers and interim staging of containers;

E. Transportation of the treated material to the NTS; and

F. Safe shutdown of facilities.

G.2.21.8 Proof of Process Testing

Upon completion of the SOT and ORR process, the contractor would be given approval to operate its facility with a non-radioactive surrogate that simulates Silos 1 and 2 material. Proof of Process Testing would encompass testing of the contractor's optimized formulation determined on a full-scale basis. The purpose of this activity would be to confirm and establish full-scale operability and operation parameters. It is likely that process adjustments would be necessary (e.g., waste loading, throughput rate) due to inherent operational differences associated with scaleup and working with the Silos 1 and 2 material.

G.2.21.9 Remediation Operations

Once the full-scale operational envelope has been established, the remediation operations would continue until all of the Silos 1 and 2 material, secondary wastes, and off-specification treated material has been reprocessed. Before remediation operations are considered complete, all treated material and secondary wastes would be verified to meet NTS WAC for disposal.

G.2.21.10 Safe Shutdown and D&D of Facilities

At the completion of remediation of the Silos 1 and 2 material and secondary wastes, the contractor would be required to remove gross quantities of hold-up material from existing equipment pipes and sumps, perform gross decontamination to prepare for dismantlement, and isolate utilities to its remedial facilities. The facilities would then be turned over to the DOE contractor for dismantlement and proper disposal of remaining facilities.

G.2.22 Process Systems and Equipment Numbering

The process numbering scheme used with this design is given in given in **Table G.2.22-1 — *Silos 1 and 2 Project System Numbering Scheme*.**

TABLE G.2.22-1
SILOS 1 AND 2 PROJECT SYSTEM NUMBERING SCHEME

	FACILITIES
00	Remediation Building
01	Product Handling and Storage Facility
02	Waste Retrieval Facilities
03	Analytical Laboratory
04	Maintenance and Warehouse Facilities
05	Misc. Facilities
06	Not Used
07	Not Used
08	Not Used
09	Not Used
	RETRIEVAL
10	Full-Scale Mockup System
11	Silos Waste Retrieval System
12	Transfer Tank System
13	TTA Waste Retrieval System
14	Not Used
	PROCESSING
15	Feed Preparation System
16	Processor Feed System
17	Processor System
18	Process Off-gas System
19	Vessel Vent System
20	Radon Control System
21	Not Used
22	Not Used
	PRODUCT HANDLING
23	Product Forming and Handling System
24	Product Packaging System
25	Container Receipt and Handling System
26	Product Recycle System
27	Not Used
28	Not Used
29	Not Used
	ELECTRICAL
30	High Voltage System
31	480 Volt Distribution System
32	Standby Electrical System
33	Uninterruptable Power System
34	Lighting System
35	Grounding System
36	Not Used
37	Not Used
38	Not Used
39	Miscellaneous Electrical
	UTILITIES AND CHEMICALS
40	Plant and Instrument Air System
41	Breathing Air System
42	Utility Steam System
43	Cold Chemical System
44	Product Additive System
45	Not Used
46	Not Used
47	Not Used
48	Not Used
49	Not Used
	WATER SYSTEMS
50	Process Water System
51	Potable Water System
52	Fire Water System
53	Cooling Water System
54	Melter Cooling Water System
55	Process Chilled Water System
56	Recycle System
57	Container Decontamination System
58	Not Used
59	Not Used
	WASTE SYSTEMS
60	Sanitary Sewer System
61	Non-radioactive Liquid Waste System
62	Radioactive Liquid Waste System
63	Laboratory Waste System
64	Radioactive Solid Waste System
65	Stormwater System
66	Not Used
67	Not Used
68	Not Used
69	Not Used
	HVAC SYSTEMS
70	Remediation Bldg Supply Air System
71	Remediation Bldg Exhaust Air System
72	HVAC Chilled Water System
73	Product Handling Bldg HVAC System
74	Waste Retrieval Facility HVAC System
75	Analytical Laboratory HVAC System
76	Maint. and Warehouse Fac. HVAC Systems
77	Misc Facilities HVAC System
78	Not Used
79	Not Used
	MECHANICAL AND ANALYTICAL SYSTEMS
80	Maintenance Equipment
81	Mechanical Handling Equipment
82	Remote Handling Equipment
83	Radiation Shielding Equipment
84	Sampling System
85	Inspection System
86	Not Used
87	Not Used
88	Not Used
89	Not Used
	INFORMATION AND CONTROL SYSTEMS
90	Distributed Control System
91	Management Information System
92	Fire Detection and Alarm System
93	Health Protection System
94	Analytical Laboratory System
95	Not Used
96	Not Used
97	Not Used
98	Not Used
99	Not Used

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Section G.3

G.3.0 POP GENERATED CRITERIA

As summarized in **Appendix H**, the POP testing provided technology-specific information on the performance, safety, reliability, implementability, cost, and schedule for the full-scale remediation of the Silos 1 and 2 material. This information was used in the development of the preconceptual process designs for the four alternatives. The detailed evaluation and comparative analysis of alternatives in **Sections 3** and **4**, and **Section G.3** provide a discussion of the pertinent POP information that was used as design criteria. In some cases, basic engineering judgement or best management practices (BMP) determined that contractor-supplied information was either not technically supported or inappropriate for use in this revised FS design basis. Where such instances occur, proper justification is provided.

G.3.1 Waste Loading Criteria

Waste loading is a method to express how much treated material will be made from the Silos 1 and 2 material on a per unit weight basis. The Silos 1 and 2 material is considered to be dry to eliminate any confusion of how much moisture might be in the wastestream. The waste loading equation (Equation 1) was presented earlier. In simple terms the waste loading equation is:

$$\text{Waste loading (wl)} = \frac{\text{Dry weight of Silos 1 and 2 material w/ BentoGrout™} \times 100\ \text{wt\%}}{\text{Weight of treated Silos 1 and 2 material w/ BentoGrout™}}$$

(Equation 1)

Dry weight is defined as the resulting weight of the Silos 1 and 2 material dried at 105°C.

Table G.3.1-1 summarizes the waste loadings achieved during the POP demonstrations and the waste loadings used in the revised FS design.

TABLE G.3.1-1
WASTE LOADING BY TECHNOLOGY

Technology	POP Demonstration, wt%	FS Design, wt%
Vitrification — Joule-heated	92.9	90
Vitrification — Other	87	87
Chemical Stabilization — Cement-based	40	30
Chemical Stabilization — Other	18.6	24

The following is the basis for the waste loadings used in the revised FS for each treatment technology.

G.3.1.1 Vitrification — Joule-heated

If all the compounds in the surrogate were bound in the glass matrix, the calculated waste loading of the glass would be approximately 83.9 wt%. However, some of the compounds in the surrogate thermally break down into gases or volatilize and leave via the off-gas system.

Silica is the main constituent in the Silos 1 and 2 material and is not volatile. Based on glass chemistry, it is known that essentially all of the silica will enter the glass matrix. Also, since silica is not used as an additive, comparing silica concentrations in the slurry and glass gives a good indication of waste loading. The surrogate solids contained 62.63 wt% silica and the demonstration glass contained 58.2 wt% silica. Using Equation 1, this equates to a waste loading of 92.9 wt% (58.2/62.63 x 100 wt% = 92.9 wt%). The POP demonstration showed that less than 0.5 wt% of the solids went to the off-gas system that is recycled during a full-scale facility.

Laboratory results showed that the operating envelope, at which the glass does not exceed RCRA TCLP limits, is rather large. Therefore, 90 wt% waste loading will be used for this technology.

G.3.1.2 Vitrification — Other

Silica is also used to determine the waste loading for this alternative. The surrogate solids contained 62.63 wt% silica and the POP demonstration glass contained an average of 54.02 to 54.82 wt% silica. Based on Equation 1, this equates to a waste loading of 87 wt%. However, all the lead (Pb) did not go into the glass. An average of 4.6 grams of lead oxide (PbO) per 100 grams of glass made went to the off-gas that will be returned to the glass. Also, the glass contains an average of 4.7 grams of alumina per 100 grams of glass resulting from refractory erosion. The full-scale facility will use a chemically different refractory that will resist erosion and less refractory will enter the glass[21]. Factoring the recycling of the lead into Equation 1 will decrease the waste loading approximately as much as eliminating the alumina from the glass.

Laboratory results showed that the operating envelope, at which the glass does not exceed RCRA TCLP limits, is rather large. Also, good glass was produced even with variability in the feed composition from poor mixing in the mix tank during the POP demonstration. Therefore, 87 wt% waste loading is being used for this technology.

G.3.1.3 Chemical Stabilization — Cement-based

Approximately 12,900 lb of cement were made during the POP demonstration and 40 wt% waste loading was reported. However, approximately 200 lb of material were lost into the process and 180 lb of solids (some dissolved) remained in the filter press decant. Some of these materials (assume 200 lb) would be recycled back into the product during operation of a full-scale facility. These factors reduce the waste loading to approximately 38 wt%.

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[21] The full-scale remediation contractor will utilize an optimized refractory material which will be compatible with the glass chemistry. This would minimize the erosion of the refractory and any negative effects upon the waste loading, as was observed during the POP testing.

Other factors noticed during the POP demonstration that could adversely affect waste loading and need consideration when designing the full-scale facility are:

A. The treated product was observed to be nonflowing. The general consensus of those that witnessed the POP demonstration (FDF, DOE, and the OEPA) was that the final product was too stiff and non-flowing at the mixer discharge chute. Shovels and hoes were manually used to remove and guide the final product from the mixer discharge chute to the drums. The drums had to be bounced and rapped against the floor with the fork lift to force the final product to settle in the drums. A flowable grout would lend itself better to processing, remote operation, contamination control, and radon control. Modifying the treatment formula by adding extra water increases the treated product's flowability, but lowers the waste loading. Also, more cement may then need to be added to ensure the treated wasteform sets, which also lowers the waste loading.

B. The treated wasteform took a long time to cure and harden. At 6 to 8 days, the final product was observed to be wet and pliable like a potter's clay with unconfined compressive strength (UCS) measured between 5 and 16 psi. A minimum of 50 psi was set in the design basis. At 14 days, 5 of 11 batches had strengths ranging between 9 and 49 psi UCS. All batches were above 50 psi at 28 days with the lowest being at 63 psi. Long cure/set times require large environmentally controlled staging facilities until the final product cures. A cure time of no more than 6 days is desired to minimize the size of the internal, environmentally controlled staging facilities to 7 days storage, which includes 1 day to run the TCLP. A product is considered cured when it is no longer damp and has UCS strength of at least 50 psi.

Decreasing the cure time or set requires modifying the treatment formula by adding more cement. However, more water is also needed to make the grout mixable and flowable. Both of these additions decrease waste loading.

C. Unbound water. Because of the lower cement content, little of the water is bound in the mix formulations. For example, a two-inch cured cube, weighing 200 grams, lost 66 grams of moisture in a week when exposed to room air. This loss of moisture produces a porous and friable wasteform. The loss of weight indicates that the final product's matrix is porous, which can provide more channels for radon release. The impact of the drying on the TCLP and compressive strength is not known. Some of the unbound water may separate

from the grout matrix during extended staging or transportation due to temperature changes or movement.

Extra cement (or other absorbents) may be necessary to contain excess water and make the grout less friable. This addition decreases the waste loading.

D. Process control is sensitive. Lead is the main RCRA constituent of concern. Successful treatment requires a TCLP leach value for lead of less than 5 ppm. Chemical stabilization POP laboratory results indicate that controlling the leachability of the RCRA metals to TCLP limits, especially lead, is not as straightforward as originally envisioned. This is attributed to lead's amphoteric nature, that is, it is soluble under both basic and acidic conditions; it is least soluble with a pH around 9.5. Plotting the TCLP results for the various laboratory tested cement mixes against the final pH of the TCLP extraction fluid generally shows this amphoteric character[22].

Only one of the 12 bench-scale demonstration surrogate (DS), cement formulations passed the USC and remained within RCRA TCLP requirements. The formulations contained different blends of cement, hydrated lime, calcium sulfate (Plaster of Paris or gypsum), ferrous sulfate, and phosphate to treat the DS. The first two compounds have a great impact on the final TCLP pH, and adding too little or too much can cause the RCRA TCLP limit for lead to be exceeded. This occurred in spite of phosphate addition. The formulations tested generally contained about 2 wt% TSP, although some samples had little or no phosphate. A comparison of the laboratory results showed that additional phosphate had little affect or no reduction of lead leaching characteristics. Buffering capability, pH and set (see later discussion) appeared to be the dominant controlling factors. Calculations showed that known variability in the Silos 1 and 2 material frequently put the grout mix outside the operating envelope. Thus, the 40 wt% formulation is considered to have a narrow operating window; that is, it lacks robustness.

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22 Lead generally shows this nature. The solubility curves take on different shapes and shift with respect to specific lead compounds and the environment in which the compounds are located. Consequently, the chemistry of Silos 1 and 2 material can be complex and its interaction with lead and grouts can present anomalies and unexplained results and trends. Some of this is evident in the POP test results and gives merit to sampling and pretesting feed batches before the grout is made.

More material (additives) needs to be added to the mix to give it a wider operating window. One approach may be "tuning" the mix[23] to the TCLP Extraction Fluid No. 2, which will require more cement (or alkaline like calcium hydroxide). Another approach may be to use less calcium hydroxide and more cement and the addition of fly ash as used by the Chemical Stabilization — Other technology. The addition of more material will reduce the waste loading.

Cure time (degree of "set" or firmness of a sample) appears to have a significant bearing on the TCLP results. POP results show that partially cured samples required the Extraction Fluid No. 2 to perform the TCLP and cured samples required Extraction Fluid No. 1. Therefore, running the TCLP samples early can give erroneous results. The extra cement used in making the grout faster-setting probably forces "tuning" the grout to Extraction Fluid No. 2. A DS cement mix (1174-52-01) with a waste loading of approximately 33 wt% cured to 53.8 psi in seven days and used Extraction Fluid No. 2, but it was non-flowable and had a high TCLP. This would require extra water for thinning the formulation and extra cement, calcium hydroxide, fly ash, etc. to "tune" the formulation. Upon consideration of all the aforementioned chemistry issues, a final waste loading of 30 wt% is used for this technology.

G.3.1.4 Chemical Stabilization — Other

Both chemical stabilization technologies use similar formulations. Their main difference is that the Chemical Stabilization — Other technology uses more cement and water to make a more flowable formulation for in-container mixing. This formulation uses a significant amount of cement and fly ash, which indicates that Extraction Fluid No. 2 was used in the TCLP test. This "tuning" to the TCLP Extraction Fluid No. 2 gives it more latitude in its operating window. The chosen DS recipe was formulated and tested at 24-25 wt% waste loading using a slurry decanted to 37 wt%. However, decanting was more challenging than planned during the POP

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23 The TCLP analysis process uses two different extraction fluids - Extraction Fluid No. 1 is sodium acetate at a pH of 4.93 and Extraction Fluid No. 2 is an acetic acid at pH 2.88. The pH and acid neutralization ability of the waste determines which extraction fluid is used. The DS demonstration formulation was "tuned" to Extraction Fluid #1 and had an operating window of approximately 1 wt%. In other words, adding 6 wt% cement instead of 5 wt% cement to the DS surrogate was enough to shift the pH to failure. Variability in the Silos 1 and 2 material can also change the pH and exceed the 1 wt% variance. For example, calcium carbonate (known to vary up to 16 wt% in Silo 2) can neutralize the TCLP acid and change the final TCLP pH. This increases process control sensitivity. The stronger acid concentration in Extraction Fluid No. 2 helps decrease sensitivity via overshadowing some of the pH and buffering variability in the Silos 1 and 2 material.

demonstration and only 18.6 wt% waste loading was achieved[24]. The solids did not settle in the slurry as well as they did during the laboratory and bench-scale tests. This was probably due to the numerous days of agitation of the surrogate slurry in the mix tank resulting in the erosion of the solids to fine particulate that did not settle easily. Long mix times are not expected in the full-scale facility and the actual Silos 1 and 2 material solids are expected to settle more easily than some constituents in the surrogate.

During the demonstration, the grout was mixable and appeared flowable; but, it became hard overnight. The addition of a 5.4 wt% Silos 1 and 2 material to obtain 24 wt% waste loading means that the solids content of the mix will be increased 5.4 wt% and the water content of the mix will be decreased by 5.4 wt%. Both actions will increase the thickness of the grout. The mixing of a thicker 24 wt% grout was not demonstrated and is a concern since the planned full-scale container is 15 times larger than demonstrated. However, it is assumed that the mechanics of mixing the higher concentrations of solids can be resolved if necessary (i.e., install a higher torque motor and/or more substantial mixer paddle). Cost estimates and the facility design are based on a waste loading of 24 wt% for this technology.[25]

On-going settling tests being performed with actual Silos 1 and 2 material indicate that the Silos 1 and 2 material react with the BentoGrout™ (or vice versa) and hinders or prevents the settling of the fines in the Silos 1 and 2 material. The percentage may be significant[26]. This

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24 The mass balance around the POP demonstration shows that decanted slurry contained 3,808 lb of solids with 9,175 lb water from the surrogate slurry plus an additional 591 lb of water used to move the slurry. Then 6,922 lb of additives were used to make 20,496 lb of grout held in 22.4 drums with an 18.6 wt% waste loading. Unfortunately, the decant also had to be made into grout. The decant contained 874 lb of solids contained in 2,407 lb of water from the surrogate slurry plus an additional 216 lb water used for moving the slurry. This made 5,280 lb of grout in 6 drums of grout with a waste loading of 16.6 wt%. The POP demonstration actually performed at a waste loading of 18.2 wt% if the treatment of the decant were included in the overall waste loading calculation; i.e., (874 + 3,808)/(20,496 + 5,280) x 100 wt% = 18.2 wt%. Three hundred and six lb of untreated surrogate material was held-up in the feed tank that was not treated. This was not used in the calculations since it is assumed accumulated, and as such, would become insignificant in a full-scale facility.

25 To estimate the disposal quantities at the demonstrated18.6 wt%waste loading, multiply the 24 wt% quantities by 1.29. Also, it is estimated that a fourth production line would be necessary to meet the schedule.

26 FDF Report 40700-RP-0007, *K-65 Settling Test Results*, Revision O, November 1999, showed that significant portions (up to 50 wt%) of the Silos 1 and 2 material do not settle in 4 wt% BentoGrout™ solution and remain in the decant. This will be factored into the future design efforts of the selected technology.

implies that fines will be recycled back to the TTA with the decanted operation becoming more difficult as the operation continues. Also, the grout waste loading may also be affected and decrease with time.

G.3.2 Process Control

Characterization of the feed materials is critical for both vitrification and chemical stabilization technologies. The desired constituents that need characterization are different and discussed below. However, the determination of moisture content (or percent solids) is critical for both technologies and needs to be accurately determined. These determinations are necessary to determine the amount of additives needed. Also, the accurate measurement and delivery of additives to the process is critical to both technologies.

G.3.2.1 Vitrification Technologies

The major constituents that need to be measured for the vitrification process are silica and calcium (only for Silo 2). Argonne National Laboratory (ANL) analyzed samples of Silos 1 and 2 material and gave a high reading of calcium, this may require adjustment of the glass formula. Analysis for sulfate may be important in determining the production rate (i.e., a high sulfate concentration would require that the joule-heated melter run at a slower production rate to give time for the decomposition of the sulfates, which is the rate limiting step (or bottleneck) of the vitrification process. The POP testing demonstrated 0.8 metric ton/day·meter^2 production rate based on the DS, which contained similar sulfate concentrations found in the Silos 1 and 2 material. Therefore, it is assumed that the desired production rate of any single joule-heated melter can be achieved without the formation of sulfates being an issue, if the melter's size is properly adjusted based upon the 0.8 metric ton/day meter^2 factor.

G.3.2.2 Chemical Stabilization Technologies

Good characterization and process control of the batch makeup is essential in making cement-based grouts that do not exceed RCRA TCLP limits and cure properly.

A. A good test consists of: (1) blending Silos 1 and 2 material, cement, additives, and TCLP acid (in prescribed ratios) and then (2) determining the pH of the mix before mixing the batches. This gives an indication of what the pH should be when the actual TCLP test is performed. If the pH is significantly different than 9.5 pH, adjustments should be made in the ratios to prevent probable exceeding the RCRA TCLP limits due to high lead leachability. Also, if the pretest contains lead in the leachate, adjustments should be made to reduce the leachate.

   Basis: POP results and studies done at other sites. See **Attachment G-2** and **Section G.3.3 - *Robustness*** for details.

B. The official TCLP analysis can be performed on cured samples of the treated Silos 1 and 2 material.

   Basis: See **Attachment G-2** for details.

C. Known weights of materials going into the batch are very important to determining the correct mix and need to be measured accurately.

   Basis: POP results. See **Attachment G-2** and **Section G.3.3 - *Robustness*** for details.

G.3.3 Robustness

Robustness is defined as the ease of treatment process to handle variability in the slurry. The range of robustness is defined as follows:

- Extremely Good Robustness One treatment recipe (formulation) treats all the Silos 1 and 2 material without need for characterization of the slurry delivered to the process. Slurry characterization is performed as a quality function.
- Very Good Robustness Adjustments in the water or solids content of the slurry feed to accommodate a treatment recipe. No other characterization of slurry is required. Slurry characterization is performed as a quality function.
- Good Robustness The slurry needs to be characterized to ensure that the recipe

is adequate. Infrequent modifications to the recipe are expected to produce a good result.

- Marginal Robustness The slurry needs to be characterized to ensure that the recipe is adequate. Some modifications to the recipe are expected to produce a good result. Additives need accurate measurement.
- Poor Robustness The slurry needs to be characterized. The recipe needs to be adjusted according the slurry analysis. Additives need accurate measurement.
- Sensitive Robustness Even with good analysis of the slurry and accurate measurement of the additives, some failures of the treated product are expected.

Quantifying the robustness of a technology is best accomplished by subjecting a known treatment recipe to variable waste feed (slurry feed) to see how well the recipe performs. Also, the ability to measure variations in the slurry and to make the appropriate adjustments needs to be ascertained.

Limited information is available to make a definitive statement for all of the technologies. However, some information is available from the POP results and previous work done with vitrification and chemical stabilization using surrogates and actual Silos 1 and 2 material.

The POP demonstrations were performed with a well-defined surrogate and with only one treatment recipe. Therefore, variability in the product results (i.e., TCLP) is an indication of robustness sensitivity. Further, good product (i.e., product that does not exceed RCRA TCLP limits) continually made with a variable feed and additive composition (e.g., due to poor mixing in the feed tank) is an indication of process insensitivity.

The Vitrification — Joule-heated POP demonstration went well. The feed preparation and melter systems operated continuously with little variation. The TCLP of the glass produced from this demonstration was also consistent with a range between 1.3 to 2.1 ppm lead. A stable operation gives good credit to the process, but it makes a robustness determination difficult. The determination of the robustness for this technology was better determined from the laboratory/bench-scale development activities when significant changes were introduced

into the glass melts. The laboratory results showed "very good robustness" and are discussed in greater detail later.

The Vitrification — Other POP demonstration showed "very good" robustness. The batch tank with the surrogate and additives did not perform well and the feed composition to the melter varied with time because of settling in the tank. As a result, the composition of the glass varied in silica (47 to 57%), alumina, lead, additives, etc. However, it still produced a glass product that met specified WAC (i.e., TCLP varied from 0.42 to 0.93 ppm for lead). (The TCLP for the joule-heated technology ranged from 1.3 to 2.1 ppm lead during its demonstration runs.)

The Chemical Stabilization — Cement-based technology POP demonstration showed "sensitive" robustness. A consistent filter cake was made and measured with little variation. The additives were accurately measured and added to the filter cake, but the resulting set times and compressive strengths of the grout varied. Likewise, the TCLP results of the grout varied by orders of magnitude, from 0.0122 to 2.240 ppm for lead.

The Chemical Stabilization — Other showed better results ("good robustness") with the TCLP results of the grout varying from non-detect to 0.043 ppm lead, except for the first batch, which was 0.812 ppm lead. This may indicate some possible sensitivity to mixing because mixing of the first batch did not go as smoothly as mixing of the later batches.

Laboratory bench-scale results can also give an indication of robustness. For example, several variations in a formula are performed to find the better mix. An indication of a possible large operating window and good robustness would be a good performance of most or all of the recipe variations. An indication of a narrow operating window and poor robustness would be a good performance of only a few or one of the variations. The two vitrification technologies showed very good robustness. The Vitrification — Joule-heated technology performed the most melts. Several melts were performed with different additives (not just varying concentrations of the same constituents) and the results indicated a "very good" robustness. The Chemical Stabilization — Cement-based showed sensitive robustness. This is because 12

DS mixes were performed and only two remained with the RCRA TCLP limits for lead, but only one passed both the TCLP for lead and 50 psi USC requirements. Less is known about the Chemical Stabilization — Other technology because only a few mixes were made with different concentrations of the same binders and phosphate, but the results were good. It appears to have marginal to "good robustness." Therefore, the designs are based on the Chemical Stabilization — Other type formula. The Chemical Stabilization — Other is expected to be somewhat more robust than the Chemical Stabilization — Cement-based (as designed) because of its lower waste loading (i.e., 24 wt% vs. 30 wt%).

G.3.3.1 Operational Envelope and Robustness Diagrams for the Vitrification Technologies

None of the technologies' recipes, except for Vitrification — Other (because of poor mixing in the tank) was challenged by variability in the slurry's composition. Contractors for each of the vitrification technologies provided robustness triangles based on the results of the laboratory melts and the POP demonstration run. These triangles are presented in **Figures G.3.3-1** and **G.3.3-2.** The composition of the glass shown in these figures is defined on three axises:

SiO_2	Silica
RO or MO	Alkaline Fluxes, etc. These are the elements that have a valence of +2 (e.g., calcium, magnesium, barium, and lead).
R_2O or M_2O	Alkali Fluxes. These are the elements that have a valence of +1 (e.g., sodium, potassium, and lithium).

In order for these charts to work, each point on the chart must add up to 100 wt%. However, there are some other elements (in small concentration) that do not directly fit into the above three categories. The Vitrification — Other technology simply assumes that 10 wt% exists in the other elements of the mixes (points). Therefore, the above three categories total 90 wt%, the addition of the 10 wt% allowance for other elements results in a total of 100 wt%. The Vitrification — Joule-heated technology included iron and sulfur in the RO category and the other elements were included in with SiO_2 category.

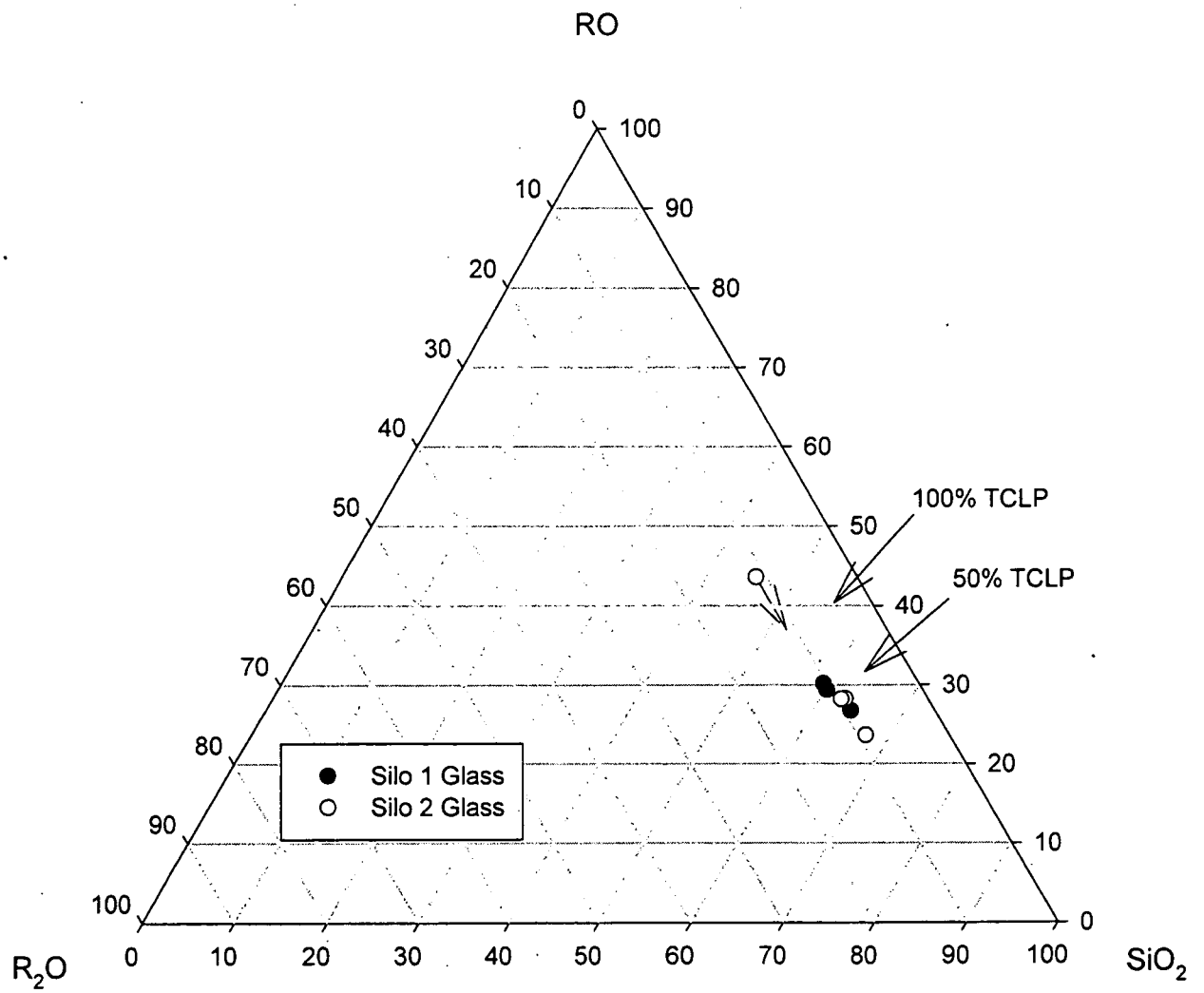

FIGURE G.3.3-1
OPERATING ENVELOPE DIAGRAM
VITRIFICATION — JOULE-HEATED

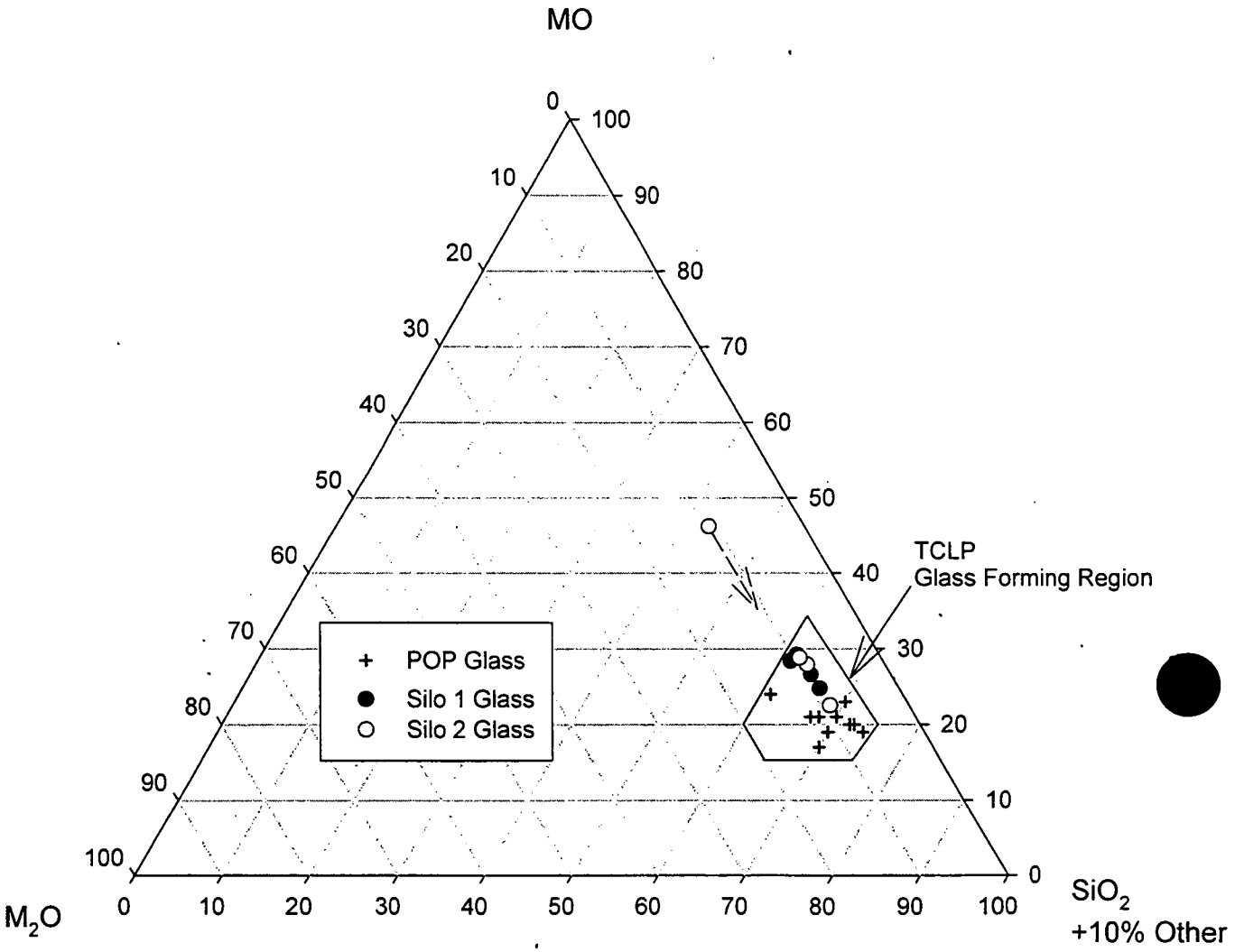

FIGURE G.3.3-2
OPERATING ENVELOPE DIAGRAM
VITRIFICATION — OTHER

To show robustness, calculations were performed using the contractor's POP demonstration recipe and applied to the known variations in the Silos 1 and 2 material. Glass compositions were calculated using the same additive mix used in the contractors' POP demonstration recipe and blended with analyzed Silos 1 and 2 samples presented in the PNL report, *Operable Unit 4 Treatability Study Report for the Vitrification of Residues from Silos 1, 2, and 3*, February 1993 (AR Index No. U-006-409.1); and the ANL report, *Chemical Analysis of Samples from Operable Unit 4*, December 10, 1997. PNL provided analysis from three different zones and a composite for each silo. ANL provided analysis on a sample from each silo. Other analyses of the Silos 1 and 2 material exist, but PNL's and ANL's are considered the most complete and accurate because they are comprehensive elemental/compound analyses.

To perform the calculations, equal amounts from each zone were substituted for the surrogate and the resulting calculated glasses were plotted on the triangles. Notice that all glasses fit within the operation envelopes, except for one. This point is derived from an ANL sample that contained visible calcium carbonate nodules. These nodules are what drive the glass composition outside the envelope. This sample appears to be an outlier, but it is not known how many of the nodules exist in the silos. The glass formula can easily be adjusted to produce a glass in the operating envelope by replacing the calcium carbonate, which is used as one of the glass additives, with silica. The analysis indicates that the vitrification formulation shows very good robustness and that feed analysis for calcium (or silica) and total solids contents may be all that is necessary for process control. However, transferring the Silos 1 and 2 material to the TTA will result in mixing of the Silos 1 and 2 material and reduce this concern. The Silos 1 and 2 material will be sampled as it is placed in the TTAs. This will result in a map of the variability of the Silos 1 and 2 material as it is placed in the TTA.

G.3.3.2 Operational Envelope and Robustness Diagrams for the Chemical Stabilization Technologies

In comparison to the vitrification technologies, the task of developing operational envelopes for the chemical stabilization technology was more challenging because the chemical makeup, pH, extent of cure, and chemistry of the grout mixes are more important than the elemental makeup required for vitrification. As seen by the POP results, it appears that there are more factors affecting the quality of the grout than are included in the calculations for the operational envelopes. To establish an operating envelope for robustness comparison, the results from the POP testing and the attached report **(Attachment G-2)** were investigated. These reports indicate that cement concentration and components that affect pH or have the ability to neutralize the TCLP acids have an effect on the TCLP results for lead.

Most of the pH producers in cement are generated from the production of calcium hydroxide during the hydration of calcium silicate compounds in the Portland Cement grout. The remaining portion comes from the hydration of fly ash. The Chemical Stabilization — Cement-based technology introduces additional calcium hydroxide directly to the filter press operation and into the grout mix. The results of two bench-scale laboratory mixes performed during POP testing for the Chemical Stabilization — Cement-based technology help define the boundaries of the operating envelope with respect to cement concentration and pH concentrations.

Both recipes are the same except for the amount of cement used in the grout. The grout with a cement concentration of 8.42 wt% passed TCLP of 0.0144 ppm for lead. The grout with a cement concentration of 12.11 wt% failed with a TCLP of 301 ppm for lead. Also, given that the passing grout requires 28 days to reach the required strength of 50 psi (i.e., grout with less cement probably would not be acceptable), the envelope in **Figure G.3.3-3 - *Chemical Stabilization — Cement-based Operating Window Determination*** was established. The y-axis is the log of the TCLP. The x-axis is termed "Acid Neutralization Strength" and is shown as an equivalent hydroxide <OH> concentration. One mole of equivalent hydroxide <OH> will neutralize one mole of acetic acid in the TCLP test and adjust the resulting pH of the TCLP test

accordingly. The ability to neutralize the acid can be provided by the cement, calcium hydroxides, carbonates in the surrogate/Silos 1 and 2 material, etc. and are calculated and summed together in the hydroxide equivalent <OH> concentration.

To determine robustness (like the vitrification technologies) calculations were performed by applying the contractor's POP demonstration recipe to the same known variations in the Silos 1 and 2 material used for evaluating the vitrification technologies. PNL provided analysis from three different zones and a composite for each silo. ANL provided analysis on a sample from each silo. Equal amounts from each zone were substituted for the surrogate and the resulting calculated grout plotted in the diagrams in **Figures G.3.3-4** - ***Chemical Stabilization — Cement-based Operating Envelope Diagram*** and **G.3.3-5** - ***Chemical Stabilization — Other Operating Envelope Diagram***. **Figure G.3.3-4** depicts the Chemical Stabilization — Cement-based formulation as having a sensitive robustness. **Figure G.3.3-5** for the Chemical Stabilization — Other formulations shows most grouts (points) fitting within the envelope, and hence, showing good robustness. Therefore, it appears that a recipe formulation more like the Chemical Stabilization — Other, which gives a wider operating envelope, should be used in the design of this technology. Characterization of the feed and TCLP pretests are recommended to reduce the number of container failures with this recipe.

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The calculations were done to gain some insight into the robustness of the chemical stabilization wasteforms. As evident by the POP results, there are more factors affecting the qualities of the grout than were included in the calculations and figures. Further development work is required to establish the operating envelope for the chemical stabilization wasteforms. For example, these calculations and figures do not include the impact of the hydroxides assumed to be in the Silos 1 and 2 material[27] (as indicated by the variability of the high pH in the Silos 1 and 2 material sample). Other factors that may affect the operating envelope (e.g., free standing water, cure time, and compressive strength of the grout) were not considered in this evaluation.

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[27] See Table G.2.1-3 - ***Silos 1 and 2 Elemental Compositions According To PNL Analysis and FDF Analysis for SO_3.***

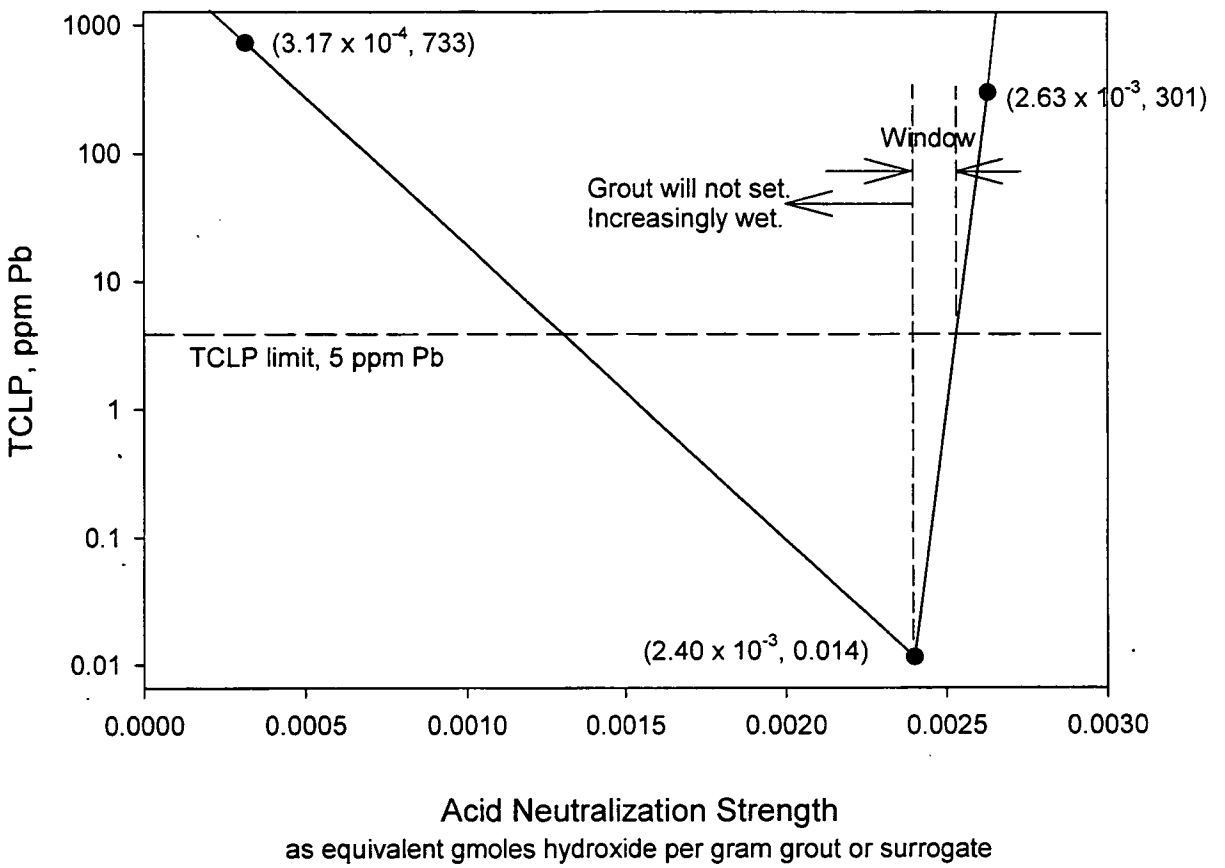
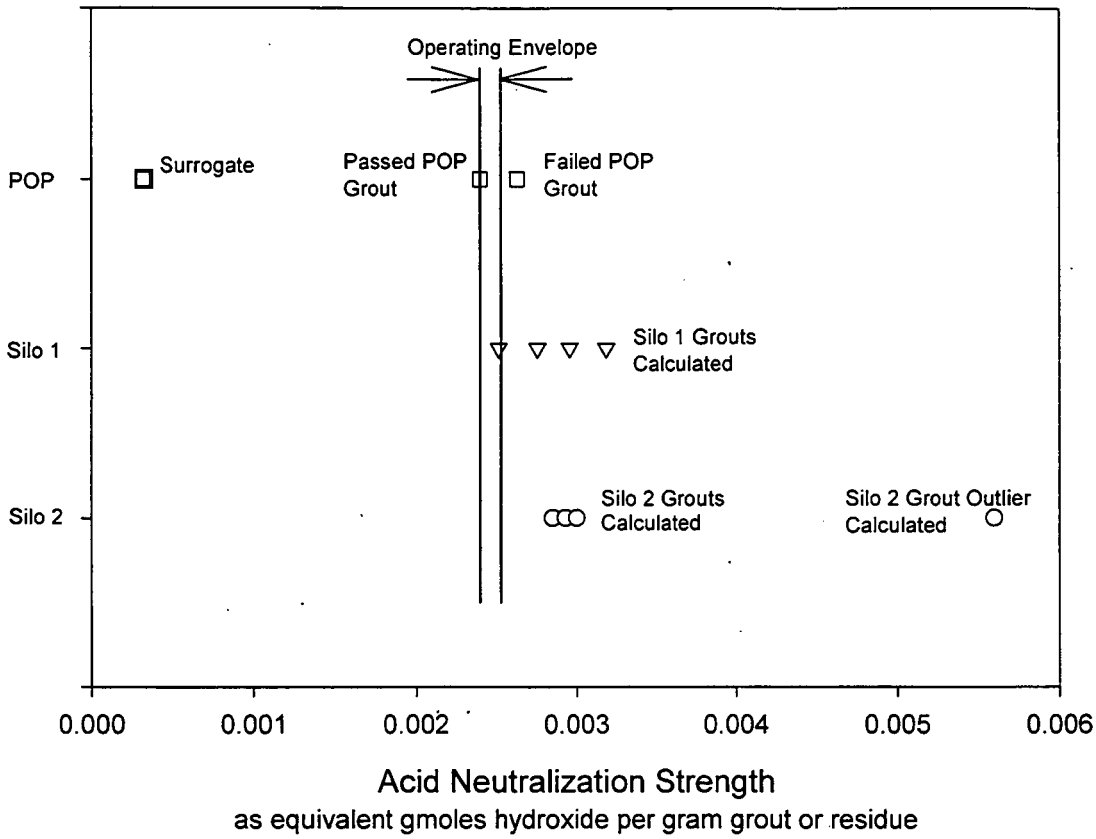
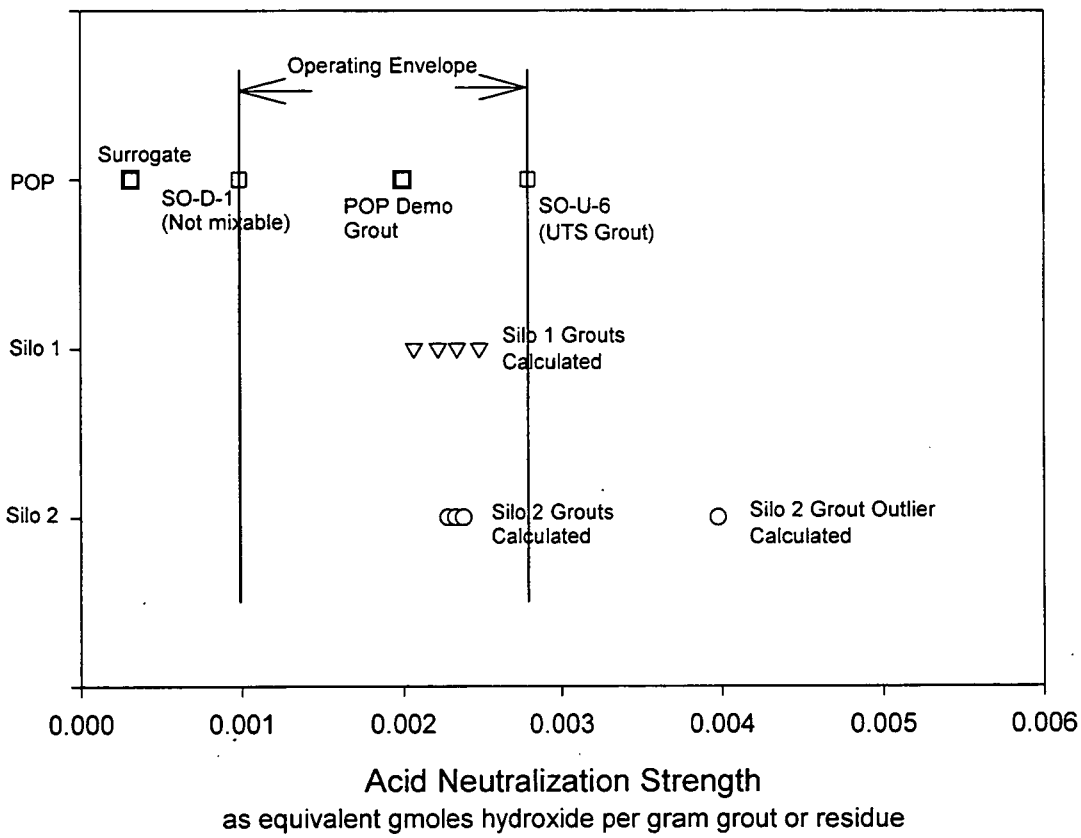


FIGURE G.3.3-3
OPERATING WINDOW DETERMINATION
CHEMICAL STABILIZATION — CEMENT-BASED



Note: The above includes only the calculated impact of carbonates in the residues. The impact of other compounds, like hydroxides, are not given because the concentration of these are not known at this time. However, the pH is know to vary in Silo 1 between 9.1 and 10.7 pH units and in Silo 2 between 7.5 and 10.5 pH units which indicates some variation.

FIGURE G.3.3-4
OPERATING ENVELOPE DIAGRAM
CHEMICAL STABILIZATION — CEMENT-BASED



Note: The above includes only the calculated impact of carbonates in the residues. The impact of other compounds, like hydroxides, are not given because the concentration of these are not known at this time. However, the pH is know to vary in Silo 1 between 9.1 and 10.7 pH units and in Silo 2 between 7.5 and 10.5 pH units which indicates some variation.

FIGURE G.3.3-5
OPERATING ENVELOPE DIAGRAM
CHEMICAL STABILIZATION — OTHER

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Section G.4

G.4.0 VITRIFICATION — JOULE-HEATED

G.4.1 Summary

The Vitrification — Joule-heated technology processes the Silos 1 and 2 material and chemical additives to remediate the Silos 1 and 2 material constituents of concern. The treatment recipe is optimized to obtain a high waste loading, meets NTS WAC, and maintain steady-state operations. For this process, the Silos 1 and 2 material slurry is dewatered and combined with chemical additives to create a mixture that is continuously fed to the joule-heated melter. After sufficient retention in the melter, the glass is discharged to a monolith transfer container (MTC). The filled MTC is cooled and placed into a concrete shipping and disposal container (4 MTCs per container) for shipment. Off-gas from the melter is treated for acid gases and particulates before it is forwarded to the existing RCS for radon removal. The melter is cooled with water.

G.4.1.1 Functional Analysis

A functional analysis has been performed for the Vitrification — Joule-heated technology. **Figure G.4.1-1 - *System Block Flow Diagram Vitrification — Joule-heated***, presents the individual functional requirements for the joule-heated treatment facility. The first level functions are high level functions to be accomplished by the treatment facility systems, structures and components. The subsequent levels in the functional analysis diagrams describe the means by which the high level functions are to be accomplished. **Table G.4.1-1** gives a brief description of the individual functional blocks shown in **Figure G.4.1-1.**

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Figure G.4-1
Functional Analysis Diagram
Vitrifiction - Joule Heated

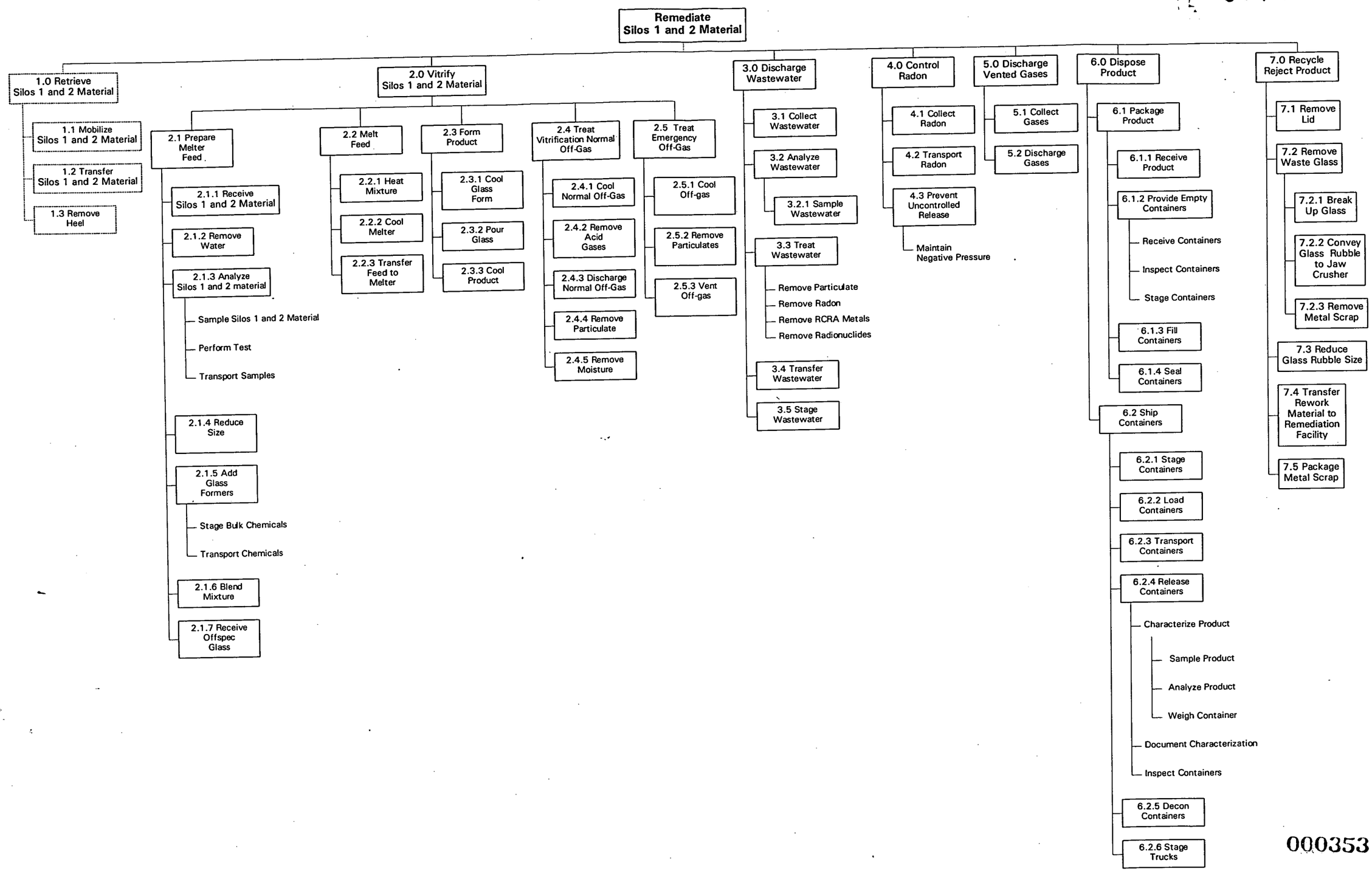

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TABLE G.4.1-1
FUNCTIONAL BLOCK DESCRIPTIONS
VITRIFICATION — JOULE-HEATED

Function ID	Function Title	Functional Description
Overall System Function	Remediate Silos 1 and 2 Material	The Silos 1 and 2 material is retrieved, mixed with glass forming additives, and vitrified in the joule-heated melter to produce a product that can be disposed of safely. The process requires systems for normal and emergency off-gas treatment, secondary waste treatment, radon control (existing), venting gases, recycled cooling water and disposal of product.
1.0	Retrieve Silos 1 and 2 Material	The Silos 1 and 2 material being stored in the TTA tanks is retrieved in a form suitable for feeding to the treatment process.
1.1	Mobilize Silos 1 and 2 Material	The Silos 1 and 2 material is mobilized using high-pressure water jets for the slurry.
1.2	Transfer Silos 1 and 2 Material	The Silos 1 and 2 material is transferred with a sludge pump at approximately 10 wt% solids through a pipe at a velocity high enough to prevent settling and plugging.
1.3	Remove Heel	The remaining material after the normal pumping operation is removed.
2.0	Vitrify Silos 1 and 2 Material	The Silos 1 and 2 material slurry and glass forming additives are blended and heated to 2165°F in a joule-heated melter. The glass product and off-gas are separated. The glass product is cooled, transported, and packed in containers.
2.1	Prepare Melter Feed	The Silos 1 and 2 material slurry is blended with additives.
2.1.1	Receive Silos 1 and 2 Material	The Silos 1 and 2 material slurry is pumped from the TTA, passes through a screen to separate oversized material, and is stored in the slurry receipt tank.

TABLE G.4.1-1 (cont.)

Function ID	Function Title	Functional Description
2.1.2	Remove Water	The slurry is continuously fed to a gravity clarifier to produce a 30 wt% sludge and an overflow with less than 1 wt% Silos 1 and 2 material solids, plus up to approximately 4 wt% BentoGrout™.
2.1.3	Analyze Silos 1 and 2 Material	The slurry from the clarifier is sampled and analyzed to ensure that a glass product suitable for disposal can be produced.
2.1.4	Reduce Size	The feed to the melter should be free from oversize particles for proper vitrification. Oversized particles are reduced in a hammer mill.
2.1.5	Add Glass Formers	Additives are formulated to the Silos 1 and 2 material for proper vitrification.
2.1.6	Blend Mixture	The Silos 1 and 2 material and glass forming additives are mixed thoroughly to produce good glass product. The required quantities of materials are transferred sequentially to the feed preparation tanks and mixed thoroughly.
2.1.7	Receive Off Spec Glass	Off spec glass is recycled. It is ground and mixed with the feed to the melter.
2.2	Melt Feed	When heated, the mixture of Silos 1 and 2 material and additives melt to form glass. The cooled glass product becomes a material suitable for safe disposal.
2.2.1	Heat Mixture	Approximately 2.5 megawatts (MW) electrical power is used to heat the slurry feed to the melter to drive off water and degradation products and produce glass.
2.2.2	Cool Melter	Cooling tower water is used to cool the outer surface of the melter.
2.2.3	Transfer Feed to the Melter	The mixed feed from the melter feed tank is fed continuously to the melter.
2.3	Form Product	The molten glass pours into MTCs to form monoliths.

TABLE G.4.1-1 (cont.)

Function ID	Function Title	Functional Description
2.3.1	Cool Glass Form	The molten glass from the melter goes into an MTC surrounded by a water-cooled jacket for rapid cooling and to maintain container integrity.
2.3.2	Pour Glass	The molten glass product pours directly from the discharge chamber of the melter into a MTC.
2.3.3	Cool Product	The filled MTC is further cooled by water jackets immediately after being filled, and is then air-cooled for approximately two days.
2.4	Treat Vitrification Normal Off-gas	The off-gas from the melter undergoes normal treatment for cooling and the removal of acid gases, particulates, moisture, and radon. In the case of equipment malfunction, the off-gas from the melter is sent to emergency treatment for cooling and particulate removal.
2.4.1	Cool Normal Off-gas	The off-gas is cooled to 140° F in the quench tower that condenses most of the water vapor. Water used for quenching is cooled in a heat exchanger before recirculating to the quench tower spray nozzles. The condensed water leaves in a purge stream that is directed to the precipitator tank.
2.4.2	Remove Acid Gases	The off-gas is scrubbed with a dilute caustic solution to remove SO_2. In the process, the off-gas is cooled to 110° F. The caustic solution, which is heated in the scrubber, is cooled in an exchanger before returning to the scrubber for recirculation. A purge stream from the scrubber removes condensate and solids. An NO_x treatment system removes acid gases.
2.4.3	Discharge Normal Off-gas	The 500 (max) scfm of off-gas is directed to the existing RCS.
2.4.4	Remove Particulates	The off-gas from the scrubber is sent to a WESP to remove the remaining particulate matter. The solids are flushed out as a 10% slurry and collected in the precipitator tank. The material from this tank is transferred to the slurry receipt tank for recycle in the treatment system.

TABLE G.4.1-1 (cont.)

Function ID	Function Title	Functional Description
2.4.5	Remove Moisture	The off-gas is cooled to 45° F in the RCS condenser using chilled glycol solution. Most of the water in the off-gas gets condensed. The condensed water is collected in the condensate tank and then is transferred to the wastewater treatment area for treatment.
2.5	Treat Emergency Off-gas	In case of an emergency, which prevents regular off-gas treatment, the off-gas from the melter is mixed with diluent air and cooled to 500° F. The cooled off-gas is sent to the emergency off-gas (EOG) knock out tank and filter where the bulk of the particulate matter is removed. Then, it passes through HEPA filters where most of the remaining particulates are removed before the gas is vented to the EOG stack.
2.5.1	Cool Off-gas	The off-gas is cooled to 500° F with atmospheric diluent air.
2.5.2	Remove Particulates	The cooled off-gas passes through a knock out tank with integral high-temperature bag filter to capture most of the particulate particles. The off-gas passes through HEPA filters to remove most of the remaining particulates.
2.5.3	Vent Off-gas to Stack	The cooled emergency off-gas, free of most particulates, is vented to the atmosphere through a dedicated stack.
3.0	Discharge Wastewater	The wastewater discharged from different areas of the process is collected. Samples are collected and analyzed to determine the type of treatment required. The treatment process includes removal of particulates, metals, and radionuclides. The treated wastewater is transferred to staging equipment, tested, and disposed of properly.
3.1	Collect Wastewater	The wastewater discharged from the different areas of the process is collected and transferred to the treatment area.
3.2	Analyze Wastewater	Samples of the wastewater are collected for testing. Tests are conducted to determine the type and quantity of pollutants and the treatment required.

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TABLE G.4.1-1 (cont.)

Function ID	Function Title	Functional Description
3.3	Treat Wastewater	The wastewater is treated for the removal of pollutants such as particulates, RCRA or other metals, and radionuclides.
3.4	Transfer Wastewater	The treated wastewater suitable for disposal is transferred to the AWWT.
3.5	Stage Wastewater	The treated wastewater is staged and sampled to ensure that it meets the acceptance criteria of the AWWT
4.0	Control Radon	Off-gas and vents containing radon from different areas of the process are collected and transported to the RCS. The RCS treatment process includes cooling the gas to the required temperature and passing the gas through carbon beds to remove radon. Uncontrolled release of radon is prevented.
4.1	Collect Radon	Off-gas and vents from all process equipment containing radon are collected for treatment.
4.2	Transport Radon	The radon-containing gases are transported in air-tight pipelines to the existing RCS.
4.3	Prevent Uncontrolled Release	Uncontrolled releases of radon are prevented by maintaining a negative pressure throughout the collection and transport treatment system.
5.0	Discharge Vented Gases	The vent streams are collected and discharged to the off-gas stream.
5.1	Collect Gases	The vessel vent streams are collected from different sources and are sent to the pipeline carrying off-gas from the melter. At this point, the off-gas stream and vessel vent stream are mixed.

TABLE G.4.1-1 (cont.)

Function ID	Function Title	Functional Description
5.2	Discharge Gases	These gases are discharged to the Normal Off-gas System where they are processed for transfer to the RCS.
6.0	Dispose Product	The product from the vitrification system is received and packed into containers. The containers are sealed and loaded onto trucks. The trucks transport disposal of the containers to the licensed disposal facility.
6.1	Package Product	The vitrified product is received and packed into concrete shipping containers.
6.1.1	Receive Product	The vitrified product is received as monoliths in MTCs.
6.1.2	Provide Empty Containers	The concrete shipping containers, into which the MTCs will be packed, are received, inspected, and staged.
6.1.3	Fill Containers	The concrete shipping containers are filled with the MTCs using a remotely operated crane.
6.1.4	Seal Containers	The filled concrete shipping containers are lidded and sealed via remotely operated mechanisms.
6.2	Ship Containers	The concrete shipping containers with the product are loaded onto trucks. Radiological smears are collected, analyzed, and documented. The concrete shipping containers are weighed and inspected. Exposure rates are taken and documented. The trucks are then released.
6.2.1	Stage Containers	The concrete shipping containers, which are filled with product, are staged for shipment.

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TABLE G.4.1-1 (cont.)

Function ID	Function Title	Functional Description
6.2.2	Transport Containers	Loaded trucks leave the FEMP for their ultimate disposal site.
6.2.3	Release Containers	The product is characterized. Samples of the product are collected and analyzed. The concrete shipping containers are weighed. The characterization is documented. The concrete shipping containers are inspected, paperwork is completed, and the concrete shipping containers are released for shipment.
6.2.4	Load Containers	The concrete shipping containers ready for shipment are loaded onto trucks.
6.2.5	Decon Containers	Concrete shipping containers having external contamination are taken to a decontamination bay for surface washing.
6.2.6	Stage Trucks	The trucks are staged and released.
7.0	Recycle Reject Product	A separate facility is provided to handle operations associated with the rework activities of the reject glass containers. This system interfaces with the Treatment System and the Process Vent System (PVS).
7.1	Remove Lid	The container of reject glass opened to access the treated material. Facility operators use a remote bolt removing device to remove the bolts from the container lid.
7.2	Remove Waste Glass	A facility is designated for the removal of reject material from the disposal containers. The SSCs associated with removing the reject material operate concurrent with normal operating activities.
7.2.1	Break up Glass	Equipment is provided to size reduce the glass in the disposal containers. Equipment associated with size reducing the reject grout is remotely operated.

TABLE G.4.1-1 (cont.)

Function ID	Function Title	Functional Description
7.2.2	Convey Glass Rubble to Jaw Crusher	A vacuum retrieval unit is employed to automatically convey the size reduced glass to the rubble jaw crusher.
7.2.3	Remove Metal Scrap	Removal metal scrap from the broken glass monolith.
7.3	Reduce Glass Rubble Size	A means to remotely and automatically reduce the size of the glass is available to ensure that the rework final product is homogeneous.
7.4	Transfer Rework Material to Remediation Facility	A Bucket Conveyor System to transfer the crushed rework glass to the rework hopper is provided. This system interfaces with the PVS.
7.5	Package Metal Scrap	Collect package and ship the metal scrap from rework operations.

G.4.1.2 System Model

Figure G.4.1-2 presents a block flow diagram for the treatment of the silos residues using joule-heated vitrification.

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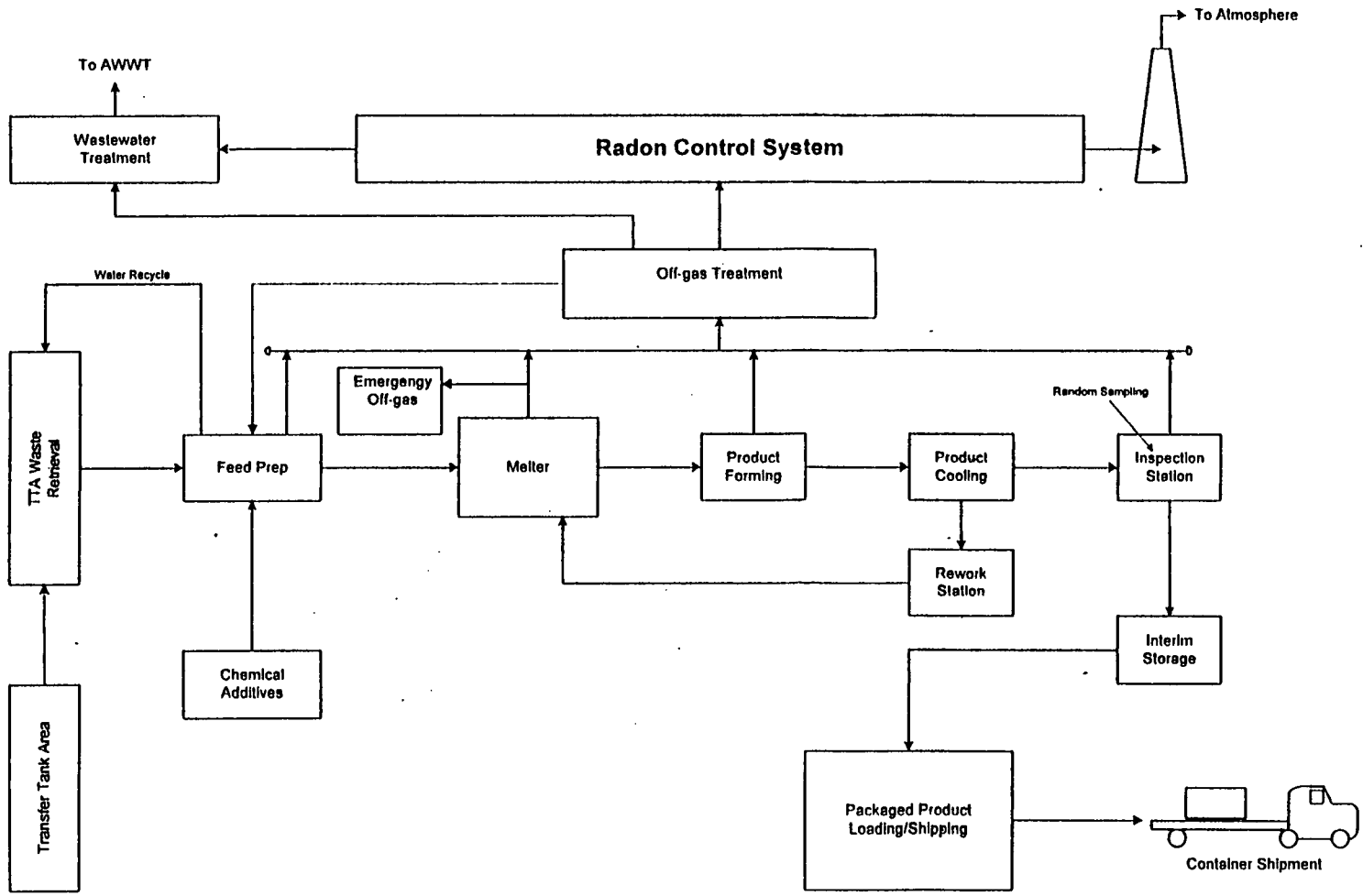
FIGURE G.4.1-2
SYSTEM BLOCK FLOW DIAGRAM
VITRIFICATION — JOULE-HEATED



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G.4.1.3 Treatment Recipe

The treatment recipe was developed by EnVitCo, Inc. under contract as the Proof of Principle Contractor for Vitrification — Joule-heated. In the development of the treatment recipe, EnVitCo met the objectives to produce a treated wasteform that passes TCLP, retains a relatively high concentration of sulfate, and maximizes waste loading.

G.4.1.4 Mass and Energy Balance Overview

The mass and energy balance is inserted in **Attachment G.4.I** in the form of process flow diagrams (PFDs) and associated spread sheets.

G.4.1.5 Availability and Work Schedule

The plant operates 24 hr/day, 7 days/week.

Basis: Continuous operation is normal to high-temperature melter operation for overall operating efficiency and minimal wear on the melter.

G.4.2 Feed and Additives Preparation (Systems 15, 16, and 44)

The feed and additives preparation systems prepare Silos 1 and 2 material for transfer to the treatment process.

G.4.2.1 System Description

The Feed Preparation System receives slurry from the TTA containing approximately 25,400 lb/day of dry Silos 1 and 2 material. The slurry is pumped with approximately 10 wt% solids. The slurry is thickened to approximately 30 wt% solids and stored in tanks for blending and feeding to the melter system. The water separated from the slurry is recycled to the TTA for use in the slurrying operation. Additives are received into the additive feed system in bulk, stored in bins, and then added to the slurry in the feed preparation tanks by means of a weigh hopper and feeder and dense-phase pumping system.

The slurry receipt tank (15-TK-006), with a capacity of 30,000 gallons, receives slurry from the TTA. Slurry percent solids can only be roughly controlled. An in-line densitometer in the slurry line to the slurry receipt tank provides specific gravity information to convert to percent solids. Vessel levels are monitored. The inventory in the slurry receipt tank is equivalent to approximately four hours of slurry pumping. The slurry is milled (15-ML-001) and screened (15-SR-001) through 30 mesh to limit maximum particle size to 0.6 millimeter (mm).

Slurry from the receipt tank is pumped to the clarifier (15-TK-001) where solids and liquid are separated by gravity. The overflow is directed to the overflow tank (15-TK-005) and is pumped back to the TTA. The solids underflow from the clarifier is pumped to the slurry surge tank (15-TK-002). The slurry is pumped batch-wise to a feed preparation tank (15-TK-003 or -004) where it is mixed with the correct proportion of additives transferred from the additive bins (44-BN-001, -002, and -003). The amount of additives for making glass is determined by the batch analysis and the amount of Silos 1 and 2 material (dry basis) determined by volume and weight measures in the feed preparation tanks. However, by using a robust glass formulation as demonstrated in the POP testing, only minor variations in additives (per batch) are anticipated. Densitometers are used to provide a rough control of percent solids in the feed system.

Slurry from the feed preparation tanks is transferred batch-wise to a melter feed tank (16-TK-001 or -002). The slurry is continuously recirculated through melter feed loop piping to reliably supply the melter feed pumps (16-PM-002 A & B). All tank levels are monitored.

G.4.2.2 Assumptions

A. **Assumption:** A clarifier system is employed to receive the 10 wt% solids slurry feed and to produce a 30 wt% solids underflow. The thickened solids slurry from the clarifier is forwarded to the process. The overflow stream from the clarifier is directed to the recycle water system at the TTA for reuse in the slurrying operation.

Basis: Operating conditions of settling based on previous experience. Single in-line clarifier expected to support 70% overall plant availability.

B. **Assumption:** One surge tank receives the thickened solids slurry and dispenses it to the feed preparation tanks as needed. The surge tank has the capacity to hold an approximate 2-day supply of 30 wt% solids slurry.

Basis: The surge tank is sized to provide two days of feed for the process when the clarifier is being repaired.

C. **Assumption:** The two feed preparation tanks, each capable of holding a 24-hr batch, are agitated. A batch is transferred from the surge tank to one of the feed preparation tanks in three hours. Additives are transferred within a half hour. The batch is continuously stirred and is sampled upon thorough mixing. Once analytical results confirm the appropriate formulation, the contents of the feed preparation tanks are transferred to the melter feed tanks. The process time for preparing a batch of feed is approximately eight hours.

Basis: The feed preparation tanks must be filled, agitated, and sampled in a timely manner in order to maintain a continuous treatment process.

D. **Assumption:** For a 24-hr batch with 1,090 lb/hr of Silos 1 and 2 material, and waste oxide loading ranging from 55 wt% to 90 wt%, additive rates are 892 to 192 lb/hr, respectively. Assuming 70 wt% waste loading, 467 lb/hr of additives are needed for a 11,208-lb batch (plant size).

Basis: Required for production rate of 15 tons/day of glass.

E. **Assumption:** Each melter feed tank is sized to hold one-half of a 24-hr batch in order to provide continuous feed to the melter.

Basis: Engineering Judgement

G.4.2.3 Key Equipment Descriptions

The clarifier (15-TK-001) is a standard gravity thickener with a cone bottom and slowly rotating rake (15-AG-001) at the bottom. The rake delivers the settled solids to the center of

the cone so that the thickened sludge can be removed by an underflow pump (15-PM-001 A or B).

G.4.2.4 System Interfaces

The Feed and Additive Preparation Systems interface with the following structures, systems, or components (SSC):

- Electrical power for instrumentation, monitors, and motors.
- Compressed air is required for pneumatically operated valves, bin aerators, air slides, dense phase pumps, instrumentation, and controls.
- Silos 1 and 2 material slurry that enters via a pipeline from the TTA residue retrieval process.
- Prepared feed slurry that exits via a pipeline to the treatment system.
- The clarifier overflow (clarified liquid) that leaves via a pipe returning to the residue retrieval process at the TTA.
- Vessels containing Silos 1 and 2 material that vent to the process vessel vent (PVV) system.
- Recycled glass (off-specification) from the rework system.
- Solids from the WESP (off-gas system).

G.4.2.5 Recycle Back to the TTA

The Silos 1 and 2 material is retrieved from the TTA as a slurry. The clarifier effects the separation of the water and solids, thus providing a source of water for the ongoing slurrying operation. This reuse of clarifier overflow for slurrying is necessary because of the large amount of slurry water needed.

G.4.3 Treatment (System 17)

The treatment system centers around a high-temperature melter constructed for continuous operation above 1450°C. However, the POP Testing Project developed glass formulations that allowed the melter to operate at low glass making temperatures (<1200°C) during the POP demonstration. Operating at low temperatures increases the life of the melter.

G.4.3.1 System Description

The melter is a joule-heated glass melter (17-PE-001) that continuously receives slurry from the Feed Preparation System. The off-gas is vented to the Normal Off-gas Treatment System. The glass product is poured into MTCs to form monoliths. A normal capacity of approximately 30,000 lb of glass is produced each day, which fills approximately 13 MTCs daily. The monoliths are partially cooled by retractable water jackets before final air cooling.

The melter is located in a room with a dedicated air handling system in order to control emissions and maintain environmental conditions. Room air is monitored for radon and acid gases. Upon leak detection, feed to the melter is suspended. A catch basin sized to hold the glass volume in the melter is underneath the melter should glass leak.

Feed to the melter is flow-regulated and interlocked with the Normal Off-gas System. Melter temperature and pressure are monitored to control the melting process.

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).

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.

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.

000369

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* 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

is then conveyed through an airlock to the MTC loading area. The remotely operated monorail hoist grapples the MTC in the adjacent airlock and transports it to the MTC loading area for placement into the shipping container. Two MTCs are placed into the shipping container and the shipping container is indexed forward. Two additional MTCs are loaded in the shipping container, for a total of four. After the final MTC is loaded, the filled shipping container is conveyed to the lid installation station where the lid is remotely lifted and placed onto the shipping container.

After the lid is installed, the filled shipping container is conveyed to the lid fastening station. After the lid is fastened, the shipping container is conveyed to the survey and decontamination station. Once the shipping container meets the radiological survey requirement for off-site shipment, it is conveyed through an enclosed passage to the interim staging facility. The shipping container is then removed from the conveyor by a remotely operated bridge crane and placed in the shielded staging area for processing before off-site shipment.

G.4.4.2 Assumptions

Assumption: A 48-hour MTC storage capacity (32 MTCs) is required for the MCR, following the jacketed cooling of the MTC in the fill and cooling room.

Basis: *EnVitCo POP Final Report* **(Appendix H, Attachment H1)**.

G.4.4.3 Key Equipment Descriptions

Roller Conveyors

The roller conveyors are 4 ft wide (5 ton capacity) and 5 ft wide (10.5 ton capacity) heavy duty, motorized, chain driven, two-directional, roller conveyors of various lengths. 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 containers and/or MTCs. They are equipped with special features for lifting containers above the rollers, for 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. Two kinds of conveyors are supplied, depending on their application, for handling MTCs (4 ft wide) or shipping containers (5 ft wide). The conveyors located in the filling and cooling room are specifically designed to operate under high temperature conditions.

MCR Bridge Crane

The MCR bridge crane is a remotely operated bridge crane with a rated capacity of 5 tons and a span of 30 ft. The crane is equipped with a special grapple device for lifting filled MTCs. In addition, the crane has CCTV capacity to ensure positive grappling and placement of the filled MTCs.

Interim Staging Facility Bridge Crane

This crane is a remotely operated bridge crane with a rated capacity of 15 tons, a span of 82 ft, a travel of 158 ft, and a lift height of 20 ft. The crane is equipped with a special grapple device for lifting a full shipping container. In addition, the bridge crane has CCTV capacity to ensure positive grappling and placement of the shipping container.

Monorail Hoist

The monorail hoist is equipped with a remotely operated hoist that travels between the MTC staging area through the connecting airlock into the container loading area. The monorail has a rated capacity of five tons with a lift height of 15 ft. The hoist employs a grapple to secure and transport a full MTC into the loading area for placement into a container.

MTC Fill Station

The MTC fill station provides for MTC lifting and filling. The MTC is positioned at the fill station by the conveyor system. The MTC is hydraulically lifted and sealed to the melter pour glass discharge orifice.

MTC Cooling Stations

The cooling stations are to cool the MTCs before placement into the cooling room. The two cooling stations consist of a split cooling jacket that contacts the four sides of the MTC. Actuators on either side of the MTC engage/disengage the cooling jackets. The first cooling station is located at the filling station and provides structural support to the filling MTC. The second cooling station is located adjacent to the MCR air lock door and provides additional cooling to the MTC before it is moved into the MCR. Cooling water is supplied by the cooling tower (53-HE-001).

Lid Installation Station

The lid installation station consists of custom-designed equipment for grappling, lifting, and installing the shipping container lid. The lid installation station has a grapple for capturing and lifting the lid. The grapple uses rigid mechanical linkages for accurate and efficient operations. The operator views the lidding operation either by CCTV or through shielded glass viewing windows.

Lid Fastening Station

The lid fastening function consists of a remote wrench mounted on a frame that aligns with the bolt pattern of the shipping container. The operator views the fastening operation either by CCTV or through the shielded glass viewing windows. The wrench is actuated up and down and is lowered to engage the bolt heads and tighten or loosen them as required.

G.4.4.4 System Interfaces

The Product Handling System interfaces with the following SSC:

- Electrical power for motors, instrumentation and monitors.
- The joule-heated melter that couples with the hydraulically lifted MTC during glass filling.

- Cooling water that is provided to the cooling jackets during glass filling and secondary cooling of a MTC.
- HVAC that is provided for heat removal from the cooling and filling room during MCT glass filling and convective cooling of the MTCs in the MCR.
- Shielded and unshielded airlock doors and window systems that are employed to protect workers and segregate work stations.
- Thermal shielding systems that are employed to preclude degradation of structural systems and equipment adjacent to cooling MTCs.
- The CCTV system that is used to ensure positive control of MTC and/or shipping container operations.
- A forklift that transports and places empty MTCs and shipping containers onto the load-in conveyors.
- The concrete shipping containers that are introduced to the rework process using the load-in conveyor for the MTC shipping container.
- The treatment facility transfer conveyor, the shipping container, and the staging facility crane that work together as a system.

G.4.5 Gaseous Emission Control (Systems 18 and 20)

The Gaseous Emission Control System is responsible for collecting all off-gas and vent streams and properly treating them.

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000375

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. (PROD Index No. 4-406.8)

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)

000377

D. Assumption: Off-gas quenching and particulate removal in the WESP are performed as separate process steps from acid gas scrubbing.

Basis: Particulates should be recycled to the melter and acid gas solids (sulfates) should not be recycled to the melter, thus the separate operations.

E. **Assumption:** The quench tower water and the scrubber liquor is cooled by indirect heat exchange, with cooling water from a new cooling tower installed specifically for this project. The cooling water temperature is 85 °F.

Basis: The FEMP does not have cooling water available for melter cooling requirements. The water temperature is a function of the maximum 78 °F wet-bulb temperature at the FEMP.

G.4.5.3 Key Equipment Descriptions

The quench tower is a direct-contact gas cooler-condenser. It is approximately 5 ½ ft long by 2 ½ ft wide by 10 ft high. It contains multiple spray nozzles to provide gas-liquid contact for most of its height. It recirculates approximately 280 gpm of water through the spray nozzles. The recycled water is cooled by approximately 430 gpm of cooling tower water in the quench heat exchanger. No pH adjustment is performed in the quench tower so it operates under acidic conditions (pH ~ 2.5), which prevents the absorption of acid gases.

The scrubber is a packed tower unit approximately 30 ft in diameter by 35 ft in height. It recirculates approximately 50 gpm of scrubber liquor that is controlled at a pH of 8.0-9.0 to effect the absorption of SO_X. The recirculating liquor is cooled in the scrubber heat exchanger with approximately 50 gpm of cooling tower water.

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The WESP uses high voltage electric fields to efficiently collect the particulate entering from the scrubber.

The package for the destruction of NO_x in the off-gas can handle 500 scfm. It consists of four NO_x reactors, two effluent coolers, one effluent chiller, and one off-gas knockout drum.

The coolant consists of 30 gpm of chilled glycol solution at an inlet and outlet temperature of 35° and 55° F, respectively.

G.4.5.4 System Interfaces

The Gaseous Emission Control System interfaces with the following SSC:

- Electrical power for motors, instrumentation, and monitors.
- Compressed air for the pneumatically operated valves and WESP.
- Off-gas that enters via a pipe from the Joule-heated Melter System.
- Caustic solution that arrives by truck and is transferred to the caustic tank.
- Recycle solids that are sent back to the slurry receipt tank for reprocessing.
- Off-gas that is exhausted to the RCS.
- Cooling tower water that is used for cooling the quench and scrubber recirculation loops.
- Potable water that is used as flush water in the WESP.
- Wastewater from the scrubber and off-gas condenser that is transferred to the Wastewater Treatment System.

G.4.5.5 Emergency Off-gas System

The Emergency Off-gas System is auxiliary to the Normal Off-gas System and consists of a knock-out tank (with an integral high-temperature filter) to remove gross solids or liquids, a dilution air line to cool the off-gas, a high-temperature HEPA filter, and a fan to a dedicated stack. The Emergency Off-gas System activates when the Normal Off-gas System fails. In the event that the Emergency Off-gas System is required, feed to the melter is immediately suspended. Portions of the Emergency Off-gas System may become slightly contaminated.

The temperature of the exiting gases is monitored. Pressure drops across the in-line filters are monitored.

G.4.6 Secondary Liquid Waste Treatment

All vessels, piping, etc., that contain either hazardous or liquid radioactive material require secondary confinement. Generally, this confinement consists of a diked pad with a sump and leak detection. All vessels and tanks containing untreated Silos 1 and 2 material are vented to the RCS.

The quench tower, scrubber, WESP, and RCS condenser contain hazardous or contaminated liquids and are installed on diked pads. Any liquid collected from these pads is contained until it is characterized to determine its disposition. Purge streams from the quench tower and WESP are routed through the precipitator tank to the slurry receipt tank for reprocessing of the solids therein. The scrubber purge stream contains dissolved sulfate solids and cannot be recycled to the process.

Recycle

The purge streams from the quench tower and WESP are recycled to the slurry receipt tank. These streams are not directed to the FEMP AWWT.

The overflow from the clarifier, which contains fine particles, is returned to the TTA and is reprocessed.

Discharge to the FEMP AWWT

The purge streams from the scrubber and RCS condenser (approximately 500 gallons per day) are staged, characterized, pretreated if necessary, and sent to the FEMP AWWT for treatment and disposal. (It is anticipated that this stream will meet the acceptance criteria for the AWWT; however, if it does not, a hold tank and filter may be required for pretreatment.)

G.4.7 Secondary Solid Waste Treatment

Secondary solid waste typically consists of the following:

- PPE;
- HEPA and pre filters;
- Wastewater treatment bag filters;
- Debris;
- Empty rework containers;
- D&D waste (e.g., refractory material);
- Molten sulfate salts (not expected); and
- Metallic lead.

Solid waste is collected and stored in appropriate containers, and characterized and disposed of per site procedures.

G.4.8 Shipping Container Operations (System 25)

The filled shipping containers are stored in the interim staging facility before off-site shipment to the NTS. The lifting and placement of shipping containers are performed remotely; however, intermittent contact, by the work force, with the shipping containers is necessary to secure and prepare the shipment before it departs from the FEMP.

G.4.8.1 System Description

Note: The external surface of a shipping container is anticipated to be essentially free of loose surface radioactivity. However, radiological surveys are performed and documented before shipment in accordance with FDF procedures, DOE orders, and DOT regulations.

A filled shipping container is grappled in the interim staging facility by a remotely operated bridge crane, lifted over a shield wall, and placed onto an open transport (i.e., flatbed truck) in the loading/shipping operations area. Here, the filled shipping containers are secured and

prepared for off-site shipment. Documentation is provided to the shipper who transports them to an approved disposal site.

Note: The generation and buildup of radon gas is not anticipated to be a concern in the interim staging facility since the filled shipping containers are sealed before staging; therefore, the facility does not require special ventilation.

G.4.8.2 Assumptions

A. **Assumption:** Each shipment includes two containers.
Basis: Standard FDF shipping practice for a two-axle truck (limited to maximum of 42,000 lb).

B. **Assumption:** 10 shipments are made per day, 4 days per week.
Basis: Limits established to attain public acceptance.

G.4.8.3 Key Equipment Descriptions

Staging Facility Remote Bridge Crane

The crane is a remotely operated bridge crane with a rated capacity of 15 tons, and a span of 82 ft, a travel of 158 ft, and a lift height of 20 ft. The crane is equipped with a grappling device and CCTV system to ensure positive grappling, movement, and placement of the filled shipping containers.

G.4.8.4 System Interfaces

The Shipping Container Operations System interfaces with the following SSC:

- Electrical power for motors, instrumentation and CCTV support equipment.
- The staging facility crane and the shipping container.
- The treatment facility conveyor and the staging facility crane.
- The CCTV viewing system.
- The FEMP Waste Management shipping organization.

G.4.9 Product Rework (System 26)

In addition to the federal, state, and local shipping requirements, the vitrified product must meet the NTS WAC. Therefore, provisions must be made to re-process any rejected vitrified product. Rework of the rejected vitrified product requires removing it from the MTC, segregating the metal components, crushing the reject vitrified product, and reintroducing it into the melter.

The TCLP analysis and other testing are completed before loading a filled MTC into a shipping container. The rejected MTCs are taken directly from the MCR, after a minimum cooling time of 48 hours, to the rework room to be size reduced. After size reduction, the rejected vitrified product is reintroduced into the melter.

G.4.9.1 System Description

Note: Rework operations are carefully confined and performed remotely at the rework station. The MTC breaking, crushing, and conveyance components are remotely controlled by operators in the adjacent corridor.

The MCR bridge crane lifts the rejected MTC and places it onto the rework conveyor in the MCR. The rework conveyor passes through a remotely operated, shielded airlock into the rework room.

The rework bridge crane lifts the rejected MTC and places it into the rework box. A remote glass breaker with an impact hammer tool breaks up the vitrified product contained in the MTC. This method is anticipated to minimize the amount of vitrified product that will adhere to the metal surface of the MTC. The MTC is opened using the remote glass breaker with a hammer or shear attachment end effector. The remaining MTC metal is then removed with an electromagnet attached to the rework bridge crane and placed into a standard metal shipping container.

The remote glass breaker then continues to crush the vitrified product until it can be picked up by the vacuum system and collected in the vacuum bin. The vacuum hose is remotely maneuvered by the robotic arm mounted on the rework bridge crane until all the glass is extracted. When the vacuum bin is full, it will be emptied into the hammermill for further size reduction. After the vitrified product has been sufficiently size reduced, it is transferred to the frit bin located above the melter for direct addition into the melter. A standard metal shipping container is brought into the room and metal debris from the MTC is placed into the box. The lid is installed manually, and the box is surveyed and decontaminated if needed.

G.4.9.2 Assumptions

A. **Assumption**: The number of MTCs that are expected to fail the TCLP criteria and/or disposal facility's WAC is approximately 1% of the disposal containers (up to 36 full shipping containers).

B: **Assumption**: The size and configuration of the broken glass allows it to be effectively collected by the vacuum system.

G.4.9.3 Key Equipment Descriptions

Roller Conveyors

The roller conveyors are 7 ft wide, standard heavy duty, motorized, chain driven, two-directional, roller conveyors for conveyance of the standard metal shipping containers with a rated capacity of five tons. The rework conveyor, which connects with the cooling room, is a 3-ft wide by 20-ft long, gravity-feed type heavy duty, roller conveyor with a rated capacity of 2½ tons; it is capable of holding ten rejected MTCs.

Rework Hammermill

The rework hammermill is standard production equipment. It receives the vitrified product from the rework bin, further size reduces it, and then discharges it to the rework frit bin. The hammermill is connected to the PVV system for the confinement of airborne radioactivity.

Rework Vacuum

The rework vacuum is a production model with a HEPA filtered discharge. The system includes a cyclone bin to collect captured debris, a 6-inch diameter vacuum hose, and a rated capacity of 30 tons/hr.

Vacuum Bin

The vacuum bin is attached to the rework vacuum. The bin has a volume of 15 cubic feet (ft^3).

Frit Bin

The frit bin is a holdup bin for the recovered and crushed vitrified product. The bin is 36 ft^3 and includes load cells, a vibrator, and rotary plug and gate valves. The air is filtered and returned to the vacuum unit.

Remote Glass Breaker

The remote glass breaker is a production model. It is mounted on crawler-type tracks with a maneuverable boom with a maximum reach of 10 ft and is electrically powered. It has changeable end effectors to accomplish drilling, crushing, and impacting tasks, and has a rated capacity of 400 ft-lb per impact.

Rework Bridge Crane

The rework bridge crane is a remotely operated bridge crane with a rated capacity of five tons and a span of 24 ft. The crane is equipped with a robotic arm and a 2-ton hoist for miscellaneous lifting operations, including recovering steel scrap using the electromagnet. The robotic arm is used to handle the vacuum hose, perform clean up of the rework room, and provide versatility for performing many tasks, as the rework operation is not completely defined.

G.4.9.4 System Interfaces

The Rework System interfaces with the following SSC:

- Product handling conveyors for conveyance of the standard metal shipping containers.
- Electrical power for motors, instrumentation, and the CCTV Monitoring System.
- A facility HVAC System that provides the required heating and ventilation of the rework station.
- The PVV System that collects the airborne particulate generated by the hammermill.
- The frit bin that reintroduces the size-reduced vitrified product into the joule-heated melter (i.e., Process System).

G.4.10 Facility Design

Facility drawings are provided in **Attachment G.4.II** at the end of **Section G.4.**

G.4.10.1 Bulk Additive Building

The Bulk Additive Building provides for receiving, storage, and transfer of bulk glass formers to the Feed Preparation System. The building structure is a commercial grade sheet metal building. The height of the building is based upon the storage bin requirements to support production. Stairs and platforms provide access to the storage bins and filter assemblies. Within the building, limited space is provided for maintenance requirements. The building has a large double door to allow for access.

An unloading pad is provided next to the facility for bulk chemical truck deliveries and to contain accidental spills. Large quantities of additives are received by truck and are pneumatically transferred into the appropriate storage bin.

The Bulk Additive Building and the surrounding area is a non-radiological area. Access is not controlled.

G.4.10.2 Feed Preparation System

The Feed Preparation System receives the slurried Silos 1 and 2 material from the TTA. The area contains the process tanks, pumps, and equipment to perform the receipt, settling, blending, and pumping required to support the process.

All equipment is in a radiologically controlled area due to the Silos 1 and 2 material's high inventory level of radium and radium daughter products. The area around the tanks is assumed to be a RAZ 5, high radiation area from preliminary dose calculations. The work area requires shielding, less time spent within the area and, where possible, lower sources (volume) to ensure lower dose rates for operations and maintenance workers over the plant life. The tanks containing the material are segregated and shielded to maintain ALARA principles of minimizing worker dose rates. They are surrounded by 2-ft shield walls due to the radiation field presented by the volume of Silos 1 and 2 material. The shield walls are modular in construction. The shield walls and concrete floor also serve as secondary containment in case of a spill or leakage from the tanks. The primary containment consists of the tanks and vessels themselves.

Although surrounded by concrete walls, the Feed Preparation System still requires access for general maintenance of the mechanical equipment. Access to each tank at grade is through a controlled egress. A sump is located in the area to collect spills or leakage. The top of each tank is accessible by ladder and platform. The platform on top of the tanks allows for maintenance to be performed on the agitators, control valves, and piping components. The pumps for the tanks are located outside of the shield wall due to general service and maintenance requirements. The pumps are located behind half or partial height walls to control access, minimize dose rates, and contain leaks and spills.

The Feed Preparation System is covered by a roof. The roof allows for operations and maintenance tasks to take place during local seasonal weather extremes. Portions of the roof can be removed to facilitate crane access to equipment.

G.4.10.3 Melter Room

The melter feed pumps, recycle bin, melter, quench, and scrubber tower are located in the Melter Room. The melter feed tanks and recirculating pumps are located outside with the Feed Preparation System. The walls and roof of the Melter Room consist of typical 'framed' architectural construction; they are shielded, as necessary, and covered by a removable coating to control contamination. The walls are fire-rated for two hours. The melter and melter feed pumps are accessed by a series of stairs and platforms.

Below the melter, an emergency dump container is located to catch leaking molten glass in the event of melter containment failure. It also provides a safe method to empty the glass from the melter in case of an emergency.

Space is provided within the room for equipment supporting the melter operation. A bridge crane services the equipment within the room and allows for disassembly of large components. The crane is serviced from a platform within the Melter Room. Supporting utilities (i.e., electrical, control system, melter cooling water, plant air) are brought into the Melter Room to support operations.

One wall of the Melter Room is constructed to allow for large equipment removal. This allows for melter installation and replacement if necessary (although not anticipated).

The Melter Room benefits from the removal of radon by the Normal Off-gas System and is considered to be a RAZ 3, controlled area. Shielding is not required because the melter refractory provides sufficient shielding from the melter contents. Maintenance and operations tasks can be performed in the Melter Room up to a maximum of three hours a week per worker.

G.4.10.4 MTC Load-In Area

The MTC load-in area provides access to the facility to allow MTCs to enter the facility. Empty containers are carried by forklifts into the facility through this area. A roll-up door allows a forklift to enter the facility. Within the area, space is provide for staging containers to be used during the next two shifts. An airlock adjacent to the areas furnishes access to the Melter Room.

The MTC load-in area is enclosed in a prefabricated structure. The structure has an internal, engineered steel framework. A PVC coated polyester fabric is stretched over the structural framework. HVAC for the area is provided by the facility system.

The MTC load-in area is a RAZ 1, controlled area. Radiological guidelines for a RAZ 1 area allow for 40 hr/week occupancy.

G.4.10.5 Fill Station

The MTCs are remotely filled with glass, weighed, partially cooled, and sealed in the fill station. The fill station is located below the melter glass discharge orifice; it contains the equipment used to fill the MTC.

The Process Sampling System, which provides for process control, accountability, diagnosis, and certifying compliance with waste acceptance product specifications, produces samples that must be archived. The sample system allows for capture of glass samples. The samples are removed from the fill station through the adjacent airlock. The samples for TCLP and other analysis are transported to the Analytical Laboratory in a shielded sample carrier. The archive samples are removed to the access point for the Glass Sample Archive System in the MCR.

The Fill Station Room is normally occupied for only regulated maintenance tasks. The room is considered to be a RAZ 3, controlled area. It is potentially contaminated by glass from the filling and sampling operation. Access is allowed for a maximum of three hours a week per worker.

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G.4.10.6 Off-Gas

The Normal Off-gas System area contains the process equipment to remove particulate and condition the gas stream before it's released to the RCS. If the Normal Off-gas System fails to function, the Emergency Off-gas System is activated.

The primary components of the Normal Off-gas System, the quench tower and scrubber, are located in the Melter Room. The remaining portion of the system and the Emergency Off-gas System are located outside of the building next to the Feed Receipt System and are serviced by a small pipe rack. The equipment for the system is located on concrete pads and the area is defined by a curb around the perimeter of the area. The floor is sloped to a sump. The concrete is sealed to protect against potentially radioactive liquids penetrating the surfaces. The area has a roof to protect operators and maintenance crews from seasonal inclement weather.

The Emergency Off-gas System is located in the same area as the Normal Off-gas System. It has an emergency exhaust stack that is 80 ft high and is accessed by ladder and platform. The stack is isokinetically monitored. The air, before being exhausted, is analyzed for air quality and the results are recorded.

Access into the area is controlled because of the possibility of contamination from equipment and component leaks and to protect against the spread of contamination. There is a chain barrier to stop casual entrance into the unit. Because there is a minimal dose rate from the equipment but a potential for contamination to be present, the area is considered to be a RAZ 1 area. It allows personnel to spend up to forty hours per week within the area for operation and maintenance tasks.

G.4.10.7 Monolith Cooling Room

The MCR provides space for final cooling of the MTC. The room allows the glass to cool to an acceptable temperature before over-packing.

Above and offset to the MCR is a partially shielded area where the bridge crane can be moved for maintenance. The crane maintenance area can be accessed from a second floor corridor. The maintenance area is separated from the corridor by an airlock.

MTCs that have cooled are removed from the cooling rack by the overhead bridge crane and placed onto a roller conveyor. The conveyor moves the MTC into the Glass Packaging Room.

The Glass Sample Archive System is located in the MCR and provides for access and storage of archived samples until they are no longer required. An access point in an adjacent airlock allows for individual samples to be placed into, or retrieved from, the system.

The MCR was designed to limit worker dose rates while ensuring control over the potential spread of contaminants. The room is shielded by concrete walls because each container holds a concentrated volume of radioactive constituents entrapped in the glass product. The area is considered to be a RAZ 5, high radiation area. Normal access is not allowed. The equipment in this area should not require manned access for maintenance, although a number of access doors are provided from adjacent airlocks. Because of the potential for contamination, the concrete floor is sealed and the walls have a strippable coating to aid in decontaminating the room at the end of the facility's mission.

G.4.10.8 Shipping Container Area

The shipping container area furnishes the space and equipment to load the MTCs into the shipping container, seal the container, and survey/decon the outside of the shipping container.

G.4.10.9 Rework Room

The Rework Room is equipped to handle MTCs and remove the failed glass product and reduce the size of the MTCs for overpacking.

The Rework Room is normally an unoccupied area because of the exposure rate from the rework MTC and the likelihood for contamination being present within the room. Minimal servicing is required for equipment within the room. Large pieces like the glass breaker can be remotely moved into an adjacent airlock or neighboring room for maintenance or repair. The Rework Room is considered to be a RAZ 4.

G.4.10.10 Load-In Areas

The load-in areas provide access to the facility for the entry of shipping containers. Empty shipping containers and disposal containers are carried by forklifts into the facility through these areas. A roll-up door allows normal forklifts to enter the facility. Within the area, space is provide for staging shipping containers that will be used during the next two shifts. An airlock adjacent to the areas furnishes access to the glass packaging area. Radiological technician and maintenance personnel enter through this airlock to perform their tasks. Space outside of the airlock, in the load-in areas, is provided for doffing PPE equipment.

The load-in areas are enclosed in prefabricated structures. The structures have an internal, engineered steel framework. A PVC coated polyester fabric is stretched over the structural framework. HVAC for the area is provided by the Facility System.

The load-in areas are RAZ 1, controlled areas. Radiological guidelines for RAZ 1 areas allow for 40 hr/week occupancy.

G.4.10.11 Facility Entrance

The facility entrance controls all entering/exiting of the facility.

The facility entrance is the main entrance and exit point for personnel working within the facility. Personnel log in when entering the facility. To exit the facility, personnel pass through radiation detection monitors and log out. All other shipments arrive or depart through the load-in/out area and under the supervision of a radiological technician. A desk is provided in the facility entrance for a radiological technician to supervise personnel movement.

The facility entrance is not expected to encounter a radiation source but may see contamination carried by personnel attempting to exit. Because the treatment facility contains radioactive substances and has the potential to be contaminated, entering or exiting the facility must be supervised and controlled. For these reasons, the facility entrance is considered to be a RAZ 1. Personnel may occupy the area for up to 40 hr/week.

G.4.11 HVAC (Systems 73, 75, 76, and 77)

The areas in the treatment facility are designated as Zone 1, Zone 2, and Zone 3 and have three HVAC Systems: one system exclusively for Zone 3, one for the cooling room, and one combined for the remainder of Zone 2 and all of Zone 1. Following are the designated areas with equipment details for each zone.

G.4.11.1 Zone 3

A. The designated areas for Zone 3 are as follows:

- MTC off loading;
- Shipping container area;
- Fill room;
- Melter room; and
- Rework room.

B. The HVAC details for Zone 3 are as follows:

- Air handler with supply fan, filters and electric heat;
- Supply fan -12,000 cubic feet per minute (cfm);
- Electric Heat - 300 kW;
- Exhaust fan - 12,000 cfm; and
- Exhaust filter that includes a pre-filter with two stage HEPA filters and has 50% capacity backup.

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C. The air handling unit and exhaust fans are designed for 100% capacity and 100% backup. Air handling units and exhaust fans are connected to emergency power because of the potential for hazards and equipment damage resulting from elevated temperatures if the systems are lost due to power failure. There are three exhaust filters with 50% capacity (two are required for normal operation). The electric heaters are not connected to emergency power.

D. The radon in the Silos 1 and 2 material is expected to be released to the Normal Off-gas System from the melter and treated through the RCS. The following are assumed for design basis: (1) all of the free radon is driven off in the melter to the Normal Off-gas System and (2) the glass will sufficiently contain the radon gas generated thereafter, such that treatment of the ventilation air around the glass through the RCS is not necessary. However, HEPA filtration is supplied on processing equipment vent systems downstream of the melter system.

G.4.11.2 Zone 2

A. The designated area for Zone 2 is the MCR. The HVAC details for Zone 2 are as follows:

- Air handler with supply fan, filters, electric heat and air conditioning cooling unit;
- 35 ton air conditioning cooling unit;
- Supply fan -10,000 cfm;
- Electric heat - 241kW;
- Exhaust fan - 10;000 cfm; and
- Exhaust filter that includes a pre-filter with two stage HEPA filters and has 50% capacity backup.
-

B. The air handling unit and exhaust fans are designed for 100% capacity and 100% backup. Air handling units and exhaust fans are connected to emergency power because of the potential for hazards and equipment damage resulting from elevated temperatures if the systems are lost due to power failure. There are three exhaust filters with 50% capacity (two are required for normal operation).

C. The electric heaters and air conditioning units are not connected to emergency power.

G.4.11.3 Zones 1 and 2

A. The designated areas for Zone 1 are as follows:

- HVAC room, and
- Access control room.

B. The designated area (remainder)of Zone 2 consists of the corridor.

C. The HVAC details for Zones 1 and 2 are as follows:

- Air handler with supply fan, filters and electric heat;
- Supply fan — 20,000 cfm;
- Electric Heat — Separate electric heat are provided for each room.
- HVAC room — 280 kW
- Access control room — 20 kW
- Corridor — 225 kW
- Exhaust fan — 20,000 cfm; and
- Exhaust filter that includes a pre-filter with two stage HEPA filters and has 50% capacity backup.

The air handling units are designed for 100% capacity without any backup. Air handling units and exhaust fans are connected to emergency power because of the potential for hazards and equipment damage resulting from elevated temperatures if the systems are lost due to power failure.

There are two exhaust fans and two exhaust filters with 50% capacity (two are required for normal operation).

The electric heaters are not connected to emergency power.

G.4.11.4 HVAC Stack

Two HVAC stacks are provided: one for Zone 3 and one for both Zone 1 and Zone 2. The stacks are serviced by ladders and platforms. The air, before being exhausted, is analyzed for air quality and the results are recorded.

G.4.12 Support (Systems 53 and 94)

G.4.12.1 Analytical Support Laboratory/Services

The analytical laboratory has the instruments and facilities required for testing: the feed, additives, the process, off-gas and wastestreams at different stages of the process, the products, and chemicals used.

G.4.12.2 Special Support Systems - Cooling Water

The cooling tower cools 1,000 gpm of water from 115° to 85° F. This is a standard recirculating Cooling Tower System using evaporative cooling and servicing all of the plant's cooling water needs. Standard cooling tower controls are used. The cooling tower fan is controlled by the cooling water temperature. Makeup water is controlled to maintain the level in the cooling tower basin. The blowdown rate is controlled by the dissolved solids that buildup in the cooling water. Standard, commercially available water treatment chemicals are used. The cooling tower blow down is sent directly to the AWWT.

G.4.12.2.1 System Description

Cooling water is provided by a standard recirculating Cooling Tower System using evaporative cooling and servicing all of the plant's cooling water needs. Standard cooling tower controls are used. The cooling tower fan is controlled by the cooling water temperature. Makeup water is controlled to maintain the level in the cooling tower basin. The blowdown rate is controlled to limit the dissolved solids buildup in the cooling water.

G.4.12.2.2 Assumptions

A. **Assumption:** The maximum wet bulb temperature at the FEMP is 78°F.

Basis: Indicated in the responses to the RFP and used for the design of the VITPP cooling tower.

B. **Assumption:** The cooling water inlet is 110°F and the outlet is 85°F.

Basis: Standard engineering practice.

C. **Assumption:** The Cooling Tower water is at a higher pressure than any other area where contaminated liquid is being cooled.

Basis: Standard practice to prevent contamination from entering the Cooling Tower System.

G.4.12.2.3 System Interfaces

The Cooling Water System interfaces with the following systems:

- Cooling water enters the Cooling Tower System in pipes from the various users.
- Cooling water leaves the Cooling Tower System in pipes to the various users.
- Potable water enters the Cooling Tower System (as makeup water) in a pipe from the potable water header.
- Blowdown water leaves the Cooling Tower System in a pipe to wastewater treatment.
- Compressed air is required for pneumatically operated valves.
- Electrical power is required for various instruments and motors.

G.4.13 Utilities (Systems 30, 31, 32, 33, 40, 51, 52, 60, 90, and 94)

Compressed Air

Compressed air from 40-CM-001 is used for dense phase pneumatic transfers.

Instrument Air

Instrument air is provided for all instrumentation and valve actuation.

Potable Water

Potable water is an existing site utility and allowances for a potable water system have been incorporated into the cost estimate.

Fire Water

Fire water is an existing site utility and allowances for a fire water system have been incorporated into the cost estimate.

Sanitary System

The treatment facility design does not include sanitation lines. Existing site sewage facilities will be used by plant personnel.

Electrical

A. Normal Power System

The facility is supplied with electrical power at 13.2kV from the site distribution system. An outdoor unit substation with two oil-filled transformers, rated 2500/3125 kilovoltampere (kVa) each, transforms the voltage to 480 Volts, three--phase, three-wire, 60 Hertz for use by the facility. Metering is provided to monitor the power consumption at 13.2 kV. One transformer is dedicated exclusively to the joule-heated melter and auxiliaries (17-PE-001), and the other is dedicated to all other facility loads. There is no secondary tie breaker. The total connected load is 6562 kVa, and the normal demand is 5120 kVa. Usage is 25,120,000 kiloWatt hours (kWh) per year.

A 480 Volt switchgear in the unit substation distributes power to six MCCs located in the Mechanical/Electrical Building, and to the 2500 kW joule-heated melter.

B. Standby Power System

The facility includes an outdoor 1500 kW standby generator. The generator provides power at 480 Volts to MCCs 31-MC-003 and 31-MC-005 through automatic transfer switches, and to the 2500 kW joule-heated melter through a manual transfer switch. All other MCCs remain de-energized. The automatic transfer switches start the generator on loss of normal power and then switch the MCC to the generator when voltage is available. The joule-heated melter load must be manually reduced to 500 kW before the generator is manually started and the manual transfer switch is thrown. An integral fuel tank is sized for eight hours of operation. The melter will not be de-inventoried during a power outage and no out-of-spec waste is anticipated due to a power loss.

The system includes an exercise panel that starts the generator once a week and runs it for 30 minutes. It sends an alarm to the control room if the generator fails to start.

Critical facility loads are connected to MCC 003 or MCC 005. These are loads that are:

- required to prevent contamination to the treatment facility;
- required to prevent contamination to the outside environment;
- required for the safety of FEMP personnel; and
- required to prevent damage to equipment.

C. Uninterruptable Power System

The facility has a battery backed UPS rated 25 kVa for instrumentation and control system loads. This system filters power system anomalies that could cause false information to be sent to the Distributed Control System (DCS) or cause damage to sensitive electronic equipment.

The UPS receives power at 480 Volts, three-phase from MCC 003 and converts it to 208Y/120 Volt three-phase four-wire 60 Hertz power. The UPS includes a battery charger. The batteries provide power continuation for thirty minutes without any normal power input.

- Motor Control Centers

  The MCCs are standard, commercially available Underwriters' Laboratory (UL) listed equipment rated 800 Amps at 480 Volts, three-phase, three-wire. They are indoor units, 90 inches tall, 20 inches deep, and are composed of a series of vertical sections each 20 inches wide. They contain motor starters, feeder circuit breakers, and variable speed drive units. Each motor starter has a power circuit protector pad-lockable in the off position, indicator lights to indicate motor status, start and stop pushbuttons, and a hand/off/auto (HOA) selector switch. The selector switch selects between DCS control and control from the MCC. Extra contacts are provided on the selector switch, motor contactor, and circuit protector to send status information to the DCS.

  The starters, feeder circuit breakers, and variable speed drive units are capable of draw-out removal for maintenance and replacement.

- Control Systems

  The facility operation is monitored and controlled by a DCS that consists of many remote input/output (I/O) racks inside the plant (i.e., an I/O rack next to each cluster of equipment), with all the I/O racks connected to the control room. The control system is capable, at a minimum, of the following functions:

  - Collecting pertinent process parameters (e.g., temperature, pressure, density, and flow).
  - Displaying information in an organized and logical manner on video monitors (the display program includes graphic features for displaying process parameters).

- Automatically or manually operating selected control loops and digital output signals for control of equipment (e.g., start, stop, speed up, and slow down) from the operator console.
- Initiating audible and visual alarms when designated process parameters are outside preset limits or status.
- Providing status indication of motor driven equipment HOA switches, motor contactors, and power disconnecting devices.
- Reporting and displaying historical data.
- Operating pneumatically operated pumps and on/off (fully open / fully closed) valves by solenoid valves and controlling them from the DCS with "run" and "stop" outputs for pumps and "open" and "close" outputs for the valves and interlocking functions. (Each of these pumps has an attached manual operator.)
- Providing status to the DCS with pneumatically operated ON/OFF valves that have limit switches.
- Indicating the HOA switch position of the motorized valves in the MCC. The DCS also indicates the direction the valve is being driven since there is no positive feedback from the valve position switches until it reaches the fully opened or closed position.
- Controlling the emergency shutdown and fire alarm events as described by the control philosophy.
- Using butterfly valves on vessel vent connections to create and maintain negative air pressure in vessels that contain contaminated material; this excludes off-gas treatment systems.

G.4.14 Special Health and Safety Considerations

During the "Detailed Design" phase of the project, a safety review of the process is conducted. This review considers all credible "what if" scenarios with input from people with different specialties such as Process, Mechanical, Electrical, Operations, Maintenance, etc. The recommendations of this review are implemented to ensure safety of the process.

An "Ergonomic Review" of the design ensures that the operation does not cause any undue strain to the operators or maintenance people. Input from people with different specialties maximizes the value of this effort.

A "Constructability Review" is conducted before starting construction to ensure that it is safe and practical to install the equipment and complete all construction as per design.

G.4.15 Special Environmental Considerations

The design basis for this alternative ensures protection of human health and the environment during the remediation of the Silos 1 and 2 material by incorporating the pertinent environmental regulatory requirements in the system design and using the principles of environmental ALARA. The design allows all contaminated gas, liquid, and solid wastestreams generated during remediation to be collected and treated before being released to ensure adequate protection of human health and the environment.

Air emissions from the process and off-gas from the melter are controlled by containment and treatment. The off-gas system uses a scrubber and NO_x destructor to control acid gases. A WESP and HEPA units control particulate. Volatile metals (e.g., selenium) released into the off-gas are removed in the quench, scrubber, or WESP liquid streams. The off-gas is vented to the RCS, which uses carbon beds for adsorption of radon. Radon in ventilation air from tanks and process equipment containing Silos 1 and 2 material is also controlled by ventilation to the RCS. All tanks and lines with radon source material are totally enclosed, and the gas flow control uses backup redundancy for critical equipment. The Emergency Off-gas System includes a knockout tank and dual filters for control of particulate.

Building ventilation is controlled through designation of zones on the basis of expected contamination; the air is either routed to the RCS for radon control, or treated locally for particulate control using HEPA filtration before discharge. Airlocks and dampers are used to control air flow and confine contamination. Discrete particulate sources such as dry feed or additive bins are controlled by filtration. Particulate dusting from poured or spilled glass is expected to be minimal. Particulate from reworked glass is confined by the rework room ventilation system, and treated using HEPA filtration. HEPA filters and prefilters are changed using a bag-in and bag-out approach to prevent airborne release of contaminants.

Liquid waste is also controlled by containment and treatment. During operations, excess liquids from the clarifier are recycled to the TTA for waste retrieval. Quench purge and WESP slurry is precipitated with caustic and recycled to the melter feed. Wastewater that cannot be recycled, such as the scrubber purge water and off-gas condensate, requires pretreatment (if necessary) before discharge to the site AWWT facility. Volatile metals such as lead and selenium, and radionuclides that are removed from the off-gas, are treated to acceptance levels before discharge to the AWWT facility. Any solids removed during pretreatment are also recycled in the treatment process to the extent practicable in order to minimize solid waste generation.

All tank systems containing Silos 1 and 2 material with free liquids are designed with secondary containment and leak detection. The melter is designed with a catch basin for containment of molten glass in case of a spill or leak. With the possible exception of the diesel tank for the emergency generator, all tank systems with secondary containment are located under roof, which greatly minimizes the amount of excess liquids requiring characterization and management.

Protection of surface waters is ensured by double containment of exterior piping that contains retrieved Silos 1 and 2 material, and by segregation of the treatment process in a roofed and enclosed building. Areas used for processing material is protected from precipitation and stormwater run on and runoff. Clean and contaminated runoff is not combined. Clean runoff, including building roof drains and runoff from areas of fixed contamination, is discharged either into the stormwater collection basin, or routed to adjacent drainage systems.

While some secondary waste is recycled (e.g., off-gas sludges from the WESP), other wastes are expected to be generated that cannot be recycled, which requires management as hazardous or mixed waste. For example, metallic lead, and salt (slag) compounds high in radium may be drained from the melter during operation; also, refractory materials high in chromium may be generated during D&D. Process holdup wastes, and wastewater treatment sludges or solids high in activity or metals such as selenium may also require additional treatment before disposal. Facilities to accommodate staging and characterization of wastes during operation, and later during D&D, are included in the design.

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8074

Section G.4
Attachments

1

Attachment G.4.I

Mass and Energy Balance for the

Vitrification — Joule-heated Technology

Attachment G.4.I
Mass Balance
Vitrification - Joule Heated

Stream #	1	1A	1B	2	3 or 3A	4	5	6	12	13	14	15
Component	TTA Retrieval	Slot Screen Filtrate	Milled Solids	Receipt Tank Underflow	Settling Tank Underflow	Settling Tank Overflow	Thickener Overflow Tank	Makeup Water	Receipt Tank Vent	Settling Tank Vent	Flush Water	Surge Tank Vent
Oxygen (lb/hr)									11	11		11
Nitrogen (lb/hr)									37	37		37
Methane (lb/hr)												
Carbon Dioxide (lb/hr)												
Water (lb/hr)	9859	9662	197	9859	2545	7314	7314	25000			25000	
K-65 Material (lb/hr)	1095	1095		1095	1090	5.45	5.45					
Additives												
Total (lb/hr)	10955	10757	197	10955	3635	7320	7320	25000	48	48	25000	48
Flow (scfm @ 70 °F)									10	10		10
Flow (gpm)	20.8			20.8	6.1	14.7	14.7	50			50	
Radon concentration (nCi/L)												
Radon flow (Ci/hr)												
Temperature (°F)	70			70	70	70	70	70				
Pressure (in. H2O)												
Notes	On Average		2% screened		Recycle to Clarifier (3A) when Slurry Surge Tank is full.			Intermittent, for flushing and dilution.			Intermittent, for flushing and dilution.	
Dwg. Number 94X-5500-F-SK-	3410	3410	3410	3410	3410	3410	3410	3410	3410	3410	3410	3410

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Attachment G.4.I
Mass Balance
Vitrification - Joule Heated

Stream #	8 or 9	10 or 11	16 or 17	18	19 or 20	21 or 22
Component	Surge Tank Transfer	Feed Tank Transfer	Feed Prep Tank Vent	Compressed Air	Additive to Dust Coll.	Additive Feed
Oxygen (lb/hr)			11	72	72	
Nitrogen (lb/hr)			37	237	237	
Methane (lb/hr)						
Carbon Dioxide (lb/hr)						
Water (lb/hr)	20360	20360				
K-65 Material (lb/hr)	8720	8720				
$CaCO_3$		1,120			3,361	3,361
Na_2CO_3		871			2,613	2,613
Li_2CO_3		1,745			5,234	5,234
Total (lb/hr)	29080	32816	48	309	11517	11208
Flow (scfm @ 70 °F)			10	67		
Flow (gpm)	48.8	54.0				15.6
Radon concentration (nCi/L)						
Radon flow (Ci/hr)						
Temperature (°F)	70	70		70	70	
Pressure (in. H2O)						
Notes	3 hr. per day	3 hr. per day	Intermittent			1 hr. per day
Dwg. Number 94X-5500-F-SK-	3410 3411	3410	3411	3416	3416	3411 3416

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Attachment G.4.I
Mass Balance
Vitrification - Joule Heated

Stream #	10 or 11	23	24	25	26	27 or 28	29	30	31	32 or 33
Component	Feed Prep Transfer	Melter Air Inleakage	Instrument Air	Metals Drain	Glass Product	Melter Feed Recirculation	Melter Feed	Salt Drain	Off-Gas Line	Melter Feed Tank Vents
Oxygen (lb/hr)		200	172						372	11
Nitrogen (lb/hr)		689	555						1,244	37
Methane (lb/hr)										
Carbon Dioxide (lb/hr)									152	
Sulfur Dioxide (lb/hr)									15	
NO_x (lb/hr)									5	
Water (lb/hr)	20,360					20,360	2,545		2,545	
K-65 Material (lb/hr)	8,720				1,023	8,720	1,090	27		
$CaCO_3$	1,120				77	1,120	140			
Na_2CO_3	871				63	871	109			
Li_2CO_3	1,745				86	1,745	218			
solids									16	
Total (lb/hr)	32,816	889	727	0	1,249	32,816	4,102	27	4,349	48
Flow (scfm @ 70 °F)		199	163						1,298	10
Flow (gpm)	54	-	-	-	1	54	7	0		
Radon concentration (nCi/L)										
Radon flow (Ci/hr)									0.200	
Temperature (°F)	70	70	70	2165	2165	70	70	2165	1750	70
Pressure (in. H2O)										
Line Size										
Notes	3 hr. per day			Intermittent	1)					
Dwg. Number 94X-5500-F-SK-	3411 3412	3412	3412	3412	3412	3412	3412	3412	3412 3413	3412

1) Carbonate additives remain in glass as the oxides from their respective decomposition reactions. The remaining additive mass goes up the stack as carbon dioxide.

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F-8074

Attachment G.4.I
Mass Balance
Vitrification - Joule Heated

Stream #	31	34	35	36	37	38	39	40	41	42	43	44
Component	Melter Off-Gas Line	Quench Underflow	Quench Off-Gas	Quench Spray	Quench Heat Exchanger CWS	Quench Heat Exchanger CWR	Quench Purge	Scrubber Underflow	Scrubber Exhaust	Scrubber Heat Exchanger CWS	Scrubber Heat Exchanger CWR	Scrubber Spray
Oxygen (lb/hr)	372		372						372			
Nitrogen (lb/hr)	1,244		1,244						1,244			
Methane (lb/hr)												
Carbon Dioxide (lb/hr)	152		152						152			
Sulfur Dioxide (lb/hr)	15		15						5			
NO_x (lb/hr)	5		5									
Water (lb/hr)	2,545	141272	273	139000	212000	212000	2272	24,268	105	24100	24100	24100
solids (lb/hr)	16		16						16			
Total (lb/hr)	4,349	141272	2,077	139000	212000	212000	2272	24268	1,894	24100	24100	24100
Flow (scfm @ 70 °F)	1,298		484						422			
Flow (gpm)		284		279	426	426	4.6	48.7		48	48	46.4
Radon concentration (nCi/L)			270						270			
Radon flow (Ci/hr)	0.20		0.20						0.20			
Temperature (°F)	1,750	140	140	95	85	115	95	110	110	85	100	95
Pressure (in. H2O)												
Notes												
Dwg. Number 94X-5500-F-SK-	3413	3413	3413	3413	3413	3413	3413	3413	3413	3413	3413	3413

Attachment G.4.I
Mass Balance
Vitrification - Joule Heated

Stream #	45	46	47	48	49	51	52
Component	Scrubber Purge	WESP Exhaust	WESP Compres'd Air	WESP Wash Water	WESP Underflow	Recycle to Slurry Reciept Tank	Purge to AWWT
Oxygen (lb/hr)		384	11.6				
Nitrogen (lb/hr)		1,282	38.4				
Methane (lb/hr)							
Carbon Dioxide (lb/hr)		152					
Sulfur Dioxide (lb/hr)		0					
NO_x (lb/hr)		5					
Water (lb/hr)	168	108		149	146	2418	168
solids (lb/hr)					16	16	
Total (lb/hr)	168	1,931	50	149	162	2434	168
Flow (scfm @ 70 °F)		434	11				
Flow (gpm)	0.3			0.3	0.3	5.0	0.3
Radon concentration (nCi/L)		270					
Radon flow (Ci/hr)		0.20					
Temperature (°F)	110	110	90	90	110	90	110
Pressure (in. H2O)							
Notes				Potable Water			
Dwg. Number 94X-5500-F-SK-	3413	3413 3414	3413	3413	3413	3410 3413	3413

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F-8074

Attachment G.4.I
Mass Balance
Vitrification - Joule Heated

Stream #	46	53	54	56	62	63	64	68	70	71
Component	WESP Exhaust	Process Vessel Vent Header	Air from WESP and PVV	Air from Condenser	Condensate from Condenser	Condensate from Air Dryer	Condensate to Waste Treatment	Coolant to Condenser	Coolant Return	Coolant from Chiller
Oxygen (lb/hr)	384	115	499	499						
Nitrogen (lb/hr)	1,282	370	1,652	1,652						
Methane (lb/hr)										
Carbon Dioxide (lb/hr)	152		152	152						
Water (lb/hr)	108		108	15	93	15	108	15000	15000	77724
K-65 Material (lb/hr)										
Additives										
Total (lb/hr)	1,926	485	2,411	2,318	93	15	108	15000	15000	77724
Flow (scfm @ 70 °F)	434	108	542	509						
Flow (gpm)					0.19	0.03	0.22	30	30.0	156.1
Radon concentration (nCi/L)	270		220	230						
Radon flow (Ci/hr)	0.20		0.20	0.20						
Temperature (°F)	110	90	108	45	45	85	45	40	50	38
Pressure (in. H2O)										
Notes				Maximum of 20ppm NOX						
Dwg. Number 94X-5500-F-SK-	3414 3413	3413	3414	3414	3414		3414	3414	3414	3414

000411

Attachment G.4.I
Mass Balance
Vitrification - Joule Heated

Stream #	37	38	42	43	85	86	87	88	89	90
Component	Quench Heat Exchanger CWS	Quench Heat Exchanger CWR	Scrubber Heat Exchanger CWS	Scrubber Heat Exchanger CWR	Cooling Tower Underflow	Cooling Tower Spray	Makeup Water	Cooling Tower Purge	Melter CWS	Melter CWR
Oxygen (lb/hr)										
Nitrogen (lb/hr)										
Methane (lb/hr)										
Carbon Dioxide (lb/hr)										
Water (lb/hr)	212000	212000	24100	24100	263,610	261,000	10,440	2,610	24,900	24,900
K-65 Material (lb/hr)										
Additives										
Total (lb/hr)	212000	212000	24100	24100	263,610	261,000	10440	2610	24,900	24,900
Flow (scfm @ 70 °F)										
Flow (gpm)	426	426	48	48	527	524	21	5.2	50	50
Radon concentration (nCi/L)										
Radon flow (Ci/hr)										
Temperature (°F)	115	85	85	100	85	113	85	85	85	115
Pressure (in. H2O)										
Notes										
Dwg. Number 94X-5500-F-SK-	3417	3417	3417	3417	3417	3417	3417	3417	3412 3417	3412

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F-8074

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Attachment G.4.II

Drawings for the

Vitrification — Joule-heated Technology

DRAWING LIST FOR VITRIFICATION — JOULE-HEATED

Drawing Number	Title	Rev.
Process Flow Diagrams 94X-5500-F-		
SK-3410	FEED PREPARATION SYSTEM	2
SK-3411	FEED PREPARATION SYSTEM	2
SK-3412	MELTER	2
SK-3413	NORMAL OFF-GAS TREATMENT	2
SK-3414	RADON CONTROL SYSTEM	2
SK-3416	ADDITIVE FEED SYSTEM	2
SK-3417	EMERGENCY OFF-GAS & COOLING TOWER	2
Mechanical Flow/ Handling Diagrams 94X-5500-F-		
SK-6016	MONOLITH REWORK	2
SK-6014	MONOLITH GLASS PRODUCTION	2
Layout Drawings 94X-5500-P-		
SK-1039	PLOT PLAN	2
SK-7050	ADDITIVE STORAGE BINS	2
SK-7408	PLAN @ EL. 0'-0" TO EL. 15'-0"	2
SK-7409	PLAN @ EL. 15'-0" AND ABOVE	2
SK-7410	SECTIONS AND DETAILS	2

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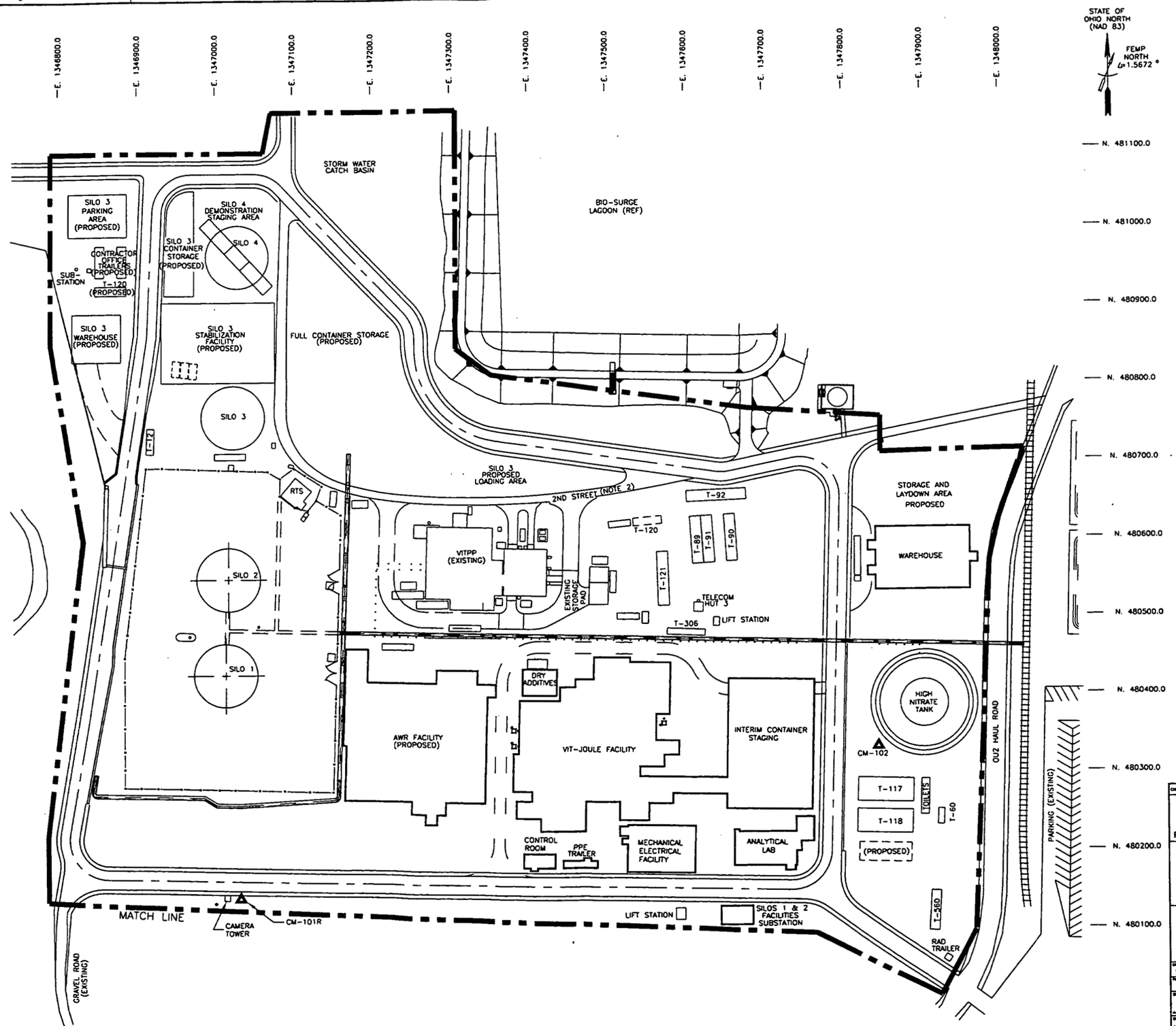

STATE OF OHIO NORTH (NAD 83)

FEMP NORTH $\angle$ 1.5672 °

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NOTES:

1. LOCATION OF FENCES, GATES AND CHECK POINTS TO BE DETERMINED.
2. THIS SECTION OF 2nd STREET TO BE USED BY PEDESTRIAN, LIGHT DUTY, OCCASIONAL DELIVERIES TO OU1, AND EMERGENCY TRAFFIC ONLY.
3. FACILITY LAYOUTS FOR SILO 3 AND AWR ARE SHOWN AS PRE-CONCEPTUAL ONLY.
4. CONSTRUCTION AND OPERATIONS PERSONNEL WILL USE EXISTING SITE PARKING LOT.
5. FDF SHALL COORDINATE LAND USE WITH THE WASTE PIT REMEDIAL ACTION PROJECT (WPRAP) HEALTH AND SAFETY REPRESENTATIVE, PRIOR TO FINALIZATION OF LAND USE. FAILURE TO DO SO COULD PRESENT AN UNREVIEWED SAFETY QUESTION, THUS INVALIDATING EITHER OF THE PROJECT'S (SILO 3 AND/OR WPRAP) SAFETY BASIS.
6. INFRASTRUCTURE ROAD IS TO BE DOUBLE LANE.

LEGEND OF SYMBOLS

▲ = MONUMENT

PRELIMINARY DRAWING

0 25 50 100 150 200 250

GRAPHIC SCALE 1" = 50'

CC0717

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FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

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FLUOR DANIEL FERNALD
SILOS PROJECT
CINCINNATI, OHIO

DRAWING TITLE
PLOT PLAN
VITRIFICATION – JOULE HEATED
REVISED FEASIBILITY STUDY FOR SILOS 1 & 2

DRAWN BY S. M. YANKEY	DATE 12/15/98	DESIGNED, CHECKED BY	DATE	CHECKED BY J. THOMPSON	DATE 3/18/99
SUBSYS/AREA/SYS NO. OU4		FLOOR		SCALE 1"=50'	CLASS
SUBMITTED FOR APPROVAL A-E DATE		APPROVAL RECOMMENDED OPERATING CONTRACTOR DATE			
DOE PROJECT NO. WBS2.1.3.G.P	OPER. CONTR. PROJ. NO. 40730	DRAWING NO. 94X-5500-G-SK-1039		SHEET NO. 1	REV. NO. 2

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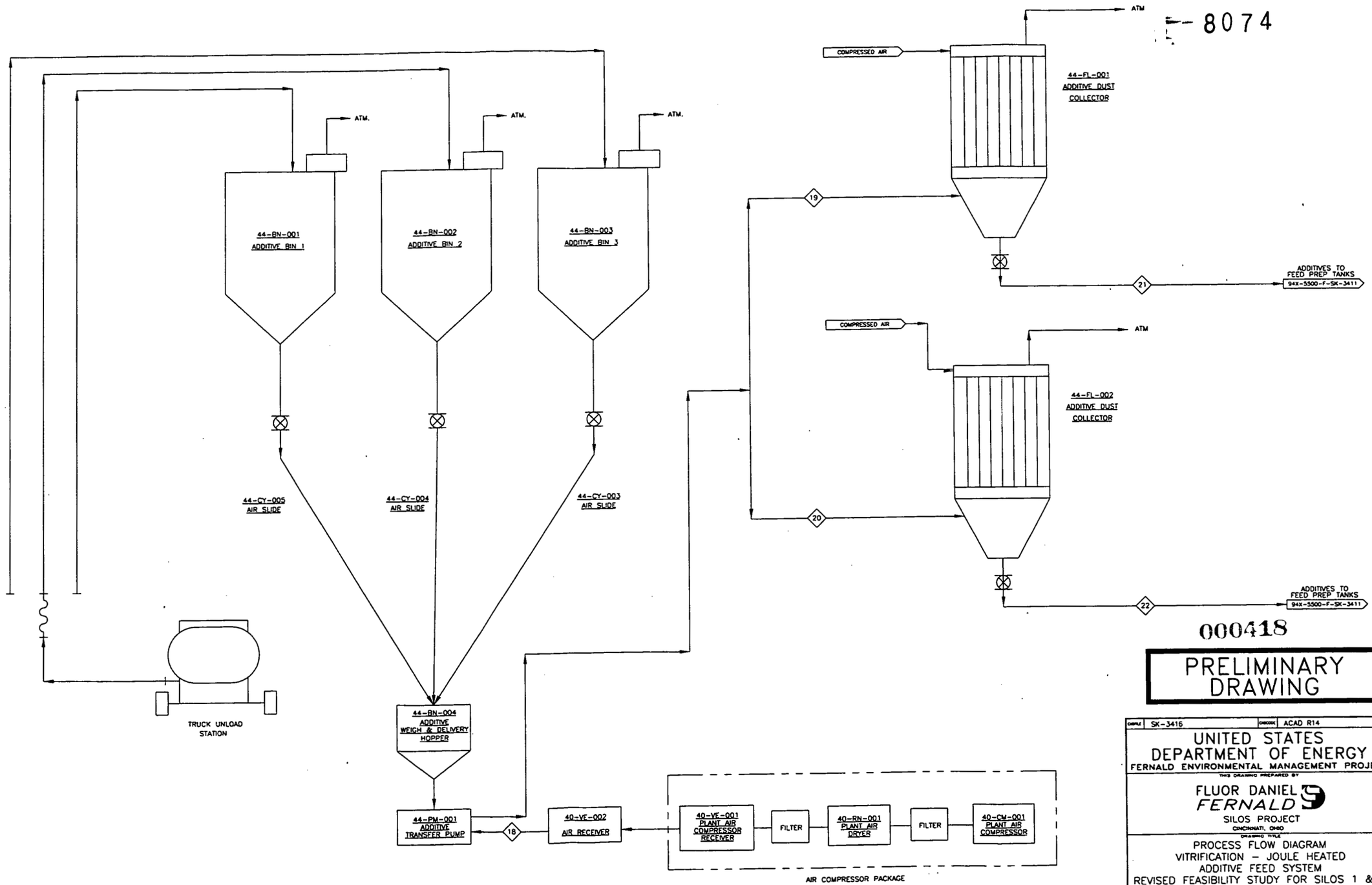

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CINCINNATI, OHIO

DRAWING TITLE

PROCESS FLOW DIAGRAM
VITRIFICATION – JOULE HEATED
ADDITIVE FEED SYSTEM
REVISED FEASIBILITY STUDY FOR SILOS 1 & 2

DRAWN BY S.M. YANKEY	DATE 09/2/98	DESIGNED, CHECKED BY	DATE	CHECKED BY B. BRUSH	DATE 8/16/99
PLANT/BLDG. NO. OU4		FLOOR		SCALE NONE	CLASS
SUBMITTED FOR APPROVAL A-E	DATE	APPROVAL RECOMMENDED APPROVING CONTRACTOR	DATE		
DOE PROJECT NO. 40730	SPEC. CONTL PROJ. NO. WBS2.1.3.G.P	DRAWING NO. 94X-5500-F-SK-3416		SHEET NO. 1	TOT. NO. 2

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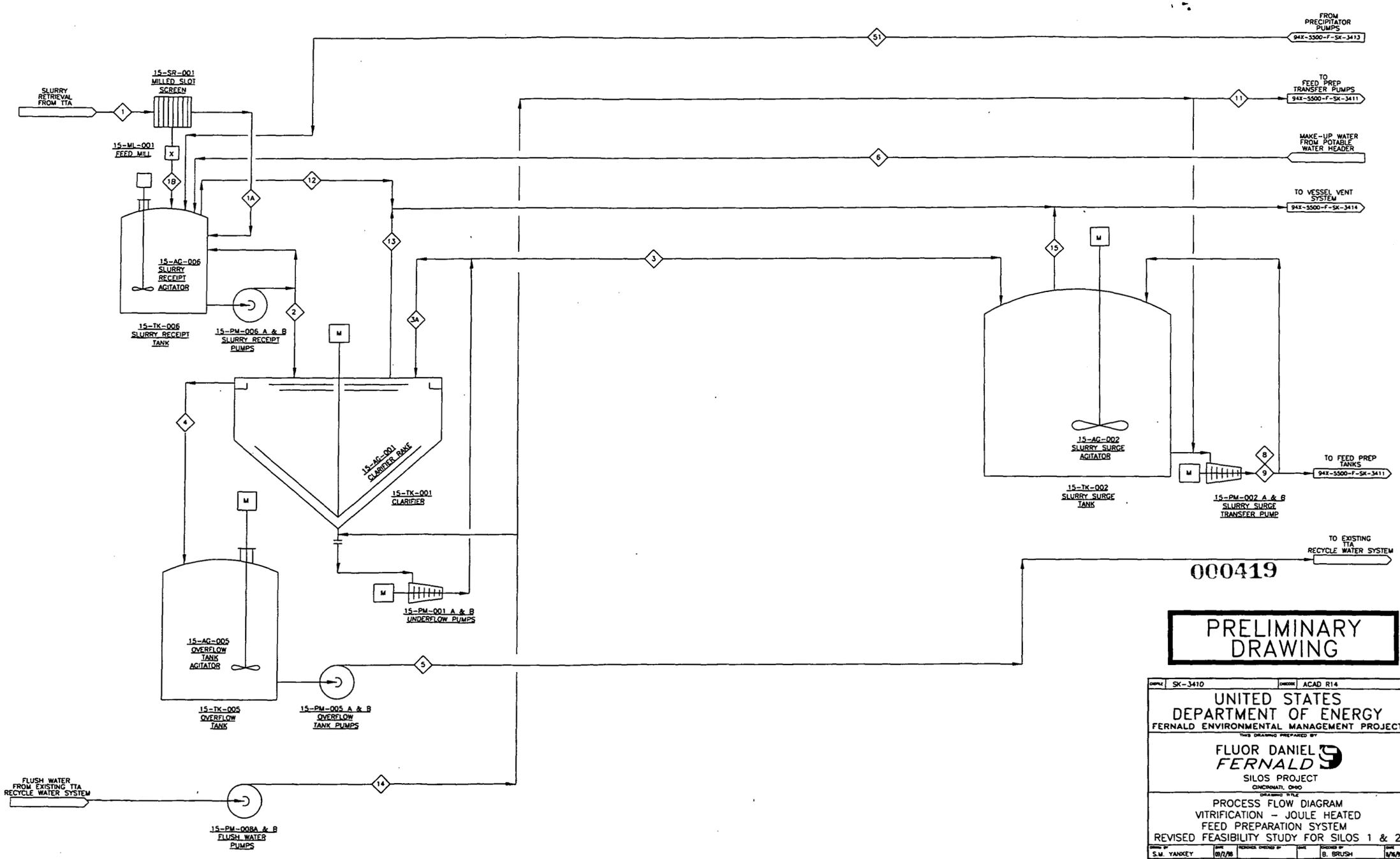

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CINCINNATI, OHIO

DRAWING TITLE

PROCESS FLOW DIAGRAM
VITRIFICATION – JOULE HEATED
FEED PREPARATION SYSTEM
REVISED FEASIBILITY STUDY FOR SILOS 1 & 2

DRAWN BY S.M. YANKEY	DATE 09/2/98	REVIEWED, CHECKED BY	DATE	CHECKED BY B. BRUSH	DATE 9/18/99
PLANT/BLDG. NO. OU4		FLOOR		SCALE NONE	CLASS
SUBMITTED FOR APPROVAL		APPROVAL RECOMMENDED			
A-E	DATE	OPERATING CONTRACTOR	DATE		

DOE PROJECT NO.	SPEC. COMM. PROJ. NO.	DRAWING NO.	SHEET NO.	REV. NO.
40730	WBS2.1.3.C.P	94X-5500-F-SK-3410	1	2

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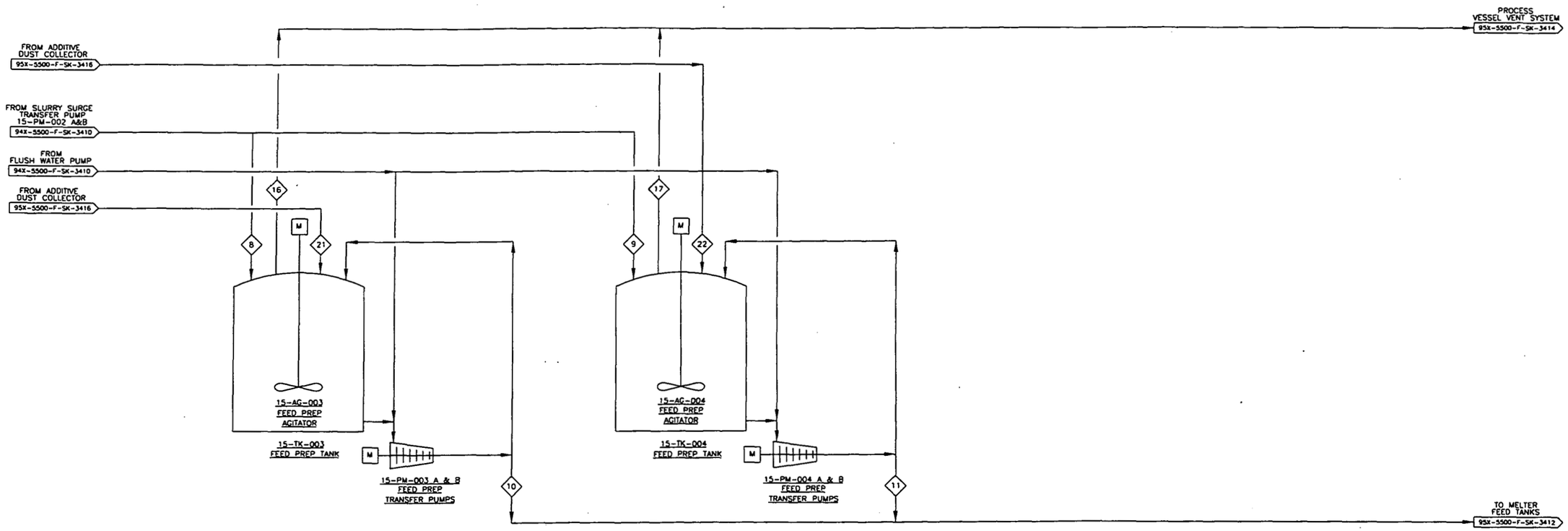

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PROCESS FLOW DIAGRAM
VITRIFICATION - JOULE-HEATED
FEED PREPARATION SYSTEM
REVISED FEASIBILITY STUDY FOR SILOS 1 & 2

DRAWN BY S.M. YANKEY	DATE 05/25/99	DESIGNED, CHECKED BY	DATE	CHECKED BY B. BRUSH	DATE 11/16/99
PLANT/BUILDING NO. OU4		PLOT		SCALE NONE	COLOR
SUBMITTED FOR APPROVAL		APPROVAL RECOMMENDED			
A-E	DATE	ORIGINATING CONTRACTOR	DATE		
DOE PROJECT NO. 40730	OPER. CONTR. PROJ. NO. WBS2.1.3.G.P	DRAWING NO. 94X-5500-F-SK-3411		SHEET NO. 1	REV. NO. 2

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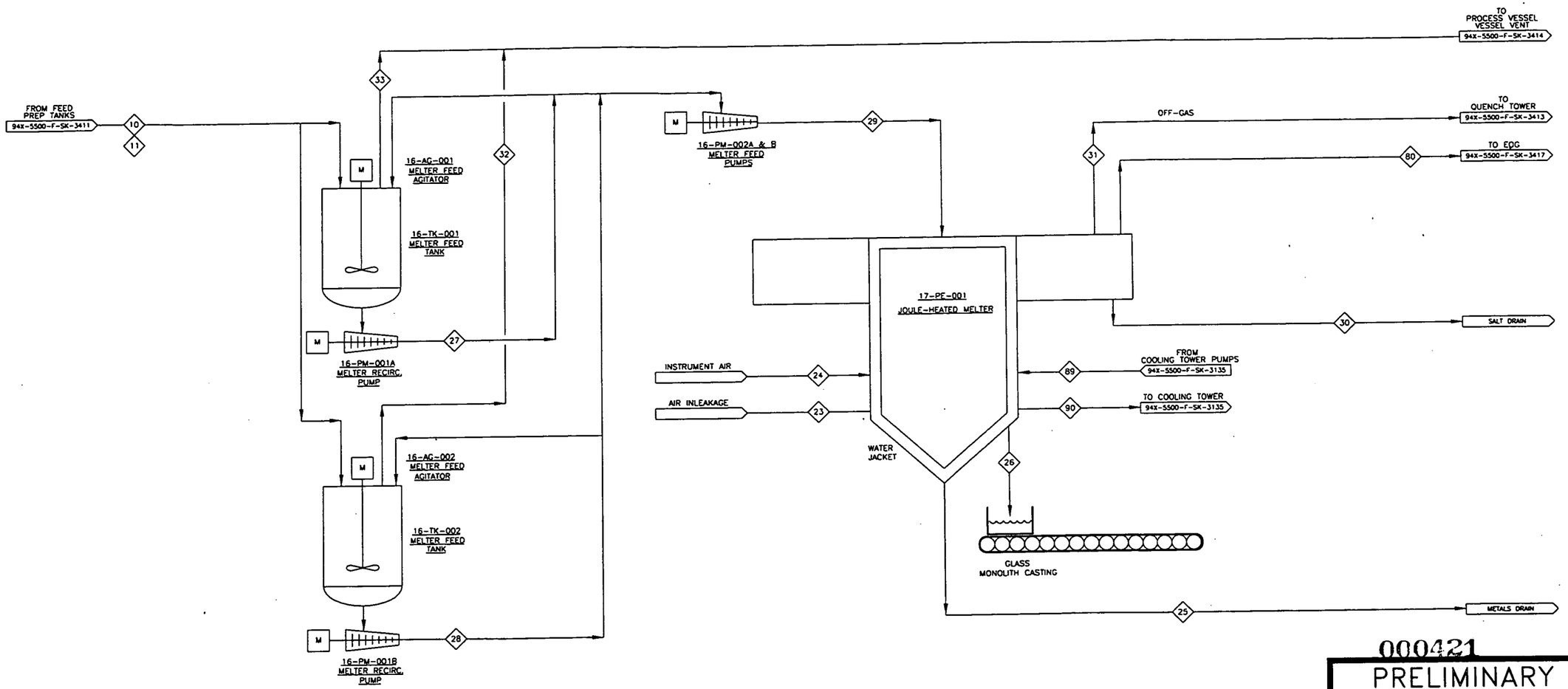

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DRAWING TITLE

PROCESS FLOW DIAGRAM
VITRIFICATION - JOULE HEATED MELTER
REVISED FEASIBILITY STUDY FOR SILOS 1 & 2

DRAWN BY R. STENSBY II	DATE 05/31/98	DESIGNED, CHECKED BY	DATE	CHECKED BY B. BRUSH	DATE 8/18/99
PLANT/BLDG. NO. OU4		FLOOR		SCALE NONE	CLASS
SUBMITTED FOR APPROVAL A-E DATE		APPROVAL RECOMMENDED CONTRACTOR DATE			
SOE PROJECT NO. 40730	OPER. CONTR. PROJ. NO. WBS2.1.3.G.P	DRAWING NO. 94X-5500-F-SK-3412		SHEET NO. 1	REV. NO. 2

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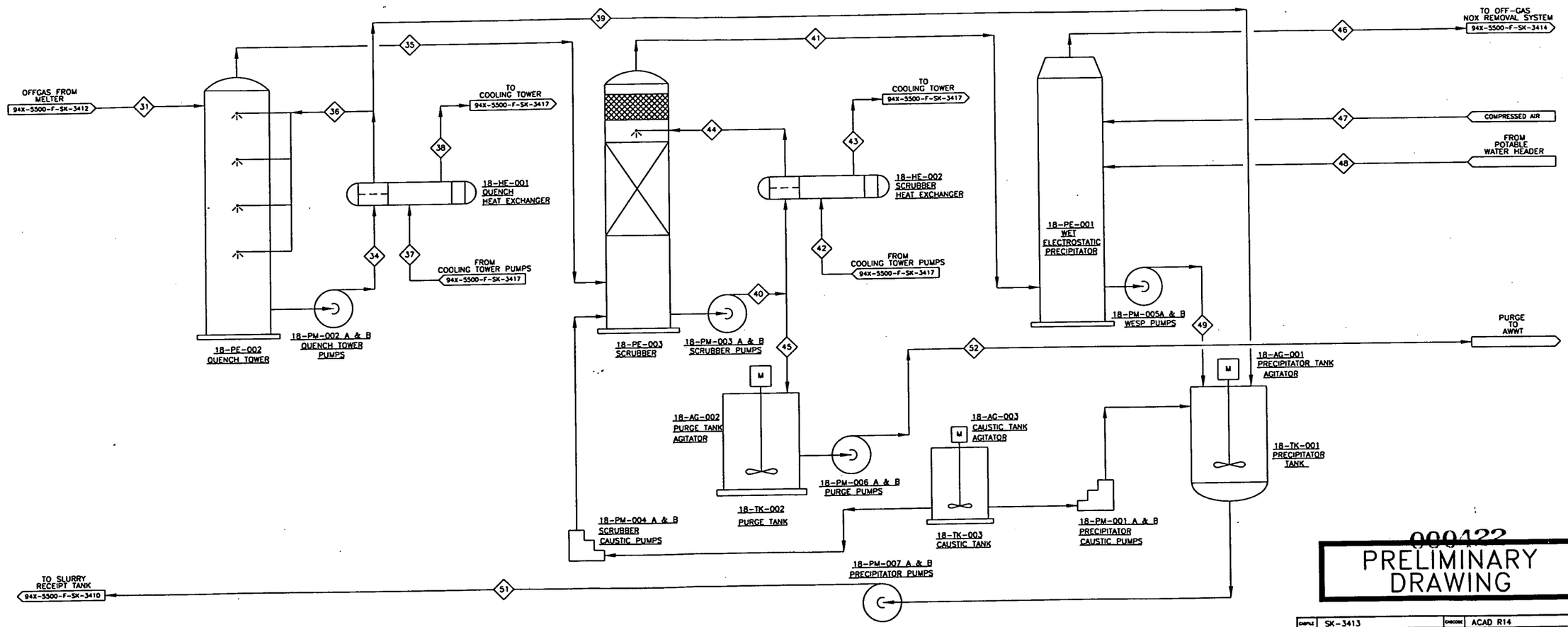

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SILOS PROJECT
CINCINNATI, OHIO

DRAWING TITLE

PROCESS FLOW DIAGRAM
VITRIFICATION – JOULE HEATED
NORMAL OFF-GAS TREATMENT
REVISED FEASIBILITY STUDY FOR SILOS 1 & 2

DRAWN BY S. M. YANKEY	DATE 01/27/98	REVIEWED, CHECKED BY	DATE	CHECKED BY B. BRUSH	DATE 6/16/99
PLANT/AREA NO. OU4		PLOT#		SCALE NONE	
SUBMITTED FOR APPROVAL		APPROVAL RECOMMENDED			
DOE	DATE	OPERATING CONTRACTOR	DATE		
DOE PROJECT NO. 40730	SPEC. CONTR. PROJ. NO. WBS2.1.3.G.P	DRAWING NO. 94X-5500-F-SK-3413		SHEET NO. 1	REV. NO. 2

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DATE: 11/30/99

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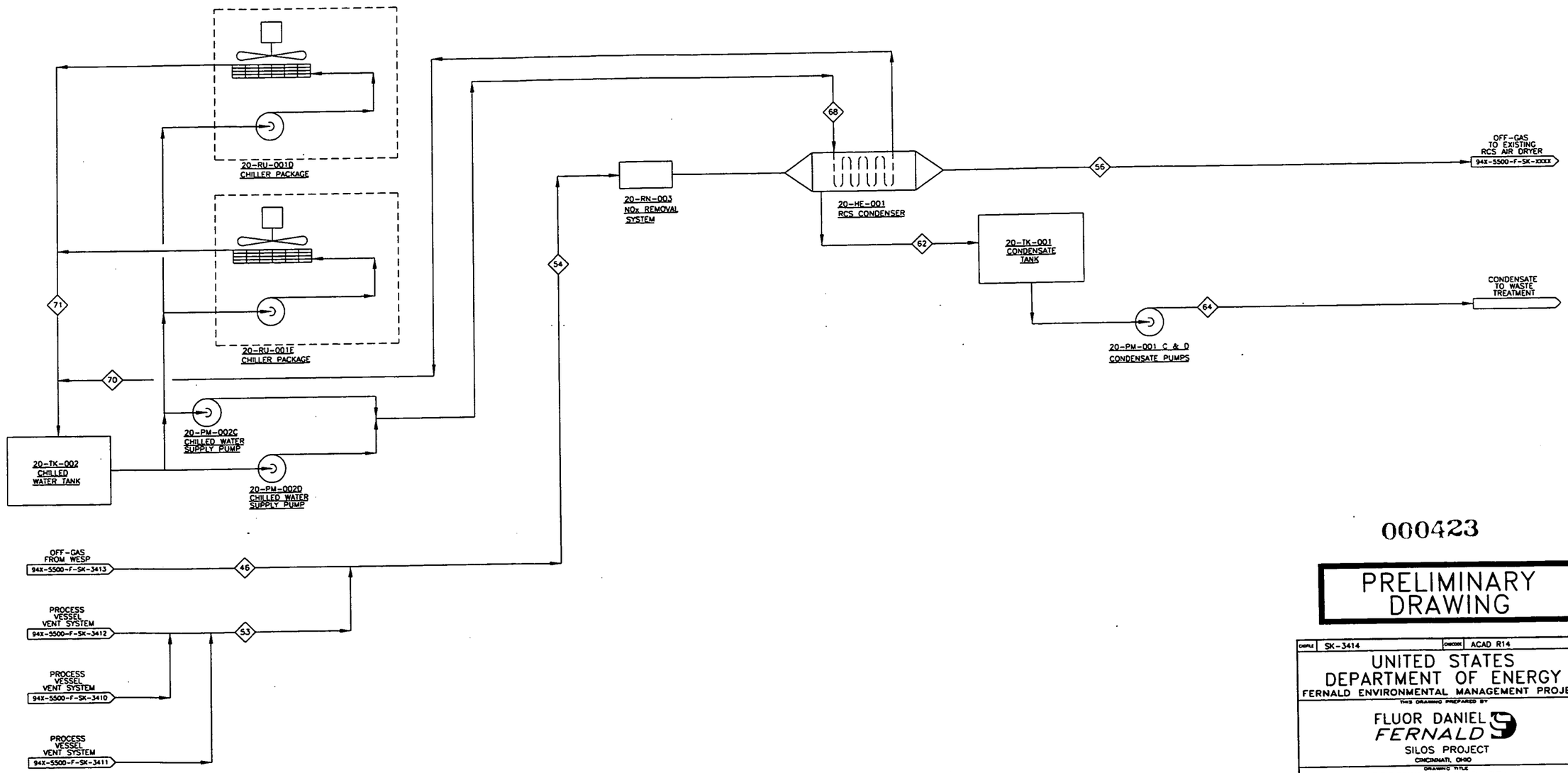

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CINCINNATI, OHIO

DRAWING TITLE

PROCESS FLOW DIAGRAM
VITRIFICATION – JOULE HEATED
RADON CONTROL SYSTEM
REVISED FEASIBILITY STUDY FOR SILOS 1 & 2

DRAWN BY S. M. YANKEY	DATE 08/26/98	DESIGNER CHECKED BY	DATE	CHECKED BY B. BRUSH	DATE 8/16/99
RUNIT/BLDG. NO. OU4		FLOOR		SCALE NONE	CLASS
SUBMITTED FOR APPROVAL		APPROVAL RECOMMENDED			
A-E DATE		OPERATING CONTRACTOR DATE			
DOE PROJECT NO. 40730	SPECIAL CONTROL PROJECT NO. WBS2.1.3.G.P	DRAWING NO. 94X-5500-F-SK-3414		SHEET NO. 1	REV. NO. 2

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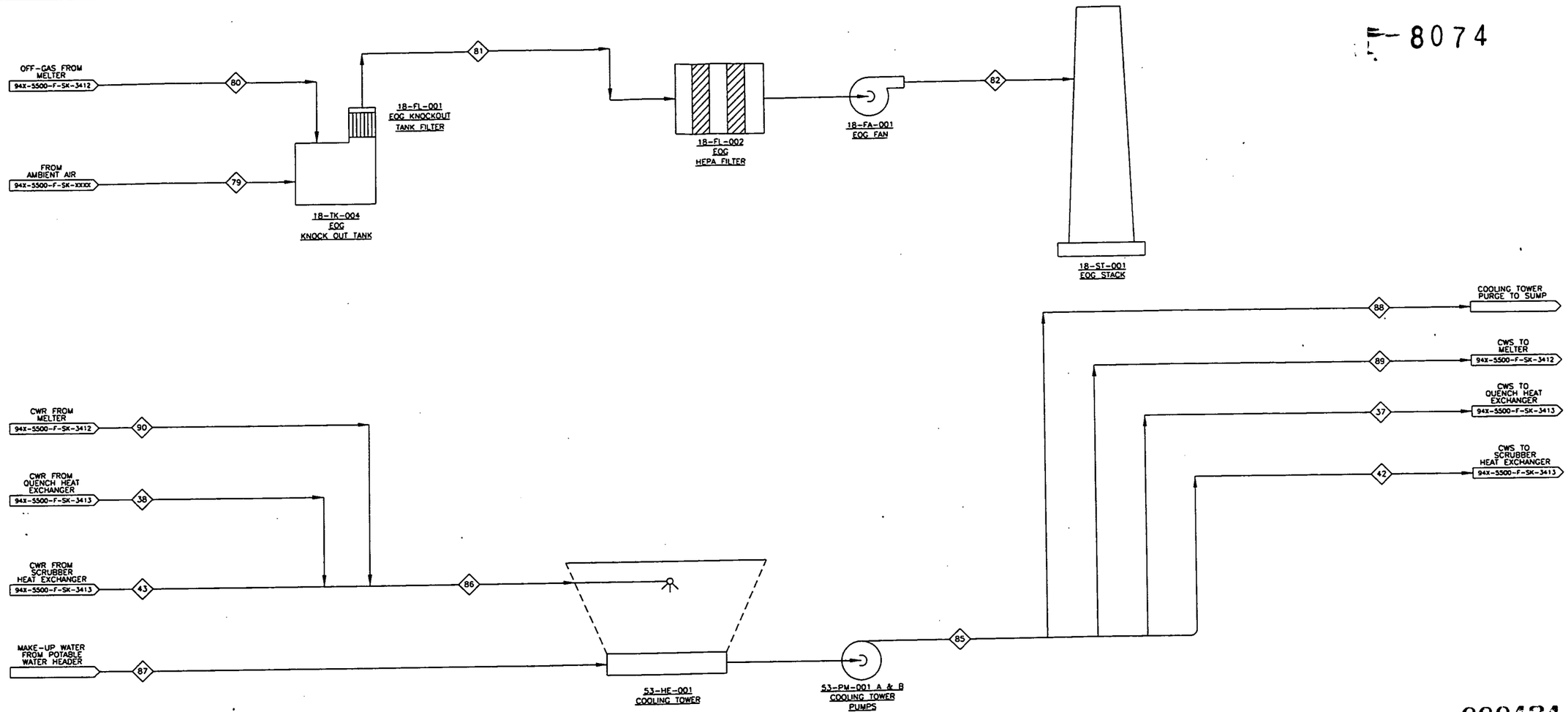

000424

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UNITED STATES DEPARTMENT OF ENERGY FERNALD ENVIRONMENTAL MANAGEMENT PROJECT			
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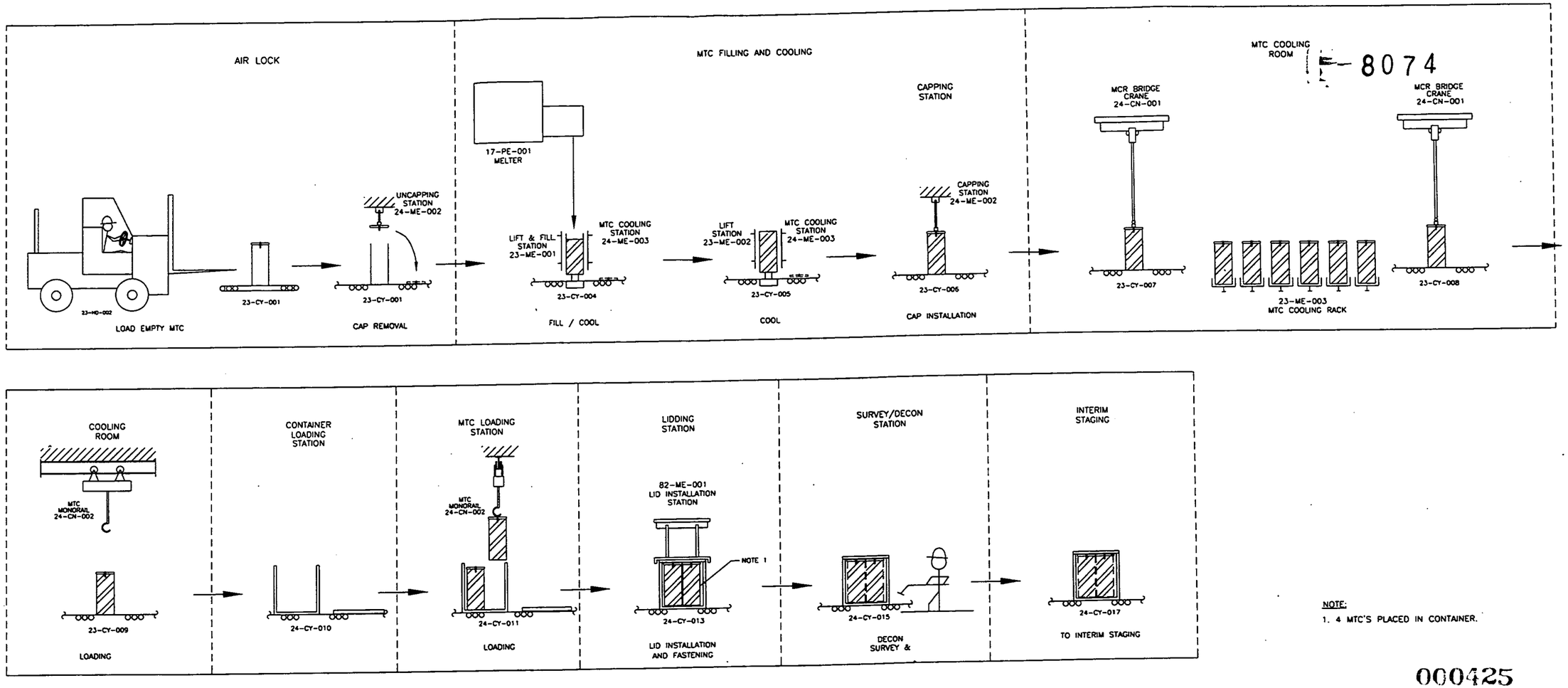
DRAWING TITLE PROCESS FLOW DIAGRAM VITRIFICATION – JOULE HEATED EMERGENCY OFF-GAS & COOLING TOWER REVISED FEASIBILITY STUDY FOR SILOS 1 & 2			
DRAWN BY S. M. YANKEY	DATE 09/3/98	REVIEWED, CHECKED BY	DATE
CHECKED BY B. BRUSH	DATE 8/16/99	PLANT/BLDG. NO. OU4	FLOOR
SCALE NONE	CLASS	SUBMITTED FOR APPROVAL	APPROVAL RECOMMENDED
DATE	DATE	DATE	ENGINEERING CONTRACTOR DATE
EDS PROJECT NO. 40730	SPEC. CONTR. PROJ. NO. WBS2.1.3.G.P	DRAWING NO. 94X-5500-F-SK-3417	SHEET NO. 1 / REV. NO. 2
DISTRIBUTION CODE: XXX	ACAD	INITIALS: RWR DATE: 11/30/99	



NOTE:

1. 4 MTC'S PLACED IN CONTAINER.

000425

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CASFILE	SK-6014	CHECKER	ACAD

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SILOS PROJECT
CINCINNATI, OHIO

DRAWING TITLE

MECHANICAL FLOW DIAGRAM
MONOLITH GLASS PRODUCTION
VITRIFICATION - JOULE
REVISED FEASIBILITY STUDY FOR SILOS 1 & 2

DRAWN BY RW REDMAN	DATE 7/7/98	DESIGNED, CHECKED BY	DATE
CHECKED BY C. SCHILLING	DATE 8/20/99	PLANT/BLDG. NO. OU4	FLOOR
SCALE NONE	DATE	SUBMITTED FOR APPROVAL A-E DATE	APPROVAL RECOMMENDED OPERATING CONTRACTOR DATE
DOE PROJECT NO. 40730	OPER. CONTR. PROJ. NO.	DRAWING NO. 94X-5500-F-SK-6014	SHEET NO. 1 / REV. NO. 2

DISTRIBUTION CODE: XXX

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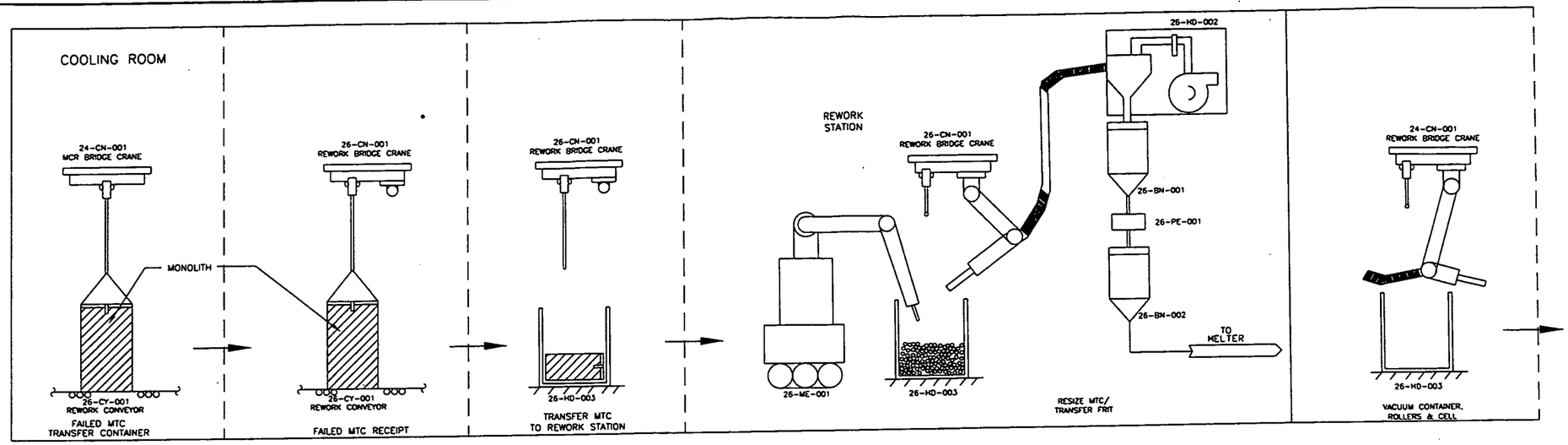
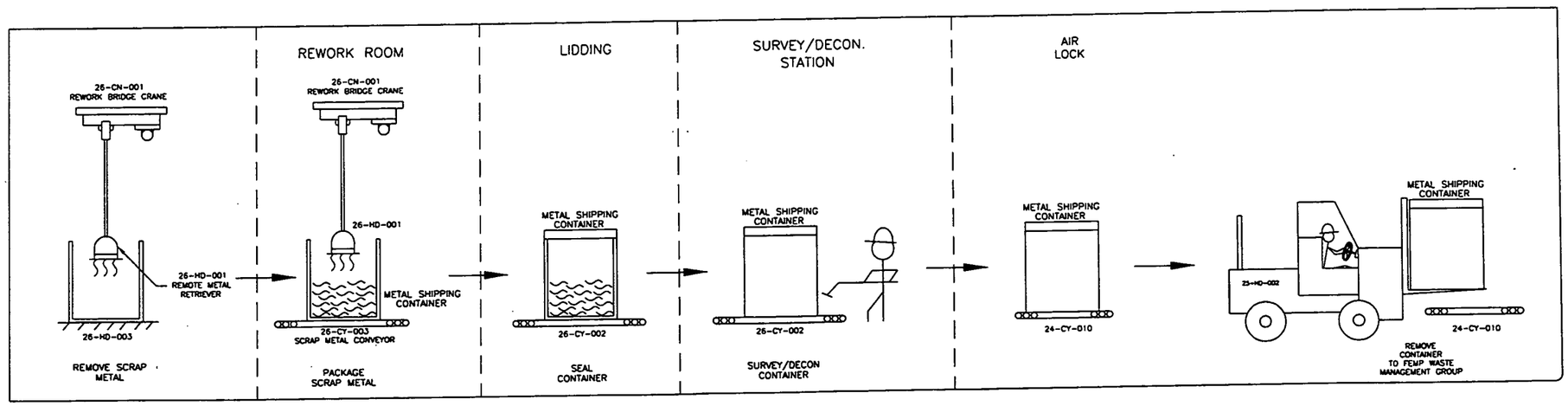
INITIALS: RWR
DATE: 11/30/99

8074





000426

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CAD FILE	SK-6016	CAD SOFT.	ACAD R14

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FLUOR DANIEL FERNALD
SILOS PROJECT
CINCINNATI, OHIO

DRAWING TITLE

MECHANICAL HANDLING DIAGRAM
MONOLITH REWORK
VITRIFICATION – JOULE
REVISED FEASIBILITY STUDY FOR SILOS 1 & 2

DRAWN BY D. LANDER	DATE 1-07-99	DESIGNED, CHECKED BY	DATE	CHECKED BY C. SCHILLING	DATE 9/30/99
PLANT/BLDG. NO. OU4		AUDIT		SCALE NONE	CLASS
SUBMITTED FOR APPROVAL A-E DATE		APPROVAL RECOMMENDED OPERATING CONTRACTOR DATE			
SDS PROJECT NO. 40730	SPEC. CONTR. FIELD NO. WBS2.1.3.G.P	DRAWING NO. 94X-5500-F-SK-6016		SHEET NO. 1	REV. NO. 2

DISTRIBUTION CODE: XXX

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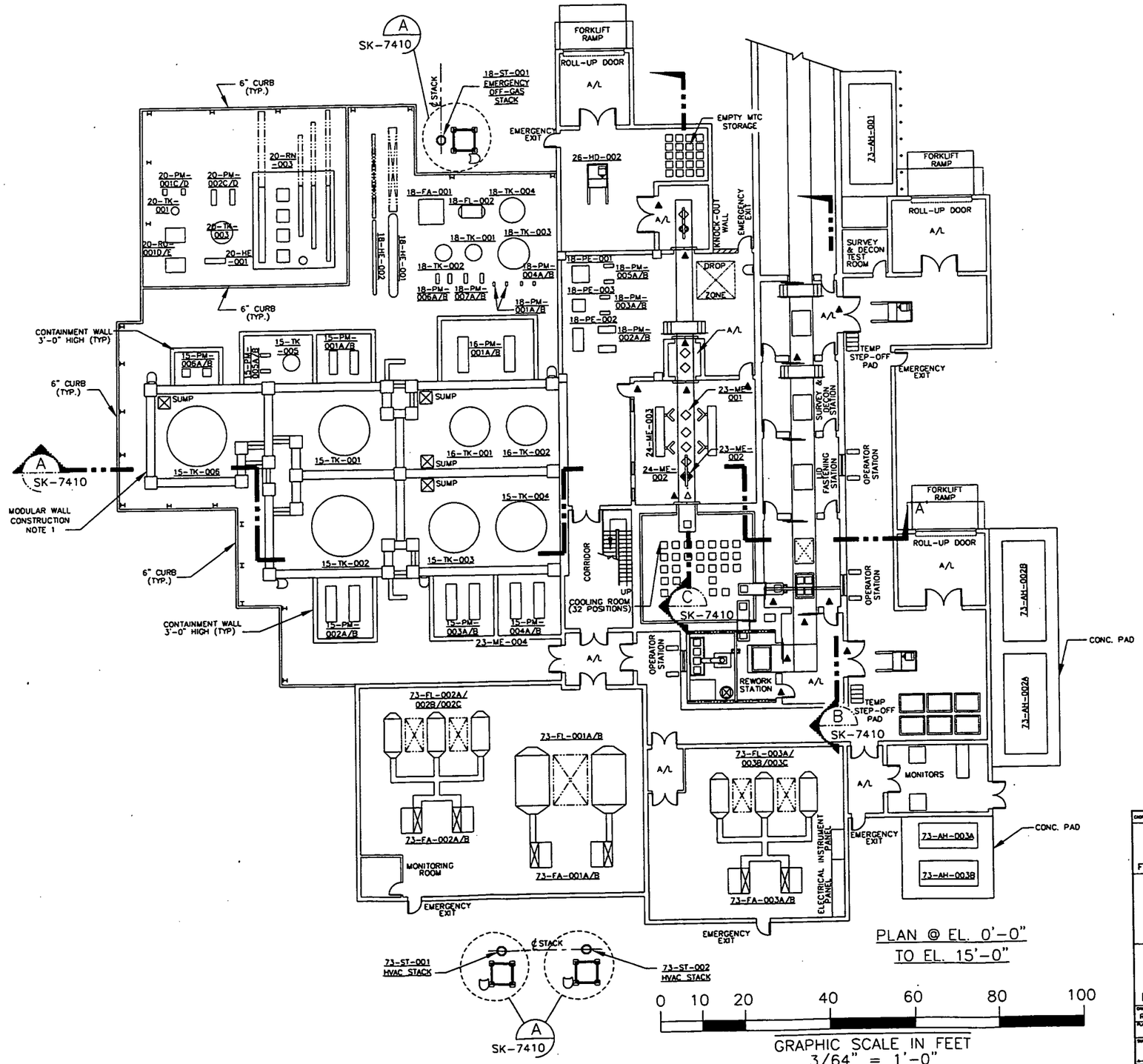
INITIALS: RWR
DATE: 11/30/99

8074



NOTES:

1. BUILDING CONSTRUCTION
   - CONCRETE FLOOR SLAB AND FOUNDATIONS.
   - ARCHITECTURAL TYPE WALLS CONSIST OF STEEL FRAME STRUCTURE, INSULATED METAL SIDING, MEMBRANE ROOFING SUPPORTED BY STEEL DECKING AND INSULATION BOARD.
   - MODULAR WALL CONSTRUCTION CONSISTS OF INTERLOCKING PREFABRICATED SHIELDING WALLS AND COLUMNS.
   - ALL OTHER SHIELDING WALLS ARE 1'-0" THICK CONCRETE (UNLESS SHOWN OTHERWISE).
2. SHIELDED FORKLIFT DEDICATED TO VITRIFICATION FACILITY.
3. EMPTY CONTAINER STORAGE IS SINGLE STACK.
4. SHIELD DOOR = ▲

REFERENCE DRAWINGS

94X-5500-P-SK-7433
94X-5500-P-SK-7434

000427

PRELIMINARY DRAWING

CAD FILE	SK-7408	CHECK	ACAD R14

UNITED STATES DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

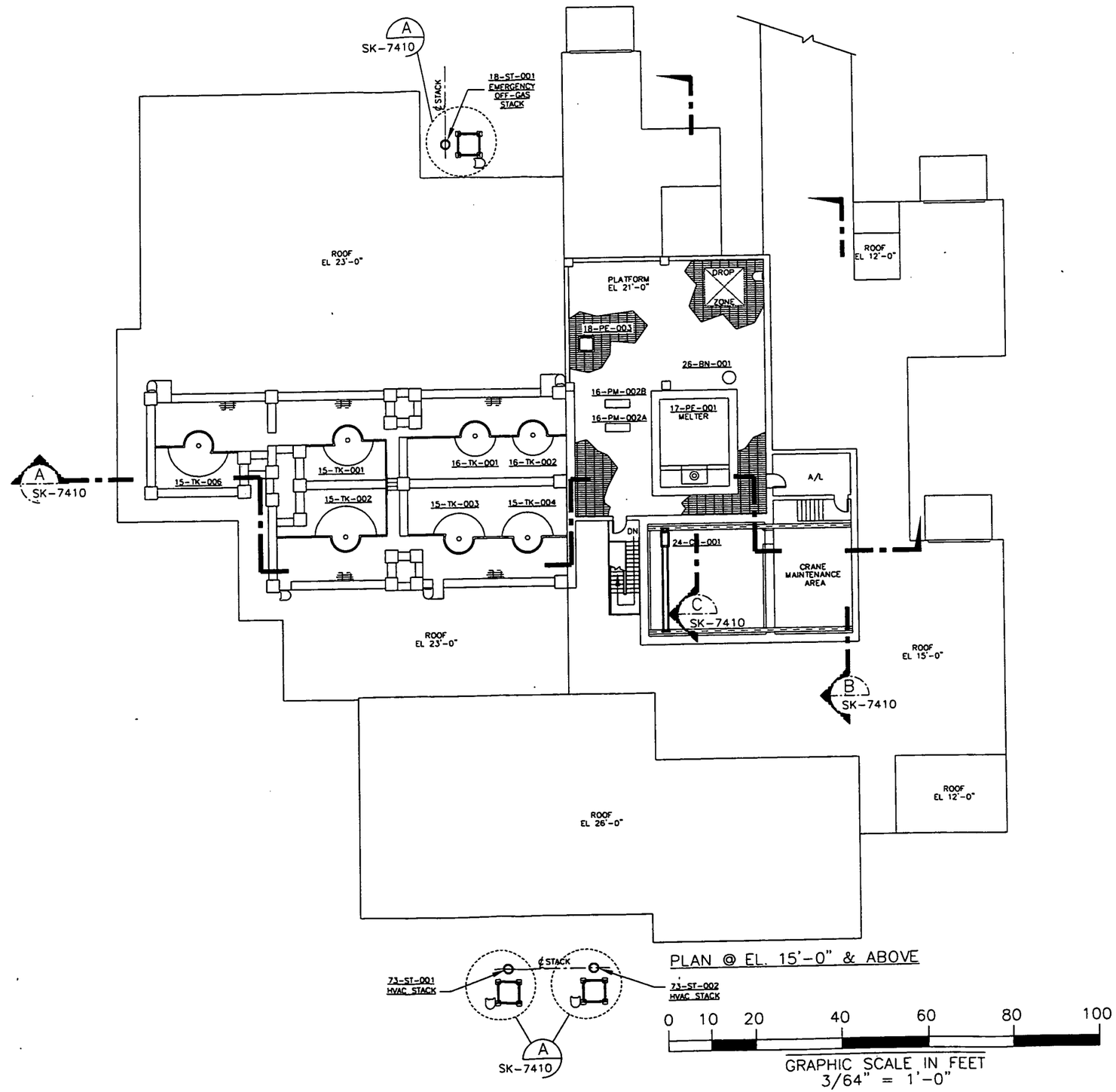
THIS DRAWING PREPARED BY
FLUOR DANIEL FERNALD
SILOS PROJECT
CINCINNATI, OHIO

DRAWING TITLE
FACILITY LAYOUT
VITRIFICATION FACILITY - JOULE HEATED
PLAN @ EL. 0'-0" TO EL. 15'-0"
REVISED FEASIBILITY STUDY FOR SILOS 1 & 2

DRAWN BY RW REDMAN	DATE 8/7/99	ECONOMICS CHECKED BY	DATE	CHECKED BY J.THOMPSON	DATE 8/16/99
PLANT/BLDG. NO. OU4		FLOOR		SCALE 3/64" = 1'-0"	
SUBMITTED FOR APPROVAL A-E DATE		APPROVAL RECOMMENDED OPERATING CONTRACTOR DATE			
DOE PROJECT NO. 40730		OPER. CONTR. PROJ. NO. WBS2.1.3.G.P	DRAWING NO. 94X-5500-P-SK-7408	SHEET NO. 1	REV. NO. 2

DISTRIBUTION CODE: XXX ACAD INITIALS: RWR DATE: 11/30/99

F-8074



PLAN @ EL. 15'-0" & ABOVE

0 10 20 40 60 80 100

GRAPHIC SCALE IN FEET
3/64" = 1'-0"

NOTES:

1. BUILDING CONSTRUCTION
   - CONCRETE FLOOR SLAB AND FOUNDATIONS.
   - ARCHITECTURAL TYPE WALLS CONSIST OF STEEL FRAME STRUCTURE, INSULATED METAL SIDING, MEMBRANE ROOFING SUPPORTED BY STEEL DECKING AND INSULATION BOARD.
   - MODULAR WALL CONSTRUCTION CONSISTS OF INTERLOCKING PREFABRICATED SHIELDING WALLS AND COLUMNS.
   - ALL OTHER SHIELDING WALLS ARE 2'-0" THICK CONCRETE.
2. SHIELD DOOR = ▲

REFERENCE DRAWINGS
94X-5500-P-SK-7433
94X-5500-P-SK-7434

000428

PRELIMINARY DRAWING

CHFILE SK-7409	CHECKER ACAD R14

UNITED STATES
DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

THIS DRAWING PREPARED BY
FLUOR DANIEL FERNALD
SILOS PROJECT
CINCINNATI, OHIO

DRAWING TITLE
FACILITY LAYOUT
VITRIFICATION FACILITY - JOULE HEATED
PLAN @ 15'-0" AND ABOVE
REVISED FEASIBILITY STUDY FOR SILOS 1 & 2

DRAWN BY RW REDMAN	DATE 9/7/99	DESIGNED, CHECKED BY	DATE	CHECKED BY J. THOMPSON	DATE 9/16/99
PLANT/BLDG. NO. OU4		PLOOR		SCALE 3/64" = 1'-0"	CLASS
SUBMITTED FOR APPROVAL A-E DATE		APPROVAL RECOMMENDED OPERATING CONTRACTOR DATE			
EDS PROJECT NO. 40730	OPER. CONTR. PROJ. NO. WBS2.1.3.G.P	DRAWING NO. 94X-5500-P-SK-7409		SHEET NO. 1	REV. NO. 2

DISTRIBUTION CODE: XXX

ACAD

INITIALS: RWR
DATE: 11/30/99

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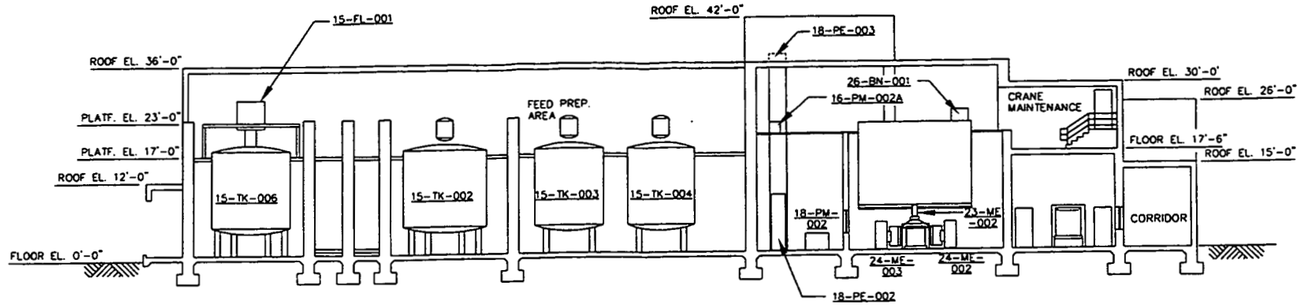
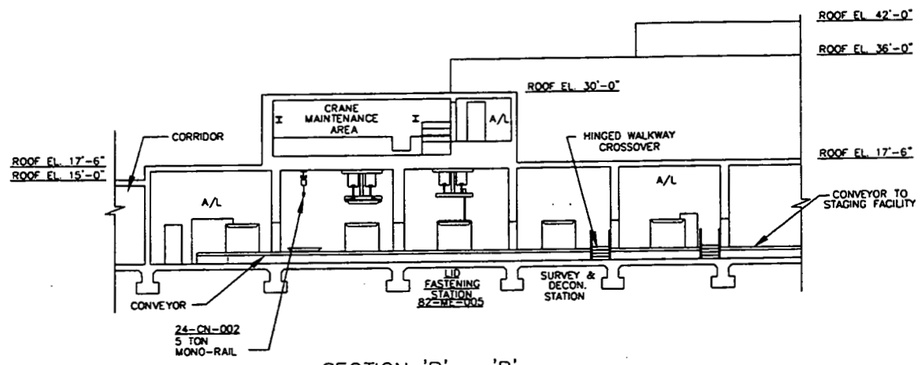


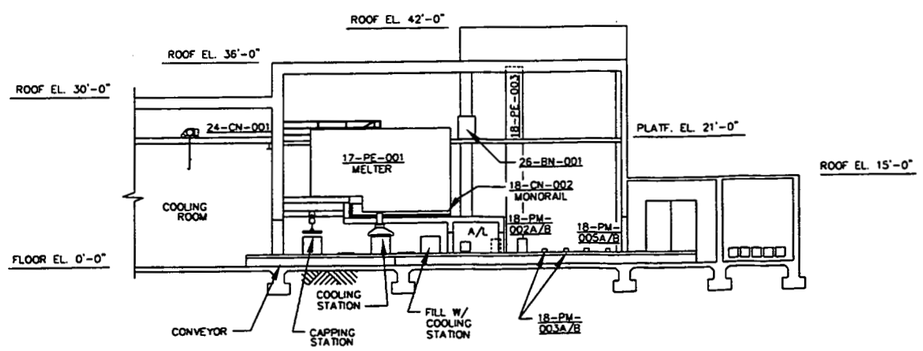
SECTION 'A' – 'A'

SEE SK-7408 & SK-7409



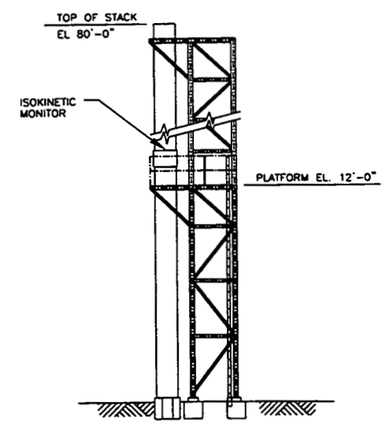
SECTION 'B' – 'B'

SEE SK-7408 & SK-7409



SECTION 'C' – 'C'

SEE SK-7408 & SK-7409



DETAIL A

N.T.S.

(TYP. EL. FOR HVAC & OFF-GAS STACKS)

SEE SK-7408 & SK-7409

NOTES:

1. BUILDING CONSTRUCTION
   - CONCRETE FLOOR SLAB AND FOUNDATIONS
   - STEEL FRAME STRUCTURE
   - INSULATED METAL SIDING
   - MEMBRANE ROOFING SUPPORTED BY STEEL DECKING AND INSULATION BOARD
   - RUBB BUILDING AS NOTED. RUBB BUILDING CONSISTS OF A FABRIC MEMBRANE COVERING STEEL FRAMING.
2. SHIELDED FORKLIFT DEDICATED TO VITRIFICATION FACILITY.
3. EMPTY CONTAINER STORAGE IS SINGLE STACK.

000429

PRELIMINARY DRAWING

0 10 20 40 60 80 100

GRAPHIC SCALE IN FEET
3/64" = 1'-0"

DRAWN SK-7410 CHECKED ACAD R14

UNITED STATES DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

THIS DRAWING PREPARED BY
FLUOR DANIEL FERNALD
SILOS PROJECT
CINCINNATI, OHIO

DRAWING TITLE
FACILITY LAYOUT
VITRIFICATION FACILITY – JOULE HEATED
SECTIONS AND DETAILS
REVISED FEASIBILITY STUDY FOR SILOS 1 & 2

DRAWN BY S. M. YANKEY	DATE 11/3/98	CHECKED BY J. THOMPSON	DATE 3/15/99
PLANT/BLDG. NO. OU4	FLOOR	SCALE AS NOTED	CLASS
SUBMITTED FOR APPROVAL	APPROVAL RECOMMENDED		
PLANT DATE	OPERATING CONTRACTOR DATE		
DOE PROJECT NO. 40730	UNIT CONTROL PROJ. NO. WB2.1.3.G.P	DRAWING NO. 94X-5500-P-SK-7410	SHEET NO. 1 REV. NO. 2

DISTRIBUTION CODE: XXX ACAD INITIALS: RMR DATE: 11/30/99

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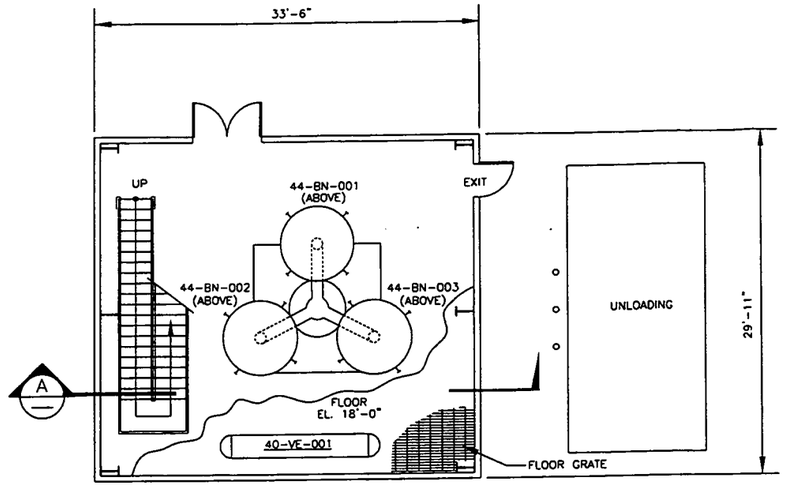
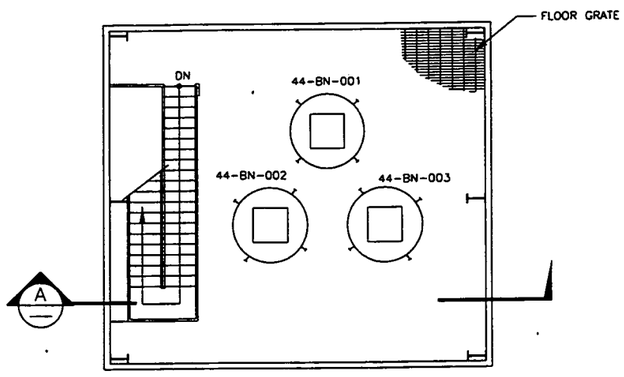
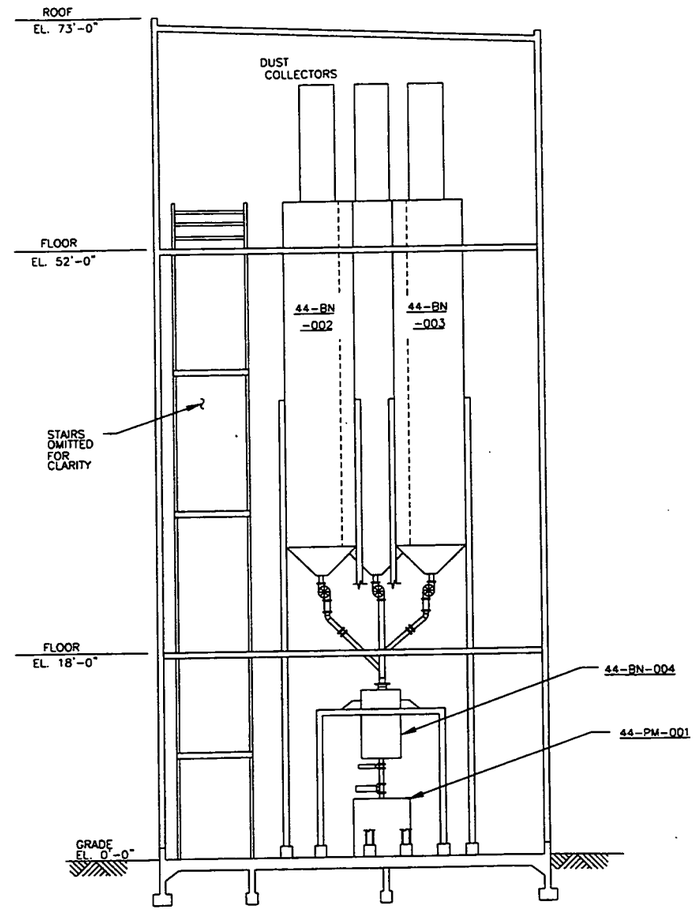


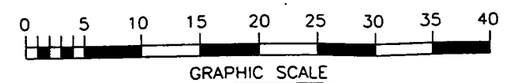
PLAN @ GRADE
TO EL. 52'-0"



PLAN @ EL. 52'-0"
AND ABOVE



SECTION 'A'-'A'



GRAPHIC SCALE
1/8" = 1'-0"

NOTES:

BUILDING CONSTRUCTION

- CONCRETE FLOOR SLAB AND FOUNDATIONS
- STEEL FRAME STRUCTURE
- INSULATED METAL SIDING
- MEMBRANE ROOFING SUPPORTED BY STEEL DECKING AND INSULATION BOARD

000430

PRELIMINARY DRAWING

CHAPLE SK-7050 | CHECKER ACAD R14

UNITED STATES
DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

THIS DRAWING PREPARED BY

FLUOR DANIEL
FERNALD

SILOS PROJECT
CINCINNATI, OHIO

DRAWING TITLE

FACILITY LAYOUT
VITRIFICATION – JOULE HEATED
ADDITIVE STORAGE BINS
REVISED FEASIBILITY STUDY FOR SILOS 1 & 2

DRAWN BY S. M. YANKEY	DATE 09/22/98	DESIGNED, CHECKED BY	DATE	CHECKED BY	DATE
PLANT/BLDG. NO. OU4		FLOOR		SCALE 1/8"=1'-0"	CLASS
SUBMITTED FOR APPROVAL		APPROVAL RECOMMENDED			
R-C DATE		OPERATING CONTRACTOR DATE			
DOE PROJECT NO. WBS2.1.3.G.P	SPGA CONTR. PROJ. NO. 40730	DRAWING NO. 94X-5500-A-SK-7050		SHEET NO. 1	REV. NO. 2

DISTRIBUTION CODE: XXX

ACAD

INITIALS: RWR
DATE: 11/30/99

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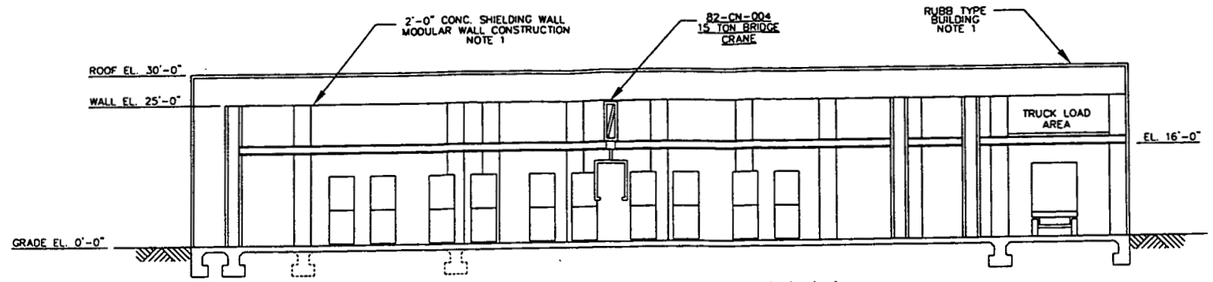
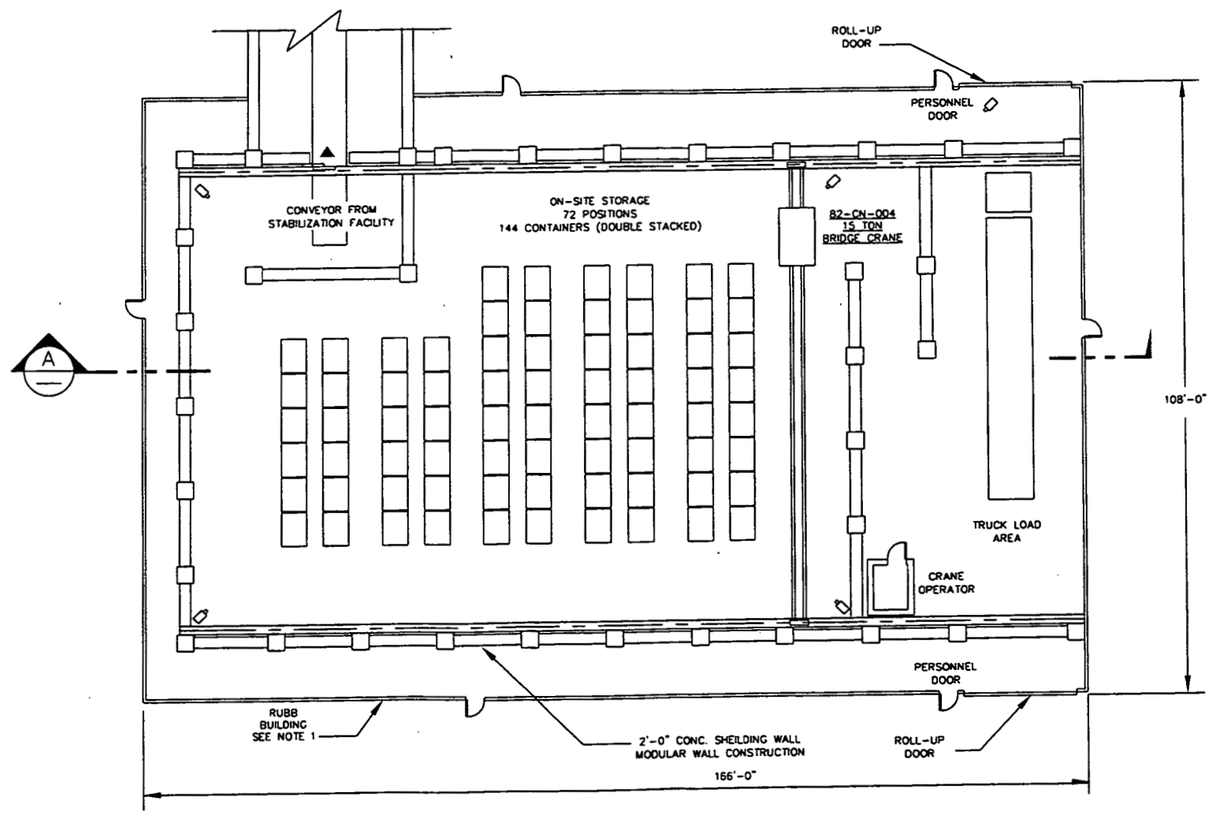


SECTION 'A'-'A'



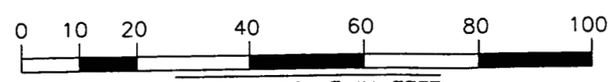
PLAN @ EL. 0'-0"

NOTES:

1. BUILDING CONSTRUCTION
   - CONCRETE FLOOR SLAB AND FOUNDATIONS
   - CONC. SHEILDING WALLS ONLY AS NOTED.
   - RUBB BUILDING AS NOTED. RUBB BUILDING CONSISTS OF A FABRIC MEMBRANE COVERING STEEL FRAMING.
2. CONTAINER STORAGE IS DOUBLE STACK.
3. SHIELD DOOR = ▲

000431

PRELIMINARY DRAWING



GRAPHIC SCALE IN FEET
3/64" = 1'-0"

DWG/FILE SK-7424		CHECKER ACAD R14	
UNITED STATES DEPARTMENT OF ENERGY FERNALD ENVIRONMENTAL MANAGEMENT PROJECT			
THIS DRAWING PREPARED BY FLUOR DANIEL FERNALD SILOS PROJECT CINCINNATI, OHIO			
DRAWING TITLE FACILITY LAYOUT VITRIFICATION - JOULE HEATED INTERIM CONTAINER STAGING REVISED FEASIBILITY STUDY FOR SILOS 1 & 2			
DRAWN BY S. M. YANKEY	DATE 12/14/98	REVISED, CHECKED BY	DATE
CHECKED BY J. THOMPSON	DATE 3/16/99	PLANT/BLDG. NO. OU4	FLOOR
SCALE 3/64" = 1'-0"	CLASS	SUBMITTED FOR APPROVAL	APPROVAL RECOMMENDED
A-E	DATE	OPERATING CONTRACTOR	DATE
CODE PROJECT NO. 40730	OPER. CONTR. PROJ. NO.	DRAWING NO. 94X-5500-P-SK-7424	SHEET NO. 1 / REV. NO. 2
DISTRIBUTION CODE: XXX	ACAD	INITIALS: RWR DATE: 11/30/99	

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Section G.5

G.5.0 VITRIFICATION — OTHER

G.5.1 Summary

The Vitrification — Other technology processes the Silos 1 and 2 material with chemical additives to remediate the waste constituents of concern. The treatment recipe is optimized to obtain a high waste loading and meet disposal facility WAC. For this process, the Silos 1 and 2 material slurry is dewatered, dried, and combined with chemical additives to create a mixture that is continuously fed to the gas-fueled combustion melter. After sufficient retention in the separator/reservoir section of the melter, the glass is discharged to a water-filled quench tank and formed into frit. Cooled and dried frit is conveyed to a concrete shipping and disposal container for shipment to a licensed disposal facility. Approximately 500 scfm of the off-gas from the melter is treated for acid gases and particulates before it is forwarded to the existing RCS for radon removal. The remaining off-gas is treated by a supplemental radon removal system designed for this facility.

G.5.1.1 Functional Analysis

A functional analysis has been performed for the Vitrification — Other technology. **Figure G.5.1-1** presents the individual functional requirements for the treatment facility. The first level functions are the high level functions to be accomplished by the treatment facility SSC. The subsequent levels in the functional analysis diagrams describe the means for accomplishing the high level functions. **Table G.5.1-1** gives a brief description of the individual functional blocks shown in **Figure G.5.1-1**.

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Figure G.5.1-1
Functional Analysis Diagram
Vitrification - Other

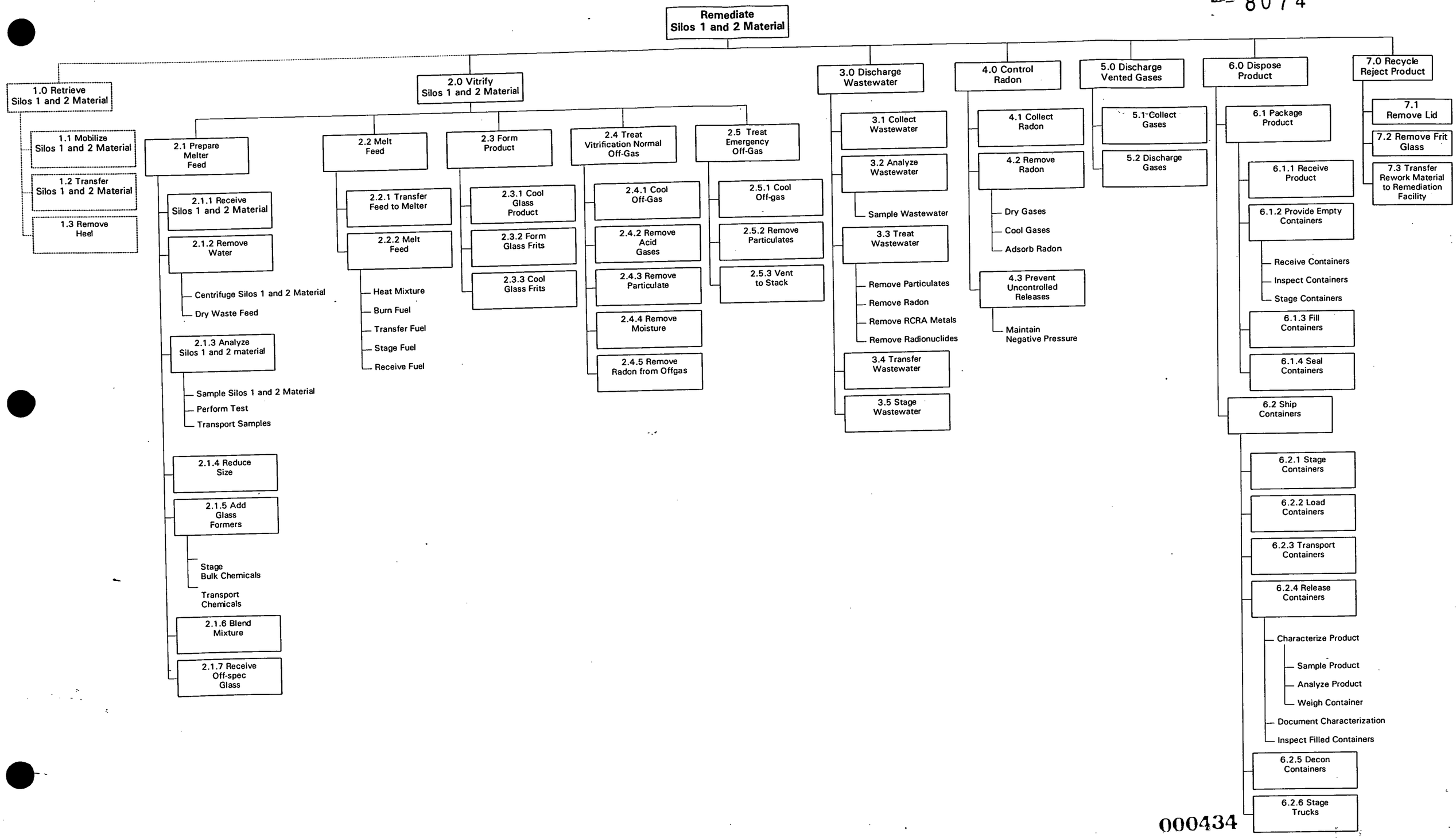

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TABLE G.5.1-1
FUNCTIONAL BLOCK DESCRIPTIONS
VITRIFICATION — OTHER

Function ID	Function Title	Functional Description
Overall System Function	Remediate Silos 1 and 2 Material	The Silos 1 and 2 material is retrieved as a 10 wt% solids slurry that is dried, mixed with glass forming additives, and vitrified in the cyclone melter by burning fuel directly in it to vitrify a product that can be disposed of safely. The process requires systems for normal and emergency off-gas treatment, wastewater treatment, radon control, venting gases, and disposal of product.
1.0	Retrieve Silos 1 and 2 Material	The Silos 1 and 2 material, stored in the TTA tanks, is retrieved in a form suitable for feeding to the treatment process.
1.1	Mobilize Silos 1 and 2 Material	The Silos 1 and 2 material is mobilized using high-pressure water jets.
1.2	Transfer Silos 1 and 2 Material	The Silos 1 and 2 material is transferred with a sludge pump at approximately 10 wt% solids through a pipe at a velocity high enough (>5 ft/sec) to prevent settling and plugging.
1.3	Remove Heel	The Silos 1 and 2 material in each tank left after the normal pumping operation is removed.
2.0	Vitrify Silos 1 and 2 Material	The dried Silos 1 and 2 material and glass forming additives are blended and heated to 2350° F in a direct fired, Vortec cyclone melter. The glass product and combustion products (off-gas) are separated. The glass product is cooled, transported, and packed into shipping and disposal containers.

TABLE G.5.1-1 (cont.)

Function ID	Function Title	Functional Description
2.1	Prepare Melter Feed	The Silos 1 and 2 material feed to the melter is dried in order to reduce the volume of off-gas to be treated. The Silos 1 and 2 material is centrifuged, dried, milled, and blended with glass forming additives in a feed mixer and fed continuously to the melter.
2.1.1	Receive Silos 1 and 2 Material	The Silos 1 and 2 material, pumped from the TTA, passes through a screen and is stored in the slurry receipt tank. The oversize particles are reduced in a mill before going to the slurry receipt tank.
2.1.2	Remove Water	The slurry is centrifuged to generate a wet cake containing 50 wt% solids, which is dried in a hot oil heated screw-type dryer. The centrate containing fine solids is recycled back to the TTA. Part of the dry product is recycled and mixed with the incoming wet cake to prevent operating problems.
2.1.3	Analyze Silos 1 and 2 Material	The dried Silos 1 and 2 material from the dryer is analyzed to ensure that a glass product suitable for disposal can be produced.
2.1.4	Reduce Size	For proper vitrification, the feed to the melter should be free from oversize particles . The particle size is reduced in a hammer-type dry feed mill.
2.1.5	Add Glass Formers	Based on laboratory analysis, additives have to be added to the Silos 1 and 2 material for proper vitrification. The additives are stored in bins. The additives are pneumatically conveyed to the feed mixer.
2.1.6	Blend Mixture	It is necessary to mix the dry Silos 1 and 2 material and glass forming additives thoroughly before feeding the melter to produce good glass product. The required quantity of materials are transferred sequentially to a feed mixer, which is on weigh cells, and mixed thoroughly.
2.1.7	Receive Off-spec Glass	Off-spec glass frit is recycled. It is ground and mixed with the feed to the melter.

TABLE G.5.1-1 (cont.)

Function ID	Function Title	Functional Description
2.2	Melt Feed	The mixture of dry Silos 1 and 2 material feed and additives, when heated to 2,350° F, melts and forms glass. The cooled glass product becomes a material that meets the WAC of the licensed disposal facility.
2.2.1	Transfer Feed to the Melter	The mixed feed from the surge bin is fed continuously to the melter through a weigh feeder.
2.2.2	Melt Feed	The melter temperature is maintained at 2350° F to melt the feed. Natural gas and preheated air, which is 20% in excess of theoretically required quantity, are burned in the melter. The fuel is transferred, staged, and received. The required rate of preheated air at 1,200°F is also supplied.
2.2.3	Cool Melter	Cooling of the melter is accomplished by circulating cooling tower water around the melter shell.
2.2.4	Separate Glass and Off-Gas	The glass and off-gas are separated in the separator/reservoir. The glass exits through the bottom or side tap and the off-gas exits through the Normal Off-gas System orifice.
2.3	Form Product	The molten glass is cooled in the quench tank and forms the glass frit. The product is cooled and carried by a drag conveyor to the containers.
2.3.1	Cool Glass Product	The molten glass from the separator/reservoir is transferred to a quench tank where it is cooled.
2.3.2	Form Glass Frit	The glass product forms glass frit on cooling.
2.3.3	Cool Glass Frit	The glass frit is cooled and dried before the shipping and disposal containers are filled.
2.4	Treat Vitrification Normal Off-gas	The off-gas from the melter, containing particulates, is cooled with water to 140° F in a quench tower, scrubbed with a caustic solution to remove SO_2, and then sent to a WESP to remove particulate matter. It is also necessary to remove NO_x and moisture before 500 scfm of this off-gas stream is sent to the existing RCS system prior to venting. The remaining gas (~300 scfm) passes through an air dryer package, is cooled to 45° F, passes through carbon beds for radon removal, and flows through HEPA filters before being vented to the RCS stack.

TABLE G.5.1-1 (cont.)

Function ID	Function Title	Functional Description
2.4.1	Cool Normal Off-gas	The off-gas is cooled to 140° F in the quench tower by direct contact with sprayed water. Volatiles in the off-gas are condensed. Water used for quenching is cooled in a heat exchanger before recirculating to the quench tower. A purge stream limits the particulate concentration in the tower to 0.5 wt%. Part of the filtrate from the particulate filter is recycled to the quench tower along with some make up water.
2.4.2	Remove Acid Gases	The off-gas is scrubbed with a dilute caustic solution to remove SO_2. It also is cooled to 110° F. The caustic solution, which is heated in the scrubber, is cooled in a heat exchanger before being recirculated. A purge stream is tapped from the scrubber. Part of the filtrate from the particulate filter and make up caustic solution are pumped to the scrubber. The off-gas passes through the NO_x removal system downstream of the scrubber.
2.4.3	Remove Particulates	The off-gas from the scrubber is sent to a WESP to remove the remaining particulate matter. The solids are flushed out as a 10 wt% slurry and collected in the filter feed tank. The material from this tank is transferred to a precipitate filter from which the wet cake as well as the filtrate are recycled.
2.4.4	Remove Moisture	The off-gas is cooled to 45° F in the off-gas condenser with chilled glycol. Most of the water in the off-gas is condensed. The condensed water is collected in the condensate tank and then transferred to the wastewater treatment area for treatment. After NO_x removal, 500 scfm of the off-gas is directed to the existing RCS. The remainder is directed to an air dryer package and cooled to 45° F.

000438

TABLE G.5.1-1 (cont.)

Function ID	Function Title	Functional Description
2.4.5	Remove Radon	The cooled off-gas passes through a set of carbon beds where the radon from the off-gas is adsorbed.
2.5	Treat Emergency Off-gas	In case of an emergency that prevents regular off-gas treatment, the off-gas from the melter is mixed with atmospheric diluent air and thereby cooled to 500° F. The cooled off-gas is directed to a knock-out tank containing a high-temperature bag filter where most of the particulate matter is removed. Then, it passes through HEPA filters where the remaining particulates are removed before being vented to the atmosphere through an exhaust stack.
2.5.1	Cool Off-gas	The off-gas is cooled to 500° F with atmospheric diluent air.
2.5.2	Remove Particulates	The cooled off-gas passes through a knock-out tank with an integral high-temperature bag filter to capture most of the particulate particles. The off-gas passes through HEPA filters to remove the remaining particulates.
2.5.3	Vent Off-gas	The cooled emergency off-gas, free of most particulates, is vented to the atmosphere through a dedicated stack.
3.0	Discharge Wastewater	The wastewater generated from different areas of the process is collected and analyzed to determine the type of treatment required. The treatment process includes removal of particulates, radon, RCRA metals, and radionuclides. The treated wastewater is transferred, tested, and disposed properly.
3.1	Collect Wastewater	The wastewater discharged from the different areas of the process is collected and transferred to the treatment area.
3.2	Analyze Wastewater	Samples of the wastewater are collected for testing. Tests are conducted to determine the type and quantity of pollutants and the treatment required.

TABLE G.5.1-1 (cont.)

Function ID	Function Title	Functional Description
3.3	Treat Wastewater	The wastewater is treated for the removal of pollutants such as particulates, metals, and radionuclides.
3.4	Transfer Wastewater	The treated wastewater, suitable for disposal, is transferred to the appropriate area.
3.5	Stage Wastewater	The treated wastewater, suitable for disposal, is staged and disposed of properly.
4.0	Control Radon	Vent streams containing radon from different areas of the process are collected properly and treated for the removal of radon. The treatment process removes particulate matter, cools the streams, and passes them through carbon beds to remove radon. Uncontrolled release of radon is prevented by maintaining a negative pressure throughout the radon treatment system. The treated gases are vented through the RCS stack.
4.1	Collect Radon	Vent streams from different areas of the process containing radon are collected for treatment.
4.2	Remove Radon	The dried gases are cooled to the required temperature in a heat exchanger. The radon in the gases is removed by drying and cooling the gases before passing them through the carbon beds where the radon is adsorbed.
4.3	Prevent Uncontrolled Release	Uncontrolled release of radon in the system is prevented by maintaining a negative pressure throughout the treatment system and by maintaining constant operating conditions for the carbon beds.
5.0	Discharge Vented Gases	The process vessel vent streams are collected and discharged to the off-gas stream.

TABLE G.5.1-1 (cont.)

Function ID	Function Title	Functional Description
5.1	Collect Gases	The vent streams are collected from different sources and sent to a pipe that also carries off-gases.
5.2	Discharge Gases	These gases are discharged to the suction of the melter's forced draft fan.
6.0	Dispose Product	The product from the vitrification system is received and packed in shipping and disposal containers. The shipping and disposal containers are sealed and loaded onto a truck. The trucks are then released for shipment and disposal of the containers.
6.1	Package Product	The product from the vitrification system is received and packed in shipping and disposal containers.
6.1.1	Receive Product	The glass product from the vitrification system is received as a granular frit.
6.1.2	Provide Empty Containers	The shipping and disposal containers for the product are received, inspected, and staged.
6.1.3	Fill Containers	The shipping and disposal containers are filled with the product. (An absorbent material may be placed in the bottom of the containers to preclude free standing water.)
6.1.4	Seal Containers	The shipping and disposal containers filled with the product are sealed.
6.2	Ship Containers	The shipping and disposal containers of product are loaded onto trucks. Samples are collected, analyzed, and documented. The shipping and disposal containers are weighed and inspected. The trucks are then released.

TABLE G.5.1-1 (cont.)

Function ID	Function Title	Functional Description
6.2.1	Stage Containers	The shipping and disposal containers of product are staged for shipment.
6.2.2	Load Containers	The shipping and disposal containers ready for shipment are loaded onto a truck.
6.2.3	Transport Containers	Loaded trucks leave the FEMP for their ultimate disposal site.
6.2.4	Release Containers	The product is characterized. Samples of the product are analyzed. The shipping and disposal containers are weighed and the characterization is documented. The containers are inspected and released.
6.2.5	Decon Containers	Shipping and disposal containers having external contamination are taken to a decon bay for surface washing.
6.2.6	Stage Trucks	The trucks are staged and released.
7.0	Recycle Reject Product	A separate facility is provided to handle operations associated with the rework activities of the reject glass containers. This system interfaces with the Treatment System and the PVS.
7.1	Remove Lid	The container of the reject glass is opened to access the treated material. Facility operators use a remote bolt removing device to remove the bolts from the container lid.
7.2	Remove Frit Glass	A facility is designated for the removal of reject material from the disposal containers. The SSCs associated with removing the reject material operate concurrent with normal operating activities.
7.3	Transfer Rework Material to Remediation Facility	A Vacuum Conveyor System to transfer the rework frit to the rework hopper is provided. This system interfaces with the PVS.

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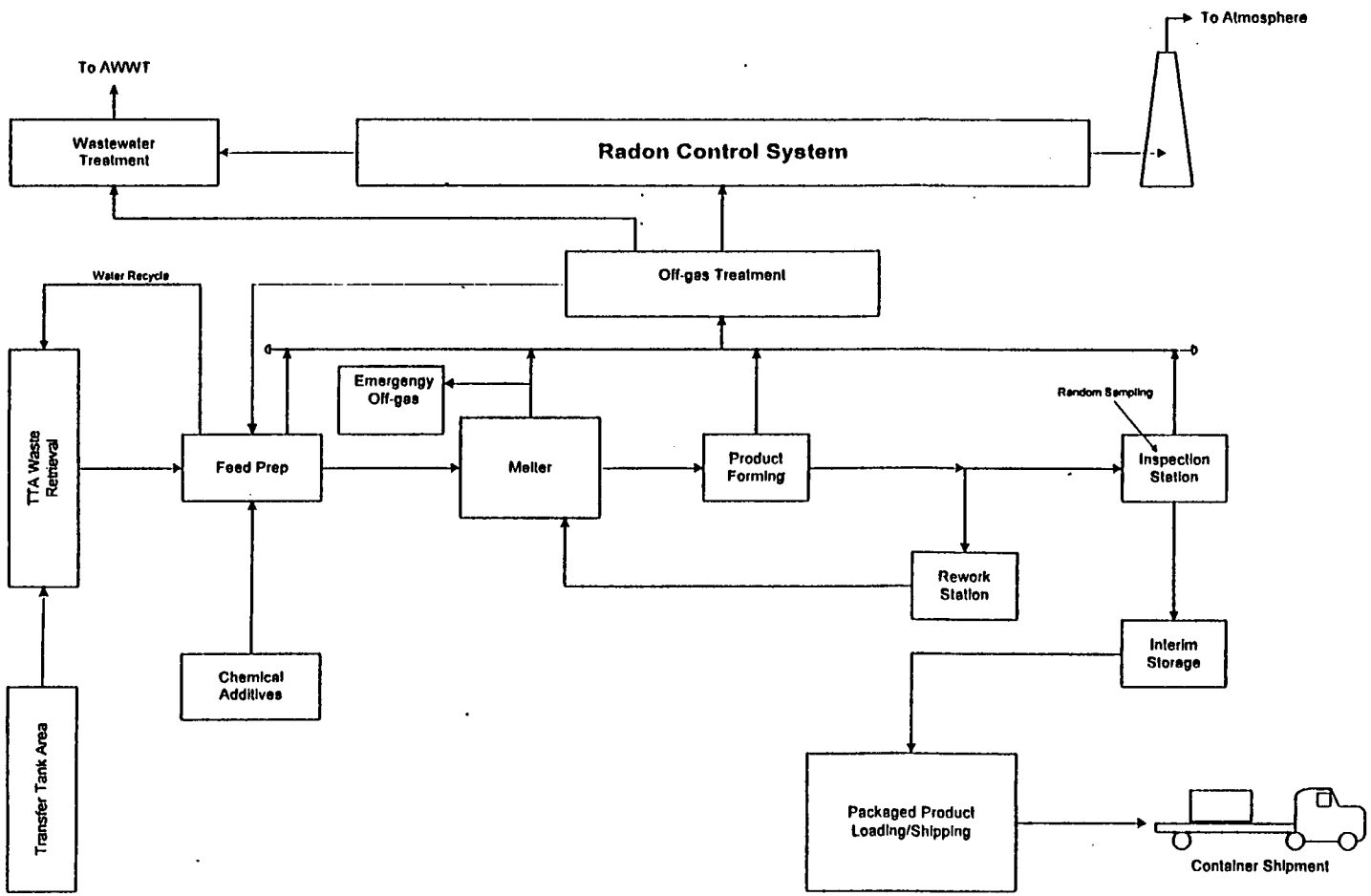
G.5.1.2 System Model

Figure G.5.1-2 presents a block flow diagram for the treatment of the silos residues using Vitrification — Other.

<END OF PAGE>

FIGURE G.5.1-2
SYSTEM BLOCK FLOW DIAGRAM
VITRIFICATION — OTHER



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G.5.1.3 Treatment Recipe

The treatment recipe was developed by Vortec Corporation, under contract as the Proof of Principle subcontractor for the "Vitrification — Other" technology (**Appendix H, Attachment H2**).

G.5.1.4 Mass and Energy Balance Overview

The mass and energy balance in the form of PFDs and the associated material balance spread sheets are included in **Attachment G.5.I.**

G.5.1.5 Availability and Work Schedule

The vitrification plant operates 24 hr/day, 7 days/week.

Basis: High temperature melters operate most efficiently when operated continuously. Cycling on and off damages the refractory and increases energy use.

G.5.2 Feed and Additives Preparation (Systems 15, 16, and 44)

The Feed Preparation System prepares the Silos 1 and 2 material, from the TTA, for feed to the treatment process.

G.5.2.1 System Description

The Feed Preparation System receives bulk additives and prepares them for feeding into the process. All additives are dry powdery solids and are handled with conventional pneumatic conveying equipment, bins, dust collectors, etc. The additives are not hazardous. Additive bins have bin vent filters to prevent dust emissions.

The Silos 1 and 2 material is retrieved from the TTA at approximately 10 wt% solids, using a slurry pump, at a nominal rate of 5,900 lb/hr dry solids.

The slurry receipt tank (15-TK-006), with a capacity of 30,000 gallons, receives slurry from the TTA. Slurry percent solids can only be roughly controlled. An in-line densitometer in the slurry

line to the slurry receipt tank provides specific gravity information to convert to percent solids. Vessel levels are monitored. The slurry receipt tank has an inventory equivalent to approximately four hours of slurry pumping and approximately 24 hours of feed to the drying process. The slurry is milled (15-ML-001) and screened (15-SR-001) through 30 mesh to limit maximum particle size to 0.6 mm.

Slurry from the receipt tank is uniformly fed to one of two solid bowl centrifuges (15-CE-001 and -002); the second centrifuge is a full capacity spare. The centrifuge produces a wet cake containing 50 wt% solids and a centrate that carries the fine solids (mostly BentoGrout™ clay) from the feed. The concentration of solids in the centrate depends upon the percentage of the fines in the feed and the operating parameters of the centrifuge. The centrate from the centrifuge flows, by gravity, into the centrate tank (15-TK-005), from which it is pumped back to the TTA for the slurrying operation.

The wet cake from the centrifuge is discharged, by gravity, into one of the dryer mixers (15-MX-001 and -002). There are two sets of dryers (15-RN-001 A & B and -002 A & B), one is a full capacity spare. The dryers are gas-fired hot oil, multiple screw-type. Each set has two dryers and can process 72,000 lb of wet solids at 15 wt% moisture. The moisture content of the dried solids is 5 wt%. Seven of eight parts of the dried solids from the dryers are recycled back to the dryer mixer where the dried material is mixed with the 50 wt% wet cake from the centrifuge to produce a mixture containing 15 wt% moisture, which is fed to the dryer. The dryer screws are driven by variable-speed electric motors.

The water-cooled dryer/condenser (15-PE-001) condenses the water evaporated from the feed in the dryers. The water circulating through the condenser spray nozzles absorbs the heat released by the condensing vapor and is cooled in the dryer condenser cooler (15-HE-001) with cooling water before recirculating back to the spray nozzles. A purge stream is diverted from the recirculating water stream of the dryer condenser, which represents the water being condensed. This purge stream goes to the filter feed tank (18-TK-003), which is a part of the equipment for treating the off-gas from the melter (17-PE-001).

A hammer-type dry feed mill (15-ML-002) reduces the dry feed material from the dryers to particles under 30 mesh (600 microns). The material from the mill passes into the milled waste bin (15-BN-006). The material is transferred from the milled waste bin into feed bins (15-BN-001, -002, and-003) by a dense-phase pneumatic conveyor (15-PM-001). The air from the feed bins flows to the air intake FD fan of the melter. The feed bins can store the feed material required for operation of the melter at 24 hr/day, 7 days/week.

The Additive System has storage bins (44-BN-001, -002, and -003) with capacity to hold bulk truck shipments of additives. Truck shipments of additives are pneumatically transferred into these bins.

The dense-phase pneumatic transfer system consists of a blower and dust collector. The system transfers, from the feed storage bins to a batch feed mixer (15-MX-003), the amount of Silos 1 and 2 material required for four hours of operation of the melter. The air used for conveying is vented from the feed dust collector to the FD fan (17-FA-001). A similar system transports additives (the quantity required for four hours of operation of the melter) from the additive bins to the feed mixer. The air used for conveying additives is vented from the additive dust collector to the atmosphere through a cartridge filter.

The feed mixer is a 100-ft^3 batch blender and rests on weigh cells, so that the successful transfer quantities of materials can be monitored. The feed mixer has a double ribbon agitator. After the feed and additives are mixed thoroughly, feed mixture is discharged to the feed surge bin (15-BN-004). From the feed surge bin, the feed mixture passes through the weigh feeder, which consists of a weigh hopper and metering screw, and is continuously fed to the melter at the required rate.

G.5.2.2 Assumptions

A. **Assumption:** The Feed Preparation System receives slurry from the TTA on demand at 10 wt% to 30 wt% solids.

Basis: This is the projected operating regime of the slurry pump that transfers slurry from the TTA to the system.

B. **Assumption:** The Feed Preparation System continuously supplies a mixture of dry Silos 1 and 2 material feed and additives at the rate of 1,592 lb/hr to the melter.

Basis: Vortec Corporation. 1999. *Silos 1 and 2 Proof of Principle Project, Final Report; Process Flow Diagram.* (Appendix H, Attachment H2)

C. **Assumption:** The slurry feed is screened through a 30 mesh screen so that maximum particle size is less than 0.6 mm. Oversize particulates must be size reduced to less than 0.6 mm. Oversize particulates average 13 wt% of the Silos 1 and 2 material.

Basis: Weight fraction <30 mesh averaged from the two analytical reports from International Technology Corporation (IT) Analytical Services dated March 22, 1990 and June 29, 1992.

D. **Assumption:** The off-spec product recycle stream is estimated to be approximately 1.0 wt% and, thus, is not significant enough to consider for material balances and equipment sizing.

Basis: Engineering judgement.

E. **Assumption:** The Feed Preparation System receives additive chemicals in bulk trucks that can pneumatically transfer their contents to the storage bins.

Basis: Bulk delivery and unloading provides the safest and most efficient operation, given the quantity of additives handled.

F. **Assumption:** The Feed Preparation System provides 30 days of additive inventory.

Basis: Enough bulk storage is available so that shipments can be easily

scheduled and plant operations are not threatened by short-term interruptions in delivery.

G. **Assumption:** The feed and additives required by the melter are blended in a batch blender.

Basis: Engineering judgement.

G.5.2.3 Key Equipment Descriptions

The Additive System consists of three 2,000-ft^3, carbon steel, storage bins with conical bottoms, rotary plug valves, bin vibrators, blowers, and baghouses. There is a Pneumatic Conveying System for transferring bulk additive deliveries from trucks to the bins and for transferring the required quantity of material from the bins to the feed mixer.

The slurry receipt tank that stores Silos 1 and 2 material slurry from the TTA is a 30,000-gallon carbon steel tank with a top mounted agitator. At the maximum inlet feed rate of 59,000 lb/hr, it has a storage capacity of four hours.

The milled slot screen separates feed into a product stream with particles smaller than 30 mesh, oversize stream with particles >30 mesh, and a trash stream with particles above 0.75 inches. The feed mill reduces oversize stream particles to <30 mesh and sends them to the slurry receipt tank. The mill can handle up to 2,100 lb/hr.

The centrifuge consists of a horizontal solid bowl fitted with an inner contoured scroll conveyor. It uses a cyclo-gear speed reducer for changing the differential speed between the rotating bowl and the scroll conveyor. All wetted parts are 316 L stainless steel. The centrifuge has a tight fitting cover. Tungsten carbide scrapers are used to eliminate sludge build up in the cake discharge section. Each centrifuge has a 200 horse power (HP) variable speed main drive and a 40 HP variable speed back drive.

The slurry receipt transfer pumps, which feed the centrifuges, are 140 gpm Moyno-type positive displacement pumps, whereas the centrate pumps from the centrifuges are centrifugal pumps.

The centrate tank is a 5,000-gallon carbon steel tank with a top mounted agitator.

The dryer mixer can mix up to 56,000 lb of dry material with 5 wt% moisture and 8,000 lb of filter cake with 8,000 lb/hr of water; and, the resultant material, with 15 wt% moisture, enters the dryers. The material of construction is carbon steel including mix trough, paddle assembly, and inlet/outlet nozzles. Each agitator assembly has two shafts with 40 paddles on each shaft and is driven by a 15 HP motor. Each dryer pair has its own dryer mixer.

There are two sets of dryers, one being a spare, that can each dry 72,000 lb of material from 15 wt% moisture to 5 wt%. Each has an integral scale. The heating is done by a high-temperature thermal fluid at an inlet temperature of 550° F. The screws on each dryer are driven by a 40 HP motor.

The 16 million British thermal units (Btu) per hour Thermal Fluid Heating System for the dryers includes: a modulation burner, air blower and motor, gas train and flame safety system, fluid circulation pumps, a 1,000-gallon expansion tank, a 2,000-gallon drain tank, an exhaust stack, and necessary controls.

There are two sets of drag chain recycle conveyors for recycling up to 56,000 lb/hr of the dry material back to the dryer mixer. The drag chain conveyor has a "Z" path configuration. It is driven by a 10 HP motor.

The dry feed mill reduces the particle size of the material from the dryer to <30 mesh. It is made of carbon steel and has a split top housing and a hinged removable cover to change screens and hammers. The solid shaft has slip-on hammer arms. It is driven by a 15 HP motor.

The direct-contact spray condenser for the dryers can condense approximately 8,000 lb/hr of steam. The dimensions are 4 ft in diameter by 19 ft in height and the material of construction is 304 low carbon stainless steel. The condenser circulates 800 gpm water through eight spray nozzles.

The dryer condenser cooler consists of two shell and tube exchangers in series. The hot side flow rate is 800 gpm, 145° F in and 125° F out; the cold side flow rate is 550 gpm of cooling water, 85° F in and 115° F out.

There are three feed storage bins that are approximately 730 ft^3 in capacity, and 8 ft in diameter and 20 ft in height. They are constructed of carbon steel with conical bottoms, rotary feeder valves, bin vibrators, and baghouse vent filters. There are Pneumatic Conveying Systems for both transferring material from the milled waste bin to the feed storage bins and for transferring the required quantity of feed material from the bins to the feed mixer.

The feed mixer has a capacity of 100 ft^3 and is 42 inches in diameter by 10 ft in length; it's constructed of carbon steel, and has a ribbon mixer driven by a 40 HP motor. It is installed on weigh cells so that the required quantity of feed material and additives is transferred to it sequentially and readily measured.

The feed surge bin also has a capacity of 100 ft^3 and is 4 ft in diameter by 12 ft in height with a bin vibrator, an air pad in the cone section, and a rotary valve.

The feed weigh feeder consists of a weigh hopper, auger feeder, weigh cells, and controls to continuously feed 1,535 lb/hr of material to the melter.

G.5.2.4 System Interfaces

The Feed Preparation System interfaces with the following SSC:

- Electrical power for instrumentation and motors.
- Compressed air for solids transfer and various pneumatically operated valves, diverters, bin aerators, air slides, dense phase pumps, dust collectors and instrumentation and controls.
- Silos 1 and 2 material slurry that enters via a pipeline from the Silos 1 and 2 material retrieval process.
- Bulk additive trucks that have standard pneumatic transfer couplings for connection to bulk storage tank piping.
- Additives leaving their storage bins that go through a dense-phase pneumatic transfer line to the feed mixer.
- Process vessel vents that exhaust via pipeline to the RCS.

G.5.2.5 Recycle Back to the TTA

The centrate containing fine solids is recycled back to the TTA to be used as slurrying water.

G.5.3 Treatment (System 17)

G.5.3.1 System Description

The Melter (and Product Handling) System receives a blended mixture containing Silos 1 and 2 material feed and additives from the Feed Preparation System. The blended mixture of Silos 1 and 2 material slurry and dry additives is accurately metered and continuously fed to the melter, where it is heated to 2350°F in a cyclonic natural gas flame and converted into a molten glass product. Control of the natural gas and combustion air to the melter is conventional with ultraviolet flame detection. The off-gas and molten glass from the combustion section of the melter passes through a separator/reservoir section at the bottom. Following discharge into a cooling water reservoir, the glass frit that forms is cooled and conveyed directly into concrete shipping and disposal containers. The off-gas is vented to the Normal Off-gas System for removal of particulates, acid gases, and radon. The melter operates at a slight positive pressure while the downstream Normal Off-gas Treatment System is maintained at a negative pressure.

The melter is placed over a catchment sized to contain any glass spill. The melter is inside a building that serves as secondary confinement. Radon detectors inside the building provide real-time notification of radon leakage from the melter. If radon is detected, stoppage of material feed to the melter quickly stops radon releases.

G.5.3.2 Assumptions

A. **Assumption:** The melter operates 24 hr/day, 7 days/week and production is only interrupted for maintenance, emergencies, and planned outages.

Basis: High temperature melters operate most efficiently when operated continuously. Cycling on and off damages the refractory and increases energy use.

B. **Assumption:** The melter is fed continuously with 1,535 lb/hr of the feed mixture containing dry Silos 1 and 2 material and additives.

Basis: Vortec Corporation. 1999. *Silos 1 and 2 Proof of Principle Project, Final Report*; Process Flow Diagram **(Appendix H, Attachment H2)**.

C. **Assumption:** The total feed required for the continuous (24 hr/day, 7 days/week) operation of the melter is stored in the feed storage bins.

D. **Assumption:** The melter is cooled with cooling water from a new cooling tower installed specifically for this project. The cooling water temperature is 85° F.

Basis: The FEMP site does not have cooling water available for process cooling requirements. The water temperature is a function of the 78° F maximum wet bulb temperature at the FEMP.

G.5.3.3 Key Equipment Descriptions

The combustion melter is an integral unit complete with the melter, reservoir/separator, forced draft (FD) fan, and gas-fired combustion air preheater. The overall dimensions are 22 ft wide by 22 ft long by 50 ft high.

The primary components of the melter are the counter-rotating vortex (CRV) reactor and the cyclone melter. The CRV provides for rapid suspension heating and oxidation of feedstock materials before physical and chemical melting processes that occur within the cyclone melter directly below it.

Organic contaminants in the feedstocks are effectively oxidized. Gaseous products and preheated feedstock from the CRV reactor enter the cyclone melter where the solids are separated to the chamber walls, and glass forming chemical reactions occur. The molten material and the gases exit the cyclone melter to the separator/reservoir, where a pool of the molten material is collected. The molten material exits the reservoir through a bottom or side tap, and the flue gases are treated by the Normal Off-gas Treatment System before being exhausted through the stack.

The glass product is cooled by direct contact with water to form granular frit. The cooled frit is conveyed from the water bath by a drag conveyor and deposited directly into shipping and disposal containers. Residual heat should dry the frit sufficiently while being packaged. An absorbent is placed in the container if all of the water does not evaporate from the frit.

G.5.3.4 System Interfaces

The treatment system interfaces with the following SSC:

- The mixture of feed and additives, which have been blended together, that is fed continuously, at a controlled rate, from the feed weigh feeder.
- Molten glass that exits the melter to produce a granular frit that is deposited in the shipping and disposal containers by the glass handling system.
- Glass product that leaves the glass packaging facility via a conveyor.
- Melter off-gas that leaves via one of two pipelines, one to the Normal Off-gas System and one to the Emergency Off-gas System.
- Natural gas that enters via a pipeline from the FEMP site natural gas header.
- Electrical power for instrumentation and motors.
- Compressed air for pneumatically operated valves.
- Cooling tower water that is required for cooling the melter shell.

G.5.3.4 System Interfaces

The treatment system interfaces with the following SSC:

- The mixture of feed and additives, which have been blended together, that is fed continuously, at a controlled rate, from the feed weigh feeder.
- Molten glass that exits the melter to produce a granular frit that is deposited in the shipping and disposal containers by the glass handling system.
- Glass product that leaves the glass packaging facility via a conveyor.
- Melter off-gas that leaves via one of two pipelines, one to the Normal Off-gas System and one to the Emergency Off-gas System.
- Natural gas that enters via a pipeline from the FEMP site natural gas header.
- Electrical power for instrumentation and motors.
- Compressed air for pneumatically operated valves.
- Cooling tower water that is required for cooling the melter shell.

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 Trade Study* 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.

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.

Interim Staging Facility Crane

This crane is a remotely operated bridge crane with a rated capacity of 15 tons, with a span of 70 ft, a travel of 173 ft and a lift height of 20 ft. The crane is equipped with a special grapple device to lift, move, and place the shipping and disposal containers. In addition, the bridge crane has CCTV capacity to ensure positive grappling and placement of the shipping container.

Fill Station

The fill station deposits the glass frit into a shipping container. The frit is conveyed by a drag conveyor with two strands of deslagger chain and 5-inch channel flights spaced 3 ft apart and a discharge height of 8 ft. The frit conveyor is operated continuously while pouring glass to prevent overcooling of the glass in the water tank. A shipping container is positioned and sealed to the discharge opening using a hydraulic lift to raise the shipping container. The shipping container supports are equipped with load cells for weighing the deposited glass frit remotely and indicating the weight on a display in the control room.

Lid Installation Station

The lid installation station consists of custom designed equipment for grappling and removing and/or installing shipping container lids. The grapple uses rigid mechanical linkages for accurate and efficient operations.

Lid Fastening Station

The lid fastening station consists of a remote wrench mounted on a frame that aligns with the bolt pattern of the shipping container. The operator views the lidding operation either by CCTV or through shielded glass viewing windows. The wrench is actuated up and down and may be lowered to engage the bolt heads and tighten or loosen them as required.

G.5.4.4 System Interfaces

The Product Handling System interfaces with the following SSC:

- Electrical power for motors, instrumentation, and monitors.
- The glass forming system quench tank drag conveyor discharge that couples with the shipping container.
- The shielded and unshielded airlock doors and window systems that are employed to protect workers and segregate work stations.
- CCTV cameras and monitors that are used to ensure positive control of shipping container operations.
- A forklift that transports and places empty shipping and disposal containers on the load-in conveyor.
- The treatment facility transfer conveyor, the shipping container, and the staging facility crane that work together as a system.

G.5.5 Gaseous Emission Control (Systems 18 and 20)

The Gaseous Emission Control System is responsible for collecting all off-gas and vent streams and properly treating them.

G.5.5.1 System Description

Process Exhaust

Hot off-gas from the melter is introduced to the Quench Tower (18-PE-001) where point quench spray nozzles deliver water to cool and condense the melter off-gas. The quench spray water is recycled through the Quench Tower Cooler (18-HE-001), which is cooled by cooling tower water. A purge/blowdown stream is drawn off and sent to the Filter Feed Tank (18-TK-003) for pH adjustment. Solids are separated from the purge stream by filtration and then recycled to the Feed Preparation System.

The remaining air and acid gases are treated in a Packed-Tower Scrubber (18-PE-002). 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 Cooler (18-HE-002), which is cooled by cooling tower water. The pH is monitored with a real-time pH sensor and 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 coming from the scrubber is vented to the WESP (18-PE-003). The WESP removes the smaller particles with >99% efficiency. Captured particulate from the WESP is directed to the filter feed tank for pH adjustment and filtration before being recycled to the Feed Preparation System.

The off-gas from the WESP passes to the NO_x removal system (20-RN-001) to reduce NO_x levels to a maximum of 20 ppm. The off-gas then passes through the off-gas condenser (20-HE-001) where it is cooled with chilled water/glycol solution to condense the remaining water. The condensate is collected and staged for wastewater treatment. The off-gas is now acceptable for feed to the RCS.

Approximately 500 scfm of the off-gas from the off-gas condenser is directed to the existing RCS. After treatment, this off-gas is vented to the RCS stack.

The remaining off-gas (approximately 300 scfm) passes through an air dryer package (20-RN-002 A or B) to remove all water. The off-gas is then cooled in the off-gas cooler (20-HE-002) before going to the multiple carbon beds (20-RN-003 and -004) for radon removal. The off-gas from the carbon beds passes through a HEPA filter (20 FL-001 A or B) and fan (20-FA-001 A or B) before finally being discharged from the RCS stack. The off-gas is monitored at the stack and the radon and particulate data is logged.

Process Vessel Vents

Vessels containing radon are vented to a process vessel vent (PVV) header. This 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 Zone 3 exhaust stack.

G.5.5.2 Assumptions

A. **Assumption:** The radon in the off-gas is equal to the radon that is in secular equilibrium with the radium in the melter feed.

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)

B. **Assumption:** Off-gas quenching and particulate removal in the WESP are performed in separate process steps from acid gas scrubbing.

Basis: Particulates should be recycled to the melter and acid gas solids (sulfates) should not be recycled to the melter, thus the separate operations.

C. **Assumption:** The quench tower water and the scrubber liquor are cooled by indirect heat exchange, with cooling water from a new cooling tower installed specifically for this project. The cooling water temperature is 85° F.

Basis: The FEMP site does not have cooling water available for melter cooling requirements. The water temperature is a function of the maximum 78° F wet-bulb temperature at the FEMP.

G.5.5.3 Key Equipment Descriptions

The quench tower is a direct-contact gas cooler-condenser. It is approximately 5½ ft long by 2½ ft wide by 10 ft high. It contains multiple spray nozzles to provide gas-liquid contact for most of its height. It recirculates approximately 230 gpm of water through the spray nozzles; this water is cooled by approximately 200 gpm of cooling tower water in the quench heat exchanger. No pH adjustment is performed in the Quench Tower, which allows it operates under acidic conditions (pH ~ 2.5) and prevents the absorption of acid gases.

The scrubber is a packed tower unit approximately 3 ft wide by 3 ft long by 35 ft high. It recirculates approximately 50 gpm of scrubber liquor that is controlled to a pH of 8.0-9.0 in order to effect the absorption of SO_x. The recirculating liquor is cooled in the scrubber heat exchanger with approximately 50 gpm of cooling tower water.

The WESP uses high voltage electric fields to efficiently collect the particulate entering from the scrubber.

The system for the filtration of the purge streams from the quench tower and the WESP consists of a 1,500-gallon collection tank, a 70-gpm centrifugal filter feed pump, a precipitate filter for filtering 70 gpm of water containing 1 wt% solids, and a 60-gpm centrifugal pump for recycling the filtrate.

The package for the destruction of NO_x in the off-gas can handle 800 scfm. It consists of four NO_x reactors, two effluent coolers, one effluent chiller, and one off-gas knockout drum.

The off-gas condenser is made of 304SS. The coolant consists of 30 gpm of chilled glycol solution at an inlet and outlet temperature of 35° and 55° F, respectively.

The air dryer package includes two desiccant beds, a regenerative heater, and a recirculation blower. The dew point of the outlet air from the package is -20° F.

The off-gas cooler is made of 304SS. The coolant consists of chilled glycol solution with an inlet temperature of 35 ° F.

There are two carbon beds in series, each containing 48,000 lb of carbon. The dimensions of each bed are 18 ft long by 10 ft wide by 10 ft high.

The HEPA filter systems have a prefilter and a single-stage final filter.

The off-gas fan discharging to the existing RCS stack has the capacity of 330 scfm and has a 10 HP motor. There is a spare unit.

G.5.5.4 System Interfaces

The Gaseous Emission Control System interfaces with the following SSC:

- Electrical power for various instruments and motors.
- Compressed air that is required for pneumatically operated valves.
- Off-gas that enters via a pipe from the Melter and Product Handling Systems.
- Off-gas that is exhausted through the stack to the atmosphere.
- Caustic solution that arrives by truck and is transferred to the caustic tank.
- Recycle solids that leave via a chute from the precipitate filters to the Feed Preparation System.
- Cooling tower water that is required for cooling the quench tower and scrubber recirculation loops.
- Condensate that is collected in a condensate tank and sent for wastewater treatment.

G.5.5.5 Emergency Off-gas System

The Emergency Off-gas System is auxiliary to the Normal Off-gas System and consists of a knock-out tank (18-TK-005) with an integral high-temperature filter (18-FL-002) to remove gross solids or liquids, a dilution air line to cool the off-gas, a high-temperature HEPA filter (18-FL-003), and a fan (18-FA-001) to a dedicated stack (18-ST-001). The Emergency Off-gas System activates when the Normal Off-gas System fails. In the event that the Emergency Off-gas System is required, feed to the melter is immediately suspended.

- Portions of the Emergency Off-gas System may become contaminated.
- The temperature of the exiting gases is monitored. Pressure drops across the in-line filters are monitored.
- The Emergency Off-gas System tank is equipped with an iso-kinetic monitor.

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G.5.6 Secondary Liquid Waste Treatment

G.5.6.1 System Description

All vessels, piping, etc., that contain either hazardous or liquid radioactive material require secondary confinement. Generally, this confinement consists of a diked pad with a sump and leak detection. All vessels and tanks containing unstabilized Silos 1 and 2 material are vented to the RCS.

The quench tower, scrubber, WESP, and off-gas condenser contain hazardous or contaminated liquids and are installed on diked pads. Any liquid collected from these pads is contained until characterized to determine its disposition. Purge streams from the quench tower and WESP are routed through the filter feed tank to the precipitate filters. Filter cake is returned to the slurry receipt tank for reprocessing of the solids therein. Filtrate is recycled to the quench tower and scrubber. The scrubber purge stream contains dissolved sulfate solids and cannot be recycled to the process.

G.5.6.2 Recycle

The purge streams from the quench tower, dryer condenser, and WESP are filtered and recycled to the quench tower and scrubber. These streams are not directed to the FEMP AWWT.

The centrate from the centrifuges, which contains fine particles, is returned to the TTA and is reprocessed. As water is inventoried in the recycle loop, it eventually has to be filtered and sent the AWWT for treatment and disposal. Ultrafiltration equipment from the AWR Project will be available for this requirement.

G.5.6.3 Discharge to FEMP AWWT

The purge stream from the scrubber and off-gas condenser (approximately 8,000 gallons per day) is staged, characterized, pretreated if necessary, and sent to the FEMP AWWT for treatment and disposal. (It is anticipated that this stream will meet the acceptance criteria for the AWWT; however, if it does not, a hold tank and filter may be required for pretreatment.)

G.5.7 Secondary Solid Waste Treatment

Secondary solid waste typically consists of the following:

- PPE;
- HEPA and prefilters;
- Wastewater treatment bag filters;
- Debris;
- Empty rework containers;
- D&D waste; and
- Filter cake from the precipitate filter.

G.5.7.1 System Description

Solid waste is collected and stored in appropriate shipping and disposal containers. It is characterized and disposed of per site procedures.

G.5.7.2 Recycle

The filter cake from the precipitate filter, at a rate of approximately 300 lb/hr, is sent to the slurry receipt tank and is recycled to the process area. It is not possible to recycle it directly to the dryers. The waste from the precipitate filter is generated continuously, since the melter section operates continuously. However, the dryers operate only 8 hr/day, 4 days/week.

G.5.7.3 Key Equipment Descriptions

The precipitate filter is an automated filter press located above the slurry receipt tank so it can gravity discharge down a chute into the tank.

G.5.8 Shipping Container Operations (System 25)

The filled shipping and disposal containers are stored in the interim staging facility before off-site shipment to an approved disposal site. The lifting and placement of shipping and disposal containers are performed remotely; however, intermittent contact, by the workforce, with the shipping and disposal containers is necessary to secure and prepare the shipment.

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G.5.8.1 System Description

A shipping container is grappled in the interim staging facility by a remotely operated bridge crane, lifted over a shield wall, and placed onto an open transport (i.e., flatbed truck) in the loading/shipping operations area. The shipping container is secured and prepared for off-site shipment. The external surfaces of the shipping and disposal containers are considered to be free of loose surface contamination. Documentation is provided to the shipping contractor who transports the shipment to an approved disposal site. The generation and buildup of radon is not anticipated to be a concern in the interim staging facility since the shipping and disposal containers are sealed before staging; therefore, the facility does not require special ventilation.

G.5.8.2 Assumptions

A. **Assumption:** One shipment consists of two filled shipping and disposal containers.

Basis: Standard FEMP shipping practice for a two-axle truck (limited to 42,000 lb).

B. **Assumption:** 10 shipments are made per day, 4 days per week.

Basis: Limits established to obtain public acceptance.

G.5.8.3 Key Equipment Descriptions

Staging Facility Remote Bridge Crane

The crane is a remotely operated bridge crane with a rated capacity of 15 tons, and a span of 70 ft, a travel of 173 ft, and a lift height of 20 ft. The crane is equipped with a grappling device and CCTV system camera to ensure positive grappling, movement, and placement of the filled shipping and disposal containers.

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G.5.8.4 System Interfaces

The shipping container operations interfaces with the following SSC:

- Electrical power for motors, instrumentation, and CCTV support equipment.
- Containerized frit that enters via the treatment facility transfer conveyor.
- A CCTV inspection system is used.
- The FEMP Waste Shipping Organization that monitors shipments.

G.5.9 Product Rework (System 26)

In addition to the federal, state and local shipping requirements, the glass frit must meet the NTS WAC. Therefore, provisions must be made to re-process any rejected glass frit. Rework of the rejected glass frit requires removing it from the shipping container and reintroducing it into the melter.

The TCLP and other characterization testing may not be completed before conveying the shipping container to the interim staging facility. The rejected shipping and disposal containers are taken to the rework room for emptying and then reintroduced to the melter.

G.5.9.1 System Description

Rework operations are carefully confined and performed remotely at the rework station. The glass frit conveyance components are remotely controlled by operators in the adjacent corridor. The rejected shipping containers are conveyed to the lid fastening station where the bolts are disengaged and the lids are removed. The containers are then conveyed to the rework station.

The vacuum hose is maneuvered by the robotic arm mounted on the rework bridge crane to collect all of the glass product. When the vacuum bin is full, it is emptied into the frit bin located above the melter for direct addition to the melter in accordance with product rework procedures.

G.5.9.2 Assumptions

A. **Assumption:** The number of shipping and disposal containers that are filled with frit and expected to fail the TCLP RCRA limits and/or NTS WAC is approximately 1% of the total quantity of disposal shipping and disposal containers (approximately 21 shipping and disposal containers).

B. **Assumption:** Frit pieces do not exceed ½ inch and move freely to be collected by the vacuum system.

G.5.9.3 Key Equipment Descriptions

Roller Conveyors

The roller conveyors are 7-ft wide heavy duty, motorized, chain driven, two-directional, roller conveyors of various length 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 above the rollers, 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.

Rework Vacuum

The rework vacuum is a standard production model with a HEPA filtered discharge. The system includes a cyclone bin to collect captured debris, a 6-inch diameter vacuum hose, and a rated capacity of 30 tons/hr.

Vacuum Bin

The vacuum bin is attached to the rework vacuum. The bin has a volume of 15 ft^3.

Frit Bin

The frit bin is a holdup bin for the recovered glass frit. The bin has a volume of 36 ft^3 and includes load cells, a vibrator, a rotary feeder valve, and gate valves. The air is filtered and returned to the vacuum unit.

Rework Bridge Crane

The rework bridge crane is a remotely operated bridge crane with a rated capacity of five tons and a span of 24 ft. The crane is equipped with a robotic arm and a 2-ton hoist for miscellaneous lifting operations. The robotic arm is used to handle the vacuum hose, perform clean up of the rework room, and provide versatility for performing many tasks.

G.5.9.4 System Interfaces

The Product Rework System interfaces with the following SSC:

- The product handling conveyors for conveyance of shipping containers.
- Electrical power is for motors, instrumentation, and a CCTV monitoring system.
- Facility HVAC System that provides the required heating and ventilation of the rework station.
- The frit bin that discharges the glass frit into the combustion melter.

G.5.10 Facility Design

G.5.10.1 Bulk Additives

The bulk additive building provides for receiving, storage, and transfer of bulk glassformer to the Feed Preparation System. The design uses three large bins and a pneumatic system to support production requirements for the glass former. The glass forming additives are pneumatically transferred to the additive bins inside the facility.

The building structure is a commercial grade sheet metal building. The height of the building is based upon the requirements of the storage bin that supports production. Stairs and platforms provide access to the storage bins and filter assemblies. Within the building, limited space is provided for maintenance requirements. The building has a large double door to allow for access. Filters and dust collectors are provided on the bins to prevent release of particulates during filling operations.

An unloading pad is provided next to the facility for bulk chemical truck deliveries and to contain accidental spills. Large quantities of additives are received by truck and are pneumatically transferred into the appropriate storage bin. Additives from the bins are pneumatically transferred to the Feed Preparation System.

The bulk additive building and the surrounding area is a non-radiological area. Access is not controlled.

G.5.10.2 Feed Preparation System

The system contains the process tanks, pumps and equipment to receive, concentrate, mix, and dry the silos material.

Equipment is in a radiologically controlled area due to the Silos 1 and 2 material's high concentrations of radium and radium daughter products. The area around the tanks is assumed to be a RAZ 5, high radiation area based on preliminary dose calculations. Because of this, the work area requires shielding, less time spent within those areas and, where possible, minimal sources (volume) to ensure lower dose rates for operations and maintenance workers over the plant life. The tanks containing the material are segregated and shielded in keeping with the ALARA principles of minimizing worker dose rates. They are surrounded by two-foot thick shielded walls due to the radiation field presented by the volume of Silos 1 and 2 material. The shield walls are modular in construction. The shield walls and concrete floor also perform duty as secondary containment in case of a spill or leakage from the tanks. The primary containment consists of the tanks themselves.

Although surrounded by concrete walls, the concentrate tank still requires accessibility for general maintenance of the mechanical equipment. Access to the tank at grade is through a labyrinth. A sump is located in the area to collect runoff. The top of the tank is accessible by ladder and platform. The platform on top of the tanks allows for maintenance to be performed on the agitators, control valves, and piping components. The pumps for the tank are located outside of the shield wall due to general service and maintenance requirements. The pumps are located behind half or "partial height" walls to control access, minimize dose rates, and contain leaks and spills.

Above the Normal Off-gas System is the remaining Feed Preparation System. The remaining equipment is located in separate rooms, within the facility, on different floors to control contamination. The room provides control access and controls the spread of airborne contamination. During normal routine maintenance, the room provides a controlled environment in which to perform maintenance tasks. The walls in the rooms provide shielding and are coated with a strippable paint. The rooms are accessed through airdock with space provided for step off pads outside of the airlock. Components can be lowered from upper floors through a vertical airlock containing hoist equipment. Personnel access to tall equipment and bins is by ladder and platforms.

The Feed Preparation System is covered by a roof over the tanks. The roof allows for operations and maintenance tasks to take place during local seasonal weather extremes. Portions of the roof can be removed for equipment removal by crane.

Radiation calculations show that the concrete wall alone is not enough to lower dose rates to personnel outside of the feed preparation area. To mitigate the dose rates to an acceptable level, a chain-link fence needs to be placed 10 ft away from the process area to isolate the area from casual personnel in the area.

G.5.10.3 Melter Feed System

The Feed Preparation System delivers the feed to the melter feed system. The feed and additives are fed into the melter. The recycled glass system also delivers crushed glass directly to the melter. The melter processes the feed into glass by combustion. During processing, the off-gas from the melter is removed and preliminary quenching and scrubbing of the gases is done.

The melter feed pumps, feed surge bin, recycle bin, melter, quench tank, quench tower, scrubber, and associated off-gas pumps are located in the melter room. The walls and roof are of typical 'stick built' architectural construction and are covered by a removable coating to facilitate decontamination. The walls are fire rated for two hours. The melter and melter feed pumps are accessed by a series of stairs in an adjacent airlock. The platform structure for the melter and associated equipment is very tall to allow for access.

Below the melter, an emergency dump container is located to catch leaking molten glass. It provides a safe method to empty the glass from the melter in case of an emergency.

Space is provided within the room for equipment that supports the melter operation. Platforms at various levels around the melter allow for servicing and disassembly of the equipment, and provides lay down space for large components. A davit crane allows for equipment components to be lowered from the platform structure to the floor. Dedicated drop zones have been identified. Supporting utilities (e.g., electrical, control system, melter cooling water, plant air) are brought into the melter room to support operations.

The glass cooling operation, frit forming package, is also located in the melter room. The frit quench tank and supporting pumps and exchanger are located within the room. Molten glass is poured from the melter into an enclosed trough. The trough flows into the quench tank. The cooled glass is removed from the tank by conveyor. The package allows the glass to anneal to an acceptable temperature level before packing.

The melter room benefits from the removal of radon by the Normal Off-gas System and is considered to be a RAZ 2, controlled area. Shielding is generally not required. Maintenance and operations tasks can be performed in the melter room up to a maximum of eight hours a week per worker.

G.5.10.4 Load-In Areas

The load-in areas provide access to the facility to allow shipping and disposal containers to enter the facility. Empty shipping and disposal containers are carried by forklifts into the facility through this area. A roll-up door allows normal forklifts to enter the facility. Within the area, space is provided for staging shipping and disposal containers to be used during the next two shifts. An airlock adjacent to the areas furnishes access to the frit loading (glass packaging) area and rework room.

The load-in area is enclosed in a prefabricated-type structure. The structure has an internal, engineered, steel framework. A PVC coated polyester fabric is stretched over the structural framework. HVAC for the area is provided by the facility system.

The load-in area is a RAZ 1, controlled area. Radiological guidelines for RAZ 1 areas allow for 40 hr/week occupancy.

G.5.10.5 Fill Station

The shipping container is remotely filled with glass, weighed, and sealed in the fill station room.

The fill station is located adjacent to the melter room and the frit forming package area. The room contains the equipment used to fill the shipping container.

With the container sealed, radiological technicians, dressed in appropriate PPE, move through the adjacent airlock into the survey/decon room and along each side of the conveyer. Because of the 70 mrem/hour exposure rate from the container, the technicians smear the outside of the container from a distance with long reach tools. If the container is found to be contaminated,

these same tools are used to decontaminate the container. Once released, the container is moved by the roller conveyor into the airlock and then through an enclosed corridor to the interim container staging area.

The Process Sampling Systems, which provide for process control, accountability, diagnosis, and certification of compliance with waste acceptance product specifications, produce samples that must be archived. The Sample System allows for capture of a glass sample for TCLP testing. The sample is removed from the fill station through the adjacent airlock. The TCLP sample is collected to the analytical laboratory. Additional archive samples are collected and removed to the access point for the glass sample archive system in the cooling room.

The fill station room is only occupied for regulated maintenance tasks. The room is considered to be a RAZ 3, controlled area. It is potentially contaminated by glass from the filling and sampling operation. Access is allowed for a maximum of three hours a week per worker.

G.5.10.6 Off-gas

The off-gas area contains the additional process equipment to remove particulate and condition the gas stream before release to the RCS. If the Normal Off-gas System fails to function, the Emergency Off-gas System activates.

The primary components of the Normal Off-gas System, a quench tower and scrubber, are located in the melter room. The remaining portion of the system and the Emergency Off-gas System are located adjacent to the melter room next to the Feed Receipt System and are serviced by a small pipe rack. The equipment for the system is located on concrete pads. The floor within the room is sloped to a sump. The concrete is sealed to protect against potentially radioactive liquids penetrating the surfaces.

The emergency off-gas stack is approximately 80 ft tall and is accessed by ladder and platform. The stack is isokinetically monitored. The air, before being exhausted, is analyzed for air quality and the results are recorded.

Access into the area is controlled because of the possibility of contamination from equipment and component leaks and to protect against the spread of contamination. There is a chain barrier to stop casual access into the unit. Because there is a minimal dose rate from the equipment but a potential for contamination to be present, the area is considered to be a RAZ 1. It allows personnel to spend up to 40 hr/week within the area for operation and maintenance tasks.

G.5.10.7 Rework Room

The rework room is equipped to handle shipping and disposal containers and remove the failed glass product.

The glass frit that has failed TCLP is identified after the sample is analyzed in the fill station. A shipping container of failed product to be reworked is moved into the rework room during off hours by the roller conveyor.

The rework room is equipped with a small overhead bridge crane, a remotely controlled machine to vacuum the frit from the container, and a pneumatic system for transferring the rework glass to a hopper above the melter. A vacuum hose is attached to an arm to vacuum up the glass to a hopper that gravity feeds the melter. The container can then be moved into the fill station to be reused.

The rework room is normally an unoccupied area because of the exposure rate from the open container and the likelihood for contamination being present within the room. Minimal manual servicing is required for equipment within the room. Because of the potential for contamination being present, the concrete floor is sealed and the walls and equipment have a strippable coating to aid in decontamination of the room and equipment at the end of the facility's mission. The rework room is considered to be a RAZ 4, radiological area. Access is controlled by FEMP Health and Safety guidelines and requires a radiological work permit (RWP) and additional dosimetry before entering.

G.5.10.8 Facility Entrance

The facility entrance controls the entering/exiting of the facility.

The facility entrance is the main entrance and exit point for personnel working within the facility. Personnel log in when entering the facility. To exit the facility, personnel pass through radiation detection monitors and log out. Any other in-coming or out-going shipment passes through the load-in area under the control of a radiological technician. A desk is provided in the facility entrance for a radiological technician to supervise personnel movement.

The facility entrance is not expected to see a radiation source, but may see contamination carried by personnel attempting to exit. Because the treatment facility contains radioactive substances and has the potential to be contaminated, entering or exiting the facility must be supervised and controlled. For these reasons, the facility entrance is considered to be a RAZ 1. Personnel may occupy the area for up to 40 hr/week.

G.5.11 HVAC (Systems 73, 75, 76, and 77)

The areas in the treatment facility are designated as Zone 1, Zone 2, and Zone 3 and will have two HVAC Systems: one system exclusively for Zone 3 and the other for the combined Zones 1 and 2. Zone 2 does not have a dedicated HVAC System.

The following are the designated areas with corresponding equipment details for each zone.

G.5.11.1 Zone 3

A. The designated areas for Zone 3 are:

- Dry feed preparation area;
- Survey & decontamination room;
- Fill room;
- Melter room;
- Rework room;
- Feed pump room;

- Head installation room; and
- Dry feed storage room.

B. The HVAC details for Zone 3 include:

- Air handler with supply fan, filters and electric heat;
- Supply fan — 20,000 cfm;
- Electric heat — 500 kW;
- Exhaust fan — 20,000 cfm; and
- Exhaust filter that includes a pre filter with two stage HEPA filters and has 50% capacity backup.

The air handling unit and exhaust fans are designed for 100% capacity and 100% backup. Air handling units and exhaust fans are connected to emergency power because of the potential for hazards and equipment damage resulting from elevated temperatures if the systems are lost due to power failure.

There are three exhaust filters with 50% capacity (two are required for normal operation).

The electric heaters are not connected to emergency power.

C. Radon

The radon in the Silos 1 and 2 material is expected to be released to the off-gas system from the melter and treated through the RCS. The following are assumed for design basis: (1) all of the radon is initially driven off in the melter to the off-gas system; and (2) the glass will sufficiently contain the radon generated thereafter, such that treatment of the ventilation air around the glass through the RCS is not necessary. However, HEPA filtration is supplied on PVV systems downstream of the melter system.

G.5.11.2 Zones 1 and 2

A. The designated areas for Zone 1 are:

- HVAC room; and
- Access control room.

B. The designated areas (remainder)of Zone 2 are:

- Corridor; and
- Off-gas room.

C. The HVAC details for Zones 1 and 2 are:

- Air handler with supply fan, filters and electric heat;
- Supply fan - 17,000 cfm;
  - Electric Heat — Separate electric heat is provided for each room;
  - HVAC room 193 kW;
  - Access control room 14 kW;
  - Corridor 96 kW;
  - Off-gas room 128 kW;
  - Exhaust fan — 17,000 cfm; and
  - Exhaust filter that includes a prefilter with two stage HEPA filters and has 50% capacity backup.

The air handling units are designed for 100% capacity, without any backup. Air handling units and exhaust fans are connected to emergency power because of the potential for hazards and equipment damage resulting from elevated temperatures if the systems are lost due to power failure. There are two exhaust fans and two exhaust filters with 50% capacity (two are required for normal operation). The electric heaters are not connected to emergency power.

G.5.11.3 HVAC Stack

Two HVAC stacks are provided, one for Zone 3 and one for the combined Zones 1 and 2. The air, before being exhausted, is analyzed for air quality and the results are recorded.

G.5.12 Support Systems

The main support systems required are:

- A chiller package, designed for 20-ton capacity, supplying chilled water at 35°F. The chilled water return temperature is 55° F;
- A plant air compressor package, rotary screw-type, rated for 500 scfm @ 100 psig;
- A plant air dryer package, heatless twin tower regenerative desiccant-type, type, 475 scfm @ 100 psig;
- An instrument air dryer package, heatless twin tower regenerative desiccant-type,

45 scfm @ 100 psig; and

- A breathing air system consisting of a trailer with an air compressor, purification system, controls, alarms, 700 ft of hose, and a full capacity spare unit.

G.5.12.1 Analytical Support Laboratory/Services

The analytical laboratory has the instruments and facilities required for testing the feed, additives, process streams, off-gas, and wastestreams at different stages of the process.

G.5.12.2 Special Support Systems - Cooling Water

The Cooling Tower cools 1,000 gpm of water from 115° to 85° F. This is a standard recirculating Cooling Tower System using evaporative cooling and servicing all the plant's cooling water needs. Standard cooling tower controls are used. The cooling tower fan is controlled by the cooling water temperature. Makeup water is controlled to maintain the level in the cooling tower basin. The blowdown rate is controlled by the dissolved solids buildup in the cooling water. Standard, commercially available water treatment chemicals are used.

G.5.12.2.1 <u>Assumptions</u>

A. **Assumption:** The maximum wet bulb temperature at the FEMP site is 78 °F.

Basis: Standard engineering practice at the FEMP.

B. **Assumption:** The cooling water inlet is 115°F and the outlet is 85 °F.

Basis: Standard engineering practice at the FEMP.

C. **Assumption:** The cooling tower water is at a higher pressure than any other area where contaminate liquid is being cooled.

Basis: Standard practice to prevent contamination from entering Cooling Tower System.

G.5.12.2.2 <u>System Interfaces</u>

The support systems interface with the following SSC:

- Cooling water that enters the Cooling Tower System in pipes from the various users.

- Cooling water that leaves the Cooling Tower System in pipes to the various users.
- Potable water that enters the Cooling Tower System (as makeup water) in a pipe from the potable water header.
  - Blowdown water that leaves the Cooling Tower System in a pipe to wastewater treatment.
  - Compressed air for pneumatically operated valves.
  - Electrical power for various instruments and motors.

G.5.13 Utilities (Systems 30, 31, 32, 33, 40, 51, 52, 60, 90, and 94)

G.5.13.1 Natural Gas

Natural gas is used for direct heating inside the combustion melter, for indirect heating of the combustion air for the combustion melter, and for the hot oil, furnace heating for the screw dryers.

G.5.13.2 Compressed Air

Compressed air from 40-CM-001 is used for dense phase pneumatic transfers. The plant air system is used to blow down the filter cake during filter press operations.

G.5.13.3 Electrical

Normal Power System

The facility is supplied with electrical power at 13.2kV from the site distribution system. Two outdoor unit substations with oil-filled transformers rated 2500 kVa each transform the voltage to 480 Volts, three-phase, three-wire, 60 Hertz for use by the facility. Metering is provided to monitor the power consumption at 13.2 kV. The load is equally divided between the two unit substations. There is no secondary tie breaker. The total connected load is 4661 kVa, and the normal demand is 3041 kVa. Usage is estimated at 15,950,000 kWh/yr.

A 480-Volt switchgear in the unit substations distributes power to six motor control centers located in the Mechanical / Electrical Building, and to two (redundant) 500 kW heaters for Zone 3.

Standby Power System

The facility includes an outdoor 700 kW standby generator. The generator provides power at 480 Volts to MCC 31-MC-003 through an automatic transfer switch that starts the generator on loss of normal power and then switches the MCC to the generator when voltage is available. An integral fuel tank is sized for eight hours of operation.

The system includes an exercise panel that starts the generator once a week and runs it for 30 minutes. It sends an alarm to the control room if the generator fails to start.

All critical facility loads are connected to MCC 003. The critical facility loads are:

- required to prevent contamination to the treatment facility;
- required to prevent contamination to the outside environment;
- required for the safety of FEMP personnel; and
- required to prevent damage to equipment.

Uninterruptable Power System

The facility has a battery backed UPS rated 25 kVa for instrumentation and control system loads. This system filters out power system anomalies that could cause false information to be sent to the DCS or cause damage to sensitive electronic equipment.

The UPS receives power at 480 Volts, three-phase from MCC 003 and converts it to 208Y/120-Volt three-phase four-wire 60 Hertz power. The UPS includes a battery charger. The batteries provide power continuation for thirty minutes without any normal power input.

Motor Control Centers

The motor control centers are standard, commercially available UL listed equipment rated 800 Amps at 480 Volts, three-phase, three-wire. They are indoor units, 90 inches tall, 20 inches deep, and are composed of a series of vertical sections each 20 inches wide. They contain motor starters, feeder circuit breakers, and variable speed drive units. Each motor starter has a power

circuit protector that is pad-lockable in the off position, indicator lights to indicate motor status, start and stop pushbuttons, and a HOA selector switch. The selector switch selects between DCS control and control from the MCC. Extra contacts are provided on the selector switch, motor contactor, and circuit protector to send status information to the DCS.

The starters, feeder circuit breakers, and variable speed drive units are capable of draw-out removal for maintenance and replacement.

G.5.13.4 Control Systems

The facility operation is monitored and controlled by a DCS. The DCS consists of many remote I/O racks inside the plant (i.e., an I/O rack next to each cluster of equipment), and all the I/O racks are connected to the control room. The control system is capable, at a minimum, of the following functions:

- Collecting pertinent process parameters (e.g., temperature, pressure, density, and flow);
- Displaying information in an organized and logical manner on video monitors (the display program includes graphic features for displaying process parameters);
- Automatically or manually operating selected control loops and digital output signals for control of equipment (e.g., start, stop, speed up, and slow down) from the operator console;
- Initiating audible and visual alarms when designated process parameters are outside preset limits or status;
- Providing status indication of motor driven equipment HOA switches, motor contactors, and power disconnecting devices; and
- Reporting and displaying historical data.

Pneumatically operated pumps and on/off (fully open / fully closed) valves are operated by solenoid valves and controlled from the DCS with "run" and "stop" outputs for pumps and "open" and "close" outputs for the valves and interlocking functions. Each of these pumps has an attached manual operator.

Pneumatically operated ON/OFF valves have limit switches to provide status to the DCS.

Motorized valves have HOA switches in the MCC. The DCS provides indication or the HOA switch position. The DCS also indicates the direction the valve is being driven since there is no positive feedback from the valve position switches until it reaches the fully opened or closed position.

The emergency shutdown and fire alarm events, as described by the control philosophy, are controlled by the DCS.

Vessels, excluding off-gas treatment systems, containing contaminated material have butterfly valves on the vessel vent connection for creating and maintaining a negative air pressure in the vessels.

G.5.14 Special Health and Safety Considerations

During the "Detailed Design" phase of the project, a safety review of the process is conducted. This review considers all credible "what if" scenarios with input from people with different specialties such as Process, Mechanical, Electrical, Operations, Maintenance etc. The recommendations of this review are implemented to ensure safety of the process.

An "Ergonomic Review" of the design ensures that the operation does not cause any undue strain to the operators or maintenance people. A "Constructability Review" is conducted during the detailed design phase to ensure that it is safe and practical to install the equipment and complete all construction as per the design.

G.5.15 Special Environmental Considerations

The design basis for this alternative ensures protection of human health and the environment during the remediation of the Silos 1 and 2 material by incorporating the pertinent environmental regulatory requirements in the system design using the principles of environmental ALARA. The design allows all contaminated gas, liquid, and solid wastestreams generated during remediation to be collected and treated before being released to ensure adequate protection of human health and the environment.

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Attachment G.5.I

Mass and Energy Balance for the Vitrification — Other Technology

Attachment G.5.I
Mass Balance
Vitrification - Other

Stream #	1	2	3	4	5	6	7	7A	7B
Component	Air for Additive Transfer to Bins	Additive plus Air for Additive Transfer to Bins	Air for Additive Transfer to Weigh Feeder	Additive plus Air for Additive Transfer to weigh Feeder	Air for additive Transfer	Additives	Slurry	Milled Slurry	Milled Solids
Oxygen (LB/hr)	1,498	1,498	72	72	72				
Nitrogen (LB/hr)	4,932	4,932	237	237	237				
Methane (LB/hr)									
Carbon Dioxide (LB/hr)									
Water (LB/hr)							53,100	52,333	767
Solids (LB/hr)		24,000		6,000	10	6,000	5,900	5,133	767
Total (LB/hr)	6,430	30,430	309	6,309	319	6,000	59,000	57,466	1,534
Flow (scfm @70F and 1 Atm)	1,404		67			(67 C. Ft. /hour)			
Flow (gpm)							113	110	
Radon concentration (nCi/L)									
Radon flow (Ci/hr)									
Temperature (°F)	70	70	70	70	70	70	70	70	70
Pressure (in. H2O)									
Pressure (PSIG)									
Notes						Intermittent transfer. Additives and waste feed are mixed in the feedmixer in batches. The feed mixer can mix, per batch, material used up in the melter in 2 - 3 hours.	This is the intermittent, nominal filling rate. The actual rate (flow and % solids) will vary depending on pumping conditions.		
Dwg. Number 94X-5500-F-SK-	3396	3396	3396	3396	3396	3396 3419	3397	3397	3397

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Attachment G.5.I
Mass Balance
Vitrification - Other

Stream #	8	9	10	11	12	14	16	17	18
Component	Slurry	Wet Cake	Wet Cake	Centrate	Centrate	Make up water	Dry Solid (5%) Recycle	Dry Solid (5%) Recycle	Dry Solids (5%)
Oxygen (LB/hr)									
Nitrogen (LB/hr)									
Methane (LB/hr)									
Carbon Dioxide (LB/hr)									
Water (LB/hr)	78,376	8,000	8,000	70,376	70,376	25,000	2,800	2,800	421
Solids (LB/hr)	8,708	8,000	8,000	708	708		53,200	53,200	7,975
Total (LB/hr)	87,084	16,000	16,000	71,084	71,084	25,000	56,000	56,000	8,396
Flow (scfm @70F and 1 Atm)		(210 Ft^3/hour)	(210 Ft^3/hour)						
Flow (gpm)	166.4			141.0	141.0	50			
Radon concentration (nCi/L)									
Radon flow (Ci/hr)									
Temperature (°F)	70	70	70	70	70	70	212	212	212
Pressure (in. H2O)									
Pressure (PSIG)									
Notes	Designed for 8000 lbs/hour solids (dry basis), 32 Hours per week. However, the actual solids transfer rate will vary depending on slurry flow, % solids, and operating time.	One Centrifuge in operation, one full spare.	One Centrifuge in operation, one full spare.		Existing Tank and Pump	Intermittent, for flushing and dilution.	Design capacity @ 32 hours/week.	Design capacity @ 32 hours/week.	Design capacity @ 32 hours/week.
Dwg. Number 94X-5500-F-SK-	3397	3397 3421	3397 3421	3397	3397	3397	3421	3421	3421

Attachment G.5.I
Mass Balance
Vitrification - Other

Stream #	19	20	21	22	23	24	25	26A	26B
Component	Water Vapor	Air for Waste Transfer	Waste Plus Transfer Air	Condenser Circulating Water	Condenser Circulating Water	Condenser Circulating Water	Dryer Condenser Exhaust	Cooling Water Supply	Cooling Water Return
Oxygen (LB/hr)	10	118	118				10		
Nitrogen (LB/hr)	40	389	389				40		
Methane (LB/hr)									
Carbon Dioxide (LB/hr)									
Water (LB/hr)	7,579		421	274,606	26,703	7,576	3	274,600	274,600
Solids (LB/hr)	25		7,975	362	351	10	1		
Total (LB/hr)	7,654	507	8,903	274,968	27,054	7,586	54	274,600	274,600
Flow (scfm @70F and 1 Atm)		110					2		
Flow (gpm)				550	534	16		550	550
Radon concentration (nCi/L)									
Radon flow (Ci/hr)									
Temperature (°F)	212	70	70	125	95	95	110	85	115
Pressure (in. H2O)			10						
Pressure (PSIG)								50	20
Notes	Design capacity @ 32 hours/week.		8 hr/day, 4 Days per Week. Only one Dryer operating at a time	Solids will accumulate in the spray condenser until it attains the equillibrium solids concentration of 0.1 % while getting purged as 15 gpm as a 0.1% slurry.	0.1 % Slurry	Equivalent to an average flow entering the Filter Feed Tank of 1443 lb/hr water and 2 lb/hr solids.			
Dwg. Number 94X-5500-F-SK-	3421 3420	3421 3396	3421 3419	3420	3420	3420 3099	3420 3098	3420 3135	3420 3135

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Attachment G.5.I
Mass Balance
Vitrification - Other

Stream #	27A	27B	28A	28B	29	30	31	32
Component	Air for Dry feed Transfer	Air plus Dry Feed	Dry Feed	Dry Mixed Feed	Air	Dry Mixed Feed	Natural Gas	Combustion Air for Air Preheater Burners
Oxygen (LB/hr)	72	72			72			269
Nitrogen (LB/hr)	237	237			237			885
Methane (LB/hr)							61	
Carbon Dioxide (LB/hr)								
Water (LB/hr)		300	300	138		69		
Solids (LB/hr)		6,000	6,000	3,046	10	1,523		
Total (LB/hr)	309	6,609	6,300	3,184	319	1,592	61	1,154
Flow (scfm @70F and 1 Atm)	67				67		24	251
Flow (gpm)								
Radon concentration (nCi/L)								
Radon flow (Ci/hr)								
Temperature (°F)	70		70	70		70	70	70
Pressure (in. H2O)								
Pressure (PSIG)	90							
Notes	Intermittent transfer. Additives and waste feed are mixed in the feedmixer in batches. The feed mixer can mix, per batch, material used up in the melter in 2 - 3 hours.	Intermittent transfer. Additives and waste feed are mixed in the feedmixer in batches. The feed mixer can mix, per batch, material used up in the melter in 2 - 3 hours.	Intermittent transfer. Additives and waste feed are mixed in the feedmixer in batches. The feed mixer can mix, per batch, material used up in the melter in 2 - 3 hours.	Intermittent transfer. Additives and waste feed are mixed in the feed mixer in batches. The feed mixer can mix, per batch, material used up in the melter in 2 - 3 hours.				
Dwg. Number 94X-5500-F-SK-	3396 3419	3419	3419	3419	3419 3098	3419 3098	3098	3098

Attachment G.5.I
Mass Balance
Vitrification - Other

Stream #	33	34	35A	35B	36	37	38	39	40
Component	Compressed Air for Solids Transportation	Compressed Air for Atomization	Make up Air for Melter Burners Before Preheating	Combustion Air for Melter Burners Before Preheating	Combustion Air for Melter Burners after Preheating	Natural Gas to Melter	Melter Products and Off Gas to Reservoir	Cooling Water In	Cooling Water Out
Oxygen (LB/hr)	17	17	816	826	826		138		
Nitrogen (LB/hr)	57	57	2,677	2,717	2,717		2,717		
Methane (LB/hr)						172			
Carbon Dioxide (LB/hr)							473		
Water (LB/hr)			3	3	3		456	32,500	32,500
Solids (LB/hr)			10	10	10		1,523		
Total (LB/hr)	74	74	3,506	3,556	3,556	172	5,307	32,500	32,500
Flow (scfm @70F and 1 Atm)	16	16	772	774	774	68	873+GLASS		
Flow (gpm)								65	65
Radon concentration (nCi/L)									
Radon flow (Ci/hr)							0.19		
Temperature (°F)	70	70	60	60	1200	70	2350	85	115
Pressure (in. H2O)					13		1	50	20
Pressure (PSIG)	90	90				5			
Notes			The air available from the feed dust collector (Stream 29) is intermittent and, when present, will reduce Stream 35A by an equal amount.				Does Not Include Misc. Degradation Products: NOx, SOx, some CO2		
Dwg. Number 94X-5500-F-SK-	3098	3098	3098	3098	3098	3098	3098	3098 3135	3098 3135

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Attachment G.5.I
Mass Balance
Vitrification - Other

Stream #	41	42	43	44	45	46	47	48	50
Component	Molten Glass Product	Off- Gas from Reservoir /Separator	Emergency Off-Gas from Reservoir /Separator	Cooling Tower Water to Melter	Cooling Tower Water from Melter	Off-Gas from Quench Tower	Quench Tower Recirculation Water	Water to Quench Tower Spray Nozzles	Purge from Quench Tower
Oxygen (LB/hr)		138	138			138			
Nitrogen (LB/hr)		2,717	2,717			2,717			
Methane (LB/hr)									
Carbon Dioxide (LB/hr)		473	473			473			
Water (LB/hr)		456	456	57,130	57,130	496	114,424	84,547	29,850
Solids (LB/hr)	1,228	295	295			145	567	417	150
Total (LB/hr)	1,228	4,079	4,079	57,130	57,130	3,969	114,991	84,964	30,000
Flow (scfm @70F and 1 Atm)		873	873			900			
Flow (gpm)				115	115		230	169	60
Radon concentration (nCi/L)						125			28
Radon flow (Ci/hr)		0.19	0.19			0.19			0.003
Temperature (°F)	2350	2350	2350	85	115	140	125	95	95
Pressure (in. H2O)		-0.1	-0.1			-2			
Pressure (PSIG)				50	20		30	20	20
Notes		Plus a maximum of 6 LB/hr SOx	Plus a maximum of 6 LB/hr SOx			Plus Approx. 20 LB/hr SOx			
Dwg. Number 94X-5500-F-SK-	3098	3098 3099	3098 3135	3098 3135	3098 3135	3099	3099	3099	3099

Attachment G.5.I
Mass Balance
Vitrification - Other

Stream #	51	52	53	54	55	56	57	58A	58B
Component	Scrubber Recirculation Water	Water to Scrubber Spray Nozzles	Off-Gas from Scrubber	Comp. Air to WESP	Flush Water to WESP	Flush Slurry from WESP	Slurry Feed to Pressure Filter	Filtrate Recycle	Filtrate to Quench Tower
Oxygen (LB/hr)			138	13					
Nitrogen (LB/hr)			2,717	47					
Methane (LB/hr)									
Carbon Dioxide (LB/hr)			473						
Water (LB/hr)	28,212	25,500	195		1,305	1,305	32,598	32,301	29,890
Solids (LB/hr)			145			145	297		
Total (LB/hr)	28,212	25,500	3,668	60	1,305	1,450	32,895	32,301	29,890
Flow (scfm @70F and 1 Atm)			776	12					
Flow (gpm)	56	51			3	3.0	65	65	60
Radon concentration (nCi/L)			140			28	28	28	28
Radon flow (Ci/hr)			0.19			0.00014	0.003	0.003	0.003
Temperature (°F)	110	110	110	70	70	110	96	95	95
Pressure (in. H2O)			-4						
Pressure (PSIG)	30	30		90	50		100	20	20
Notes	Solids Are Neglected	Assuming that no solids get scrubbed out of the gas stream							
Dwg. Number 94X-5500-F-SK-	3099	3099	3099	3099 3396	3099	3099	3099	3099	3099

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Attachment G.5.I
Mass Balance
Vitrification - Other

Stream #	58C	59	60	61	62	63	64	65	66
Component	Filtrate to Scrubber	Filter Cake to Feed Prep	Purge From Scrubber	Purge to Waste Treatment	Off-Gas from WESP	Cooling Tower Water to Quench Tower Cooler	Cooling Tower Water from Quench Tower Cooler	Cooling Tower Water to Scrubber Cooler	Cooling Tower Water from Scrubber Cooler
Oxygen (LB/hr)					152				
Nitrogen (LB/hr)					2,763				
Methane (LB/hr)									
Carbon Dioxide (LB/hr)					473				
Water (LB/hr)	2,411	297	2,712	2,712	195	98,700	98,700	25,350	25,350
Solids (LB/hr)		297							
Total (LB/hr)	2,411	594	2,712	2,712	3,583	98,700	98,700	25,350	25,350
Flow (scfm @70F and 1 Atm)		(8 Ft^3 / Hour)			806				
Flow (gpm)	4.8		5.4	5.4		200	200	51	51
Radon concentration (nCi/L)	28	28	28	28	140				
Radon flow (Ci/hr)	0.0002	0.00005	0.00025	0.00025	0.19				
Temperature (°F)	95	95	110	110	110	85	115	85	100
Pressure (in. H2O)					-5				
Pressure (PSIG)	20		20	60		50	50	50	40
Notes									
Dwg. Number 94X-5500-F-SK-	3099	3397	3099	3099	3099 3114	3099 3135	3099 3135	3099 3135	3099 3135

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Attachment G.5.I
Mass Balance
Vitrification - Other

Stream #	67	68	69	70 A&B	71	72	73	74	75
Component	Off-Gas from NOX Package	Off Gas	Off-Gas	Off-Gas	Condensate from Off-Gas Condenser	Condensate from Air Dryers	Condensate to Waste Treatment	Chilled Water to Off-Gas Cooler	Chilled Water
Oxygen (LB/hr)	152	152	98	54					
Nitrogen (LB/hr)	2,763	2,763	1,769	994					
Methane (LB/hr)									
Carbon Dioxide (LB/hr)	473	473	303	170					
Water (LB/hr)	195	24	15	9	171	9	200	753	753
Solids (LB/hr)									
Total (LB/hr)	3,583	3,412	2,185	1,227	171	9	200	753	753
Flow (scfm @70F and 1 Atm)	806	745	477	268					
Flow (gpm)					0.4	0.0	0.4	2	2
Radon concentration (nCi/L)	140	150	150	150	7		6		
Radon flow (Ci/hr)	0.19	0.190	0.120	0.070	5.4E-6		5.4E-6		
Temperature (°F)	110	45	45	45	45	100		35	40
Pressure (in. H2O)	-5	-8	-8	-8					
Pressure (PSIG)									
Notes	Maximum of 20ppm NOx					Intermittent Flow Is Higher than above Average Flow		The Coolant is 50% Glycol	The Coolant is 50% Glycol
Dwg. Number 94X-5500-F-SK-	3114	3114	3114	3114	3114	3114	3114	3114	3114

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Attachment G.5.I
Mass Balance
Vitrification - Other

Stream #	76 A/B	77	78	79 A/B	80 A/B	81 A/B	82	83
Component	Chilled Water	Chilled Water Return From Process	Chilled Water Return From Chillers	Off-Gas From Air Dryer	Cooling Tower Water to Air Dryer	Cooling Tower Water From Air Dryer	Off Gas	Off Gas
Oxygen (LB/hr)				54			54	54
Nitrogen (LB/hr)				994			994	994
Methane (LB/hr)								
Carbon Dioxide (LB/hr)				170			170	170
Water (LB/hr)	15,740	16,493	35,000	8	5,000	5,000	8	8
Solids (LB/hr)								
Total (LB/hr)	15,740	16,493	35,000	1,227	5,000	5,000	1,227	1,227
Flow (scfm @70F and 1 Atm)				281			281	281
Flow (gpm)	30	32	70		10	10		
Radon concentration (nCi/L)				150			150	150
Radon flow (Ci/hr)				0.070			0.07	0.07
Temperature (°F)	35/55	52	25	80	85	105	80	45
Pressure (in. H2O)				-36			-36	-47
Pressure (PSIG)								
Notes	The Coolant is 50% Glycol	The Coolant is 50% Glycol						
Dwg. Number 94X-5500-F-SK-	3114	3114	3114	3114	3114 3135	3114 3135	3114	3114 3115

Attachment G.5.I
Mass Balance
Vitrification - Other

Stream #	84	85	86	43	87	88	89	90	91
Component	Off-Gas From Carbon Beds	Off-Gas to Stack	Diluent Air	EmergencyOff-Gas to EOG Knockout Tank	Off-Gas From EOG Knockout Tank Filter	Off-Gas From EOG HEPA Filter	Cooling Tower Water to Cooling Tower	Cooling Tower Makeup Water	Cooling Tower Water From Cooling Tower
Oxygen (LB/hr)	54	54	4,321	138	138	138			
Nitrogen (LB/hr)	994	994	16,253	2,717	2,717	2,717			
Methane (LB/hr)									
Carbon Dioxide (LB/hr)	170	170		473	473	473			
Water (LB/hr)	8	8		456	456	456	500,000	20,000	505,000
Solids (LB/hr)				295	30	10			
					0	0			
					0	0			
Total (LB/hr)	1,227	1,227	20,574	4,079	3,814	3,794	500,000	20,000	505,000
Flow (scfm @70F and 1 Atm)	281	281	4,510	873	5,383	5,383			
Flow (gpm)							1,000	40	1,010
Radon concentration (nCi/L)	3	3							
Radon flow (Ci/hr)	0.0014	0.0014							
Temperature (°F)	60	120	60	2350	500	500	115	60	85
Pressure (in. H2O)	-62	2		-1	-3	2			
Pressure (PSIG)			5				20	60	60
Notes			Intermittent. Runs only during emergency off-gas venting	Intermittent. Runs only during emergency off-gas venting	Intermittent. Runs only during emergency off-gas venting	Intermittent. Runs only during emergency off-gas venting	Does not include water to EOG Knockout Tank		Does not include water from EOG Knockout Tank
Dwg. Number 94X-5500-F-SK-	3115	3115	3135	3098 3135		3135	3135	3135	3135

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Stream #	92
Component	Cooling Tower Blowdown
Oxygen (LB/hr)	
Nitrogen (LB/hr)	
Methane (LB/hr)	
Carbon Dioxide (LB/hr)	
Water (LB/hr)	5,000
Solids (LB/hr)	
Total (LB/hr)	5,000
Flow (scfm @70F and 1 Atm)	
Flow (gpm)	10
Radon concentration (nCi/L)	
Radon flow (Ci/hr)	
Temperature (°F)	85
Pressure (in. H2O)	
Pressure (PSIG)	60
Notes	
Dwg. Number 94X-5500-F-SK-	3135

Attachment G.5.II

Drawings for the

Vitrification — Other Technology

DRAWING LIST
FOR
VITRIFICATION — OTHER TECHNOLOGY

Drawing Number	Title	Rev.
Process Flow Diagrams	94X-5500-F-	
SK-3419	FEED PREPARATION SYSTEM	2
SK-3420	FEED PREPARATION SYSTEM	2
SK-3421	FEED PREPARATION SYSTEM	2
SK-3099	NORMAL OFF-GAS TREATMENT	2
SK-3115	NORMAL OFF-GAS TREATMENT	2
SK-3135	EMERGENCY OFF-GAS & COOLING TOWER	2
SK-3098	MELTER AND GLASS HANDLING SYSTEM	2
SK-3114	NORMAL OFF-GAS TREATMENT	2
SK-3396	ADDITIVE PREPARATION SYSTEM	2
SK-3397	FEED PREPARATION SYSTEM	2
Mechanical Handling Diagram	94X-5500-M-	
SK-6017	REWORK	2
SK-6015	CULLET PRODUCTION	2
Facility Layout Drawings		
SK-1040	PLOT PLAN	2
SK-7427	INTERIM CONTAINER STAGING	2
SK-7411	PLAN @ EL. 0'-0" TO 15'-0"	2
SK-7412	PLAN @ EL. 15'-0" AND ABOVE	2
SK-7414	DETACHED PLANS	2
SK-7413	SECTIONS	2
SK-7415	ADDITIVE STORAGE BINS	2
SK-7444	SECTIONS	2
SK-7443	SECTIONS AND DETAILS	2
SK-7445	RCS PLAN AND SECTION	2

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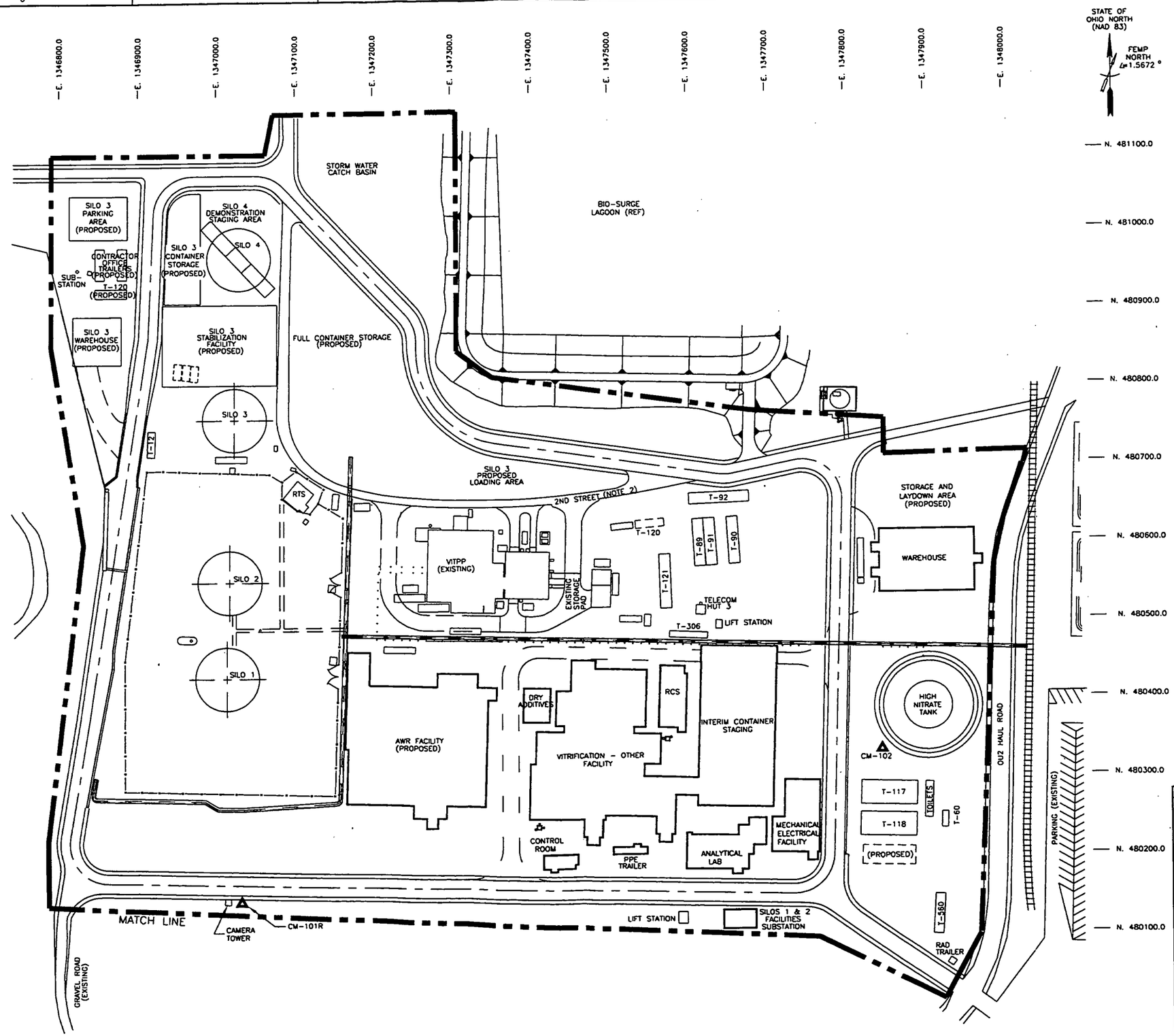


NOTES:

1. LOCATION OF FENCES, GATES AND CHECK POINTS TO BE DETERMINED.
2. THIS SECTION OF 2nd STREET TO BE USED BY PEDESTRIAN, LIGHT DUTY, OCCASIONAL DELIVERIES TO OU1, AND EMERGENCY TRAFFIC ONLY.
4. CONSTRUCTION AND OPERATIONS PERSONNEL WILL USE EXISTING SITE PARKING LOT.
5. FDF SHALL COORDINATE LAND USE WITH THE WASTE PIT REMEDIAL ACTION PROJECT (WPRAP) HEALTH AND SAFETY REPRESENTATIVE, PRIOR TO FINALIZATION OF LAND USE. FAILURE TO DO SO COULD PRESENT AN UNREVIEWED SAFETY QUESTION, THUS INVALIDATING EITHER OF THE PROJECT'S (SILO 3 AND/OR WPRAP) SAFETY BASIS.
6. INFRASTRUCTURE ROAD IS TO BE DOUBLE LANE.

LEGEND OF SYMBOLS

▲ = MONUMENT

PRELIMINARY DRAWING

0 25 50 100 150 200 250
GRAPHIC SCALE
1" = 50'

000501

CADFILE SK-1040	CADSOFT ACAD R14

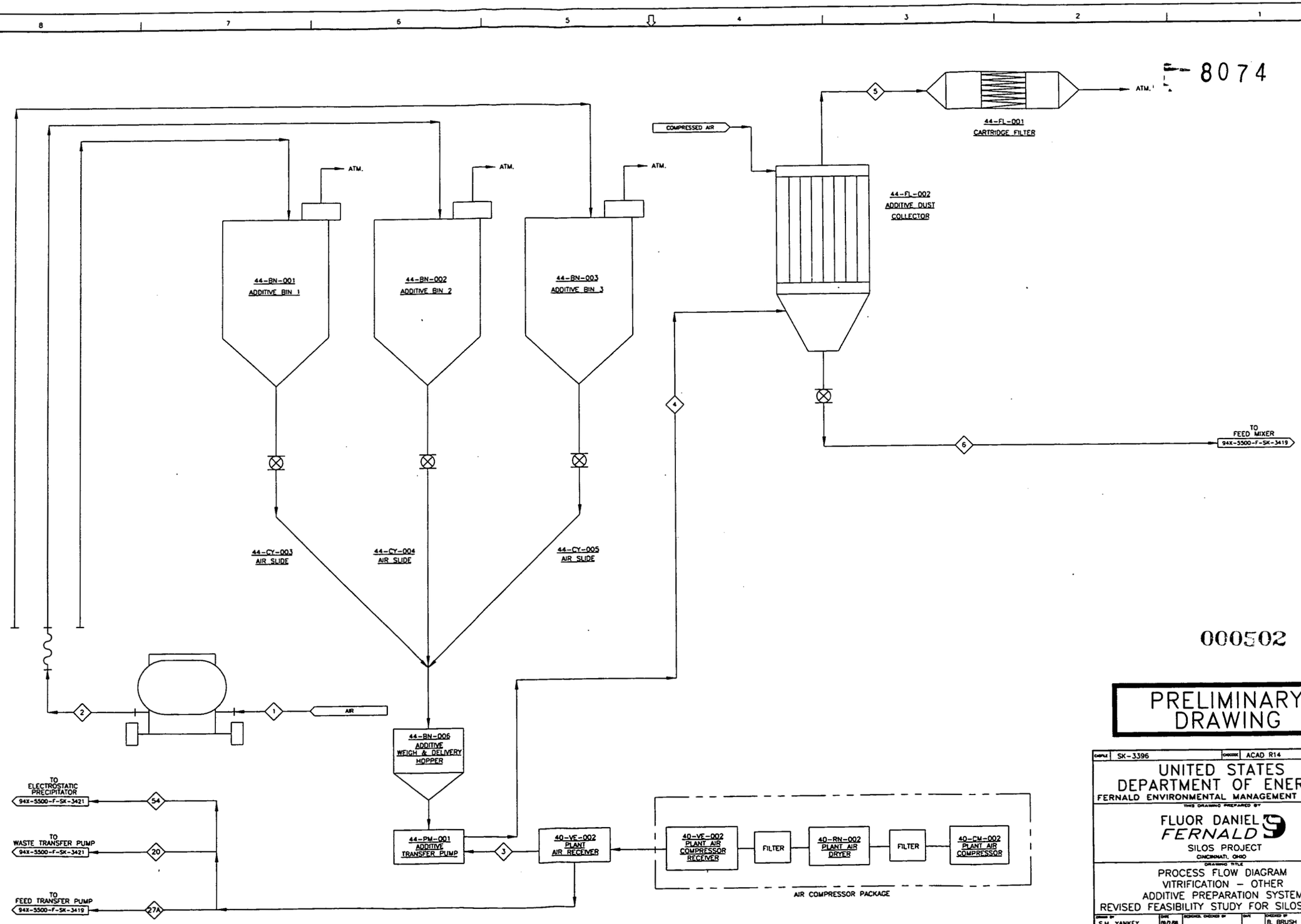
UNITED STATES
DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

THIS DRAWING PREPARED BY
FLUOR DANIEL FERNALD
SILOS PROJECT
CINCINNATI, OHIO

DRAWING TITLE
FACILITY LAYOUT
VITRIFICATION -OTHER
PLOT PLAN
REVISED FEASIBILITY STUDY FOR SILOS 1 & 2

DRAWN BY S.M. YANKEY	DATE 12/15/98	SCIENCE CHECKED BY	DATE	CHECKED BY J. THOMPSON	DATE 8/16/99
PLANT/BLDG. NO. OU4		FLOOR		SCALE 1"=50'	CLASS
SUBMITTED FOR APPROVAL		APPROVAL RECOMMENDED			
A-E DATE		OPERATING CONTRACTOR DATE			
CDE PROJECT NO. 40730	OPER. CONTR. PROJ. NO. WBS2.1.3.G.P	DRAWING NO. 94X-5500-G-SK-1040		SHEET NO. 1	REV. NO. 2

DISTRIBUTION CODE: XXX ACAD INITIALS: RWR DATE: 12/1/99



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CAD FILE	SK-3396
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FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

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FLUOR DANIEL
FERNALD
SILOS PROJECT
CINCINNATI, OHIO

DRAWING TITLE

PROCESS FLOW DIAGRAM
VITRIFICATION – OTHER
ADDITIVE PREPARATION SYSTEM
REVISED FEASIBILITY STUDY FOR SILOS 1 & 2

DRAWN BY S.M. YANKEY	DATE 09/2/98	REVIEWED, CHECKED BY	DATE	CHECKED BY B. BRUSH	DATE 1/31/99
PLANT/AREA NO. OU4		FLOOR		SCALE NONE	CLASS
SUBMITTED FOR APPROVAL		APPROVAL RECOMMENDED			
A-E	DATE	OPERATING CONTRACTOR	DATE		

DOE PROJECT NO.	OPER. CONTR. PROJ. NO.	DRAWING NO.	SHEET NO.	REV. NO.
40730	WBS2.1.3.G.P	94X-5500-F-SK-3396	1	2

DISTRIBUTION CODE: XXX

ACAD

INITIALS: RMR
DATE: 12/1/99

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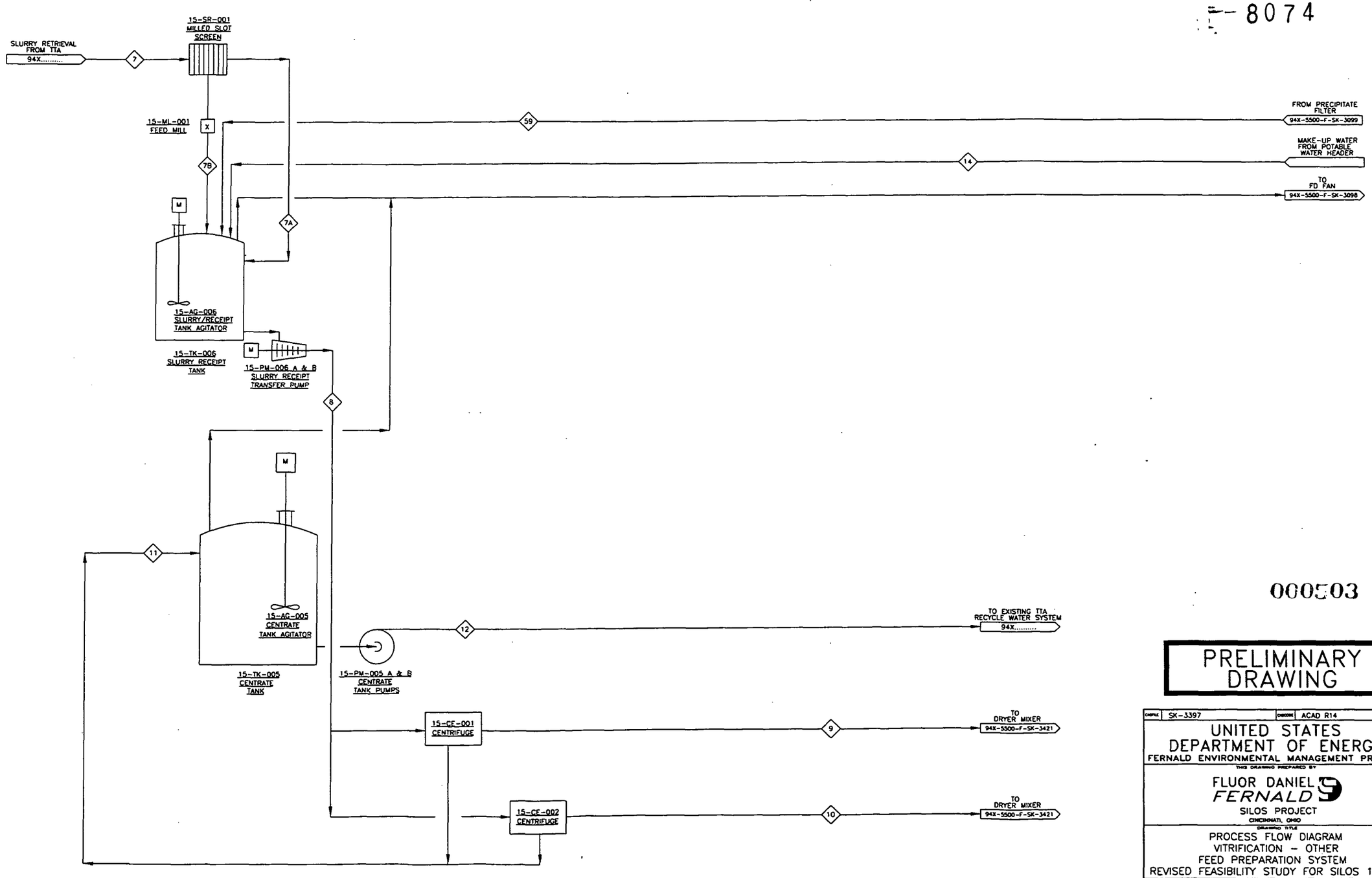

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PRELIMINARY DRAWING

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DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

THIS DRAWING PREPARED BY

FLUOR DANIEL FERNALD
SILOS PROJECT
CINCINNATI, OHIO

DRAWING TITLE

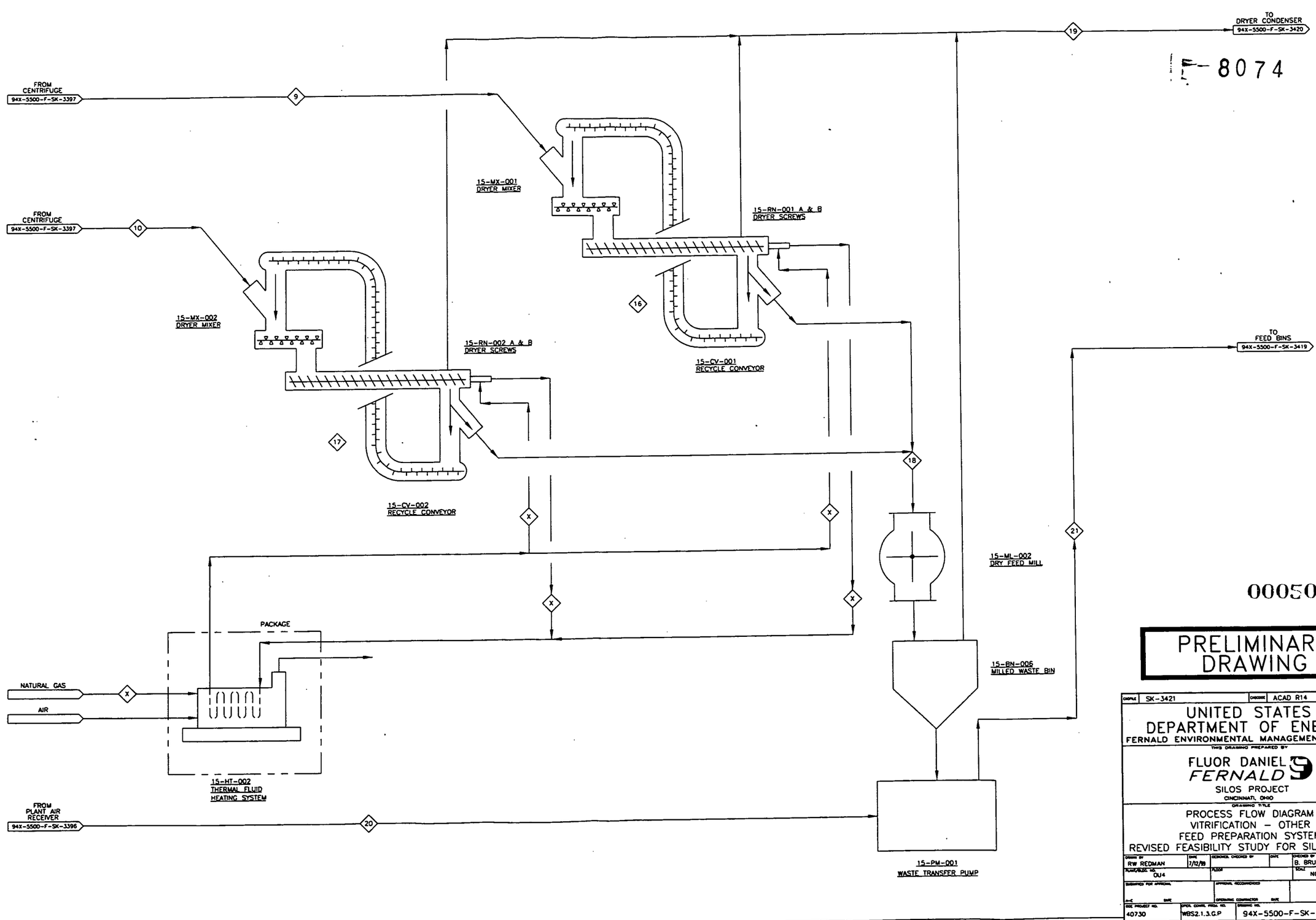
PROCESS FLOW DIAGRAM
VITRIFICATION - OTHER
FEED PREPARATION SYSTEM
REVISED FEASIBILITY STUDY FOR SILOS 1 & 2

DRAWN BY S.M. YANKEY	DATE 09/2/98	DESIGNED, CHECKED BY	DATE	CHECKED BY B. BRUSH	DATE 7/30/99
PLANT/BLDG. NO. OU4	FLOOR			SCALE NONE	SCALE
SUBMITTED FOR APPROVAL		APPROVAL RECOMMENDED			
A-E	DATE	OPERATING CONTRACTOR	DATE		
DOE PROJECT NO. 40730	OPER. CONTR. PROJ. NO. WBS2.1.3.G.P	DRAWING NO. 94X-5500-F-SK-3397		SHEET NO. 1	REV. NO. 2

DISTRIBUTION CODE: XXX

ACAD

INITIALS: RWR
DATE: 12/1/99



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PRELIMINARY DRAWING

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UNITED STATES
DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

THIS DRAWING PREPARED BY

FLUOR DANIEL FERNALD
SILOS PROJECT
CINCINNATI, OHIO

DRAWING TITLE

PROCESS FLOW DIAGRAM
VITRIFICATION – OTHER
FEED PREPARATION SYSTEM
REVISED FEASIBILITY STUDY FOR SILOS 1 & 2

DRAWN BY: RW REDMAN	DATE: 7/12/99	REVIEWED, CHECKED BY	DATE	CHECKED BY: B. BRUSH	DATE: 7/23/99
PLANT/BLDG. NO.: OU4		FLOOR		SCALE: NONE	CLASS
SUBMITTED FOR APPROVAL		APPROVAL RECOMMENDED			
FMC	DATE	OPERATING CONTRACTOR	DATE		
FMC PROJECT NO.: 40730		OPER. CONTR. PROJ. NO.: WBS2.1.3.G.P		DRAWING NO.: 94X-5500-F-SK-3421	SHEET NO.: 1 / REV. NO.: 2

DISTRIBUTION CODE: XXX

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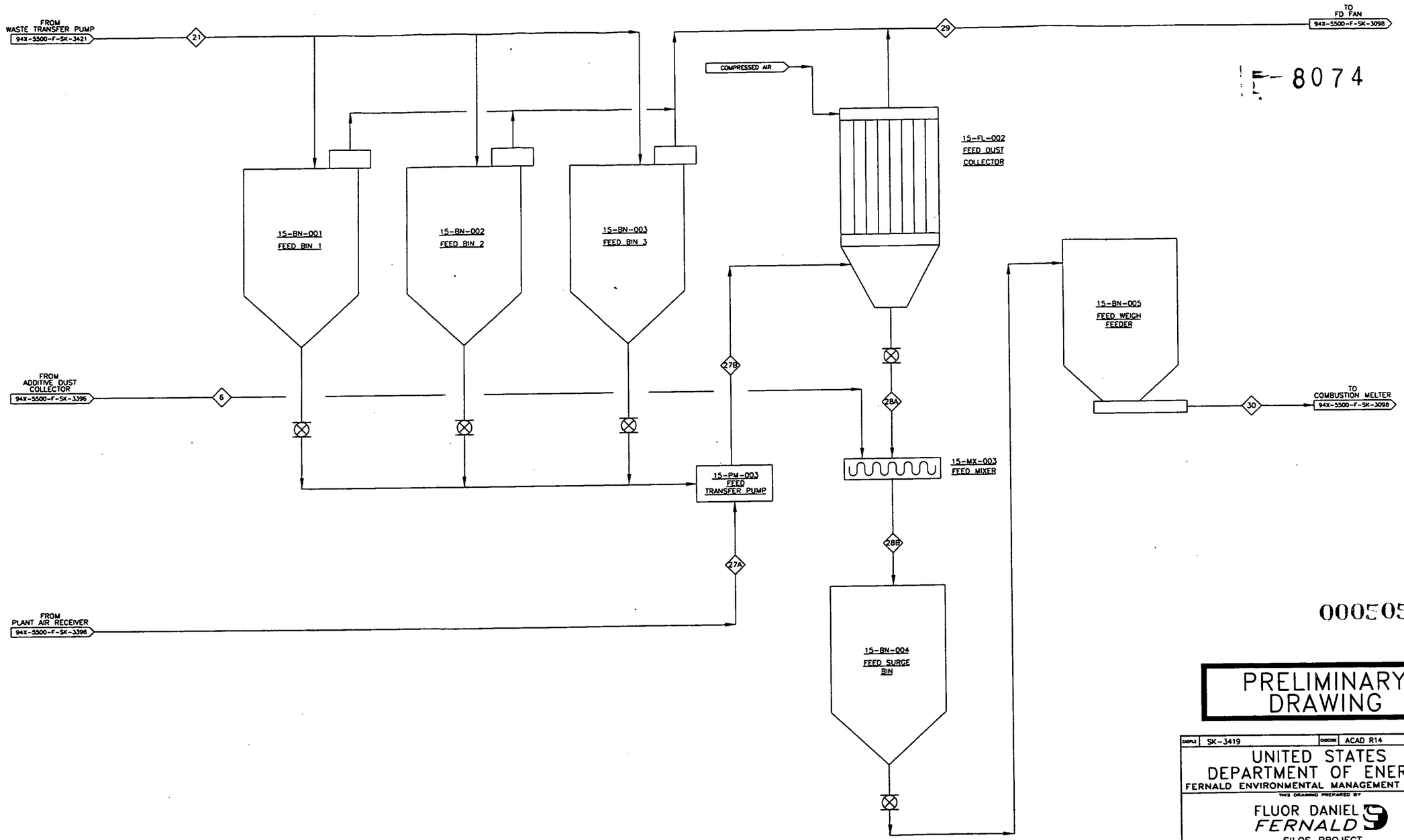
INITIALS: RWR
DATE: 12/1/99



8074

000505

PRELIMINARY DRAWING

CADFILE	SK-3419	CHECKSUM	ACAD R14

UNITED STATES
DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

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FLUOR DANIEL
FERNALD

SILOS PROJECT
CINCINNATI, OHIO

DRAWING TITLE

PROCESS FLOW DIAGRAM
VITRIFICATION - OTHER
FEED PREPARATION SYSTEM
REVISED FEASIBILITY STUDY FOR SILOS 1 & 2

DRAWN BY: RW REDMAN	DATE: 7/12/99	DESIGNED, CHECKED BY	DATE	CHECKED BY: B. BRUSH	DATE: 7/30/99
PLANT/BLDG. NO.: OU4		PLANT		SCALE: NONE	CLASS
SUBMITTED FOR APPROVAL: A-E	DATE	APPROVAL RECOMMENDED: CONSTRUCTION	DATE		
DOE PROJECT NO.: 40730	OPER. COMM. FIELD NO.: WBS2.1.3.G.P	DRAWING NO.: 94X-5500-F-SK-3419		SHEET NO.: 1	REV. NO.: 2

DISTRIBUTION CODE: XXX

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INITIALS: RWR
DATE: 12/1/99

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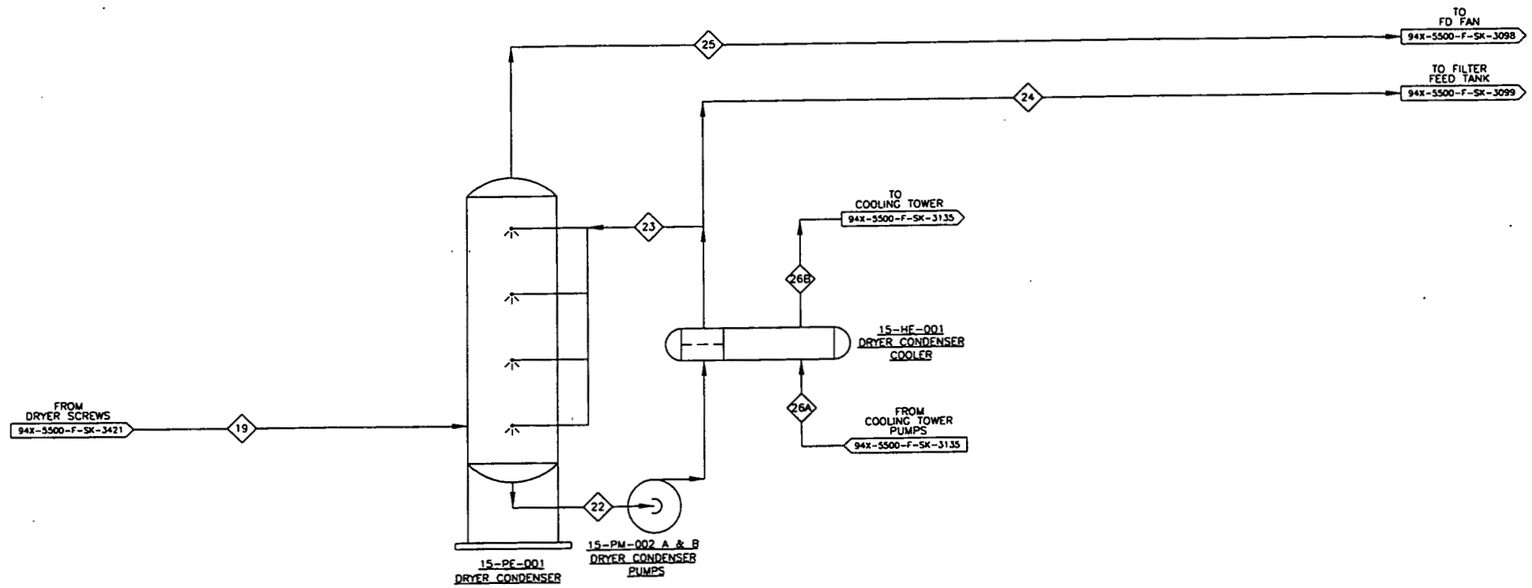

000506

PRELIMINARY DRAWING

CAD FILE	SK-3420	CAD SOFTWARE	ACAD R14

UNITED STATES
DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

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FLUOR DANIEL
FERNALD
SILOS PROJECT
CINCINNATI, OHIO

DRAWING TITLE

PROCESS FLOW DIAGRAM
VITRIFICATION – OTHER
FEED PREPARATION SYSTEM
REVISED FEASIBILITY STUDY FOR SILOS 1 & 2

DRAWN BY	RW REDMAN	DATE 7/12/99	DESIGNED, CHECKED BY	DATE	CHECKED BY B. BRUSH DATE 7/30/99
PLANT/BLDG. NO.	OU4	PLAN			SCALE NONE SIZE
SUBMITTED FOR APPROVAL		APPROVAL RECOMMENDED			
A-E	DATE	OPERATING CONTRACTOR	DATE		
SOE PROJECT NO.	40730	OPER. CONTR. PROJ. NO.	W852.1.3.G.P	DRAWING NO.	94X-5500-F-SK-3420 SHEET NO. 1 REV. NO. 2

DISTRIBUTION CODE: XXX

ACAD

INITIALS: RWR
DATE: 12/1/99

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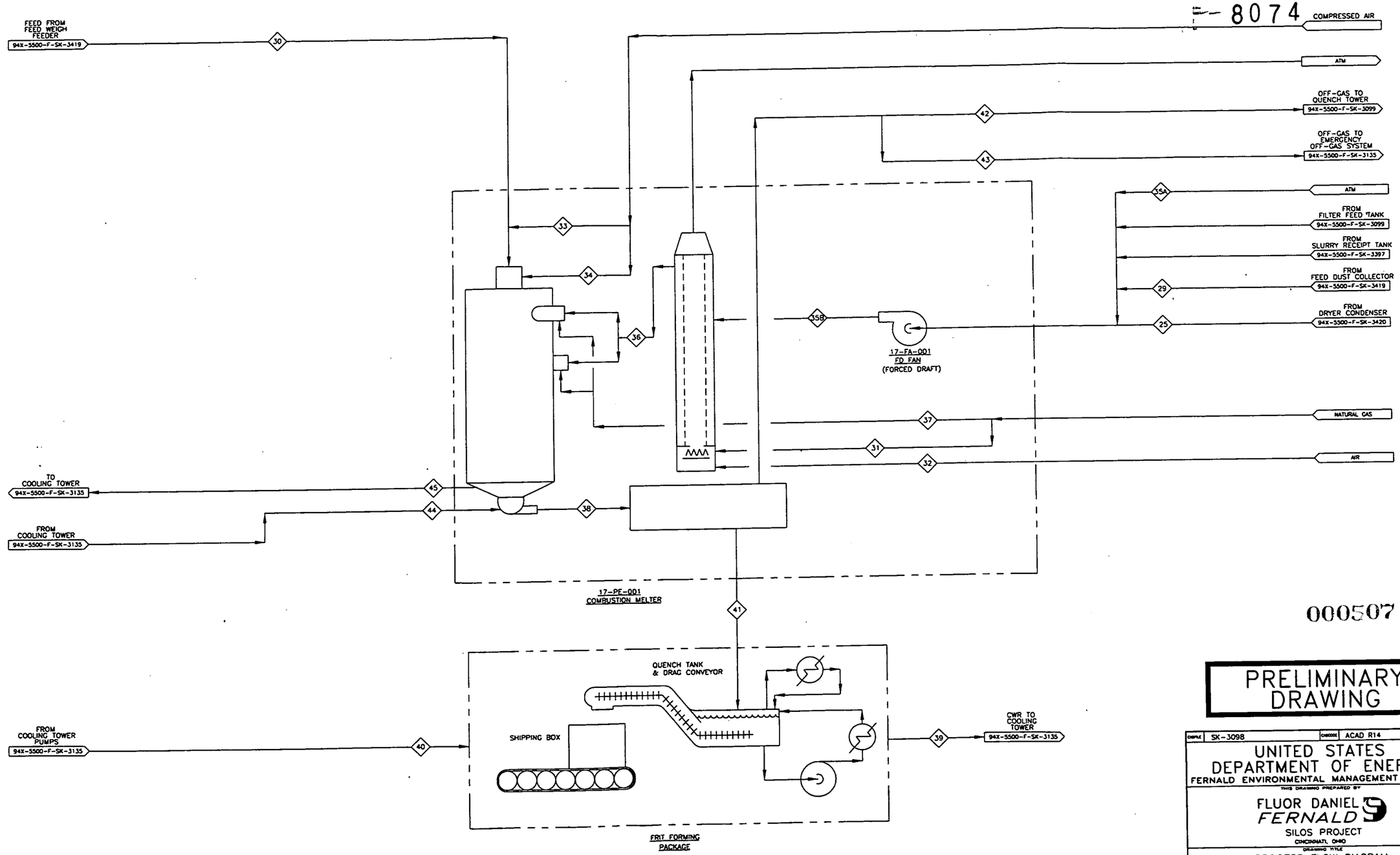

000507

PRELIMINARY DRAWING

DWG FILE	SK-3098	CHECKER	ACAD R14

UNITED STATES
DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

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FLUOR DANIEL FERNALD
SILOS PROJECT
CINCINNATI, OHIO

DRAWING TITLE

PROCESS FLOW DIAGRAM
VITRIFICATION – OTHER
MELTER AND GLASS HANDLING SYSTEM
REVISED FEASIBILITY STUDY FOR SILOS 1 & 2

DRAWN BY S. M. YANKEY	DATE 08/2/98	DESIGNED, CHECKED BY	DATE	CHECKED BY B. BRUSH	DATE 7/30/99
PLANT/BLDG. NO. OU4		FLOOR		SCALE NONE	COLOR
SUBMITTED FOR APPROVAL		APPROVAL RECOMMENDED			
A-E	DATE	OPERATING CONTRACTOR	DATE		
DOE PROJECT NO. 40730	OPER. CONTR. PROJ. NO. WBS2.1.3.G.P	DRAWING NO. 94X-5500-F-SK-3098		SHEET NO. 1	TOTAL NO. 2

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ACAD

INITIALS: RWR
DATE: 12/1/99

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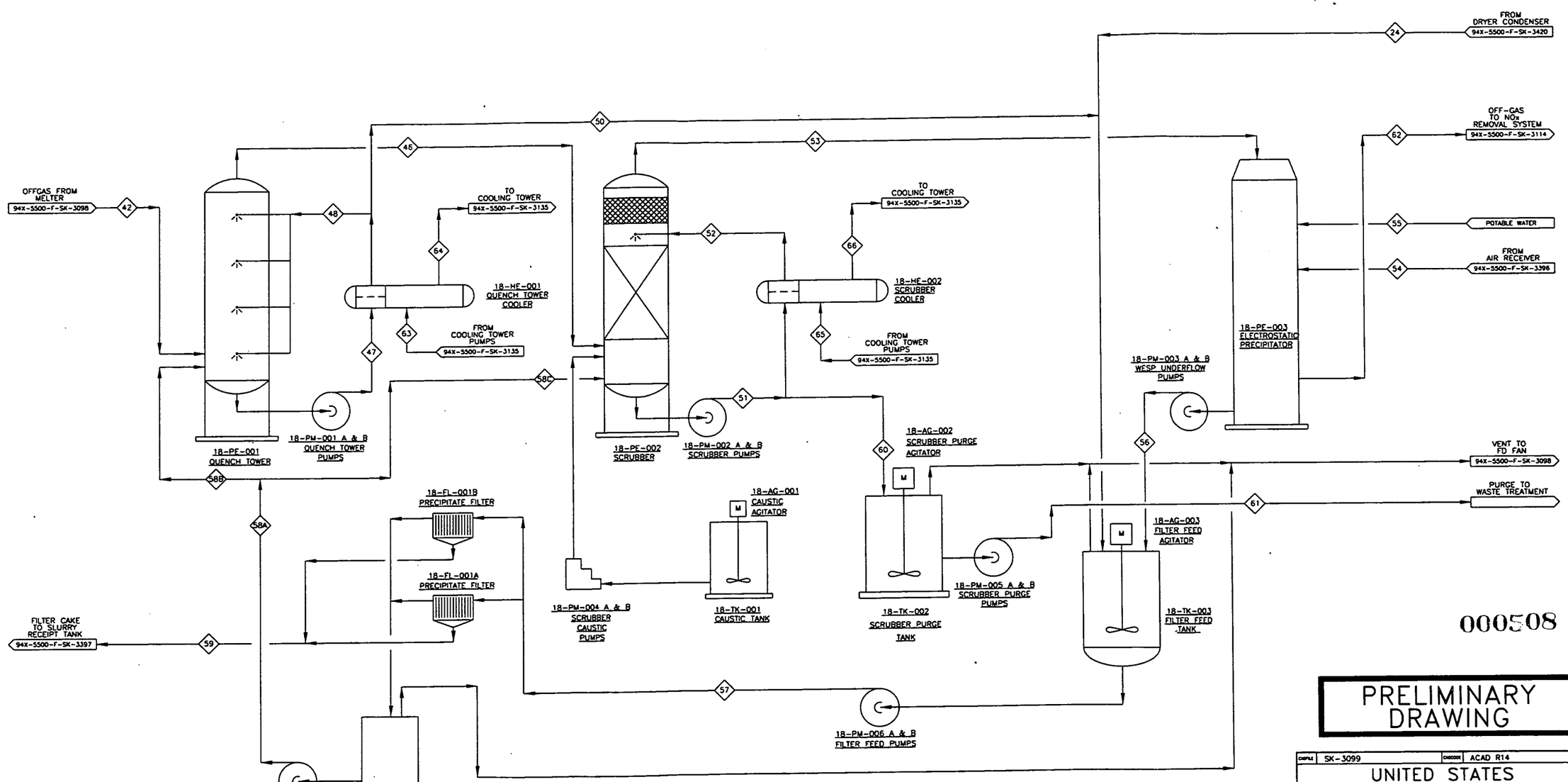


000508

PRELIMINARY DRAWING

CHFILE	SK-3099	CHECKER	ACAD R14

UNITED STATES
DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

THIS DRAWING PREPARED BY

FLUOR DANIEL FERNALD
SILOS PROJECT
CINCINNATI, OHIO

DRAWING TITLE

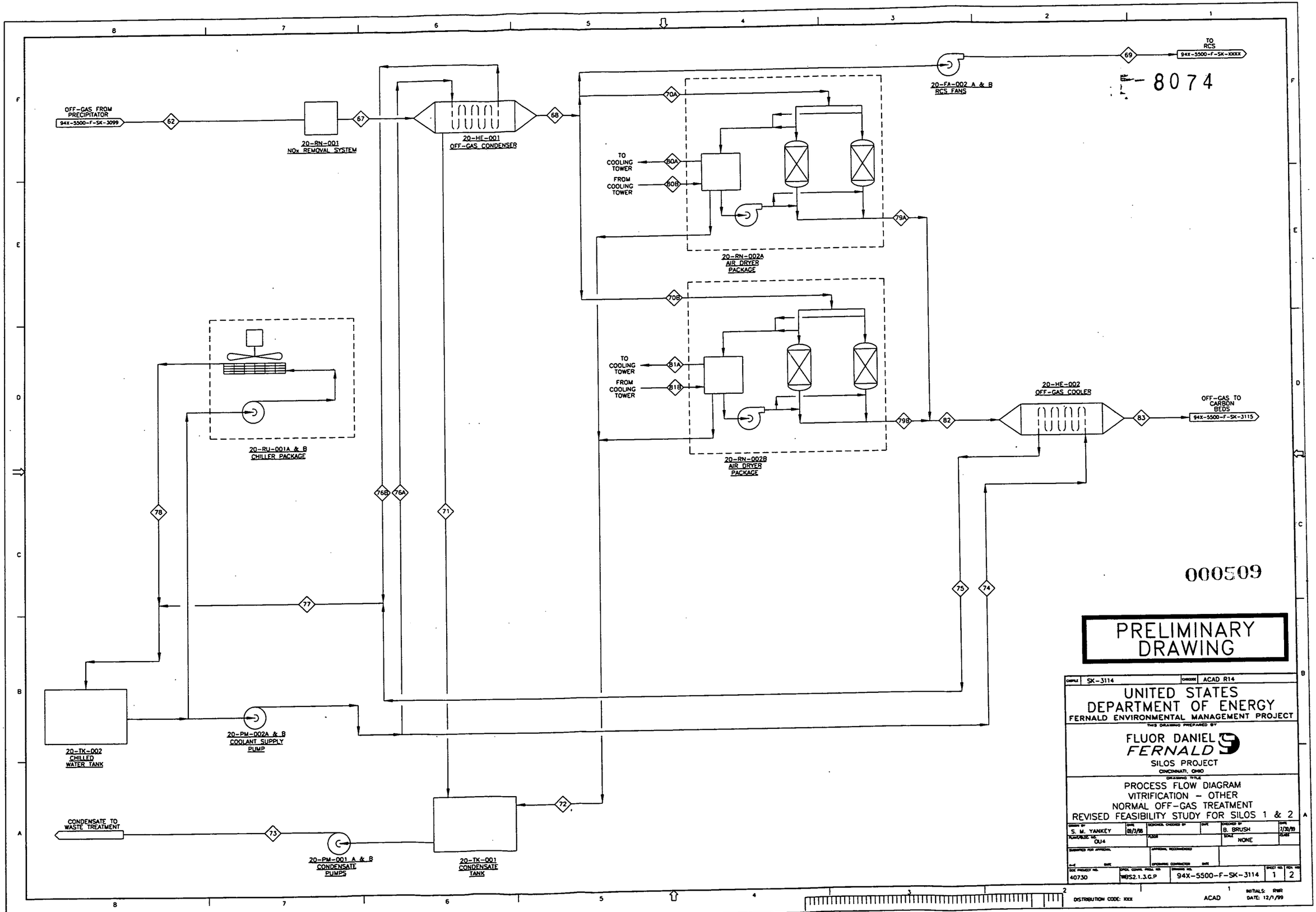
PROCESS FLOW DIAGRAM
VITRIFICATION – OTHER
NORMAL OFF-GAS TREATMENT
REVISED FEASIBILITY STUDY FOR SILOS 1 & 2

DRAWN BY S. M. YANKEY	DATE 09/1/98	DESIGNED, CHECKED BY	DATE	CHECKED BY B. BRUSH	DATE 7/31/99
PLANT/BLDG. NO. OU4		FLOOR		SCALE NONE	CLASS
SUBMITTED FOR APPROVAL: DATE		APPROVAL RECOMMENDED: DATE		APPROVAL CONTRACTOR: DATE	
DOE PROJECT NO. 40730	OPER. CONTL. PROJ. NO. WBS2.1.3.G.P	DRAWING NO. 94X-5500-F-SK-3099		SHEET NO. 1	REV. NO. 2

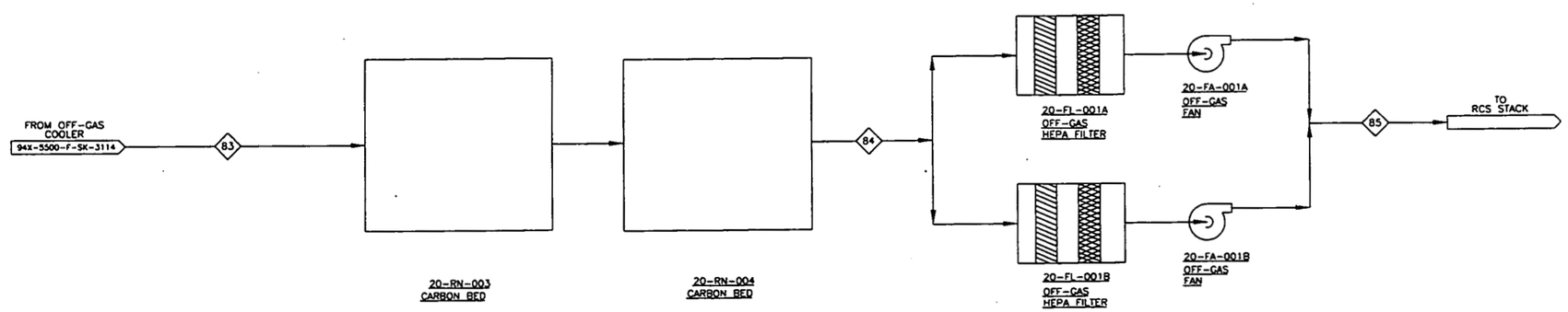
DISTRIBUTION CODE: XXX

ACAD

INITIALS: RWR
DATE: 12/1/99


OFF-GAS FROM PRECIPITATOR
94X-5500-F-SK-3099
62
20-RN-001
NOx REMOVAL SYSTEM
67
20-HE-001
OFF-GAS CONDENSER
68
20-FA-002 A & B
RCS FANS
69
TO RCS
94X-5500-F-SK-XXXX
70A
TO COOLING TOWER
80A
FROM COOLING TOWER
80B
79A
20-RN-002A
AIR DRYER PACKAGE
70B
TO COOLING TOWER
81A
FROM COOLING TOWER
81B
79B
20-RN-002B
AIR DRYER PACKAGE
82
20-HE-002
OFF-GAS COOLER
83
OFF-GAS TO CARBON BEDS
94X-5500-F-SK-3115
20-RU-001A & B
CHILLER PACKAGE
78
76B
76A
71
77
75
74
20-TK-002
CHILLED WATER TANK
20-PM-002A & B
COOLANT SUPPLY PUMP
72
CONDENSATE TO WASTE TREATMENT
73
20-PM-001 A & B
CONDENSATE PUMPS
20-TK-001
CONDENSATE TANK
8074
000509
PRELIMINARY DRAWING
SK-3114
ACAD R14
UNITED STATES
DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT
THIS DRAWING PREPARED BY
FLUOR DANIEL
FERNALD
SILOS PROJECT
CINCINNATI, OHIO
DRAWING TITLE
PROCESS FLOW DIAGRAM
VITRIFICATION - OTHER
NORMAL OFF-GAS TREATMENT
REVISED FEASIBILITY STUDY FOR SILOS 1 & 2
S. M. YANKEY
08/3/98
B. BRUSH
7/30/99
OU4
NONE
40730
WBS2.1.3.C.P
94X-5500-F-SK-3114
1
2
DISTRIBUTION CODE: XXX
ACAD
INITIALS: RMR
DATE: 12/1/99

8074



000510

PRELIMINARY DRAWING

DWG/FILE	SK-3115	CHECKER	ACAD R14

UNITED STATES
DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

THIS DRAWING PREPARED BY

FLUOR DANIEL FERNALD
SILOS PROJECT
CINCINNATI, OHIO

DRAWING TITLE

PROCESS FLOW DIAGRAM
VITRIFICATION – OTHER
NORMAL OFF-GAS TREATMENT
REVISED FEASIBILITY STUDY FOR SILOS 1 & 2

DRAWN BY	S. M. YANKEY	DATE	09/3/98	DESIGNER CHECKED BY	DATE	CHECKED BY	B. BRUSH	DATE 1/30/99
PLANT/BLDG. NO.	OU4	FLOOR				SCALE	NONE	PLANS
SUBMITTED FOR APPROVAL				APPROVAL RECOMMENDED				
A-E	DATE			OPERATING CONTRACTOR	DATE			
DOE PROJECT NO.	40730	OPER. CONTR. PROJ. NO.	WBS2.1.3.G.P	DRAWING NO.	94X-5500-F-SK-3115	SHEET NO. 1	REV. NO. 2

DISTRIBUTION CODE: XXX

ACAD

INITIALS: RWR
DATE: 12/1/99

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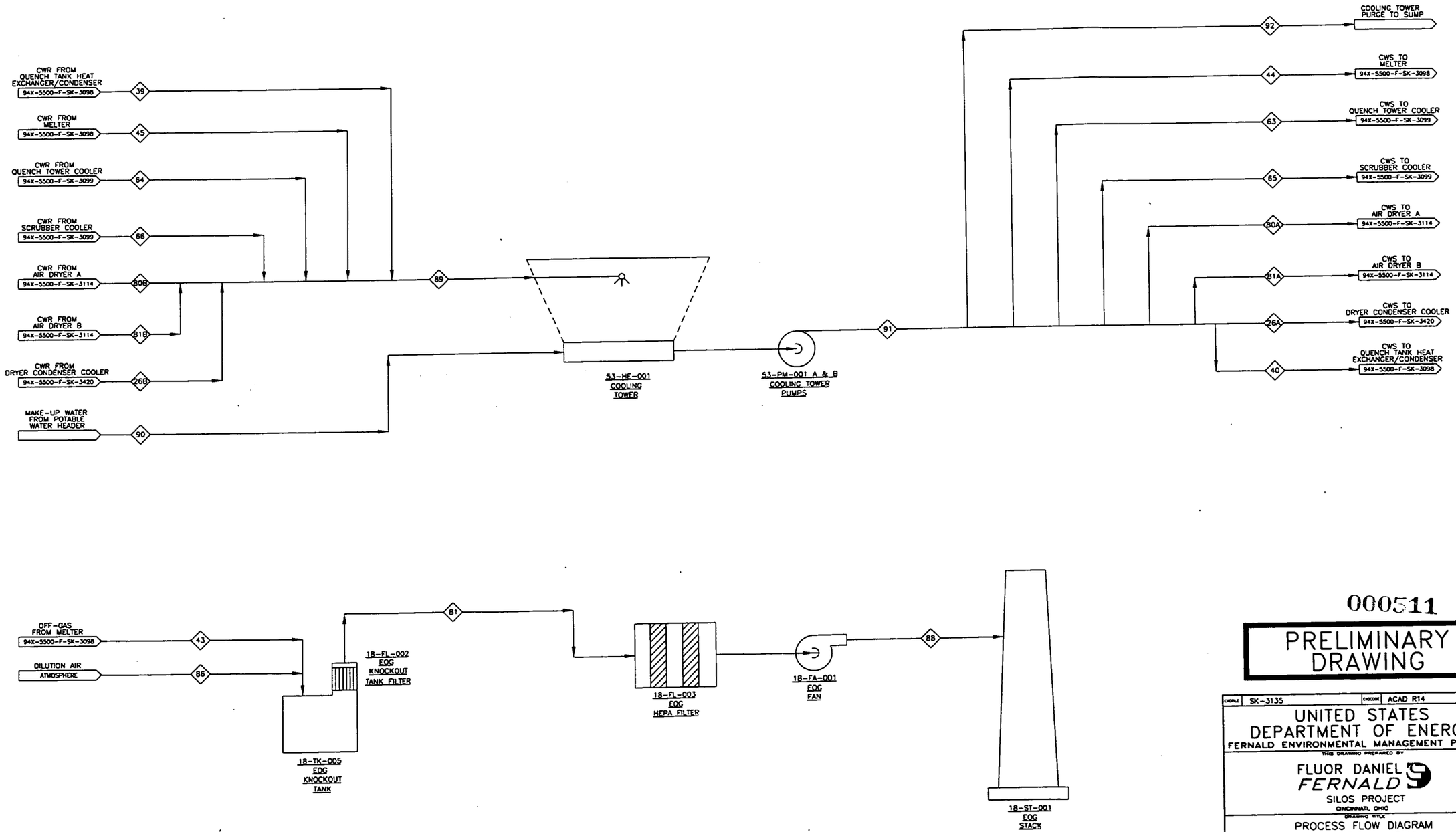

000511

PRELIMINARY DRAWING

CADFILE	SK-3135	CADSYSTEM	ACAD R14

UNITED STATES
DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

THIS DRAWING PREPARED BY

FLUOR DANIEL FERNALD
SILOS PROJECT
CINCINNATI, OHIO

DRAWING TITLE

PROCESS FLOW DIAGRAM
VITRIFICATION – OTHER
EMERGENCY OFF-GAS & COOLING TOWER
REVISED FEASIBILITY STUDY FOR SILOS 1 & 2

DRAWN BY S. M. YANKEY	DATE 08/3/98	REVIEWED, CHECKED BY	DATE	CHECKED BY B. BRUSH	DATE 7/30/99
PLANT/BLDG. NO. OU4		FLOOR		SCALE NONE	CLASS
SUBMITTED FOR APPROVAL		APPROVAL RECOMMENDED			
E&C	DATE	OPERATING CONTRACTOR	DATE		
DOE PROJECT NO. 40730	CPDL CONTR. PROJ. NO. WBS2.1.3.G.P	DRAWING NO. 94X-5500-F-SK-3135		SHEET NO. 1	REV. NO. 2

DISTRIBUTION CODE: XXX

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INITIALS: RWR
DATE: 12/1/99

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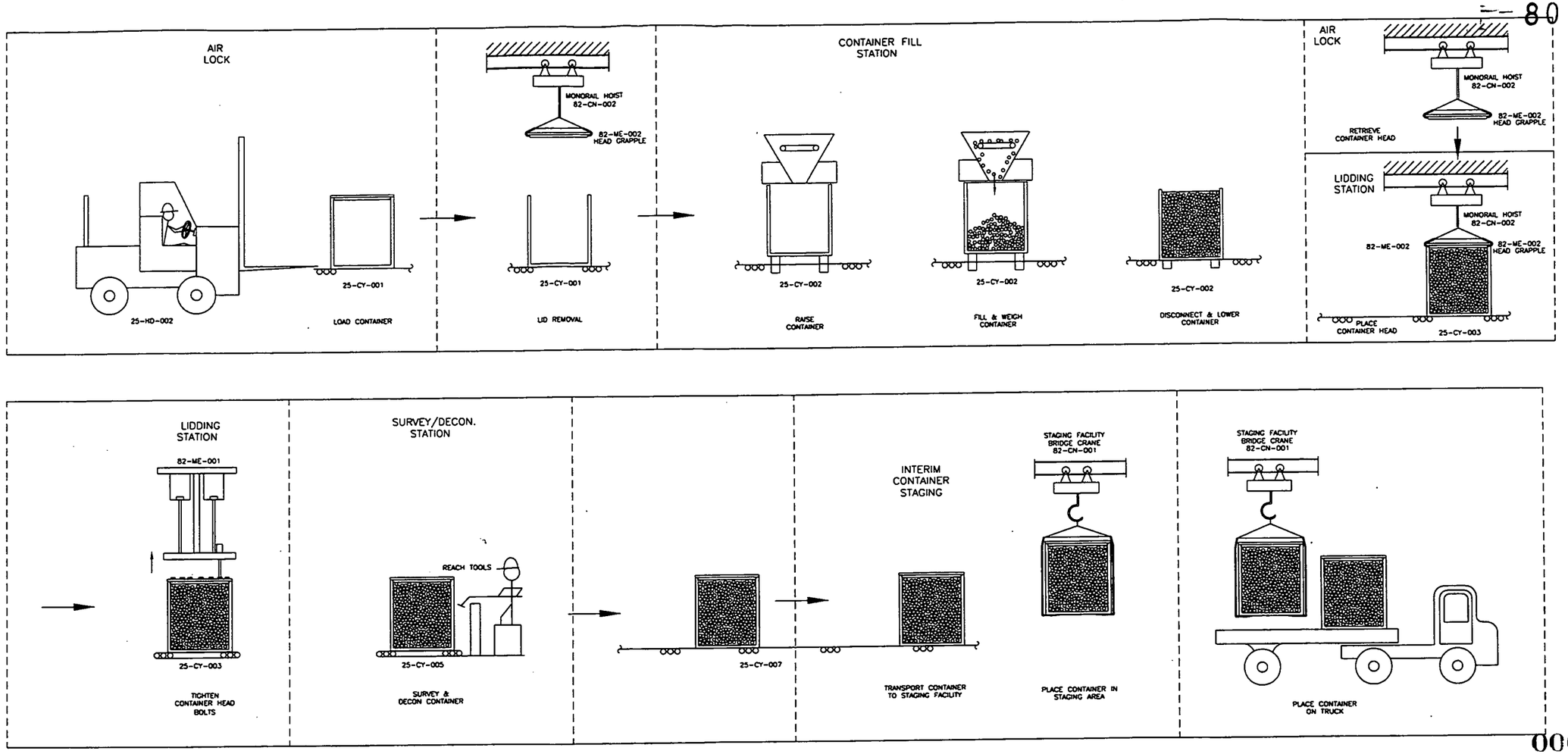


000512

PRELIMINARY DRAWING

CHIPLE	SK-6015	CHECKER	ACAD R14

UNITED STATES
DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

THIS DRAWING PREPARED BY

FLUOR DANIEL FERNALD
SILOS PROJECT
CINCINNATI, OHIO

DRAWING TITLE

MECHNICAL FLOW DIAGRAM
VITRIFICATION – OTHER
CULLET PRODUCTION
REVISED FEASIBILITY STUDY FOR SILOS 1 & 2

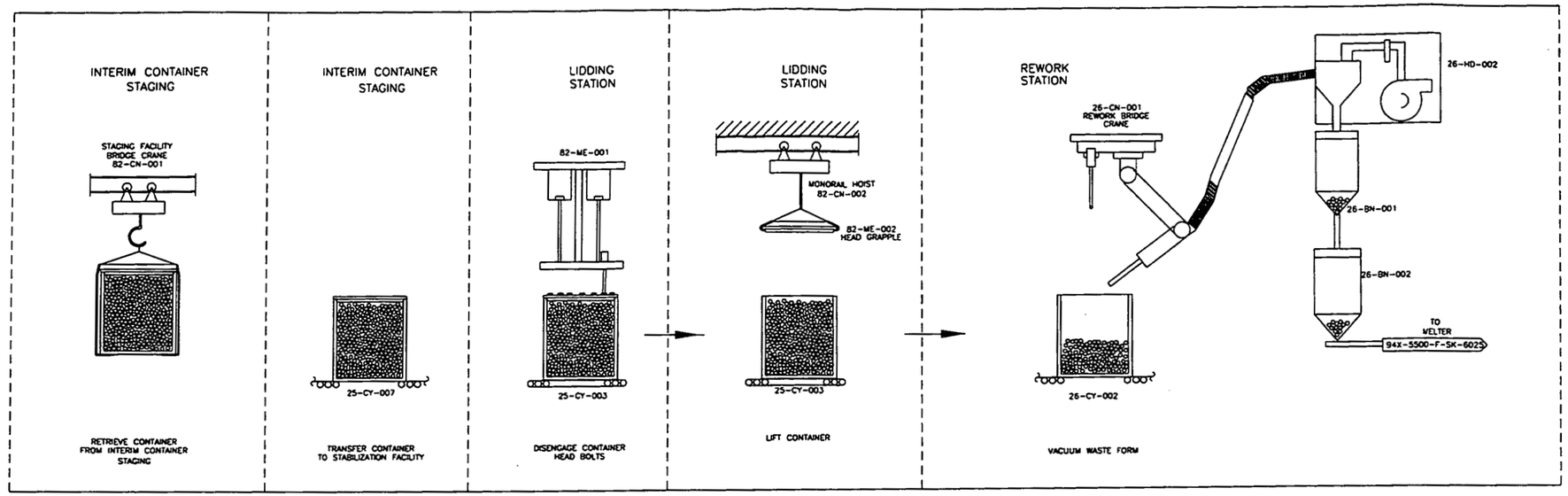
DRAWN BY J. SCHILLING	DATE 7/16/99	DESIGNER, CHECKED BY	DATE	CHECKED BY C. SCHILLING	DATE 7/30/99
PLANT/BLDG. NO. OU4		AUDIT		SCALE NONE	CLASS
SUBMITTED FOR APPROVAL		APPROVAL RECOMMENDED			
A-E	DATE	OPERATING CONTRACTOR	DATE		
EDC PROJECT NO. 40730	OPER. CONTR. PROJ. NO. WBS2.1.3.G.P	DRAWING NO. 94X-5500-F-SK-6015		SHEET NO. 1	REV. NO. 2

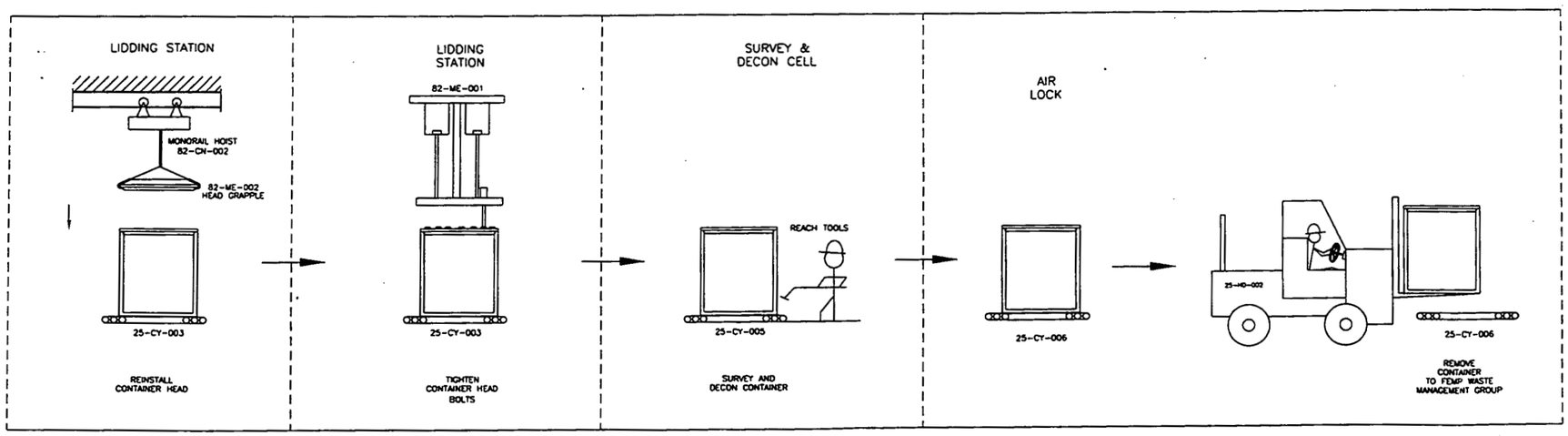
DISTRIBUTION CODE: XXX

ACAD

INITIALS: RWR
DATE: 12/1/99

8074





000513

PRELIMINARY DRAWING

CHFILE	SK-6017	CHECKER	ACAD R14

UNITED STATES
DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

THIS DRAWING PREPARED BY

FLUOR DANIEL FERNALD
SILOS PROJECT
CINCINNATI, OHIO

DRAWING TITLE

MECHNICAL FLOW DIAGRAM
VITRIFICATION – OTHER
REWORK
REVISED FEASIBILITY STUDY FOR SILOS 1 & 2

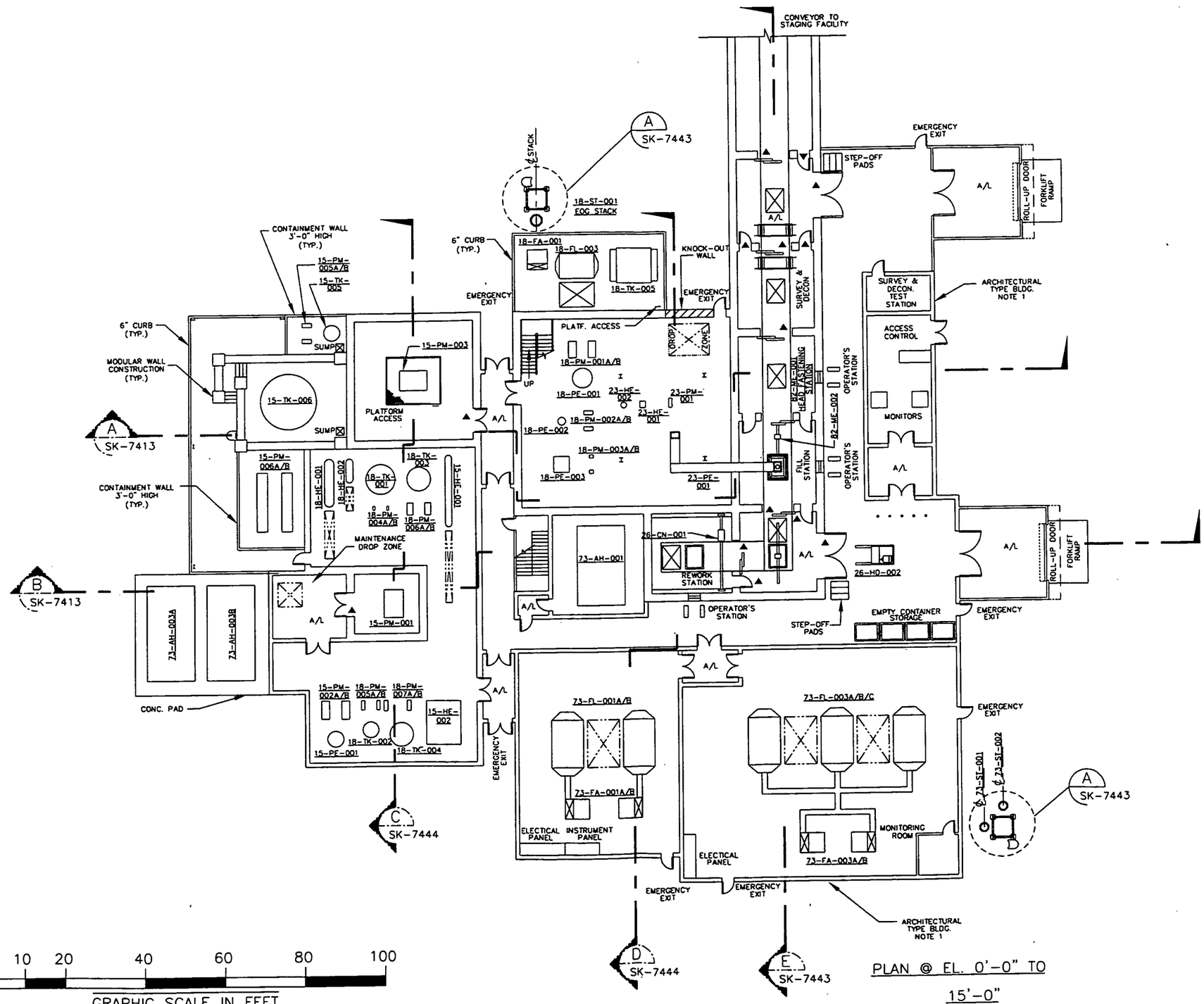
DRAWN BY J. SCHILLING	DATE 7/1/99	SECTION CHECKED BY	DATE	CHECKED BY C. SCHILLING	DATE 7/30/99
PLANT/BLDG. NO. OU4		FLOOR		SCALE NONE	CLASS
SUBMITTED FOR APPROVAL A-E	DATE	APPROVAL RECOMMENDED OPERATING CONTRACTOR	DATE		
SITE PROJECT NO. 40730	SPEC. CONTR. PROJ. NO. WBS2.1.3.G.P	DRAWING NO. 94X-5500-F-SK-6017		SHEET NO. 1	REV. NO. 2

DISTRIBUTION CODE: XXX

ACAD

INITIALS: RWR
DATE: 12/1/99

8074



PLAN @ EL. 0'-0" TO 15'-0"

NOTES:

1. BUILDING CONSTRUCTION
   - CONCRETE FLOOR SLAB AND FOUNDATIONS.
   - ARCHITECTURAL TYPE WALLS CONSIST OF STEEL FRAME STRUCTURE, INSULATED METAL SIDING, MEMBRANE ROOFING SUPPORTED BY STEEL DECKING AND INSULATION BOARD.
   - MODULAR WALL CONSTRUCTION CONSISTS OF INTERLOCKING PREFABRICATED SHIELDING WALLS AND COLUMNS.
   - ALL OTHER SHEILDING WALLS ARE 2'-0" THICK CONCRETE.
2. EMPTY CONTAINER STORAGE IS SINGLE STACK.
3. SHIELD DOOR = ▲

REFERENCE DRAWINGS

94X-5500-P-SK-7412
94X-5500-P-SK-7413
94X-5500-P-SK-7414
94X-5500-P-SK-7443
94X-5500-P-SK-7444

000514

PRELIMINARY DRAWING

CHIPPLE SK-7411	CHECKER ACAD R14		
UNITED STATES DEPARTMENT OF ENERGY FERNALD ENVIRONMENTAL MANAGEMENT PROJECT THIS DRAWING PREPARED BY FLUOR DANIEL FERNALD SILOS PROJECT CINCINNATI, OHIO			
DRAWING TITLE FACILITY LAYOUT VITRIFICATION – OTHER PLAN @ EL. 0'-0" TO EL. 15'-0" REVISED FEASIBILITY STUDY FOR SILOS 1 & 2			
DRAWN BY S. M. YANKEY	DATE 11/3/98	DESIGNED, CHECKED BY	DATE
CHECKED BY J. THOMPSON	DATE 12/6/99		
PLANT/BLDG. NO. OU4	FLOOR	SCALE 3/64" = 1'-0"	
SUBMITTED FOR APPROVAL	APPROVAL RECOMMENDED		
A-E DATE	OPERATING CONTRACTOR DATE		
DOE PROJECT NO. 40730	OPER. CONTR. PROJ. NO. WBS2.1.3.G.P	DRAWING NO. 94X-5500-P-SK-7411	SHEET NO. 1 REV. NO. 2
DISTRIBUTION CODE: XXX	ACAD	INITIALS: RWR DATE: 12/1/99	

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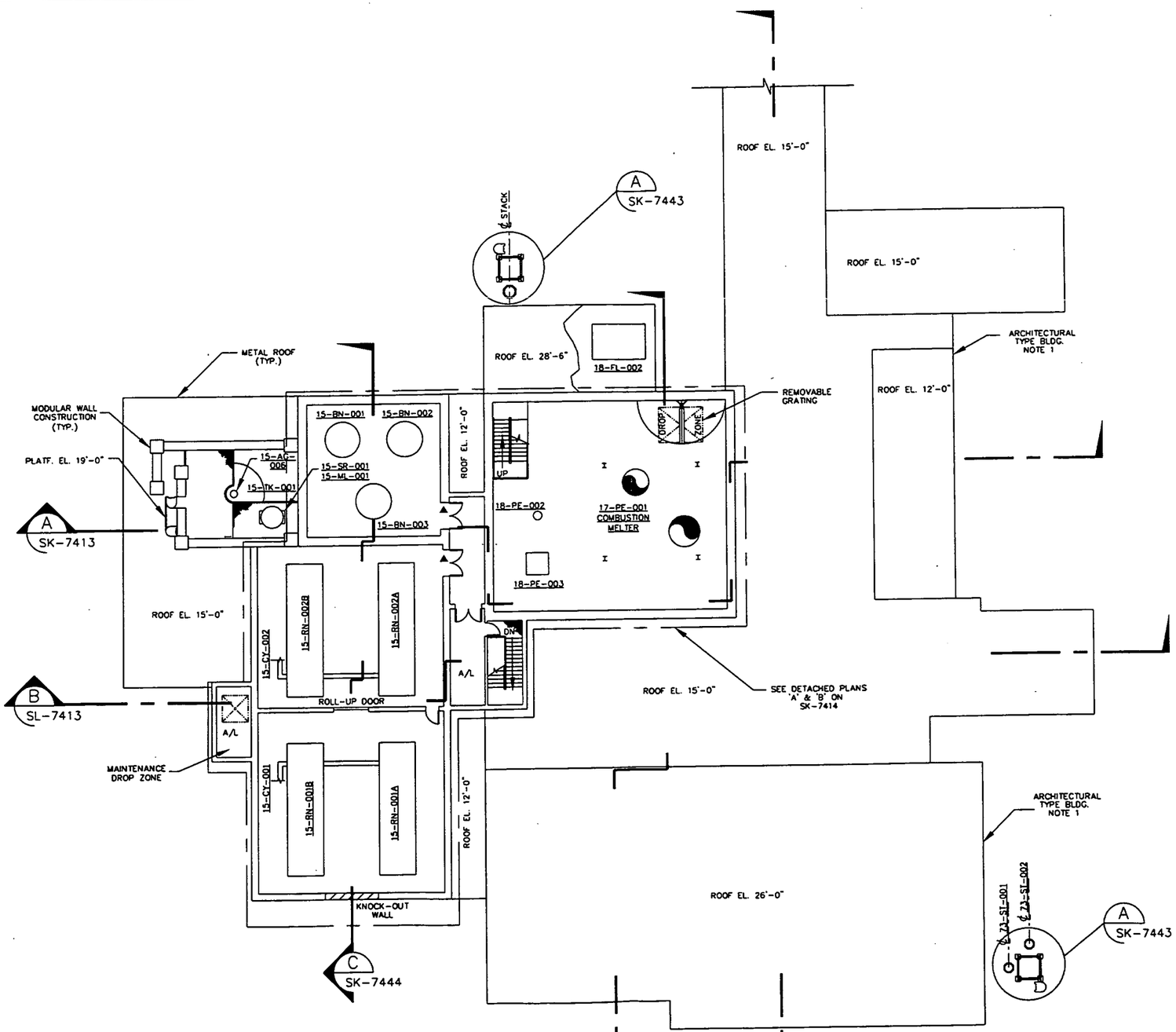

0 10 20 40 60 80 100

GRAPHIC SCALE IN FEET
3/64" = 1'-0"

PLAN @ EL. 15'-0" & ABOVE
(UNLESS NOTED OTHERWISE)

NOTES:

1. BUILDING CONSTRUCTION
   - CONCRETE FLOOR SLAB AND FOUNDATIONS.
   - ARCHITECTURAL TYPE WALLS CONSIST OF STEEL FRAME STRUCTURE, INSULATED METAL SIDING, MEMBRANE ROOFING SUPPORTED BY STEEL DECKING AND INSULATION BOARD.
   - MODULAR WALL CONSTRUCTION CONSISTS OF INTERLOCKING PREFABRICATED SHIELDING WALLS AND COLUMNS.
   - ALL OTHER SHEILDING WALLS ARE 2'-0" THICK CONCRETE.
2. EMPTY CONTAINER STORAGE IS SINGLE STACK.
3. SHIELD DOOR = ▲

REFERENCE DRAWINGS

94X-5500-P-SK-7411
94X-5500-P-SK-7413
94X-5500-P-SK-7414
94X-5500-P-SK-7443
94X-5500-P-SK-7444

000515

PRELIMINARY DRAWING

DWG/FILE SK-7412	CADCODE ACAD R14

UNITED STATES
DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

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FLUOR DANIEL FERNALD

SILOS PROJECT
CINCINNATI, OHIO

DRAWING TITLE

FACILITY LAYOUT
VITRIFICATION – OTHER
PLAN @ EL. 15'-0" & ABOVE
REVISED FEASIBILITY STUDY FOR SILOS 1 & 2

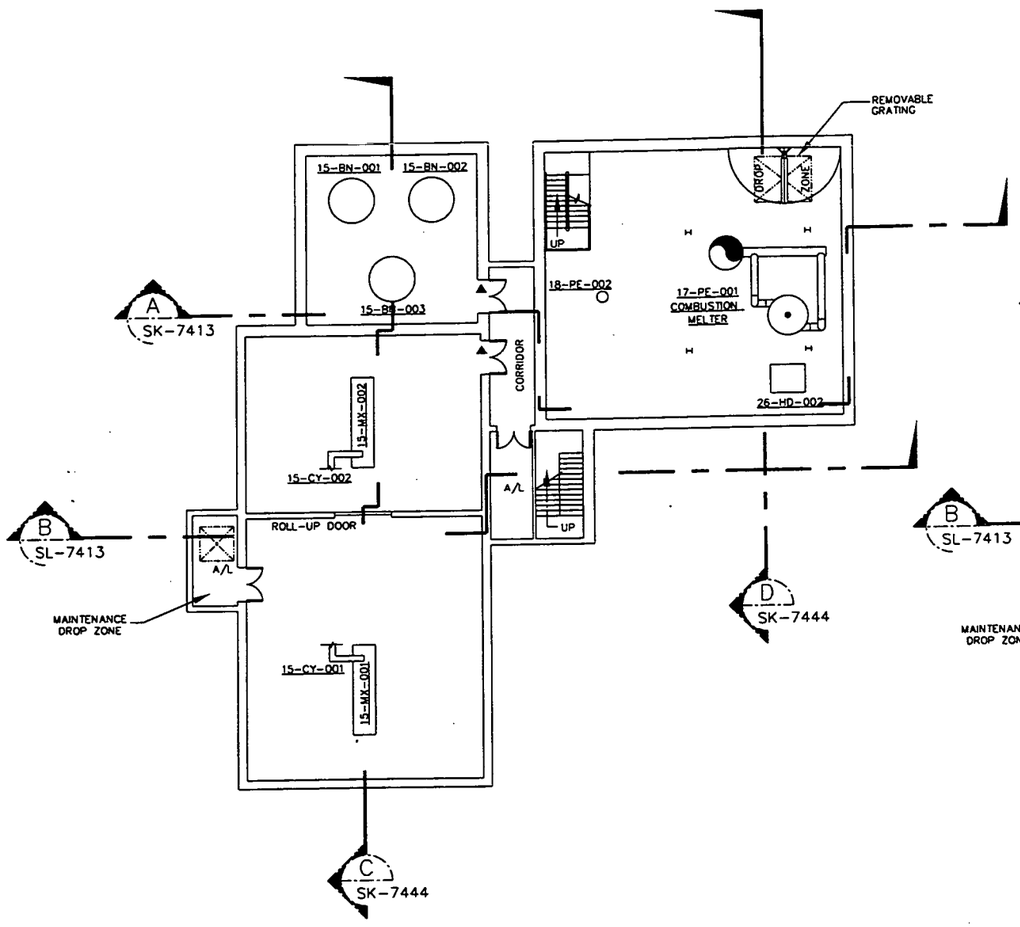
DRAWN BY S. M. YANKEY	DATE 7/26/99	DESIGNED, CHECKED BY	DATE	CHECKED BY J. THOMPSON	DATE 1/14/99
PLANT/BLDG. NO. OU4		FLOOR		SCALE 3/64" = 1'-0"	SIZE
SUBMITTED FOR APPROVAL		APPROVAL RECOMMENDED			
A-E	DATE	OPERATING CONTRACTOR	DATE		
DOE PROJECT NO. 40730	SPEC. CONTR. PROJ. NO. WBS2.1.3.G.P	DRAWING NO. 94X-5500-P-SK-7412		SHEET NO. 1	REV. NO. 2

DISTRIBUTION CODE: XXX

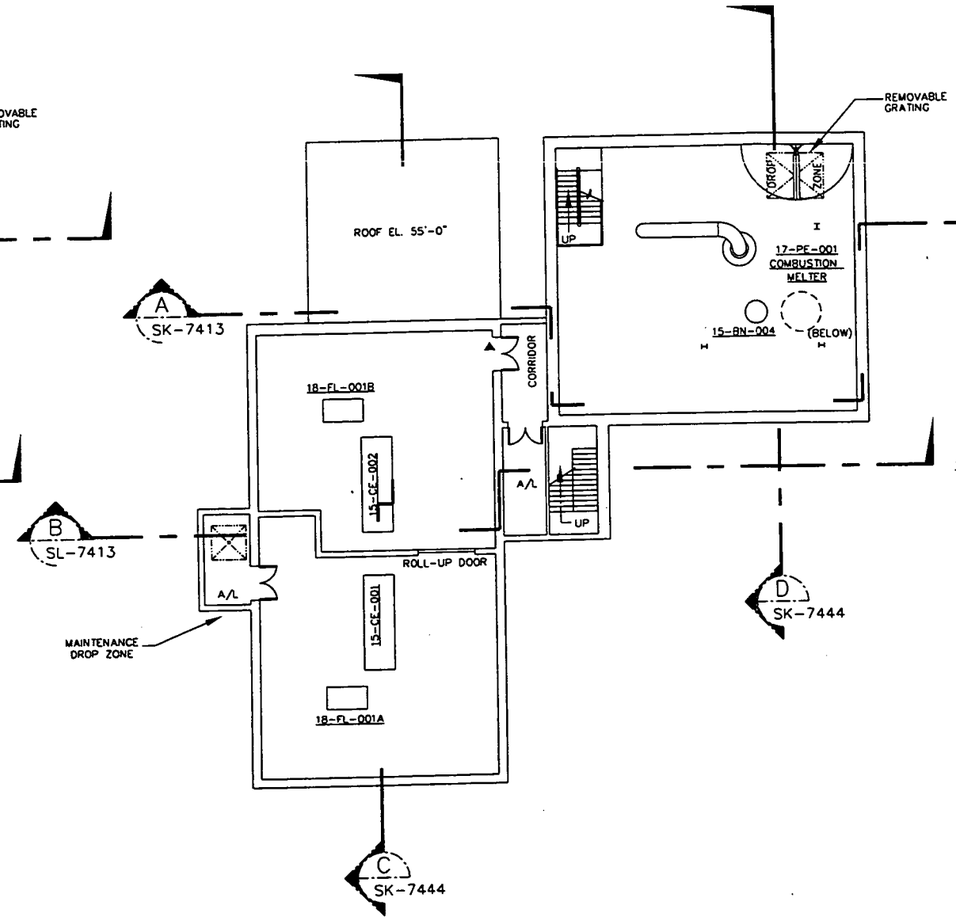
ACAD

DETAILS: FWR
DATE: 12/1/99

8074



DETACHED PLAN 'A'
EL. @ 34'-0" TO 50'-6"
SEE SK-7412



DETACHED PLAN 'B'
EL. @ 50'-6" & ABOVE
SEE SK-7412

NOTES:

1. BUILDING CONSTRUCTION
   - CONCRETE FLOOR SLAB AND FOUNDATIONS.
   - ARCHITECTURAL TYPE WALLS CONSIST OF STEEL FRAME STRUCTURE, INSULATED METAL SIDING, MEMBRANE ROOFING SUPPORTED BY STEEL DECKING AND INSULATION BOARD.
   - MODULAR WALL CONSTRUCTION CONSISTS OF INTERLOCKING PREFABRICATED SHIELDING WALLS AND COLUMNS.
   - ALL OTHER SHEILDING WALLS ARE 2'-0" THICK CONCRETE.
2. EMPTY CONTAINER STORAGE IS SINGLE STACK.

REFERENCE DRAWINGS

94X-5500-P-SK-7411
94X-5500-P-SK-7412
94X-5500-P-SK-7413
94X-5500-P-SK-7443
94X-5500-P-SK-7444

000516

PRELIMINARY DRAWING

0 10 20 40 60 80 100
GRAPHIC SCALE IN FEET
3/64" = 1'-0"

CHGFILE SK-7414 CHECKER ACAD R14

UNITED STATES
DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

THIS DRAWING PREPARED BY
FLUOR DANIEL FERNALD
SILOS PROJECT
CINCINNATI, OHIO

DRAWING TITLE
FACILITY LAYOUT
VITRIFICATION – OTHER
DETACHED PLANS
REVISED FEASIBILITY STUDY FOR SILOS 1 & 2

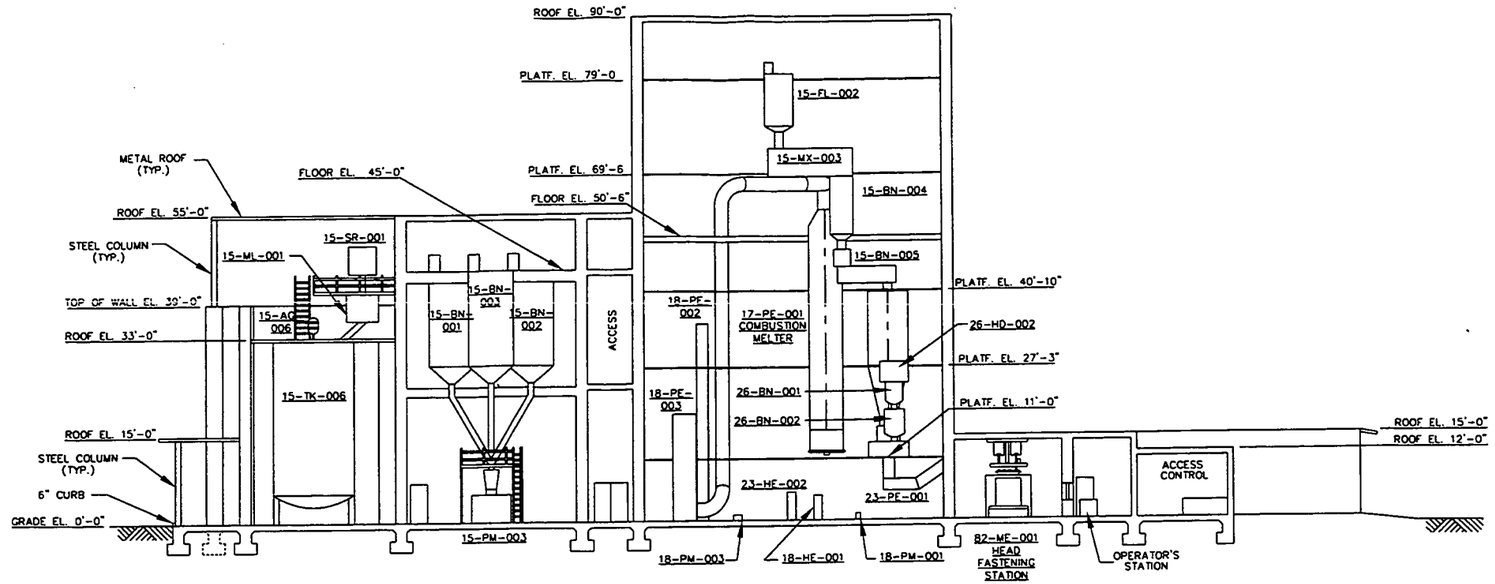
DRAWN BY S. M. YANKEY	DATE 7/21/99	DESIGNED, CHECKED BY	DATE
CHECKED BY J. THOMPSON	DATE 8/19/99	PROJ/WBS/ACT NO. OU4	AZ08
SCALE AS NOTED	CLASS	SUBMITTED FOR APPROVAL	DATE
APPROVAL RECOMMENDED	DATE	APPROVAL CONCURRENCE	DATE
SITE PROJECT NO. 40730	OPER. COMM. PROJ. NO. WBS2.1.3.G.P	DRAWING NO. 94X-5500-P-SK-7414	SHEET NO. 1
REV. NO. 2			

DISTRIBUTION CODE: XXX

ACAD

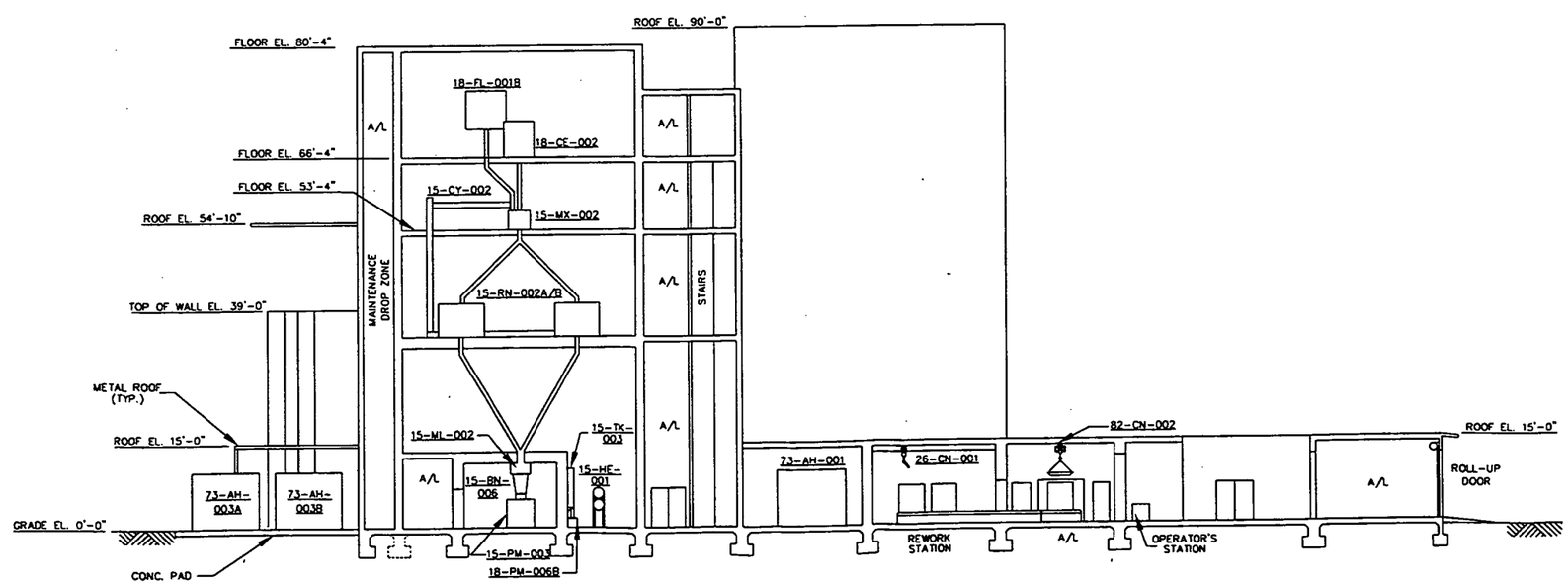
INITIALS: RHR
DATE: 12/1/99

8074



SECTION 'A'-'A'

SEE SK-7411, SK-7412 & SK-7414



SECTION 'B'-'B'

SEE SK-7411, SK-7412 & SK-7414

0 10 20 40 60 80 100

GRAPHIC SCALE IN FEET
3/64" = 1'-0"

NOTES:

1. BUILDING CONSTRUCTION
   - # CONCRETE FLOOR SLAB AND FOUNDATIONS.
   - # ARCHITECTURAL TYPE WALLS CONSIST OF STEEL FRAME STRUCTURE, INSULATED METAL SIDING, MEMBRANE ROOFING SUPPORTED BY STEEL DECKING AND INSULATION BOARD.
   - MODULAR WALL CONSTRUCTION CONSISTS OF INTERLOCKING PREFABRICATED SHIELDING WALLS AND COLUMNS.
   - ALL OTHER SHEILDING WALLS ARE 2'-0" THICK CONCRETE.
2. EMPTY CONTAINER STORAGE IS SINGLE STACK.

REFERENCE DRAWINGS

94X-5500-P-SK-7411
94X-5500-P-SK-7412
94X-5500-P-SK-7414
94X-5500-P-SK-7443
94X-5500-P-SK-7444

000517

PRELIMINARY DRAWING

SK-7413 | ACAD R14

UNITED STATES DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

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FLUOR DANIEL FERNALD

SILOS PROJECT
CINCINNATI, OHIO

DRAWING TITLE

FACILITY LAYOUT
VITRIFICATION - OTHER SECTIONS
REVISED FEASIBILITY STUDY FOR SILOS 1 & 2

DRAWN BY S. M. YANKEY	DATE 11/18/98	REVIEWED, CHECKED BY	CHECKED BY J. THOMPSON
PLANT/BLDG. NO. OU4	FLOOR		SCALE AS NOTED
SUBMITTED FOR APPROVAL		APPROVAL RECOMMENDED	
DATE	DATE	OPERATING CONTRACTOR	DATE
DOE PROJECT NO. 40730	OPER. CONTR. PROJ. NO. WBS2.1.3.G.P	DRAWING NO. 94X-5500-P-SK-7413	SHEET NO. 1 REV. NO. 2

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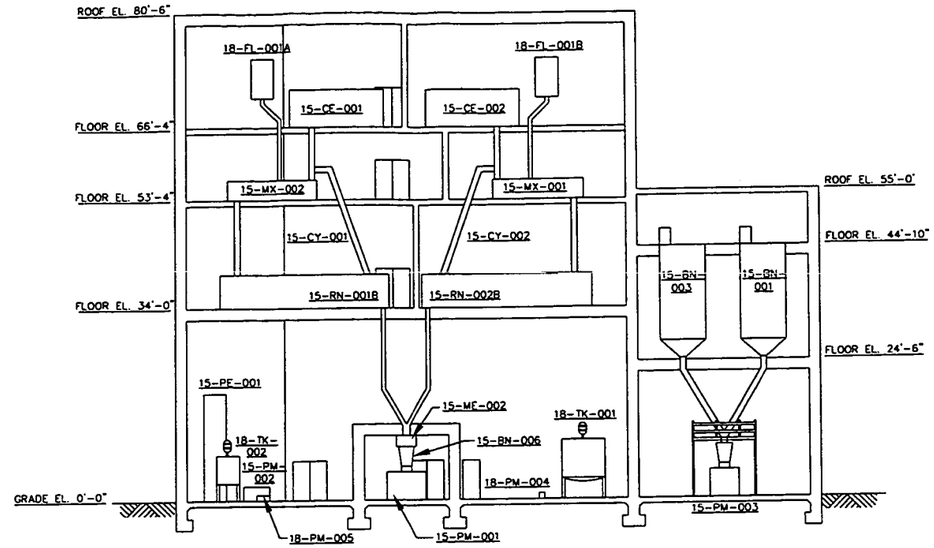
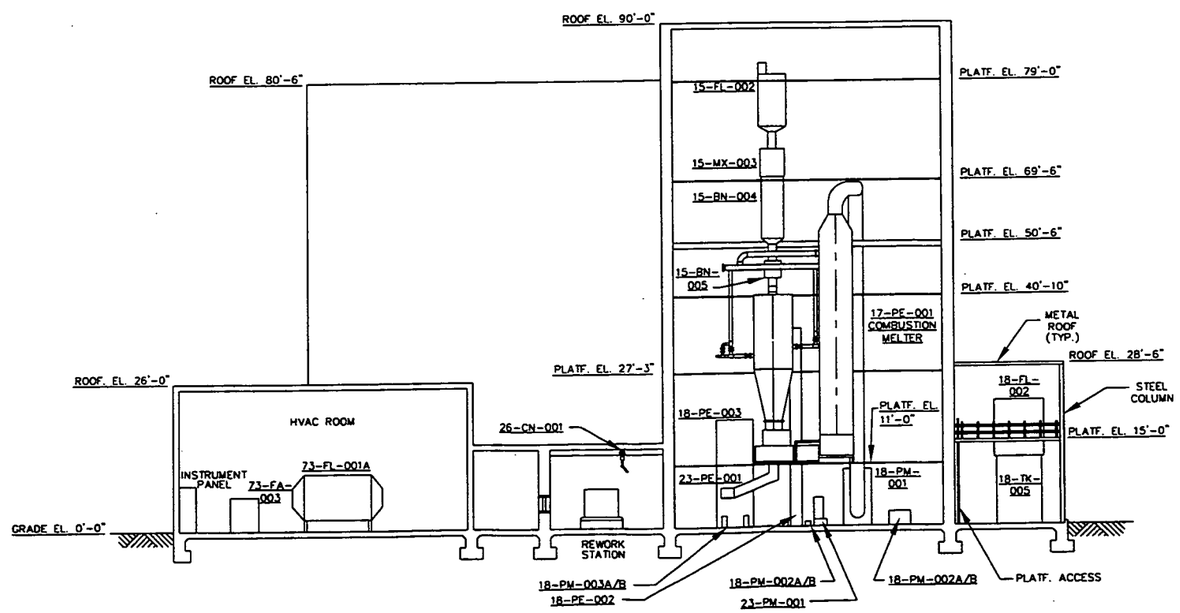
INITIALS: RWR
DATE: 12/1/99

8074



SECTION 'C'-'C'
SEE SK-7411, SK-7412 & SK-7414



SECTION 'D'-'D'
SEE SK-7411, SK-7412 & SK-7414

0 10 20 40 60 80 100

GRAPHIC SCALE IN FEET
3/64" = 1'-0"

NOTES:

1. BUILDING CONSTRUCTION
   - CONCRETE FLOOR SLAB AND FOUNDATIONS.
   - ARCHITECTURAL TYPE WALLS CONSIST OF STEEL FRAME STRUCTURE, INSULATED METAL SIDING, MEMBRANE ROOFING SUPPORTED BY STEEL DECKING AND INSULATION BOARD.
   - MODULAR WALL CONSTRUCTION CONSISTS OF INTERLOCKING PREFABRICATED SHIELDING WALLS AND COLUMNS.
   - ALL OTHER SHEILDING WALLS ARE 2'-0" THICK CONCRETE.
2. EMPTY CONTAINER STORAGE IS SINGLE STACK.

REFERENCE DRAWINGS

94X-5500-P-SK-7411
94X-5500-P-SK-7412
94X-5500-P-SK-7413
94X-5500-P-SK-7414
94X-5500-P-SK-7443

000518

PRELIMINARY DRAWING

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FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

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FLUOR DANIEL FERNALD
SILOS PROJECT
CINCINNATI, OHIO

DRAWING TITLE
FACILITY LAYOUT
VITRIFICATION - OTHER SECTIONS
REVISED FEASIBILITY STUDY FOR SILOS 1 & 2

DRAWN BY S. M. YANKEY	DATE 11/10/98	REVIEWED, CHECKED BY	DATE
CHECKED BY J. THOMPSON	DATE 3/16/99	PLANT/BLDG. NO. OU4	FLOOR
SCALE AS NOTED	CLASS	SUBMITTED FOR APPROVAL A-E	DATE
APPROVAL RECOMMENDED ENGINEERING CONTRACTOR	DATE	DOE PROJECT NO. 40730	OPER. CONTR. PROJ. NO. WBS2.1.3.G.P
DRAWING NO. 94X-5500-P-SK-7444	SHEET NO. 1	REV. NO. 2	

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DATE: 12/1/99

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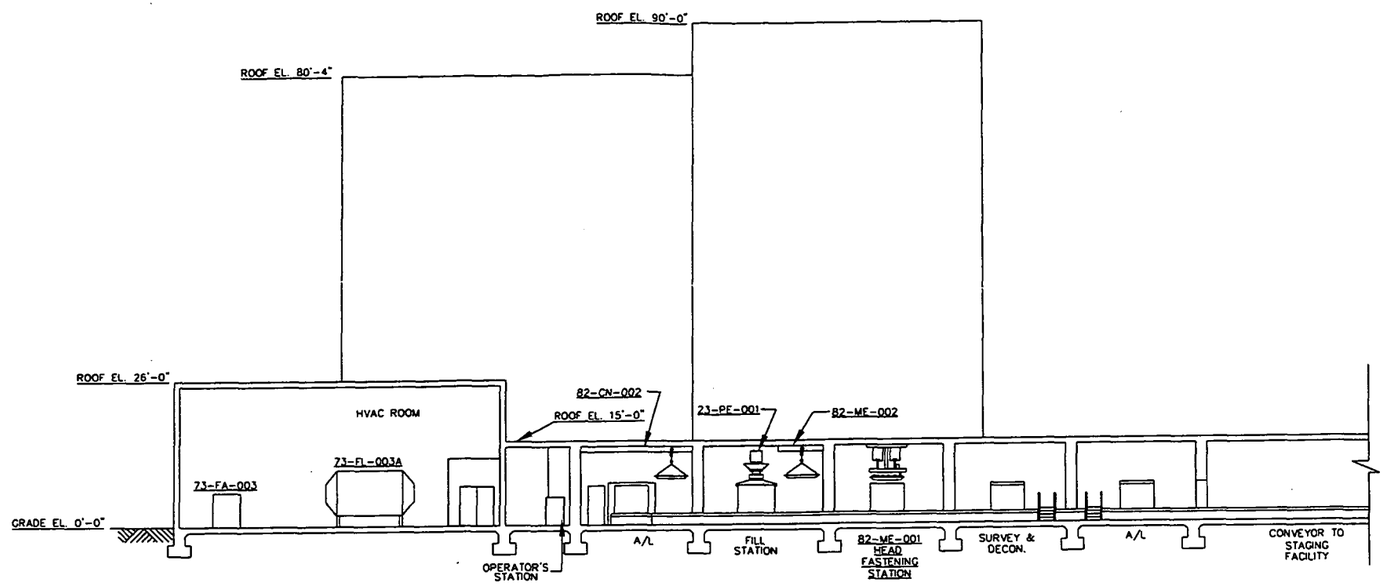
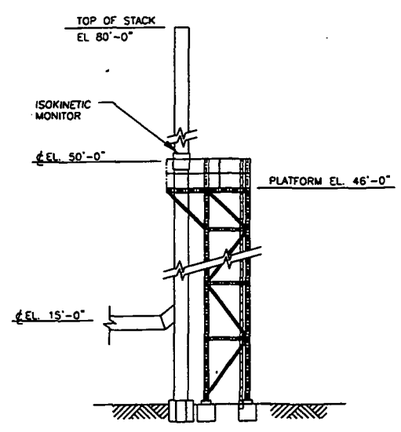


SECTION 'E'-'E'

SEE SK-7411 & SK-7412



DETAIL A

TYPICAL FOR 18-ST-001, 73-ST-001 & 73-ST-002

N.T.S.

SEE SK-7411 & SK-7412

GRAPHIC SCALE IN FEET

3/64" = 1'-0"

NOTES:

1. BUILDING CONSTRUCTION
   - CONCRETE FLOOR SLAB AND FOUNDATIONS.
   - ARCHITECTURAL TYPE WALLS CONSIST OF STEEL FRAME STRUCTURE, INSULATED METAL SIDING, MEMBRANE ROOFING SUPPORTED BY STEEL DECKING AND INSULATION BOARD.
   - MODULAR WALL CONSTRUCTION CONSISTS OF INTERLOCKING PREFABRICATED SHIELDING WALLS AND COLUMNS.
   - ALL OTHER SHEILDING WALLS ARE 2'-0" THICK CONCRETE.
2. EMPTY CONTAINER STORAGE IS SINGLE STACK.

REFERENCE DRAWINGS

94X-5500-P-SK-7411
94X-5500-P-SK-7412
94X-5500-P-SK-7413
94X-5500-P-SK-7414
94X-5500-P-SK-7444

000519

PRELIMINARY DRAWING

CHPLE SK-7443 | CHECKER ACAD R14

UNITED STATES DEPARTMENT OF ENERGY

FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

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FLUOR DANIEL FERNALD

SILOS PROJECT

CINCINNATI, OHIO

DRAWING TITLE

FACILITY LAYOUT
VITRIFICATION - OTHER
SECTIONS & DETAILS
REVISED FEASIBILITY STUDY FOR SILOS 1 & 2

DRAWN BY S. M. YANKEY	DATE 7/21/99	SCREENED, CHECKED BY	DATE	CHECKED BY J. THOMPSON	DATE 8/16/99
PLANT/BLDG. NO. OU4		FLOOR		SCALE AS NOTED	CLASS
SUBMITTED FOR APPROVAL A-E DATE		APPROVAL RECOMMENDED CONSULTING CONTRACTOR DATE			
DOE PROJECT NO. 40730	CPDR, CONTR, PROJ. NO. WBS2.1.3.G.P	DRAWING NO. 94X-5500-P-SK-7443		SHEET NO. 1	TOTAL NO. 2

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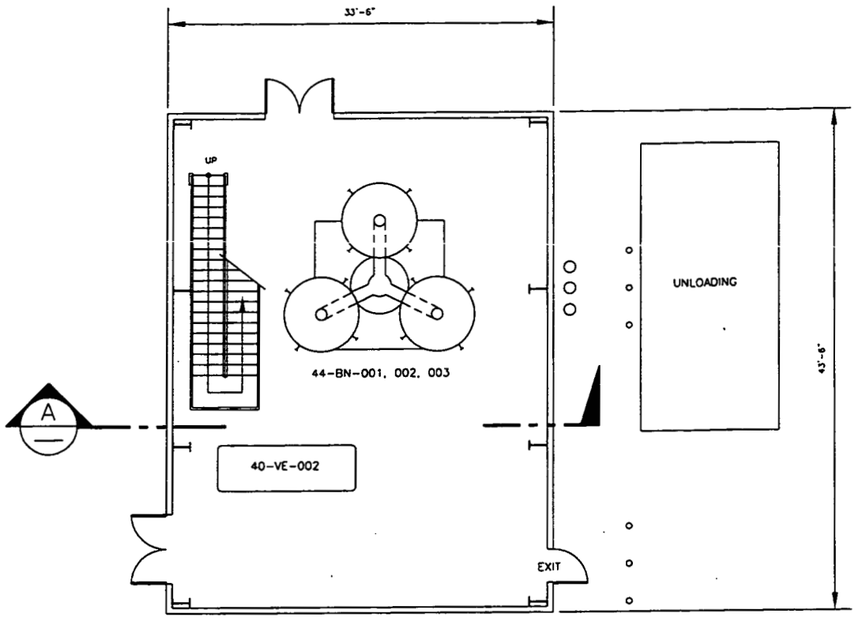
INITIALS: RWR

DATE: 12/1/99

8074



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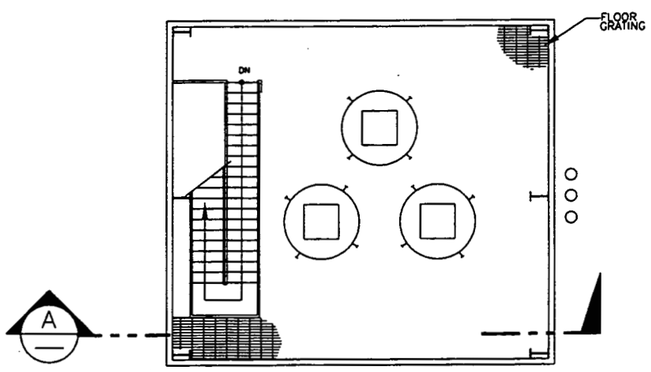

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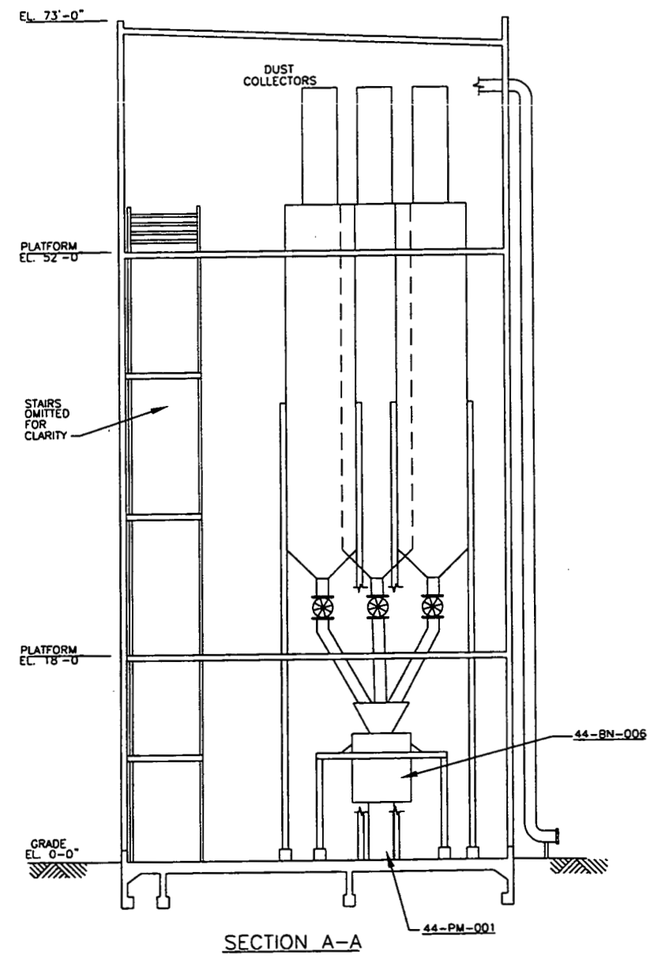

SECTION A-A

NOTES:

BUILDING CONSTRUCTION

- CONCRETE FLOOR SLAB AND FOUNDATIONS
- STEEL FRAME STRUCTURE
- INSULATED METAL SIDING
- MEMBRANE ROOFING SUPPORTED BY STEEL DECKING AND INSULATION BOARD

000520

PRELIMINARY DRAWING

0 5 10 15 20 25 30 35 40

GRAPHIC SCALE
1/8" = 1'-0"

CHFILE SK-7415 | CHECKER ACAD R14

UNITED STATES
DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

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SILOS PROJECT
CINCINNATI, OHIO

DRAWING TITLE

FACILITY LAYOUT
VITRIFICATION – OTHER
ADDITIVE STORAGE BINS
REVISED FEASIBILITY STUDY FOR SILOS 1 & 2

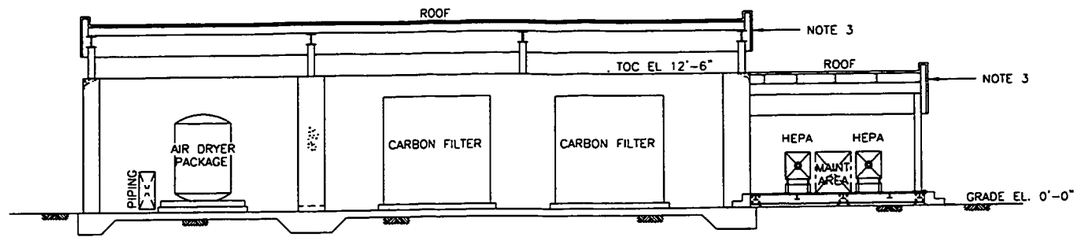
DRAWN BY S. M. YANKEY	DATE 09/22/98	DESIGNED, CHECKED BY	DATE	CHECKED BY J. THOMPSON	DATE 9/16/99
PLANT/BLDG. NO. OU4		FLOOR		SCALE 1/8"=1'-0"	CLASS
SUBMITTED FOR APPROVAL		APPROVAL RECOMMENDED			
A-E	DATE	OPERATING CONTRACTOR	DATE		
DOE PROJECT NO. 40730	SPEC. CONTR. PROJ. NO. WBS2.1.3.G.P	DRAWING NO. 94X-5500-A-SK-7415		SHEET NO. 1	NO. NO. 2

DISTRIBUTION CODE: XXX

ACAD

INITIALS: RWR
DATE: 12/1/99

8074



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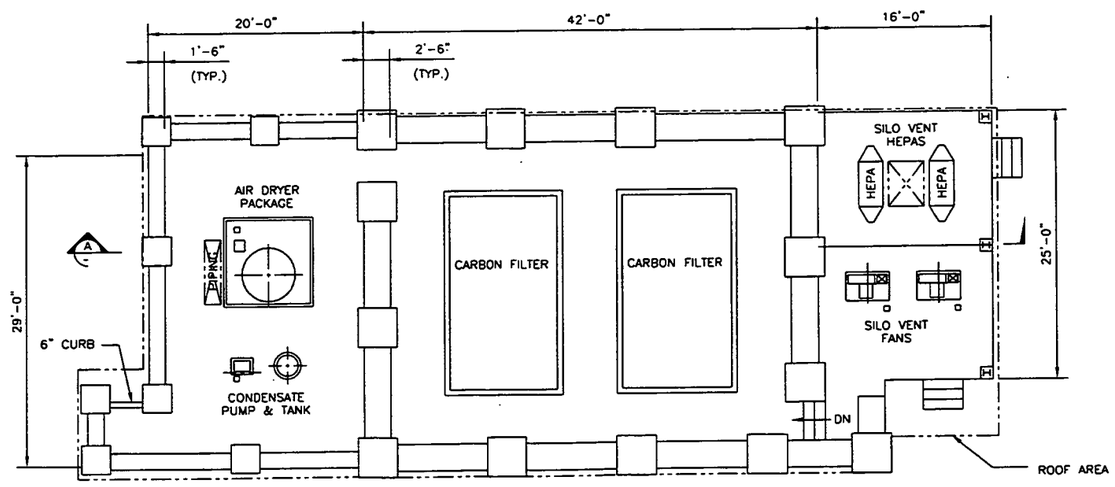

PLAN VIEW

NOTES:

1. CONCRETE FLOOR SLAB AND FOUNDATIONS
2. STEEL FRAME STRUCTURE
3. INSULATED METAL SIDING.
4. MEMBRANE ROOFING SUPPORTED BY STEEL DECKING AND INSULATION BOARD.
5. CONCRETE SHIELDING ONLY AS NOTED.
6. THIS DESIGN INCLUDES 2 MODULES
   1 = CONDENSATE PUMP & TANK
   2 = CARBON FILTER BEDS
   3 = HEPA FILTERS
   4 = HEPA FILTER FANS
   5 = LOWER EXHAUST STACK
   6 = UPPER EXHAUST STACK
7. MODULES TO BE MAXIMUM BOLT-UP CONSTRUCTION. LIMITED FIELD ERECTION.
8. MAXIMUM 24 FEET WIDE ON MODULES. OVERSIZED PERMIT FOR TRANSPORT ON OHIO STATE HIGHWAYS REQUIRED.
9. MODULES TO FIT ON 53 FOOT TRAILER AND TRACTOR (OHIO MAX.). MUST MEET ALL OHIO STATE ROAD LOADING REQUIREMENTS.
10. ROOF TO BE ASSEMBLED AFTER MODULES HAVE BEEN LOACATED AND ANCHORED.

000521

PRELIMINARY DRAWING

0 5 10 15 20 25
GRAPHIC SCALE
3/16" = 1'-0"

CAD FILE SK-7445		CADD CODE ACAD R14	
UNITED STATES DEPARTMENT OF ENERGY FERNALD ENVIRONMENTAL MANAGEMENT PROJECT			
THIS DRAWING PREPARED BY FLUOR DANIEL FERNALD SILOS PROJECT CINCINNATI, OHIO			
DRAWING TITLE FACILITY LAYOUT VITRIFICATION – OTHER RCS PLAN & SECTION REVISED FEASIBILITY STUDY FOR SILOS 1 & 2			
DRAWN BY RW REDMAN	DATE 8/5/99	REVIEWED, CHECKED BY / DATE	CHECKED BY J. THOMPSON / DATE 8/18/99
PLANT/BLDG. NO. OU4	FLOOR	SCALE 3/16" = 1'-0"	SIZE
SUBMITTED FOR APPROVAL / A-E / DATE	APPROVAL RECOMMENDED / OPERATING CONTRACTOR / DATE		
DOE PROJECT NO. WBS2.1.3.G.P	OPER. CONTR. PROJ. NO. 04424331	DRAWING NO. 94X-5500-P-SK-7445	SHEET NO. 1 / TOTAL NO. 2
DISTRIBUTION CODE: XXX	ACAD	INITIALS: RWR DATE: 12/1/99	

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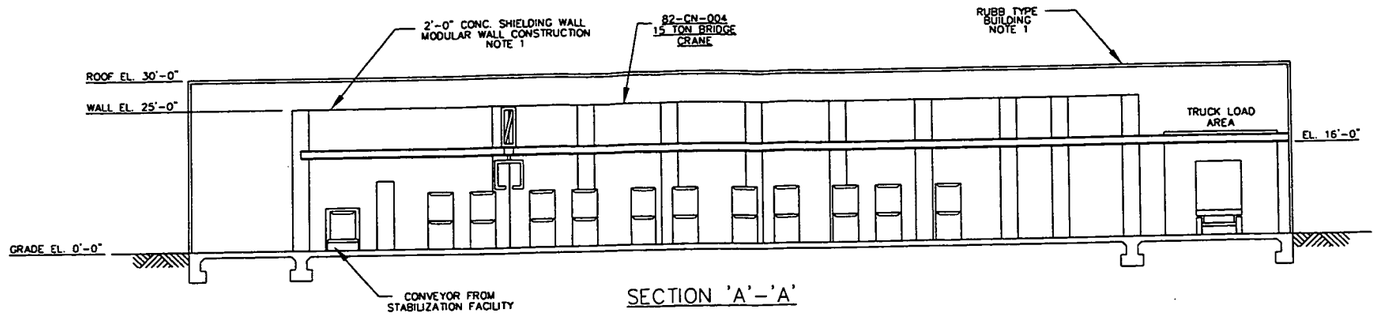
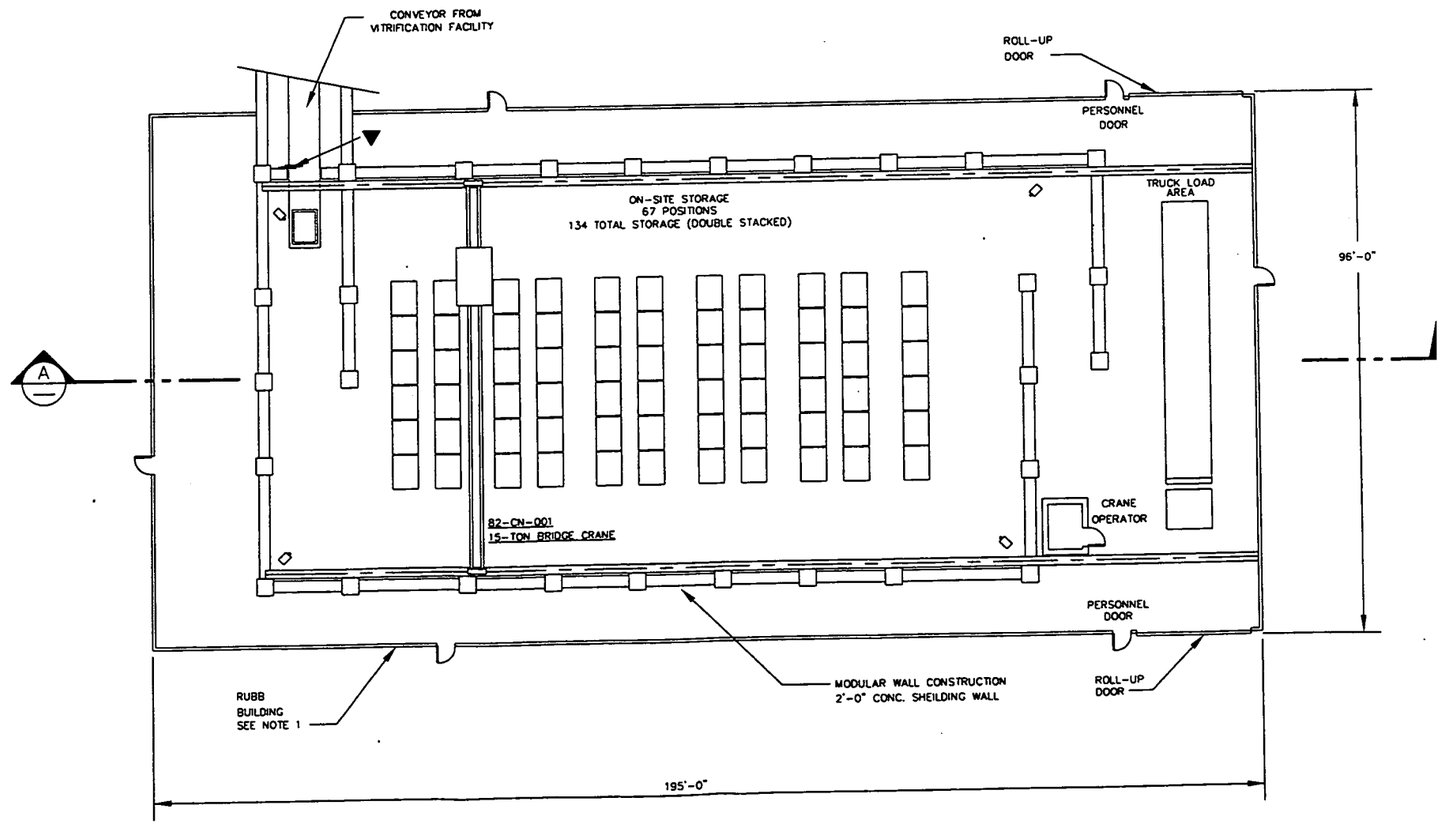


SECTION 'A'-'A'



PLAN @ EL. 0'-0"

0 10 20 40 60 80 100

GRAPHIC SCALE IN FEET
3/64" = 1'-0"

NOTES:

1. BUILDING CONSTRUCTION
   - CONCRETE FLOOR SLAB AND FOUNDATIONS
   - CONC. SHEILDING WALLS ONLY AS NOTED.
   - RUBB BUILDING AS NOTED. RUBB BUILDING CONSISTS OF A FABRIC MEMBRANE COVERING STEEL FRAMING.
2. CONTAINER STORAGE IS DOUBLE STACK.
3. SHIELD DOOR = ▲

000522

PRELIMINARY DRAWING

CAD FILE SK-7427 CHECKED ACAD R14

UNITED STATES
DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

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FLUOR DANIEL FERNALD
SILOS PROJECT
CINCINNATI, OHIO

DRAWING TITLE

FACILITY LAYOUT
VITRIFICATION - OTHER
INTERIM CONTAINER STAGING
REVISED FEASIBILITY STUDY FOR SILOS 1 & 2

DRAWN BY EMM	DATE 12/17/98	REVIEWED, CHECKED BY	DATE	CHECKED BY J. THOMPSON	DATE 3/16/99
PLANT/BLDG. NO. OU4		FLOOR		SCALE 3/64" = 1'-0"	CLASS
SUBMITTED FOR APPROVAL				APPROVAL RECOMMENDED	
A-E	DATE			OPERATING CONTRACTOR	DATE
EDE PROJECT NO. 40730	OPER. CONTR. PROJ. NO. WBS2.1.3.G.P	DRAWING NO. 94X-5500-P-SK-7427		SHEET NO. 1	REV. NO. 2

DISTRIBUTION CODE: XXX ACAD INITIALS: RWR DATE: 12/1/99

F-8074

Section G.6

G.6.0 CHEMICAL STABILIZATION — CEMENT-BASED

G.6.1 Summary

The Chemical Stabilization — Cement-based technology combines the Silos 1 and 2 material, cement, and dry chemical additives to remediate the waste constituents of concern. For this process, the Silos 1 and 2 material is dewatered and combined with stabilization reagents in a cement batch mixer. After mixing the Silos 1 and 2 material and stabilization reagents thoroughly, the grout mixture is discharged to a concrete, shielded disposal container. The loaded container is used for product shipment and disposal. A formula to optimize the waste loading and processibility using additives has been developed to meet the TCLP limits for the wasteform disposal.

G.6.1.1 Functional Analysis

A functional analysis has been performed for the Chemical Stabilization — Cement-based Technology. **Figure G.6.1-1** presents the individual functional requirements for the treatment facility. The first level functions are the high level functions to be accomplished by the treatment facility SSC. The subordinate levels in the functional analysis diagram describe the means for accomplishing the high level functions. **Table G.6.1-1** gives a brief description of the individual functional blocks shown in **Figure G.6.1-1**.

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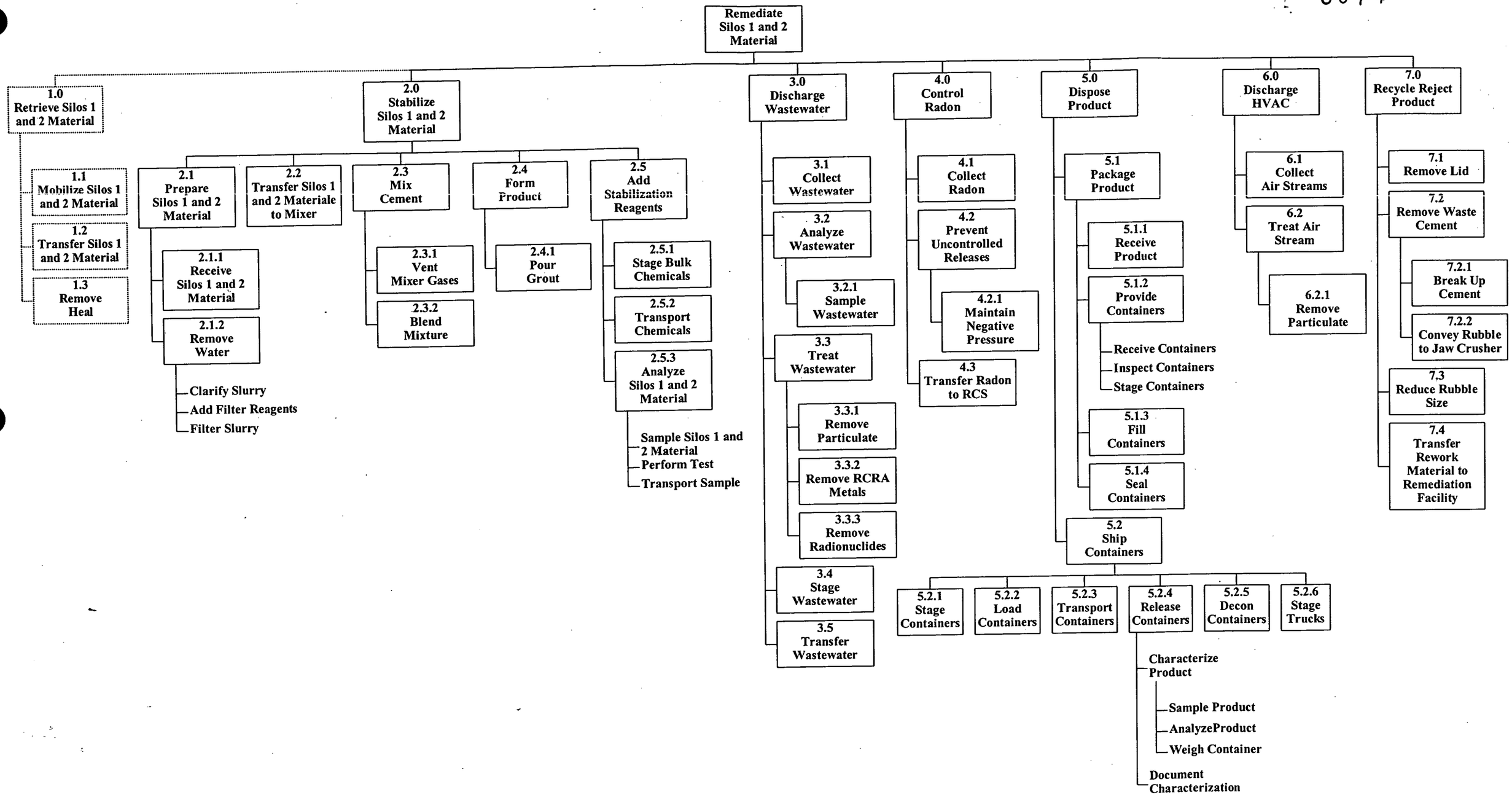
Figure G.6.1-1
Functional Analysis Diagram
Chemical Stabilization - Cement



000525

Functional Analysis Table

The functional descriptions in this section provide general information of the functions illustrated in **Figure G.6.1-1**. The functional description includes an overview of a function and identifies significant activities that define the scope of the function.

TABLE G.6.1-1
FUNCTION BLOCK DESCRIPTIONS
CHEMICAL STABILIZATION — CEMENT-BASED

Function ID	Function Title	Functional Description
Function	Remediate Silos 1 and 2 material	The 10 wt% slurry is clarified to 30 wt% solids, filtered, mixed with grout forming additives, and mixed in a batch mixer to produce a product that can be disposed of safely. The process interfaces with systems for venting vessel gases to the RCS, treating wastewater, and disposing of product.
1.0	Retrieve Silos 1 and 2 Material	The existing slurry's SSCs are used to hydraulically remove the Silos 1 and 2 material from the TTA.
1.1	Mobilize Silos 1 and 2 Material	The silos material is sluiced with water jets in order to form a slurry so that the material can be mobilized and removed by the slurry pumps.
1.2	Transfer Silos 1 and 2 Material	The silos material slurry is hydraulically transferred from the TTA to the treatment facility. This function is defined by material removal from the TTA.
1.3	Remove Heel	Any remaining silos material in the TTA is removed so the TTA storage tanks can be decontaminated and disposed.

TABLE G.6.1-1 (cont.)

Function ID	Function Title	Functional Description
2.0	Stabilize Silos 1 and 2 material	The dewatered silos material and cement forming additives are blended in a cement batch mixer. The stabilized product is poured into a disposal container, allowed to cure, and disposed of at an appropriate off-site disposal facility.
2.1	Prepare Silos 1 and 2 material	The silos material slurry is dewatered in a clarifier to 30 wt% solids. The thickened slurry is treated with filtering reagents and filtered in a filter press.
2.1.1	Receive Silos 1 and 2 material	The silos material is received from the TTA at approximately 10 wt% solids and inventoried in a receiving tank.
2.1.2	Remove Water	The water content of the 10 wt% slurry is reduced to reach a solids content of approximately 50 wt% solids. The 10 wt% slurry is thickened to 30 wt% slurry in order to reduce the volume of water discharged to the Wastewater Treatment System and to provide the slurry retrieval system with sluicing water. The 30 wt% solids slurry is treated with filtering reagents to aid in the filter press operations. The treated 30 wt% solids slurry is pumped through a filter press to increase the solids content to approximately 50 wt%.
2.2	Transfer Silos 1 and 2 Material to Mixer	The filter cake is discharged from the filter press into the cement batch mixer.
2.3	Mix Cement	The filter cake is mixed with cement and other stabilization reagents to form an acceptable waste product.
2.3.1	Vent Mixer Gases	The gases are collected from the batch mixer in the PVS.
2.3.2	Blend Mixture	The filter cake, cement, and other stabilization reagents are mixed in order to produce a homogenous treated wasteform.

TABLE G.6.1-1 (cont.)

Function ID	Function Title	Functional Description
2.4	Form Product	The mixed grout is formed into an acceptable wasteform.
2.4.1	Pour Grout	The mixed grout is discharged from the mixer into a disposal container. The mixed grout is formulated to be a flowable mixture.
2.5	Add Stabilization Reagents	Stabilization reagents are added to the cement batch mixer in order to treat the filter cake. The stabilization reagents produce a grout that passes waste disposal acceptance criteria.
2.5.1	Stage Bulk Chemicals	The bulk chemicals are inventoried at the treatment facility. The storage vessels protect the bulk chemicals from moisture.
2.5.2	Transport Chemicals	The bulk chemicals are transported to a batch bin to be weighed. The bulk chemicals are transferred from the batch bin to the cement batch mixer in the correct proportion. Weights of the bulk chemicals are recorded.
2.5.3	Analyze Silos 1 and 2 material	The dewatered slurry is analyzed in order to determine the correct proportion of stabilization reagents to be added to the grout mixture to produce an acceptable wasteform.
3.0	Discharge Wastewater	Any water characterized as secondary waste is discharged to the wastewater treatment system before being released to the AWWT.
3.1	Collect Wastewater	The wastewater discharged from any piece of equipment or system is collected and transferred to the wastewater treatment system.
3.2	Analyze Wastewater	Before releasing the wastewater to the AWWT, the treated wastewater is analyzed to ensure that it meets the AWWT acceptance criteria.
3.2.1	Sample Wastewater	Treated wastewater effluent is sampled in order to analyze the secondary wastestream.

TABLE G.6.1-1 (cont.)

Function ID	Function Title	Functional Description
3.3	Treat Wastewater	All secondary wastewater is treated to meet the AWWT acceptance criteria.
3.3.1	Remove Particulate	Particulate in the treated wastewater is reduced to less than 1,000 ppm of suspended solids in order to meet the AWWT acceptance criteria.
3.3.2	Remove RCRA Metals	Suspended and dissolved metals concentrations are reduced to a limit that meets the AWWT acceptance criteria.
3.3.3	Remove Radionuclides	Radionuclide concentrations are reduced to limits that meet the AWWT acceptance criteria.
3.4	Stage Wastewater	The means to inventory treated wastewater is made available to allow discrete batches of wastewater to be sampled and analyzed before being released for final treatment at the AWWT.
3.5	Transfer Wastewater	The means to transfer the treated wastewater to AWWT is available. The maximum discharge rate to the AWWT is 10 gpm (14,400 gallons per day).
4.0	Control Radon	The treatment facility is designed to control radon discharge in accordance with applicable requirements, including ALARA principles.
4.1	Collect Radon	The treatment facility is designed to collect radon from any location or discharge point that contains significant radon concentrations.
4.2	Prevent Uncontrolled Releases	Uncontrolled releases of radon in the system are prevented by maintaining a negative pressure in the processing rooms and equipment throughout the treatment facility.
4.2.1	Maintain Negative Pressure	Negative pressure is maintained by keeping a slight vacuum on all processing rooms and equipment in the treatment facility.

TABLE G.6.1-1 (cont.)

Function ID	Function Title	Functional Description
4.3	Transfer Radon to RCS	The treatment facility design ensures that radon is collected for treatment by venting streams from different processing areas and equipment to the existing RCS.
5.0	Dispose Product	The treated Silos 1 and 2 material is disposed at the disposal facility.
5.1	Package Product	The treated Silos 1 and 2 material is packaged in an IP2 or a DOT 7A Class A container.
5.1.1	Receive Product	The treated Silos 1 and 2 material is received from the cement batch mixer in an acceptable disposal container.
5.1.2	Provide Containers	Empty containers are provided to accommodate the discharge of treated Silos 1 and 2 material from the cement batch mixer.
5.1.3	Fill containers	The product is discharged from the cement batch mixer into an empty container. A discharge chute from the mixer to the container is provided. Equipment or a means to prevent contamination of the external surface of the disposal container is provided.
5.1.4	Seal Containers	Containers are sealed before release to the waste management or shipping department. Gaskets are provided to ensure that the containers are sealed water tight and nearly air tight.
5.2	Ship Containers	Containers filled with treated waste that meet the NTS waste acceptance criteria are shipped by truck to the NTS.
5.2.1	Stage containers	Interim storage is provided to stage filled, cured containers while preparations for container shipment are being made. A facility is dedicated to inventory a maximum of 360 filled, cured containers.
5.2.2	Load Containers	Personnel load the containers onto the delivery truck with minimal amount of contact with the container.

TABLE G.6.1-1 (cont.)

Function ID	Function Title	Functional Description
5.2.3	Transport Containers	Containers are removed from the treatment plant's interim staging facility by an overhead crane and subsequently placed onto a transport vehicle.
5.2.4	Release Containers	Once proper documentation is received by the waste management group, the container is released to the shipping department for transport to the NTS.
5.2.5	Decontaminate Containers	Disposal containers are decontaminated to acceptable limits before being shipped to the NTS.
5.2.6	Stage Trucks	Area is provided to stage the required number of trucks to support the production rate of filled and acceptable disposal containers.
6.0	Discharge HVAC	Gas streams that do not contain significant concentrations of radon are discharged through the HVAC System.
6.1	Collect Air Streams	Room ventilation and other HVAC streams are collected and routed to the necessary HVAC equipment.
6.2	Treat Air Streams	The HVAC air streams are treated to meet all discharge requirements.
6.2.1	Remove Particulate	The HVAC air streams are filtered to remove any particulate present before discharging the air to the atmosphere.
7.0	Recycle Reject Product	A separate facility is provided to handle operations associated with the rework activities of the reject glass containers. This system interfaces with the Treatment System and the PVS.
7.1	Remove Lid	The container of reject glass opened to access the treated material. Facility operators use a remote bolt removing device to remove the bolts from the container lid.

000531

TABLE G.6.1-1 (cont.)

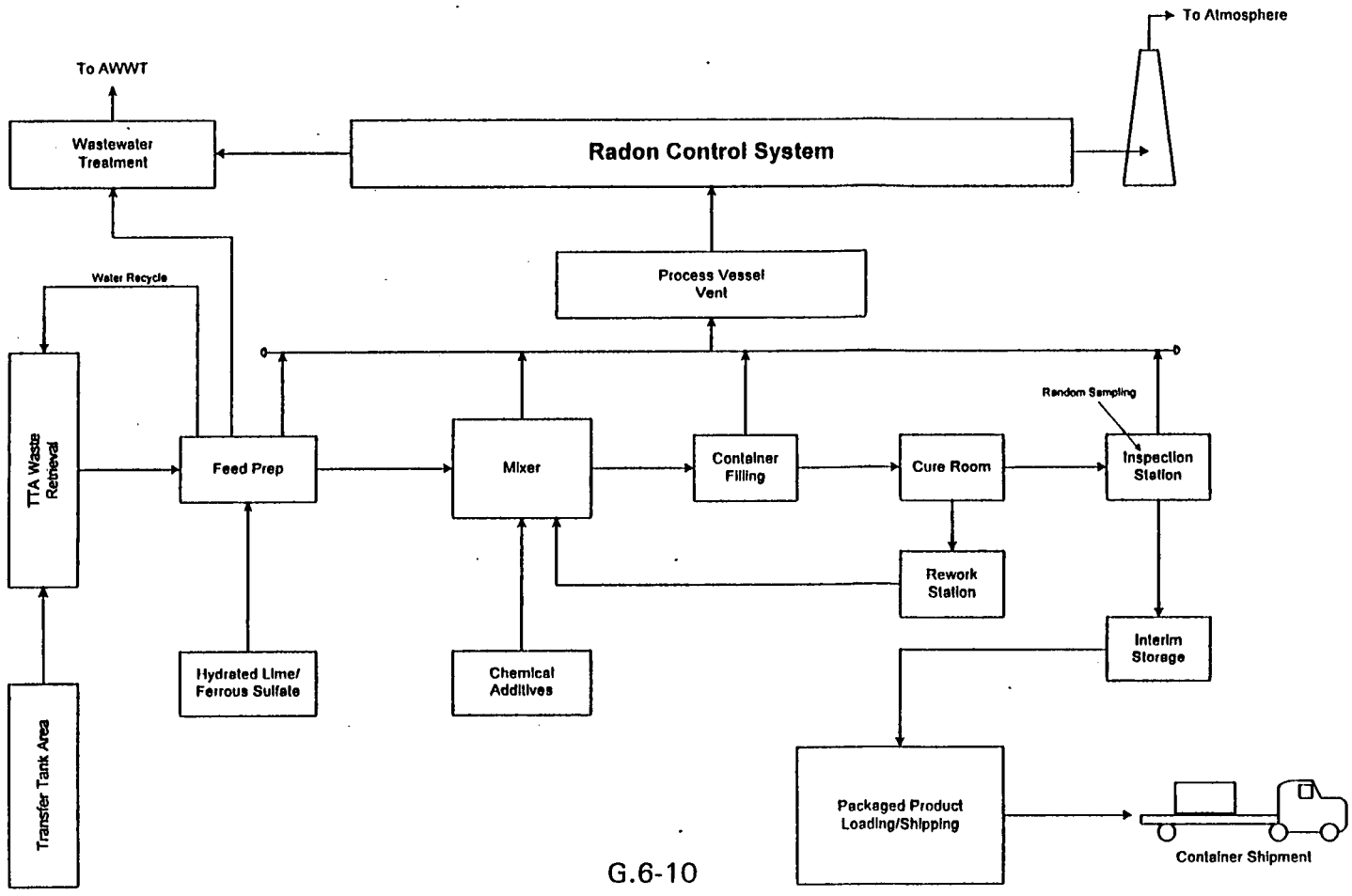
Function ID	Function Title	Functional Description
7.2	Remove Waste Cement	A facility is designated for the removal of reject material from the disposal containers. The SSCs associated with removing the reject material operate concurrent with normal operating activities.
7.2.1	Break up Cement	Equipment is provided to size reduce the glass in the disposal containers. Equipment associated with size reducing the reject grout is remotely operated.
7.2.2	Convey Rubble to Jaw Crusher	A vacuum retrieval unit is employed to automatically convey the size reduced grout to the rubble jaw crusher.
7.3	Reduce Rubble Size	A means to remotely and automatically reduce the size of the grout is available to ensure that the rework final product is homogeneous.
7.4	Transfer Rework Material to Remediation Facility	A Bucket Conveyor System to transfer the crushed rework grout to the rework hopper is provided. This system interfaces with the PVS.

G.6.1.2 System Model

Figure G.6.1-2 presents a block flow diagram for the treatment of the Silos 1 and 2 material using Chemical Stabilization — Cement-based technology.

000533

FIGURE G.6.1-2
SYSTEM BLOCK FLOW DIAGRAM
CHEMICAL STABILIZATION — CEMENT-BASED



G.6.1.3 Treatment Recipe

Grout formulas for cement stabilization have ranged between 15 wt% waste loading and 40 wt% waste loading. The basis for the cement stabilization formula is 30 wt% waste loading and contains the following approximate constituent concentrations:

- 22 wt% cement;
- 16 wt% dry additives;
- 30 wt% dry Silos 1 and 2 material; and
- 32 wt% water

G.6.1.4 Mass and Energy Balance Overview

A detailed mass and energy balance is provided in **Attachment G.6.I.**

The full-scale treatment facility is designed to produce approximately 80.5 tons of grout per day (11 filled disposal containers). The operating schedule is two 8-hr shifts/day, 5 days/week. Five days per week during one shift per day, the Feed Preparation System receives slurry from the TTA, between 10 wt% and 30 wt% solids, which results in a transfer of approximately 5,900 lb/hr of solids. Feed to the clarifier is approximately 20,000 lb/hr (40 gpm) of 10 wt% solids slurry. This produces an underflow flow rate of 7,000 lb/hr (11 gpm) of 30 wt% solids slurry to the slurry batch tanks and a supernatant overflow to the supernatant sump tank of approximately 13,500 lb/hr (27 gpm) of water. Hydrated lime and ferrous sulfate are added to the slurry batch tanks once per shift per tank at approximately 5 gpm. Once the slurry has been amended with hydrated lime and ferrous sulfate, it is transferred to the filter press at 140 gpm and 100 psi. The filter press operation produces an average of 7,500 lb/hr of 50 wt% solids filter cake and 6,300 lb/hr (approximately10 gpm) of filtrate. Cement and additives are transferred on a batch basis and consist of approximately 2,500 lb of cement per batch and 1,800 lb of additives per batch. Water is added to the batch mixer as needed to produce a grout that minimizes material handling difficulties. Filled

containers of grout are transported to the curing room where they cure for seven days before being transported to external storage. A container of grout is expected to have an approximate temperature rise of 5° to 10°F. The Wastewater Treatment System processes and discharges to the AWWT approximately 10,000 gallons of water per day. All process equipment is maintained at a negative pressure by the vacuum blowers in the RCS. The total flow of the PVS is limited to 500 scfm.

G.6.1.5 Availability and Work Schedule

The design of the Chemical Stabilization — Cement-based facility is based on a 3-year operating campaign at 70% availability of the plant systems and equipment. Normal processing operations are performed two 8-hr shifts/day, 5 days/week. However, in order to reduce the number of times flow is interrupted to and from the clarifier, the clarifier and receipt tank (including ancillary equipment) are operated 24 hr/day, 5 days/week. At the end of the normal operating week, and during any process interruptions, the feed to the clarifier is stopped and the underflow stream is circulated back to the inlet of the clarifier.

G.6.2 Feed Preparation (Systems 15, 43 and 44)

The Feed Preparation System is comprised of (1) the waste slurry receiving tank, clarifier, slurry batch tanks (SBTs), supernatant sump tank, and all associated transfer equipment shown on process flow diagram (PFD) 94X-5500-F-SK-3353, and (2) the filter press and filter cake weigh and delivery hopper shown on PFD 94X-5500-F-SK-3409. The Cement and Additive System, System 44, includes the cement and additive storage silos, transfer equipment, the batch weigh hopper shown on PFD 94X-5500-F-SK-3408, and the cement mix delivery hopper shown on PFD 94X--5500-F-SK-3409. The Wet Additive System, System 43, includes the hydrated lime and ferrous sulfate slurry tanks and transfer equipment shown on PFD 94X-5500-F-SK-3118. (PFDs are included in **Appendix G, Attachment G.6.II**).

In-line densitometers and flow meters monitor the solids content and flow rates of the slurry lines in the Feed Preparation System.

G.6.2.1 System Description

The Feed Preparation System is designed to receive slurry from the TTA intermittently at approximately 5,900 lb/hr (110 gpm) of solids. Because the minimum flow capacity of the slurry retrieval system (5,900 lb/hr) exceeds the required throughput of the treatment process, and to assure a uniform feed to the clarifier, a waste slurry receiving tank, 15-TK-001 (receiving tank), is used to receive a twelve hour inventory of slurry [approximately 27,000 gallons (gal)] transferred from the TTA. The receiving tank receives the slurry from the TTA at approximately 10 wt% to 30 wt% solids (10 wt% is used as a basis for mass balance calculations) and continuously agitates the contents in the tank to prevent the solids from settling to the bottom. Low level switches within the receiving tank alarm when the waste retrieval system operations need to be initiated to charge the receiving tank with another shift worth of slurry.

Transfer of the 10 wt% solids slurry from the receiving tank to the clarifier, 15-TK-002, is accomplished using 30 gpm progressive cavity pumps 15-PM-001 A&B (receiving tank transfer pumps). Slurry transfer to the clarifier is maintained 24 hr/day, 5 days/week with a continuous feed from the receiving tank to help prevent surges of material that may disturb the settled solids in the clarifier. Upon interruption of normal operations, the feed to the clarifier is suspended and the underflow stream is circulated back to the clarifier inlet until operations are restored.

Concurrent with feed transfers, a partially clarified supernatant spills over a weir inside the clarifier tank and gravity flows to the supernatant sump tank 15-TK-008. Most of the incoming suspended solids undergo gravity settling to form a dense layer in the bottom cone of the clarifier. The continuous slow rotation of the clarifier rake, 15-AG-002, pushes the settled solids (underflow) to the outlet at the base of the clarifier cone. The underflow stream has a solids concentration of approximately 30 wt% and is continuously pumped to one of three SBTs with 10 gpm progressive cavity pumps - 15-PM-002 A&B (clarifier underflow transfer pumps). Both the receipt tank transfer pumps and the clarifier underflow pumps are

equipped with variable frequency drives to enable the operators to make any necessary flow rate adjustments to the process.

The concentrated underflow stream is transferred 24 hr/day, 5 days/week to one of the three SBTs, 15-TK-003, 15-TK-004 or 15-TK-005. Transfer of one shift worth of slurry to a slurry batch tank (SBT) takes approximately eight hours for a total working capacity of approximately 6,500 gal of 30 wt% solids slurry. After the transfer of slurry from the clarifier to a SBT is complete, the underflow stream begins to fill the next SBT.

After an SBT has been filled, the contents are agitated for approximately one hour and subsequently sampled for percent solids concentration and elemental analysis. Once the solids content and elemental analysis are complete, hydrated lime and ferrous sulfate solutions are added to the contents of the SBT. The hydrated lime and ferrous sulfate aid in the slurry filtering process. Subsequent to the addition of the hydrated lime and ferrous sulfate, the SBT contents are mixed until the SBT contents are required to charge the filter press. Therefore, at any given time, one SBT is charging the filter press (15-FL-001 on PFD 94X-5500-F-SK-3409), one SBT is in the process of being sampled and amended with hydrated lime and ferrous sulfate, and the third SBT is in the process of being filled and mixed.

The addition of ferrous sulfate and hydrated lime is accomplished by preparing separate solutions of the two chemicals and transferring them to the SBT's (system 43). The hydrated lime is delivered to the treatment facility as a bulk dry chemical and is stored on the bulk chemical pad. On a daily basis, bags of the hydrated lime are emptied into Bag Dump Station 43-BN-001 and pneumatically transferred to a filter receiver where the hydrated lime is gravity fed into the hydrated lime slurry tank 43-TK-001 and combined with plant water and agitated until the solution is transferred to one of the three SBT's. Enough hydrated lime solution is prepared to amend one day's worth of slurry. The required amount of lime solution is transferred to a SBT in approximately 10 minutes wherein the Silos 1 and 2 material is mixed for approximately 15 to 20 minutes. Subsequent to the addition of lime to the SBT, the prescribed amount of ferrous sulfate solution is added to the slurry. The ferrous sulfate is

delivered to the processing facility as a 60% ferrous sulfate solution in a tote tank. The tote tank contents are pumped to Tank 43-TK-002 (ferrous sulfate addition slurry tank). The addition of ferrous sulfate to the SBT follows the same procedure as the lime solution addition.

Once the slurry in the SBT has been sampled, analyzed, amended with ferrous sulfate and hydrated lime, then mixed, it is transferred to the filter press in discrete batches. The slurry is transferred using progressive cavity pumps 15-PM-003A&B, 004A&B and 005A&B (slurry batch transfer pumps). Enough slurry is transferred to produce a sufficient amount of 50 wt% moisture filter cake for one batch (disposal container) of grout. After the filter press has compressed the slurry, plant air is used to blow down the filter cake for further de-watering and it is subsequently discharged to the filter cake weigh and delivery hopper, 15-TK-006. The processes of transferring the slurry from the SBT, filter press compression, air blow down, and discharge of the filter cake requires approximately one hour. While the filter press is being charged with the next batch of slurry, the filter cake in the filter cake weigh and delivery hopper can be sampled and analyzed for moisture content, as necessary. The filtrate from the filter press is discharged and treated by the Wastewater Treatment System as secondary waste.

The Cement and Additive System is designed to receive and store the cement and additive materials and deliver the additives to the batch mixer. Additive constituents proposed for use in the grout formulations are: Type II Portland Cement, Type F Flyash, blast furnace slag, and triple super phosphate (TSP). Various combinations of these materials are evaluated based on desired grout processing properties and performance criteria. All additives are handled with conventional bins and feeders.

Concurrent with the preparation of the filter cake, a cement and additive mix is also prepared and transferred to the treatment system. PFD 94X-5500-F-SK-3408 depicts the flow logic of the cement and additives system. Cement and additives are delivered to the treatment facility by truck and pneumatically conveyed to the cement and additive storage bins 44-BN-001, 002, 003, and 004. All storage bins are equipped with exhaust fans, bag filters and air pads, which

fluidize the dry material. After the analyses of the slurry and filter cake have been completed, the amount of cement and additives required to stabilize the batch are determined. Once determined, the necessary amount of cement (or additive) is conveyed by means of a rotary star feeder and an air slide to the batch weigh hopper 44-BN-005. After the correct amount of material has been weighed, the material is transferred from the batch weigh hopper to the cement mix delivery hopper 44-BN-006 (shown on PFD 94X-5500-F-SK-3409) by cement and additive transfer pump (dense phase) 44-PM-001. The cement and additives are individually weighed and transferred to the cement mix delivery hopper since there is no requirement to thoroughly mix the cement and additives before feeding them to the mixer. The individual constituents from the Cement and Additive System are weighed before being transferred from the batch weigh hopper and as they are received by the delivery hopper to ensure that the correct amount of material is being added to the grout batch.

G.6.2.2 Assumptions

Assumptions have been made for the Feed Preparation System to complete mass balance and design efforts. The primary assumptions used in the Feed Preparation System are outlined below, along with the basis for each assumption.

A. **Assumption:** Cement and additives material are delivered in trucks with self-contained, pneumatic unloading conveyors.

Basis: Bulk delivery by truck and unloading provides the safest and most efficient operation given the quantity of additives handled.

B. **Assumption:** Manual sampling and/or automatic sampling of dry additives is required and samples are analyzed at an on-site process control laboratory.

Basis: Raw materials are required to meet purchase specifications and blended materials must have been blended in the proper proportions to meet process specifications.

000539

C. **Assumption:** The Feed Preparation System provides five days inventory of additives.

Basis: Enough storage is available so that shipments can be easily scheduled such that plant operations are not threatened by short-term interruptions in delivery.

D. **Assumption:** The minimum processing rate is nine tons of the Silos 1 and 2 material (dry basis) per day, two 8-hr shifts/ day, 5 days/week.

Basis: This is the process rate required to remediate the contents of the TTA in three years.

E. **Assumption:** The minimum flow rate from the TTA to the receiving tank is 110 gpm and 10 wt% solids.

Basis: This is the projected operating regime of the waste retrieval pump that transfers slurry from the TTA to the Feed Preparation System.

F. **Assumption:** The cement mixer can process one container of treated Silos 1 and 2 material per hour.

Basis: Time motion study for Chemical Stabilization — Cement-based treatment facility.

G. **Assumption:** Grout density is approximately 2,400-3,000 lb/yd^3 (89-114 lb/ft^3).

Basis: Preliminary calculations based upon the POP testing results **(Appendix H, Attachment H3).**

G.6.2.3 Key Equipment Descriptions

Receipt Tank

The waste slurry receiving tank, 15-TK-001, is a 32,000-gallon, 16-ft diameter, 22-ft high carbon steel tank with a top mounted agitator, level alarms, and a maximum liquid level of 18 ft. The receipt tank is equipped with a top mounted agitator, 15-AG-001, to aid in the homogenization of the feed and to prevent the solids from settling to the bottom of the tank.

Clarifier

The clarifier, 15-TK-002, is a 10,000-gallon, carbon steel settling tank with a diameter of 14 ft and a straight wall height of 8 ft. The design of the clarifier incorporates a conical bottom to allow for the collection and discharge of the settled solids. The continuous slow rotation of the clarifier rake, 15-AG-002, keeps the dense phase mobile by pushing the settled solids to the outlet of the cone section of the clarifier.

Slurry Batch Tanks

Each SBT (15-TK-003, 004 and 005) is a 7,700-gallon carbon steel tank with a 10-ft diameter and a 14-ft wall height. Each tank has a top mounted agitator, high and low level alarms, and a maximum liquid level of 12 ft.

Filter Press

The filter press is an automatic, four chamber filter press. The four chambers are designed with a conveyor of filter media. Sequentially, each chamber is filled with slurry and compressed using a water bladder. Following the water bladder compression, the chamber is blown down with 100-psi compressed air to further de-water the filter cake. The filter cake is then conveyed to the discharge chute where it is scraped from the filter media and gravity fed into the filter cake weigh and delivery hopper. The filter press is designed to wash down the filter media following the discharge of the filter cake. A diverter valve is included to prevent the wash water from discharging to the filter cake weigh and delivery hopper.

Filter Cake Weigh Hopper

The filter cake weigh and delivery hopper is a 83 ft^3, stainless steel hopper with a 4-ft diameter and a height of 8 ft. The hopper is mounted on load cells and is interlocked with the PLC to indicate the weight of filter cake that has been added to the batch mixer.

Cement and Additive Storage Silos

The cement and additive storage silos are industry standard, carbon steel silos that are designed to receive the cement and stabilization reagents from delivery trucks with on board pneumatic conveying equipment. Each silo is equipped with vibrators, internal aeration to prevent the material from bridging, as well as air slides and rotary star feeders to transfer the material to the cement and additive weigh hopper. Level switches within each silo indicate the material level to the operator.

The storage silos, 44-BN-001 and 44-BN-004, are each 3,500 ft^3 silos (3,000 ft^3 working volume) with 12-ft diameters and heights of 37 ft. The remaining two storage silos, 44-BN-002 and 44-BN-003, are each 2,027 ft^3 silos (1,800 ft^3 working volume) with 10-ft diameters and heights of 31 ft.

Lime Addition Bag Dump Station Package

The lime bag dump station, 43-BN-001, has a 10-ft^3 capacity and is equipped with a vacuum blower, 43-BL-001, to transport the hydrated lime powder to the filter receiver, 43-BN-002, which in turn gravity feeds the hydrated lime to the hydrated lime slurry tank. The lime addition bag dump station is a manual operation.

Lime Addition Slurry Tank

The lime addition slurry tank is an 800-gallon polyethylene tank with a 5-ft diameter and a 5-ft height. The tank is equipped with a top mounted agitator, 43-AG-001, to ensure that the hydrated lime powder is thoroughly mixed.

Ferrous Sulfate Addition Slurry Tank

The ferrous sulfate addition slurry tank is an 800-gallon polyethylene tank with a 5-ft diameter and a 5-ft height. The tank is equipped with a top mounted agitator, 43-AG-002, to ensure that the ferrous sulfate slurry is thoroughly mixed.

G.6.2.4 System Interfaces

The Feed Preparation System interfaces with the following SSC:

- Silos 1 and 2 material slurry that is pumped from the TTA storage facility by way of the slurry retrieval process at a rate of 5,900 lb/hr.
- The clarifier supernatant that is decanted to the supernatant sump tank and subsequently pumped to the TTA Recycle Water System. Additionally, the recycled water system provides the treatment facility flush water.
- All feed preparation equipment, including tanks and the filter press, that are vented to the RCS.
- The Feed Preparation System that interfaces with the Treatment System.
- Bulk additive trucks that convey the additives to the storage bins.
- Dewatered filter cake that is fed to the Treatment System.
- Compressed air that is used for bulk solids transfer, as well as pneumatically operated valves, bin aerators, air slides, filter press, instrumentation and controls.
- Electrical power for instrumentation and motors.

G.6.2.5 Recycle back to the TTA

The Recycle Water System is comprised of supernatant sump tank 15-TK-008 and the supernatant tank transfer pumps 15-PM-008 A&B and is represented on PFD 94X-5500-F-SK-3353 **(Appendix G, Attachment G.6.II)**. The clarified overflow from the clarifier tank is gravity fed to the supernatant sump tank and is subsequently transferred back to the TTA Recycle Water System using two centrifugal pumps. An inlet line to the

supernatant sump tank from the filter press room sump pump is provided so that in the event of a rupture in the filter press or a filter press line, any material leaked to the filter press room can be discharged back to the TTA.

G.6.3 Treatment (System 17)

The Treatment System consists of the batch mixer 17-MX-001 and the mixer flush tank 17-TK-001. PFD 94X-5500-F-SK-3409 **(Appendix G, Attachment G.6-II)** depicts the flow logic of the Treatment System.

G.6.3.1 System Description

The batch mixer is designed to produce one batch (disposal container) of grout in approximately one hour. The filter cake from the filter cake weigh and delivery hopper is discharged to the batch mixer through a chute connection. The weigh elements on the filter cake hopper transmit, to the PLC, the weight of filter cake that is added to the mixer. The PLC verifies that the amount of cement and additives delivered to the cement mix delivery hopper is within specified parameters before discharging the cement mix to the batch mixer. After necessary water additions are made to the grout batch, the mixer runs for approximately 30 minutes to ensure that all constituents have ample mixing time.

At or before the end of the mixing cycle, the enclosed discharge chute with a container fill head is clamped to an empty disposal container. After the fill head connection is made and the grout has been thoroughly mixed, the mixer discharge chute valve is opened and the mixer contents are transferred to the disposal container. The weigh elements under the box and level indicators within the fill head ensure that neither the maximum weight nor the maximum volume of the container are exceeded. The disposal container is vibrated as the grout is discharged from the batch mixer to ensure that the grout is leveled as it is transferred, reducing the number of air pockets within the grout monolith.

A discharge port for flush water is located at the bottom of the mixer. The frequency of mixer flush cycles is determined during operations. If it is necessary to reduce the build-up of cured grout, the mixer has the capability of being flushed after every batch. After a batch of grout is discharged to a disposal container, the discharge chute valve is closed and the mixer is charged with either process water or recycle water from the supernatant sump tank. The mixing action is engaged to provide a means for removing grout from the mixer walls and paddles. Following the batch mixer clean out, the flush water is discharged to the mixer flush tank where it is subsequently transferred to one of the SBTs.

G.6.3.2 Assumptions

Assumptions have been made for the Treatment System to complete mass balance and design efforts. The primary assumptions used in the Treatment System are outlined below, along with the basis for each assumption.

A. **Assumption:** Grout density is approximately 2,400 - 3,000 lb/yd^3 (89 - 114 lb/ft^3).

Basis: Preliminary calculations based upon the POP testing results **(Appendix H, Attachment H3).**

B. **Assumption:** Grout composition is assumed to be approximately:

- 22 wt% cement;
- 16 wt% dry additives;
- 30 wt% dry Silos 1 and 2 material; and
- 32 wt% water.

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

forklift places the container, lid, and absorbent mat onto the conveyor, all container handling operations are remote.

The disposal container, with the lid and absorbent mat leading, is conveyed and aligned with the fill head at the fill station. A lifting actuator raises the container above the conveyor rollers, then the fill head is lowered and secured to the container to form a tight seal. The fill head clamps onto the container, rather than bolting it on, to reduce the processing time requirements. The PVV is opened. The disposal container is vibrated to level the accumulated grout as the batch of mixed grout is discharged from the mixer into the container.

When the disposal container is full, the mixer discharge door closes, the head clamps disengage, and the PVV is shut off. In order to ventilate the container's freeboard space, a sweep hood is positioned to capture radon. The radon is exhausted to the RCS by way of the process hood ventilation system. The sweep hood vent valve is opened before the fill head is raised to the stand-by position.

The container is conveyed to the sampling location, then sampled by means of a remote system for testing concrete properties and for archiving. The sweep hood vent valve is closed during sampling. After sampling, the filled container is conveyed to the lidding station.

Lidding Station

The container lid and absorbent mat are remotely connected to the lid installation monorail hoist grapple. The hoist conveys both the container lid and the absorbent mat to the lidding station. The lid installation hoist and grapple are moved to the lidding station where they are staged until the filled container is received. When the container is positioned at the lidding station, the absorbent mat is aligned with the container opening and released onto the surface of the grout, by means of remote operation and CCTV viewing and/or shielded glass viewing windows. Next, the hoist is indexed to align the lid with the container opening and the lid is placed onto the container, but not fastened.

Wash Station

The conveyor moves the container inside the wash station, the doors close, and spray nozzles thoroughly wash and rinse the exterior of the container with 30-40 psi decontamination solution. When the container has adequately drip dried, the doors open and the container is conveyed into the curing room.

Curing Room Operations

The washed container is conveyed into the curing room, lifted by a remotely operated overhead bridge crane, and placed in a designated storage location for a seven calendar day initial curing.

Inspection and Staging Operations

On a periodic and random basis, containers are inspected for free liquids in the inspection station. Upon completion of the initial 7-day curing period, the container is retrieved from the curing room by a remotely operated overhead bridge crane, placed onto a conveyor, and conveyed to the inspection station. The container is aligned with the lid lifting equipment. In order to ventilate the container's freeboard space, a sweep hood is positioned to capture radon venting to the room when the container lid is removed. The gas is exhausted to the RCS by way of the process hood ventilation system. The lid is grappled and removed from the field of view by the lid lifting equipment. The operator observes and inspects the interior of the container by a CCTV camera and monitor and/or through the shielded viewing windows. After completing the inspection, the container lid is reinstalled.

Lid Fastening Station

The container is conveyed into the lid fastening station, and aligned with the lid fastening equipment. The remote wrench lowers and tightens all of the bolts until they are fully engaged with the container.

Survey and Decontamination Station

The container is conveyed to the survey and decontamination room, where its exterior surface is surveyed and decontaminated, as necessary, to meet surface radioactivity limits.

Interim Staging Facility

The 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. The interim staging facility has the capacity to inventory a maximum of a 45 calendar days worth of container production at a target production of 11 containers per day (approximately 360 containers).

G.6.4.2 Assumptions

A. **Assumption:** A daily target production rate of 11 disposal packages.

Basis: POP requirement for complete remediation in three years.

B. **Assumption:** The RCS has a 500 scfm capacity for use in a sweep hood to capture radon.

Basis: AWR design.

G.6.4.3 Key Equipment Descriptions

Conveyors

The roller conveyors are either 5-ft or 7-ft wide. They are heavy duty, motorized, chain driven, two-directional conveyors of various lengths with rated capacities 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 containers. They are equipped with special features for lifting containers above the rollers and vibrating the containers as they are filled, for right angle transfers, and for 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.

Interim Staging Facility Crane

This crane is a remotely operated bridge crane with a rated capacity of 15 tons and 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 containers. In addition, the bridge crane has CCTV capacity to ensure positive grappling and placement of the container.

Monorail Hoist

The monorail hoist is remotely operated, with a rated capacity of 15 tons and a travel of 30 ft. The crane is equipped with two special grapples: one grapple lifts and carries the absorbent mat and places it in the filled container, and the other grapple lifts and carries the container lid and aligns and seats it on the container.

Fill Head

The fill head consists of custom designed equipment for filling the container with grout. It is connected to the batch mixer's enclosed discharge chute. It is mounted on actuators for raising and lowering. It provides confinement of the grout during pouring operations and prevents grout from being deposited on the outside of the container. The fill head has flexible connections to the PVS and a grout filling connection to the mixer. The PVS maintains a negative pressure within the container as the grout is poured into the container. The fill head has a level detection system and a drip catch tray to prevent dripping of grout on the fill station equipment when a container is not located underneath. The tray automatically moves in and out of catch position when the fill head is raised or lowered.

Curing Room Bridge Crane

The curing room bridge crane is a remotely operated bridge crane with a rated capacity of 15 tons and a span of 80 ft, a travel of 100 ft, and a lift height of 16 ft. The crane is equipped with a special grapple device for lifting filled containers. In addition, the crane has CCTV capacity to ensure positive grappling and placement of the filled containers.

Inspection Station

The inspection station consists of custom designed equipment for remotely observing and inspecting inside the filled container. The inspection station has a grapple for capturing and lifting the lid from the container. The grapple uses rigid mechanical linkages for accurate and efficient operations. It positions the lid such that CCTV viewing is possible. It replaces the lid on the container when the inspections are complete.

Lid Fastening Station

The lid fastening station consists of a remotely operated wrench mounted on a frame that aligns with the bolt pattern of the container. The operator views the lidding operation either by CCTV or through the shielded glass viewing windows. The wrench is actuated up and down and may be lowered to engage the bolt heads and tighten or loosen them as required.

Sample Station

The sample station is intended to provide the capability to sample the grout from the container, then package it in an acceptable storage container, and store it in a controlled environment where it is conveniently retrievable. Sampling is a remote operation performed in the fill room. A sample collector is attached to an actuator that has vertical positioning and travels on a ceiling mounted track in a horizontal motion. The track mounted trolley aligns the actuator with the container and the sample is taken. The trolley moves the sample to the glove station where an operator cleans up the sample and places it in a storage container with a bar code identifier. The sample is placed onto the actuator and the trolley takes it to the sample storage rack where it is deposited. The storage provides heated storage for acceptable curing

conditions. The system retrieves the requested sample according to the operator's instructions.

Sweep Hood

The sweep hood is a ventilation device connected to the PVS for the purpose of radon capture. It is specifically designed to capture radon that could escape from an open, filled container, using the available flow rate of 500 scfm or less. Sweep hoods are featured at the fill station, rework station, and inspection station.

Wash Station

The wash station is a standard, industrial, automated 80-inch turntable part washer with a rated capacity of 21,000 lb. The booth has a pass-through conveyor with hatch doors on both ends. The conveyor rollers have sealed bearings. Spray nozzles are located so as to provide coverage to the outside of the container. The station is self-contained with controls, pumps, tanks, and filters to wash, rinse, and dry as needed. The wash water can be collected from the room sump, sampled, and treated as necessary before discharging the decontamination solution to the AWWT.

G.6.4.4 System Interfaces

The Product Handling System interfaces with the following SSC:

- Electrical power for motors, instrumentation and monitors.
- The Grout Mixing and Filling System.
- Shielded and unshielded air lock doors and window systems that are employed to protect workers and segregate work stations.
- CCTV cameras and monitors that are used to ensure positive control of container operations.
- A forklift that transports and places empty containers onto the load-in conveyor.
- The treatment facility's domestic water supply for the wash station.

- The PVS header for sweep hoods, maximum of 500 scfm.
- The HVAC System.

G.6.5 Gaseous Emission Control

The Chemical Stabilization — Cement-based treatment process does not generate an off-gas stream. All secondary gaseous wastestreams are vented from process vessels, rooms, and equipment. Therefore, the only component of the Gaseous Emissions Control System is the PVS, which is designed to capture all process vessel, room, and equipment gases containing radon and transport them to the existing RCS. Detectors and monitors within the facility provide real-time alarm if radon escapes from any of the process vessels, rooms, or equipment.

G.6.5.1 System Description

Process Exhaust

Process vessels and equipment containing unstabilized Silos 1 and 2 material are vented to the PVS.

Room Exhaust

Open containers, vessels, and room/cells that contain Silos 1 and 2 material are vented to the PVS by direct ventilation of room air or by the use of a sweep hood. Rework operations are performed in a dedicated work enclosure. The enclosure is connected to the facility HVAC System. Detectors and monitors provide real-time alarm of radon present in the rework enclosure. The interim container staging facility is normally ventilated and provided with radon detectors, alarms, and data loggers to detect, alarm, and log the presence of radon.

Process Vent System

A PVS header is run throughout the treatment facility to capture and transport any radon contaminated air streams from all the process equipment, vessels, and rooms. The PVS system is designed to maintain a negative pressure in all vessels and equipment where the containment of airborne contaminants, including radon, is a concern. The PVS maintains an airflow between 250 and 500 scfm with the vacuum provided by the RCS blowers. All vessels are maintained at approximately -2 inches water column (in. W.C.) relative to room pressures to ensure that the vessel gases do not leak to the environment, thus confining airborne contamination within the boundaries of the ventilation system.

Ventilation from vessels and primary confinement rooms, with expected airborne contamination (including radon), are connected to the PVS which, in turn, is connected to the RCS.

The product packaging and staging area are normally ventilated and provided with radon detectors and alarms to detect the presence of elevated levels of radon.

The 250-scfm gaseous emissions stream associated with the PVS is directly routed to the existing RCS without any pretreatment.

G.6.5.2 Assumptions

There are no driving assumptions associated with the Gaseous Emissions Control Systems.

G.6.5.3 Key Equipment Descriptions

The Gaseous Emissions Control System uses a vent line and header system to collect and transport the PVS gases to the existing RCS. There are no key equipment components associated with the PVS. The motive force to transport the PVS stream is provided by the RCS blowers.

G.6.5.4 System Interfaces

The Gaseous Emission Control System interfaces with the following SSC:

- Electrical power for instrumentation and motors.
- Compressed air that is required for pneumatically operated valves.
- Ventilation - from vessels, equipment and hoods with the potential for airborne contamination with radon gas - that is connected to the PVS. This includes equipment and hoods from the Feed Preparation System, the Treatment System and the Secondary Liquid Waste System.

G.6.6 Secondary Liquid Waste Treatment (System 62)

All secondary liquid waste from the treatment facility must either be treated by the Wastewater Treatment System in order to meet the AWWT WAC (as shown on PFD 94X-5500-F-SK-3110), or be recycled back to the TTA recycle water tank. All secondary liquid waste that contains treatment chemicals is treated by the Wastewater Treatment System.

Secondary liquid wastestreams that require treatment by the Wastewater Treatment System includes the filter press filtrate and any discharge water from the decontamination wash stations.

G.6.6.1 System Description

Filtrate from the filter press is gravity discharged to the filter press filtrate tank (filtrate tank), 62-TK-001. The filtrate tank is sized to inventory one day's worth of filtrate if necessary. The Wastewater Treatment System is designed to process 2,000-gallon batches. The first water treatment step is the oxidation step, which takes approximately four hours, while subsequent steps take three hours or less. Therefore, batches can be cycled approximately every four hours.

A 2,000-gallon batch of wastewater is transferred from the filtrate tank to the oxidation tank, 62-TK-002, by the filtrate tank transfer pumps, 62-PM-001 A&B. Bleach is added to the batch in the oxidation tank and is allowed to react for four hours. After the oxidation reaction is complete, centrifugal pumps 62-PM-002 A&B transfer the batch to the wastewater treatment (WWT) tank , 62-TK-003 where the rest of the treatment chemicals are sequentially added and allowed to react for approximately three hours. The treatment chemicals include barium chloride, phosphoric acid, hydrochloric acid, and sodium sulfate and precipitate the dissolved solids in the batch. The chemical treatment forms solids that are allowed to settle out of the water and are pumped to the SBTs for feed to the filter press. Following the transfer of solids to the SBTs, the clarified batch is transferred by 62-PM-003A&B through bag filters to one of the two effluent tanks, 62-TK-004 & 62-TK-005, where the water is sampled and inventoried until analysis of the batch is complete. Once it has been determined that the wastewater batch meets the AWWT WAC, the batch is transferred to the AWWT for final treatment and discharge.

All wastewater treatment reagents are stored in individual tote tanks and are transferred to the WWT tank by chemical metering pumps 62-PM-006, 007, 009, 010, and 011.

G.6.6.2 Assumptions

There are no driving assumptions associated with the Secondary Liquid Waste Treatment System.

G.6.6.3 Discharge to AWWT

The treated wastewater from the Wastewater Treatment System is either discharged to the AWWT or transferred to the Supernatant Sump Tank by Effluent Tank Transfer Pumps 62-PM-004 A&B and 62-PM-005 A&B.

G.6.6.4 Key Equipment Descriptions

Filter Press Filtrate Tank

The filter press filtrate tank is a 10,000-gallon 12-ft diameter carbon steel tank, with a height of 12 ft, that collects and inventories the filtrate from the filter press. The filtrate tank is sized to inventory one day's worth of filtrate.

Oxidation Tank

The oxidation tank is a 2,000-gallon carbon steel tank with a diameter of 6 ft and a height of 10 ft.

Wastewater Treatment Tank

The WWT tank is a 2,000-gallon, carbon steel tank with a diameter of 6 ft and a straight wall height of 10 ft. The WWT tank employs a conical bottom to collect precipitated solids for discharge to the SBTs.

Effluent Tanks

The two effluent tanks are 4,000-gallon carbon steel tanks with 8.5-ft diameters and wall heights of 9.5 ft.

Treatment Chemical Tote Tanks

The chemical treatment reagents are delivered to the treatment facility as tote tanks and are connected to the Wastewater Treatment System chemical metering pumps to add the reagents to the respective water treatment tank.

G.6.6.5 Recycle

The treated wastewater from the Wastewater Treatment System is discharged to the AWWT or transferred to the supernatant sump tank by effluent tank transfer pumps 62-PM-004A&B and 62-PM-005A&B. From the supernatant sump tank, the treated wastewater is subsequently discharged to the TTA recycle water tank.

The clarifier overflow to the supernatant sump tank is transferred back to the TTA Recycle Water System and is used for subsequent waste slurry retrieval and transfer to the treatment facility.

G.6.6.6 Secondary Solid Waste Treatment

Secondary solid wastestreams are treated and disposed appropriately. Reference **Section G.2.13.2** for a general description of secondary solid waste treatment. A list of potential solids wastestreams is provided below.

- PPE;
- HEPA and prefilters;
- Filter press filter media;
- Wastewater treatment bag filters;
- D&D waste;
- Debris; and
- Empty rework containers.

G.6.6.6.1 Recycle

Precipitated Solids from the WWT System

The WWT System is designed to precipitate dissolved solids from the filter press filtrate. The precipitated solids are settled in the WWT tank and reintroduced into the treatment system by pumping them back to one of the SBTs.

G.6.7 Container Operations

The filled containers are stored in the interim staging facility before off-site shipment to an approved disposal site. The lifting and placement of containers are performed remotely.

G.6.7.1 System Description

A container is grappled in the interim staging facility by a remotely operated bridge crane, lifted over a shield wall, and placed onto a transport vehicle in the loading/shipping operations area within the interim staging facility. The container is secured and prepared for off-site shipment. The external surface of the container is anticipated to be essentially free of loose surface radioactivity. Documentation is provided to the shipper who transports the container to an approved disposal site.

Note: The generation and buildup of radon is not anticipated to be a concern in interim staging facility, since the containers are sealed before staging; therefore, the facility does not require special ventilation.

G.6.7.2 Assumptions

A. **Assumption:** Two containers per truck shipment.

Basis: Standard FEMP shipping practice for a two-axle truck (payload limited to 42,000 lb).

G.6.7.3 Key Equipment Descriptions

Staging Facility Remote Bridge Crane

The crane is a remotely operated bridge crane with a rated capacity of 15 tons and a span of 120 ft, a travel of 210 ft, and a lift height of 16 ft. The crane is equipped with a grappling device and CCTV system camera to ensure positive grappling, movement, and placement of the filled containers.

Treated Waste Disposal Container

The disposal container is 78 inches long by 67 inches wide by 70 inches high (including 4-inch forklift runners). The 4-inch thick walls are constructed of high density concrete with wire mesh reinforcement. The container weighs approximately 9,700 lb (including the absorbent pad, plastic liner, and metall foil liner). Each container has the capacity to ship approximately 11,000 lb of treated Silos 1 and 2 material.

G.6.7.4 System Interfaces

The system interfaces for the container operations are:

- Electrical power for lighting, motors, instrumentation and CCTV support equipment;
- The treatment facility transfer conveyor;
- The CCTV inspection system;
- The FEMP waste management shipping organization; and
- Infrastructure Roadways.

G.6.8 Product Rework (System 26)

In addition to the federal, state and local shipping requirements, the stabilized cement must meet the NTS WAC. Therefore, provisions are made to re-process any rejected stabilized cement. Rework of the rejected stabilized cement requires removing it from the disposal container and reintroducing it into the Waste Processing System.

G.6.8.1 System Description

Rework operations are carefully confined and performed remotely at the rework station. The breaking, crushing, and conveyance components are remotely controlled by operators in the adjacent corridor. After the stabilized cement is size reduced, the rubble is reintroduced to the Waste Processing System.

The lid removal, placement, and fastening stations used for normal container tasks are used for reworking the rejected containers. A sweep hood is used for rework operations for radon release. Captured radon is diverted to the RCS by means of the Process Hood Ventilation System.

The reject disposal container is retrieved by the remotely operated overhead bridge crane in the curing room or from the interim staging facility and conveyed to the rework station. If the container is retrieved from the interim staging facility, it is conveyed to the lid fastening station, where the disposal container is aligned with the remote wrench and the lid bolts are disengaged. Next (or first if the disposal container is retrieved from the curing room), the disposal container is conveyed to the inspection room where the disposal container is aligned with the lid placement equipment and the lid is removed by the remote grapple. Before lid removal, the sweep hood is activated to sweep hood the area surrounding the container opening, removing the accumulated radon in the disposal container as the lid is raised. The remote grapple holds the disposal container lid while the rework operations are performed.

The opened disposal container is conveyed into the rework room. This operation can be viewed by operators by means of CCTV and/or through shielded viewing windows. The radon from the disposal container is collected by the rework room sweep hood during rework operations. The remotely controlled impact hammer, attached to an extendable boom with interchangeable end effectors, fractures the reject stabilized cement in the container. This operation size reduces the remediated cement into pieces small enough to be vacuumed. A HEPA filtered vacuum unit provides the motive force for the vacuum hose. The vacuum hose is remotely positioned by a robotic arm to remove the rubble from the container. The rubble vacuumed from the container is collected in the rubble collection hopper and gravity fed into the remotely operated rubble jaw crusher. The jaw crusher reduces the rubble to pieces less than ½-inch. The crushed rubble is transferred to the rework batch bin using the rubble bucket conveyor. The dry materials for the rework grout formulation are transferred into the rework batch bin from the cement/additive storage bins. The rework batch bin is a weigh bin that measures the required amount of solid constituents for the rework grout formulation.

The empty reworked container is conveyed to the inspection station where the lid is replaced. The lidded container is conveyed to the lid fastening station. The remotely operated wrench is used to tighten the lid bolts. The container is conveyed to the survey and decontamination station where the container exterior surface is surveyed and decontaminated, as necessary, to meet surface radioactivity limits.

G.6.8.2 Assumptions

The number of containers of remediated Silos 1 and 2 material that fail to meet the NTS WAC and are rejected is assumed to be approximately 1% of the original disposal containers produced (approximately 60 original containers). For every original container that fails to meet NTS WAC and has to be re-processed, three rework containers are produced (approximately 180 rework containers).

G.6.8.3 Key Equipment Descriptions

Roller Conveyor

The rework roller conveyor, 26-CY-001, is a 5-ft wide by 12-ft long heavy duty, motorized, chain driven, two-directional, roller conveyor with a rated capacity of 21,000 lb. Standard fabrication materials are used; however, the conveyors are a special order due to size and load capacity requirements. In addition, the rework conveyor is provided with special features for lifting the containers above the rollers, with a hydraulic system.

Bucket Conveyor

The bucket conveyor, 26-CY-002, is a sealed unit with a rated capacity of two tons and a vertical lift of 30 ft. It is connected to the PVS for the confinement of radon gas.

Rework Vacuum

The rework vacuum, 26-FL-001, is a production model with a 6-inch diameter hose, HEPA filtered discharge, and a rated capacity of 30 tons/hr. The system includes a cyclone bin to collect captured debris. The cyclone bin is the source of feed material to the rubble collection hopper. To confine radon gas that may be present in the air stream to the vacuum, the system must release its discharge air to the rework room. The rework room sweep hood maintains the rework room at a negative pressure, directing an exhaust stream to the PVS.

Rubble Collection Hopper

The rubble collection hopper, 26-BN-001, is a 64-ft^3 hopper with level alarms, vibrator, air pads in the cone section, and a RCS vent connection; it is mounted on load cells for weight determinations.

Rework Batch Bin

The rework batch bin, 26-BN-002, is a 100-ft^3 bin with level alarms, a vibrator, a cone air pad, and a RCS connection; it is mounted on loads cells for weight determination.

Remotely Controlled Impact Hammer

The remotely controlled impact hammer, 26-ME-004, is a production model with a reach of 10 ft and 400 ft-lb per impact. It is mounted on tank tracks with a maneuverable boom and is electrically powered. It has changeable end effectors and can accomplish drilling, crushing, and impacting with available accessories.

Rubble Jaw Crusher

The rubble jaw crusher, 26-ME-007, is a production model with a feed opening of 8 inches by 10 inches, capable of reducing particles to less than 0.5 inch.

Rework Bridge Crane

The rework bridge crane, 26-CN-001, is a remotely operated bridge crane with a rated capacity of 5 tons and a span of 15 ft, a travel of 12 ft, and a lift height of 12 ft. The crane is equipped with a robotic arm and a 2-ton hoist for miscellaneous lifting operations. The robotic arm is used to handle the vacuum hose, perform clean up of the rework room, and provide a versatility for performing many tasks, as the true nature of the rework operations is largely unknown.

Sweep Hood

The sweep hood is a ventilation device connected to the PVS for the purpose of radon gas release capture. It is specifically designed to capture radon that could escape from the open containers in the rework room, using the available flow rate of 500 scfm or less.

G.6.8.4 System Interfaces

The interfaces with the Product Rework System are:

- Cement and chemical additives that are pneumatically transferred as dry materials to the rework batch bin.
- The product handling conveyor system that is used to convey the rejected container to the various stations before entering the rework room.
- The rework batch bin and sweep hood that are connected to the process vent header to collect the off-gas radon to the RCS for treatment and discharge.
- Compressed air, electrical power, and a hydraulic power source utility that are required for the rework operations.
- Power and signal connections between the process control room, local control stations, and process stations that are required for instrumentation, CCTV, lighting, and equipment control. Signal connection is required to the data logging system.

G.6.9 Facility Design

Bulk Additives

The bulk additive building provides for receiving, storage, and transfer of bulk chemicals and cement to the Feed Preparation System. The design uses four large bins and a pneumatic system to support production requirements for cement production.

The building structure is a commercial grade sheet metal building. The height of the building is based upon the storage bin requirements to support production. Stairs and platforms provide access to the storage bins and filters assemblies. Within the building, limited space is provided for maintenance requirements. The building has a large double door to allow for access.

An unloading pad is provided next to the facility for bulk truck deliveries and to contain accidental spills. Large quantities of additives are received by truck and are pneumatically transferred into the appropriate storage bin. Additives from the bins are pneumatically transferred to the Feed Preparation System.

The bulk additive building and the surrounding area is a non-radiological area. Access is not controlled.

Feed Preparation System

All equipment is in a radiologically controlled area due to the Silos 1 and 2 material's high inventory level of radium and radium daughter products. From preliminary dose calculations, the area around the tanks is assumed to be a RAZ 5, high radiation area. The work area requires shielding, less time spent within those areas and, where possible, lower radiation sources (volume) to ensure lower dose rates for operations and maintenance workers over the plant life. The tanks containing the material are segregated and shielded in keeping with the ALARA principles of minimizing worker dose rates. They are surrounded by2-feet thick shield walls due to the radiation field presented by the volume of the Silos 1 and 2 material. The shield walls are modular in construction. Modular shield walls sealed to the concrete floor and sealed between joints also perform duty as secondary containment by having the ability to contain a spill or leak from the tanks. The primary containment consists of the tank vessels themselves.

The lime and ferrous sulfate bins, totes, and pumps are enclosed by 3-ft high containment walls to control leakage and protect personnel in the area. The concrete floor is sealed and the walls and equipment have a strippable coating to protect them and to aid in decontaminating the room and equipment at the end of the facility mission.

Although surrounded by concrete walls, the Feed Preparation System still requires accessibility for general maintenance of the mechanical equipment. Access to each tank at grade is through a labyrinth. A sump is located in the area to collect runoff. The top of each tank is accessible by ladder and platform. The platform on top of the tanks allows for maintenance to be performed on the agitators, control valves, and piping components.

The pumps for the tanks are located outside of the shield wall due to general service and maintenance requirements. The pumps are located behind half or "partial height" walls to control access, minimize casual dose rates, and contain leaks and spills. The supporting systems, such as the recycle water tank and pumps, are segregated by a curb to provide secondary containment. The supporting equipment, pumps, tank and service corridor are RAZ 1 controlled areas; but, they are accessible to operations and maintenance personnel for up to 40 hours a week.

The Feed Preparation System is covered by a roof. The roof allows for operations and maintenance tasks to take place during local seasonal weather extremes. Portions of the roof can be removed for equipment removal by crane.

Wastewater Treatment System

The Wastewater Treatment System conditions the wastewater before returning it to the TTA or discharging it to the AWWT.

The Filtrate and Wastewater Treatment System is co-located with the Feed Preparation and Lime/Ferrous Sulfate Additive System. It contains the process tote-tanks, filters, tanks, and pumps.

The tote bins and pumps are enclosed by 6-inch high curb to control leakage and protect personnel in the area from chemicals . The effluent tanks and pumps are enclosed by a 3-ft high containment wall to provide for secondary containment. The concrete floor in both areas

is sealed and the walls and equipment have a strippable coating to protect them and to aid in decontaminating the area and equipment at the end of the facility's mission.

The pumps are located behind half or "partial height" walls to control access and contain leaks and spills. The supporting systems, like the tote bins and pumps, are segregated by a curb to provide secondary containment. The supporting equipment, pumps, tank and service corridor are RAZ 1controlled areas; but, they are accessible to operations and maintenance personnel for up to 40 hours a week.

Filter Press Room

The filter press removes water from the feed, weighs the product, and feeds the mixer. Water is removed from the Silos 1 and 2 material by the press and transferred to the filtrate and water treatment tanks outside of the facility.

Because of the potential for contamination, the filter press is located in a separate room – above the mixer, product and additive bins – to allow for gravity flow. The room provides controlled access and contains the spread of contamination. During normal routine maintenance, the room provides a controlled environment in which maintenance tasks are performed. Personnel access the filter press room through the adjacent airlock/stairs.

The room is considered to be a RAZ 4, radiation area because of the dose source from the filter cake and the residual contamination in the equipment. The potential for contamination to be present within the room is very high. Operations and maintenance work to be performed in the filter press room is controlled by RWPs and requires additional dosimetry for personnel entering the area.

Mixer System

The filter press system delivers the feed to a bin in the mixer room. The feed gravity flows into a bin above the mixer. The Cement and Additive System transfers cement mix to the delivery hopper above the mixer for gravity feed. The Rework System also delivers crushed

product to a bin above the mixer for addition. The mixer combines the process feed into a grout mix ready for packaging. During processing, the ventilation air from the mixer is removed by the PVS and sent to the RCS.

The mixer and supporting additive and recycle bins are located above the fill station in the mixer room on the second floor. This layout allows gravity pour of the product into the container. The filter press is located above the mixer room. The walls of the Mixer System are shield walls because of the dose source contained within the equipment. All surfaces within the system rooms are covered by a removable coating to control contamination and aid in decontamination of the facility. The mixer and supporting bins are accessed for maintenance by a series of stairs and platforms within the room. Entry is made from the second floor corridor through an airlock/stairs.

Within the room, space is furnished for equipment that supports the mixing operation. Supporting utilities (i.e., electrical, control system, domestic water, and plant air) are brought into the mixer room to support operations.

The mixer room is considered to be a RAZ 4, radiation area. Shielding and space around the mixer is required to meet ALARA consideration. Maintenance and operations tasks can be performed in the mixer room but are controlled by RWP. All personnel entering the room are required to wear additional dosimetry.

Load-In Area

The load-in area provides access to the facility to allow disposal containers to enter the facility and be staged. It also furnishes space for operators to perform filling operations.

Disposal containers to be filled are carried by forklift into the facility through this area. A roll-up door allows normal and heavy forklifts to enter the facility. Within the area, space is provided for staging disposal containers to be used during the next two shifts. Airlocks adjacent to the area furnish access to the fill station. The load-in area also contains the

operator stations in front of each of the filling stations. At each fill station, the operators use a remote CCTV and the shielded window to perform assigned tasks.

The load-in area is enclosed in a prefabricated type structure. The structure has an internal, engineered steel framework. A PVC coated polyester fabric is stretched over the structural framework. HVAC for the area is provided by the facility system.

The load-in area is a RAZ 1, controlled area. Personnel access and movement is not restricted. Radiological guidelines for RAZ 1 areas allow for 40 hr/week occupancy.

Fill Station

The special containers are remotely handled and filled with concrete mix, weighed, closed, and washed in the fill station and adjacent room.

The fill station is located underneath the mixer. The room contains the equipment used to fill the disposal container. The disposal container, without its lid, is placed onto a roller conveyor in an airlock by a forklift. The conveyor moves the container into the fill station room. The disposal container is lifted up to meet the fill head and is held in place and vibrated during filling. Once filled, the disposal container is lowered back down onto the conveyor and moved to the next station where a sample is collected and the disposal container is weighed. The disposal container is moved to the next room where the lid enters from an adjacent airlock. The lid is placed by forklift in the second airlock. It is manually attached to the overhead monorail. The monorail transfers the lid from the airlock to the lidding station where it is remotely placed onto the disposal container. The disposal container is moved by the conveyor through a wash station and then into the curing room. The filling and lidding operations are viewed from the load-in area. Equipment in these rooms is accessed for maintenance through the adjacent airlocks.

The process sampling equipment collects a sample from the open disposal container after the disposal container is moved from the filling station to the lidding station. The system provides

for process control, accountability, diagnosis, and certification of compliance with waste acceptance product specifications. The system also produces samples that are cured, tested, and/or archived. The Sample System allows for collection of a TCLP sample. The sample is placed in the curing room where it is cured in a heated environment. After the sample is cured, it is passed through the fill station into a glove/pass-thru box. The TCLP sample is then transported to the analytical laboratory. Additional archive samples are collected and removed to the access point in the curing room.

The fill station room, sealing room, and wash station are normally only occupied for regulated maintenance tasks. The rooms are considered to be RAZ 4, radiation areas. They are potentially contaminated by cement from the filling and sampling operation. Access is allowed for maintenance servicing; but, it is controlled by RWPs and the requirement of additional dosimetry.

Curing Room

The curing room provides space for a maximum of 72 containers to cure for seven days in a temperature controlled environment.

The filled disposal container is transferred from the wash station by roller conveyor into the curing room. An overhead bridge crane lifts the container and places it in one of 72 curing positions. After 1 week of initial curing, the container is moved out of the room to have the lid bolted on.

A shielded maintenance space is provided for the crane. The area is accessed through an adjoining airlock. The bridge portion of the crane is maintained from elevated platforms that are accessed by ladders.

The curing room also contains the grout Sample Archive System that holds all of the archived samples until they are no longer needed, at which time they are either introduced into the rework system or packaged into a disposal container and sent to the NTS.

The curing room is a RAZ 5, high radiation area based on preliminary calculations. The basis for the assessment is the number of containers and the accumulative dose from the containers. Personnel should not need to enter into the room while containers are present. The overhead crane can be maintained while being shielded from the curing room. The maintenance area is considered to be a RAZ 1, controlled area and is accessible up to 40 hr/week to allow general servicing or repair of the crane. The curing room has a dedicated HVAC System.

Packaging

The packaging station allows for inspection of the product, addition of an absorbent, securing of the lid, survey and decontamination of the container.

The container is remotely lifted by the overhead bridge crane in the curing room and placed onto a roller conveyor. The conveyor moves the container into the inspection station. The lid is lifted, as necessary, to allow for visual inspection by camera. The lid is replaced and the container is transferred by conveyor into the lid fastening station. There, the lid is remotely bolted in place by the lid fastening device. From that station, the container is conveyed to the survey/decontamination room. With the container sealed, radiological technicians, dressed in appropriate PPE, move through the airlock and along each side of the conveyer. Because of the 70 mrem/hr exposure rate from the container, the technicians smear the outside of the container from a distance with long reach tools. If the container is found to be contaminated, these same tools are used to decontaminate the container. Once released, the container is moved by the roller conveyor through an airlock and then through an enclosed corridor to the Interim Container Staging Area.

The inspection and lid fastening rooms are non-occupied areas during operation. Maintenance on the equipment can be performed when containers are not present. Because of the potential for contamination, the concrete floors are sealed and the walls are coated with a strippable coating to allow for decontamination. These areas are considered to be RAZ 4, radiation areas. Maintenance access is by RWP and requires additional dosimetry.

The survey/decontamination room is also considered to be a RAZ 4, radiation area even though radiological technicians need to enter the area on a continual basis to survey the filled containers. The technicians are not allowed to approach within 3 ft of the container. Long reach tools are used to perform tasks. Consideration is also given to the use of partial shield walls to limit access and protect personnel.

The airlock, where radiological technicians enter the survey/decontamination room, is a special radiation area. The airlock allows for personnel to enter the curing room crane maintenance area and the survey/decontamination room. The room is considered to be a RAZ 1, controlled area when a container is not present in the room. When a container is present, the room is a RAZ 4, radiation area. Because of the radiation source in the container, the general area surrounding the airlock needs to be cleared of personnel during the transfer of filled containers.

Operation of the inspection, absorbent, and lid fastening equipment is done at remote stations located in the corridor adjacent to these rooms. The wall provides radiation shielding for the operator. These tasks are performed using cameras and shielded windows in front of the operator to provide for ALARA considerations.

Rework Area

The rework room is equipped to handle containers and remove the failed cement product. The containers containing grout that have failed TCLP are identified following the sample analysis. In the curing room, the container to be reworked is moved by the overhead bridge crane to the roller conveyor. The conveyor transfers the container into the inspection station where the lid is removed. The open container is then conveyed into the rework room.

The rework room is equipped with a small overhead bridge crane, a remotely controlled impact hammer for breaking the concrete, a glove/pass-thru box, and a vacuum system for picking up and transferring the reworked cement. A vacuum hose is attached to the remote cement breaker. It vacuums up cement to a canister that gravity feeds the hammermill in the adjacent room. The crushed cement is pneumatically transferred to a bin for addition to the mixer. The

operation of the equipment is performed from a remote station in the load-out area. Cameras and a shield window allow the operator to see the work area.

When the container is empty, it is moved back into the inspection station where the lid is replaced on the container. It is moved into the lidding station where the lid is secured. Afterwards, the container is transferred to the survey/decontamination room by the conveyor. The container is surveyed for contamination and decontaminated, if necessary. Once completed, the container is moved to the airlock and removed by the forklift to be used for general waste disposal that is sent to the waste management organization.

Load-out Area

The load-out area provides access to the facility for the removal of reworked containers from the facility. It also furnishes space for operators to perform packing, loading, and rework operations.

The load-out area is enclosed in a prefabricated type structure. The structure has an internal, engineered steel framework. A PVC coated polyester fabric is stretched over the structural framework. HVAC for the area is provided by the Facility System.

The load-out area is a special RAZ 4 or RAZ 1 area. When a filled container is transferred through the area, the area becomes a RAZ 4, radiation area. Personnel access and movement is restricted in the area during these times. At all other times, when no source is present, the area is a RAZ 1, controlled area. Radiological guidelines for RAZ 1 areas allow for 40 hr/week occupancy. RAZ 4 areas require a RWP and additional dosimetry for personnel within the area.

Facility Entrance

The facility entrance controls the entering/ exiting of the facility. The facility entrance is the main entrance and exit point for personnel working within the facility. Personnel log in when entering the facility. To exit the facility, personnel pass through radiation detection monitors and log out. Any other in-coming or out-going shipment passes through the load-in/out area

under the control of a radiation (RAD) technician. A desk is provided in the facility entrance for a radiological technician to supervise personnel movement.

The facility entrance is not expected to see a radiation source but may see contamination carried by personnel attempting to exit. Because the treatment facility contains radioactive substances and has the potential to be contaminated, entering or exiting the facility is supervised and controlled. For these reasons, the facility entrance is considered to be a RAZ 1, controlled area. Personnel may occupy the area for up to 40 hr/week.

G.6.9.1 Unique Features

The Chemical Stabilization — Cement-based treatment facility design uses commercially available equipment wherever possible. However, some components of the treatment facility have to be custom designed, including nuclearization of all equipment intended to handle material containing Silos 1 and 2 material.

The batch mixer discharge chute and fill head are designed to mate with the disposal container and maintain negative pressure within the system as well as prevent any grout from contaminating the outer surface of the container. Other key pieces of equipment and unique features of the facility include the lid fastening, washing, sampling, and rework stations and are described in **Sections G.6.4.3.**

G.6.10 HVAC (Systems 73, 75, 76 and 77)

(Refer to **Section G.2.16** for HVAC design criteria)

The areas in the remediation facilities are designated as Zone 1, Zone 2 and Zone 3 and have three HVAC systems: one system is exclusively for Zone 3, one for the curing room, and one combined for the remainder of Zone 2 and all of Zone 1. Following are the designated areas with equipment details for each zone.

G.6.10.1 Zone 3

A. The designated areas for Zone 3 are:

- Loading area;
- Cement mix room;
- Survey & decontamination room;
- Lid installation room;
- Wash station;
- Filter press room;
- Lid fastening room;
- Inspection room;
- Rework equipment room;
- Container fill station; and
- Rework station.

B. The HVAC details for Zone 3 are:

- Air handler with supply fans, filters and electric heat;
- Supply fans (73-AH-003 A&B) - 12,000 cfm;
- Electric heat - 309 kW;
- Exhaust fans (73-FA-003 A&B) - 12,000 cfm; and
- Exhaust filter that includes a pre filter with two stage HEPA filters and has 50% capacity backup.

000577

- The air handling unit and exhaust fans that are designed for 100% capacity and 100% backup. Air handling units and exhaust fans are connected to emergency power because of the potential for hazards and equipment damage resulting from elevated temperatures if the systems are lost due to power failure. There are three exhaust filters with 50% capacity(two are required for normal operation). The electric heaters are not connected to emergency power.

C. Air sweep hoods that are provided in the inspection room, rework station, and container fill station. The discharge vent from air sweep hoods are connected to the RCS and the total flow rate does not exceed 500 cfm.

G.6.10.2 Zone 2

A. The curing room is the only designated area for Zone 2.

B. The HVAC details for Zone 2 are:

- Air handler with supply fans, filters, and electric heat;
- Supply fans (73-AH-002 A&B) -20,000 cfm;
- Electric heat - 483 kW;
- Exhaust fans (73-FA-002 A&B) - 20,000 cfm; and
- Exhaust filter that includes a prefilter with two stage HEPA filters and has 50% capacity backup.

- The air handling unit and exhaust fans that are designed for 100% capacity and 100% backup. Air handling units and exhaust fans are connected to emergency power because of the potential for hazards and equipment damage resulting from elevated temperatures if the systems are lost due to power failure. There are three exhaust filters with 50% capacity (two are required for normal operation). The electric heaters are not connected to emergency power.
- A curing room that is heated to 70°F during winter; cooling is not provided. The expected temperature during summer is 105°F (outside design temperature 95° + 10° F rise).

G.6.10.3 Zones 1 and 2

A. The designated areas for Zone 1 are:

- HVAC room; and
- Access control room.

B. The corridor is the only designated area (remainder) of Zone 2.

C. The HVAC details for Zones 1 and 2 are:

- Air handler with supply fans, filters and electric heat;
- Supply fans (73-AH-001) -17,000 cfm;
- Electric Heat - Separate electric heat is provided for each room;
  - HVAC room, 265 kW
  - Access control room, 27 kW
  - Corridor, 137 kW
- Exhaust fans (73-FA-001 A&B) (2 Fans @ 8,500 cfm) - 17,000 cfm;

- Exhaust filter that includes a prefilter with two stage HEPA filters and has 50% capacity backup.

D. The air handling unit that is designed for 100% capacity; without any backup. Air handling unit and exhaust fans are connected to emergency power because of the potential for hazards and equipment damage resulting from elevated temperatures if the systems are lost due to power failure. There are two exhaust fans and two exhaust filters with 50% capacity (two are required for normal operation). The electric heaters are not connected to emergency power.

G.6.10.4 HVAC Stacks

Two HVAC stacks are provided, one for Zone 3 and one for the combined Zones 1 and 2, and are serviced by ladders and platforms. The air, before being exhausted, is analyzed for air quality and the results are recorded.

G.6.11 Support Systems

G.6.11.1 Analytical Support Laboratory/Services

The process facility uses an on-site dedicated laboratory. It is staffed by site personnel to analyze their process samples and provide for any additional requirements as space and equipment allow. The laboratory is composed of a trailer complex, modified to provide the working space and conditions for the laboratory facility.

The trailer HVAC and Drain Systems are designed to control the spread of contamination. There are separate HVAC and filtration systems for the laboratory hoods and environmental spaces. The facility is divided into two separate ventilation systems. One system is dedicated for non-potentially contaminated areas such as the office areas. The other system serves the laboratory areas where hazardous materials may be handled. This system discharges the exhaust air through HEPA filters and establishes air flow and pressure gradients that minimize

the potential for the spread of contamination. Two separate drain systems, potentially radioactive and non-radioactive, are provided for the lab spaces. Individual catch tanks are provided for each system. They are located in a covered concrete vault adjacent to the trailer complex.

The laboratory space is considered to be a RAZ 4 because of the number of process and TCLP samples being handled daily within the laboratory and the potential for radioactive contamination being present. The office space within the complex is considered to be a RAZ 1. The complex is divided into a non-radioactive area for office work space and the potentially radioactive lab space. To check the spread of contamination, a survey/monitoring room is provided to control entrance and egress for the laboratory space.

Table G.6.11-1 lists the potential analyses and the proposed equipment required to complete the analyses.

TABLE G.6.11-1
LABORATORY ANALYSES AND REQUIRED EQUIPMENT

Analysis	Laboratory Equipment
Percent Solids Determination	Laboratory Oven
TCLP	AA-ICP, Ball Mill
Elemental Analysis	AA-ICP or X-Ray Fluorescence (XRF)
Unconfined Compressive Strength	Load Cell
pH	pH Meter

G.6.12 Utilities

Compressed Air

Compressed air from 44-CM-001 is used for dense phase pneumatic transfers. A Plant Air System is used in the treatment facility but it is not shown in the design. The Plant Air System is used to blow down the filter cake during filter press operations.

Potable Water

A potable water system design has not been completed for the facility design. However, potable water is an existing site utility and allowances for potable water have been incorporated into the cost estimate.

Fire Water

A fire water system design has not been completed for the facility design. However, allowances for a fire water system have been incorporated in the cost estimate. The assumption has been made that a pressurized fire water main will exist on-site. The cost estimate will only include the tie-in and distribution portion of the Fire Water System.

Sanitary System

The treatment facility design does not include sanitation lines. Existing site sewage facilities are used by plant personnel.

Electrical

Normal Power System

The facility is supplied with electrical power at 13.2kV from the site distribution system. Two outdoor unit substations with oil-filled transformers, rated 2500 kVa each, transform the voltage to 480 Volts, three-phase, three-wire, 60 Hertz for use by the facility. Metering monitors the power consumption at 13.2 kV. The load is equally divided between the two unit

substations. There is no secondary tie breaker. The total connected load is 5163 kVa, and the normal demand is 3249 kVa. Usage is estimated to be 16,000,000 kWh/yr.

480-Volt switchgear in the unit substations distributes power to six MCCs located in the mechanical/electrical building, and to two (redundant), 580-kW, curing room air handler heaters.

Standby Power System

The facility includes an outdoor 700-kW standby generator. The generator provides power at 480 Volts to motor control center 31-MC-003 through an automatic transfer switch that starts the generator on loss of normal power and then switches the MCC to the generator when voltage is available. An integral fuel tank is sized for eight hours of operation.

The system includes an exercise panel that starts the generator once a week and runs it for 30 minutes. It sends an alarm to the control room if the generator fails to start.

All critical facility loads are connected to MCC 003. These loads:

- prevent contamination to the treatment facility;
- prevent contamination to the outside environment;
- ensure the safety of FEMP personnel; and
- prevent damage to equipment.

Uninterruptable Power System

The facility has a battery backed UPS rated 25 kVa for instrumentation and control system loads. This system filters out power system anomalies that could cause false information to be sent to the DCS or cause damage to sensitive electronic equipment.

The UPS receives power at 480 Volts, three-phase from MCC 003 and converts it to 208Y/120 Volt three-phase four-wire 60 Hertz power. The UPS includes a battery charger. The batteries provide power continuation for thirty minutes without any normal power input.

Motor Control Centers

The MCCs are standard, commercially available UL listed equipment rated 800 Amps at 480 Volts, three-phase, three-wire. They are indoor units, 90 inches tall, 20 inches deep, and are composed of a series of 20-inch wide vertical sections. They contain motor starters, feeder circuit breakers, and variable speed drive units. Each motor starter has a power circuit protector, pad-lockable in the off position, indicator lights to indicate motor status, start and stop pushbuttons, and a HOA selector switch. The selector switch selects between DCS control and control from the MCC. Extra contacts are provided on the selector switch, motor contactor, and circuit protector to send status information to the DCS.

The starters, feeder circuit breakers, and variable speed drive units are capable of draw-out removal for maintenance and replacement.

Control Systems

The facility operation is monitored and controlled by a DCS that consists of many remote I/O racks inside the plant (i.e., an I/O rack next to each cluster of equipment), with all the I/O racks connected to the control room. The control system is capable, at a minimum, of the following functions:

- Collecting pertinent process parameters (e.g., temperature, pressure, density, and flow);
- Displaying information in an organized and logical manner on video monitors (the display program includes graphic features for displaying process parameters);
- Automatically or manually operating selected control loops and digital output signals for control of equipment (e.g., start, stop, speed up, and slow down) from the operator console;

- Initiating audible and visual alarms when designated process parameters are outside preset limits or status;
- Providing status indication of motor driven equipment, HOA switches, motor contactors, and power disconnecting devices; and
- Reporting and displaying historical data.

Pneumatically operated pumps and on/off (fully open / fully closed) valves are operated by solenoid valves and controlled from the DCS with "run" and "stop" outputs for pumps and "open" and "close" outputs for the valves and interlocking functions. Each pump has an attached manual operator. Pneumatically operated ON/OFF valves have limit switches to provide status to the DCS. Motorized valves have HOA switches in the MCC. The DCS provides indication of the HOA switch position. The DCS also indicates the direction the valve is being driven since there is no positive feedback from the valve position switches until it reaches the fully opened or closed position.

The emergency shutdown and fire alarm events, as described by the control philosophy, are controlled by the DCS.

Vessels, excluding off-gas treatment systems, containing contaminated material have butterfly valves on the vessel vent connection for creating and maintaining negative air pressure in the vessels.

<u>CCTV Monitoring</u>

Closed circuit monitoring is used for inspection operations when it is necessary to view system components located in restricted areas or to inspect for free standing water inside a disposal container.

G.6.13 Special Health and Safety Considerations

During the "Detailed Design" phase of the project, a safety review of the process is conducted. This review considers all credible "what if" scenarios with input from people with different specialties such as process, mechanical, electrical, operations, maintenance, etc. The recommendations of this review are implemented to ensure safety of the process.

An "Ergonomic Review" of the design ensures that the operation does not cause any undue strain to the operators or maintenance people. A "Constructability Review" is conducted during the detailed design phase to ensure that it is safe and practical to install the equipment and complete all construction as per the design.

G.6.14 Special Environmental Considerations

The design basis for this alternative ensures protection of human health and the environment during the remediation of the Silos 1 and 2 material by incorporating the pertinent environmental regulatory requirements in the system design, using the principles of environmental ALARA. The design allows all contaminated gas, liquid, and solid wastestreams generated during remediation to be collected and treated before release to ensure adequate protection of human health and the environment.

Air emissions from the process are controlled by containment and treatment. Since the treatment process does not generate off-gas, an Off-gas System is not included in the design. Along with a Process Vent Header connection to all tanks and vessels containing Silos 1 and 2 material, sweep hoods are used in areas of expected radon to ventilate air from process equipment to the RCS, which uses carbon beds for adsorption of radon. All tanks and lines with radon source material are totally enclosed, and the Ventilation Control System uses backup redundancy for critical equipment.

Building ventilation is controlled through designation of zones on the basis of expected contamination; the air is either routed to the RCS for radon control, or treated locally for particulate control using HEPA filtration before discharge. Airlocks and dampers control air

flow and confine contamination. Discrete particulate sources such as dry feed or additive bins are controlled by filtration. Particulate dusting from reworked cement is confined by the rework room ventilation system, and treated using HEPA filtration. HEPA filters and prefilters are changed using a bag-in and bag-out approach to prevent airborne release of contaminants.

All tank systems containing source material with free liquids are designed with secondary containment and leak detection. The mixer room is designed with secondary containment of waste in case of a spill or leak from the mixer. With the possible exception of the diesel tank for the emergency generator, all tank systems with secondary containment are located under roof, which greatly minimizes the amount of excess liquids requiring characterization and management.

Protection of surface waters is ensured by double containment of exterior piping that conveys retrieved waste, and by segregation of the treatment process in a roofed and enclosed building. Areas used for processing material are protected from precipitation and stormwater run on and runoff. Clean and contaminated runoff is not combined. Clean run-off, including building roof drains and runoff from areas of fixed contamination, are discharged either into the stormwater collection basin, or routed to adjacent drainage systems.

Some secondary waste is recycled (e.g., clarifier overflow); but, some process operations generate wastes that cannot be recycled and require management as radiologic, hazardous, or mixed waste. For example, spent HEPA filters, PPE, and maintenance wastes are routinely generated during operations. Process holdup wastes, and wastewater treatment sludges that are not recycled may require additional treatment before disposal. Facilities to accommodate staging and characterization of wastes during operation, and later during D&D, are included in the design.

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8074

Section G.6
Attachments

Attachment G.6.I

Mass and Energy Balance for the

Chemical Stabilization — Cement-based Technology

Attachment G.6.I
Mass Balance
Chemical - Cement

STREAM #	1	2	3	4	5	6	7	8
Component	Transfer from TTA to Receiving Tank	10% Solids Slurry from the Receiving Tank to the Clarifier	Clarifier Underflow to Slurry Batch Tanks	From Slurry Batch Tank to Filter Press	Filter Cake Dicharge to Weigh Hopper	Filter Press Filtrate	Clarifier Supernatant Overflow	Sump Tank to Recycle Water Tank Transfer
Water (lb/day)	436,680	436,860	112,700	140,752	53,000	87,752	324,160	324,160
Waste Solids (lb/day)	48,540	48,540	48,300	51,037	50,387	650	240	240
Air (lb/day)								
Cement & Additives (lb/hr)								
CaOH (lb/day)				1,758	1,758			
Ferrous Sulfate (lb/day)				855	855			
Hypochlorite (lb/day)								
Water Treat. Rgts. (lb/day)								
Total Solids in Wstwtr (lb/day)								
Total (lb/day)	485,220	485,400	161,000	194,402	106,000	88,402	324,400	324,400
Flow (scfm)								
Flow (gpm)	113	38	11	140		11	27	100
Temperature (F)	Ambient	Ambient	Ambient	Ambient	Ambient	Ambient	Ambient	Ambient
Pressure (psi)	100	80	80	100	-1" W.C.	Atm.	Atm.	45
Line Size (in)	4"	1 1/2"	1"	3"	Discharge Chut	2"	4"	3"
Notes	5,900 lb solids per hour (approx. 110 - 120 gpm). Intermittant as necessary	Feed to the thickener is 24 hr/day, 5 days/wk	Discharge from the thickener is 24 hr/day, 5 days/wk	14 Batches per day Maximum	-1" W.C. vacuum held in the filter press housing	Gravity flow to Filtrate Tank (assume all solids caryover is K-65)	Supernatant overflow is gravity fed to the sump tank	Flow is intermittent, activated by level switch in sump tank
Dwg. Number 94X-5500-F-SK-	3353	3353	3353	3353	3409	3409 3110	3353	3353

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F-8074

Attachment G.6.I
Mass Balance
Chemical - Cement

STREAM #	9	10	11	12 - 14	15	16	17	18	19 - 21
Component	Process Vessel Vent Header	Stream 10 Deleted	Cement and Additives Transfer Line	Stream 12 - 14 Deleted	Additives Transfer from Delivery Truck to Additive Bin	Additives Transfer from Delivery Truck to Additive Bin	Additives Transfer from Delivery Truck to Additive Bin	Additives Transfer from Delivery Truck to Additive Bin	Stream 19 - 21 Deleted
Water (lb/day)	1,200								
Waste Solids (lb/day)									
Air (lb/day)	54,000		1,471		1,554 lb/hr	1,554 lb/hr	1,554 lb/hr	1,554 lb/hr	
Cement & Additives (lb/hr)			64,210		108,000 lb/hr	108,000 lb/hr	108,000 lb/hr	108,000 lb/hr	
CaOH (lb/day)									
Ferrous Sulfate (lb/day)									
Hypochlorite (lb/day)									
Water Treat. Rgts. (lb/day)									
Total Solids in Wstwtr (lb/day)									
Total (lb/day)	55,200		65,681		109,554 lb/hr	109,554 lb/hr	109,554 lb/hr	109,554 lb/hr	
Flow (scfm)	500		287		350	350	350	350	
Flow (gpm)									
Temperature (F)	Ambient								
Pressure (psi)			80		15	15	15	15	
Line Size (in)	variable		12"		4"	4"	4"	4"	
Notes					Provide for one week inventory. Flow rates may vary.	Provide for one week inventory. Flow rates may vary.	Provide for one week inventory. Flow rates may vary.	Provide for one week inventory. Flow rates may vary.	
Dwg. Number 94X-5500-F-SK-	3409 3133		3409 3408		3408	3408	3408	3408	

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Attachment G.6.I
Mass Balance
Chemical - Cement

STREAM #	22	23	24	25	26	27	28	29
Component	CaOH Transfer from Bag Dump to Filter/Receiver	Transfer from Filter/Receiver to Lime Add'n Slurry Tank	Lime Slurry transfer to K-65 Slurry Batch Tanks	Filter/Receiver Exhaust Line	Lime Add'n Vacuum Blower Discharge	Process Water for Lime Slurry Make-up	Filter/Receiver Back Pulse Air	Filtrate Transfer to Filtrate Oxidation Tank
Water (lb/day)			15,822			15,822		87,752
Waste Solids (lb/day)								650
Air (lb/day)	7,911	0		7,911	7,911		Pulse	
Cement & Additives (lb/hr)								
CaOH (lb/day)	1,758	1,758	1,758					
Ferrous Sulfate (lb/day)								
Hypochlorite (lb/day)								
Water Treat. Rgts. (lb/day)								
Total Solids in Wstwtr (lb/day)								650
Total (lb/day)	9,669	1,758	17,580	7,911	7,911	15,822	0	88,402
Flow (scfm)				3,000	3,000			
Flow (gpm)			5					200
Temperature (F)						Ambient		Ambient
Pressure (psi)			40				80	80
Line Size (in)	3"	6"	3/4"	3"	3"	3/4"		
Notes	transfer rate = 6000 lb/hr	transfer rate = 6000 lb/hr				Hydrated lime will be slurried to 10 wt% solids for delivery to Batch Tanks		Processed in 2,000 gallon batches - 4 hours for oxidation
Dwg. Number 94X-5500-F-SK-	3118	3118	3353 3118	3118	3118	3118	3118	3110

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F-8074

Attachment G.6.I
Mass Balance
Chemical - Cement

STREAM #	30	31	32	33	34	35	36	37
Component	Filtrate Transfer to WWT Tank	Filtrate Transfer to WWT Filters	Filtrate Transfer to Effluent Tank	Hypochlorite Addition to Oxidation Tank	WWT Treatment Chemical Transfer	Treated Wastewater to AWWT	Treated Wastewater solids to SBTs	Stream 37 deleted
Water (lb/day)	90,073	88,617	88,617	2,321	9,492	88,617	10,948	
Waste Solids (lb/day)	650							
Air (lb/day)								
Cement & Additives (lb/hr)								
CaOH (lb/day)								
Ferrous Sulfate (lb/day)								
Hypochlorite (lb/day)	410			410				
Water Treat. Rgts. (lb/day)					1,675			
Total Solids in Wstwtr (lb/day)	1,060	0	0	410	1,675	0	2,737	
Total (lb/day)	91,133	88,617	88,617	2,731	11,167	88,617	13,685	
Flow (scfm)								
Flow (gpm)	200	200	200	1	1	10	200	
Temperature (F)	Ambient	Ambient	Ambient	Ambient	Ambient	Ambient	Ambient	
Pressure (psi)	80	80	80			50	80	
Line Size (in)								
Notes		K-65 solids included as total solids in Wastewater						
Dwg. Number 94X-5500-F-SK-	3110	3110	3110	3110	3110	3110	3110	

Attachment G.6.I
Mass Balance
Chemical - Cement

STREAM #	38	39
Component	Ferrous Sulfate Transfer to Slurry Batch Tanks	Rework Grout Transfer to Treatment System
Water (lb/day)	1,282	
Waste Solids (lb/day)		
Air (lb/day)		
Cement & Additives (lb/hr)		
CaOH (lb/day)		
Ferrous Sulfate (lb/day)	855	
Hypochlorite (lb/day)		
Water Treat. Rgts. (lb/day)		
Total Solids in Wstwtr (lb/day)		
Total (lb/day)	2,137	
Flow (scfm)		
Flow (gpm)	10	
Temperature (F)	Ambient	
Pressure (psi)	40	
Line Size (in)		
Notes	Ferrous Sulfate Solution approximately 40% Solids	Line 39 used intermittantly for rework grout. Not included in steady state
Dwg. Number 94X-5500-F-SK-	3353 3118	3111

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F-8074

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Attachment G.6.II

Drawings for the

Chemical Stabilization — Cement-based Technology

DRAWING LIST
FOR
CHEMICAL STABILIZATION — CEMENT-BASED TECHNOLOGY

Drawing Number	Title	Rev.
	Process Flow Diagrams 94X-5500-F-	
SK-3408	CEMENT & ADDITIVE SYSTEM	2
SK-3118	LIME/FERROUS ADDITION SYSTEM	2
SK-3133	PROCESS VESSEL VENT SYSTEM	2
SK-3353	FEED PREPARATION / MIXER SYSTEM	2
SK-3409	FEED PREPARATION / MIXER SYSTEM	2
SK-3110	FILTRATE AND WATER TREATMENT	2
SK-3111	REJECT WASTE REWORK	2
	Mechanical Handling Diagram 94X-5500-M-	
SK-6025	PRODUCT LOAD	2
SK-6026	REWORK / RECYCLE	2
	Facility Layout Drawings 94X-5500-P-	
SK-1042	PLOT PLAN	2
SK-7416	PLAN @ EL. 15'-0" AND ABOVE	2
SK-7417	SECTIONS & DETAILS	2
SK-7418	DETACHED PLANS, DETAILS, & SECTION	2
SK-7425	INTERIM CONTAINER STAGING	2
SK-7428	CEMENT / ADDITIVE STORAGE BINS	2
SK-7441	PLAN @ EL. 0'-0" TO 15'-0"	2

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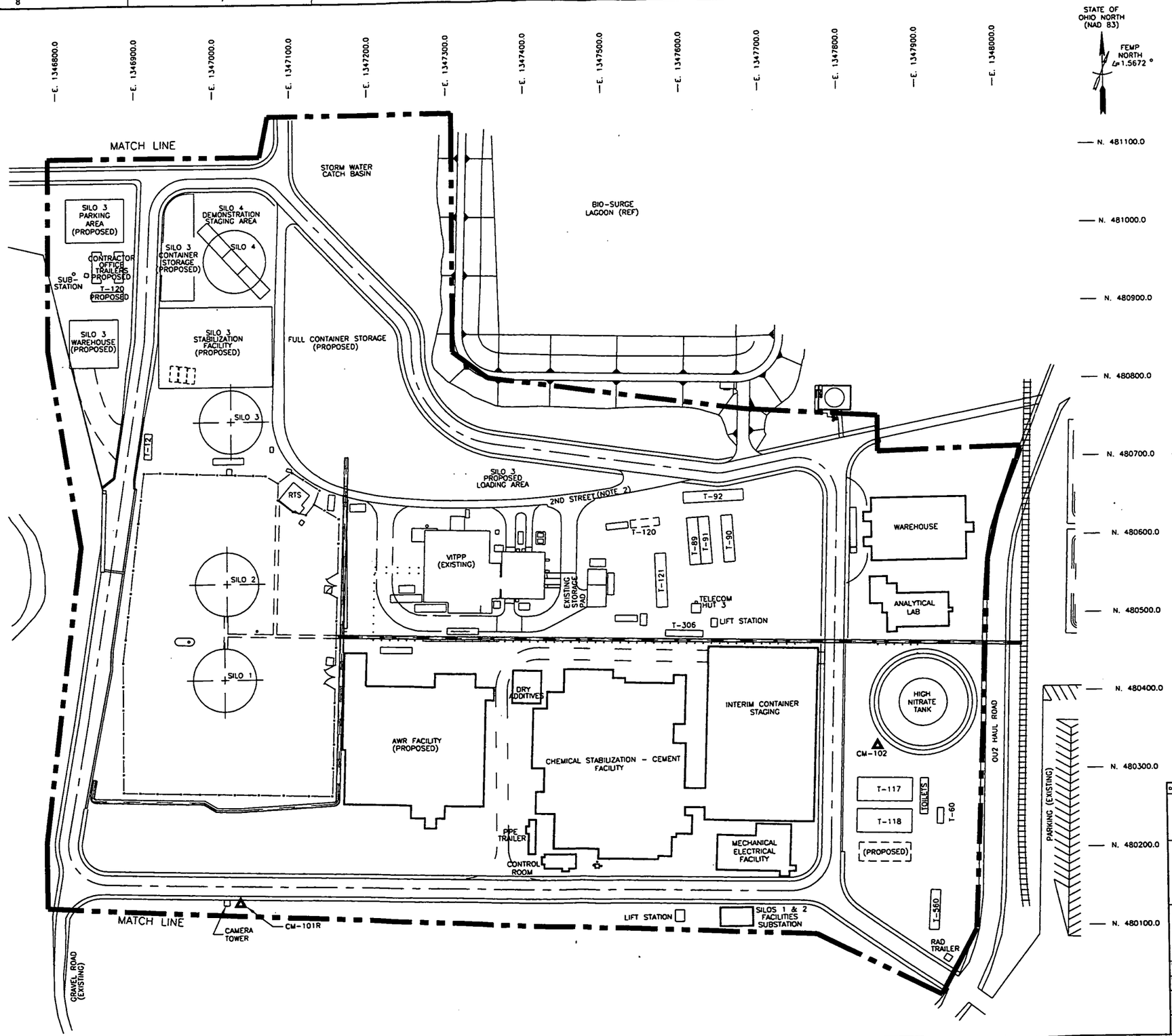

NOTES:

1. LOCATION OF FENCES, GATES AND CHECK POINTS TO BE DETERMINED.
2. THIS SECTION OF 2nd STREET TO BE USED BY PEDESTRIAN, LIGHT DUTY, OCCASIONAL DELIVERIES TO OU1, AND EMERGENCY TRAFFIC ONLY.
4. CONSTRUCTION AND OPERATIONS PERSONNEL WILL USE EXISTING SITE PARKING LOT.
5. INFRASTRUCTURE ROAD IS TO BE DOUBLE LANE.

LEGEND OF SYMBOLS

▲ = MONUMENT

0 25 50 100 150 200 250

GRAPHIC SCALE 1" = 50'

000598

PRELIMINARY DRAWING

CADFILE SK-1042 CHECKER ACADR14

UNITED STATES DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

THIS DRAWING PREPARED BY
FLUOR DANIEL FERNALD
SILOS PROJECT
CINCINNATI, OHIO

DRAWING TITLE
PLOT PLAN
CHEMICAL STABILIZATION - CEMENT
REVISED FEASIBILITY STUDY FOR SILOS 1 & 2

DRAWN BY S. M. YANKEY	DATE 12/29/98	DESIGNED, CHECKED BY	DATE
CHECKED BY J. THOMPSON	DATE 3/16/99	PLANT/AREA NO. OU4	FLOOR
SCALE 1"=50'	DATE	SUBMITTED FOR APPROVAL	APPROVAL RECOMMENDED
A-E	DATE	OPERATING CONTRACTOR	DATE
CDC PROJECT NO. 40730	OPER. CONTR. PROJ. NO. WBS2.1.3.G.P	DRAWING NO. 94X-5500-G-SK-1042	SHEET NO. 1 REV. NO. 2

DISTRIBUTION CODE: XXX ACAD INITIALS: RWR DATE: 12/1/99

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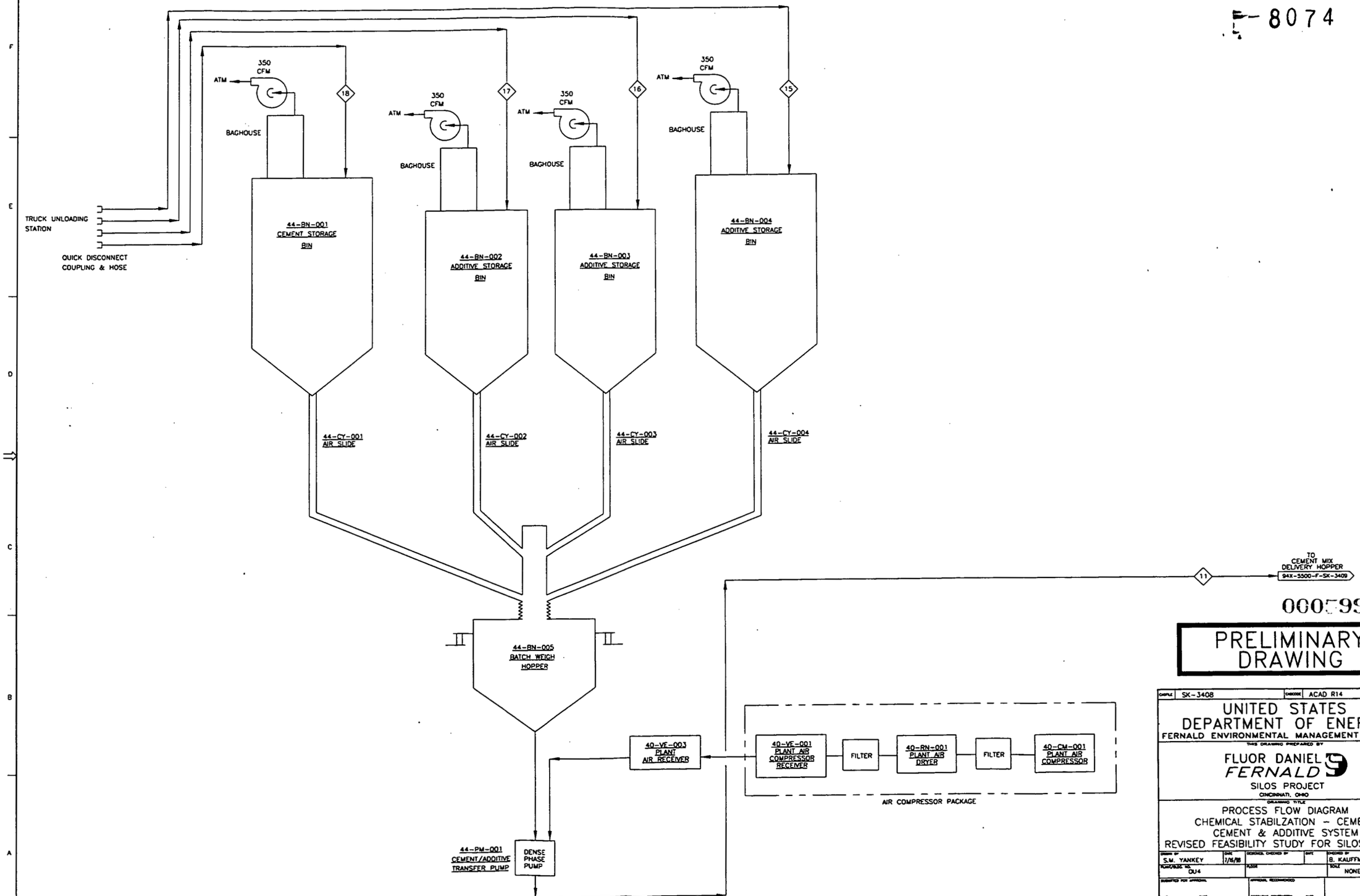

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PRELIMINARY DRAWING

CHFILE	SK-3408	CHECKER	ACAD R14

UNITED STATES DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

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SILOS PROJECT
CINCINNATI, OHIO

DRAWING TITLE
PROCESS FLOW DIAGRAM
CHEMICAL STABILZATION - CEMENT
CEMENT & ADDITIVE SYSTEM
REVISED FEASIBILITY STUDY FOR SILOS 1 & 2

DRAWN BY S.M. YANKEY	DATE 1/16/98	DESIGNED, CHECKED BY	DATE	CHECKED BY B. KAUFFMAN	DATE 7/30/99
PLANT/BLDG. NO. OU4		FLOOR		SCALE NONE	CLASS
SUBMITTED FOR APPROVAL		APPROVAL RECOMMENDED			
A-E	DATE	OPERATING CONTRACTOR	DATE		
DOE PROJECT NO. 40730	SPEC. CONTR. PROJ. NO. WBS2.1.3.G.P	DRAWING NO. 94X-5500-F-SK-3408		SHEET NO. 1	REV. NO. 2

DISTRIBUTION CODE: XXX

ACAD

INITIALS: RWR
DATE: 12/1/99

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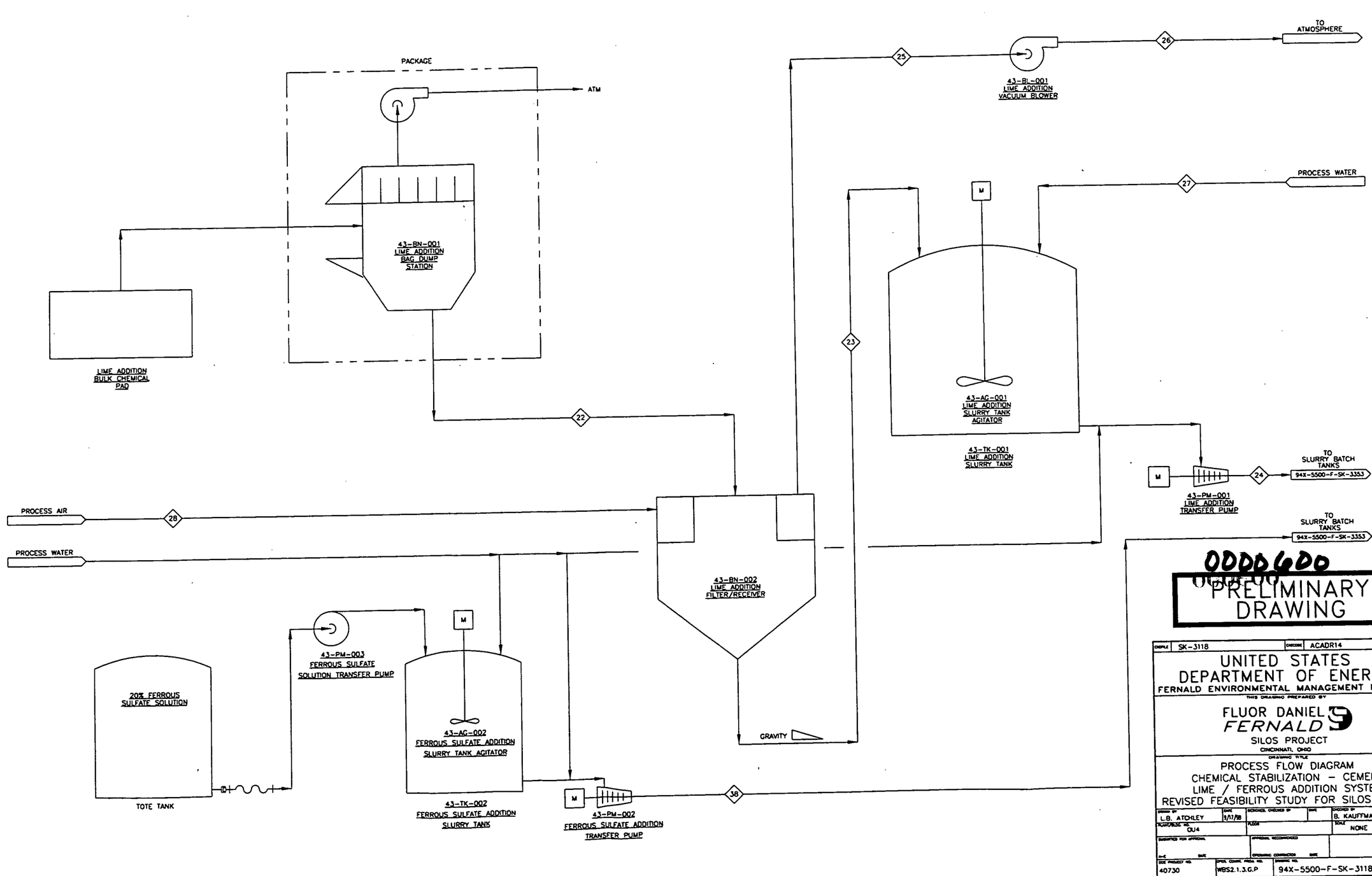

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PRELIMINARY DRAWING

DWG/FILE	SK-3118	CHECKER	ACADR14

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FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

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SILOS PROJECT
CINCINNATI, OHIO

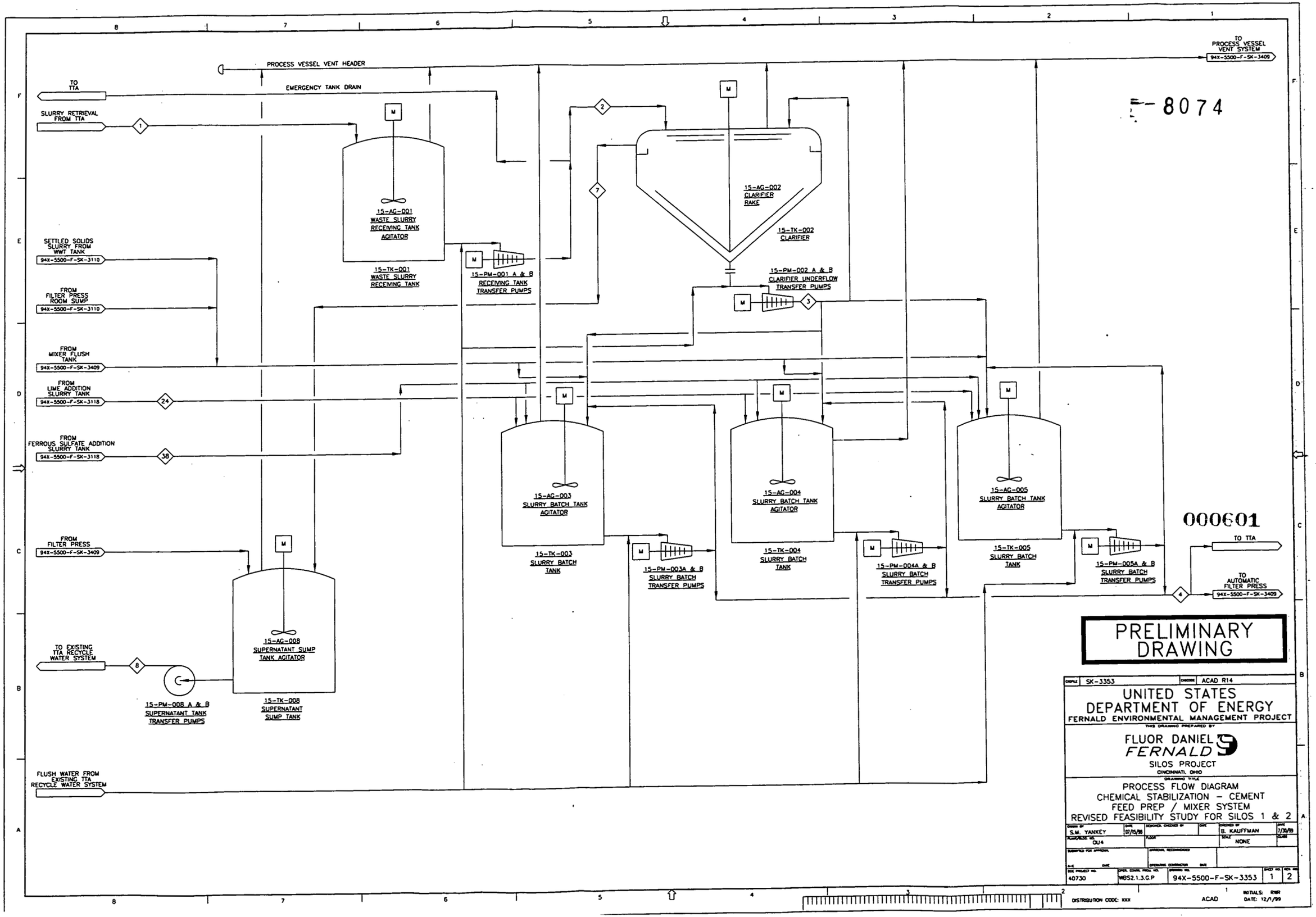
DRAWING TITLE
PROCESS FLOW DIAGRAM
CHEMICAL STABILIZATION – CEMENT
LIME / FERROUS ADDITION SYSTEM
REVISED FEASIBILITY STUDY FOR SILOS 1 & 2

DRAWN BY L.B. ATCHLEY	DATE 9/17/98	REVIEWED, CHECKED BY	DATE	CHECKED BY B. KAUFFMAN	DATE 7/30/99
SYSTEM/BLDG. NO. OU4		FLOOR		SCALE NONE	CLASS
SUBMITTED FOR APPROVAL		APPROVAL RECOMMENDED			
A/E	DATE	CONSTRUCTION CONTRACTOR	DATE		
SITE PROJECT NO. 40730		SYSTEM CONTROL FIELD NO. WBS2.1.3.G.P	DRAWING NO. 94X-5500-F-SK-3118	SHEET NO. 1	REV. NO. 2

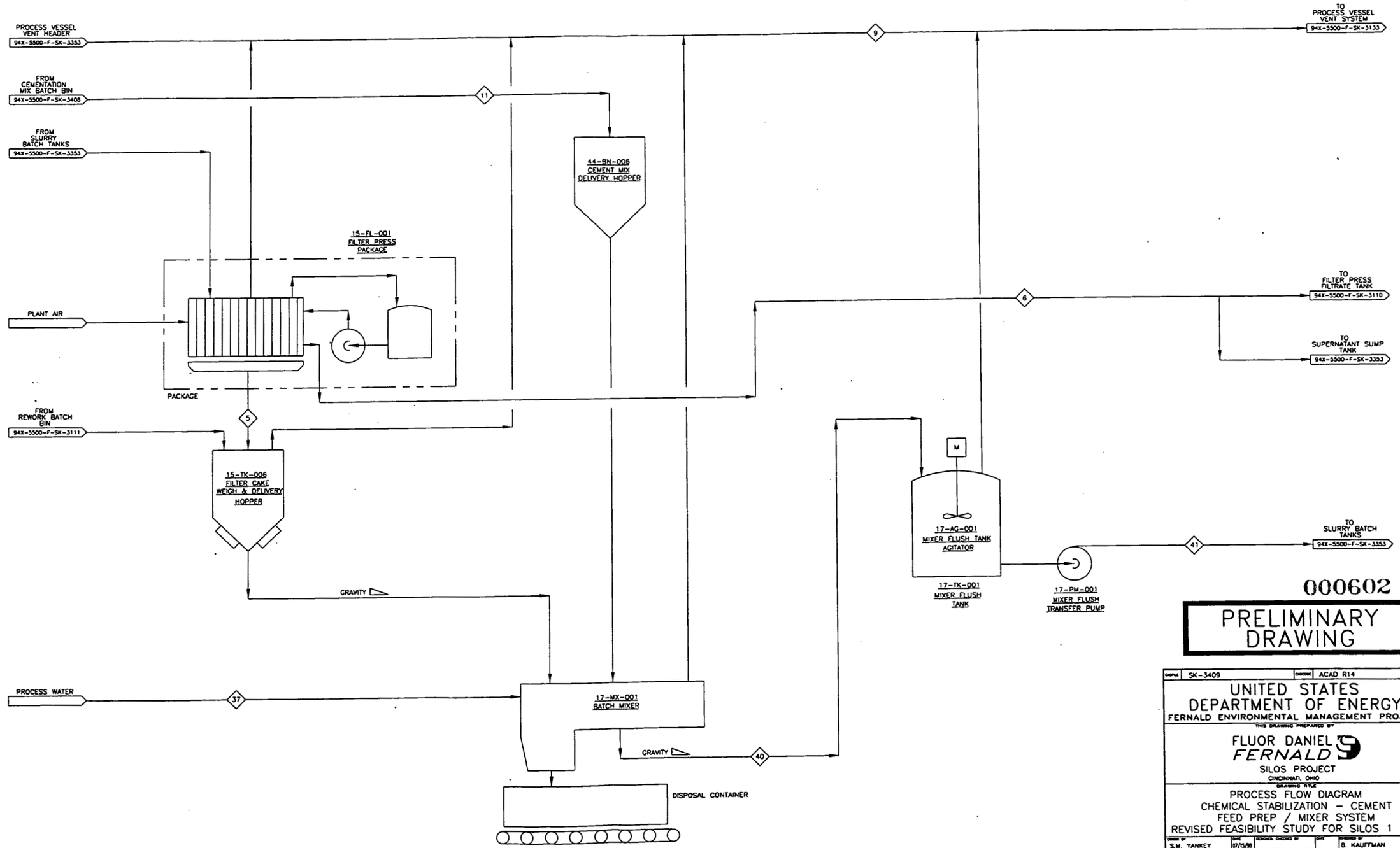
DISTRIBUTION CODE: XXX

ACAD

INITIALS: RMR
DATE: 12/1/99


PROCESS VESSEL VENT HEADER
TO PROCESS VESSEL VENT SYSTEM
94X-5500-F-SK-3409
TO TTA
EMERGENCY TANK DRAIN
SLURRY RETRIEVAL FROM TTA
15-AG-001 WASTE SLURRY RECEIVING TANK AGITATOR
15-TK-001 WASTE SLURRY RECEIVING TANK
15-PM-001 A & B RECEIVING TANK TRANSFER PUMPS
15-AG-002 CLARIFIER RAKE
15-TK-002 CLARIFIER
15-PM-002 A & B CLARIFIER UNDERFLOW TRANSFER PUMPS
SETTLED SOLIDS SLURRY FROM WWT TANK
94X-5500-F-SK-3110
FROM FILTER PRESS ROOM SUMP
94X-5500-F-SK-3110
FROM MIXER FLUSH TANK
94X-5500-F-SK-3409
FROM LIME ADDITION SLURRY TANK
94X-5500-F-SK-3118
FROM FERROUS SULFATE ADDITION SLURRY TANK
94X-5500-F-SK-3118
15-AG-003 SLURRY BATCH TANK AGITATOR
15-TK-003 SLURRY BATCH TANK
15-PM-003A & B SLURRY BATCH TRANSFER PUMPS
15-AG-004 SLURRY BATCH TANK AGITATOR
15-TK-004 SLURRY BATCH TANK
15-PM-004A & B SLURRY BATCH TRANSFER PUMPS
15-AG-005 SLURRY BATCH TANK AGITATOR
15-TK-005 SLURRY BATCH TANK
15-PM-005A & B SLURRY BATCH TRANSFER PUMPS
TO TTA
TO AUTOMATIC FILTER PRESS
94X-5500-F-SK-3409
FROM FILTER PRESS
94X-5500-F-SK-3409
15-AG-008 SUPERNATANT SUMP TANK AGITATOR
TO EXISTING TTA RECYCLE WATER SYSTEM
15-PM-008 A & B SUPERNATANT TANK TRANSFER PUMPS
15-TK-008 SUPERNATANT SUMP TANK
FLUSH WATER FROM EXISTING TTA RECYCLE WATER SYSTEM
F-8074
000601
PRELIMINARY DRAWING
SK-3353
ACAD R14
UNITED STATES DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT
FLUOR DANIEL FERNALD
SILOS PROJECT
CINCINNATI, OHIO
PROCESS FLOW DIAGRAM
CHEMICAL STABILIZATION - CEMENT
FEED PREP / MIXER SYSTEM
REVISED FEASIBILITY STUDY FOR SILOS 1 & 2
S.M. YANKEY
07/15/99
B. KAUFFMAN
7/30/99
OU4
NONE
40730
WBS2.1.3.G.P
94X-5500-F-SK-3353
1
2
DISTRIBUTION CODE: XXX
ACAD
INITIALS: RWR
DATE: 12/1/99

8074



000602

PRELIMINARY DRAWING

SHEET SK-3409	CADFILE ACAD R14

UNITED STATES DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

THIS DRAWING PREPARED BY
FLUOR DANIEL FERNALD
SILOS PROJECT
CINCINNATI, OHIO

DRAWING TITLE
PROCESS FLOW DIAGRAM
CHEMICAL STABILIZATION – CEMENT
FEED PREP / MIXER SYSTEM
REVISED FEASIBILITY STUDY FOR SILOS 1 & 2

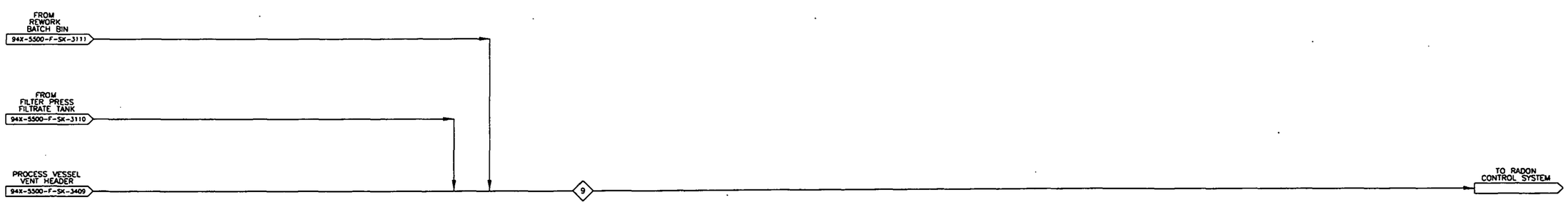
DRAWN BY S.M. YANKEY	DATE 07/15/98	DESIGNED, CHECKED BY	DATE	CHECKED BY B. KAUFFMAN	DATE 7/30/99
PLANT/BLDG. NO. OU4		PLOT		SCALE NONE	PLOTTED
SUBMITTED FOR APPROVAL		APPROVAL RECOMMENDED			
D&E	DATE	OPERATING CONTRACTOR	DATE		
SITE PROJECT NO. 40730	OPER. CONTR. PROJ. NO. WBS2.1.3.G.P	DRAWING NO. 94X-5500-F-SK-3409		SHEET NO. 1	REV. NO. 2

DISTRIBUTION CODE: XXX

ACAD

INITIALS: RWR
DATE: 12/1/99

8074



000603

~~000603~~

PRELIMINARY DRAWING

CADFILE	SK-3133	CADCODE	ACADR14

UNITED STATES
DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

THIS DRAWING PREPARED BY

FLUOR DANIEL FERNALD
SILOS PROJECT
CINCINNATI, OHIO

DRAWING TITLE

PROCESS FLOW DIAGRAM
CHEMICAL STABILIZATON – CEMENT
PROCESS VESSEL VENT SYSTEM
REVISED FEASIBILITY STUDY FOR SILOS 1 & 2

DRAWN BY S.M. YANKEY	DATE 08/24/98	REVIEWED, CHECKED BY	DATE	CHECKED BY B. KAUFFMAN	DATE 1/20/99
PLANT/AREA NO. OU4		FLOOR		SCALE NONE	POWER
SUBMITTED FOR APPROVAL: DATE	DATE	APPROVAL RECOMMENDED: CONSULTING CONTRACTOR	DATE		
CDS PROJECT NO. 40730	SPEC. CONTL. FISCAL NO. WBS2.1.3.G.P	DRAWING NO. 94X-5500-F-SK-3133		SHEET NO. 1	REV. NO. 2

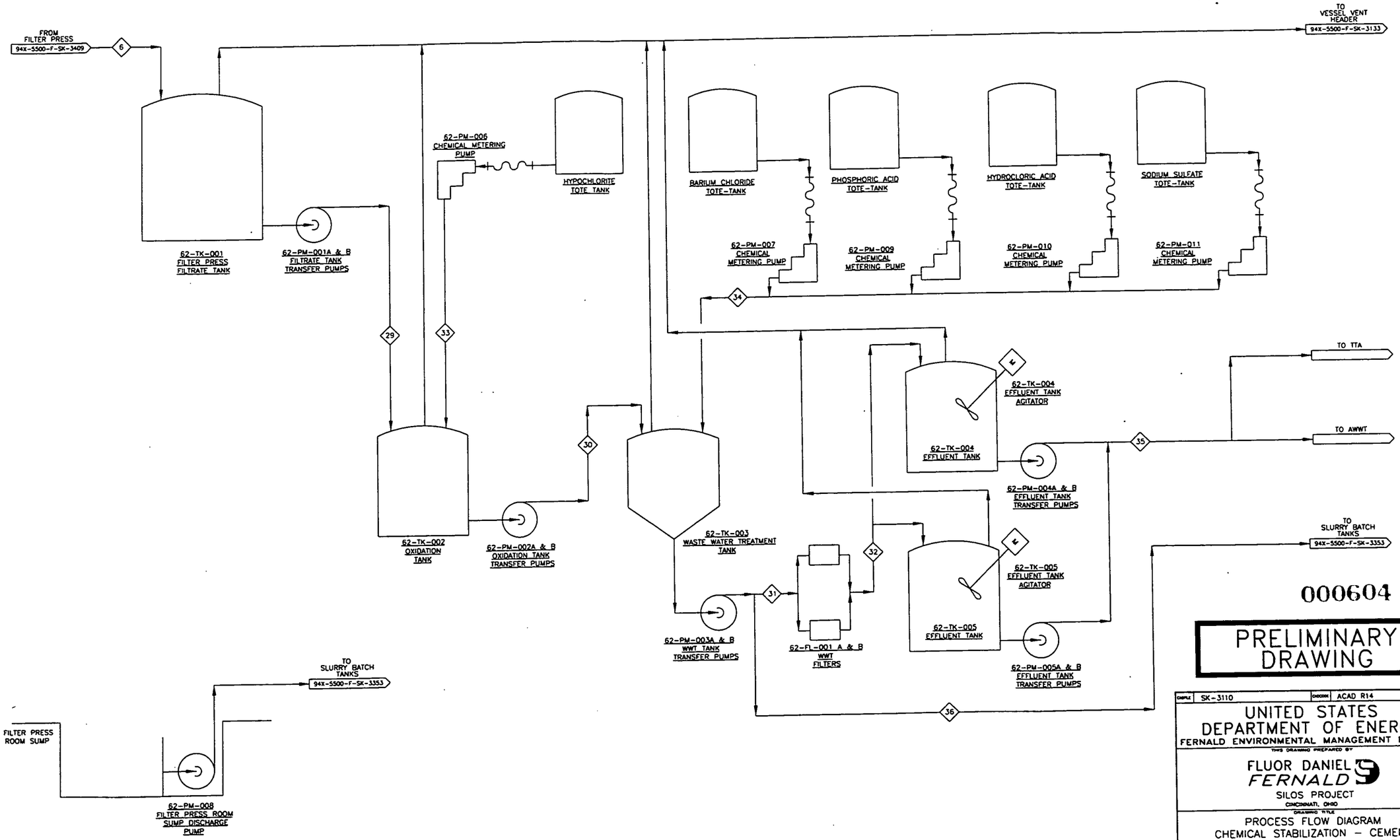
DISTRIBUTION CODE: XXX

ACAD

INITIALS: RWR
DATE: 12/1/99

L 07/10/98
BY: RCK
C:\DWG\DWG\5\4.DS1_21V3-PP\08-PG_07.DWG

8074



000604

PRELIMINARY DRAWING

DWG/LE SK-3110	CHECKER ACAD R14

UNITED STATES DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

THIS DRAWING PREPARED BY
FLUOR DANIEL FERNALD
SILOS PROJECT
CINCINNATI, OHIO

DRAWING TITLE
PROCESS FLOW DIAGRAM
CHEMICAL STABILIZATION – CEMENT
FILTRATE & WATER TREATMENT
REVISED FEASIBILITY STUDY FOR SILOS 1 & 2

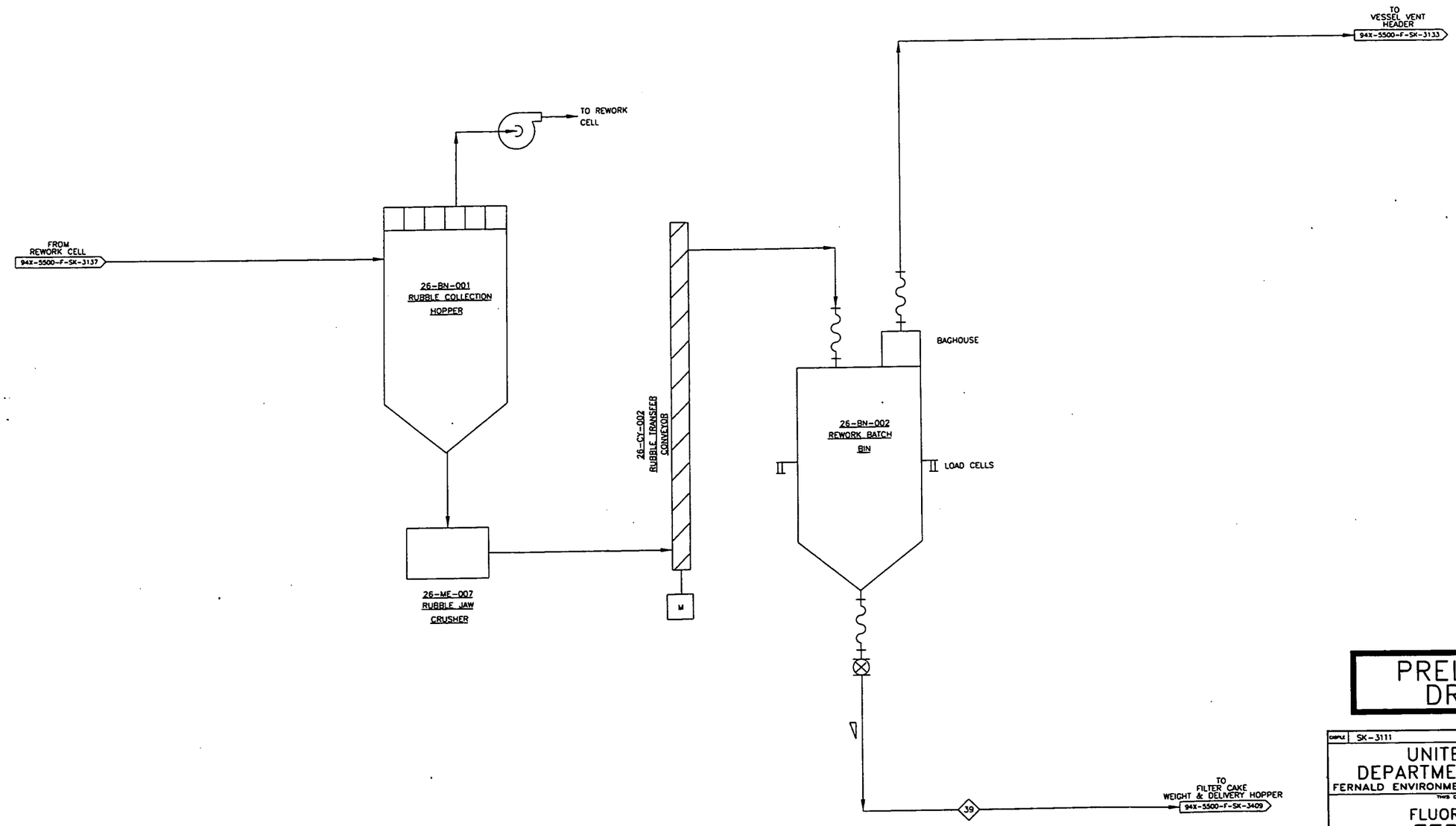
DRAWN BY S.M. YANKEY	DATE 5/3/99	REVIEWED, CHECKED BY	DATE	CHECKED BY B. KAUFFMAN	DATE 7/30/99
PLANT/AREA NO. OU4		PLANT		SCALE NONE	CLASS
SUBMITTED FOR APPROVAL		APPROVAL RECOMMENDED			
DATE	DATE	OPERATING CONTRACTOR	DATE		
SITE PRODUCT NO. 40730	SPEC. CONTR. PROJ. NO. WBS2.1.3.G.P	DRAWING NO. 94X-5500-F-SK-3110		SHEET NO. 1	REV. NO. 2

DISTRIBUTION CODE: XXX

ACAD

INITIALS: RWR
DATE: 12/1/99

8074



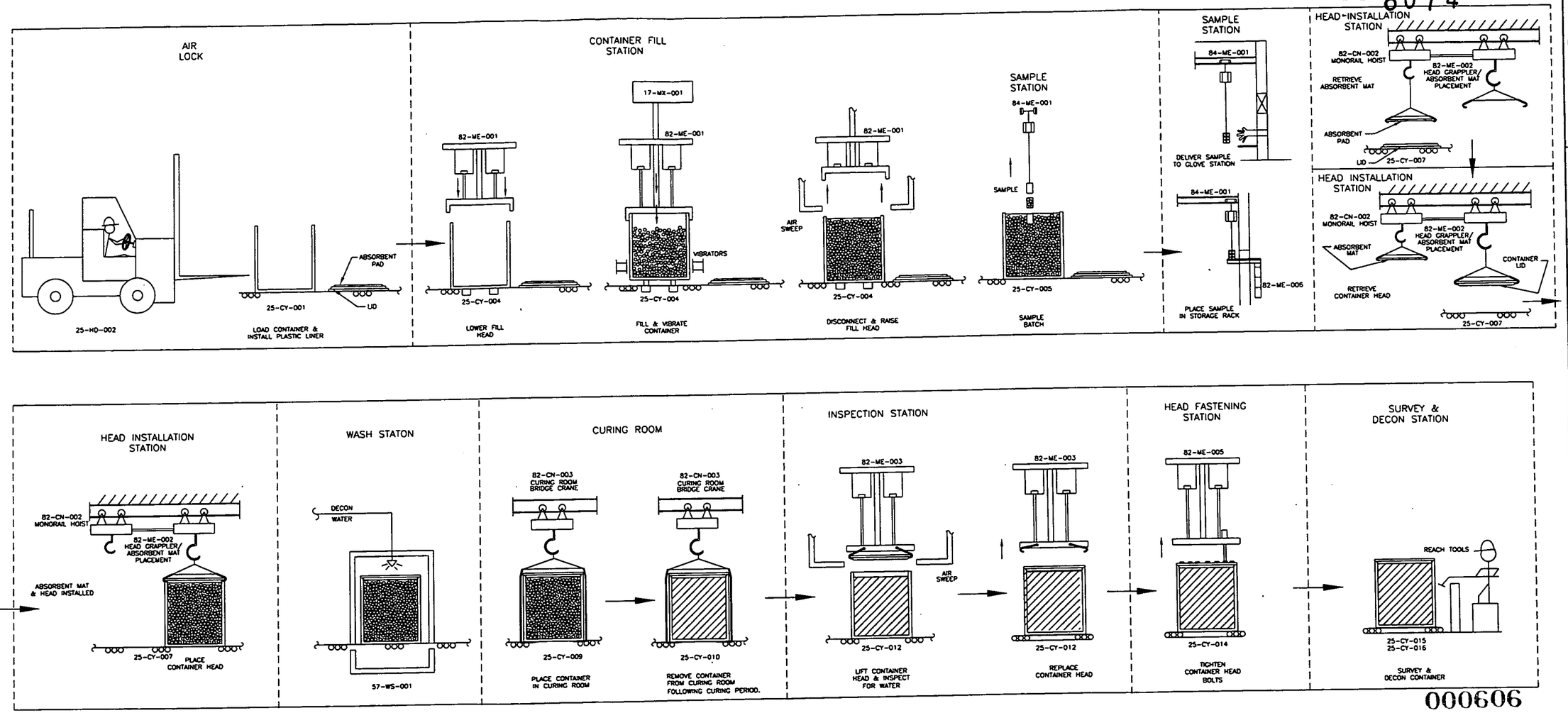
000605

PRELIMINARY DRAWING

DWFILE SK-3111		CHECKFILE ACAD R14	
UNITED STATES DEPARTMENT OF ENERGY FERNALD ENVIRONMENTAL MANAGEMENT PROJECT			
THIS DRAWING PREPARED BY FLUOR DANIEL FERNALD SILOS PROJECT CINCINNATI, OHIO			
DRAWING TITLE PROCESS FLOW DIAGRAM CHEMICAL STABILIZATION – CEMENT REJECT WASTE REWORK REVISED FEASIBILITY STUDY FOR SILOS 1 & 2			
DRAWN BY E. M. MOORE	DATE 10/21/98	CHECKED BY B. KAUFFMAN	DATE 7/30/99
PLANT/BLDG. NO. OU4	FLOOR	SCALE NONE	CLASS
DESIGNATED FOR APPROVAL A-E DATE	APPROVAL RECOMMENDED OPERATING CONTRACTOR DATE		
DOE PROJECT NO. 40730	OPER. CONTR. PROJ. NO. WBS2.1.3.G.P	DRAWING NO. 94X-5500-F-SK-3111	SHEET NO. 1 REV. NO. 2

DISTRIBUTION CODE: XXX ACAD INITIALS: RWR DATE: 12/1/99

8074



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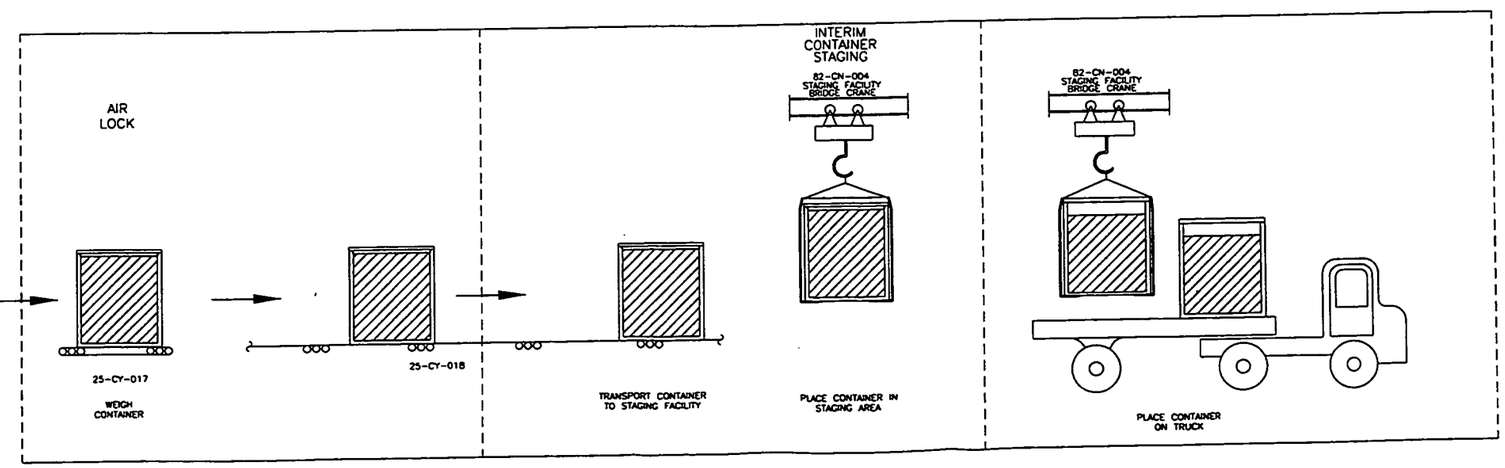
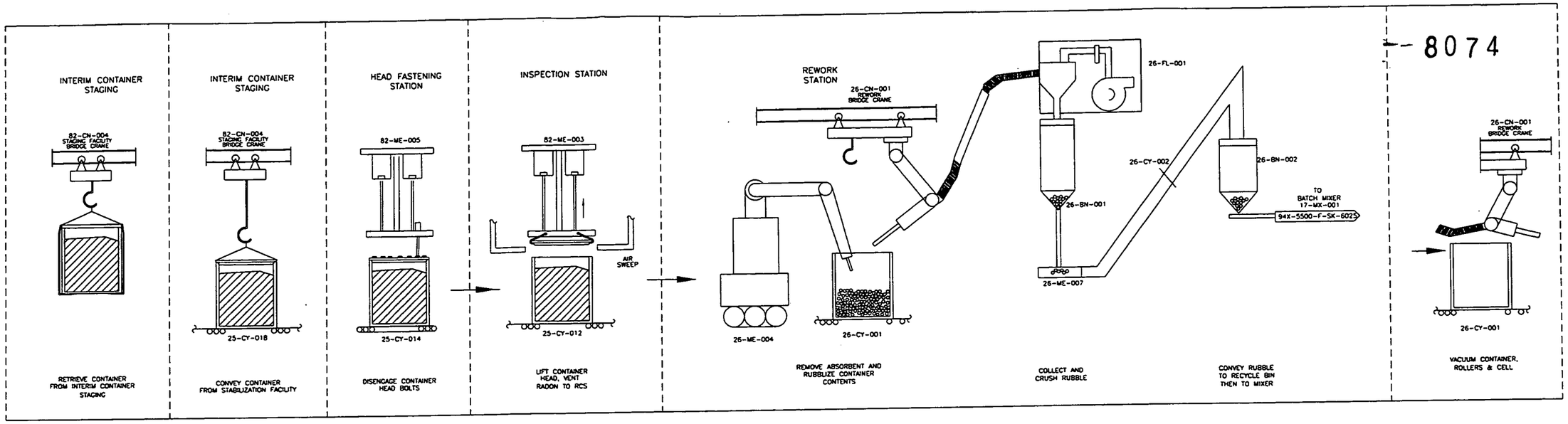
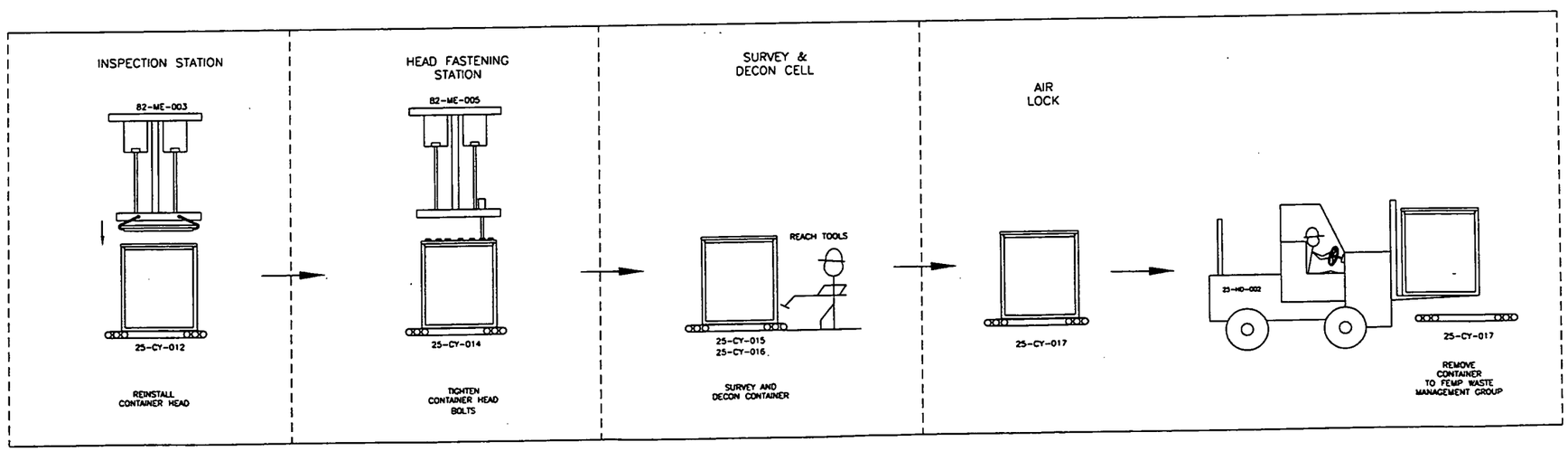
PRELIMINARY DRAWING



CAD FILE: SK-6025		CHECKER: ACAD R14	
UNITED STATES DEPARTMENT OF ENERGY FERNALD ENVIRONMENTAL MANAGEMENT PROJECT			
THIS DRAWING PREPARED BY FLUOR DANIEL FERNALD SILOS PROJECT CINCINNATI, OHIO			
DRAWING TITLE MECHANICAL FLOW DIAGRAM CHEMICAL STABILIZATION - CEMENT PRODUCT LOAD REVISED FEASIBILITY STUDY FOR SILOS 1 & 2			
DRAWN BY: D. LANDER	DATE: 12/29/98	DESIGNED, CHECKED BY:	DATE:
CHECKED BY: C. SCHILLING	DATE: 9/20/99		
PLANT/BLDG. NO.: OU4	PLOT:	SCALE: NONE	CLASS:
SUBMITTED FOR APPROVAL:		APPROVAL RECOMMENDED:	
A/E: DATE:		ENGINEERING CONTRACTOR: DATE:	
DOE PROJECT NO.: 40730	OPER. CONTR. PROJ. NO.: WBS2.1.3.G.P	DRAWING NO.: 94X-5500-F-SK-6025	SHEET NO.: 1 REV. NO.: 2
DISTRIBUTION CODE: XXX	ACAD	INITIALS: RWR DATE: 12/1/99	





000607

PRELIMINARY DRAWING

CAD FILE: SK-6026 | CADSYS: ACAD R14

UNITED STATES DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

THIS DRAWING PREPARED BY
FLUOR DANIEL FERNALD
SILOS PROJECT
CINCINNATI, OHIO

DRAWING TITLE
MECHANICAL FLOW DIAGRAM
CHEMICAL STABILIZATION – CEMENT
REWORK/RECYCLE
REVISED FEASIBILITY STUDY FOR SILOS 1 & 2

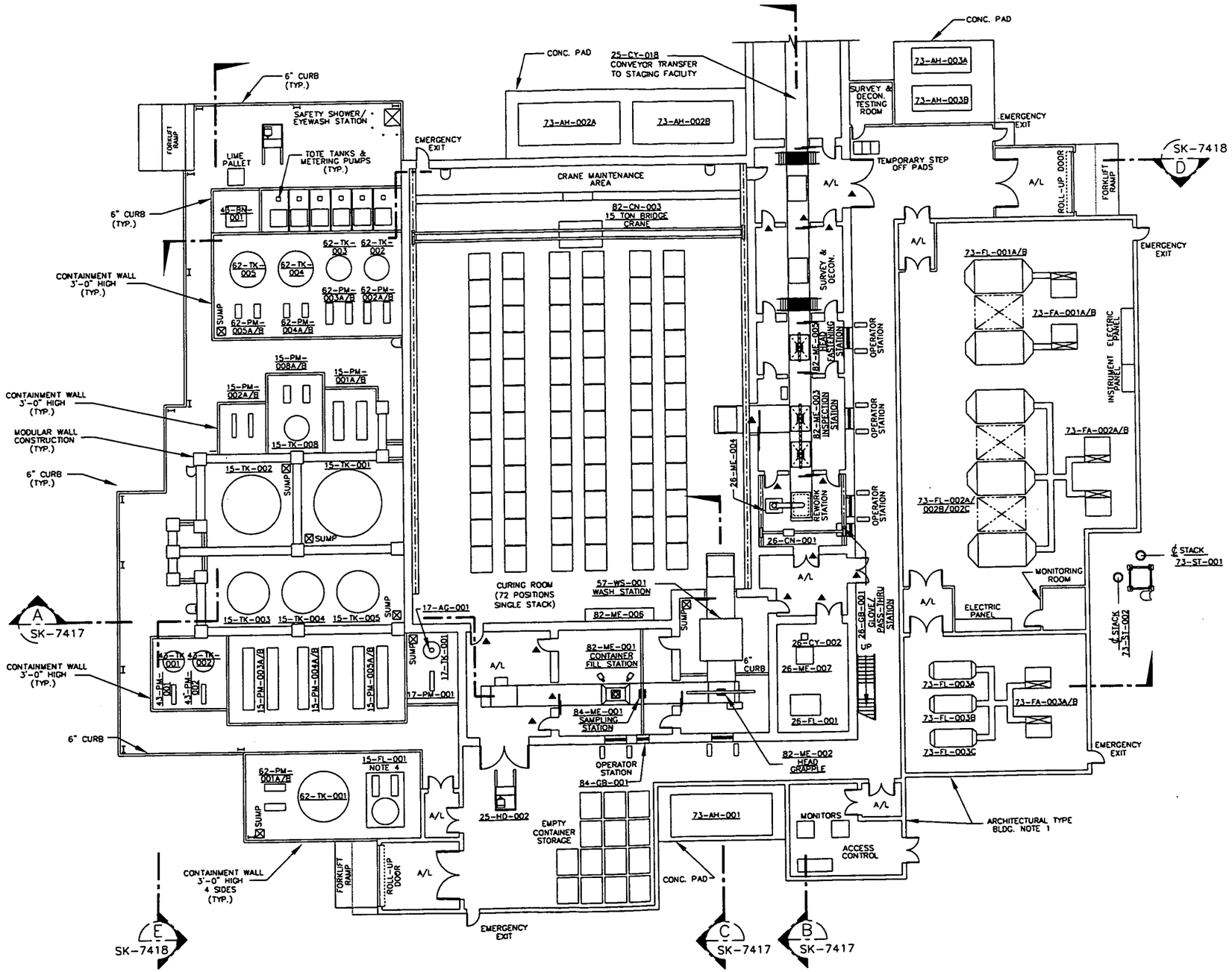
DRAWN BY: D. LANDER	DATE: 12/29/98	DESIGNER CHECKED BY:	DATE:
CHECKED BY: C. SCHILLING	DATE: 7/30/99	PLANT/BLDG. NO.: OU4	FLOOR:
SCALE: NONE	DATE:	SUBMITTED FOR APPROVAL:	APPROVAL RECOMMENDED:
DATE:	DATE:	APPROVING CONTRACTOR:	DATE:
SDC PROJECT NO.: 40730	SYSTEM CONTROL PROJ. NO.: WBS2.1.3.G.P	DRAWING NO.: 94X-5500-F-SK-6026	SHEET NO.: 1 / REV. NO.: 2

DISTRIBUTION CODE: XXX

ACAD

INITIALS: RWR
DATE: 12/1/99

8074



PLAN @ EL. 0'-0"
TO EL. 15'-0"

0 10 20 40 60 80 100
GRAPHIC SCALE IN FEET
3/64" = 1'-0"

NOTES:

1. BUILDING CONSTRUCTION
   - CONCRETE FLOOR SLAB AND FOUNDATIONS.
   - ARCHITECTURAL TYPE WALLS CONSIST OF STEEL FRAME STRUCTURE, INSULATED METAL SIDING, MEMBRANE ROOFING SUPPORTED BY STEEL DECKING AND INSULATION BOARD.
   - MODULAR WALL CONSTRUCTION CONSISTS OF INTERLOCKING PREFABRICATED SHIELDING WALLS AND COLUMNS.
   - ALL OTHER SHIELDING WALLS ARE 2'-0" THICK CONCRETE.
2. EMPTY CONTAINER STORAGE IS SINGLE STACK.
3. SHIELD DOOR= ▲
4. WATER PRESSURE SKID INCLUDED IN FILTER PRESS PACKAGE.

000608

REFERENCE DRAWINGS
94X-5500-P-SK-7416
94X-5500-P-SK-7417
94X-5500-P-SK-7418

PRELIMINARY DRAWING

SHEET SK-7441 | CHECKER ACAD R14

UNITED STATES DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

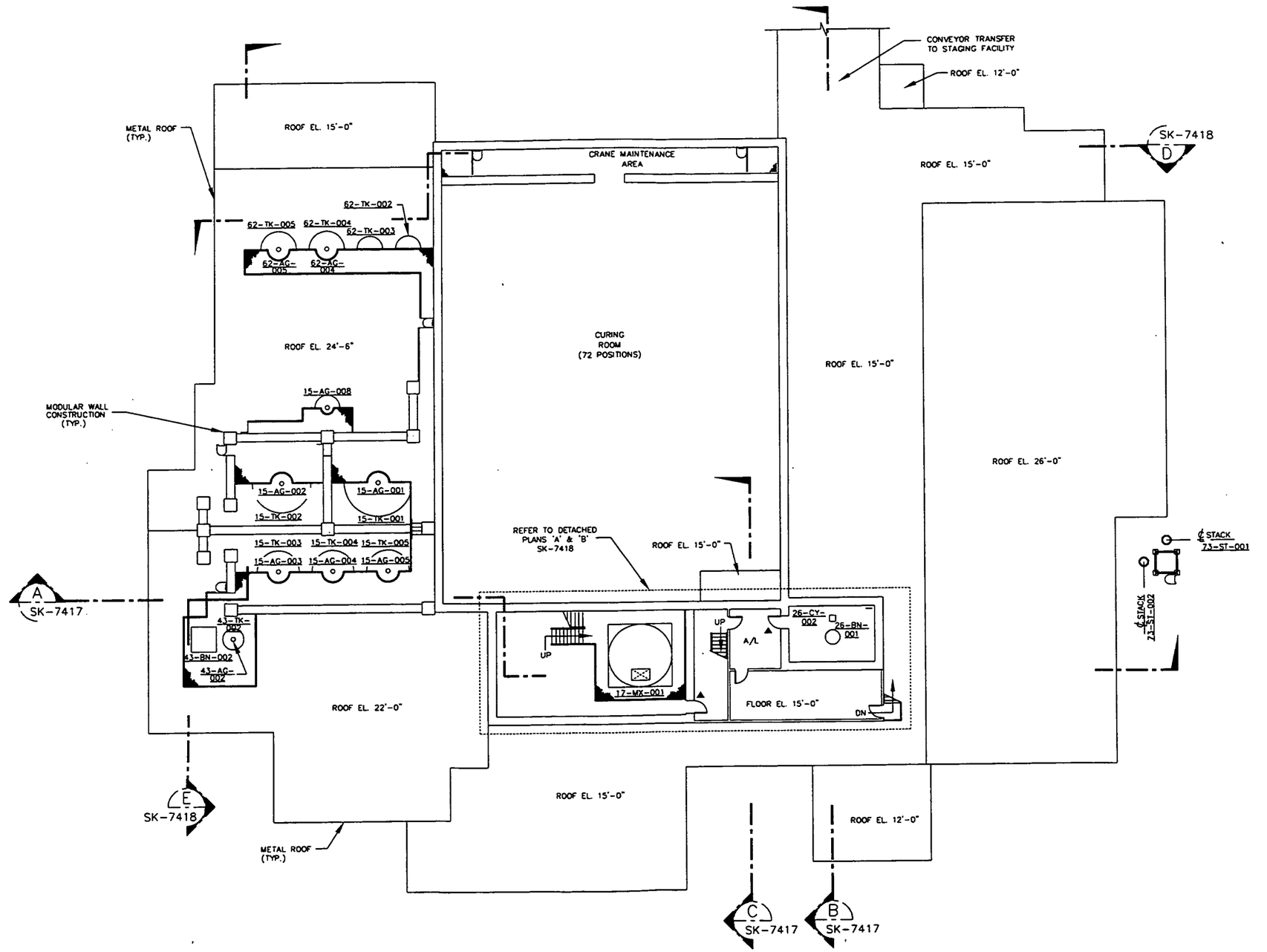
THIS DRAWING PREPARED BY
FLUOR DANIEL FERNALD
SILOS PROJECT
CINCINNATI, OHIO

DRAWING TITLE
FACILITY LAYOUT
CHEMICAL STABILIZATION – CEMENT
PLAN @ EL. 0'-0" TO 15'-0"
REVISED FEASIBILITY STUDY FOR SILOS 1 & 2

DRAWN BY S. M. YANKEY	DATE 11/23/98	DESIGNED, CHECKED BY	DATE
CHECKED BY J. THOMPSON	DATE 3/16/99	PLANT/BLDG. NO. OU4	FLOOR
SCALE 3/64" = 1'-0"	CLASS	SUBMITTED FOR APPROVAL	APPROVAL RECOMMENDED
A-E	DATE	OPERATING CONTRACTOR	DATE
DOE PROJECT NO. 40730	SPECIAL COMPL. PROJ. NO. WBS2.1.3.G.P	DRAWING NO. 94X-5500-P-SK-7441	SHEET NO. 1 / REV. NO. 2

DISTRIBUTION CODE: XXX
ACAD
INITIALS: RWR
DATE: 12/1/99

8074



PLAN @ EL. 15'-0"
AND ABOVE

0 10 20 40 60 80 100

GRAPHIC SCALE IN FEET
3/64" = 1'-0"

NOTES:

1. BUILDING CONSTRUCTION
   - CONCRETE FLOOR SLAB AND FOUNDATIONS.
   - ARCHITECTURAL TYPE WALLS CONSIST OF STEEL FRAME STRUCTURE, INSULATED METAL SIDING, MEMBRANE ROOFING SUPPORTED BY STEEL DECKING AND INSULATION BOARD.
   - MODULAR WALL CONSTRUCTION CONSISTS OF INTERLOCKING PREFABRICATED SHEILDING WALLS AND COLUMNS.
   - ALL OTHER SHEILDING WALLS ARE 2'-0" THICK CONCRETE.
2. SHIELD DOOR = ▲

REFERENCE DRAWINGS

94X-5500-P-SK-7441
94X-5500-P-SK-7417
94X-5500-P-SK-7418

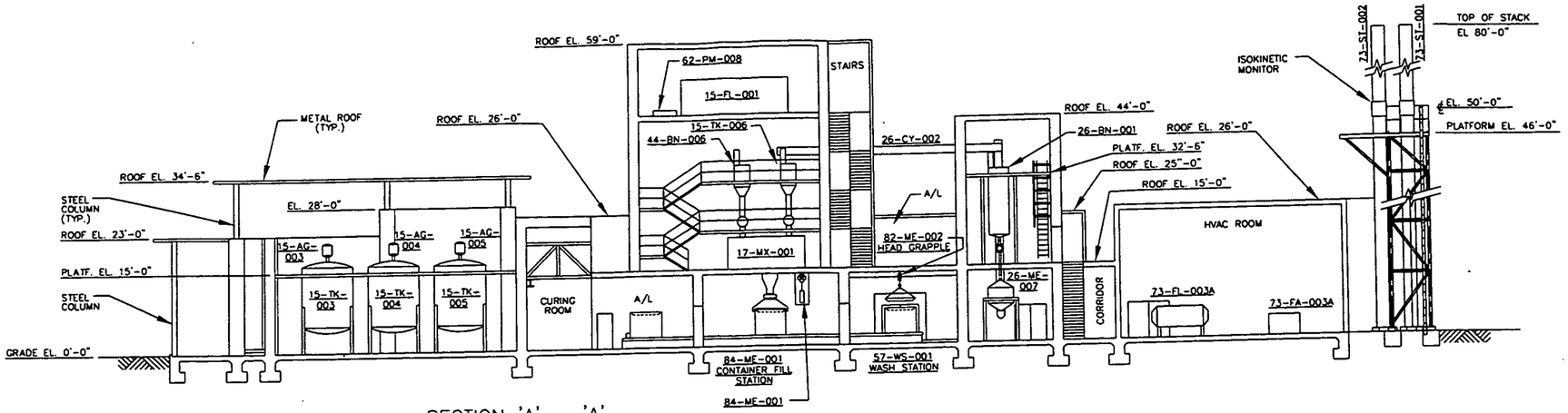
000609

PRELIMINARY DRAWING

DWG/FILE SK-7416		CHECKER ACAD R14	
UNITED STATES DEPARTMENT OF ENERGY FERNALD ENVIRONMENTAL MANAGEMENT PROJECT			
THIS DRAWING PREPARED BY FLUOR DANIEL FERNALD SILOS PROJECT CINCINNATI, OHIO			
DRAWING TITLE FACILITY LAYOUT CHEMICAL STABILIZATION - CEMENT PLAN @ EL. 15'-0" & ABOVE REVISED FEASEIBILITY STUDY FOR SILOS 1 & 2			
DRAWN BY S. M. YANKEY	DATE 11/23/98	CHECKED BY J. THOMPSON	DATE 3/16/99
PLANT/BLDG. NO. OU4	ACAD	SCALE 3/64" = 1'-0"	FOLDER
SUBMITTED FOR APPROVAL		APPROVAL RECOMMENDED	
A-E DATE		CONSTRUCTION DATE	
SITE PROJECT NO. 40730	WBS2.1.3.G.P	DRAWING NO. 94X-5500-P-SK-7416	SHEET NO. 2 / TOTAL NO. 2

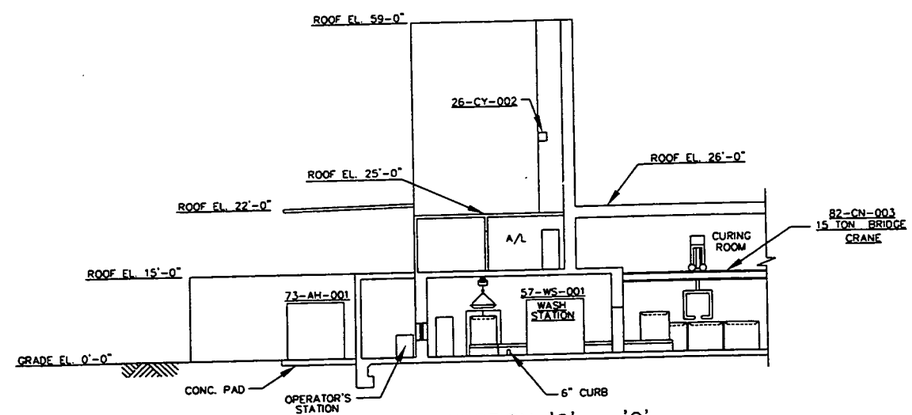
DISTRIBUTION CODE: XXX ACAD INITIALS: RWR DATE: 12/1/99

8074



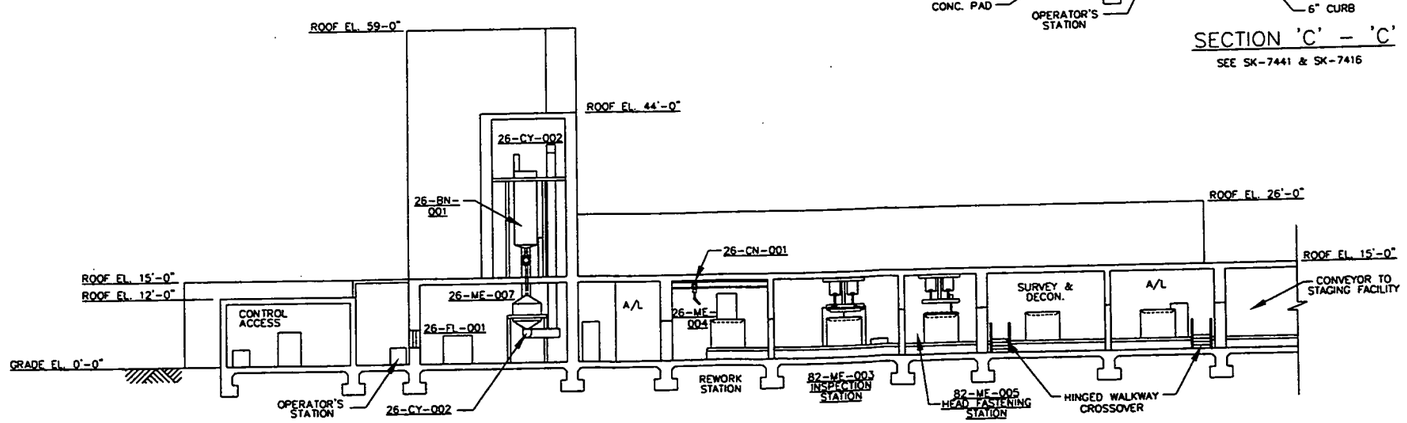
SECTION 'A' – 'A'

SEE SK-7441 & SK-7416



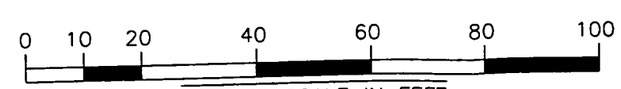
SECTION 'C' – 'C'

SEE SK-7441 & SK-7416



SECTION 'B' – 'B'

SEE SK-7441 & SK-7416



GRAPHIC SCALE IN FEET
3/64" = 1'-0"

NOTES:

1. BUILDING CONSTRUCTION
   - CONCRETE FLOOR SLAB AND FOUNDATIONS.
   - ARCHITECTURAL TYPE WALLS CONSIST OF STEEL FRAME STRUCTURE, INSULATED METAL SIDING, MEMBRANE ROOFING SUPPORTED BY STEEL DECKING AND INSULATION BOARD.
   - MODULAR WALL CONSTRUCTION CONSISTS OF INTERLOCKING PREFABRICATED SHIELDING WALLS AND COLUMNS.
   - ALL OTHER SHIELDING WALLS ARE 2'-0" THICK CONCRETE.
2. EMPTY CONTAINER STORAGE IS SINGLE STACK.

REFERENCE DRAWINGS

94X-5500-P-SK-7441
94X-5500-P-SK-7416
94X-5500-P-SK-7418

000610

PRELIMINARY DRAWING

DWG NO. SK-7417	CHECKER ACAD R14

UNITED STATES DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

THIS DRAWING PREPARED BY
FLUOR DANIEL FERNALD
SILOS PROJECT
CINCINNATI, OHIO

DRAWING TITLE
FACILITY LAYOUT
CHEMICAL STABILIZATION – CEMENT
SECTIONS & DETAILS
REVISED FEASIBILITY STUDY FOR SILOS 1 & 2

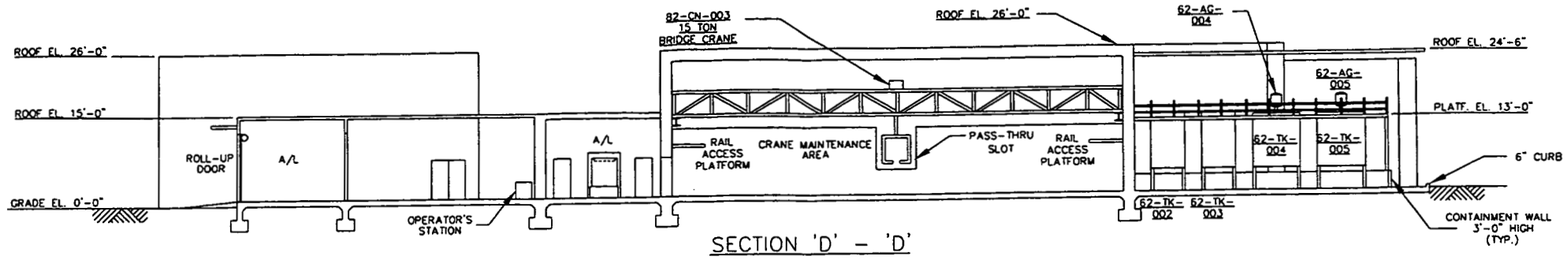
DRAWN BY S. M. YANKEY	DATE 11/23/98	DESIGNED, CHECKED BY	DATE	CHECKED BY J. THOMPSON	DATE 9/16/99
PLANT/BLDG. NO. OU4		FLOOR		SCALE 3/64" = 1'-0"	CLASS
SUBMITTED FOR APPROVAL		APPROVAL RECOMMENDED			
A-E	DATE	OPERATING CONTRACTOR	DATE		
DOE PROJECT NO. 40730	OPER. CONTR. PROJ. NO. WBS2.1.3.G.P	DRAWING NO. 94X-5500-P-SK-7417		SHEET NO. 3	REV. NO. 2

DISTRIBUTION CODE: XXX

ACAD

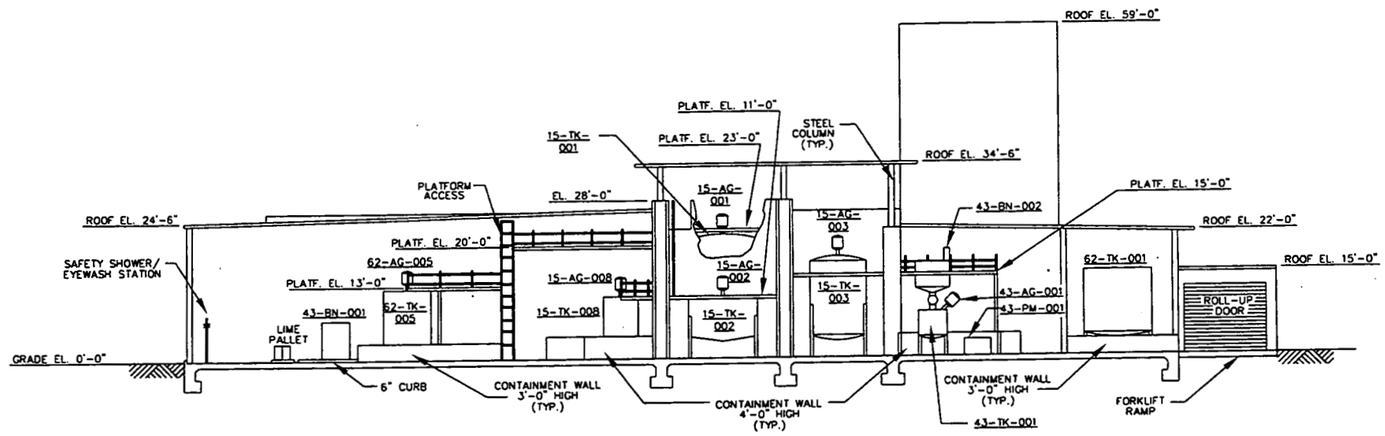
INITIALS: RWR
DATE: 12/1/99

8074



SECTION 'D' – 'D'

SEE SK-7441 & SK-7416



SECTION 'E'–'E'

SEE SK-7441 & SK-7416

NOTES:

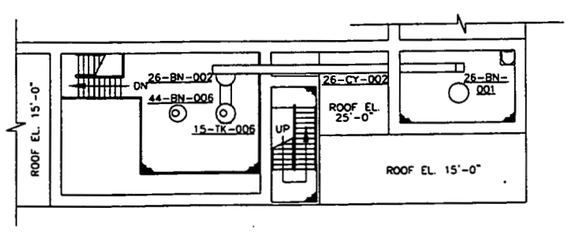
1. BUILDING CONSTRUCTION
   - CONCRETE FLOOR SLAB AND FOUNDATIONS.
   - ARCHITECTURAL TYPE WALLS CONSIST OF STEEL FRAME STRUCTURE, INSULATED METAL SIDING, MEMBRANE ROOFING SUPPORTED BY STEEL DECKING AND INSULATION BOARD.
   - MODULAR WALL CONSTRUCTION CONSISTS OF INTERLOCKING PREFABRICATED SHEILDING WALLS AND COLUMNS.
   - ALL OTHER SHEILDING WALLS ARE 2'-0" THICK CONCRETE.
2. SHEILD DOOR = ▲

REFERENCE DRAWINGS

94X-5500-P-SK-7441
94X-5500-P-SK-7416
94X-5500-P-SK-7417

000611

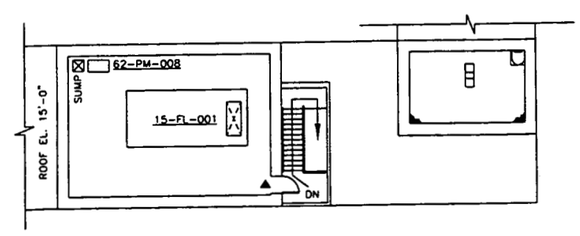
PRELIMINARY DRAWING



DETACHED PLAN 'A'

@ EL. 32'-0" TO 43'-0"

SEE SK-7416



DETACHED PLAN 'B'

@ EL. 43'-0" & ABOVE

SEE SK-7416

0 10 20 40 60 80 100

GRAPHIC SCALE IN FEET
3/64" = 1'-0"

DWG/FILE SK-7418		CHECKED ACAD R14	
UNITED STATES DEPARTMENT OF ENERGY FERNALD ENVIRONMENTAL MANAGEMENT PROJECT			
THIS DRAWING PREPARED BY FLUOR DANIEL FERNALD SILOS PROJECT CINCINNATI, OHIO			
DRAWING TITLE FACILITY LAYOUT CHEMICAL STABILIZATION – CEMENT DETACHED PLANS, DETAILS, & SECTION REVISED FEASIBILITY STUDY FOR SILOS 1 & 2			
DRAWN BY S. M. YANKEY	DATE 11/23/98	REVIEWED, CHECKED BY / DATE	CHECKED BY J. THOMPSON / DATE 8/16/99
PLANT/MUSC NO. OU4	FLOOR		SCALE 3/64" = 1'-0" / CLASS
SUBMITTED FOR APPROVAL / DATE	APPROVAL RECOMMENDED / DATE		
SGE PROJECT NO. 40730	SPCIL CONTR. PROJ. NO. WBS2.1.3.G.P	DRAWING NO. 94X-5500-P-SK-7418	SHEET NO. 4 / REV. NO. 2
DISTRIBUTION CODE: XXX		ACAD	INITIALS: RWR DATE: 12/1/99

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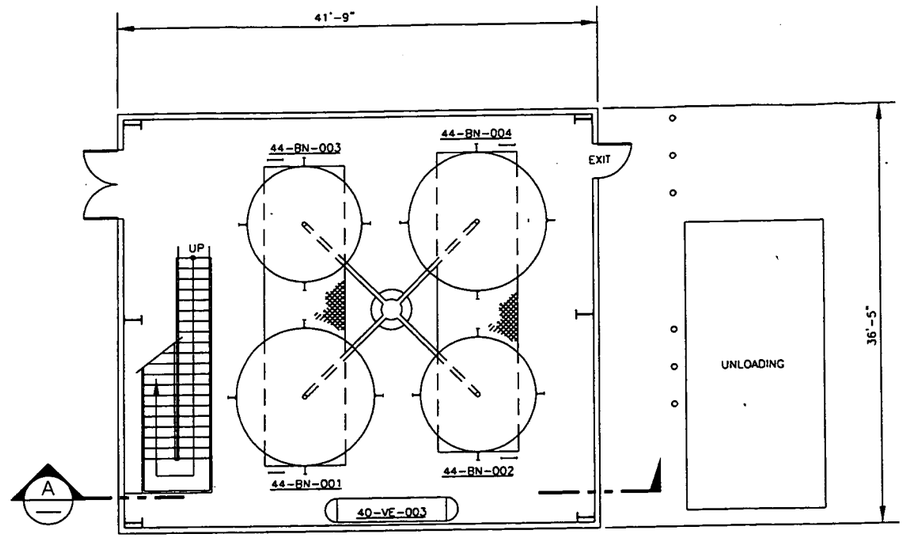

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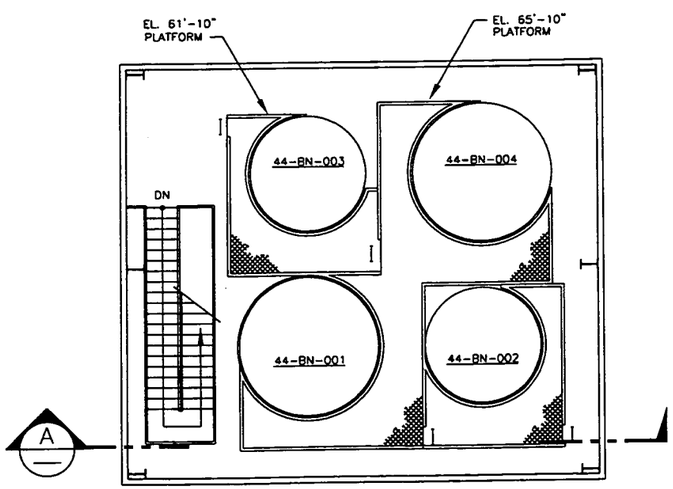
TO EL. 52'-0"



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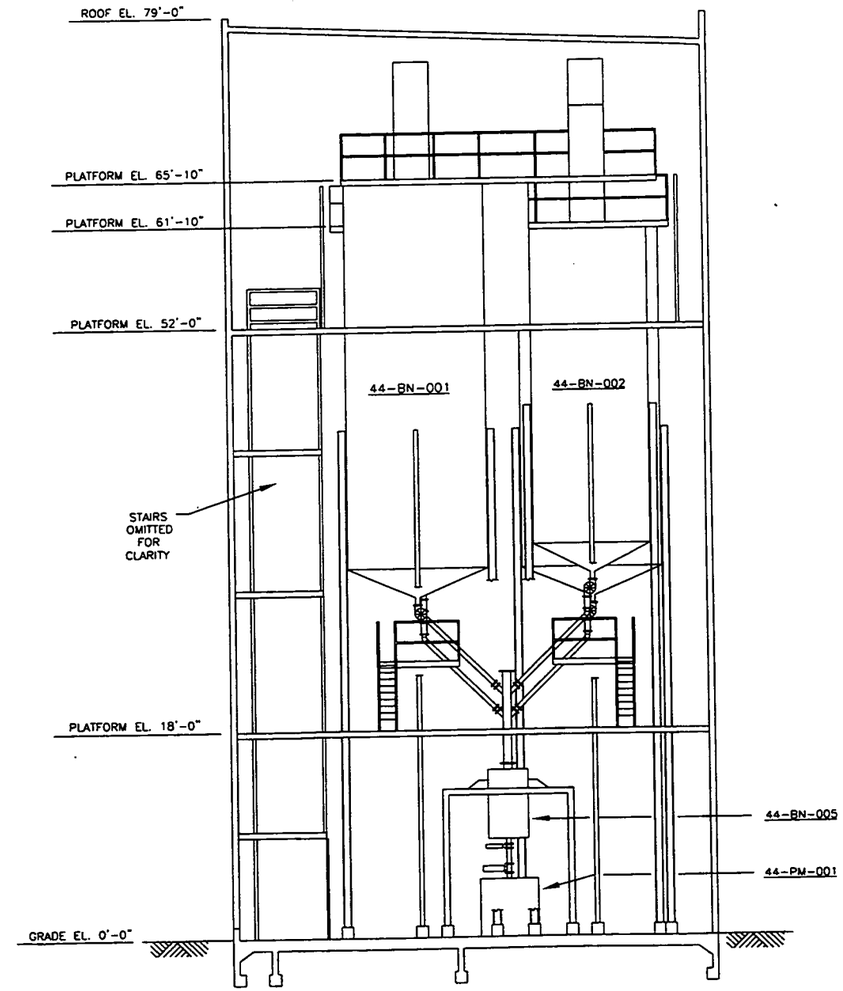

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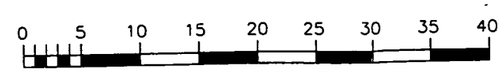

GRAPHIC SCALE
1/8" = 1'-0"

NOTES:

BUILDING CONSTRUCTION

- CONCRETE FLOOR SLAB AND FOUNDATIONS
- STEEL FRAME STRUCTURE
- INSULATED METAL SIDING
- MEMBRANE ROOFING SUPPORTED BY STEEL DECKING AND INSULATION BOARD

000612

PRELIMINARY DRAWING

CHPLE	SK-7428	CHECKER	ACAD R14

UNITED STATES
DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

THIS DRAWING PREPARED BY

FLUOR DANIEL FERNALD

SILOS PROJECT
CINCINNATI, OHIO

DRAWING TITLE

FACILITY LAYOUT
CHEMICAL STABILIZATION – CEMENT
CEMENT/ADDITIVE STORAGE BINS
REVISED FEASIBILITY STUDY FOR SILOS 1 & 2

DRAWN BY S. M. YANKEY	DATE 12/3/98	RECOMMEND. CHECKED BY / DATE	CHECKED BY J. THOMPSON / DATE 8/16/99
PLANT/BLDG. NO. OU4	FLOOR		SCALE 1/8"=1'-0" / CLASS
SUBMITTED FOR APPROVAL / DATE		APPROVAL RECOMMENDED / OPERATING CONTRACTOR / DATE	

DOE PROJECT NO.	OPER. CONTR. PROJ. NO.	DRAWING NO.	SHEET NO.	REV. NO.
40730	WBS2.1.3.G.P	94X-5500-P-SK-7428	1	2

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INITIALS: RWR
DATE: 12/1/99

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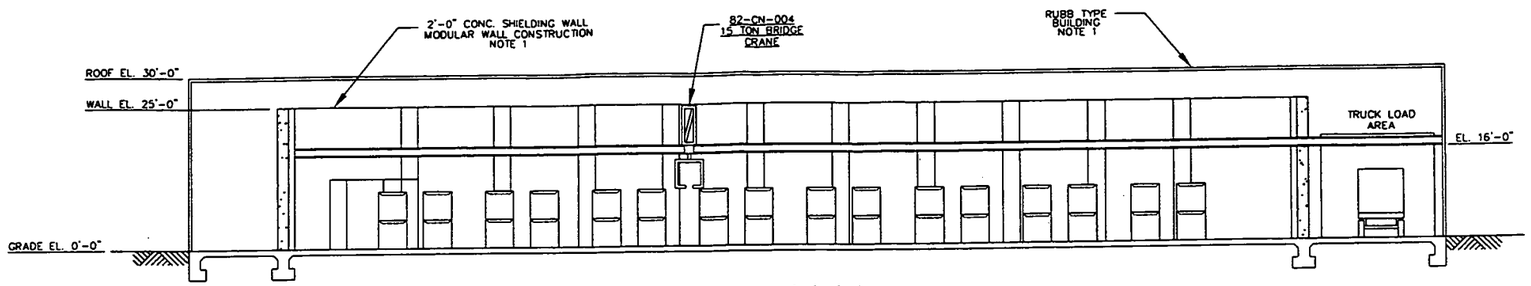
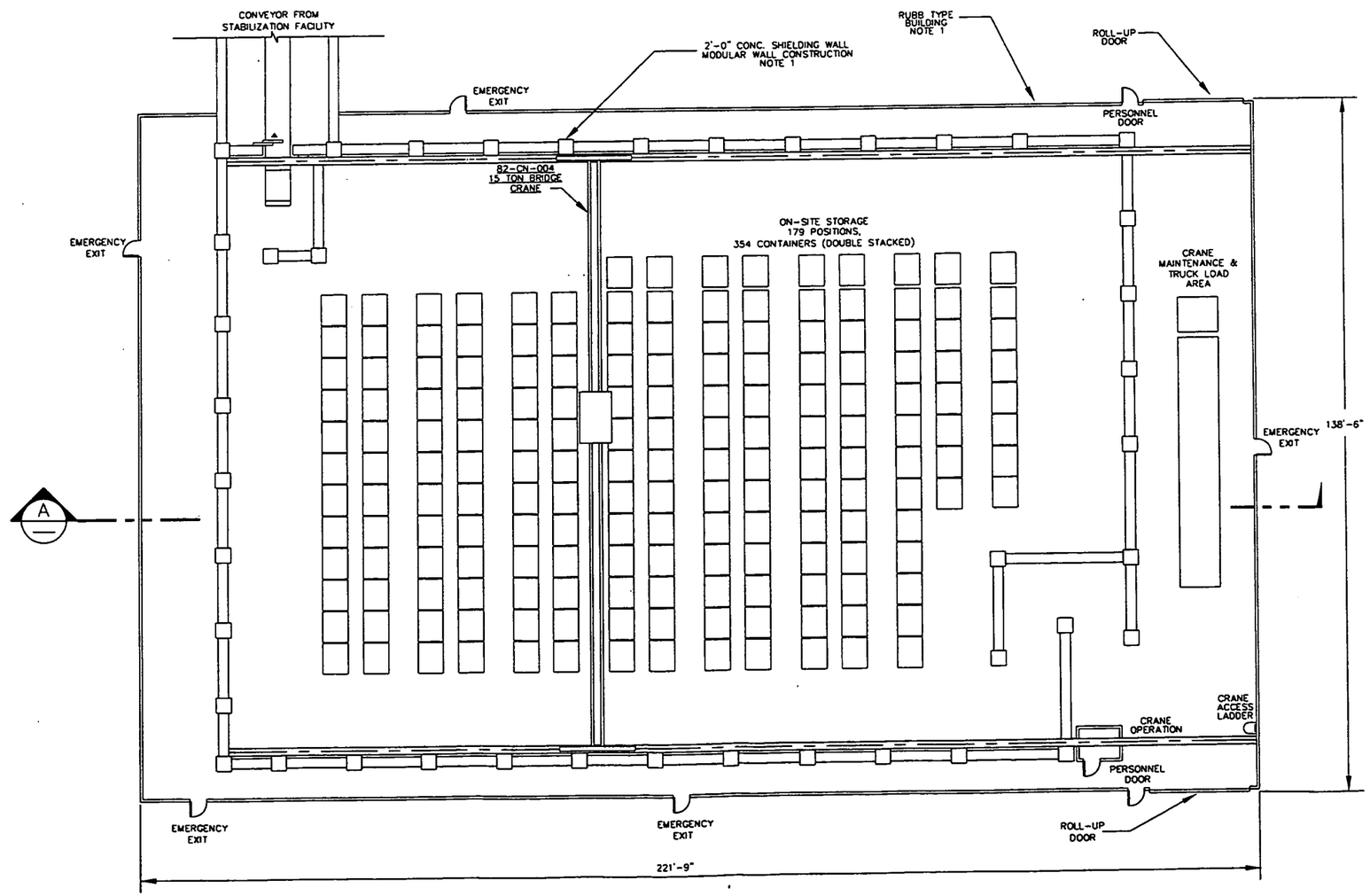


SECTION 'A'-'A'



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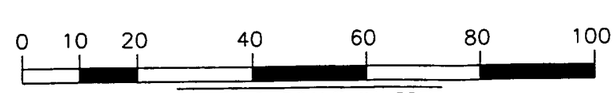

GRAPHIC SCALE IN FEET
3/64" = 1'-0"

NOTES:

1. BUILDING CONSTRUCTION
   - CONCRETE FLOOR SLAB AND FOUNDATIONS.
   - MODULAR WALL CONSTRUCTION CONSISTS OF INTERLOCKING PREFABRICATED SHEILDING WALLS AND COLUMNS.
   - RUBB TYPE BUILDING CONSISTS OF INSULATED MEMBRANE COVERING STEEL FRAMING.
2. SHIELD DOOR = ▲

000613

PRELIMINARY DRAWING

CHEPLE SK-7425		CHECKER ACAD R14	
UNITED STATES DEPARTMENT OF ENERGY FERNALD ENVIRONMENTAL MANAGEMENT PROJECT			
THIS DRAWING PREPARED BY FLUOR DANIEL FERNALD SILOS PROJECT CINCINNATI, OHIO			
DRAWING TITLE FACILITY LAYOUT CHEMICAL STABILIZATION - CEMENT INTERIM CONTAINER STAGING REVISED FEASIBILITY STUDY FOR SILOS 1 & 2			
DRAWN BY E. MOORE	DATE 12/1/99	DESIGNED, CHECKED BY / DATE	CHECKED BY J. THOMPSON / DATE 8/16/99
PLANT/BLDG. NO. OU4		FLOOR	SCALE 3/64" = 1'-0" / PLANE
SUBMITTED FOR APPROVAL / DATE		APPROVAL RECOMMENDED / CONTRACTOR / DATE	
DOE PROJECT NO. 40730	CNTR. CONTR. PROJ. NO. WBS2.1.3.G.P	DRAWING NO. 94X-5500-P-SK-7425	SHEET NO. 1 / REV. NO. 2

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Section G.7

G.7.0 CHEMICAL STABILIZATION — OTHER

G.7.1 Summary

The Chemical Stabilization — Other technology combines the Silos 1 and 2 material, cement, and dry chemical additives to remediate the constituents of concern. For this process, the Silos 1 and 2 material slurry and the stabilization reagents are combined using a disposable mixer within the container. The loaded container is used for shipment and disposal. A formula to optimize the waste loading and processibility using additives has been developed to meet the TCLP RCRA limits for the wasteform disposal.

G.7.1.1 Functional Analysis

A functional analysis has been performed for the Chemical Stabilization — Other technology. **Figure G.7.1-1** presents the individual functional requirements for the treatment facility. The first level functions are the high level functions to be accomplished by the treatment facility SSC. The subsequent levels in the functional analysis diagrams describe the means for accomplishing the high level functions are to be accomplished. **Table G.7.1-1** provides a brief description of the individual functional blocks shown in **Figure G.7.1-1.**

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Figure G.7.1-1
Chemical Stabilization - Other
Functional Analysis Diagram

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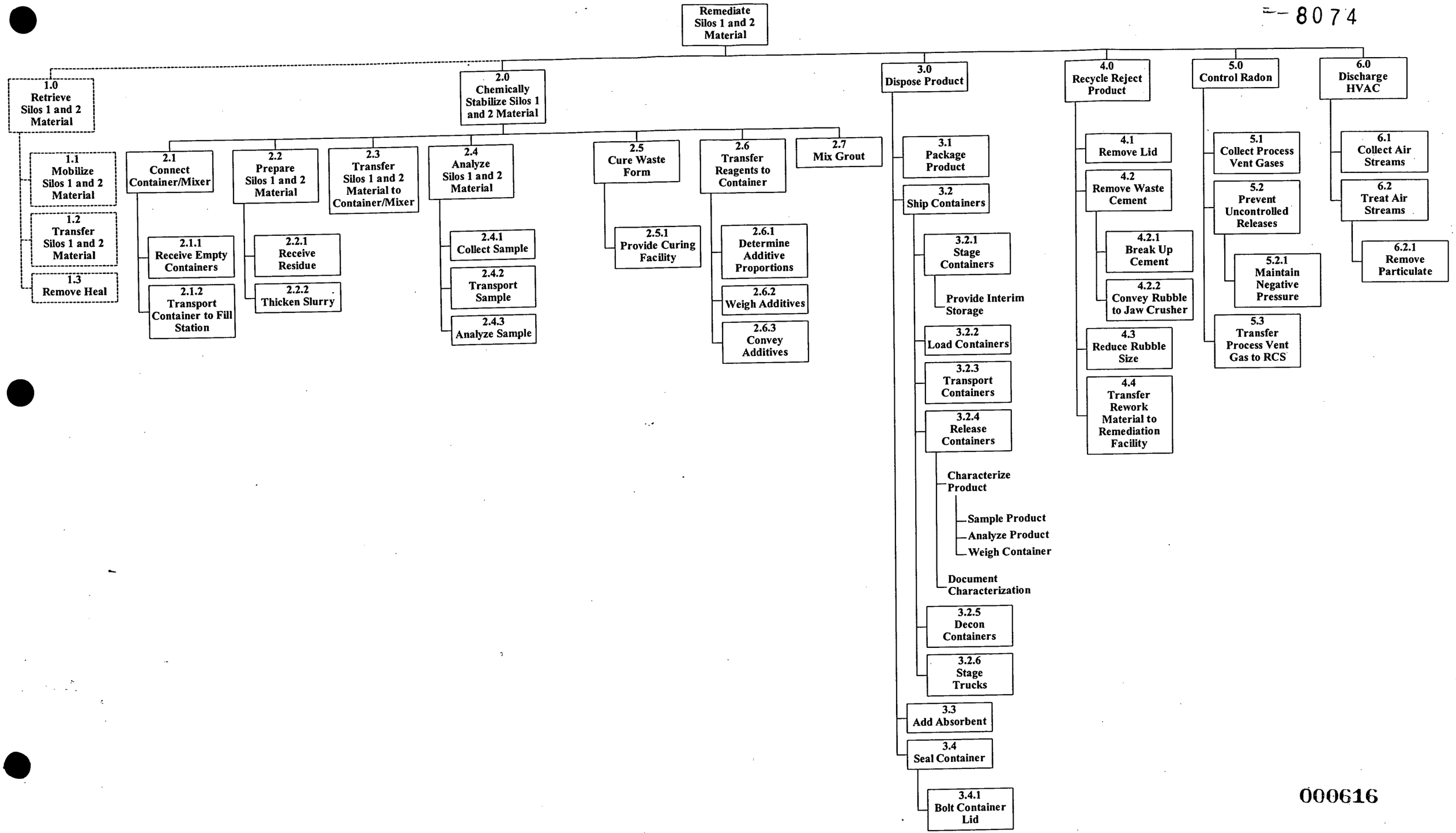

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Functional Analysis Table

The functional descriptions in this section provide general information of the functions illustrated in **Figure G.7.1-1.** The functional description includes an overview of a function and identifies significant activities that define the scope of the function.

TABLE G.7.1-1
FUNCTION BLOCK DESCRIPTIONS
CHEMICAL STABILIZATION — OTHER

Function ID	Function Title	Functional Description
Function	Remediate Silos 1 and 2 material	The 10 wt% slurry is thickened to 37 wt% solids, transferred to the disposal container/mixer, combined with grout forming additives, and mixed in the container/mixer to produce a product that can be disposed of safely. The process requires systems for venting vessel gases to the RCS and disposing of product.
1.0	Retrieve Silos 1 and 2 material	Existing TTA slurry transfer systems, structures and components (SSC's) to hydraulically remove the Silos 1 and 2 material the from TTA.
1.1	Mobilize Silos 1 and 2 material	The silos material is sluiced with water jets in order to form a slurry so that the material can be mobilized and removed by the slurry pumps.
1.2	Transfer Silos 1 and 2 material	The silos material slurry is hydraulically transferred from the TTA to the treatment facility. This function is defined by material removal from the TTA.

TABLE 7.1-1 (continued)

Function ID	Function Title	Functional Description
1.3	Remove Heel	Any remaining silos material in the TTA is removed to allow for the decontamination and disposal of the TTA storage tanks.
2.0	Chemically Stabilize Silos 1 and 2 material	The dewatered silos material and cement forming additives are blended in a disposable container/mixer. The treated silos material cures and is disposed at an off-site disposal facility.
2.1	Connect Container/Mixer	Facility operators remotely connect the fill head motor to the container/mixer shaft using a container indexing system to align the two components.
2.1.1	Receive Empty Container	The containers are received from the receipt and inspection facility. The facility has internal inventory space for 10 empty container/mixers.
2.1.2	Transport Container to Fill Station	The means and space to transport a container/mixer from the internal storage area to a conveyor and air lock system is provided to convey the container/mixers to the filling stations.
2.2	Prepare Silos 1 and 2 material	The SSCs receive the slurry between 10 wt% and 30 wt% (10 wt% solids is assumed) solids and dewater the slurry to 37 wt% solids using a clarifier.
2.2.1	Receive Silos 1 and 2 material	The silos material is received from the TTA at approximately 10 wt% solids and inventoried in a receiving tank.
2.2.2	Thicken Slurry	The 10 wt% slurry is thickened to approximately 37 wt% solids slurry in order to reduce the volume of water that is incorporated in the treated wasteform.
2.3	Transfer Silos 1 and 2 material to Container/Mixer	The 37 wt% solids slurry is discharged from the SBTs to the disposal container/mixer.

TABLE 7.1-1 (continued)

Function ID	Function Title	Functional Description
2.4	Analyze Silos 1 and 2 material	The silos material is sampled and the sample is analyzed after the slurry has been separated into a discrete batch in a SBT.
2.4.1	Collect Sample	Sampling ports are incorporated into the SBT design.
2.4.2	Transport Sample	The sample is transported from the treatment facility to the analytical laboratory using standard quality control methods.
2.4.3	Analyze Sample	The dewatered slurry is analyzed in order to determine the correct proportion of stabilization reagents to be added to the grout mixture to produce an acceptable wasteform.
2.5	Cure wasteform	The treatment formula is developed in order to produce a wasteform that cures to 50 psi compressive strength within 7 days in order to meet the NTS WAC.
2.5.1	Provide Curing Facility	The treatment facility is designed to accommodate seven days worth of container production. The treatment facility contains the necessary systems and components to allow treated Silos 1 and 2 material to cure in an environmentally controlled facility for seven days.
2.6	Transfer Reagents to Container/Mixer	Stabilization reagents are added to the container/mixer in order to treat the filter cake. The stabilization reagents produce a grout that passes the NTS WAC.
2.6.1	Determine Additive Proportions	The proportion of stabilization reagents is determined from the analysis of the waste slurry.
2.6.2	Weigh Additives	A hopper design that includes weigh elements feeds material to the dense phase pump. This provides an accurate weight of the additives being transferred to the treatment system.

TABLE 7.1-1 (continued)

Function ID	Function Title	Functional Description
2.6.3	Convey Additives	The bulk chemicals are transported to a batch bin in order to be weighed. The bulk chemicals are transferred from the batch bin to the container/mixer in the correct proportion. Weights of the bulk chemicals must be recorded.
2.7	Mix Grout	The container contents are required to undergo mixing for a minimum of 90 minutes to ensure grout constituents are thoroughly combined. The activities of the mix grout function incorporates the use of an in-container mixer.
3.0	Dispose Product	The treated Silos 1 and 2 material is disposed at the NTS.
3.1	Package Product	The treated waste is packaged in an IP2 or a DOT 7A Class A container.
3.2	Ship Containers	Containers, filled with treated Silos 1 and 2 material that meets the NTS WAC, are shipped by truck to the NTS.
3.2.1	Stage Cured Containers	Interim storage is provided to stage filled, cured containers while preparations for container shipment are being made. A facility is dedicated to inventory 360 filled, cured containers.
3.2.2	Load Containers	Containers are loaded onto the shipping truck with minimal amount of contact from personnel.
3.2.3	Transport Containers	Containers,are removed from the treatment facility's interim staging facility by an overhead crane and subsequently transported to the shipping truck.
3.2.4	Release Containers	Once proper documentation has been received by the waste management group, the container is released to the shipping department for transport of the containers to the NTS.
3.2.5	Decontaminate Containers	Disposal containers are decontaminated to acceptable limits before being shipped to the NTS.

TABLE 7.1-1 (continued)

Function ID	Function Title	Functional Description
3.2.6	Stage Trucks	Area is provided to stage enough trucks to support the production rate of filled and accepted disposal containers.
3.3	Add Absorbent	Addition of an absorbent mat to the disposal container is accomplished in an area separate from the filling station. The absorbent mat is added via remote handling equipment.
3.4	Seal Container	Containers are sealed before release to the waste management or shipping department. Gaskets are provided to ensure that the containers are sealed water tight and nearly air tight.
3.4.1	Bolt Container Lid	The facility operators use a remote bolting device to bolt the lid to the disposal container. A station is dedicated to the head bolting activities.
4.0	Recycle Reject Product	A separate facility is provided to handle operations associated with the rework activities of the reject grout containers. This system interfaces with the treatment system and the PVS.
4.1	Remove Lid	The container of reject grout is opened to access the treated material. Facility operators use a remote bolt removing device to remove the bolts from the container lid.
4.2	Remove Waste Cement	A facility is designated for the removal of reject material from the disposal containers. The SSCs associated with removing the reject material operate concurrently with normal operation activities.
4.2.1	Break up Cement	Equipment is provided to size reduce the cured material in the disposal containers. Equipment associated with size reducing the reject grout is remotely operated.
4.2.2	Convey Rubble to Jaw Crusher	A vacuum retrieval unit is employed to automatically convey the size reduced grout to the rubble jaw crusher.

TABLE 7.1-1 (continued)

Function ID	Function Title	Functional Description
4.3	Reduce Rubble Size	A means to remotely and automatically reduce the size of the grout is available to ensure that the rework final product is homogenous.
4.4	Transfer Rework Material to the Treatment Facility	A bucket conveyor system to transfer the crushed rework grout to the rework hopper is provided. This system interfaces with the PVS.
5.0	Control Radon	The treatment facility is designed to control radon discharge in accordance with applicable requirements including ALARA principles.
5.1	Collect Process Vent Gases	The treatment facility is designed to collect radon from any location or discharge point that contain significant radon concentrations.
5.2	Prevent Uncontrolled Releases	Uncontrolled releases of radon in the system are prevented by maintaining a negative pressure in the processing rooms and equipment throughout the treatment facility.
5.2.1	Maintain Negative Pressure	Negative pressure is maintained by keeping a slight vacuum on all processing rooms and equipment in the treatment facility. This function incorporates the use of the existing RCS blowers.
5.3	Transfer Process Vent Gas to RCS	The treatment facility design ensures that radon is collected for remediation by venting streams from different processing areas and equipment to the existing RCS.
6.0	Discharge HVAC	Gas streams that do not contain radon are discharged through the HVAC system.
6.1	Collect Air Streams	Room ventilation and other HVAC streams are collected and vented to the HVAC SSCs.
6.2	Treat Air Streams	The HVAC air streams are treated to meet the discharge requirements.
6.2.1	Remove Particulate	The HVAC air streams are filtered to remove any particulate present before discharging the air to the atmosphere.

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G.7.1.2 System Model

Figure G.7.1-2 presents a block flow diagram for the treatment of the Silos 1 and 2 material using the Chemical Stabilization — Other technology.

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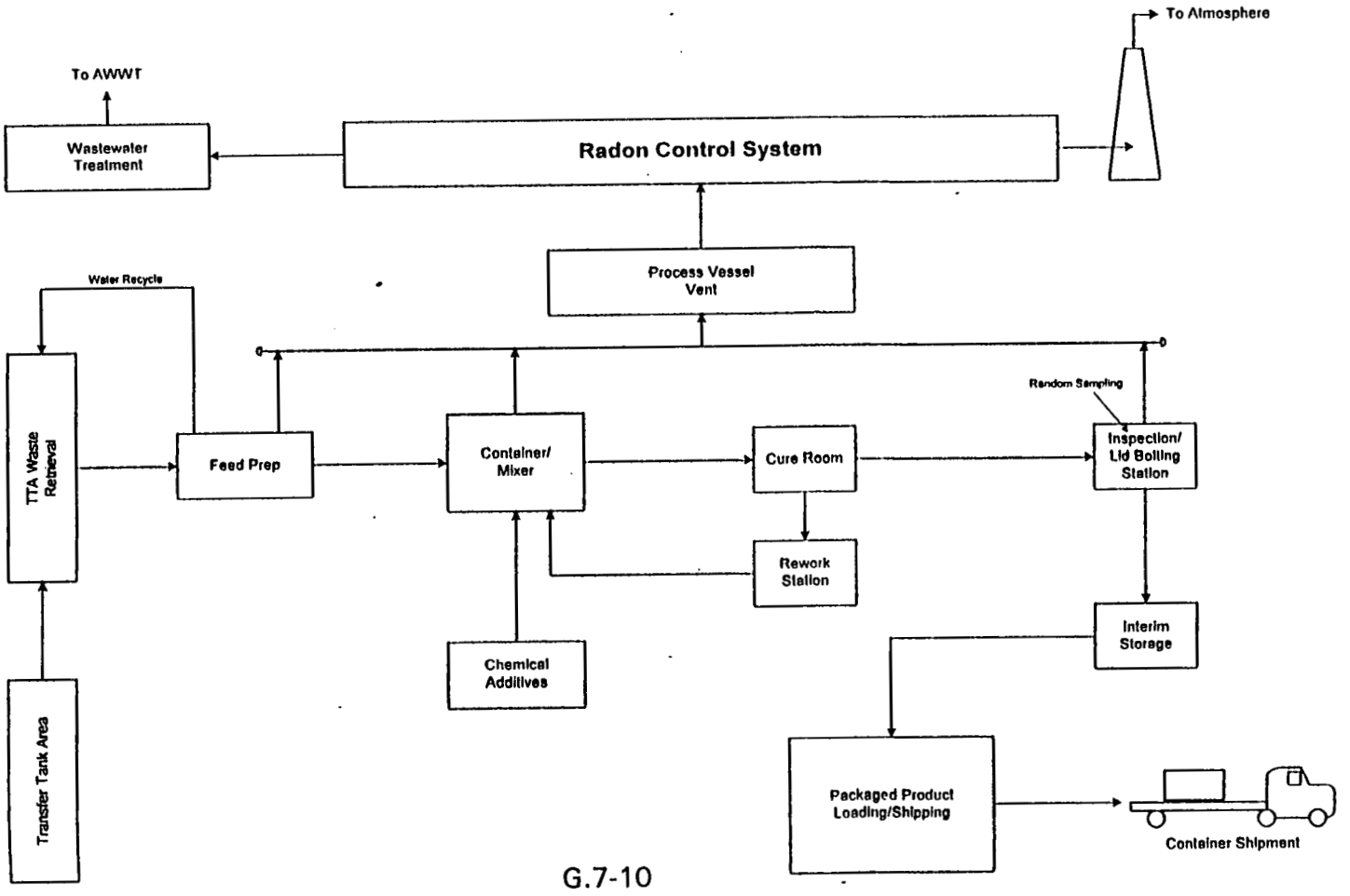
FIGURE G.7.1-2
SYSTEM BLOCK FLOW DIAGRAM
CHEMICAL STABILIZATION — OTHER



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G.7.1.3 Treatment Recipe

The grout formula for the Chemical Stabilization — Other treatment technology is based on 24% waste loading and has the following constituent make-up:

- 24 wt% cement;
- 10 wt% fly ash;
- 1 wt% tri-sodium phosphate (TSP);
- 24 wt% Silos 1 and 2 material (dry weight basis); and
- 41 wt% water.

G.7.1.4 Mass and Energy Balance Overview

A detailed mass and energy balance is provided in **Attachment G.7-I.**

The treatment facility is designed with three processing lines and produces a maximum of 105 tons/day (14.4 filled disposal containers) of treated Silos 1 and 2 material. The operating schedule is 24 hr/day, 5 days/week for 3 years. The Feed Preparation System receives slurry from the TTA between 10 wt% and 30 wt% solids intermittently, at approximately 5,900 lb/hr of solids. Feed to the clarifier is approximately 21,000 lbs/hr (40 gpm) of 10 wt% solids slurry. This produces an underflow from the clarifier to the SBTs at a rate of 5,500 lb/hr (9 gpm) of 37 wt% slurry and a supernatant overflow to the supernatant sump tank of approximately 15,000 lb/hr (30 gpm) of water. Cement and additives are transferred on a batch basis and consist of approximately 3,500 lb of cement per batch and 1,600 lb of additives per batch. Silos 1 and 2 material slurry is metered into the disposal container from a slurry recirculation line and totals approximately 9,500 lb per batch. Filled disposal containers of grout are transferred to the curing room where they cure for seven days before being transported to external storage. A container of grout is expected to have a maximum

temperature rise to approximately 160°F. All process equipment and vessels are maintained at a negative pressure by providing vacuum blowers to transport the vessel gases to the RCS. The total flow of the Process Vent System (PVS) is approximately 500 scfm.

G.7.1.5 Availability and Work Schedule

The design of the Chemical Stabilization — Other facility is based on a 3-year operating campaign at 70% availability of the plant and equipment. Normal processing operations are performed 24 hr/day, 5 days/week.

G.7.2 Feed Preparation (Systems 15, 16 and 44)

The Feed Preparation System is comprised of the waste slurry receiving tank, clarifier, supernatant sump tank, and all associated transfer equipment. System 16 includes the slurry batch tanks and associated transfer equipment. System 44 includes the cement and additives storage silos and all associated transfer equipment. PFDs, 94X-5500-F-SK-3067 and 94X-5500-F-SK-3377, describe the basic flow logic of the Feed Preparation System. PFDs are provided in Attachment G.7-V.

The use of in-line densitometers and flow meters monitor the solids content and flow rates of the slurry lines in the Feed Preparation System. However, percent solids content in slurry streams can only roughly be measured.

G.7.2.1 System Description

The Feed Preparation System is designed to receive slurry from the TTA intermittently at approximately 5,900 lb/hr (110 gpm) of solids. Because the minimum flow capacity of the waste retrieval system (120 gpm) exceeds the required throughput of the treatment process, and to ensure a uniform feed to the clarifier, a waste slurry receiving tank, 15-TK-001 (Receiving Tank), receives and inventories 12 hours worth of slurry (approximately 28,000 gal) transferred from the TTA. The receiving tank receives the slurry from the TTA at 10 wt% to 30 wt% solids (10 wt% solids is the basis for mass balance calculations) and continuously

agitates the contents in the tank to prevent the solids from settling to the bottom. Low level switches within the receiving tank alarm when the waste retrieval system operations need to be initiated to charge the receiving tank with another batch (12 hours worth) of slurry.

Transfer of the 10 wt% solids slurry from the receiving tank to the clarifier, 15-TK-002, is accomplished using 40 gpm progressive cavity pumps 15-PM-001 A&B (receiving tank transfer pumps). Slurry transfer to the clarifier is maintained 24 hr/day, 5 days/week with a continuous feed from the receiving tank to help prevent surges of material that may disturb the settled solids in the clarifier. Upon interruption of normal operations, the feed to the clarifier is suspended and the underflow stream is circulated back to the clarifier inlet until operations are restored.

Concurrent with feed transfers, a partially clarified supernatant spills over a weir inside the clarifier tank and gravity flows to the supernatant sump tank 15-TK-006. Most of the incoming suspended solids undergo gravity settling to form a dense phase layer in the bottom cone of the clarifier. The continuous slow rotation of the clarifier rake, 15-AG-002, pushes the settled solids (underflow) to the outlet at the base of the clarifier cone. The underflow stream has a solids concentration of approximately 37 wt% and is continuously pumped to one of the three SBTs with progressive cavity pumps 15-PM-002 A&B (clarifier underflow transfer pumps). Both the receipt tank transfer pumps and the clarifier underflow pumps are equipped with variable frequency drives to enable the operators to make any necessary flow rate adjustments to the process.

The concentrated underflow stream is transferred 24 hr/ day, 5 days/ week to one of the three SBTs (16-TK-001, 16-TK-002 or 16-TK-003) with 10 gpm progressive cavity pumps, 15-PM-002A&B (underflow transfer pump). Transfer of one working tank volume of slurry to a SBT takes approximately eight hours and has a total working capacity of approximately 4,000 gal of 37 wt% solids slurry. After the transfer of slurry from the clarifier to a SBT is complete, the underflow stream begins to fill the next SBT.

After an SBT has been filled, the contents are agitated for approximately one hour and subsequently sampled for percent solids concentration and elemental analysis. Once the solids content and elemental analysis are complete, the slurry in the SBT is agitated until it is necessary to use the SBT contents to feed the filling stations. Therefore, at any given time, one SBT is feeding the filling stations (82-ME-001, 82-ME-002 and 82-ME-003 on PFD's 94X-5500-F-SK-3068 and -3338), one SBT is in the process of being sampled and analyzed, and the third SBT is in the process of being filled and mixed.

In order to help maintain a thoroughly mixed slurry batch and supply the three filling stations concurrently, the slurry from the SBT is circulated in a loop at 60 gpm as shown on PFD's 94X-5500-F-SK-3067, 94X-5500-F-SK-3068, and 94X-5500-F-SK-3377. A discharge line taps off the recirculation line to provide slurry flow to its respective filling station fill head. The discharge line is controlled via a remotely operated discharge valve that directs flow from the recirculation line into the fillhead when it is opened. After a filling cycle is complete and the discharge line valve is closed, Silos 1 and 2 material slurry in the discharge line is blown into the fillhead with compressed air from a connection on the downstream side of the discharge valve.

The Cement and Additive System (System 44) is designed to receive and store the cement and additive materials and deliver the additives to the fill heads. Additive constituents proposed for use in the grout formulations are: Type II Portland Cement, Type F Flyash, and tri-sodium phosphate (TSP). Various combinations of these materials are evaluated based on the desired grout processing properties and performance criteria. All additives are handled with conventional bins and feeders.

PFD 94X-5500-F-SK-3377 depicts the flow logic of the cement and additives system. Cement and additives are delivered to the treatment facility by truck and pneumatically conveyed to the cement and additive storage bins 44-BN-001, -002, and -004. All storage bins are equipped with exhaust fans, bag filters and air pads, which fluidize the dry material. Once the amount of cement and additives required to stabilize a batch has been determined, the

necessary amount of cement (or additive) is conveyed , by a rotary star feeder and an air slide, to the batch weigh hopper 44-BN-005. After the correct amount of material has been weighed, the material is transferred from the batch weigh hopper to one of the cement/additive batch bins (44-BN-006, -008, or -009) by the cement/additive transfer pump (dense phase) 44-PM-001. The cement and additives are weighed and transferred to the cement/additive batch bin individually and sequentially. The weight of the individual constituents from the Cement and Additive System is verified before discharging the cement or additives to the fillhead.

G.7.2.2 Assumptions

Assumptions have been made for the Feed Preparation System to complete mass balance and design efforts. The primary assumptions used in the Feed Preparation System are outlined below, along with the basis for each assumption.

A. **Assumption:** Cement and additives material are delivered in trucks with self-contained pneumatic unloading conveyors.

Basis: Bulk delivery by truck and unloading provides the safest operation given the quantity of additives handled.

B. **Assumption:** Manual sampling and/or automatic sampling of dry additives is required and samples are analyzed at an on-site process control laboratory.

Basis: Raw materials are required to meet purchase specifications and blended materials must have been blended in the proper proportions to meet process specifications.

C. **Assumption:** The Feed Preparation System stores two weeks inventory of additives.

Basis: Enough storage is available so that shipments can be easily

scheduled such that plant operations are not threatened by short-term interruptions in delivery.

D. **Assumption:** The minimum average daily production rate is treatment of nine tons of Silos 1 and 2 material (dry basis) per day (365 process days per year).

Basis: This is the process rate required to stabilize the contents of the TTA in three years.

E. **Assumption:** The minimum flow rate to the receiving tank from the TTA is approximately 5,900 lb/hr (110 gpm) of solids at 10 wt% solids.

Basis: This is the projected operating regime of the Marconoflo™ pump that transfers slurry from the TTA to the Feed Preparation System.

F. **Assumption:** One fill station can produce one disposal container of treated grout in approximately five hours.

Basis: *Chem-Nuclear Systems POP Final Report* **(Appendix H, Attachment H4).**

G. **Assumption:** Grout density is approximately 2,400-3,000 lb/yd^3 (90 - 114 lb/ft^3).

Basis: Preliminary calculations based on the POP testing results **(Appendix H, Attachment H4).**

G.7.2.3 Key Equipment Descriptions

Receipt Tank

The waste slurry receiving tank, 15-TK-001, is a 27,000-gallon (working volume), 16 ft in diameter, 22 ft in height, carbon steel tank with a top mounted agitator, level alarms, and maximum liquid level capacity of 20 ft. The receipt tank is equipped with a top mounted agitator, 15-AG-001, to aid in the homogenization of the feed and to prevent the solids from settling to the bottom of the tank.

Clarifier

The clarifier, 15-TK-002, is a 9,600-gallon, carbon steel settling tank with a diameter of 14 ft and a straight wall height of 8 ft. The design of the clarifier incorporates a conical bottom to allow for the collection and discharge of the settled solids. The continuous slow rotation of the clarifier rake, 15-AG-002, keeps the dense phase mobile by pushing the settled solids to the outlet of the cone section of the clarifier.

Slurry Batch Tanks

The SBTs (15-TK-003, 004 and 005) are 4,000-gallon (working volume) carbon steel tanks, 8 ft in diameter and a 13 ft in wall height.

Cement and Additive Storage Silos

The cement and additive storage silos are industry standard, carbon steel silos that are designed to receive the cement and stabilization reagents from delivery trucks with on board pneumatic conveying equipment. Each silo is equipped with vibrators, internal aeration and air slides to prevent the material from bridging, and a rotary star feeder to transfer the material to the cement and additive weigh hopper.

The cement storage silo, 44-BN-001, is 4,500-ft^3, 12 ft in diameter, and 47 ft in height. The TSP storage silo, 44-BN-002, is 280-ft^3, 5 ft in diameter, and 20 ft in height. The flyash storage silo, 44-BN-004, is 2,000-ft^3, 10 ft in diameter, and 31 ft in height.

The cement and additive batch bins (44-BN-006, 44-BN-008 and 44-BN-009) are mounted above each of the filling stations and meter the respective additive to the container/mixer. The cement and additive batch bins are 60-ft^3 carbon steel bins, 3.5 ft in diameter and 8 ft in height

G.7.2.4 System Interfaces

The Feed Preparation System interfaces with the following SSC:

- Silos 1 and 2 material slurry that is pumped from the TTA storage facility with the Silos 1 and 2 material retrieval process at a rate of 5,900 lb/hr.
- The clarifier supernatant that is decanted and pumped to the Recycle Water System and the recycled water system that provides the treatment facility flush water.
- All feed preparation equipment, including tanks and hoods that are vented to the RCS.
- The Feed Preparation System that interfaces with the Treatment System.
- Bulk additive trucks that convey the additives to the storage bins.
- Compressed air that is used for bulk solids transfer, as well as, pneumatically operated valves, bin aerators, air slides, instrumentation and controls.
- Electrical power for instrumentation and motors.

000632

G.7.2.5 Recycle back to the TTA

The Recycle Water System is comprised of supernatant sump tank 15-TK-006 and the supernatant tank transfer pumps 15-TK-006A&B; it is represented on PFD 94X-5500-F-SK-3067. The overflow from the clarifier tank is gravity fed to the supernatant sump tank and then transferred back to the TTA recycle water tank using two 150 gpm centrifugal pumps. Since the water content of the Silos 1 and 2 material in the TTA is approximately 50 wt% and the water content of the slurry fed to the filling station is approximately 63 wt%, the treatment system is a net consumer of water. Therefore, additional water is introduced into the slurry retrieval system to maintain retrieval operations, and into the treatment process as necessary.

G.7.3 Treatment System (System 82)

The Chemical Stabilization — Other technology employs an in-container mixer, wherein the waste slurry and the stabilization additives are combined in a steel cylinder and are mixed with a disposable mixing blade. The treatment facility design incorporates the in-container mixing operations at three mixing station treatment lines that operate in parallel.

G.7.3.1 System Description

The mix and fill stations (82-ME-001, -002, -003) are presented on PFDs 94X-5500-F-SK-3068, -3338. The mix and fill station operations are remotely controlled by the operator. Transfer of the Silos 1 and 2 material slurry into the disposal container is controlled from the mixing operation control room using remotely operated valves located on the fill head. The fill amount is determined by weight-sensing elements, located on the container lift positioner at the container fill station, to sense the weight change of the container. The mixer rotation is controlled by an operator using the hydraulic motor remote controls and rotational speed element readout. Development of the slurry vortex is observed by the operator using the light source and CCTV instrumentation provided on the fill head. The addition of dry materials into the disposal container is also through the fill head. Transfer

control of the dry cement and chemical additives is provided by the motor driven, remotely controlled, rotary airlock between the cement/additive batch bins and the fill heads. Each stabilization chemical is added individually and sequentially and is mixed with the Silos 1 and 2 slurry before adding the next treatment reagent to the disposal container/mixer. Each fill station is positioned over secondary containment to prevent release of any spilled material.

G.7.3.2 Assumptions

A. **Assumption:** Plant operations are 24 hr/day, 5 days/week.

Basis: Project definition and meeting the 3-year processing window.

B. **Assumption:** Silos 1 and 2 material composition transferred to the disposal container/mixer is 37 wt% waste solids.

Basis: Calculations based on information provided by the POP testing **(Section G.3)**.

C. **Assumption:** Grout composition is approximately 24 wt% Silos 1 and 2 material solids, 41 wt% water, 35 wt% cement plus additives.

Basis: Calculations based on information provided by the POP testing **(Section G.3)**.

D. **Assumption:** Initial curing requires seven days in a temperature controlled environment. Cure temperature reaches a maximum of 160^0 F.

Basis: POP contractor's final report **(Appendix H, Attachment H4)**.

E. **Assumption:** Staging time required is 45 additional days (weather protected storage).

Basis: **Section G.2.**

000634

F. **Assumption:** Silos 1 and 2 material in the TTA storage is approximately 50 wt% solids.

Basis: **Section G.2.**

G.7.3.3 Key Equipment Descriptions

Disposal Container/Mixer

The disposal container/mixer, fillhead, and motor are described in **Section G.7.4.**

G.7.3.4 System Interfaces

The Treatment System interfaces with the following SSC:

- A discharge line that taps off the Silos 1 and 2 slurry recirculation line to provide slurry flow to its respective filling station fill head. After the slurry is discharged to the disposal container, the tap line is blown down with compressed air into the disposal container/mixer.
- Cement and chemical that additives are gravity transferred as dry materials from the cement/additive batch bins to the mixing station fill head units by remotely controlled rotary airlocks.
- The fill head that fits the container opening and introduces the feed constituents into the disposal container, and interfaces with the hydraulic power line.

Transfer lines provide dry chemical addition and slurry to the fill head from the cement/additive batch bins and the SBTs. The fill head also has connections to the PVS header, hydraulic supply and return lines (between the controller and the hydraulic motor), and a CCTV and light source.

G.7.4 Product Handling

Empty disposal containers are handled using forklifts and motorized roller conveyors. Filled disposal container/mixers 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 container/mixers 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 container/mixers.

G.7.4.1 System Description

An empty, disposal container/mixer is placed by a propane powered forklift with a rated capacity of six tons onto the load-in conveyor in the airlock. The container head is removed by the head installation monorail hoist grapple and stored in the load-in conveyor airlock.

The disposal container/mixer is conveyed and aligned with one of the three mix and fill heads. A lifting actuator raises the container/mixer above the conveyor rollers and seals it to the fill and mix head. The fill and mix head is clamped onto the disposal container/mixer. The process vent valve opens as treated Silos 1 and 2 material and chemical additives are transferred to the disposal container/mixer.

When the disposal container/mixer is full, the contents of the disposal container/mixer are mixed by the internal mixer blades in the disposal container/mixer. When the mixer has been operated for the required time, the head clamps are disengaged and the PVV is shut off. In order to ventilate the disposal container/mixer's freeboard space, a sweep hood is positioned to capture radon. The radon is exhausted to the RCS through the Process Hood Ventilation

000636

System. The sweep hood vent valve is opened before the disposal container/mixer is lowered from the fill and mix head to the stand-by position.

The disposal container/mixer is conveyed to the sampling location, then sampled by means of a remote system for testing concrete properties and for archiving. The sweep hood vent valve is closed during sampling. After sampling, the filled disposal container/mixer is conveyed to the head installation station.

Lidding Station

The previously removed disposal container/mixer lid and absorbent mat are manually connected to the lid installation monorail hoist grapple. The hoist conveys both the disposal container/mixer lid and the absorbent mat to the lid station. When the filled disposal container/mixer is positioned at the head installation station, the absorbent mat is aligned with the disposal container opening and released onto the surface of the chemically stabilized waste by means of remote operation and CCTV viewing. Next, the hoist is indexed to align the lid with the disposal container/mixer opening and the lid is placed onto the disposal container/mixer, but not bolted.

Wash Station

The conveyor moves the container/mixer inside the wash station, the doors are closed, and spray nozzles (approximately 30-40 psi) thoroughly wash and rinse the exterior of the container/mixer. When the container/mixer has adequately drip dried, the doors open and the container/mixer is conveyed into the curing room.

Curing Room Operations

The washed disposal container/mixer is lifted by a remotely operated overhead crane and placed in a designated storage location for a seven calendar day curing period.

Inspection and Staging Operations

Upon completion of initial curing, the container/mixer is retrieved from the curing room by the remotely operated overhead crane, placed onto a conveyor, and conveyed to the inspection station. The disposal container/mixer is aligned with the lid lifting equipment. In order to ventilate the disposal container/mixer's freeboard space, a sweep hood is positioned to capture radon venting to the room when the disposal container/mixer lid is removed. The radon is exhausted to the RCS by way of the Process Hood Ventilation System. The lid is grappled and removed from the field of view by the lid lifting equipment. The operator observes and inspects the interior of the disposal container/mixer by a CCTV camera and monitor and through the shielded viewing windows. After completing the inspection, the disposal container/mixer lid is reinstalled.

Lid Fastening Station

The disposal container/mixer is conveyed into the lid fastening station, and aligned with the lid fastening equipment. The remote wrench lowers and tightens all of the bolts until they are fully engaged with the disposal container/mixer.

Survey and Decontamination Station

The disposal container/mixer is conveyed to the survey and decontamination room, where its exterior surface is surveyed and decontaminated, as necessary, to meet surface radioactivity limits.

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.* 40710-RP-0001. Prepared under contract for the U.S. Department of Energy: Fernald Field Office, Fernald, OH. (PROD Index No. 4-400.2)

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.

Mix and Fill Head

The mix and fill head consists of custom designed equipment for filling disposal container/mixers with chemical additives and treated Silos 1 and 2 material, and mixing the contents using a hydraulic motor. It provides confinement of the Silos 1 and 2 material during the addition of constituents and mixing operations, and it prevents Silos 1 and 2 material from being deposited outside of the disposal container/mixer. The mix and fill head has connections to the PVS, slurry fill line, dry additives line, the operator CCTV monitoring equipment, and the mixer drive connector. There is an access area above each fill head to facilitate maintenance of these systems and equipment. The PVS maintains a negative pressure within the disposal container/mixer as filling and mixing operations are performed. The hydraulically driven motor is mounted on the fill head. A drip catch tray is also provided to prevent dripping to the floor when a disposal container/mixer is not located underneath the fill head. The tray automatically moves in and out of catch position when the disposal container/mixer raises to or lowers from the fill head.

Curing Room Bridge Crane

This crane is a remotely operated bridge crane with a rated capacity of 15 tons, a span of 80 ft, a travel of 128 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.

Inspection Station

The inspection station consists of custom designed equipment for remotely observing and inspecting inside the metal disposal container/mixer. The inspection station has a grapple for capturing and lifting the lid from the disposal container/mixer. The grapple uses rigid mechanical linkages for accurate and efficient operations. It positions the lid such that CCTV

viewing is possible. It replaces the lid onto the disposal container/mixer when inspections have been completed.

Lid Fastening Station

The lid fastening station consists of a remotely operated wrench mounted on a frame that aligns with the bolt pattern of the disposal container/mixer. The operator views the lidding operation either by CCTV or through the shielded glass viewing windows. The wrench is actuated up and down and may be lowered to engage the bolt heads and tighten or loosen them as required.

Sample Station

The sample station provides the capability to sample the grout from the disposal container/mixer, package it in an acceptable storage container, and allow it to cure in a controlled environment where it is conveniently retrievable. Sampling is a remote operation performed in the fill room. A sample collector is attached to an actuator that has vertical positioning and travels on a ceiling mounted track in a horizontal motion. The track mounted trolley aligns the actuator with the disposal container/mixer and the sample is taken. The trolley takes the sample to the glove station where an operator cleans up the sample and puts it into a storage container with a bar code identifier. The sample is placed onto the actuator and the trolley takes it to the sample storage rack where it is deposited. The storage provides heated storage for acceptable curing conditions. The system retrieves the requested sample according to the operator's instructions.

Sweep Hood

The sweep hood is a ventilation device connected to the PVS for the purpose of radon capture. It is specifically designed to capture radon that could escape from open filled disposal container/mixers, using the available flow rate of 500 scfm or less. Sweep hoods are featured at the mix and fill station, rework station, and at the inspection station.

Wash Station

The wash station is a standard industrial, automated, 80-inch turntable part washer with a rated capacity of 21,000 lb. The booth has a pass through conveyor with hatch doors on both ends. The conveyor rollers have sealed bearings. Spray nozzles are located to provide coverage to the outside of the disposal container/mixer. The station is self-contained with controls, pumps, tanks, and filters to wash rinse and dry as needed. Wash water is treated (as necessary) and recycled to the extent practical.

G.7.4.4 System Interfaces

The Product Handling Systems interface with the following SSC:

- Electrical power for motors, instrumentation and monitors;
- The Feed Preparation System;
- The Cement and Additive System;
- The Rework System that connects to fill and mix station 82-ME-003;
- Shielded and unshielded air lock doors and window systems that are employed to protect workers and segregate work stations;
- CCTV cameras and monitors that ensure positive control of disposal container/mixer operations;
- A forklift that transports and places empty disposal container/mixers onto the load-in conveyor;
- The Treatment facility domestic water supply for the wash station; and
- The PVS Header System for sweep hoods, maximum of 500 scfm.

G.7.5 Gaseous Emission Control

The Chemical Stabilization — Other treatment process does not generate an off-gas stream. All secondary gaseous wastestreams are vented from process vessels, rooms, and equipment. Therefore, the only component of the Gaseous Emissions Control System is the PVS, which is designed to capture all process vessel, room and equipment gases containing radon and transport them to the existing RCS. Detectors and monitors within the facility provide real-time alarm if radon escapes from any of the process vessels, rooms, or equipment.

G.7.5.1 System Description

Process Exhaust

Process vessels and equipment containing unstabilized Silos 1 and 2 material are vented to the PVS header.

Room Exhaust

Open containers, vessels, and room/cells that contain Silos 1 and 2 material are vented to the PVS by direct ventilation of room air or by the use of a sweep hood. Rework operations are performed in a total work enclosure. The enclosure is connected to the facility HVAC System. Detectors and monitors provide real-time alarm of radon present in the rework enclosure. In the event that radon leakage is detected, additional reject disposal containers are routed to the enclosure to limit the radon source. The interim container staging facility is normally ventilated and provided with radon detectors, alarms, and data loggers to detect, alarm, and log the presence of radon.

Process Vent

A PVS header is run throughout the treatment facility to capture and transport any radon contaminated air streams from all the process equipment, vessels and rooms. The PVS is designed to maintain a negative pressure in all vessels and equipment where the containment

of airborne contaminants, including radon, is a concern. The PVS maintains an airflow of 500 scfm with the vacuum provided by the RCS blowers. All vessels are maintained at approximately -2 inches water column relative to room pressures to ensure that the vessel gases do not leak to the environment, thus confining airborne contamination within the boundaries of the ventilation system.

The station performing container lid removal for inspection is equipped with a sweep air hood to capture the vented gas. Since the gas may contain a significant concentration of radon, it is discharged to the PVS and subsequently to the RCS.

The product packaging and staging areas are normally ventilated and provided with radon detectors and alarms to detect the presence of elevated levels of radon.

The 500 scfm gaseous emissions stream associated with the PVS is directly routed to the existing RCS without any pretreatment.

G.7.5.2 Assumptions

There are no driving assumptions associated with the Gaseous Emissions Control Systems.

G.7.5.3 Key Equipment Descriptions

The Gaseous Emissions Control System uses a vent line and header system to collect and transport the PVS gases to the existing RCS. There are no key equipment components associated with the PVS. The motive force to transport the PVS stream is provided by the RCS blowers.

G.7.5.4 System Interfaces

Process Vent System

The fill head unit is connected to the process vent header to control off-gas, dust, and radon. Area ventilation is provided. The disposal containers are sealed following the seven day curing period.

The rework batch bin is connected to the PVS header to collect and convey the vent gas and radon to the RCS for treatment and discharge.

G.7.6 Secondary Liquid Waste Treatment

The Silos 1 and 2 material in the TTA is assumed to have a moisture content of approximately 50% water. The slurry is introduced into the disposal container/mixers at approximately 63% moisture. Therefore, the treatment process is a net user of water and does not produce a secondary liquid wastestream. The water added to the system to transfer the slurry from the TTA to the Treatment System is recycled back to the TTA and used to maintain slurry retrieval operations. Towards the end of the treatment campaign, the water in the TTA Recycle Water System is processed without recycling any of the water to the TTA by treating a lower solids content slurry.

G.7.6.1 System Description

The Chemical Stabilization — Other treatment process is a net user of water and does not produce a secondary liquid wastestream.

G.7.6.2 Assumptions

There are no driving assumptions associated with the Secondary Liquid Waste Treatment System.

G.7.6.3 Key Equipment Descriptions

Since the design does not include a Secondary Liquid Waste System, there are no key equipment units to describe.

G.7.6.4 System Interfaces

Since the design does not include a Secondary Liquid Waste System, there are no system interfaces.

G.7.6.5 Recycle

The clarifier overflow to the supernatant sump tank is transferred back to the TTA Recycle Water System and is used for subsequent slurry retrieval from the TTA and transfer to the treatment facility.

G.7.6.6 Discharge to AWWT

Since there is no secondary liquid waste produced from the Chemical Stabilization — Other treatment process, there is no discharge to the AWWT.

G.7.7 Secondary Solid Waste Treatment

Secondary solid wastestreams are treated and disposed appropriately. Reference **Section G.2.13.2** for a general description of secondary solid waste treatment. A list of potential solid wastestreams is provided:

- PPE;
- HEPA and prefilters;
- D&D waste;
- Debris; and

- Empty rework containers.

G.7.8 Container/Mixer Operations

The filled disposal container/mixers are stored in the interim staging facility before off-site shipment to an approved disposal site. The lifting and placement of disposal container/mixers is performed remotely. However, personnel contact with the disposal container/mixers is necessary to secure and prepare the shipment in accordance with FEMP procedures before departure from the FEMP. Activities that require contact may include tie-down of the container to the truck and placement of the chocks onto the bed of the truck.

G.7.8.1 System Description

A disposal container/mixer is grappled in the interim staging facility by a remotely operated bridge crane, lifted over a shield wall, and placed onto an open transport (i.e., flatbed truck) in the loading/shipping operations area. The external surfaces of the disposal container/mixers are anticipated to be essentially free of loose surface radioactivity. The disposal container/mixer is secured and prepared for off-site shipment. Documentation is provided to the shipper who transports them to an approved disposal site.

Note: The generation and buildup of radon is not anticipated to be a concern in interim staging facility, since the disposal container/mixers are sealed before staging; therefore, the facility does not require special ventilation.

G.7.8.2 Assumptions

A. **Assumption:** The disposal container/mixer is fabricated from carbon steel with an internal coating to prevent corrosion from the treated material. The disposal container/mixer dimensions are approximately 76 inches in diameter by 73 inches in height (including forklift runners). The weight of the disposal container/mixer is

approximately 6,363 lb (including absorbent pad and internal components).

Basis: *CNS POP Final Report* **(Appendix H, Attachment H4).**

B. **Assumption:** Two disposal container/mixers per shipment.

Basis: Standard FEMP shipping practice for a two-axle truck (limited to 42,000 lb).

G.7.8.3 Key Equipment Descriptions

Staging Facility Remote Bridge Crane

The 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 grappling device and CCTV to ensure positive grappling, movement, and placement of the container/mixers.

G.7.8.4 System Interfaces

The disposal container/mixer operations interfaces with the following SSC:

- Electrical power for motors, instrumentation and CCTV support equipment;
- The Full-scale Treatment Facility transfer conveyor;
- The CCTV Inspection System; and
- The FEMP waste management shipping organization.

G.7.9 Product Rework (System 26)

In addition to the federal, state and local shipping requirements, the chemically stabilized Silos 1 and 2 material must meet the NTS WAC. Therefore, provisions are made to re-process any rejected chemically stabilized Silos 1 and 2 material. Rework of the rejected treated Silos 1 and 2 material consists of removing the material from the container/mixer and reintroducing it into the waste processing system.

G.7.9.1 System Description

The Rework System is presented on PFD 94X-5500-F-SK-3340, and MFD 94X-5500-M-SK-6023. The main components of the Rework System include: a Rework Bridge Crane (26-CN-001), a remotely controlled jack hammer (26-ME-004), a rubble collection hopper (26-BN-001), a rubble jaw crusher (26-ME-007), and a rework batch bin (26-BN-002). Rework operations are carefully confined and performed remotely at the rework station. The breaking, crushing, and conveyance components are remotely controlled by operators in the adjacent corridor. After the chemically stabilized Silos 1 and 2 material is size reduced, the rubble is reintroduced into the processing system.

The lid removal, placement, and fastening stations used for normal disposal container/mixer tasks are used for reworking the rejected disposal container/mixers. A sweep hood is used for rework operations for radon release. Captured radon is diverted to the RCS by the process hood ventilation system.

The reject disposal container/mixer is retrieved by the remotely operated overhead bridge crane in the curing room or from the interim staging facility and conveyed to the rework station. If the disposal container/mixer is retrieved from the interim staging facility, it is conveyed to the lid fastening station, where it is aligned with the remote wrench and the lid bolts are disengaged. Next (or the first step if the disposal container/mixer is retrieved from the curing room), the disposal container/mixer is conveyed to the inspection room where the disposal container/mixer is aligned with the lid placement equipment and the lid is removed by the

remote grapple. Before the lid is removed, the sweep hood is activated to sweep the area surrounding the disposal container/mixer opening, removing the accumulated radon in the disposal container/mixer as the lid is raised. The remote grapple holds the disposal container/mixer lid while the rework operations are performed.

The opened disposal container/mixer is conveyed into the rework room. This operation can be viewed by operators by CCTV and through shielded viewing windows. The radon off-gas from the disposal container/mixer is collected by the rework room sweep hood during rework operations. The remotely controlled impact hammer, attached to an extendable boom with interchangeable end effectors, is used to fracture the reject chemically stabilized Silos 1 and 2 material in the disposal container/mixer. This operation size reduces the chemically stabilized Silos 1 and 2 material into pieces small enough to be vacuumed. A HEPA filtered vacuum unit provides the motive force for the vacuum hose. The vacuum hose is remotely positioned by a robotic arm to remove the rubble from the disposal container/mixer. The rubble vacuumed from the disposal container/mixer is collected in the rubble collection hopper and gravity fed into the remotely operated rubble jaw crusher. The jaw crusher further reduces the rubble to pieces less than 0.5 inch. Sized aggregate is transferred to the rework batch bin using the rubble bucket conveyor. The sized aggregate is reintroduced into a new disposal container/mixer aligned with mix and fill head 82-ME-003.

The empty reworked disposal container/mixer is conveyed to the inspection station where the lid is replaced. The lidded disposal container/mixer is conveyed to the lid fastening station. The remotely operated wrench is used to tighten the lid bolts. The disposal container/mixer is conveyed to the survey and decontamination station where the disposal container/mixer exterior surface is surveyed and decontaminated, as necessary, to meet surface radioactivity limits. The used disposal container/mixers are moved to the FEMP waste management group for disposition as a secondary waste.

G.7.9.2 Assumptions

The number of disposal container/mixers of chemically stabilized Silos 1 and 2 material that will fail the TCLP criteria of the NTS WAC is assumed to be approximately 1% of the disposal containers (up to 60 containers). The rework operation results in approximately 120 additional disposal containers of treated Silos 1 and 2 material at a reduced waste loading (180 rework containers to replace 60 original rejected remediated disposal containers).

G.7.9.3 Key Equipment Descriptions

Roller Conveyor

The rework roller conveyors are 7- ft wide by 18- ft long, heavy duty, motorized, chain driven, two-directional, roller conveyors with rated capacities of 21,000 lb. Standard fabrication materials are used; however, the conveyors are a special order due to size and load capacity required. In addition, the rework conveyor is provided with special features for lifting the container/mixers above the rollers, using a hydraulic system.

Bucket Conveyor

The bucket conveyor is a sealed unit with a rated capacity of 2 tons and a vertical lift of 30 ft. It is connected to the PVV system for the confinement of radon.

Rework Vacuum

The rework vacuum is a production model with a 6-inch diameter hose, HEPA filtered discharge, and rated capacity of 30 tons/hr. The system includes a cyclone bin to collect captured debris. The cyclone bin is the source of feed material to the rubble collection hopper. In order to confine radon that may be present in the air stream to the vacuum, the system must release its discharge air to the rework room. The rework room sweep hood maintains the rework room at a negative pressure, directing an exhaust stream to the PVS.

Rubble Collection Hopper

The rubble collection hopper is a 64-ft^3 hopper with level alarms, vibrators, and air pads in the cone section; it has an RCS vent connection and is mounted on load cells for weight determinations.

Rework Batch Bin

The rework batch bin is a 100-ft^3 bin with level alarms, vibrators, and cone air pads; it has an RCS connection and is mounted on loads cells for weight determination.

Remotely Controlled Impact Hammer

The remotely controlled impact hammer is a production model with a 10-ft reach and 400 ft-lb per impact. It is mounted on tank tracks with a maneuverable boom and is electrically powered. It has changeable end effectors and can accomplish drilling, crushing, and impacting with available accessories.

Rubble Jaw Crusher

The rubble jaw crusher is a production model with a feed opening of 8 inch by 10 inch; it is and capable of reducing material to less than 0.5 inch.

Rework Bridge Crane

The rework bridge crane is a remotely operated bridge crane with a rated capacity of 5 tons, a span of 15 ft, a travel of 12 ft, and a lift height of 12 ft. The crane is equipped with a robotic arm and a 2-ton hoist for miscellaneous lifting operations. The robotic arm is used to handle the vacuum hose, perform clean up of the rework room, and provide a versatility for performing many tasks, as the true nature of the rework operations is largely unknown.

Sweep Hood

The sweep hood is a ventilation device connected to the PVS for the purpose of preventing the release of radon gas that has built up in the disposal container/mixer lid space. It is specifically designed to capture radon that could escape when the lid is removed from the disposal container/mixer in the rework room or the inspection station. The sweep hood uses the available flow rate of 500 scfm or less.

G.7.9.4 System Interfaces

The Product Rework System interfaces with the following SSC:

- The Product Handling Conveyor System that conveys the rejected cylindrical metal disposal container/mixers to the various stations before entering the rework room.
- The rework batch bin and sweep hood that is connected to the process vent header to collect the off-gas radon to the RCS for treatment and discharge.
- Compressed air, electrical power, and a hydraulic power source utility that are required for the rework operations.
- Power and signal connections between the process control room, local control stations, and process stations that are required for instrumentation, CCTV, lighting, and equipment control. Signal connection that is required to the Data Logging System.
- The Rework System that provides aggregate to fill and mix station 82-ME-003 for reprocessing.

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F-8074

G.7.10 Facility Design

Bulk Additives

The bulk additive building provides for receiving, storage, and transfer of bulk chemicals and cement to the Feed Preparation System. The design uses three storage bins and a pneumatic system to support production requirements for cement production.

The building structure is a commercial grade, sheet metal building. The height of the building is based upon the storage bin requirements to support production. Stairs and platforms provide access to the storage bins and filter assemblies. Within the building, limited space is provided for maintenance requirements. The building has a large double door to allow for access.

An unloading pad is provided next to the facility for bulk truck deliveries and to contain accidental spills. Large quantities of additives are received by truck and are pneumatically transferred into the appropriate storage bins. Additives from the bins are pneumatically transferred to the Feed Preparation System.

The bulk additive building and the surrounding area is a non-radiological area. Access is not controlled.

Feed Preparation System

The Feed Preparation System receives the slurried Silos 1 and 2 material from the TTA. Water is separated from the Silos 1 and 2 material and recycled to the TTA. In a series of tanks, the feed is dewatered and prepared to be pumped to the disposal containers. The area contains the process tanks, pumps, and equipment to perform the receipt, settling, and pumping required to support the process.

All equipment is in a radiologically controlled area due to the Silos 1 and 2 material's high inventory level of radium and radium daughter products. The area around the tanks is assumed

to be a RAZ 5, high radiation area from preliminary dose calculations. Because of this, the work area requires shielding, less time spent within those areas, and, where possible, lower quantities of K-65 material in the process to ensure lower dose rates for operations and maintenance workers over the plant life. The tanks containing the material are segregated and shielded in keeping with the ALARA principles of minimizing worker dose rates. They are surrounded by 2-ft thick shield walls due to the radiation field presented by the volume of Silos 1 and 2 material. The shield walls are modular in construction. The shield walls and concrete floor also perform duty as secondary containment in case of a spill or leakage from the tanks. The primary containment consists of the tank vessels themselves.

Although surrounded by concrete walls, the Feed Preparation System still requires access for general maintenance of the mechanical equipment. Access to each tank at grade is through a labyrinth. A sump is located in the area to provide for accidental leaks and spillage. The top of each tank is accessible by ladder and platform. The platform on top of the tanks allows for maintenance to be performed on the agitators, control valves, and piping components.

The pumps for the tanks are located outside of the shield wall due to general service and maintenance requirements. The pumps are located behind half or "partial height" walls to control access, minimize casual dose rates, and contain leaks and spills. The supporting systems like the recycle water tank and pumps are segregated by a curb to provide secondary containment. The supporting equipment, pumps, tank, and service corridor are RAZ 1, controlled areas but accessible to operations and maintenance personnel for up to 40 hr/week.

The Feed Preparation System is covered by a roof. The roof allows for operations and maintenance tasks to take place during local seasonal weather extremes. Portions of the roof can be removed for equipment removal by crane.

Load-In Area

The load-in area provides access to the facility to allow special round containers to enter the facility and be staged. It also furnishes space for operators to perform filling operations.

The load-in area is enclosed in a prefabricated type structure. The structure has an internal, engineered steel framework. A PVC coated polyester fabric is stretched over the structural framework. HVAC for the area is provided by the facility system.

The load-in area is a RAZ 1, controlled area. Personnel access and movement is not restricted. Radiological guidelines for RAZ 1 areas allow for 40 hr/week occupancy.

Fill Station

The special round containers are remotely handled and moved into one of the fill stations by a roller conveyor. The containers are sequentially filled with stabilization reagents and Silos 1 and 2 material slurry feed. They are weighed, closed, and moved to the adjacent curing room.

Curing Room

The curing room provides space for 72 disposal containers to initially cure in a temperature controlled environment.

The filled disposal container is transferred from the wash station by roller conveyor into the curing room. An overhead bridge crane lifts the container and places it into one of the 72 curing positions. After the seven day curing period, the disposal container is removed from the room to be bolted.

A shielded maintenance space is provided for the crane. The maintenance area is accessed through an adjoining airlock. The bridge portion of the crane is maintained from elevated platforms accessed by ladders.

The curing room also contains the Cement Sample Archive System that holds the archived samples until they are no longer needed.

The curing room is a RAZ 5, high radiation area based upon initial calculations. The bases for the assessment are the number of containers and the accumulative dose from the containers.

Personnel should not need to enter into the room while disposal containers are present. The overhead crane can be maintained shielded from the curing room. The maintenance area is considered to be a RAZ 1, controlled area and is accessible up to 40 hr/week to allow general servicing or repair of the crane. Personnel require appropriate PPE to enter.

Packaging

The packaging station allows for inspection of the product, securing of the lid, and survey and decontamination of the disposal container.

The disposal container is remotely lifted by the overhead bridge crane in the curing room and placed onto a roller conveyor. The conveyor moves the container into the inspection station. The lid is lifted, as necessary, to allow for visual inspection by camera. The lid is replaced and the container is transferred by conveyor into the lid fastening station. There, the lid is remotely bolted in place by the lid fastening device. From that station, the disposal container is conveyed to the survey/decontamination room. With the disposal container sealed, radiological technicians, dressed in appropriate PPE, move through the airlock and along each side of the conveyer. Because of the 70 mrem/hr exposure rate from the disposal container, the radiological technicians smear the outside of the disposal container from a distance with long reach tools. If the disposal container is found to be contaminated, these same tools are used to decontaminate the container. Once released, the disposal container is moved by the roller conveyor through an airlock and out through an enclosed corridor to the Interim Container Staging Area.

The inspection and lid fastening rooms are non-occupied areas during operation. Maintenance on the equipment can be performed when disposal containers are not present. Because of the potential for contamination, the concrete floors are sealed and the walls are coated with a strippable coating to allow for decontaminating. These areas are considered to be RAZ 4, radiation areas. Maintenance access is by RWP and requires additional dosimetry.

The survey/decontamination room is also considered to be a RAZ 4, radiation area even though radiological technicians need to enter the area on a continual basis to survey the filled containers. The technicians are not allowed to approach within 3 ft of the disposal container. Long reach tools are used to perform tasks. Consideration is also given to the use of partial shield walls to limit access and protect personnel.

The airlock, where radiological technicians enter the survey/decontamination room, is a special radiation area. The airlock allows for personnel to enter the curing room crane maintenance area and the survey/decontamination room. The room is considered to be a RAZ 1 when a disposal container is not present in the room. When a container is present, the room is a RAZ 4, radiation area. Because of the radiation source in the disposal container, the general area surrounding the airlock needs to be cleared of personnel during the transfer of filled disposal containers.

Operation of the inspection, absorbent, and lid fastening equipment is performed at remote stations located in the corridor adjacent to these rooms. The wall provides radiation shielding for the operator. These tasks are performed using cameras and by viewing through a shielded window in front of the operator to provide for ALARA considerations.

Rework Station

The Rework Room is equipped to handle the round containers and remove the failed grout.

Load-out Area

The load-out area provides access to the facility to allow for the removal of reworked disposal containers from the facility. It also furnishes space for operators to perform packing, loading, and rework operations.

Empty reworked disposal containers exit the facility through the load-out area. A roll-up door allows forklifts to enter and exit the facility. Adjoining the area is a corridor containing

operator stations for rework, inspection, and the lidding operation. An airlock in the area furnishes access for removal of the reworked disposal containers.

The load-out area is enclosed in a prefabricated type structure. The structure has an internal, engineered steel framework. A PVC coated polyester fabric is stretched over the structural framework. HVAC for the area is provided by the Facility System.

When a filled disposal container is transferred through the area, the area becomes a RAZ 4, radiation area. Personnel access and movement is restricted in the area during these times. At all other times, when no source is present, the area is a RAZ 1, controlled area. Radiological guidelines for RAZ 1 areas allow for 40 hr/week occupancy. RAZ 4 requires a radiation work permit and additional dosimetry for personnel within the area.

Facility Entrance

The facility entrance controls the entering/exiting of the facility.

The facility entrance is the main entrance and exit point for personnel working within the facility. Personnel log in when entering the facility. To exit the facility, personnel pass through radiation detection monitors and log out. Any other incoming or outgoing shipment passes through the load-in/load-out areas under the control of a RAD technician. A desk is provided in the facility entrance for a radiological technician to supervise personnel movement.

The facility entrance is not expected to see a radiation source but may see contamination carried by personnel attempting to exit. Because the treatment facility contains radioactive substances and has the potential to be contaminated, entering or exiting the facility is supervised and controlled. For these reasons, the facility entrance is considered to be a RAZ 1, controlled area. Personnel may occupy the area for up to 40 hr/week.

G.7.10.1 Unique Features

The Chemical Stabilization — Other treatment facility design incorporates the use of commercially available equipment wherever possible. However, some components of the treatment facility have to be custom designed, including nuclearization of all equipment that is required to handle material containing Silos 1 and 2 material.

The disposal container/mixer is unique to the Chemical Stabilization — Other technology and is designed to incorporate the grout mixing operations into the disposal container. A hydraulic motor and fill head couple with the mixer blade shaft in the disposal container to provide the necessary mixing action. After the mixing operations are complete, a disposal lid is placed onto the disposal container, to be bolted down after the grout has cured for seven days.

The fill station fill head is designed to mate with the disposal container/mixer and to maintain negative pressure within the system, as well as prevent any grout from contaminating the outer surface of the disposal container. Other unique features of the facility include the lid fastening station, the wash station, the sampling station, and the rework station. **Sections G.7.4.3** and **G.7.9.3** give descriptions of these key pieces of equipment.

G.7.11 HVAC (Systems 73, 75, 76 and 77)

(Refer to **Section G.2.16** for HVAC design criteria)

The areas in the treatment facility are designated as Zone 1, Zone 2 and Zone 3 and have three HVAC Systems: one system exclusively for Zone 3, one for the curing room, and one combined for the remainder of Zone 2 and all of Zone 1. Following are the designated areas with equipment details for each zone.

G.7.11.1 Zone 3

A. The designated areas for Zone 3 are:

- Loading area;
- Rework room;
- Fill head room;
- Survey & decontamination room;
- Lid fastening area;
- Wash station;
- Lid placement area;
- Inspection room;
- Rework station; and
- Mix and fill stations (three).

B. The HVAC details for Zone 3 are:

- Air handler with supply fans, filters and electric heat;
- Supply fans (73-AH-003 A&B) — 12,000 cfm;
- Electric Heat - 309 kW;
- Exhaust fans (73-FA-003 A&B) — 12,000 cfm; and
- Exhaust filter that includes a prefilter with two stage HEPA filters and has 50% capacity backup.

C. The air handling unit and exhaust fans are designed for 100% capacity and 100% backup. Air handling units and exhaust fans are connected to emergency power because of the potential for hazards and equipment damage resulting from elevated temperatures if the systems are lost due to power failure. There are

8074

three exhaust filters with 50% capacity (two are required for normal operation). The electric heaters are not connected to emergency power.

D. Air sweep hoods are provided in the inspection room, rework station, and three mix and fill stations. The discharge vent from air sweep hoods are connected to the RCS and the total flow rate does not exceed 500 cfm.

8074

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G.7.11.2 Zone 2

A. The curing room is the only designated area for Zone 2.

B. The HVAC details for Zone 2 are:

- Air handler with supply fans, filter and electric heat;
- Supply fans (73-AH-002 A&B) — 24,000 cfm;
- Electric heat — 580 kW;
- Exhaust fans (73-FA-003 A&B) — 24,000 cfm; and
- Exhaust filter that includes a prefilter with two stage HEPA filters and has 50% capacity backup.

C. The air handling unit and exhaust fans are designed for 100% capacity and 100% backup. Air handling units and exhaust fans are connected to emergency power because of the potential for hazards and equipment damage resulting from elevated temperatures if the systems are lost due to power failure.

There are three exhaust filters with 50% capacity (two are required for normal operation). The electric heaters are not connected to emergency power.

The curing room is heated to 70°F during winter, cooling is not provided. The expected temperature during summer is 105°F (outside design temperature 95° + 10° F rise).

G.7.11.3 Zones 1 and 2

A. The designated areas for Zone 1 are:

- HVAC room; and the
- Access control room.

B. The corridor is the only designated area (remainder) of Zone 2.

C. The HVAC details for Zones 1 and 2 are:

- Air handler with supply fans, filters and electric heat;
- Supply fans (73-AH-001) — 17,000 cfm;
- Electric heat — separate electric heat is provided for each room;
- HVAC room, 265 kW
- Access control room, 27 kW
- Corridor, 137 kW
- Exhaust fans (73-FA-001 A&B) (2 Fans with 8,500 cfm capacity) - 17,000 cfm; and
- Exhaust filter that includes a prefilter with two stage HEPA filters and has 50% capacity backup.

D. The air handling units are designed for 100% capacity, without any backup. Air handling units and exhaust fans are connected to emergency power because of the potential for hazards and equipment damage resulting from elevated temperatures if the systems are lost due to power failure. There are two exhaust fans and two exhaust filters with 50% capacity (two are required for normal operation). The electric heaters are not connected to emergency power.

G.7.11.4 HVAC stacks

Two HVAC stacks are provided, one for Zone 3 and one for the combined Zones 1 and 2, and are serviced by ladders and platforms. The air, before being exhausted, is analyzed for air quality and the results are recorded.

G.7.12 Support Systems

G.7.12.1 Analytical Support Laboratory/Services

The treatment facility uses an on-site dedicated laboratory staffed by site personnel to analyze the process samples and provide for any additional requirements as space and equipment allow. The laboratory is composed of a trailer complex, modified to provide the working space and conditions for the laboratory facility.

The trailer HVAC and Drain Systems are designed to control the spread of contamination. There is a separate HVAC System and filtration for the laboratory hoods and environmental spaces. The facility is divided into two separate ventilation systems. One system is dedicated for non-potentially contaminated areas such as the office areas. The other system serves the laboratory areas where hazardous materials may be handled. This system discharges all exhaust air through HEPA filters and establishes air flow and pressure gradients that minimize the potential for the spread of contamination. Two separate drain systems, potentially radioactive and non-radioactive, provide for the laboratory spaces. Individual catch tanks are provided for each system. They are located in a covered concrete vault adjacent to the trailer complex.

The laboratory space is considered to be a RAZ 4 when samples containing Silos 1 and 2 material are present and a RAZ 1 when no samples are present because of the number of process and TCLP samples being handled daily within the laboratory and the potential for radioactive contamination being present. The office space within the complex is considered to be a RAZ 1. The complex is divided into a non-radioactive area for office work space and a potentially radioactive laboratory space. To check the spread of contamination, a survey/monitoring room is provided to control entrance and egress for the laboratory space.

Table G.7.12-1 lists the potential analyses and the proposed equipment required to complete the analyses.

TABLE G.7.12-1
LABORATORY ANALYSES AND REQUIRED EQUIPMENT

Analysis	Laboratory Equipment
Percent Solids Determination	Laboratory Oven
TCLP	AA-ICP, Ball Mill
Elemental Analysis	AA-ICP or XRF
UCS	Load Cell
pH	pH Meter

G.7.13 Utilities

The general utilities required to support the treatment facility are described in **Section G.2.19.** The treatment facility uses existing site utilities. An allowance has been made in the cost estimate of the treatment facility for systems that are not existing site utilities and have not been presented in this design basis.

Compressed Air

Compressed air from 44-CM-001 is used for dense phase pneumatic transfers. The plant air system is used to blow down the filter cake during filter press operations.

Potable Water

A potable water system design has not been completed for the Chemical Stabilization — Other treatment facility. However, potable water is an existing site utility and allowances for potable have been incorporated in the cost estimate.

Fire Water

A fire water system design has not been completed for the facility design. However, allowances for a fire water system have been incorporated in the cost estimate. The assumption has been made that a pressurized fire water main will exist on-site. The cost estimate will only include the tie-in and distribution portion of the Fire Water System.

Sanitary System

The treatment facility design does not include sanitation lines. Existing site sewage facilities are used by plant personnel.

Electrical

Normal Power System

Power at 13.2 kV is tied in from site infrastructure south of Silos 1 and 2 to two 2-unit substations (30-SG-001 and 30-SG-002) that include two 2-step down transformers rated 2500 kVa OA with 480-volt, 3-phase, 4-wire, 60-Hertz secondary. The unit substation's main secondary switches are 3200-amp circuit breakers (M1/M2). Both switchboards are rated 3200-amp, 480-V, 3- phase, 60-Hertz. The feeders are rated 800/1600-amp, 480-V, 3- phase. Feeders are routed from the switchboard directly to six motor control centers and air handler heaters, which distribute power to a connected load at approximately 4915 kVa. The MCC provides power for lighting, HVAC, CCTV and process instruments via step down transformers.

Standby Power System

A 1000KW, 480-volt,3-phase, 4-wire, 60-Hertz standby diesel generator is to connected 31-MC-003 and 31-MC-006 via auto transfer switches (30-TS-001 and 30-TS-002) for power to critical plant loads during an electrical power outage. This generator is installed outside of the pilot plant.

Un-interruptible Power System

A 25-kVa, 120-volt, 3-wire, 60-Hertz un-interruptible power supply (UPS) unit supplies panel UPS for power to critical process loads during any electrical outage. The UPS is installed indoors.

CCTV Monitoring

Closed circuit monitoring is used for inspection operations when it is necessary to view system components located in restricted areas, or to inspect for free standing water inside a disposal container.

Hydraulic Drive System

A. Compressed air is provided for pneumatic transfer operations of the dry materials. Instrument air is provided for control valve actuation.

B. Compressed air, electrical power, and a hydraulic power source utility are required for the rework operations.

C. FEMP waste management operations are provided with required utilities.

G.7.14 Special Health and Safety Considerations

During the "Detailed Design" phase of the project, a safety review of the process is conducted. This review considers all credible "what if" scenarios with input from people with different specialties such as process, mechanical, electrical, operations, maintenance, etc. The recommendations of this review are implemented to ensure safety of the process.

An "Ergonomic Review" of the design ensures that the operation does not cause any undue strain to the operators or maintenance people. A "Constructability Review" is conducted

during the detailed design phase to ensure that it is safe and practical to install the equipment and complete all construction as per the design.

G.7.15 Special Environmental Considerations

The design basis for this alternative ensures protection of human health and the environment during the remediation of the Silos 1 and 2 material by incorporating the pertinent environmental regulatory requirements in the system design, using the principles of environmental ALARA. The design allows all contaminated gas, liquid, and solid wastestreams generated during remediation to be collected and treated before release to ensure adequate protection of human health and the environment.

Air emissions from the process are controlled by containment and treatment. Since the treatment process does not generate off-gas, an off-gas system is not included in the design. Along with a ventilation air header system on tanks with Silos 1 and 2 material, the specialized container fill head is used during mixing in the container to ventilate air containing radon to the RCS that uses carbon beds for adsorption of radon. All tanks and lines with radon source material are totally enclosed, and the ventilation control system uses backup redundancy for critical equipment.

Building ventilation is controlled through designation of zones on the basis of expected contamination; the air is either routed to the RCS for radon control, or treated locally for particulate control using HEPA filtration before discharge. Airlocks and dampers are used to control air flow and confine contamination. Discrete particulate sources such as dry feed or additive bins are controlled by filtration. Particulate dusting from reworked cement is confined by the rework room ventilation system, and treated using HEPA filtration. HEPA filters and prefilters are changed using a bag-in and bag-out approach to prevent airborne release of contaminants.

In this alternative, the treatment process is a net user of water; therefore, all liquid waste produced during operations is recycled or used in the process. Excess liquids from the clarifier

are recycled to the TTA for slurry retrieval. Wastewater generated during D&D is characterized before discharge to the site AWWT facility. Any wastewater requiring pretreatment is treated in a batch process on a case-by-case basis.

All tank systems containing source material with free liquids are designed with secondary containment and leak detection. In this alternative, the mixer is also the disposal container, and is located over secondary containment during filling. With the possible exception of the diesel tank for the emergency generator, all tank systems with secondary containment are located under roof, which greatly minimizes the amount of excess liquids requiring characterization and management.

Protection of surface waters is ensured by double containment of exterior piping that conveys retrieved Silos 1 and 2 material, and by segregation of the treatment process in a roofed and enclosed building. Areas used for processing material are protected from precipitation and stormwater run on and runoff. Clean and contaminated runoff is not combined. Clean runoff, including building roof drains and runoff from areas of fixed contamination, is discharged either into the stormwater collection basin, or routed to adjacent drainage systems.

Some secondary waste is recycled (e.g., clarifier overflow) but some process operations generate wastes that cannot be recycled, which requires management as radiologic, hazardous, or mixed waste. For example, spent HEPA filters, PPE, and maintenance wastes are routinely generated during operations. Process holdup wastes, and other D&D wastes that cannot be recycled may require additional treatment before disposal. Facilities to accommodate staging and characterization of wastes during operation, and later during D&D, are included in the design.

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Attachment G.7.I

Mass and Energy Balance for the

Chemical Stabilization — Other Technology

Attachment G.7.I
Mass Balance
Chem - Other

Stream #	1	2	3	4	5	6	7	8	9
Component	Bulk Portland Cement Receipt	Bulk Fly Ash Receipt	Portland Cement to Batch Weigh Hopper	Fly Ash and Other Additives to Batch Weigh Hopper	Cement to Fill-Mix Station	Fly Ash to Mix-Fill Station	Residue Slurry from TTA to Waste Slurry Receiving Tank	Residue Slurry to Clarifier	Residue Slurry to Slurry Batch Tanks
Water (lb/day)							456,624	456,624	85,537
Waste Solids (lb/day)							50,736	50,736	50,236
Air (lb/day)	1,554	1,554			1,465	637			
Cement (lb/day)	108,000		50,132		50,132				
Fly Ash (lb/day)		108,000		20,888		20,888			
TSP (lb/day)									
Total (lb/day)	109,554	109,554	50,132	20,888	51,597	21,525	507,360	507,360	135,773
Flow (gpm)							113	40	9
Flow (scfm)	350	350			287	287			
Max Flow (scfm)									
Pressure (psi)	15	15			80	80	100	80	
Temperature (F)	Ambient	Ambient	Ambient	Ambient	Ambient	Ambient	Ambient	Ambient	
Notes	Bulk Receipt from Delivery Truck. Flow rates may vary	Bulk Receipt from Delivery Truck. Flow rates may vary			Air flow is discharged through baghouse filters	Air flow is discharged through baghouse filters	5,900 lb solids per hour (approx 110 - 120 gpm). Intermittant as necessary.	Continuous operation. 24 hours per day, 5 days per week	Continuous operation. 24 hours per day, 5 days per week
Dwg. Number 94X-5500-F-SK-	3377	3377	3377	3377	3377	3377	3067	3067	3067

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8074

Stream #	10	11	12	13	14	15 thru 30	31	32 thru 33	34
Component	Clarifier Overflow to Supernatant Tank	Clarifier Recirculation	Residue Slurry to Fill-Mix Station	Supernatant to TTA Recycle Water System	Waste Grout	Not Used	Crushed Rubble to Rework Batch Bin	Not Used	Portland Cement to Batch Weigh Hopper for Rework Grout
Water (lb/day)	371,087	49,352	85,537	371,087	85,537				
Waste Solids (lb/day)	500	28,984	50,236	500	50,236		14,536		
Air (lb/day)									
Cement (lb/day)					50,132				14,536
Fly Ash (lb/day)					20,888				
TSP (lb/day)					2,089				
Total (lb/day)	371,587	78,336	135,773	371,587	208,882		14,536		14,536
Flow (gpm)	30 (gravity)	5	60	150					
Flow (scfm)									
Max Flow (scfm)									
Pressure (psi)									
Temperature (F)									
Notes	Continuous operation. 24 hours per day, 5 days per week	Continuous operation. 24 hours per day, 5 days per week	Slurry Recirculation line. Slip stream used to fill container.	Intermittant. 1/2 hour every 2 hours			1 containr of failed grout is processed in 1 day. 14,536 lb grout per container		
Dwg. Number 94X-5500-F-SK-	3067	3067	3067	3067	3068 3338		3340		3377

Attachment G.7.I
Mass Balance
Chem - Other

Stream #	35	36 thru 40	42	43	44	45	46 thru 49	50
Component	Rework Solids to Fill-Mix Station	Not Used	Flush Water to Receiving Tank Transfer Pump	Flush Water to Settling Tank Transfer Pump	Flush Water to Slurry Feed Pump -001	Flush Water to Slurry Feed Pump - 002	Not Used	Flush Water to Slurry Feed Pump - 003
Water (lb/day)			3,332 lb/use	833 lb/use	4,998 lb/use	4,998 lb/use		4,998 lb/use
Waste Solids (lb/day)	14,536							
Air (lb/day)								
Cement (lb/day)								
Fly Ash (lb/day)								
TSP (lb/day)								
Total (lb/day)	14,536		3,332	833	4,998 lb/use	4,998 lb/use		4,998 lb/use
Flow (gpm)			40	10	60	60		60
Flow (scfm)								
Max Flow (scfm)								
Pressure (psi)								
Temperature (F)								
Notes			Used only for shutdown and maintenance. Flush for 10 minute cycle	Used only for shutdown and maintenance. Flush for 10 minute cycle	Used once per day. Flush for 10 minute cycle	Used once per day. Flush for 10 minute cycle		Used once per day. Flush for 10 minute cycle
Dwg. Number 94X-5500-F-SK-	3338 3340		3067	3067	3067	3067		3067

000676

7-8074

Attachment G.7.I
Mass Balance
Chem - Other

Stream #	51 thru 53	54	55	56	57	58
Component	Not Used	Vessel Vent Header Flow to RCS	TSP Receipt	Not Used	TSP to Batch Weigh Hopper	TSP to Fill-Mix Station
Water (lb/day)						
Waste Solids (lb/day)						
Air (lb/day)						64.0
Cement (lb/day)						
Fly Ash (lb/day)						
TSP (lb/day)					2,089	2,089
Total (lb/day)						2,153
Flow (gpm)						
Flow (scfm)		140				287
Max Flow (scfm)		500				
Pressure (psi)		-0.3				80
Temperature (F)		90			Ambient	Ambient
Notes						
Dwg. Number 94X-5500-F-SK-		3341	3377		3377	3377

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Attachment G.7.II

Drawings for the

Chemical Stabilization — Other Technology

DRAWING LIST
FOR
CHEMICAL STABILIZATION — OTHER TECHNOLOGY

Drawing Number	Title	Rev.
Process Flow Diagrams 94X-5500-F-		
SK-3340	REJECT WASTE REWORK	2
SK-3067	RESIDUE SLURRY FEED PREPARATION	2
SK-3068	MIXING - FILLING STATION	2
SK-3338	MIXING - FILLING STATION	2
SK-3341	VESSEL VENT SYSTEM	2
SK-3377	CEMENT / ADDITIVES PREPARATION	2
Mechanical Handling Diagram 94X-5500-M-		
SK-6013	PRODUCT LOAD	2
SK-6023	REWORK / RECYCLE	2
Facility Layout Drawings 94X-5500-P-		
SK-1041	PLOT PLAN,	2
SK-7420	PLAN @ EL. 0'-0" TO EL. 15'-0"	2
SK-7421	PLAN @ EL. 15'-0" AND ABOVE	2
SK-7422	SECTIONS	2
SK-7423	DETAILS & SECTION	2
SK-7426	INTERIM CONTAINER STAGING.	2
SK-7428	CEMENT/ADDITIVE STORAGE BINS	2

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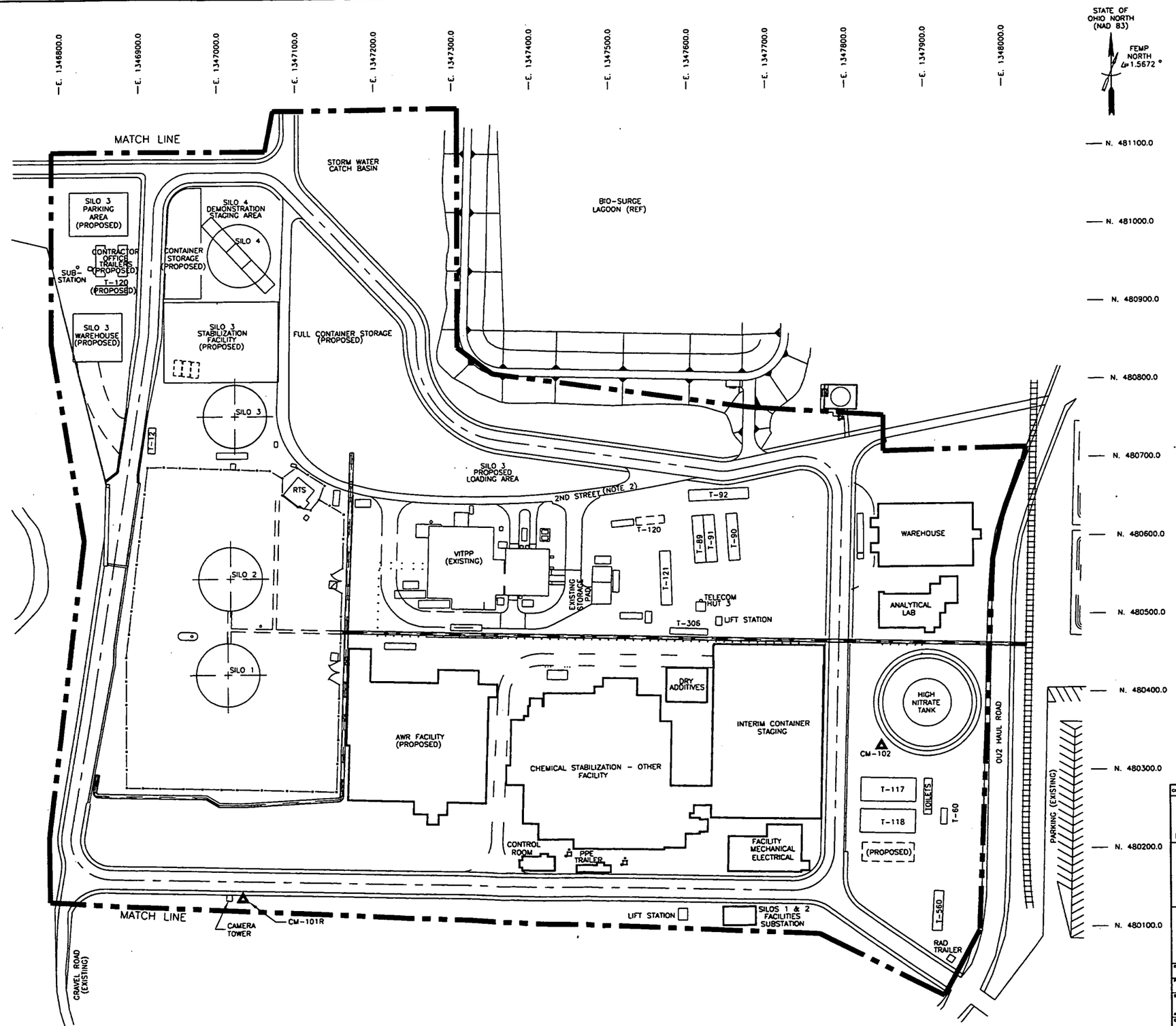

NOTES:

1. LOCATION OF FENCES, GATES AND CHECK POINTS TO BE DETERMINED.
2. THIS SECTION OF 2nd STREET TO BE USED BY PEDESTRIAN, LIGHT DUTY, OCCASIONAL DELIVERIES TO OU1, AND EMERGENCY TRAFFIC ONLY.
3. FACILITY LAYOUTS FOR SILO 3 AND AWR ARE SHOWN AS PRE-CONCEPTUAL ONLY.
4. CONSTRUCTION AND OPERATIONS PERSONNEL WILL USE EXISTING SITE PARKING LOT.
6. INFRASTRUCTURE ROAD IS TO BE DOUBLE LANE.

LEGEND OF SYMBOLS

▲ = MONUMENT

0 25 50 100 150 200 250
GRAPHIC SCALE
1" = 50'

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PRELIMINARY DRAWING

DWG FILE	SK-1041	DWG CODE	ACAD R14

UNITED STATES DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

THIS DRAWING PREPARED BY
FLUOR DANIEL FERNALD
SILOS PROJECT
CINCINNATI, OHIO

DRAWING TITLE
FACILITY LAYOUT
CHEMICAL STABILIZATION - OTHER
PLOT PLAN
REVISED FEASIBILITY STUDY FOR SILOS 1 & 2

DRAWN BY: S. M. YANKEY	DATE: 12/28/98	TECHNICAL CHECKED BY	DATE
CHECKED BY: J. THOMPSON	DATE: 8/16/99	PLANT/BLDG. NO.: OU4	FLOOR
SCALE: 1"=50'	CLASS	SUBMITTED FOR APPROVAL	APPROVAL RECOMMENDED
SIGNATURE	DATE	APPROVING CONTRACTOR	DATE
DOE PROJECT NO.: 40730	OPER. CONTR. PROJ. NO.: 04424331	DRAWING NO.: 94X-5500-G-SK-1041	SHEET NO.: 1 / REV. NO.: 2

DISTRIBUTION CODE: XXX

ACAD

INITIALS: RWR
DATE: 12/1/99

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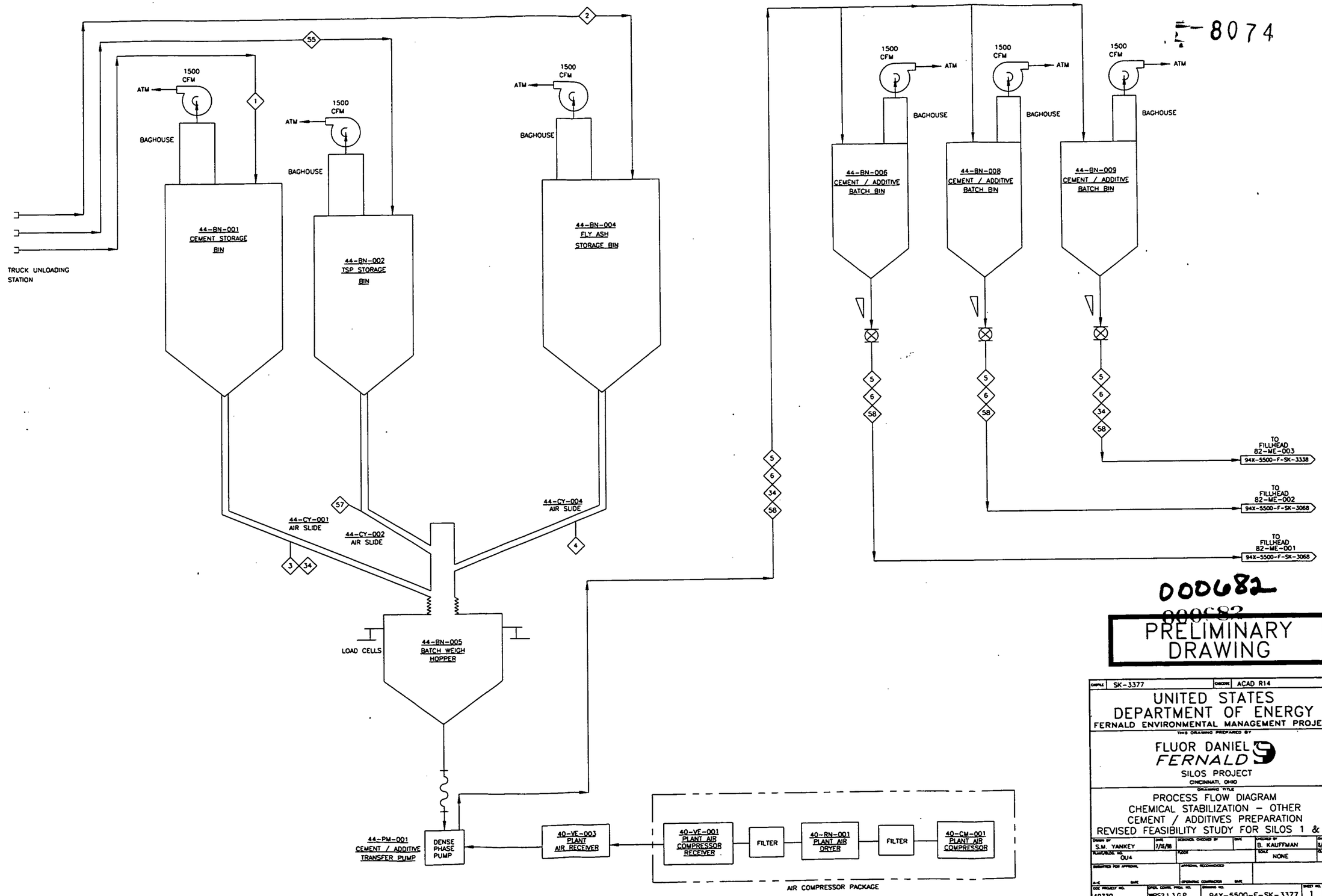

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PRELIMINARY DRAWING

SAMPLE	SK-3377	CHECKER	ACAD R14

UNITED STATES
DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

THIS DRAWING PREPARED BY

FLUOR DANIEL FERNALD
SILOS PROJECT
CINCINNATI, OHIO

DRAWING TITLE

PROCESS FLOW DIAGRAM
CHEMICAL STABILIZATION – OTHER
CEMENT / ADDITIVES PREPARATION
REVISED FEASIBILITY STUDY FOR SILOS 1 & 2

DRAWN BY S.M. YANKEY	DATE 7/16/98	REVIEWED, CHECKED BY	DATE	CHECKED BY B. KAUFFMAN	DATE 8/18/99
PLANT/BLDG. NO. OU4		PLOT		SCALE NONE	PLOTS
SUBMITTED FOR APPROVAL		APPROVAL RECOMMENDED			
A-E	DATE	OPERATING CONTRACTOR	DATE		
DOE PROJECT NO. 40730	OPER. CONTR. PROJ. NO. WBS2.1.3.G.P	DRAWING NO. 94X-5500-F-SK-3377		SHEET NO. 1	REV. NO. 2

DISTRIBUTION CODE: XXX

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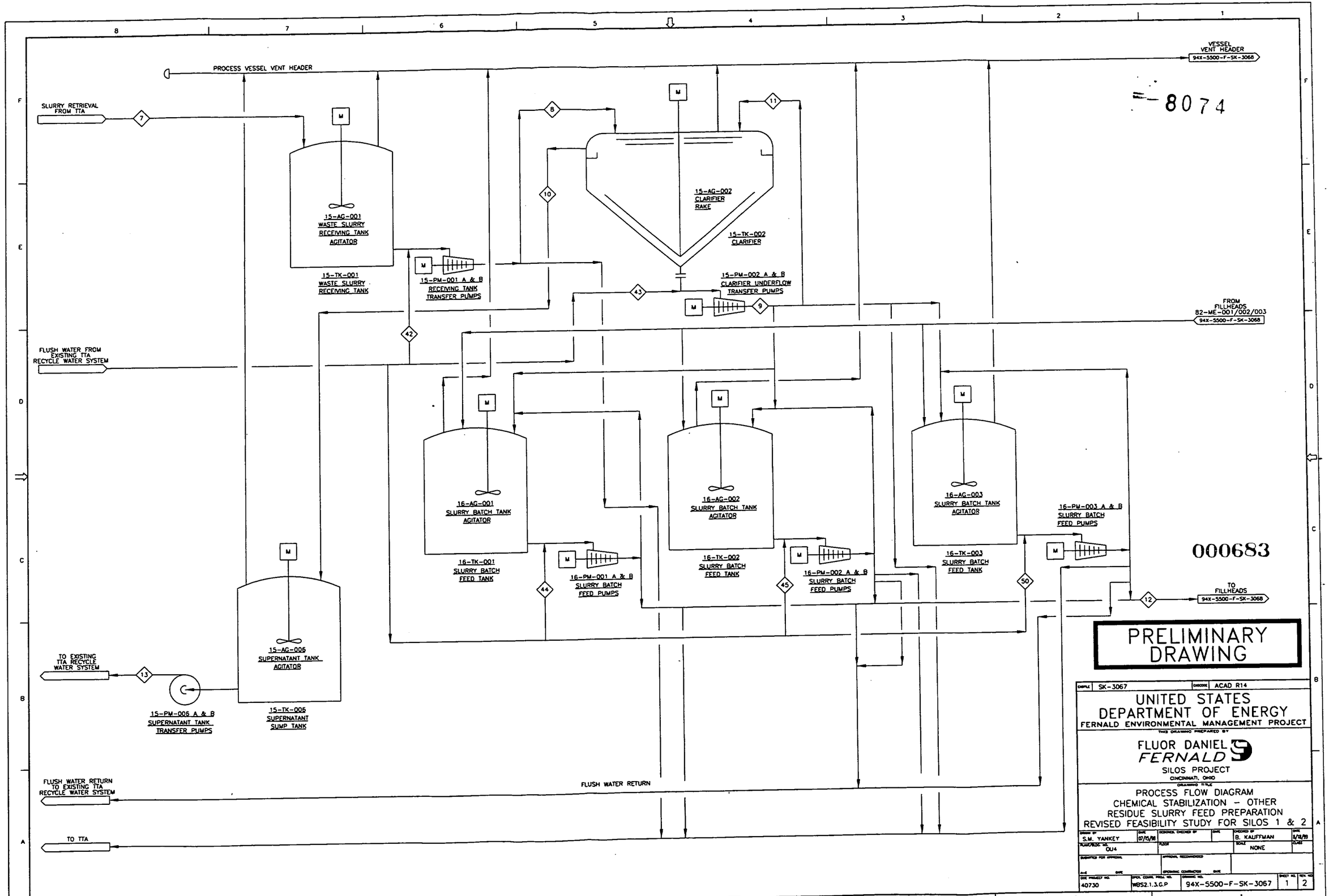
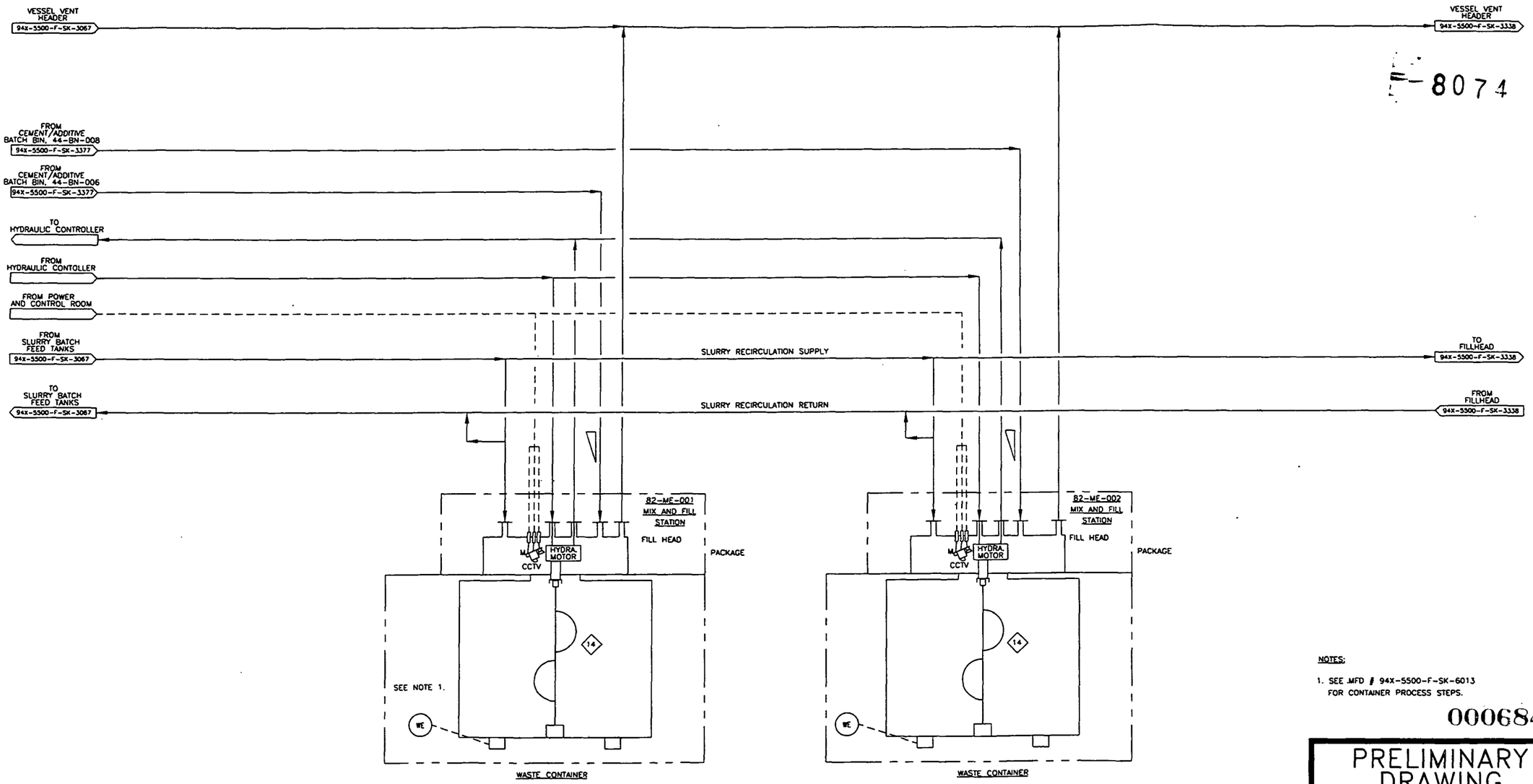
INITIALS: RWR
DATE: 12/1/99


PROCESS VESSEL VENT HEADER
VESSEL VENT HEADER
94X-5500-F-SK-3068
SLURRY RETRIEVAL FROM TTA
15-AG-001 WASTE SLURRY RECEIVING TANK AGITATOR
15-TK-001 WASTE SLURRY RECEIVING TANK
15-PM-001 A & B RECEIVING TANK TRANSFER PUMPS
15-AG-002 CLARIFIER RAKE
15-TK-002 CLARIFIER
15-PM-002 A & B CLARIFIER UNDERFLOW TRANSFER PUMPS
FROM FILLHEADS 82-ME-001/002/003
94X-5500-F-SK-3068
FLUSH WATER FROM EXISTING TTA RECYCLE WATER SYSTEM
16-AG-001 SLURRY BATCH TANK AGITATOR
16-TK-001 SLURRY BATCH FEED TANK
16-PM-001 A & B SLURRY BATCH FEED PUMPS
16-AG-002 SLURRY BATCH TANK AGITATOR
16-TK-002 SLURRY BATCH FEED TANK
16-PM-002 A & B SLURRY BATCH FEED PUMPS
16-AG-003 SLURRY BATCH TANK AGITATOR
16-TK-003 SLURRY BATCH FEED TANK
16-PM-003 A & B SLURRY BATCH FEED PUMPS
TO FILLHEADS
94X-5500-F-SK-3068
15-AG-006 SUPERNATANT TANK AGITATOR
15-TK-006 SUPERNATANT SUMP TANK
15-PM-006 A & B SUPERNATANT TANK TRANSFER PUMPS
TO EXISTING TTA RECYCLE WATER SYSTEM
FLUSH WATER RETURN TO EXISTING TTA RECYCLE WATER SYSTEM
FLUSH WATER RETURN
TO TTA
8074
000683
PRELIMINARY DRAWING
SHEET SK-3067
CHECKED ACAD R14
UNITED STATES DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT
THIS DRAWING PREPARED BY
FLUOR DANIEL FERNALD
SILOS PROJECT
CINCINNATI, OHIO
DRAWING TITLE
PROCESS FLOW DIAGRAM
CHEMICAL STABILIZATION - OTHER
RESIDUE SLURRY FEED PREPARATION
REVISED FEASIBILITY STUDY FOR SILOS 1 & 2
DRAWN BY S.M. YANKEY
DATE 07/15/98
CHECKED BY B. KAUFFMAN
DATE 8/18/99
PLANT/AREA NO. OU4
SCALE NONE
DOE PROJECT NO. 40730
WBS2.1.3.C.P
DRAWING NO. 94X-5500-F-SK-3067
SHEET NO. 1
REV. NO. 2
DISTRIBUTION CODE: XXX
ACAD
INITIALS: RWR
DATE: 12/1/99



F-8074

NOTES:

1. SEE MFD # 94X-5500-F-SK-6013 FOR CONTAINER PROCESS STEPS.

000684

PRELIMINARY DRAWING

CAD FILE	SK-3068	CHECKED	ACAD R14

UNITED STATES
DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

THIS DRAWING PREPARED BY

FLUOR DANIEL FERNALD

SILOS PROJECT
CINCINNATI, OHIO

DRAWING TITLE

PROCESS FLOW DIAGRAM
CHEMICAL STABILIZATION – OTHER
MIXING–FILLING STATION
REVISED FEASIBILITY STUDY FOR SILOS 1 & 2

DRAWN BY S.M. YANKEY	DATE 07/21/98	REVIEWED, CHECKED BY	DATE	CHECKED BY B. KAUFFMAN	DATE 8/13/99
PLANT/BLDG. NO. OU4		FLOOR		SCALE NONE	CLASS
SUBMITTED FOR APPROVAL:		APPROVAL RECOMMENDED			
A-E	DATE	OPERATING CONTRACTOR	DATE		

BDC PROJECT NO. 40730	OPER. CONTR. PROJ. NO. WBS.2.1.3.G.P	DRAWING NO. 94X-5500-F-SK-3068	SHEET NO. 1	TOTAL NO. 2	

DISTRIBUTION CODE: XXX

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INITIALS: RWR
DATE: 12/1/99

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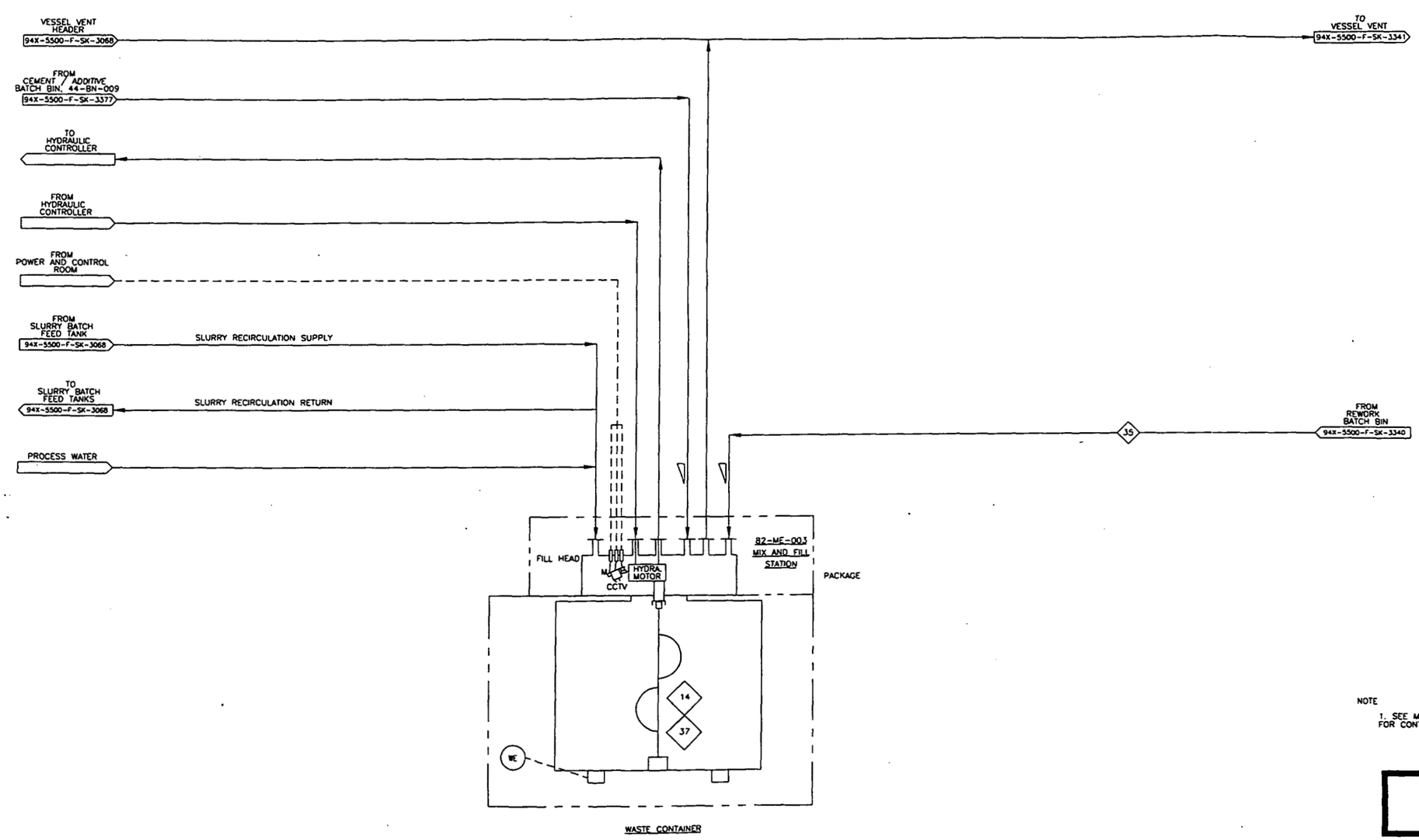

NOTE

1. SEE MFD # 94X-5500-F-SK-6013 FOR CONTAINER PROCESS STEPS.

000685

PRELIMINARY DRAWING

DWG/FILE	SK-3338	DRIVER	ACAD R14

UNITED STATES
DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

THIS DRAWING PREPARED BY

FLUOR DANIEL FERNALD
SILOS PROJECT
CINCINNATI, OHIO

DRAWING TITLE

PROCESS FLOW DIAGRAM
CHEMICAL STABILIZATION - OTHER
MIXING-FILLING STATION
REVISED FEASIBILITY STUDY FOR SILOS 1 & 2

DRAWN BY S.M. YANKEY	DATE 10/21/98	REVIEWED, CHECKED BY	DATE	CHECKED BY B. KAUFFMAN	DATE 11/13/99
FUNDING NO. OU4		FLOW		SCALE NONE	CLASS
SUBMITTED FOR APPROVAL: APP. DATE		APPROVAL RECOMMENDED: APPROVING CONTRACTOR DATE			
SITE PROJECT NO. 40730	OPER. COMPL. PROJ. NO. WBS2.1.3.G.P	DRAWING NO. 94X-5500-F-SK-3338		SHEET NO. 1	REV. NO. 2

DISTRIBUTION CODE: XXX

ACAD

INITIALS: RWR
DATE: 12/1/99

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000686

PRELIMINARY DRAWING

DWG FILE	SK-3341	CHECKER	ACADR14

UNITED STATES
DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

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FLUOR DANIEL FERNALD
SILOS PROJECT
CINCINNATI, OHIO

DRAWING TITLE

PROCESS FLOW DIAGRAM
CHEMICAL STABILIZATION - OTHER
VESSEL VENT SYSTEM
REVISED FEASIBILITY STUDY FOR SILOS 1 & 2

DRAWN BY LB ATCHLEY	DATE 10/17/98	REVIEWED, CHECKED BY	DATE	CHECKED BY B. KAUFFMAN	DATE 8/13/99
PLANT/AREA NO. OU4		PLOT#		SCALE NONE	OLDER
SUBMITTED FOR APPROVAL		APPROVAL RECOMMENDED			
A-E DATE		OPERATING CONTRACTOR DATE			

DOE PROJECT NO. 40730	OPER. CONTR. PROJ. NO. WBS2.1.3.G.P	DRAWING NO. 94X-5500-F-SK-3341	SHEET NO. 1	REV. NO. 2

DISTRIBUTION CODE: XXX

ACAD

INITIALS: RWR
DATE: 12/1/99

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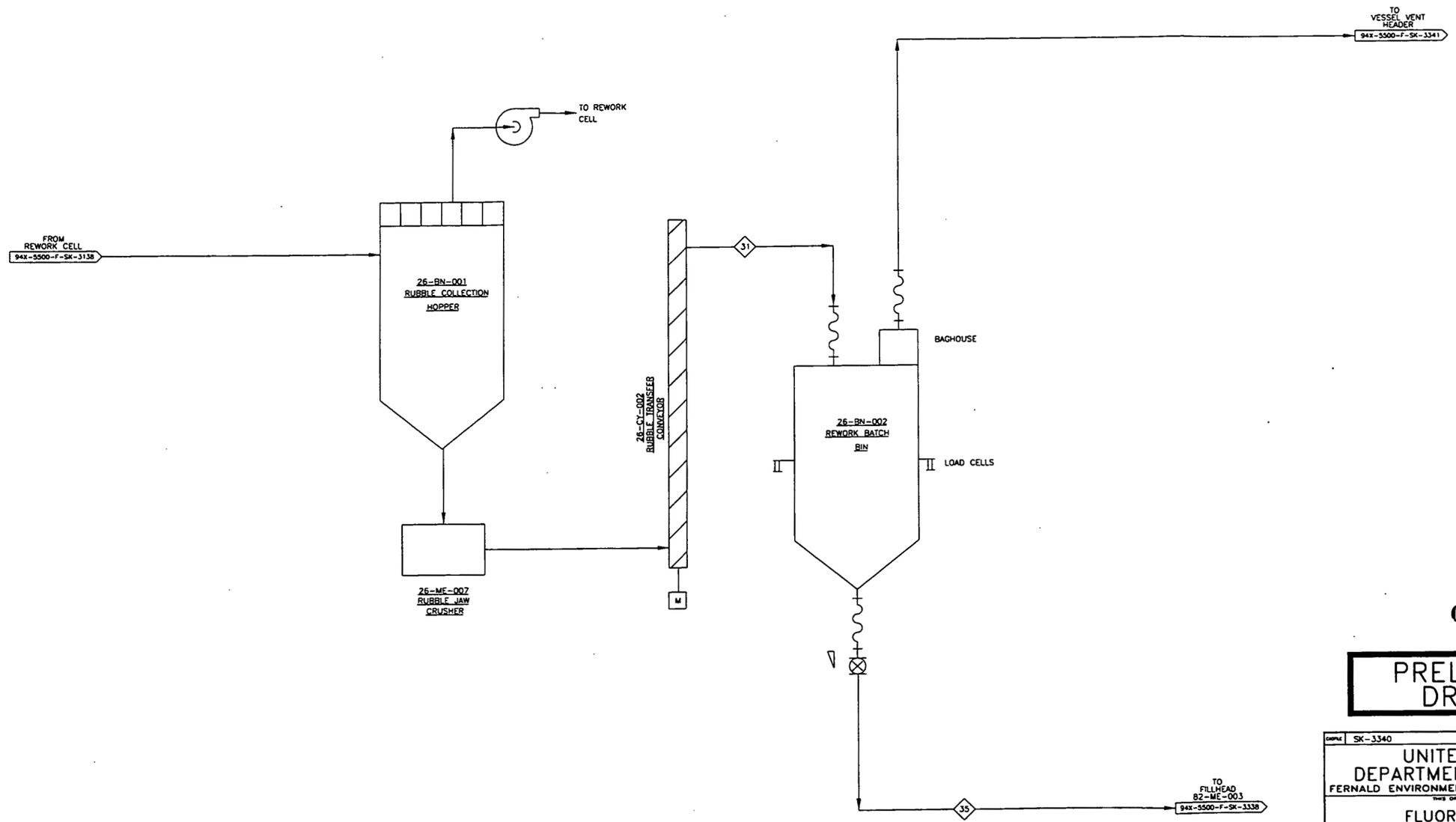

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PRELIMINARY DRAWING

CHSPLE	SK-3340	CHSCRE	ACAD R14

UNITED STATES
DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

THIS DRAWING PREPARED BY
FLUOR DANIEL FERNALD
SILOS PROJECT
CINCINNATI, OHIO

DRAWING TITLE
PROCESS FLOW DIAGRAM
CHEMICAL STABILIZATION - OTHER
REJECT WASTE REWORK
REVISED FEASIBILITY STUDY FOR SILOS 1 & 2

DRAWN BY E. M. MOORE	DATE 10/21/98	DESIGNED, CHECKED BY	DATE	CHECKED BY B. KAUFFMAN	DATE 3/12/99
PLANT/BLDG. NO. OU4		PLOAN		SCALE NONE	CLASS
SUBMITTED FOR APPROVAL A-E DATE		APPROVAL RECOMMENDED OPERATING CONTRACTOR DATE			
DOE PROJECT NO. 40730	SPOL. CONTR. PROJ. NO. WBS2.1.3.G.P	DRAWING NO. 94X-5500-F-SK-3340		SHEET NO. 1	REV. NO. 2

DISTRIBUTION CODE: XXX ACAD INITIALS: RNR DATE: 12/1/99

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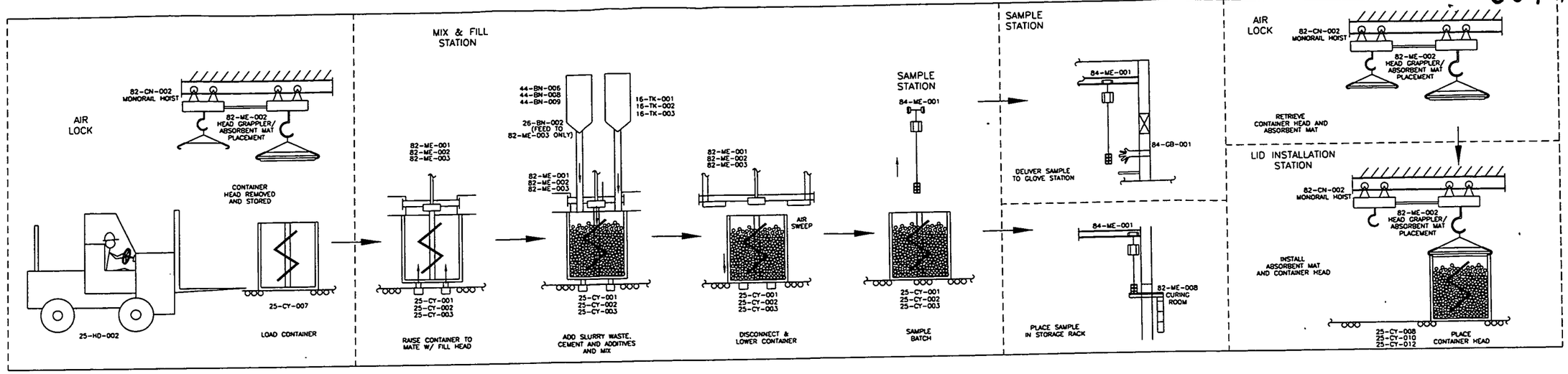

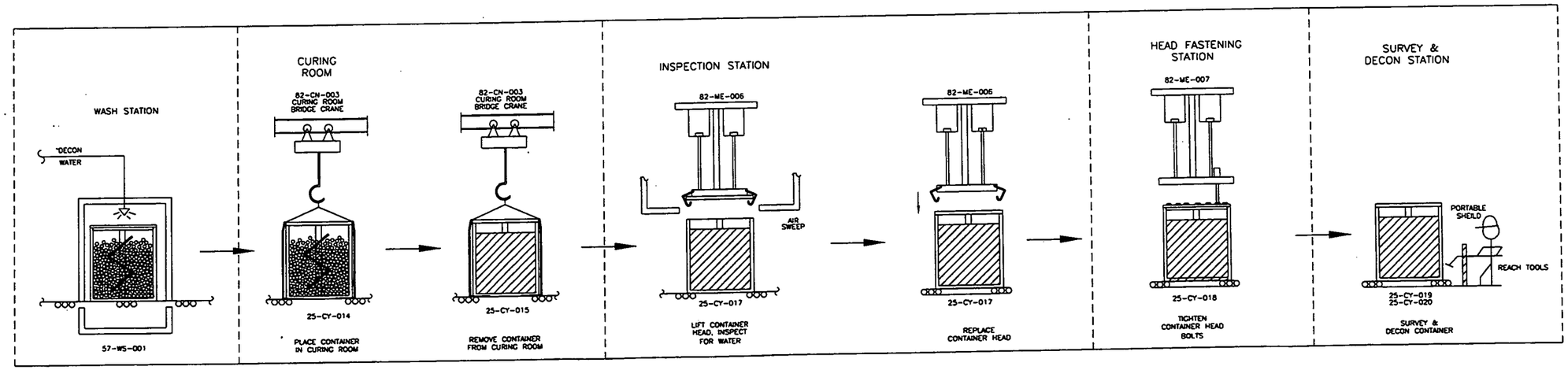

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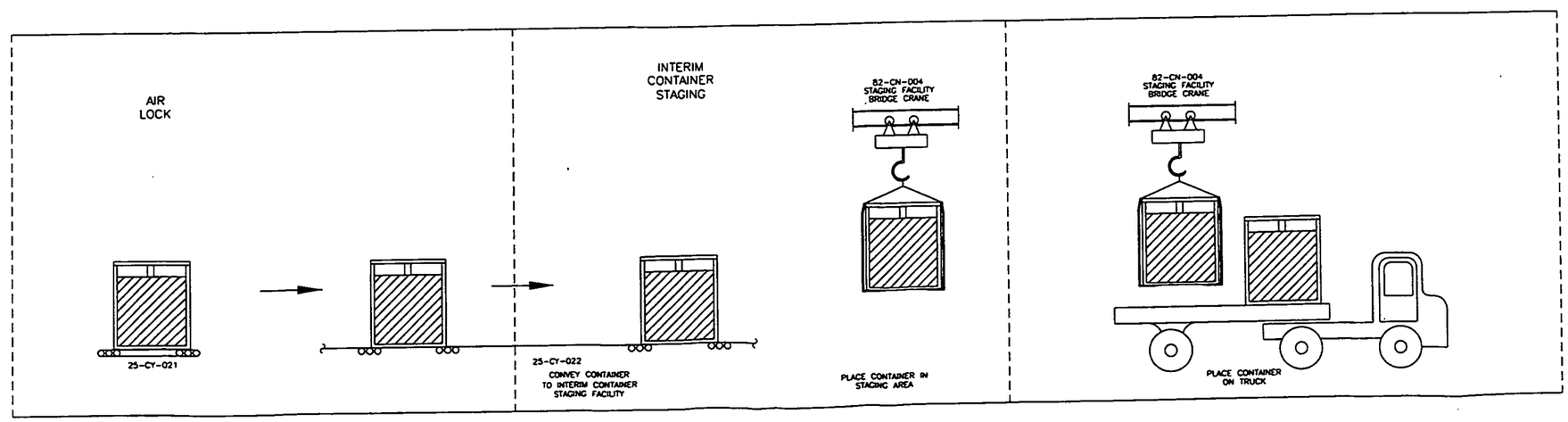


PRELIMINARY DRAWING

CAD FILE	SK-6013	CHECKER	ACAD R14

UNITED STATES
DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

THIS DRAWING PREPARED BY
FLUOR DANIEL FERNALD
SILOS PROJECT
CINCINNATI, OHIO

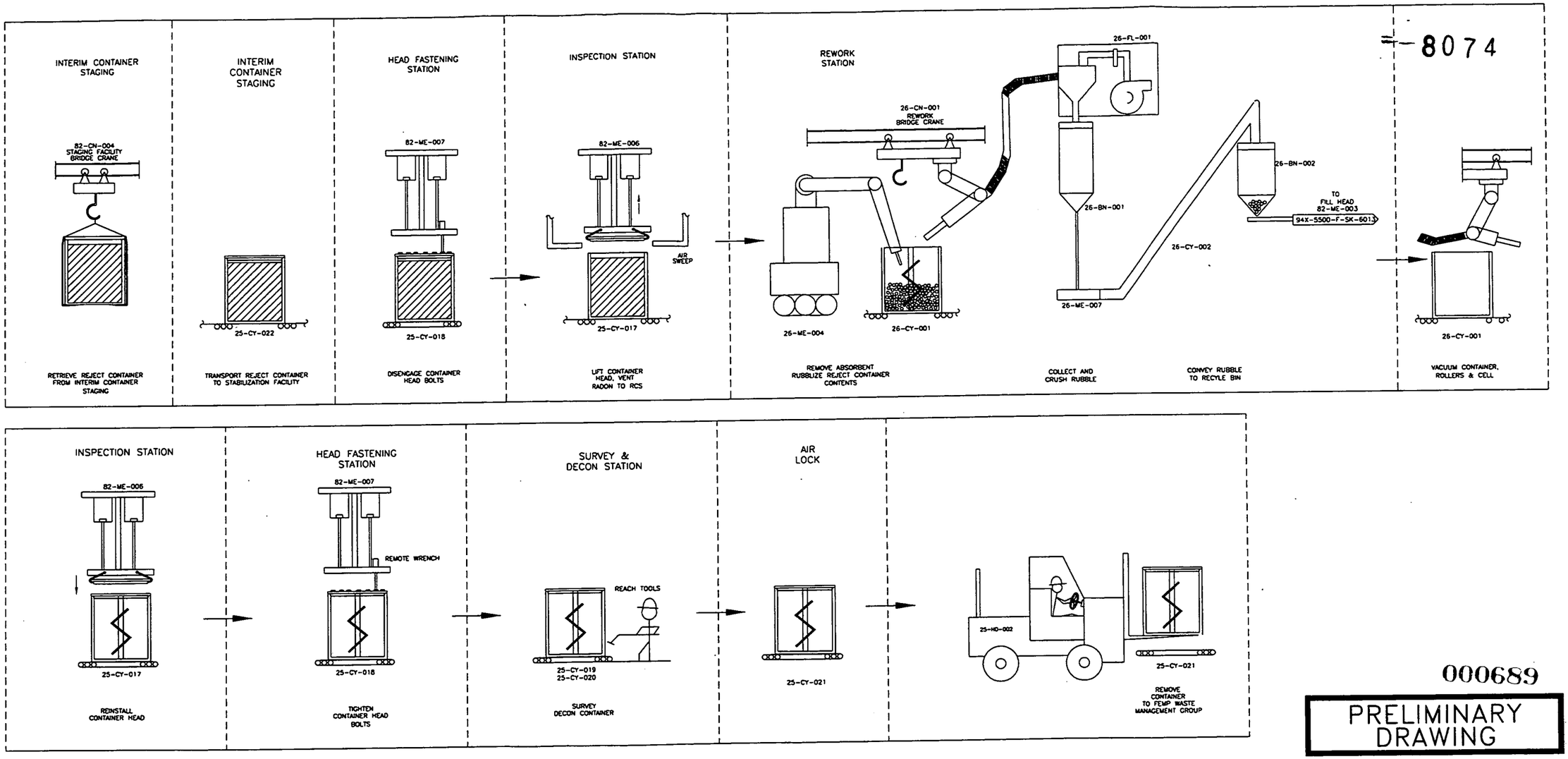
DRAWING TITLE
MECHANICAL FLOW DIAGRAM
CHEMICAL STABILIZATON - OTHER
PRODUCT LOAD
REVISED FEASIBILITY STUDY FOR SILOS 1 & 2

DRAWN BY D. LANDER	DATE 1/07/99	DESIGNED, CHECKED BY	DATE
CHECKED BY C. SCHILLING	DATE 8/20/98	PLANT/BLDG. NO. OU4	FLOOR
SCALE NONE	CLASS	SUBMITTED FOR APPROVAL	APPROVAL RECOMMENDED
A-E	DATE	OPERATING CONTRACTOR	DATE
DOE PROJECT NO. 40730	OPER. CONTR. PROJ. NO. WBS2.1.3.G.P	DRAWING NO. 94X-5500-F-SK-6013	SHEET NO. 1 / REV. NO. 2

DISTRIBUTION CODE: XXX

ACAD

INITIALS: RWR
DATE: 12/1/99



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PRELIMINARY DRAWING

CAD FILE: SK-6023 | CHECKER: ACAD R14

UNITED STATES
DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

THIS DRAWING PREPARED BY

FLUOR DANIEL FERNALD

SILOS PROJECT
CINCINNATI, OHIO

DRAWING TITLE

MECHANICAL FLOW DIAGRAM
CHEMICAL STABILIZATION - OTHER
REWORK / RECYCLE
REVISED FEASIBILITY STUDY FOR SILOS 1 & 2

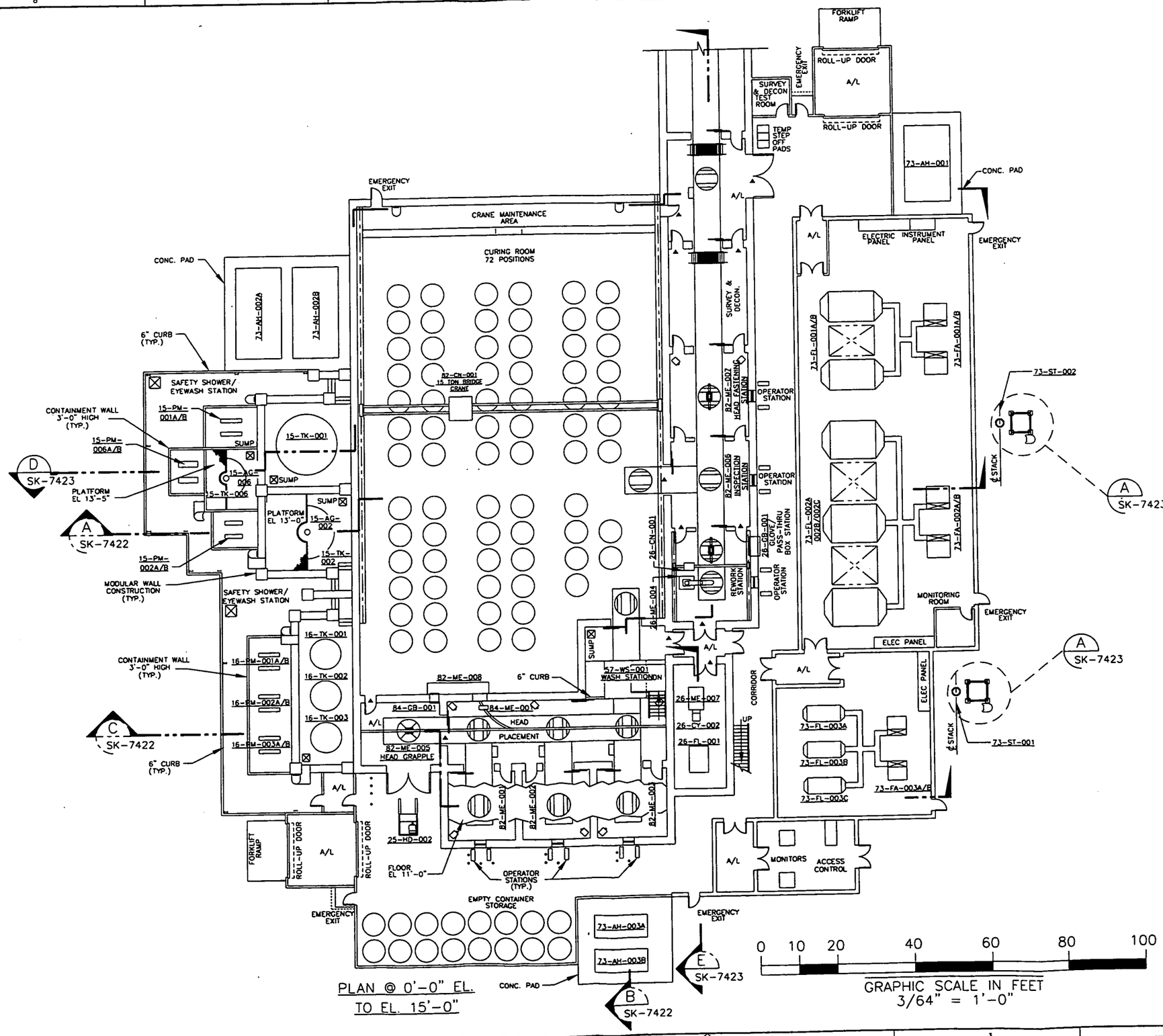
DRAWN BY: D. LANDER	DATE: 1/19/99	DESIGNER CHECKED BY	DATE	CHECKED BY: C. SCHILLING	DATE: 8/13/99
PLANT/BLDG. NO.: OU4		FLOOR		SCALE: NONE	CLASS
SUBMITTED FOR APPROVAL:		APPROVAL RECOMMENDED			
DOE	DATE	ENGINEERING CONTRACTOR	DATE		
DOE PROJECT NO.: WBS2.1.3.G.P	CPCO. CONTR. PROJ. NO.: 40730	DRAWING NO.: 94X-5500-F-SK-6023		SHEET NO.: 1	REV. NO.: 2

DISTRIBUTION CODE: XXX

ACAD

INITIALS: RWR
DATE: 12/1/99

8074



PLAN @ 0'-0" EL. TO EL. 15'-0"

NOTES:

1. BUILDING CONSTRUCTION
   - CONCRETE FLOOR SLAB AND FOUNDATIONS.
   - ARCHITECTURAL TYPE WALLS CONSIST OF STEEL FRAME STRUCTURE, INSULATED METAL SIDING, MEMBRANE ROOFING SUPPORTED BY STEEL DECKING AND INSULATION BOARD.
   - MODULAR WALL CONSTRUCTION CONSISTS OF INTERLOCKING PREFABRICATED SHIELDING WALLS AND COLUMNS.
   - ALL OTHER SHEILDING WALLS ARE 2'-0" THICK CONCRETE.
2. EMPTY CONTAINER STORAGE IS SINGLE STACK.
3. SHIELD DOOR = ▲

REFERENCE DRAWINGS

94X-5500-P-SK-7421
94X-5500-P-SK-7422
94X-5500-P-SK-7423

000690

PRELIMINARY DRAWING

CAD FILE	SK-7420	CHECKER	ACAD R14

UNITED STATES DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

THIS DRAWING PREPARED BY
FLUOR DANIEL FERNALD
SILOS PROJECT
CINCINNATI, OHIO

DRAWING TITLE
FACILITY LAYOUT
CHEMICAL STABILIZATION - OTHER
PLAN @ EL. 0'-0" TO EL. 15'-0"
REVISED FEASIBILITY STUDY FOR SILOS 1 & 2

DRAWN BY S. M. YANKEY	DATE 12/2/98	DESIGNED, CHECKED BY	DATE	CHECKED BY J. THOMPSON	DATE 8/13/99
PLANT/BLDG. NO. OU4		FLOOR		SCALE 3/64" = 1'-0"	CLASS
SUBMITTED FOR APPROVAL		APPROVAL RECOMMENDED			
DATE	DATE	OPERATING CONTRACTOR	DATE		
SITE PROJECT NO. 40730		OPER. CONTR. PROJ. NO. WBS2.1.3.C.P		DRAWING NO. 94X-5500-P-SK-7420	SHEET NO. 1 / REV. NO. 2

DISTRIBUTION CODE: XXX

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INITIALS: RWR
DATE: 12/1/99

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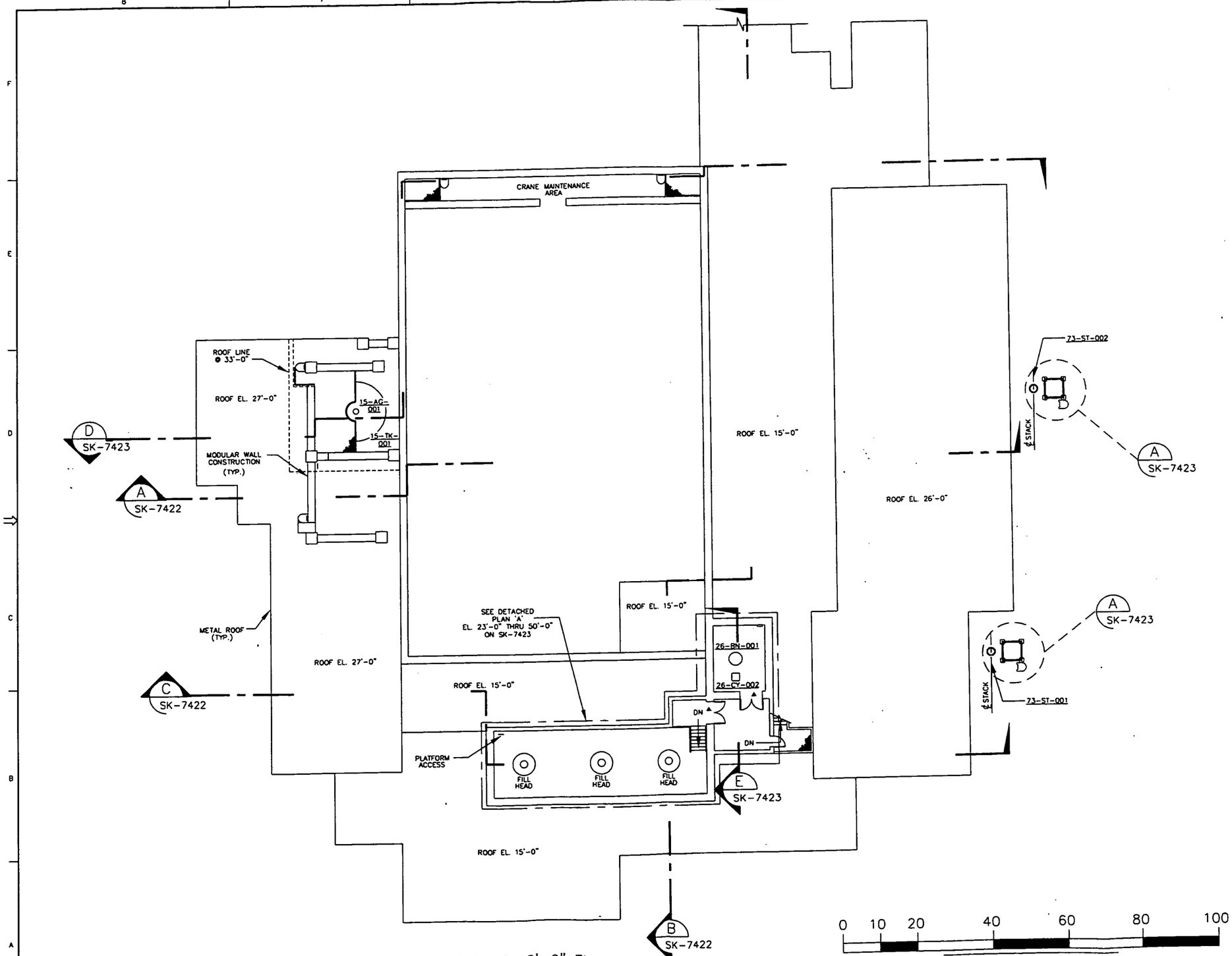

PLAN @ 15'-0" EL.
& ABOVE
UNLESS NOTED OTHERWISE

0 10 20 40 60 80 100

GRAPHIC SCALE IN FEET
3/64" = 1'-0"

NOTES:

1. BUILDING CONSTRUCTION
   - CONCRETE FLOOR SLAB AND FOUNDATIONS.
   - ARCHITECTURAL TYPE WALLS CONSIST OF STEEL FRAME STRUCTURE, INSULATED METAL SIDING, MEMBRANE ROOFING SUPPORTED BY STEEL DECKING AND INSULATION BOARD.
   - MODULAR WALL CONSTRUCTION CONSISTS OF INTERLOCKING PREFABRICATED SHIELDING WALLS AND COLUMNS.
   - ALL OTHER SHEILDING WALLS ARE 2'-0" THICK CONCRETE.
2. EMPTY CONTAINER STORAGE IS SINGLE STACK.
3. SHIELD DOOR = ▲

000691

REFERENCE DRAWINGS

94X-5500-P-SK-7420
94X-5500-P-SK-7422
94X-5500-P-SK-7423

PRELIMINARY DRAWING

CAD FILE SK-7421		CHECKER ACAD R14	
UNITED STATES DEPARTMENT OF ENERGY FERNALD ENVIRONMENTAL MANAGEMENT PROJECT			
THIS DRAWING PREPARED BY FLUOR DANIEL FERNALD SILOS PROJECT CINCINNATI, OHIO			
DRAWING TITLE FACILITY LAYOUT CHEMICAL STABILIZATION - OTHER PLAN @ EL. 15'-0" & ABOVE REVISED FEASIBILITY STUDY FOR SILOS 1 & 2			
DRAWN BY S. M. YANKEY	DATE 12/1/99	DESIGNER, CHECKED BY	DATE
CHECKED BY J. THOMPSON	DATE 12/13/99	PLANT/BLDG. NO. OU4	FLOOR
SCALE 3/64" = 1'-0"	SUBMITTED FOR APPROVAL	APPROVAL RECOMMENDED	
A/E	DATE	OPERATING CONTRACTOR	DATE
SITE PROJECT NO. 40730	SPECIAL COMPL. PROG. NO. WBS2.1.3.G.P	DRAWING NO. 94X-5500-P-SK-7421	SHEET NO. 1 / REV. NO. 2
DISTRIBUTION CODE: XXX	ACAD	INITIALS: RWR DATE: 12/1/99	

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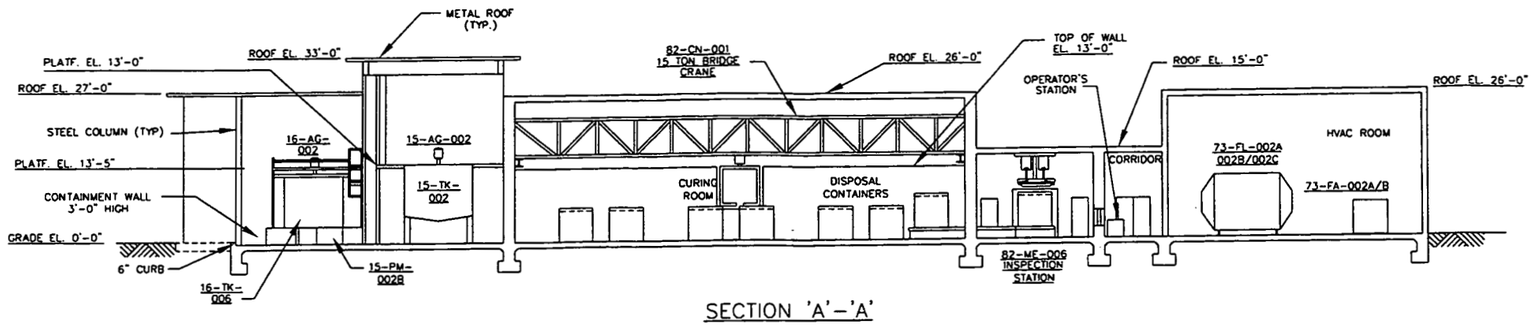
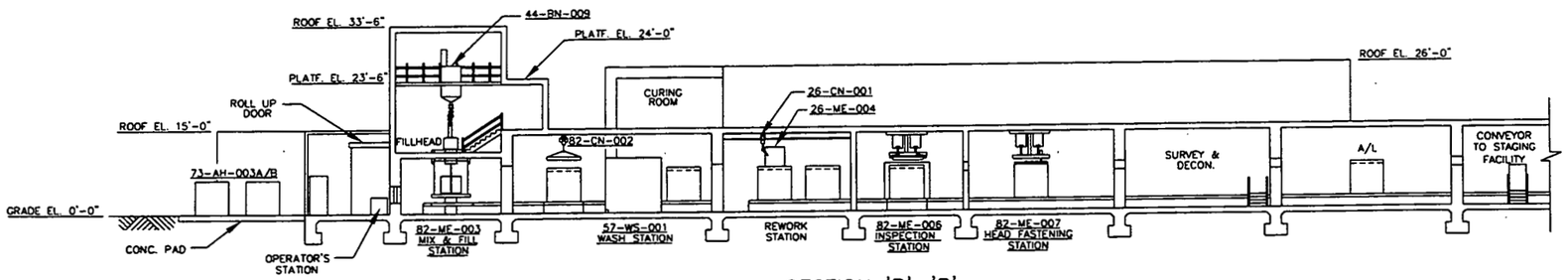


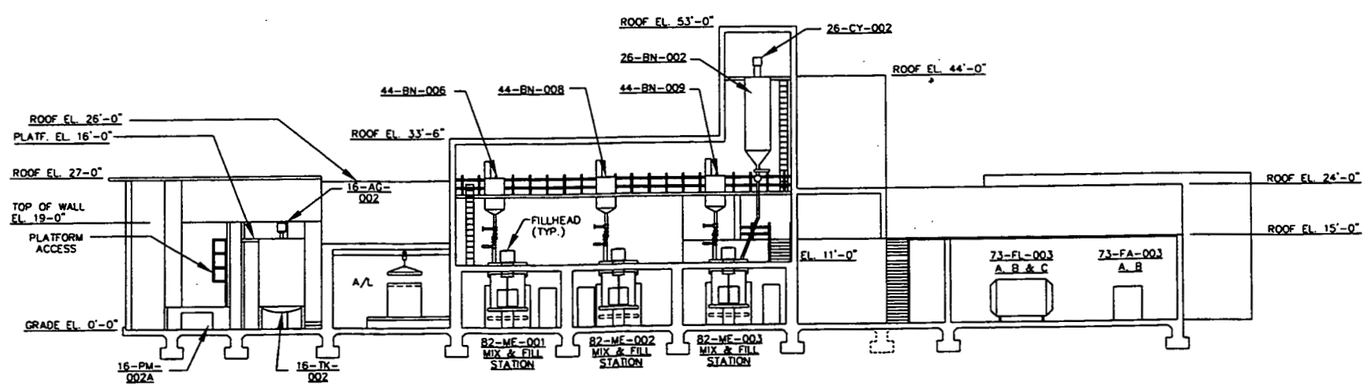
SECTION 'A'-'A'

SEE SK-7420 & SK-7421



SECTION 'B'-'B'

SEE SK-7420 & SK-7421



SECTION 'C'-'C'

SEE SK-7420 & SK-7421

0 10 20 40 60 80 100

GRAPHIC SCALE IN FEET
3/64" = 1'-0"

NOTES:

1. BUILDING CONSTRUCTION
   - CONCRETE FLOOR SLAB AND FOUNDATIONS.
   - ARCHITECTURAL TYPE WALLS CONSIST OF STEEL FRAME STRUCTURE, INSULATED METAL SIDING, MEMBRANE ROOFING SUPPORTED BY STEEL DECKING AND INSULATION BOARD.
   - MODULAR WALL CONSTRUCTION CONSISTS OF INTERLOCKING PREFABRICATED SHIELDING WALLS AND COLUMNS.
   - ALL OTHER SHEILDING WALLS ARE 2'-0" THICK CONCRETE.
2. EMPTY CONTAINER STORAGE IS SINGLE STACK.

REFERENCE DRAWINGS

94X-5500-P-SK-7420
94X-5500-P-SK-7421
94X-5500-P-SK-7423

000692

PRELIMINARY DRAWING

DWG/FILE	SK-7422	CHECKER	ACAD R14

UNITED STATES
DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

THIS DRAWING PREPARED BY

FLUOR DANIEL FERNALD

SILOS PROJECT
CINCINNATI, OHIO

DRAWING TITLE

FACILITY LAYOUT
CHEMICAL STABILIZATION - OTHER SECTIONS
REVISED FEASIBILITY STUDY FOR SILOS 1 & 2

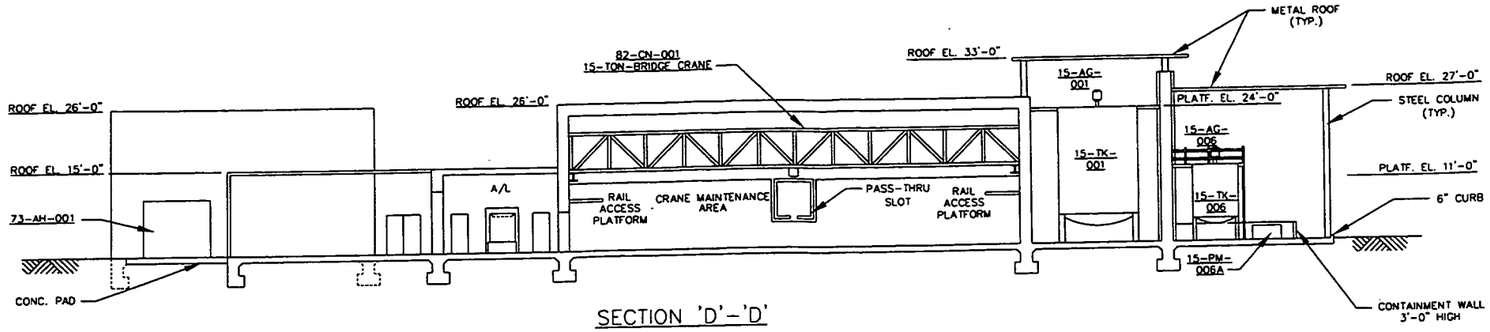
DRAWN BY S. M. YANKEY	DATE 12/3/98	SCIENTIST CHECKED BY	DATE	CHECKED BY J. THOMPSON	DATE 3/23/99
PLANT/BLDG. NO. OU4		FLOOR		SCALE 3/64" = 1'-0"	
SUBMITTED FOR APPROVAL		APPROVAL RECOMMENDED			
A-E	DATE	OPERATING CONTRACTOR	DATE		
DOE PROJECT NO. 40730	OPER. CONTR. PROJ. NO. WBS2.1.3.G.P	DRAWING NO. 94X-5500-P-SK-7422		SHEET NO. 1	REV. NO. 2

DISTRIBUTION CODE: XXX

ACAD

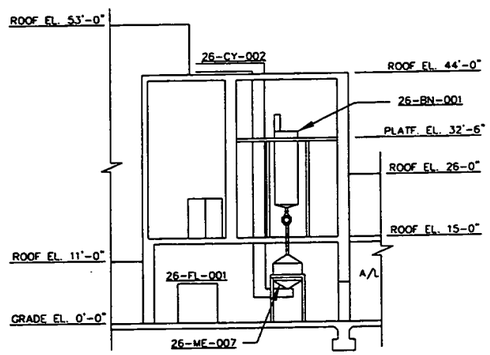
INITIALS: RWR
DATE: 12/1/99

8074



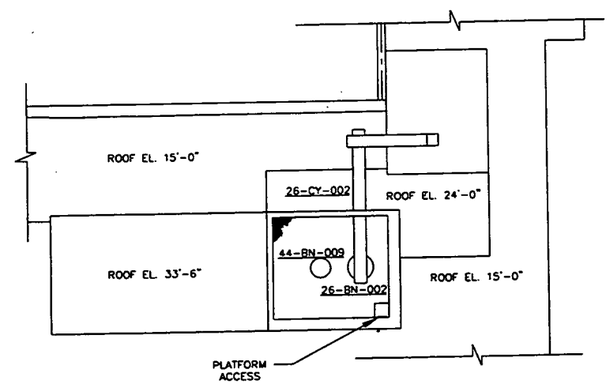
SECTION 'D'-'D'

SEE SK-7420 & SK-7421



SECTION 'E'-'E'

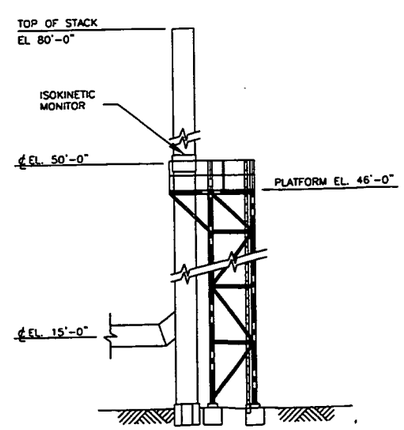
SEE SK-7420 & SK-7421



DETACHED PLAN 'A'

EL. 23'-0" THRU 50'-0"

SEE SK-7421



DETAIL A

N.T.S.

HVAC STACK 73-ST-001 & -002

SEE SK-7420 & SK-7421

GRAPHIC SCALE IN FEET
3/64" = 1'-0"

NOTES:

1. BUILDING CONSTRUCTION
   - CONCRETE FLOOR SLAB AND FOUNDATIONS.
   - ARCHITECTURAL TYPE WALLS CONSIST OF STEEL FRAME STRUCTURE, INSULATED METAL SIDING, MEMBRANE ROOFING SUPPORTED BY STEEL DECKING AND INSULATION BOARD.
   - MODULAR WALL CONSTRUCTION CONSISTS OF INTERLOCKING PREFABRICATED SHIELDING WALLS AND COLUMNS.
   - ALL OTHER SHEILDING WALLS ARE 2'-0" THICK CONCRETE.
2. EMPTY CONTAINER STORAGE IS SINGLE STACK.

REFERENCE DRAWINGS

94X-5500-P-SK-7420
94X-5500-P-SK-7421
94X-5500-P-SK-7422

000693

PRELIMINARY DRAWING

CHPLE SK-7423		CHECKER ACAD R14	
UNITED STATES DEPARTMENT OF ENERGY FERNALD ENVIRONMENTAL MANAGEMENT PROJECT			
THIS DRAWING PREPARED BY FLUOR DANIEL FERNALD SILOS PROJECT CINCINNATI, OHIO			
DRAWING TITLE FACILITY LAYOUT CHEMICAL STABILIZATION - OTHER DETAILS & SECTION REVISED FEASIBILITY STUDY FOR SILOS 1 & 2			
DRAWN BY S. M. YANKEY	DATE 12/2/98	ENGINEER CHECKED BY / DATE	CHECKED BY J. THOMPSON / DATE 9/28/99
PLANT/BLDG. NO. OU4	FLOOR		SCALE 3/64" = 1'-0"
SUBMITTED FOR APPROVAL		APPROVAL RECOMMENDED	
A-E / DATE		OPERATING CONTRACTOR / DATE	
DOE PROJECT NO. 40730	OPER. CONTR. PROJ. NO. WBS2.1.3.G.P	DRAWING NO. 94X-5500-P-SK-7423	SHEET NO. 1 / REV. NO. 2
DISTRIBUTION CODE: XXX		ACAD	INITIALS: RWR DATE: 12/1/99

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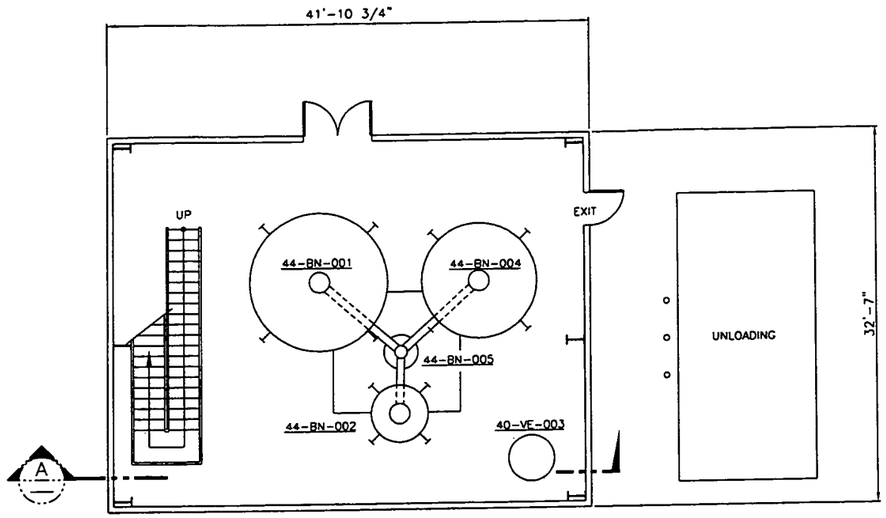
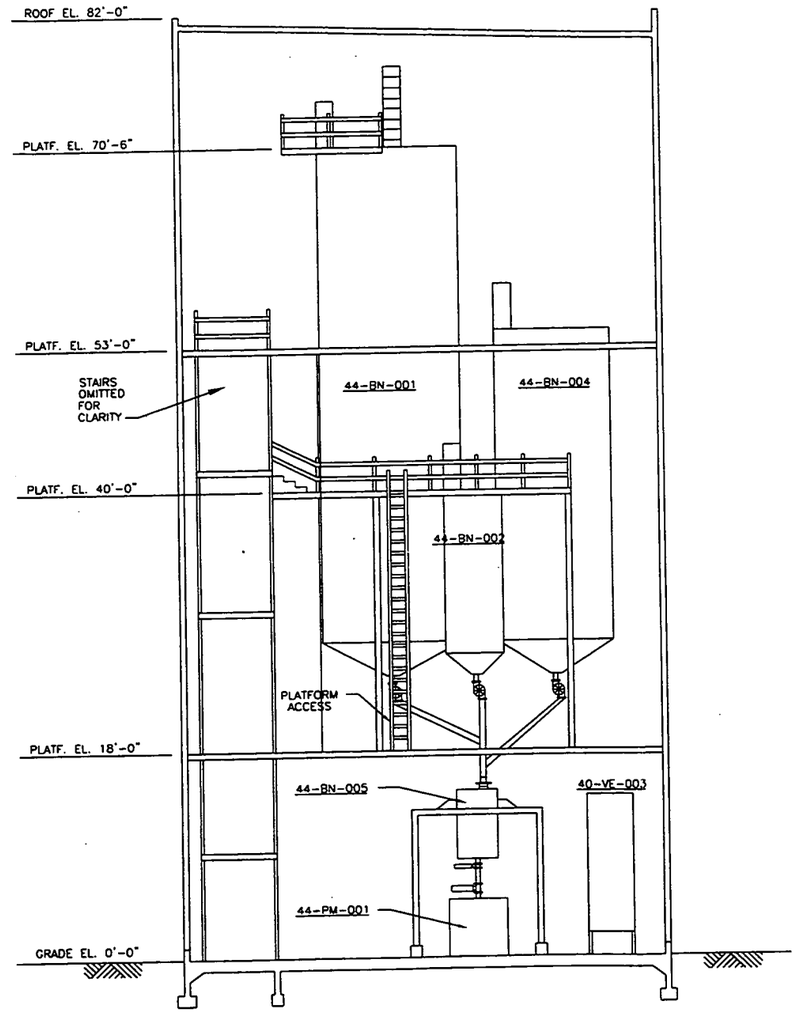
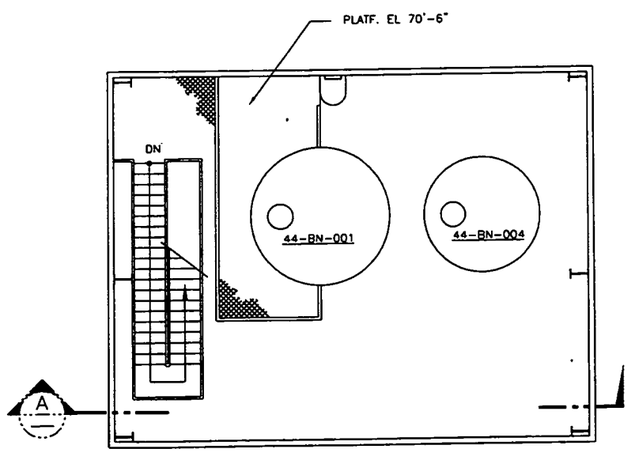


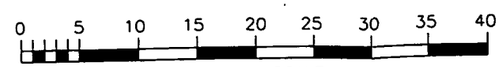
PLAN @ GRADE



SECTION 'A'-'A'



PLAN @ 53'-0" & ABOVE



GRAPHIC SCALE
1/8" = 1'-0"

NOTES:

BUILDING CONSTRUCTION

- CONCRETE FLOOR SLAB AND FOUNDATIONS
- STEEL FRAME STRUCTURE
- INSULATED METAL SIDING
- MEMBRANE ROOFING SUPPORTED BY STEEL DECKING AND INSULATION BOARD

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PRELIMINARY DRAWING

CAD FILE	SK-7428	CHECKED	ACADR14

UNITED STATES
DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

THIS DRAWING PREPARED BY

FLUOR DANIEL FERNALD
SILOS PROJECT
CINCINNATI, OHIO

DRAWING TITLE

FACILITY LAYOUT
CHEMICAL STABILIZATION - OTHER
CEMENT/ADDITIVE STORAGE BINS
REVISED FEASIBILITY STUDY FOR SILOS 1 & 2

DRAWN BY S. M. YANKEY	DATE 09/22/98	REVIEWED, CHECKED BY	DATE	CHECKED BY J. THOMPSON	DATE 8/18/99
PLANT/BLDG. NO. OU4		FLOOR		SCALE 1/8"=1'-0"	CLASS
SUBMITTED FOR APPROVAL: D.E.	DATE	APPROVAL RECOMMENDED: OPERATING CONTRACTOR	DATE		
DOE PROJECT NO. 40730	OPER. CONTR. PROJ. NO. WBS2.1.3.G.P	DRAWING NO. 94X-5500-P-SK-7428		SHEET NO. 1	REV. NO. 2

DISTRIBUTION CODE: XXX

ACAD

INITIALS: RWR
DATE: 12/1/99

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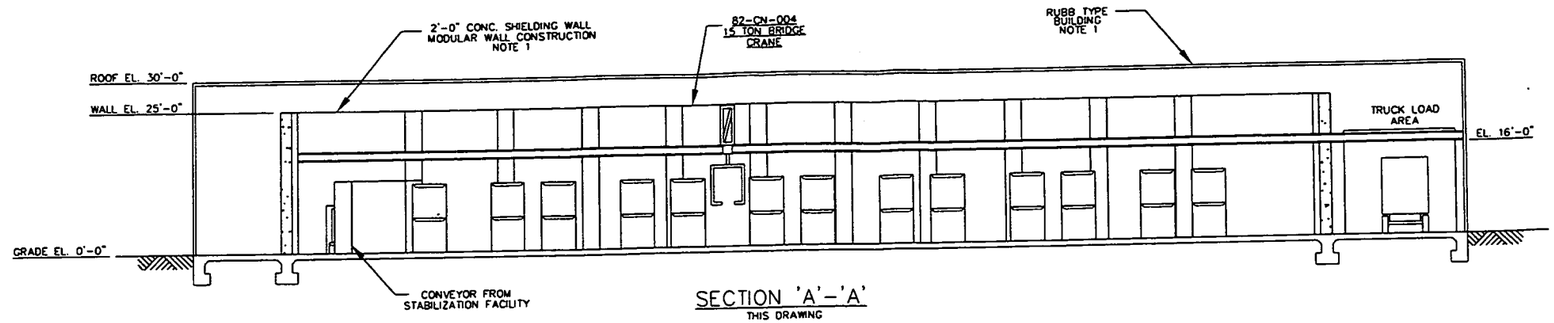
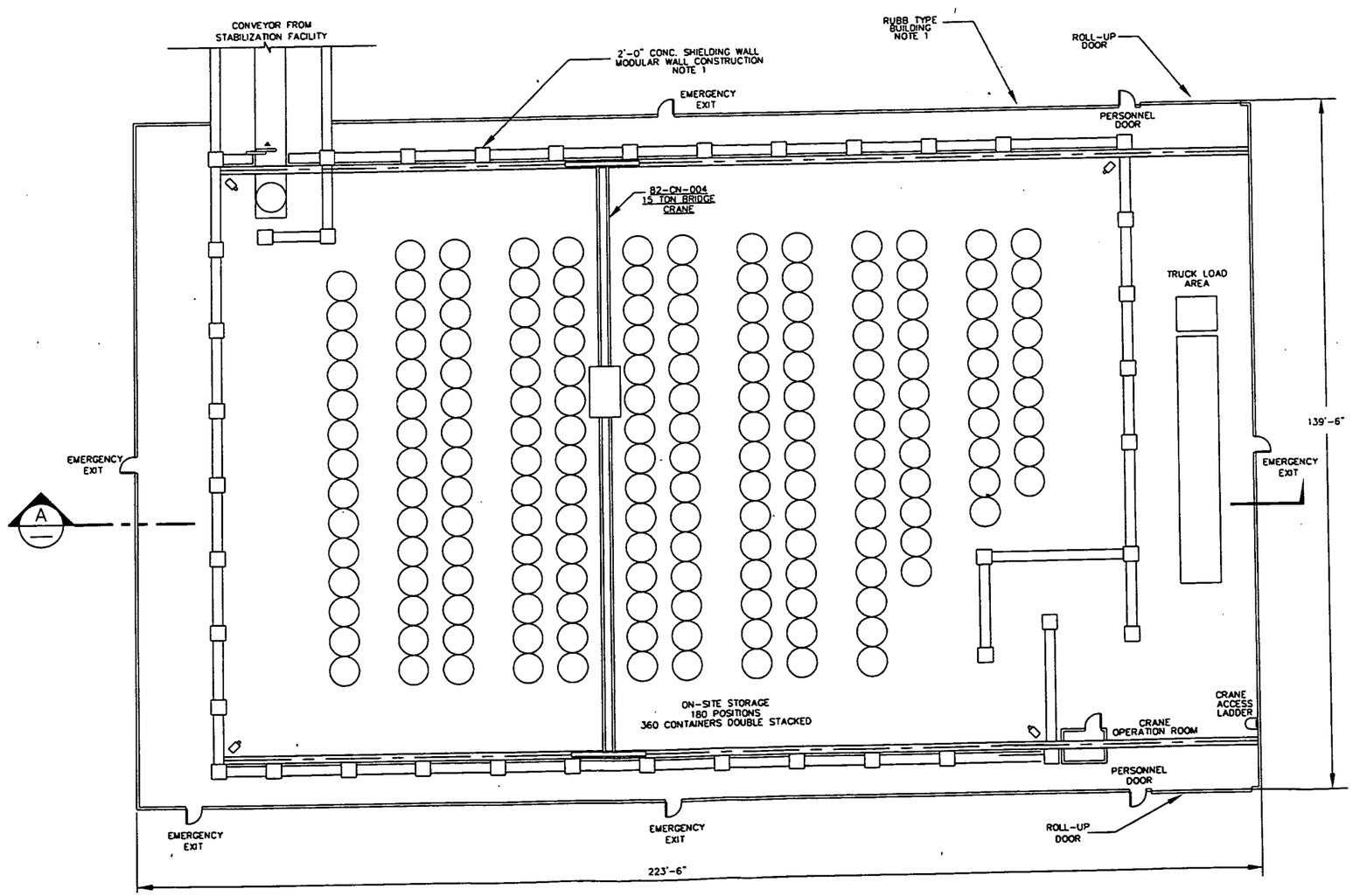


SECTION 'A'-'A'
THIS DRAWING



PLAN @ EL. 0'-0"

0 10 20 40 60 80 100

GRAPHIC SCALE IN FEET
3/64" = 1'-0"

NOTES:

1. BUILDING CONSTRUCTION
   - CONCRETE FLOOR SLAB AND FOUNDATIONS.
   - MODULAR WALL CONSTRUCTION CONSISTS OF INTERLOCKING PREFABRICATED SHEILDING WALLS AND COLUMNS.
2. SHIELD DOOR = ▲

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PRELIMINARY DRAWING

CHRFILE SK-7426		CHECKING ACAD R14	
UNITED STATES DEPARTMENT OF ENERGY FERNALD ENVIRONMENTAL MANAGEMENT PROJECT			
THIS DRAWING PREPARED BY FLUOR DANIEL FERNALD SILOS PROJECT CINCINNATI, OHIO			
DRAWING TITLE FACILITY LAYOUT CHEMICAL STABILIZATION - OTHER INTERIN CONTAINER STAGING REVISED FEASIBILITY STUDY FOR SILOS 1 & 2			
DRAWN BY S. YANKEY	DATE 12/17/98	REVIEWED, CHECKED BY / DATE	CHECKED BY J. THOMPSON / DATE 8/18/99
PLANT/BLDG. NO. OU4	FLOOR		SCALE 3/64" = 1'-0" / CLASS
SUBMITTED FOR APPROVAL / DATE	APPROVAL RECOMMENDED / DATE		
DOE PROJECT NO. 40730	OPER. CONTR. PROJ. NO. WBS2.1.3.G.P	DRAWING NO. 94X-5500-P-SK-7426	SHEET NO. 1 / REV. NO. 2
DISTRIBUTION CODE: XXX	ACAD	DETAILS: RWR DATE: 12/1/99	

Appendix G Attachments

1. *Treatment Quantity Calculations for the Technologies Presented in the Revised Feasibility Study for Silos 1 and 2*, Revision 0, Calculation No. 40730-CA-0006, dated August 20, 1999.

2. *Chemical Stabilization Treatment and TCLP Correlations with the Fernald OU4 Silos 1 and 2 Material*, dated August 16, 1999.

8074

Attachment G1

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Attachment G1

Treatment Quantity Calculations for the Technologies Presented in the Revised Feasibility Study for Silos 1 and 2

Revision 0

Calculation No. 407370-CA-0006

August 20, 1999

FLUOR DANIEL FERNALD
CALCULATION TITLE SHEET

-- 8074

Total No. of Pages 21
plus appendix

TITLE/SUBJECT: **Treatment Quantity Calculations for the Technologies Presented in the Fernald OU-4 Revised Feasibility Study**

DEPARTMENT:	Silos Project Engineering	ORIGINATOR:	Rod Gimpel	DATE:	08/20/99
CALCULATION NO.:	407370-CA-0006	CHECKER:	Brian Kauffman	DATE:	08/20/99
PROJECT:	Revised OU-4 FS	APPROVED:	John Smets	DATE:	08/20/99

RECORD OR REVISIONS:

No.	Date	Reason for Revision	Orig	Check	Approve
0	08/20/99	Original Issue	RJG 8-20-99	BMK 8-20-99	

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Treatment Quantity Calculations for Technologies Present in Fernald OU-4 Revised FS

PURPOSE

The purpose of this calculation is to determine the disposal box dimensions, the total number of boxes to dispose, and the bulking factor for the four technologies that are evaluated in the OU-4 Revised Feasibility Study.

SUMMARY

Calculations are presented in this document that determine the quantity of treated materials, etc., expected to be produced from the residues presently stored in Fernald Silos 1 and 2. Quantities were determined for each of the four technologies being investigated in the Revised Feasibility Study. The technologies and the calculated disposal quantities are summaries in the following Table 1.

Disposal Quantities Summary
Table 1

Technology	Number of Containers	Disposal Weight (includes container, tons)	Disposal Volume (includes container, yd^3)	Bulking Factor (volume increase)
Chemical Stabilization – Cement	6,078	63,637	47,652	+436%
Chemical Stabilization – Other	6,106	64,113	43,352	+388%
Vitrification – Joule Heated	2,398	25,179	11,635	+31%
Vitrification – Other	2,162	22,461	16450	+84%

The Bucking Factor is the percentage of volume increase from the residues in the silos to the packaged volume in the disposal cell.

BASIS

The volumes and densities of the silo residues used in the treatment calculations are from the Fernald Units Waste Information Manual, dated 1995. The only exception is the dry density of bentonite which is listed as 74.00 lbs/ft^3. This value is a correct density for dry bentonite; however, the bentonite "paste" placed in the silos contains an average of 75 wt% moisture or 25 wt% bentonite solids. Therefore, its effective amount of dry bentonite per volume of bentonite paste placed in the silos is assumed to be 25% of 74.00 lbs/ft^3 or 18.5 lbs/ft^3.

Intrinsic data (e.g., densities) of the treated wastes come from empirical data obtained from Proof of Principle Demonstrations, for each of the technologies, using the Demonstration Surrogates. Waste loading values used come from the Waste Loading Basis document presented in the Basis for Design document for the Revised FS. This report uses the empirically determined data during the POP Demonstrations and makes allowances (with justification given) for differences expected in the full-scale facilities operations not demonstrated in the demonstrations, for example, recycle of treated filtrate.

The SEG container was used for the Vitrification – Joule Heated alternative. The other alternatives use custom containers that optimize the economics based on the container thickness needs for radiation shielding vs. container disposal weights and volumes. The necessary container thicknesses for radiation shielding were determined using MicroShield, a specialized computer program for this purpose (see Appendix B). The containers are required to withstand the drop test defined in the DOT IP2, Type A requirements. Some metal wire-screen reinforcement was included to strengthen the container for the drop test. The actual amount of reinforcement would be calculated during detailed design of the selected container type.

Further basis, for the calculations, is contained in the Design Basis for the Revised Feasibility Study. Likewise, these calculations augment the Design Basis.

REFERENCES

Given in the Design Basis paragraphs given above.

CALCULATIONS

Follow.

Transfer to Temporary Tanks – Common to All Technologies

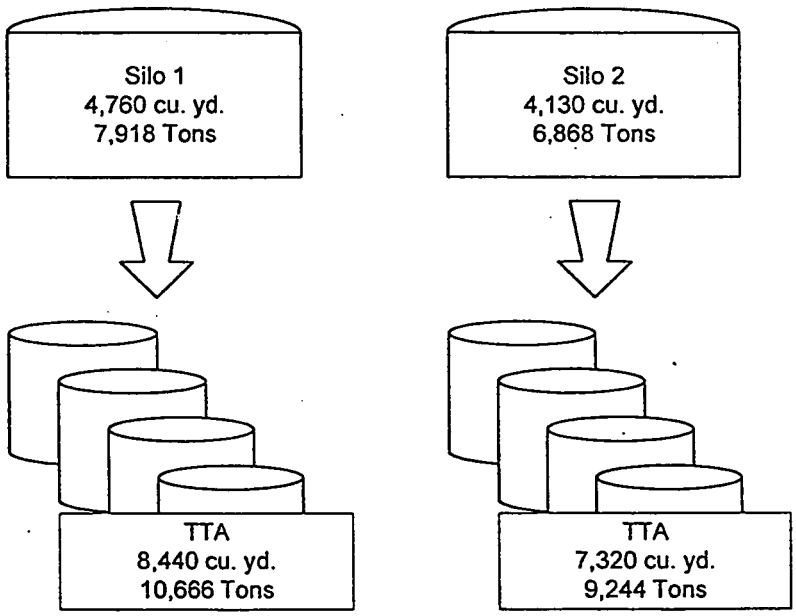
In-Situ Storage

8,890 cu. yd.
14,787 Tons at 30 wt% Moisture
9,955 Tons Dry

Temporary Storage

15,760 cu. yd.
19,976 Tons at 50 wt% Moisture
9,955 Tons Dry

Bulking Factor: +77%



TRANSFER TANK AREA (TTA) TEMPORARY STORAGE – COMMON TO ALL

Silo 1	Volume	Dry Density	Dry Weight	Dry Weight
Residues	115,911 ft^3	90 lbs./ft^3	10,431,990 lbs.	5,216 tons
Bentonite	12,609	18.50	233,267	117 tons
Total	128,520 ft^3 (or 4760 yd^3)		10,665,257 lbs.	5,333 tons

Silo 1 - Insitu	Dry Weight	% Moisture	Insitu	TTA% Moisture	TTA Insitu
Residues	5,216	30 wt%	7,451 tons	50 wt%	10,432 tons
Bentonite	117	75 wt%	467	50 wt%	234 tons
Total	5,333 tons		7,918 tons		10,666 tons

TTA1 Volume Calculation

Use specific gravity of sludge = 1.5
TTA1 volume = {(10,666 tons)(2,000 lb/ton)}/{(1.5)(62.4 lb/ft^3)(27 ft^3/yd^3)]}
TTA1 volume = 8,440 yd^3

Silo 2	Volume	Dry Density	Dry Weight	Dry Weight
Residues	100,413 ft^3	90 lbs./ft^3	9,037,170 lbs.	4,519 tons
Bentonite	11,097	18.50/ft^3	205,295	103 tons
Total	111,510 ft^3 (or 4,130 yd^3)		9,242,465 lbs.	4,622 tons

Silo 2 - Insitu	Dry Weight	% Moisture	Insitu	TTA% Moisture	TTA Insitu
Residues	4,519 tons	30 wt%	6,456 tons	50 wt%	9,038 tons
Bentonite	103	75 wt%	412	50 wt%	206 tons
Total	4,622 tons		6,868 tons		9,244 tons

TTA2 Volume Calculation

Use specific gravity of sludge = 1.5
TTA1 volume = {(9,244 tons)(2,000 lb/ton)}/{(1.5)(62.4 lb/ft^3)(27 ft^3/yd^3)]}
TTA1 volume = 7,320 yd^3

Summary

Weight = 10,666 tons + 9,244 tons = 19,976 tons
Volume = 8,440 yd^3 + 7,320 yd^3 = 15,760 yd^3

$$\text{Bulking Factor} = \frac{(15{,}760\ yd^3 - 8{,}890\ yd^3)}{8{,}890\ yd^3} \times 100\% = 77.28\%$$

Date: 08/20/99
40730-CA-0006
Author RJG
Checker BMK
Sheet 5

Vitrification - Other

8074

Situ Storage

.890 cu. yd.
14,787 Tons at 30 wt% Moisture
9,955 Tons Dry

Silo 1
4,760 cu. yd.
7,918 Tons

Silo 2
4,130 cu. yd.
6,868 Tons

Temporary Storage

15,760 cu. yd.
19,976 Tons at 50 wt% Moisture
9,955 Tons Dry
Bulking Factor: +77%

TTA
8,440 cu. yd.
10,666 Tons

TTA
7,320 cu. yd.
9,244 Tons

Transferred at 10 - 30 wt% Solids

Vitrification

Bulking Factor: -45%
8,689 cu. yd.
10,298 Tons

Process Summary

Waste Form: Glass Cullet
Additives: Fluxes, Stabilizers
Specific Gravity: 2.81
Density: 1.41 g/cc
Waste Loading: 87%
Chemically bond water, hydroxide, etc., results in approximately 10 wt% additional loss to off-gas

Frit
Packing Fraction: 50%

Packaging

Bulking Factor: +88%

Container Summary:

Dimensions:
Exterior: 78" L x 66" W x 65" H (w/o forklift runners)
Interior: 68" L x 56" W x 55" H
Material: 5-in thick high-density concrete with steel wire screen reinforcement
Runners: 2-10" x 4" concrete strips
Weight: 5.60 (with forklift runners) tons empty
Other: 90% filled

Disposal

Overall Bulking Factor: +84%
(Includes a 0.9% increase from recycle and rework.)

16,450 cu. yd.
22,461 Tons
2,162 Containers

000703

Vitrification – Joule Heated

Vitrification – 90 wt% waste loading, + 10% extra losses from hydroxides, etc., with the in-situ solids density 2.814 g/cm^3 (175.594 lbs./ft^3), 2% air pockets.

Mass Glass = (19,910,000 lbs. dry/0.9)(1 – 0.1) = 19,910,000 lbs. glass
= 19,910,000 lbs. x (1 ton/2,000 lbs.) = 9,955 tons

Volume of Glass = (19,910,000 lbs.)/(175.594 lbs./ft^3)
= 113,386 ft^3

Assume the glass monolith has approximately 2% air pockets, therefore,

Volume of Glass (adjusted for air pockets) = 113,386 ft^3 + (113,386 ft^3 x 0.02)
= 115,655 ft^3
= [115,655 ft^3 x (1 yd^3/27 ft^3)] = 4,283 yd^3

$$\text{Bulking Factor} = \frac{(4{,}283\ yd^3 - 15{,}760\ yd^3)}{15{,}760\ yd^3} \times 100\% = -72.8\%$$

Packaging

Inner Container: Monolith Transfer Container (MTC).

MTC Weight:

Steel Area = 2 x 3.33 ft x 1.67 ft + 2 x 2.5 ft x 3.33 ft + 1 x 1.67 ft x 2.5 ft
= 31.95 ft^2

Volume = (1/8 inch)(ft/12 in)(31.95 ft^2) = 0.333 ft^3

Weight = (492 lbs./ft^3)(0.333 ft^3) = 164 lbs. per MTC

Weight of 4 MTCs = (4 MTCs x 164 lbs./MTC) = 656 lbs.

MTC Volume = 3.33 ft x 2.5 ft x 1.67 ft = 13.9 ft^3

4 MTCs = 55.61 ft^3 at 90% fill = 50.05 ft^3

Weight of Glass = (50.05 ft^3/container) (2.814 g/cm^3) (62.4 lbs./ft^3/(g/cm^3)) (1 – 0.02)
= 8,613 lbs./container (Note: 0.02 is assumed for air pockets)

Outer Container Empty Weight = 12,000 lbs./container (SEG box with forklift runners as part of the box)

Estimated Total Gross Weight = 12,000 lbs. + 8,613 lbs. + 656 lbs. = 21,269 lbs.

Vitrification-Joule Heated (Continued)

Note: This is over the 21,000 lbs. limit by 269 lbs., so the glass weight is less this amount.

Adjusted Weight of Glass Per Container = 8,613 lbs. – 269 lbs. = 8,344 lbs./container

Adjusted Volume of Glass per Container = (8,344 lbs./container)/ [(2.814 g/cm^3)(62.4 lbs./ft^3/(g/cm^3))] (1-0.02) = 48.48 ft^3/container

MTC % Fill = $\frac{8{,}344 \text{lbs.}}{8{,}613 \text{lbs.}/0.90}$ x 100% = 87% Note: 90% fill is 8,613 lbs.

Container inner volume = 3.5 ft x 5.0 ft x 3.5 ft = 61.25 ft^3

Outer Container % Fill = 48.48 ft^3/61.25 ft^3 x 10.0% = 79%

Outer Container: 4 MTCs per outer container.

Outside of SEG Container Volume = 4.5 ft x 6 ft x 4.83 ft = 131 ft^3.

Volume of Glass = 48.48 ft^3 (previously calculated for 4 MTCs)

Container Bulking Factor = $\frac{(131 \text{ ft}^3 - 48.48 \text{ ft}^3)}{48.48 \text{ ft}^3}$ x 100% = +170.9%

Disposal

Number of Containers = 19,910,000 lbs./(8,344 lbs./container) = 2,386 containers

Disposal Volume = (2,386 containers)(131 ft^3/container) = 312,566 ft^3
= 312,566 ft^3 x (1 yd^3/27 ft^3) = 11,577 yd^3

Disposal Weight = (21,000 lbs./container)(2,386 containers)/2,000 lbs./ton
= 25,053 tons

Overall Bulking Factor = $\frac{(11{,}577 \text{ yd}^3 - 8{,}890 \text{ yd}^3)}{8{,}890 \text{ yd}^3}$ x 100% = +30.2%

Rework, assumed to be 1% of total containers, 1.5 new containers made for each failed container. This increases the total by 0.5 (i.e., 1.5 new containers – 1 failed container).

Extra Containers = (2,386 containers)(0.01)(0.5 extra containers/container)
= 12 containers

Vitrification-Joule Heated (Continued)

Impact of Fines in TTA Recycle Water

No impact since the fines will be made into glass and the extra water will be evaporated in the melter.

Rework and Recycle Impact:

Number of Containers = 2,398 containers

Disposal Weight = 25,179 tons

Disposal Volume = 11,635 yd^3

Adjusted Overall Bulking Factor = +30.9%

% Volume = 30.9% - 30.2% = +0.7%

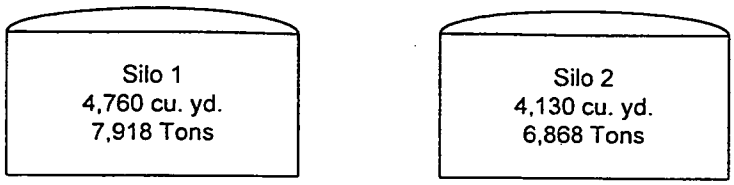
Date: 08/20/99
40730-CA-0006
Author
Checker
Sheet 9

8074

Vitrification - Other

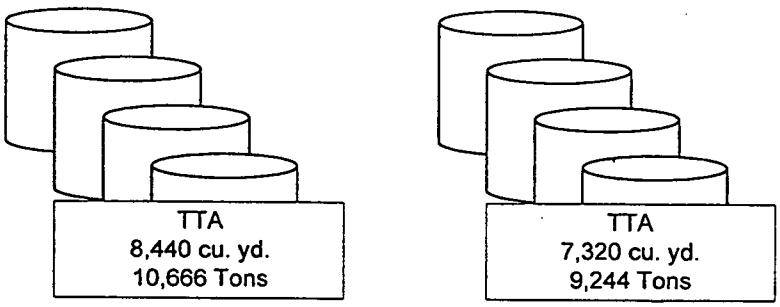
Situ Storage

,890 cu. yd.
14,787 Tons at 30 wt% Moisture
9,955 Tons Dry

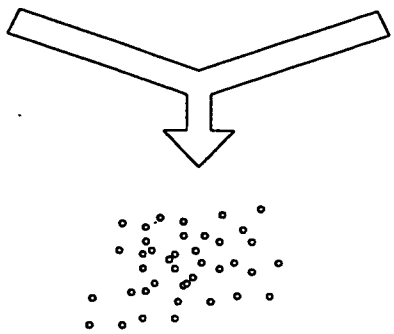


Temporary Storage

15,760 cu. yd.
19,976 Tons at 50 wt% Moisture
9,955 Tons Dry
Bulking Factor: +77%



Transferred at 10 - 30 wt% Solids



Vitrification

Bulking Factor: -45%
8,689 cu. yd.
10,298 Tons

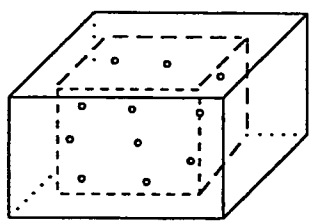
Process Summary

Waste Form: Glass Cullet
Additives: Fluxes, Stabilizers
Specific Gravity: 2.81
Density: 1.41 g/cc
Waste Loading: 87%
Chemically bond water, hydroxide, etc., results in approximately 10 wt% additional loss to off-gas

Frit
Packing Fraction: 50%

Packaging

Bulking Factor: +88%

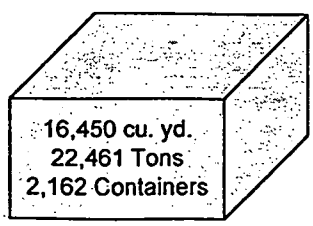


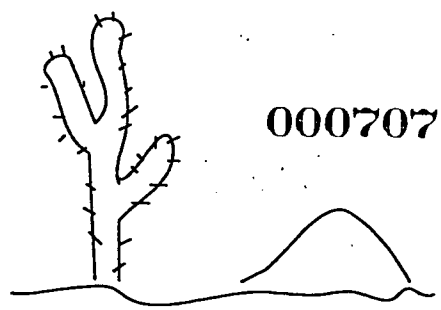
Container Summary:

Dimensions:
Exterior: 78" L x 66" W x 65" H (w/o forklift runners)
Interior: 68" L x 56" W x 55" H
Material: 5-in thick high-density concrete with steel wire screen reinforcement
Runners: 2-10" x 4" concrete strips
Weight: 5.60 (with forklift runners) tons empty
Other: 90% filled

Disposal

Overall Bulking Factor: +84%
(Includes a 0.9% increase from recycle and rework.)





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Vitrification – Other

Vitrification – 87 wt% waste loading, + 10% extra losses from hydroxides, etc., with the in-situ solid density 2.814 g/cm^3 (175.594 lbs./ft^3) .

Mass Glass = (19,910,000 lbs. dry/0.87)(1 – 0.1) = 20,596,552 lbs. glass
= 20,596,552 lbs. x (1 ton/2,000 lbs.) = 10,298 tons glass

Volume of Solid Glass = (20,596,552 lbs.)/175.594 lbs./ft^3) = 117,296 ft^3

Frit has approximately 50% packing fraction, therefore,

Volume of frit = 117,296 ft^3/0.50 = 234,592 ft^3 x (yd^3/27 ft^3) = 8,689 yd^3

$$\text{Bulking Factor} = \frac{(8{,}689\ yd^3 - 15{,}760\ yd^3)}{15{,}760\ yd^3} \times 100\% = \underline{-44.9\%}$$

Packaging

The SEG container is designed for high-density waste-loading glass. The bulk (effective) waste loading for frit is less, so using the SEG container for cullet would not be cost effective. Frit contains approximately 50% void space. The effective density and waste loading of the frit are:

Effective Density = (175.594 lbs./ft^3)(0.50) = 87.797 lbs./ ft^3
Effective Waste Loading = (0.87)(0.50) x 100 wt% = 43.5 wt%

For economics, a concrete container with an effective wall thickness of 5 inches may be best. Therefore, the following are the box dimensions:

Box Dimensions

Wall: 5-inch high-density concrete was calculated per a Microshield calculation (see appendix).
Container = 5-inch high-density concrete w/wire-screen reinforcement.

Exterior Dimensions L x W x H (w/o forklift runners)	=	78" x 66" x 65" 6.5' x 5.5' x 5.417'
Interior Dimensions L x W x H	=	68" x 56" x 55" 5.667' x 4.667' x 4.583'

External Volume (w/forklift runners) = 6.5 ft x 5.5 ft x (5.42 ft + 0.33 ft) = 205 ft^3 x (1 yd^3/27 ft^3) = $\underline{7.609\ yd^3}$

External Volume (w/o forklift runners) = 6.5 ft x 5.5 ft x 5.417 ft = 193.7 ft^3
= 193.7 ft^3 (1 yd^3/27 ft^3) = 7.174 yd^3

Inner Volume = 5.667 ft x 4.667 ft x 4.583 ft = $\underline{121.2\ ft^3}$

Vitrification - Other (Continued)

Volume Concrete = 193.7 ft^3 - 121.2 ft^3 = 72.5 ft^3

Weight of high-density concrete = (72.5 ft^3)(147 lbs./ft^3) = 10,658 lbs.
= 10,658 lbs. x (1 ton/2,000 lbs.)
= 5.329 tons

Forklift Runners: Use two 10-in wide x 4-in high concrete runners the width of the box

Runners = 2[(10 in)(1 ft/12 in)][4 in)(1 ft/12in)](5.5 ft)(147 lbs./ft^3)
= 449 lbs.

Wire-Screen Reinforcement = 94 lbs. per report 40730-ES-002

Container Weight = 10,658 lbs. + 449 lbs. + 94 lbs. = 11,201 lbs.
= 5.60 tons

90% fill = 0.90(121.2 ft^3) = 109.08 ft^3 = (109.08 ft^3)(87.797 lbs./ft^3)
= 9,577 lbs.

Container Gross Weight = 11,201 lbs. + 9,577 = 20,778 lbs. = 10.389 tons (This is below the 21,000 lb. limit.)

Disposal

Number of Containers = 20,596,522 lbs./(9,577 lbs./container) = 2,151 containers

Disposal Weight = (10.389 tons/container)(2,151 containers) = 22,347 tons

Disposal Volume = (2,151 containers)(7.609 yd^3) = 16,367 yd^3

$$\text{Container Bulking Factor} = \frac{16{,}367\ yd^3 - 8{,}689\ yd^3}{8{,}689\ yd^3} \times 100\% = +88.4\%$$

$$\text{Overall Bulking Factor} = \frac{16{,}367\ yd^3 - 8{,}890\ yd^3}{8{,}890\ yd^3} \times 100\% = +84.1\%$$

Vitrification-Other (Continued)

Rework, assumed to be 1% of total containers, 1.5 new containers made for each failed container. This increases the total by 0.5 (i.e., 1.5 new containers – 1 failed container).

Extra Containers = (2,151 containers)(0.01)(0.5 extra containers/container)
= 11 containers

Number of Containers	= 2,162 containers
Disposal Weight	= 22,461 tons
Disposal Volume	= 16,450 yd^3
Adjusted Overall Bulking Factor	= +85.0%
% Increase = 85.0% - 84.1%	= +0.9%

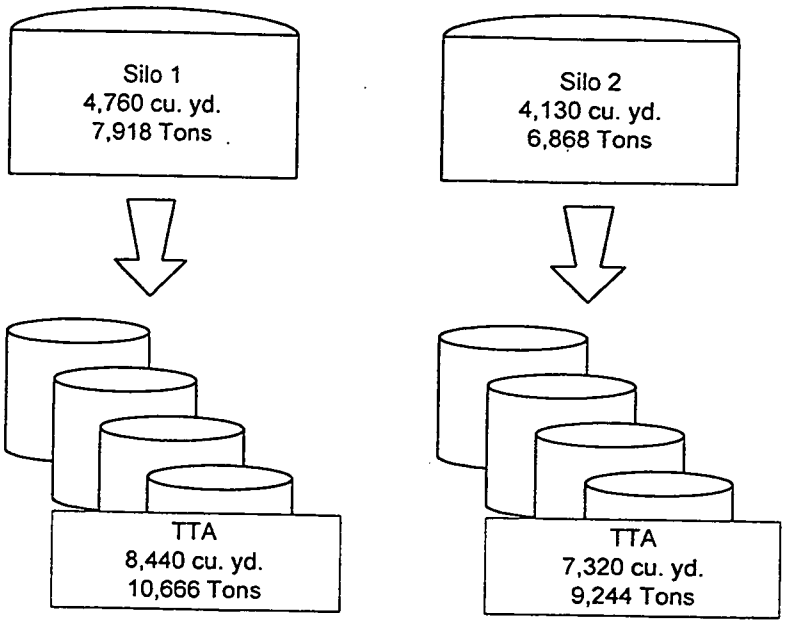
Date: 08/20/99
40730-CA-0006
Author RJG
Checker BMK
Sheet 13

Chemical Stabilization - Cement

-- 8074

In-Situ Storage

8,890 cu. yd.
14,787 Tons at 30 wt% Moisture
9,955 Tons Dry



Temporary Storage

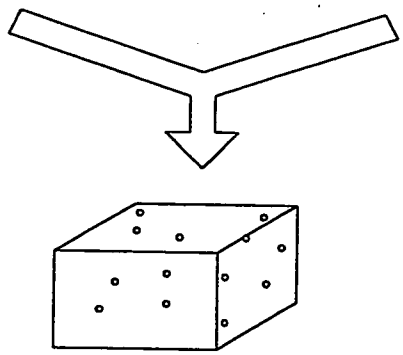
15,760 cu. yd.
19,976 Tons at 50 wt% Moisture
9,955 Tons Dry

Bulking Factor: +77%

Chemical Stabilization

Bulking Factor: +73%
27,254 cu. yd.
[illegible]3,183 Tons

Transferred at 10 - 30 wt% Solids



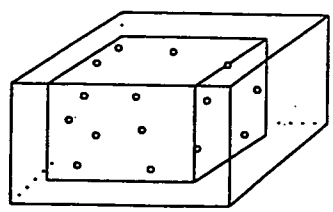
Process Summary:

Waste Form: Semiflowable Grout
Additives: Cement, Calcium Hydroxide, Phosphate, Iron Sulfate
Density: 1.52 g/cc
Waste Loading: 30 wt%
Secondary Waste: Filter Press Liquid, high Lead and Selenium

Waste Form Contains 5% Honeycombing, Airpockets

Packaging

Bulking Factor: +70%

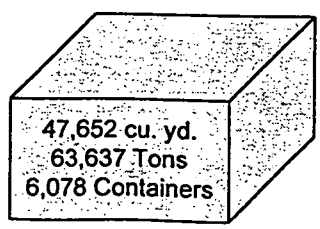


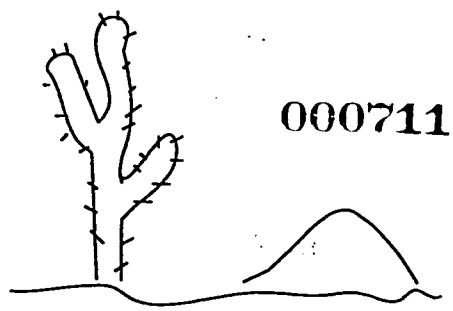
Container Summary:

Dimensions:
Exterior: 78" L x 67" W x 66" H w/o forklift runners
Interior: 70" L x 59" W x 58" H
Material: 4" high-density concrete with wire-screen reinforcement
Runners: 2-10" x 4" concrete strips
Weight: 4.59 tons empty, 90% fill by volume
Other: 25 pounds plastic, 100 pounds absorbent, 50 pounds metal-foil liner for radon control

Disposal

Overall Bulking Factor: +436%
(Includes a +16% increase from recycle and rework.)





000711

Chemical Stabilization – Cement

Chemical Stabilization – 30 wt% waste loading, density 1.52 g/cm^3 (94.7 lbs./ft^3), 5% air pockets/honey combing

Weight Concrete = (9,955 tons dry waste) (2,000 lbs./ton)/0.30 lb. waste
= 66,366,666 lbs. = 33,183 tons

Volume Concrete = (66,366,666 lbs.)/(94.7 lbs./ft^3) = 700,810 ft^3

Cement-based stabilized monolith has 5% air pockets, therefore,

Volume of Concrete
(adjusted for air pockets) = 700,810 ft^3 + (700,810 ft^3 x 0.05)
= 735,850 ft^3 = 735,850 ft^3/(27 ft^3/yd^3)
= 27,254 yd^3

$$\text{Bulking Factor} = \frac{(27{,}254\ yd^3 - 15{,}760\ yd^3)}{15{,}760\ yd^3} \times 100\% = +72.9\%$$

Packaging

Container = 4"-inch high-density concrete w/wire-screen reinforcement

Exterior Dimensions L x W x H = 78" x 67" x 66"
6.5' x 5.583' x 5.5'

Interior Dimensions L x W x H = 70" x 59" x 58"
5.833' x 4.917' x 4.833'

External Volume = (6.5 ft)(5.583 ft)[5.5 ft + 4 in/(12 in/ft)]
(with forklift runners) 211.7 ft^3 x 1 yd^3/27 ft^3 = 7.840 yd^3

External Volume = 6.5 ft x 5.583 ft x 5.5 ft = 199.6 ft^3
(w/o forklift runners) = 199.6 ft^3 (1 yd^3/27 ft^3) = 7.392 yd^3

Internal Volume = 5.833 ft x 4.917 ft x 4.833 ft
= 138.6 x (1 yd/27 ft^3 = 5.134 yd^3

Volume of High-Density Concrete = 199.6 ft^3 – 138.6 ft^3 = 61.00 ft^3

Weight of High Density Concrete = 61.00 ft^3 x (147 lbs./ft^3) = 8,967 lbs.

Forklift Runners: Use two 10-in wide x 4-in high concrete runners the width of the box

Weight Runners: 2[(10 in)(1 ft/12 in)][(4 in)(1 ft/12 in)](5.583 ft)(147 lbs./ft^3)
= 456 lbs.

Chemical Stabilization – Cement (Continued)

Wire-Screen Reinforcement = 94 lbs. per report 40730-ES-002

Container Weight = 8,967 lbs. + 456 lbs. + 94 lbs. = 9,517 lbs.

Assume: absorbent = 100 lbs., plastics = 25 lbs., metal-foil liner for radon control = 50 lbs.

Container weight adjusted = 9,517 lbs. + 100 lbs. + 25 lbs. + 50 lbs. = 9,692 lbs. or 4.846 tons

90% fill = 138.6 ft^3 (0.90) = 124.7 ft^3

Disposal

Number of Containers = (735,850 ft^3/124.7 ft^3) = 5,901 containers

Gross Container Weight = (33,183 tons/5,901) + 4.846 tons = 10.47 tons
= 10.47 tons x (2,000 lbs./ton) = 20,940 lbs.
This is below the 21,000 lb. container limit.

Disposal Weight = (10.47 tons/container)(5,901 containers) = 61,783 tons

Disposal Volume = (7.84 yd^3/Container)(5,901 containers) = 46,264 yd^3

Container Bulking Factor = $\frac{(46{,}264\ yd^3 - 27{,}254\ yd^3)}{27{,}254\ yd^3} \times 100\% = +69.8\%$

Overall Bulking Factor = $\frac{(46{,}264\ yd^3 - 8{,}890\ yd^3)}{8{,}890\ yd^3} \times 100\% = +420.4\%$

Rework, 1% of total container, 3 new containers made for each failed container. This increases the total by 2 (i.e., 3 new containers – 1 failed container).

Extra containers = (5,901 containers)(0.01)(2 extra rework containers/failed container)
= 118 extra containers

Impact of Filtrate Treatment and Recycle

Treatment of lead in filtrate and recycle add 1% of total containers. This equates to 59 containers.

Rework and Recycle Impact

Number of containers = 5,901 + 118 + 59 = 6,078 containers

Chemical Stabilization – Cement (Continued)

Disposal Weight = (6,078 containers)(10.47 tons/container) = 63,637 tons

Disposal Volume = (6,078 containers)(7.84 yd^3/container) = 47,652 yd^3

$$\text{Overall Bulking} = \frac{(47{,}652\ yd^3 - 8{,}890/yd^3)}{8{,}890\ yd^3} \times 100\% = +436.0\%$$

% increase = 436.0% – 420.4% = +15.6%

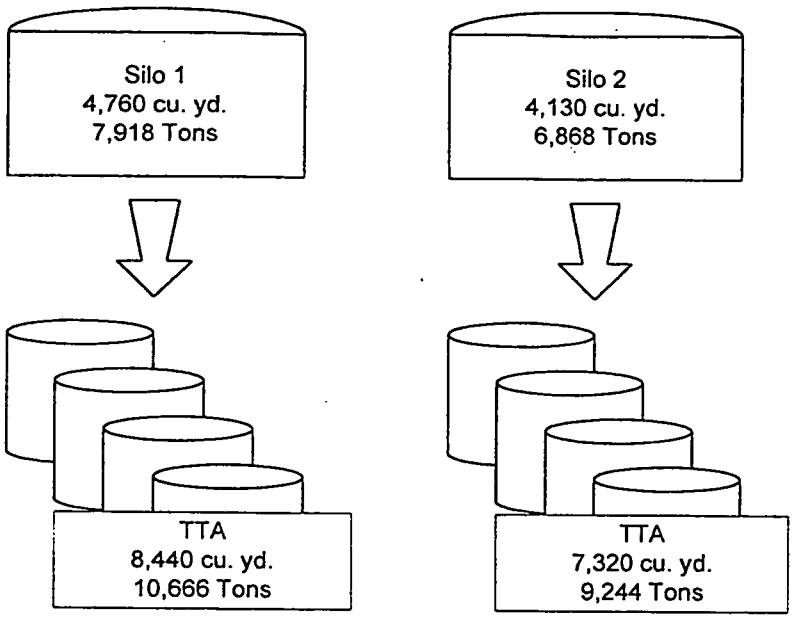
Date: 08/20/99
40730-CA-0006
Author RJG
Checker BMK
Sheet 17

Chemical Stabilization - Other

- 8074

-Situ Storage

8,890 cu. yd.
14,787 Tons at 30 wt% Moisture
9,955 Tons Dry



Temporary Storage

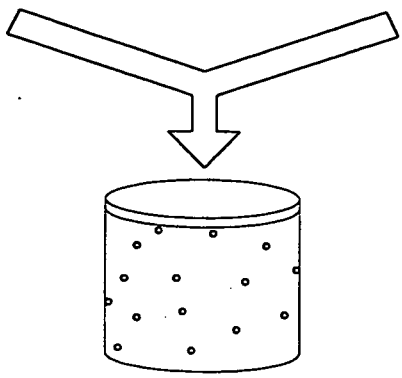
15,760 cu. yd.
19,976 Tons at 50 wt% Moisture
9,955 Tons Dry

Bulking Factor: +77%

Transferred at 10 - 30 wt% Solids

Chemical Stabilization

Bulking Factor: +90%
29,895 cu. yd.
479 Tons



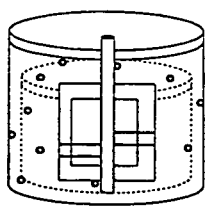
Process Summary:

Waste Form: In-container Mixing
Additives: Cement, Flyash, Phosphate
Density 1.68 g/cc
24 wt% Waste Loading
Decant Recycle and Treatment

Waste Form
Contains 2% Air Pockets

Packaging

Bulking Factor: +35%

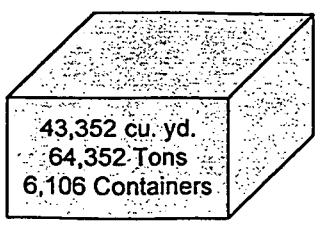


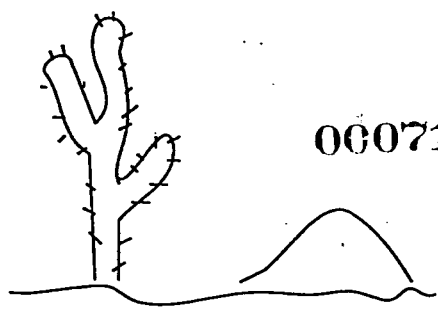
Container Summary:

Material: 3/4-inch steel plate plastic lined
Dimension: 76-inch diameter, 67.5 inches tall (excludes 1.5-in lid and 4-in forklift runners)
Weight: 2.68 tons empty
0.5 tons internals, etc.
Other: 100 pounds absorbent, 85% fill by volume

Disposal

Overall Bulking Factor: +388%
(Includes a +32% increase from cycle and rework.)





000715

Chemical Stabilization – Other

Chemical Stabilization – 24 wt% waste loading, density 1.68 g/cm^3, 2% air pockets

Weight Concrete = (9,955 tons)(2,000 lbs./ton)/0.24 = 82,958,333 lbs. of concrete = 41,479 tons

Volume Concrete = (82,958,333 lbs.)/[(1.68 g/cm^3)(62.4 lbs./ft^3/(g/cm^3)]
= 791,345 ft^3

Chemical-stabilized monolith has 2% air pockets, therefore,

Volume of Concrete
(adjusted for air pockets) = 791,345 ft^3 + (791,386 ft^3 x 0.02)
= 807,172 ft^3
= 807,172 ft^3/(27 ft^3/yd^3)
= 29,895 yd^3

$$\text{Bulking Factor} = \frac{(29{,}895\ yd^3 - 15{,}760\ yd^3)}{15{,}760\ yd^3} \times 100\% = +89.7\%$$

Packaging

Container Weight and Volumes (76-in diameter, ¾-in thick, 67.5 in height, or 6.33-ft diameter, 0.0625-ft thick, 5.625 ft height)

Volume Shell = π (76/12 ft)(0.75/12 ft)(67.5/12 ft) + $2\pi/4$ (76/12 ft)^2(0.75/12 ft) = 10.94 ft^3

Weight = (492 lbs./ ft^3)(10.94 ft^3) = 5,380 lbs. x (1 ton/2,000 lbs.)
= 2.690 tons

Metal internal mixing assembly and extra parts (i.e., lid) = 1.5 ft^3

Weight = (1.5 ft^3)(492 lbs./ft^3) = 738 lbs.

Forklift Runners: Use 4 in I-beam, 11.5 lbs./ft length. Assume 2-5.5ft pieces and 2-3ft pieces are used.

Runner Weight = (5.5 + 5.5 + 3 +3)ft (11.5 lbs./ft) = 196 lbs.

Interior Plastic Coating for Corrosion Control = 50 lbs.

Total Weight = 5,380 lbs. + 738 lbs. + 196 lbs. +50 lbs. = 6,364 lbs.
x (1 ton/2,000 lbs.) = 3.182 tons (Note: 2.68 tons + ~0.5 tons internal parts, etc.)

Chemical Stabilization – Other (Continued)

Total Weight (with absorbent) = 6,364 lbs. + 100 lbs.
= 6,464 lbs. x (1 ton/2,000 lbs.) = 3.230 tons

Internal Volume = $(\pi/4)[[76 - (2 \times 0.75)]/12]^2 (66/12)] = 166.5\ ft^3$

External Volume = $(\pi/4)(76/12)^2 [(67.5 + 1.5 + 4)/12]$
= $191.6\ ft^3 \times (1\ yd^3/27\ ft^3) = 7.10\ yd^3$ (includes 1.5 inch high lid and 4-in forklift runners)

Amount of Concrete = 21,000 lbs. Limit – 6,464 lbs. = 14,536 lbs. concrete/container

Volume Concrete = 14,536 lbs./[(1.68 g/cm^3)(1 – 0.02) (62.4 lbs./ft^3)/(g/cm^3)] [Note 0.02 is for air pockets] = 141.49 ft^3

% fill = $(141.49\ ft^3/166.5\ ft^3) \times 100\% = 85\%$

Gross Weight of Container = 14,536 lbs. + 6,464 lbs. = 21,000 lbs.
= 10.5 tons

Disposal

Number of Containers = 82,958,333 lbs. of concrete/(14,536 lbs. concrete/container) = 5,707 containers

Disposal Weight = (10.5 tons/container)(5,707 containers) = 59,924 tons

Disposal Volume = (191.6 ft^3/container)(5,707 containers)/(27 ft^3/yd^3)
= 40,499 yd^3

Container Bulking Factor = $\frac{(40{,}499\ yd^3 - 29{,}895\ yd^3)}{29{,}895\ yd^3} \times 100\% = +35.5\%$

Overall Bulking Factor = $\frac{(40{,}499\ yd^3 - 8{,}890\ yd^3)}{8{,}890\ yd^3} \times 100\% = +355.6\%$

Rework, 1% of total container, 3 new containers made for each failed container. This increases the total by 2 (i.e., 3 new containers – 1 failed container).

Extra containers = (5,707 containers)(0.01)(2 extra containers/container)
= 114 extra containers

Chemical Stabilization – Other (Continued)

Impact of Fines in TTA Recycle Water

Fines from the decanting operation are recycled back to the TTA. These fines can buildup with time and eventually become a significant part of the feed. This can affect the production of the grout.

Assume last 5% of the feed makes ½ the expected waste loading in the concrete.

Extra containers = (5,707 containers)(0.05)(1 extra container/container)
= 285 containers

Rework and Recycle Impact

Number of containers = 6,106 containers
Disposal weight = 64,113 tons
Disposal volume = 43,352 yd^3
Adjusted overall bulking factor = +387.6
% increase = 387.6% - 355.6% = +32.0%

Appendix A

MicroShield Runs to Determination Container Thickness

Contains Runs for the following technologies:

1. **Chemical Stabilization – Cement**
2. **Chemical Stabilization – Other**
3. **Vitrification – Other**

Note: The Vitrification – Joule Heated Technology uses the Scientific Ecology Group (SEG), Inc. container. The thickness determinations for the SEG container were calculated separately with the SEG container design and appears in the report for this effort, entitle, "Enduropak SIFCON Concrete Packaging for OU4 Vitrified Material."

MicroShield v5.01 (5.01-00093)
Fluor Daniel Fernald

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Date: June 11, 1999
Time: 1:44:18 PM
Duration: 00:07:41

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Date: _____
By: _____
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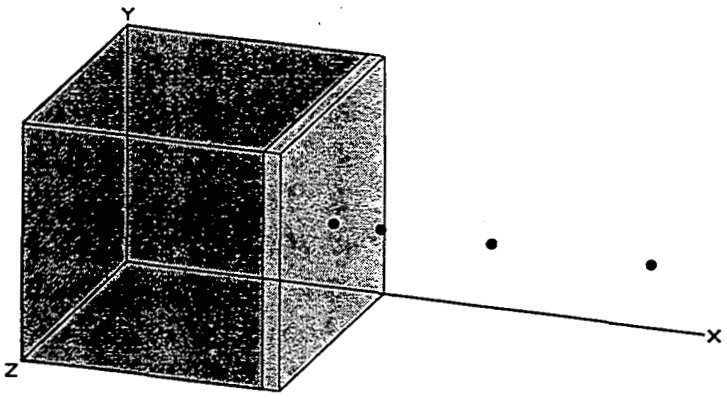
8074

Case Title: 30% waste loading
Description: 78" x 67" x 66" Concrete Box - 4" wall
Geometry: 13 - Rectangular Volume



Source Dimensions

Length	149.86 cm	4 ft 11.0 in
Width	177.8 cm	5 ft 10.0 in
Height	147.32 cm	4 ft 10.0 in

Dose Points

	X	Y	Z
# 1	161.02 cm	73.66 cm	88.9 cm
	5 ft 3.4 in	2 ft 5.0 in	2 ft 11.0 in
# 2	190.02 cm	73.66 cm	88.9 cm
	6 ft 2.8 in	2 ft 5.0 in	2 ft 11.0 in
# 3	260.02 cm	73.66 cm	88.9 cm
	8 ft 6.4 in	2 ft 5.0 in	2 ft 11.0 in
# 4	360.02 cm	73.66 cm	88.9 cm
	11 ft 9.7 in	2 ft 5.0 in	2 ft 11.0 in

Shields

Shield Name	Dimension	Material	Density
Source	3.93e+06 cm³	Concrete	1.45
Shield 1	10.16 cm	Concrete	2.35
Air Gap		Air	0.00122

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Excluded
Library : Grove

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ac-227	1.4378e-002	5.3199e+008	3.6629e-003	1.3553e+002
Ac-228	2.0378e-003	7.5400e+007	5.1914e-004	1.9208e+001
Bi-210	3.7756e-001	1.3970e+010	9.6186e-002	3.5589e+003
Bi-211	1.4378e-002	5.3199e+008	3.6629e-003	1.3553e+002
Bi-212	4.3021e-003	1.5918e+008	1.0960e-003	4.0551e+001
Bi-214	8.9155e-001	3.2987e+010	2.2713e-001	8.4037e+003
Pa-231				
Pa-234				
Pa-234m	1.2453e-003	4.6078e+007	3.1726e-004	1.1738e+001
Pb-210	3.7756e-001	1.3970e+010	9.6186e-002	3.5589e+003
Pb-211	1.4378e-002	5.3199e+008	3.6629e-003	1.3553e+002
Pb-212	4.3021e-003	1.5918e+008	1.0960e-003	4.0551e+001
Pb-214	8.9155e-001	3.2987e+010	2.2713e-001	8.4037e+003
Po-210	5.2519e-001	1.9432e+010	1.3380e-001	4.9504e+003
Po-212	4.3021e-003	1.5918e+008	1.0960e-003	4.0551e+001
Po-214	8.9155e-001	3.2987e+010	2.2713e-001	8.4037e+003
Po-215	1.4378e-002	5.3199e+008	3.6629e-003	1.3553e+002
Po-216	4.3021e-003	1.5918e+008	1.0960e-003	4.0551e+001
Po-218	8.9155e-001	3.2987e+010	2.2713e-001	8.4037e+003

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Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ra-223	1.4378e-002	5.3199e+008	3.6629e-003	1.3553e+002
Ra-224	4.3021e-003	1.5918e+008	1.0960e-003	4.0551e+001
Ra-226	8.9155e-001	3.2987e+010	2.2713e-001	8.4037e+003
Ra-228	2.0378e-003	7.5400e+007	5.1914e-004	1.9208e+001
Rn-219	1.4378e-002	5.3199e+008	3.6629e-003	1.3553e+002
Rn-220	4.3021e-003	1.5918e+008	1.0960e-003	4.0551e+001
Rn-222	8.9155e-001	3.2987e+010	2.2713e-001	8.4037e+003
Th-227	1.4378e-002	5.3199e+008	3.6629e-003	1.3553e+002
Th-228	4.3021e-003	1.5918e+008	1.0960e-003	4.0551e+001
Th-230	1.2884e-001	4.7669e+009	3.2821e-002	1.2144e+003
Th-231	1.1321e-004	4.1889e+006	2.8841e-005	1.0671e+000
Th-232	2.0378e-003	7.5400e+007	5.1914e-004	1.9208e+001
Th-234	1.2453e-003	4.6078e+007	3.1726e-004	1.1738e+001
Tl-207	1.4378e-002	5.3199e+008	3.6629e-003	1.3553e+002
Tl-208	4.3021e-003	1.5918e+008	1.0960e-003	4.0551e+001
U-234	1.6982e-003	6.2833e+007	4.3262e-004	1.6007e+001
U-235	2.2643e-004	8.3777e+006	5.7683e-005	2.1343e+000
U-238	1.2453e-003	4.6078e+007	3.1726e-004	1.1738e+001

Buildup
The material reference is : Source

Integration Parameters

X Direction	10
Y Direction	20
Z Direction	20

Results - Dose Point # 1 - (161.02,73.66,88.9) cm

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	2.006e+05	2.609e-99	3.100e-28	2.238e-100	2.659e-29
0.02	1.064e+06	3.736e-45	2.587e-27	1.294e-46	8.962e-29
0.03	1.146e+06	3.746e-17	7.321e-17	3.712e-19	7.255e-19
0.04	2.851e+06	1.130e-09	3.451e-09	4.996e-12	1.526e-11
0.05	9.762e+08	1.738e-04	8.134e-04	4.630e-07	2.167e-06
0.06	2.140e+07	6.890e-05	4.597e-04	1.368e-07	9.131e-07
0.08	7.947e+09	3.589e-01	3.715e+00	5.679e-04	5.879e-03
0.1	1.409e+08	2.157e-02	2.854e-01	3.299e-05	4.366e-04
0.15	5.987e+07	3.994e-02	6.210e-01	6.577e-05	1.023e-03
0.2	3.725e+09	5.699e+00	8.501e+01	1.006e-02	1.500e-01
0.3	7.119e+09	3.215e+01	3.921e+02	6.098e-02	7.439e-01
0.4	1.276e+10	1.217e+02	1.220e+03	2.371e-01	2.376e+00
0.5	6.311e+08	1.069e+01	9.043e+01	2.098e-02	1.775e-01
0.6	1.604e+10	4.326e+02	3.174e+03	8.445e-01	6.195e+00
0.8	3.194e+09	1.787e+02	1.051e+03	3.398e-01	1.998e+00
1.0	1.037e+10	1.017e+03	5.064e+03	1.875e+00	9.334e+00
1.5	6.293e+09	1.679e+03	6.333e+03	2.826e+00	1.066e+01
2.0	8.828e+09	4.648e+03	1.484e+04	7.188e+00	2.295e+[illegible]
[illegible].0	1.589e+08	2.052e+02	5.315e+02	2.784e-01	7.210e-[illegible]
TOTALS:	7.828e+10	8.332e+03	3.279e+04	1.368e+01	5.531e+01

Results - Dose Point # 2 - (190.02,73.66,88.9) cm

DOS File: BIGBOX.MS5
Run Date: June 11, 1999
Run Time: 1:44:18 PM
Duration: 00:07:41

8074

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	2.006e+05	1.692e-99	1.764e-28	1.451e-100	1.513e-29
0.02	1.064e+06	2.682e-45	1.472e-27	9.290e-47	5.100e-29
0.03	1.146e+06	3.880e-17	7.586e-17	3.845e-19	7.518e-19
0.04	2.851e+06	1.142e-09	3.485e-09	5.051e-12	1.541e-11
0.05	9.762e+08	1.726e-04	8.072e-04	4.597e-07	2.150e-06
0.06	2.140e+07	6.828e-05	4.558e-04	1.356e-07	9.053e-07
0.08	7.947e+09	3.558e-01	3.686e+00	5.630e-04	5.833e-03
0.1	1.409e+08	2.138e-02	2.828e-01	3.271e-05	4.326e-04
0.15	5.987e+07	3.953e-02	6.118e-01	6.510e-05	1.008e-03
0.2	3.725e+09	5.630e+00	8.322e+01	9.936e-03	1.469e-01
0.3	7.119e+09	3.162e+01	3.793e+02	5.999e-02	7.195e-01
0.4	1.276e+10	1.191e+02	1.166e+03	2.321e-01	2.273e+00
0.5	6.311e+08	1.041e+01	8.558e+01	2.043e-02	1.680e-01
0.6	1.604e+10	4.189e+02	2.973e+03	8.177e-01	5.804e+00
0.8	3.194e+09	1.710e+02	9.659e+02	3.253e-01	1.837e+00
1.0	1.037e+10	9.621e+02	4.576e+03	1.774e+00	8.435e+00
1.5	6.293e+09	1.544e+03	5.509e+03	2.598e+00	9.268e+00
2.0	8.828e+09	4.165e+03	1.252e+04	6.440e+00	1.936e+01
3.0	1.589e+08	1.764e+02	4.291e+02	2.393e-01	5.821e-01
TOTALS:	7.828e+10	7.604e+03	2.869e+04	1.252e+01	4.860e+01

Results - Dose Point # 3 - (260.02,73.66,88.9) cm

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	2.006e+05	1.554e-99	6.907e-29	1.333e-100	5.924e-30
0.02	1.064e+06	2.506e-45	5.765e-28	8.679e-47	1.997e-29
0.03	1.146e+06	3.769e-17	7.371e-17	3.736e-19	7.305e-19
0.04	2.851e+06	1.101e-09	3.357e-09	4.869e-12	1.485e-11
0.05	9.762e+08	1.596e-04	7.419e-04	4.251e-07	1.976e-06
0.06	2.140e+07	5.999e-05	3.938e-04	1.192e-07	7.822e-07
0.08	7.947e+09	2.886e-01	2.870e+00	4.568e-04	4.541e-03
0.1	1.409e+08	1.652e-02	2.049e-01	2.527e-05	3.135e-04
0.15	5.987e+07	2.864e-02	4.015e-01	4.716e-05	6.611e-04
0.2	3.725e+09	3.925e+00	5.160e+01	6.928e-03	9.107e-02
0.3	7.119e+09	2.090e+01	2.196e+02	3.964e-02	4.166e-01
0.4	1.276e+10	7.563e+01	6.471e+02	1.474e-01	1.261e+00
0.5	6.311e+08	6.394e+00	4.597e+01	1.255e-02	9.024e-02
0.6	1.604e+10	2.504e+02	1.558e+03	4.887e-01	3.041e+00
0.8	3.194e+09	9.774e+01	4.872e+02	1.859e-01	9.267e-01
1.0	1.037e+10	5.307e+02	2.245e+03	9.782e-01	4.137e+00
1.5	6.293e+09	7.985e+02	2.575e+03	1.343e+00	4.333e+00
2.0	8.828e+09	2.065e+03	5.677e+03	3.193e+00	8.779e+00
3.0	1.589e+08	8.305e+01	1.881e+02	1.127e-01	2.552e-01
TOTALS:	7.828e+10	3.932e+03	1.370e+04	6.509e+00	2.334e+01

Results - Dose Point # 4 - (360.02,73.66,88.9) cm

000722

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	2.006e+05	1.289e-99	2.895e-29	1.106e-100	2.483e-30

DOS File: BIGBOX.MS5
Run Date: June 11, 1999
Run Time: 1:44:18 PM
Duration: 00:07:41

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.02	1.064e+06	2.290e-45	2.416e-28	7.934e-47	8.370e-30
0.03	1.146e+06	3.346e-17	6.538e-17	3.316e-19	6.479e-19
0.04	2.851e+06	8.098e-10	2.453e-09	3.582e-12	1.085e-11
0.05	9.762e+08	9.953e-05	4.549e-04	2.651e-07	1.212e-06
0.06	2.140e+07	3.378e-05	2.158e-04	6.709e-08	4.287e-07
0.08	7.947e+09	1.472e-01	1.404e+00	2.329e-04	2.222e-03
0.1	1.409e+08	8.064e-03	9.513e-02	1.234e-05	1.455e-04
0.15	5.987e+07	1.335e-02	1.762e-01	2.199e-05	2.902e-04
0.2	3.725e+09	1.789e+00	2.209e+01	3.157e-03	3.899e-02
0.3	7.119e+09	9.264e+00	9.170e+01	1.757e-02	1.739e-01
0.4	1.276e+10	3.293e+01	2.667e+02	6.416e-02	5.196e-01
0.5	6.311e+08	2.747e+00	1.879e+01	5.393e-03	3.688e-02
0.6	1.604e+10	1.065e+02	6.328e+02	2.078e-01	1.235e+00
0.8	3.194e+09	4.093e+01	1.962e+02	7.785e-02	3.732e-01
1.0	1.037e+10	2.198e+02	8.993e+02	4.052e-01	1.658e+00
1.5	6.293e+09	3.252e+02	1.025e+03	5.472e-01	1.724e+00
2.0	8.828e+09	8.332e+02	2.251e+03	1.289e+00	3.481e+00
3.0	1.589e+08	3.322e+01	7.445e+01	4.507e-02	1.010e-01
TOTALS:	7.828e+10	1.606e+03	5.480e+03	2.662e+00	9.345e+00

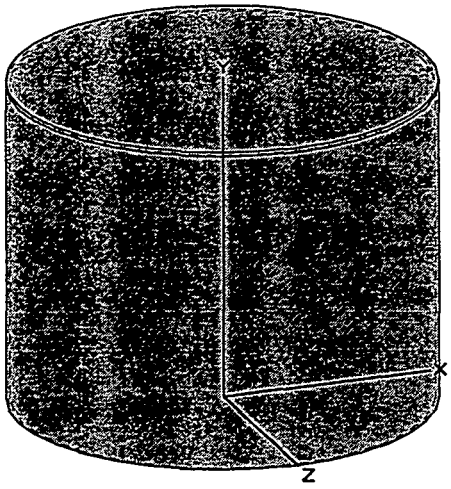
MicroShield v5.01 (5.01-00093)
Fluor Daniel Fernald

Page : 1
File: CNS2.MS5
Date: February 23, 1999
Run Time: 10:41:11 AM
Duration: 00:00:20

File Ref: _____
Date: _____
By: _____
Checked: _____

-- 8074

Case Title: Chem Nuclear Cask
Description: Contact Dose at 1 cm with 3/4" wall
Geometry: 7 - Cylinder Volume - Side Shields



Source Dimensions

Height	149.86 cm	4 ft 11.0 in
Radius	95.25 cm	3 ft 1.5 in

Dose Points

	X	Y	Z
# 1	98.155 cm	74.9808 cm	0 cm
	3 ft 2.6 in	2 ft 5.5 in	0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	4.27e+06 cm³	Concrete	1.68
Transition		Air	0.00122
Air Gap		Air	0.00122
Wall Clad	1.905 cm	Iron	7.86
Top Clad	1.905 cm	Iron	7.86

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Excluded
Library : Grove

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ac-227	1.4000e-002	5.1800e+008	3.2776e-003	1.2127e+002
Ac-228	2.0000e-003	7.4000e+007	4.6824e-004	1.7325e+001
Bi-210	3.6000e-001	1.3320e+010	8.4282e-002	3.1184e+003
Bi-211	1.4000e-002	5.1800e+008	3.2776e-003	1.2127e+002
Bi-212	4.1000e-003	1.5170e+008	9.5988e-004	3.5516e+001
Bi-214	8.6000e-001	3.1820e+010	2.0134e-001	7.4496e+003
Fr-223				
Pa-234	1.8000e-006	6.6600e+004	4.2141e-007	1.5592e-002
Pa-234m	1.2000e-003	4.4400e+007	2.8094e-004	1.0395e+001
Pb-210	3.6000e-001	1.3320e+010	8.4282e-002	3.1184e+003
Pb-211	1.4000e-002	5.1800e+008	3.2776e-003	1.2127e+002
Pb-212	4.1000e-003	1.5170e+008	9.5988e-004	3.5516e+001
Pb-214	8.6000e-001	3.1820e+010	2.0134e-001	7.4496e+003
Po-210	5.1000e-001	1.8870e+010	1.1940e-001	4.4178e+003
Po-211				
Po-212	4.1000e-003	1.5170e+008	9.5988e-004	3.5516e+001
Po-214	8.6000e-001	3.1820e+010	2.0134e-001	7.4496e+003
Po-215	1.4000e-002	5.1800e+008	3.2776e-003	1.2127e+002
Po-216	4.1000e-003	1.5170e+008	9.5988e-004	3.5516e+001
Po-218	8.6000e-001	3.1820e+010	2.0134e-001	7.4496e+003
Ra-223	1.4000e-002	5.1800e+008	3.2776e-003	1.2127e+002
Ra-224	4.1000e-003	1.5170e+008	9.5988e-004	3.5516e+001
Ra-226	8.6000e-001	3.1820e+010	2.0134e-001	7.4496e+003
Ra-228	2.0000e-003	7.4000e+007	4.6824e-004	1.7325e+001

DOS File: CNS2.MS5
Run Date: February 23, 1999
Run Time: 10:41:11 AM
Duration: 00:00:20

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Rn-219	1.4000e-002	5.1800e+008	3.2776e-003	1.2127e+002
Rn-220	4.1000e-003	1.5170e+008	9.5988e-004	3.5516e+001
Rn-222	8.6000e-001	3.1820e+010	2.0134e-001	7.4496e+003
Th-227	1.4000e-002	5.1800e+008	3.2776e-003	1.2127e+002
Th-228	4.1000e-003	1.5170e+008	9.5988e-004	3.5516e+001
Th-230	1.2000e-001	4.4400e+009	2.8094e-002	1.0395e+003
Th-231	9.7000e-005	3.5890e+006	2.2709e-005	8.4025e-001
Th-232	2.0000e-003	7.4000e+007	4.6824e-004	1.7325e+001
Th-234	1.2000e-003	4.4400e+007	2.8094e-004	1.0395e+001
Tl-207	1.4000e-002	5.1800e+008	3.2776e-003	1.2127e+002
Tl-208	4.1000e-003	1.5170e+008	9.5988e-004	3.5516e+001
U-234	1.7000e-003	6.2900e+007	3.9800e-004	1.4726e+001
U-235	1.7000e-004	6.2900e+006	3.9800e-005	1.4726e+000
U-238	1.2000e-003	4.4400e+007	2.8094e-004	1.0395e+001

Buildup
The material reference is : Source

Integration Parameters

Radial	10
Circumferential	10
Y Direction (axial)	20

Results

rgy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	1.944e+05	0.000e+00	3.158e-28	0.000e+00	2.708e-29
0.02	1.036e+06	1.893e-220	2.648e-27	6.557e-222	9.173e-29
0.03	1.044e+06	5.582e-72	5.900e-27	5.532e-74	5.848e-29
0.04	2.743e+06	1.419e-33	4.111e-26	6.274e-36	1.818e-28
0.05	9.358e+08	5.911e-17	5.600e-16	1.575e-19	1.492e-18
0.06	2.007e+07	3.738e-12	5.881e-11	7.425e-15	1.168e-13
0.08	7.668e+09	3.601e-04	8.133e-03	5.699e-07	1.287e-05
0.1	1.367e+08	7.533e-04	1.851e-02	1.152e-06	2.832e-05
0.15	5.790e+07	2.118e-02	4.371e-01	3.488e-05	7.199e-04
0.2	3.592e+09	6.032e+00	1.013e+02	1.065e-02	1.787e-01
0.3	6.870e+09	4.834e+01	5.789e+02	9.170e-02	1.098e+00
0.4	1.231e+10	1.964e+02	1.837e+03	3.826e-01	3.580e+00
0.5	6.085e+08	1.744e+01	1.343e+02	3.423e-02	2.636e-01
0.6	1.547e+10	7.015e+02	4.619e+03	1.369e+00	9.016e+00
0.8	3.081e+09	2.820e+02	1.468e+03	5.364e-01	2.793e+00
1.0	1.001e+10	1.556e+03	6.834e+03	2.869e+00	1.260e+01
1.5	6.071e+09	2.385e+03	7.963e+03	4.012e+00	1.340e+01
2.0	8.516e+09	6.164e+03	1.765e+04	9.533e+00	2.729e+01
3.0	1.514e+08	2.417e+02	5.765e+02	3.280e-01	7.822e-01
TOTALS:	7.550e+10	1.160e+04	4.176e+04	1.917e+01	7.100e+01

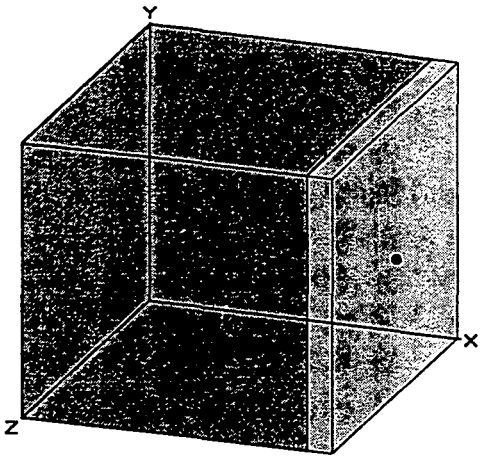
MicroShield v5.01 (5.01-00093)
Fluor Daniel Fernald

Page : 1
File: BIGVBOX.MS5
Date: June 11, 1999
Time: 3:32:33 PM
Duration: 00:02:04

File Ref: _____
Date: _____
By: _____
Checked: _____

8074

Case Title: Vit Other
Description: Frit Waste Form - 5" concrete
Geometry: 13 - Rectangular Volume



Source Dimensions

Length	142.24 cm	4 ft 8.0 in
Width	172.72 cm	5 ft 8.0 in
Height	139.7 cm	4 ft 7.0 in

Dose Points

	X	Y	Z
# 1	155.94 cm	69.85 cm	86.36 cm
	5 ft 1.4 in	2 ft 3.5 in	2 ft 10.0 in

Shields

Shield Name	Dimension	Material	Density
Source	3.43e+06 cm³	Vortec frit	1.402
Shield 1	12.7 cm	Concrete	2.35
Air Gap		Air	0.00122

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Excluded
Library : Grove

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ac-227	3.2096e-002	1.1875e+009	9.3516e-003	3.4601e+002
Ac-228	4.6158e-003	1.7078e+008	1.3449e-003	4.9761e+001
Bi-210	8.4447e-001	3.1245e+010	2.4605e-001	9.1039e+003
Bi-211	3.2096e-002	1.1875e+009	9.3516e-003	3.4601e+002
Bi-212	9.5536e-003	3.5348e+008	2.7836e-003	1.0299e+002
Bi-214	1.9940e+000	7.3778e+010	5.8099e-001	2.1497e+004
Pa-231				
Pa-234				
Pa-234m	2.8983e-003	1.0724e+008	8.4446e-004	3.1245e+001
Pb-210	8.4447e-001	3.1245e+010	2.4605e-001	9.1039e+003
Pb-211	3.2096e-002	1.1875e+009	9.3516e-003	3.4601e+002
Pb-212	9.5536e-003	3.5348e+008	2.7836e-003	1.0299e+002
Pb-214	1.9940e+000	7.3778e+010	5.8099e-001	2.1497e+004
Po-210	1.1747e+000	4.3462e+010	3.4226e-001	1.2663e+004
Po-212	9.5536e-003	3.5348e+008	2.7836e-003	1.0299e+002
Po-214	1.9940e+000	7.3778e+010	5.8099e-001	2.1497e+004
Po-215	1.1747e+000	4.3462e+010	3.4226e-001	1.2663e+004
Po-216	9.5536e-003	3.5348e+008	2.7836e-003	1.0299e+002
Po-218	1.9940e+000	7.3778e+010	5.8099e-001	2.1497e+004
Ra-223	3.2096e-002	1.1875e+009	9.3516e-003	3.4601e+002
Ra-224	9.5536e-003	3.5348e+008	2.7836e-003	1.0299e+002
Ra-226	1.9940e+000	7.3778e+010	5.8099e-001	2.1497e+004
Ra-228	4.6158e-003	1.7078e+008	1.3449e-003	4.9761e+001
Rn-219	3.2096e-002	1.1875e+009	9.3516e-003	3.4601e+002
Rn-220	9.5536e-003	3.5348e+008	2.7836e-003	1.0299e+002

DOS File: BIGVBOX.MS5
Run Date: June 11, 1999
Run Time: 3:32:33 PM
Duration: 00:02:04

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Rn-222	1.9940e+000	7.3778e+010	5.8099e-001	2.1497e+004
Th-227	3.2096e-002	1.1875e+009	9.3516e-003	3.4601e+002
Th-228	9.5536e-003	3.5348e+008	2.7836e-003	1.0299e+002
Th-230	2.8800e-001	1.0656e+010	8.3914e-002	3.1048e+003
Th-231	2.1469e-004	7.9434e+006	6.2553e-005	2.3144e+000
Th-232	4.6158e-003	1.7078e+008	1.3449e-003	4.9761e+001
Th-234	2.8983e-003	1.0724e+008	8.4446e-004	3.1245e+001
Tl-207	3.2096e-002	1.1875e+009	9.3516e-003	3.4601e+002
Tl-208	9.5536e-003	3.5348e+008	2.7836e-003	1.0299e+002
U-234	3.8644e-003	1.4298e+008	1.1259e-003	4.1660e+001
U-235	4.2937e-004	1.5887e+007	1.2511e-004	4.6289e+000
U-238	2.8983e-003	1.0724e+008	8.4446e-004	3.1245e+001

Buildup

The material reference is : Source

This buildup reference material is a mixed material with a high atomic number element (82). Buildup Factors less than and somewhat greater than 88 keV may be incorrect. Please understand your results.

Integration Parameters

X Direction	10
Y Direction	20
Z Direction	20

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	4.451e+05	1.233e-178	6.400e-28	1.058e-179	5.490e-29
0.02	2.375e+06	5.124e-101	1.541e-24	1.775e-102	5.340e-26
0.03	2.351e+06	2.719e-36	2.947e-07	2.695e-38	2.921e-09
0.04	6.346e+06	1.117e-19	6.448e-11	4.938e-22	2.852e-13
0.05	2.183e+09	4.523e-10	9.843e-08	1.205e-12	2.622e-10
0.06	4.801e+07	2.273e-08	7.326e-08	4.514e-11	1.455e-10
0.08	1.777e+10	7.363e-03	1.397e-02	1.165e-05	2.211e-05
0.1	3.150e+08	5.298e-06	8.230e-06	8.106e-09	1.259e-08
0.15	1.333e+08	1.661e-03	2.561e-03	2.735e-06	4.218e-06
0.2	8.327e+09	1.089e+00	1.960e+00	1.923e-03	3.460e-03
0.3	1.592e+10	1.653e+01	3.852e+01	3.135e-02	7.306e-02
0.4	2.856e+10	9.492e+01	2.840e+02	1.849e-01	5.534e-01
0.5	1.411e+09	1.059e+01	3.594e+01	2.078e-02	7.055e-02
0.6	3.587e+10	4.996e+02	1.787e+03	9.751e-01	3.488e+00
0.8	7.144e+09	2.477e+02	9.080e+02	4.711e-01	1.727e+00
1.0	2.320e+10	1.569e+03	5.591e+03	2.892e+00	1.031e+01
1.5	1.408e+10	2.936e+03	8.847e+03	4.939e+00	1.488e+01
2.0	1.975e+10	8.383e+03	2.312e+04	1.296e+01	3.575e+01
3.0	3.528e+08	3.627e+02	8.744e+02	4.921e-01	1.186e+00
TOTALS:	1.751e+11	1.412e+04	4.149e+04	2.297e+01	6.805e+0

Attachment G2

Attachment G2

Chemical Stabilization Treatment and TCLP Correlations with the Fernald OU4 Silos 1 and 2 Material

August 16, 1999

Attachment 2

Chemical Stabilization Treatment and TCLP Correlations with the Fernald OU4 Silos 1 and 2 Material

August 16, 1999

DRAFT

CHEMICAL STABILIZATION TREATMENT AND TCLP CORRELATIONS

with the

FERNALD OU-4 SILOS 1 AND 2 RESIDUES

August 16, 1999

1. INTRODUCTION

1.1 Background

Fernald has two Silos (known as K-65 or Silo 1 and Silo 2 wastes) that contain uranium processing residues that are laced with high concentrations of radium that emanates large quantities of radioactive Radon gas. The residues in the silos will be remediated under CERCLA and RCRA regulations. The main RCRA constituents of concern are lead (Pb) and barium (Ba). The residues contain approximately 5 to 15 wt% lead (as lead carbonate and lead sulfate) and 3 to 8 wt% barium (as barium sulfate). Treatability studies were done on actual K-65 residues and on surrogates during the Proof-of-Principle (POP) demonstrations to determine if the wastes could be remediated by chemical stabilization (CS) and/or vitrification technologies. Results are documented in the Treatability Study Report Operable Unit 4 and four POP final reports provided by vendors that performed the demonstrations for each of the four technologies.

1.2 Purpose

The paper evaluates data to determine (1) an approximate operating window for the chemical stabilization of the silo residues, (2) effectiveness of phosphates in the treatment of the silo residues, and (3) if curing time has an impact on the EPA's required Toxic Characteristic Leach Procedure (TCLP) results. Laboratory and pilot tests performed on the

actual Silo 1 and 2 residues and surrogates show that treatment is sensitive to the amounts cement binders used. Not only will too little binder in a grout mix cause failure of the TCLP, but adding too much binder can also lead to failure of the TCLP. Especially for lead (Pb). This paper correlates the results of these tests to show operating ranges for the treatment of the silo residues. The results are complimented with results from other CS projects dealing with lead.

2. CHEMICAL STABILIZATION AND TCLP RESULTS

Results of these studies show the peculiarities of treating lead with cement-based, CS formulations. Most of the later CS formulations contained phosphate to assist treatment. Results from using phosphate are presented later. Table 1, taken from the original FS report shows an example of the TCLP results from fifteen CS grouts made from two final formulations developed during the feasibility study. Positive numbers (in the table) show that the grout performed better than the raw residue by that percentage. Negative numbers show that the waste performed worse than the raw residue by that percentage. Table 2 shows grouts recipes made with actual K-65 residues. These grouts were made from different strata within Silos 1 and 2. All the TCLP leachability concentrations of the chemically stabilized K-65 residues showed only mild improvement over the raw residues or actually worsened (as shown by the negative numbers in the table) except for lead. This anomaly is because the acid-based TCLP (in combination with alkaline-based cements) actually stabilizes the lead and gives the impression that CS reduced lead leaching in the grout. Actually, CS treatment can significantly increase the leaching of lead as shown later in this document. Why this is so requires a minimum knowledge of the chemistry of lead, CS, the TCLP, and their combined reactions. The following pages give a brief understanding of their separate and combined chemistry.

Table 1[1]
Percent Reductions for Silo 1, Zone B
Dilution Adjusted Treatability Data -- Formula 1

Chemical	Mean Percent Reduction
Antimony	3.7
Barium	-66.3
Benzoic acid	na
Boron	-60.6
Chromium	-116.4
Lead	>99.9
Molybdenum	-36,325.5
Selenium	-113.5
Tributyl phosphate	na
Vanadium	-101.2
Zinc	66.1

Table 2[2]
Final Stabilization Formulas
Used During the Feasibility Studies

Constituent	Formula 1 Weight Percent	Formula 2 Weight Percent
Residues no bentonite, dry (assumes 30% moisture)	25.8 to 26.3	24.6
Portland Cement	14.8 to 15.0	17.9
Flyash		10.9
Blast Furnace Slag	14.8 to 15.0	
Ferric Chloride		0.3
Attapulgite		1.4
Clinoptilolite		1.4
Water	44.6 to 43.7	43.5
Totals	100.0 to 100.0	100.0
Waste Loading, wt%	25.8 to 26.3	24.6

[1]Data from Table 4-32A in the Remedial Investigation and Feasibility Study--Treatability Study Report Operable Unit 4 Draft, March 1993.

[2]Data from Table 3-9 in the Remedial Investigation and Feasibility Study--Treatability Study Report Operable Unit 4 Draft, March 1993.

2.1 Lead Chemistry

Lead is amphoteric, that is, it is soluble under both basic and acid conditions. Lead is fairly insoluble at pH values between 6 and 11½ . Its peak insolubility is at a pH of approximately 9 to 10. The common compounds of lead (e.g., oxide, carbonate, sulfate, sulfide) vary somewhat but are similar in behavior. At a pH below 7, lead is soluble as Pb^{++}, while at a pH above 11, it can be soluble as anionic plumbate ion.

2.2 Chemical Stabilization Chemistry

CS chemistry generally involves cementation processes with water. Cement particles in water undergo hydrolysis, with the main products being calcium hydroxide [$Ca(OH)_2$] and a less basic silicate hydrate (CSH). The reactions may be represented by the following equations:

$$2(3CaO{\cdot}SiO_2) + 6H_2O \rightarrow 3CaO{\cdot}2SiO_2{\cdot}3H_2O + 3Ca(OH)_2 \qquad \text{(Reaction 1)}$$

$$2(2CaO{\cdot}SiO_2) + 4H_2O \rightarrow 3CaO{\cdot}2SiO_2{\cdot}3H_2O + Ca(OH)_2 \qquad \text{(Reaction 2)}$$

$$3CaO{\cdot}Al_2O_3 + 31H_2O + 3CaSO_4 \rightarrow 3CaO{\cdot}Al_2O_3{\cdot}3CaSO_4{\cdot}31H_2O \qquad \text{(Reaction 3)}$$

$$4CaO{\cdot}Al_2O_3{\cdot}Fe_2O_3 + 10H_2O + 2Ca(OH)_2 \rightarrow 6CaO{\cdot}Al_2O_3{\cdot}Fe_2O_3{\cdot}12H_2O \qquad \text{(Reaction 4)}$$

Reaction 3 produces ettringite, and the hardening time is controlled by its physical hindrance effect. Reactions 1 and 2 produce CSH, which is the main strengthening component. The above reactions precipitate the formation of crystalline particles. Reaction 4 depletes calcium hydroxide. This reaction may continue for a long time.[3] Reaction 1 is responsible for most of the early pH change and strength (7 days). Reaction two is slower. Reactions 3 and 4 happen much later (weeks, months). Reaction 4 is a consumer of calcium hydroxide and can, therefore, decrease pH.

The calcium hydroxide, and to a lesser extent, oxide compounds increase the pH or

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[3] Kim, J.-H., Kim, H.-Y., Park, H.-H., and Suh, I.-S.,"Cementation of Borate Waste by Adding Slaked Lime," *Stabilization and Solidification of Hazardous, Radioactive, and Mixed Wastes, 2nd Volume, ASTM STP 1123*, T.M. Giliam and C.C. Wiles, Eds. American Society for Testing and Materials, Philadelphia, 1992, pp. 338-347.

makes the CS product more basic. Usually, the pH of CS products are normally between pH 12 and pH 13. Saturated lime or calcium hydroxide has a pH of 12.9[4]. The pH of the cured grout for the Chemical Stabilization – Other Technology measured between 12.8 and 12.9. Generally, it is the high pH producing capability of the CS process that renders most toxic metals insoluble. However, the increasing pH of the CS process can increase the leachability of lead and actually make the lead soluble. A solidification study of a lead contaminated site (average 76 ppm) in Washington D.C. lead to an "unexpected result" where the "leachability increased with cement stabilization."[5] Table 3 is an excerpt from that study that shows the Pb leachate versus amounts of cement in the treated chemically stabilized waste.

Table 3

CS Treatability Results of Contaminated Washington D.C. Site

Archive Sample	EP Tox, Lead, mg/ℓ
Control (soil)	0.471
3% Cement	2.22
6% Cement, as fragments[6] (broken monoliths)	1.684
6% Cement, as monolith	10.165

Two reasons were given for the increase of lead in the leachate. One was Pb contamination in the cement itself and "another possible reason for the increase in leachability is the change in pH during stabilization and EP TOX testing"[7].

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[4]CRC Handbook of Chemistry and Physics, 51st Edition.

[5]Kleppe, J. H., Otten, M. T., and Finn, J.T., "Stabilization/Solidification of Metal-Contaminated Soils: Two Case Histories,"*Stabilization and Solidification of Hazardous, Radioactive, and Mixed Wastes, 2nd Volume, ASTM STP 1123*, T.M. Giliam and C.C. Wiles, Eds. American Society for Testing and Materials, Philadelphia, 1992, pp. 426-439.

[6]Why might fragments leach less than monolith? Answer: Fragments can more readily react with the extraction fluid and cause shifts in the pH in the extraction fluid and solubility for lead.

[7]The initial extract was reported to have a pH of about 11, which was later lowered to about 5 at the end of the extraction process.

2.3 TCLP Chemistry

The TCLP is a leachability test where (1) the sample is crushed and (2) the sample material that passes through a 9.5 millimeter screen is placed in a leachate extraction fluid for 18 hours. Then the fluid is filtered and the clear fluid analyzed for dissolved metals.

Two extraction fluids are used in the TCLP. Extraction Fluid No. 1 is sodium acetate based with a 4.93 ±0.05 pH units. Extraction Fluid No. 2 is acetic acid based with a pH of 2.88 ±0.05 pH units. Extraction Fluid No. 2 is used with most grouts to counteract the high pH and strong buffering (acid-neutralizing) capacity of most CS samples. Extraction Fluid No. 1 is used with grouts that contain low concentrations of cement and alkaline additives, such as calcium hydroxide. A pretest is done to determine which extraction fluid to use[8]. Some grouts may require testing with one extraction fluid early in the curing process and, then later, require the other extraction fluid after it is well cured. This is because (1) the cementation reactions (Reactions 1 through 4) can either produce or reduce the concentration of calcium hydroxide during curing, (2) the rigidness of the cured sample produces larger pieces with less surface area and a harder surface that reduces the ability of the grout to neutralize the TCLP acid, or (3) weather/aging reduces the alkaline content in the grout.

The TCLP is a test intended to determine the leachability of a treated waste form. The an acidic (low pH) extractants were chosen to accelerate leaching and limit the leaching time to 18 hours so turnaround time for results is 24 hours. Generally, two liters of acid extraction fluid are added to 100 grams of sample. Acid extraction was considered to give conservative leach values (i.e., erroring on the high side). However, this may not be the case with amphoteric materials like lead.

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[8] Steps (in simple terms) for determining the correct Extraction Fluid is as follows:

a. Perform initial test by placing 5 grams of screened sample in 96.5 grams of water.
   - If the pH<5 then Extraction Fluid 1 is used for the Final TCLP.
   - If the pH is ≥5 then the pretest is run.

b. The pretest is performed by adding 3.5 mℓ of 1-normal hydrochloric acid to the initial test. Then heat, mix, and cool.
   - If the pH <5 then Extraction Fluid 1 is used for the Final TCLP.
   - If the pH is ≥5 then Extraction Fluid 2 is used for the Final TCLP.

2.4 Combined Chemistry

Lead is amphoteric, meaning that is soluble in both in acid and basic condition. For example, lead becomes more soluble towards the low and high ends of the pH scale. Therefore, the high pH of CS cementation (assuming everything stays constant) will increase the leachability of lead. However, the pH of the lead sample will be decreased with the addition of the low pH TCLP extractant.

Soils from a Superfund site containing 4 to 11% lead were evaluated during a CS feasibility study. (This waste is of slightly lower lead concentrations than the silo residues.) The prepared CS cements were subjected to a special leachate test known as the Generalized Acid Neutralization Capacity (GANC) Test. The results are presented graphically in Figures 1 and 2 on the following page.[9] The figures show how two CS formulas reacted to the GANC test. The two figures are different representations of the same data. One figure shows lead leaching as a function of how much acid is added. The GANC test takes the treated waste and adds increasing amounts (known as Equivalents) of acetic acid. The other Figure shows the measured pH when the acid equivalents were added[10]. Some important data points in the Figures should be noted:

a. The treated waste follows the expected solubility curves for lead. The lead dropped magnitudes in concentration with the addition of acetic acid until the pH of the leachate reached 9 to 10. Then the concentration of Pb increased again. The figures also show approximately where conditions exist for the TCLP test and the TCLP Regulatory Limit of 5.0 ppm for lead.

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[9] Isenbury, J. and Moore, M., "Generation Acid Neutralization Capacity Test," *Stabilization and Solidification of Hazardous, Radioactive, and Mixed Wastes, 2nd Volume, ASTM STP 1123*, T.M. Giliam and C.C. Wiles, Eds. American Society for Testing and Materials, Philadelphia, 1992, pp. 361-377.

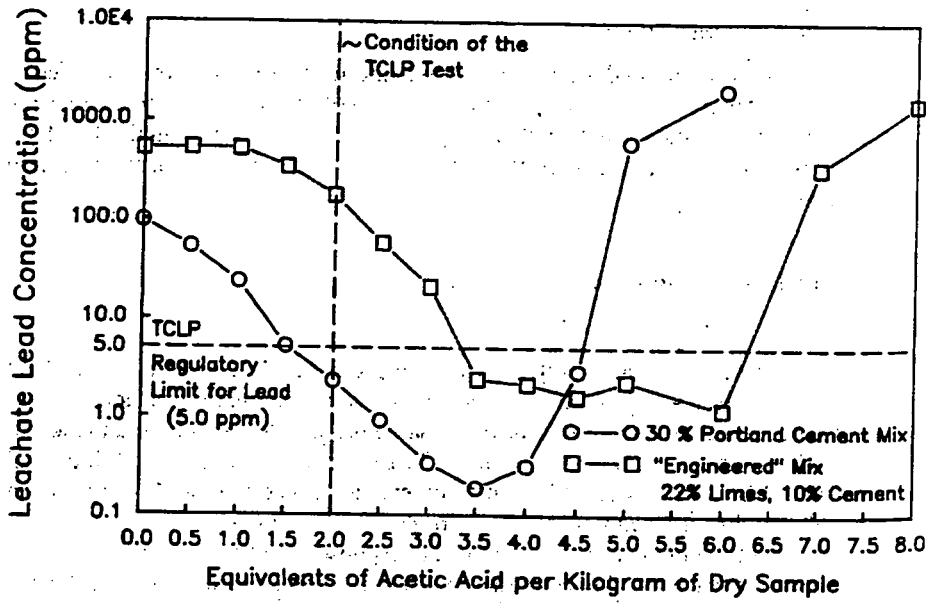
[10] To save confusion in reading the tables, notice that data points run from right to left because pH decreases as the acetic acid is added.

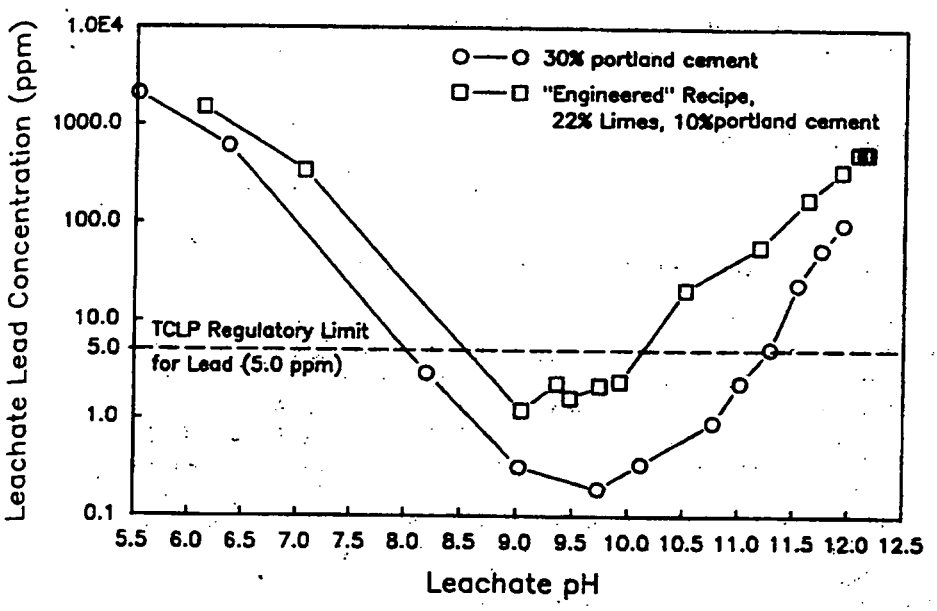
b. Two equivalents of acetic acid (added) is the same as that used in the TCLP test using Extraction Fluid No2. The line would be further to the left if Extraction Fluid No. 1 were used.

a. Zero equivalents of acetic acid (added) is the same as placing 100 grams of treated waste in water. Therefore, this a good approximation of how well the treated waste form would resist leaching in ground.

3. CHEMICAL STABILIZATION/TREATMENT RESULTS USING SILOS 1 AND 2 SURROGATES

Surrogates were developed that simulated the chemical makeup, water retention, and mixing characteristics of the waste. These surrogates where treated by the four POP technologies. Each technology performed bench-scale testing on the surrogates and came up with a formula that was carried through pilot-scale testing. Approximately one ton per day of surrogate (dry weight basis) was processed. TCLP results of the bench-scale testing are shown in Figure 3. The TCLP results were plotted against (1) cement content in the grout and (2) the final TCLP pH. The final TCLP pH is the measured pH of the extraction fluid after it has been mixed and reacted with the sample (being tested) for 18 hours. Notice that the results show the expected lead solubility curves. Two curves are shown. One curve is shown for testing with Extraction Fluid No.1 (labeled as Sodium Acetate Extraction Fluid with an initial pH of 2.88). The other curve is shown for testing with Extraction Fluid No. 2 (labeled as Acetic Acid Extraction Fluid with an initial pH of 4.93. These curves show that there are windows that require the right amount of cement be added. Adding too much cement (and additives) can bring the same negative results as adding too little cement. The Chemical Stabilization – Cement technology has grouts that show on both curves. Even though the Extraction Fluid used for the Chemical Stabilization – Other technology was not disclosed. However, this technology is shown using Extraction Fluid No. 2 because of its high cement content.

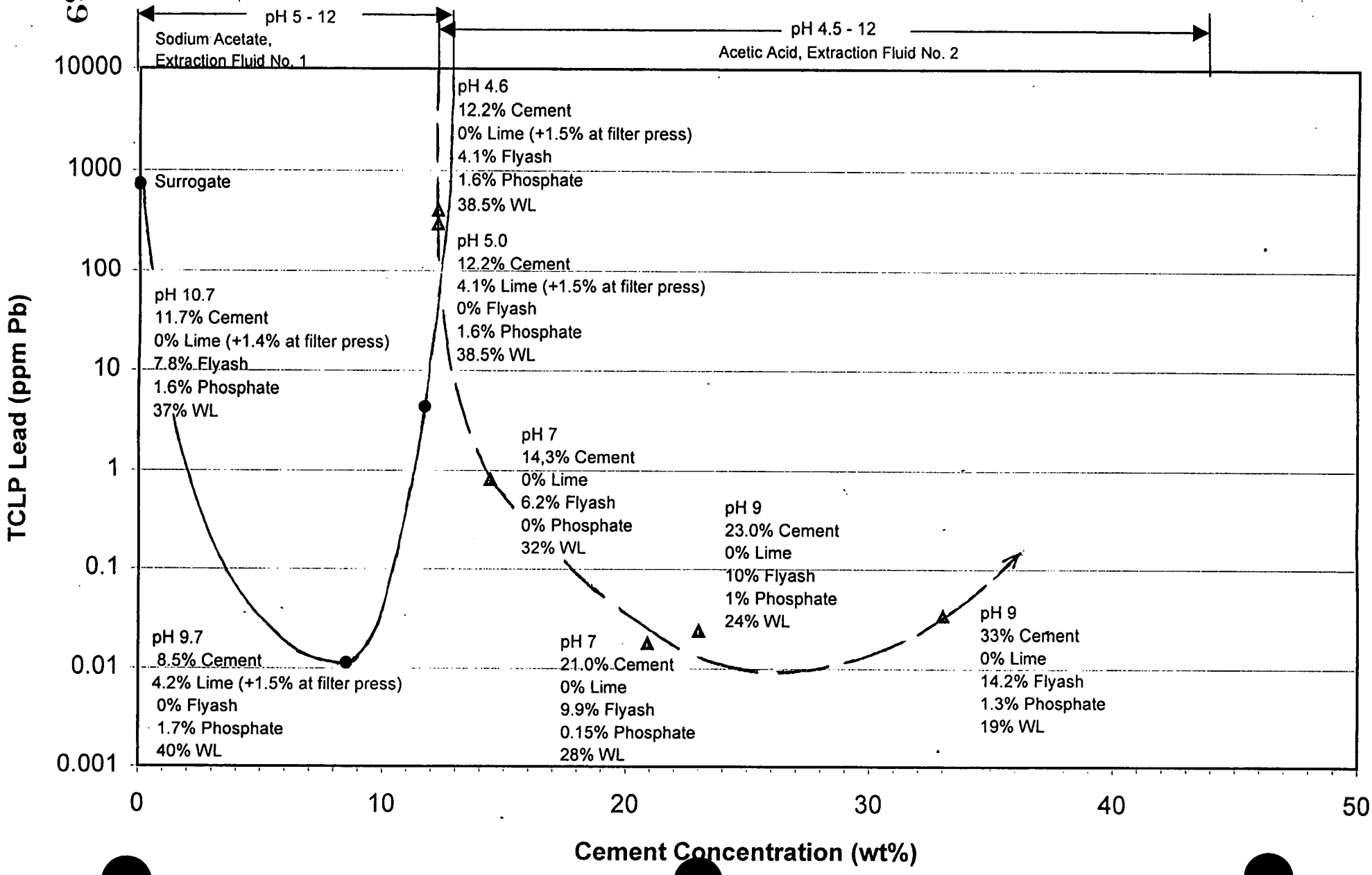




Figures 1 and 2

000739

TCLP Lead vs. Cement Content in POP Grouts



3. PHOSPHATE TREATMENT AND TCLP RESULTS

Phosphate did not appear to play a significant role in the treatment of lead in the surrogates. Both CS technologies used approximately 2 wt% phosphates in the grout mixes. Some mixes were made without phosphates as shown in Figure 3. If phosphates had worked well in treating the surrogates, the curves would have been flat, thus showing, no effect by cement concentration or pH. Likewise, some formulas listed in Figure 3 contained little or no phosphates and lead leaching should have greatly increased. However, this did not happen, again, showing that phosphate is not a dominant mechanism in the treatment of the surrogate (or Silo Residues). The use of phosphate appeared to impart a mild decrease in leaching in some formulations. Ironically, some showed an increase. Reasons whys are not known.

The reason why phosphate does not significantly treat the Silo Surrogates (and actual residues) is accredited to the fact that lead in the Silos (as carbonates and sulfates) is rather insoluble to begin with.[11] The phosphates have to chemically react with the lead to bind it up. Ironically and unfortunately, this requires that most of the lead needs to dissolve (become soluble) in the water of the grout to position itself for reaction with the phosphate. Since so little of the lead dissolves in the water, the cement cures before the phosphate has a chance to react with the lead, and is, therefore, rendered inactive.

4. CURE TIME AND TCLP RESULTS

Curing can have a significant effect on TCLP results. The following defines potential mechanisms and magnitude for the effect.

Table 4 shows grouts made to identical formulas but mixed and sampled at times. The last two entries in the table are from the same batches but the TCLP was run on the samples at different times with different results. The results of the TCLP were so markedly different

[11] The pH of the silo residues is around 9.5 which is at lead's least soluble pH. The acid used in the TCLP Test actually can increase the solubility of the lead orders of magnitudes beyond its in situ condition.

000741

Table 3[12] – TCLP of "Chemical Stabilization -- Cement" Technology's Grout Formulations Sampled at Different Times

Surrogate	Formula No.	When mixed and Sampled	Formulation, grams					Extraction Fluid	Final pH	TCLP Lead, ppm
			Cake	Cement	Phosphate	Iron sulfate	Lime			
S1	36-01	Initial Tests, full cure	2000	200	40	20	–	1 (acetate)	7.61	0.0305
"	53-01	Final Tests, partial cure	2000	200	40	20	–	2 (acid)	5.73	1.880
S2	42-01	Initial Tests, full cure	2000	200	40	20	–	1 (acetate)	7.62	0.002
"	60-01	Final Tests, partial cure	2000	200	40	20	–	2 (acid)	4.67	4.67
DS	91-01	Initial Tests, full cure	2000	200	40	20	100	1 (acetate)	9.70	0.014
DS	Batches 1 - 11	Demonstration, Partial cure	2000	200	40	20	100	2 (acid)	7.17 - 10.59[13]	0.068 - 2.24[14]
DS	Batches 1 - 11	Demonstration, cured[15]	2000	200	40	20	100	1 (acetate)	na	0.027

[12]Data from the "Final Report For Silos 1 and 2 Proof of Principle Testing," prepared by the International Technology Corporation, May 14, 1999 for the Chemical Stabilization – Cement technology. Data comes from the initial and final stages of laboratory development and the final POP demonstration run.

[13]Values from 11 batches run during the POP demonstration ranged from 7.17 -10.59 pH units with an average 9.24 pH units. All batches used the same surrogate with the same mix recipes.

[14]Values from 11 batches run during the POP demonstration ranged from 0.068 -2.24 ppm lead with an average 0.277 ppm lead. All batches used the same surrogate with the same mix recipes.

[illegible] May 1999, FDF ran TCLP tests on some of the archived samples from the P[illegible]onstration performed in December 1998. The pH values were not request[illegible] and [illegible]re, not available (na). However, sodium acetate is recorded as the extracti[illegible].

that the samples required different extraction fluids. This would indicate (1) an error in performing the test, (2) in data management, or (3) there is a fundamental difference between the grouts tested. The magnitude of the difference between the grouts (or the magnitude of the mechanism causing the difference) can be approximated by estimating the difference of acidic neutralization strength (capacity to neutralize a base) between Extraction Fluids No. 1 and No. 2 as follows:

> 64.3 ml of 1-normal sodium hydroxide solution is added to Extraction Fluid No. 2 to make Extraction Fluid No. 1. This increases the pH from 2.88 to 4.93. If the resulting pH's between the two grout is approximately the same, then the mechanism's magnitude is approximately equal to the "acid neutralization strength" (capacity to neutralize an acid) of sodium hydroxide cited. This acid neutralization strength calculates to be 0.129 moles of hydroxide ions.

Not coincidentally, the acid neutralization strength of the calcium hydroxide used in the DS Grout calculates to be 0.113 to 0.154 moles of hydroxide.[16] Cement in the grout will also add some to the acid neutralization strength as it cures and produces calcium hydroxide. (See Reactions 1 and 2 listed earlier.) The calculations imply that with one mix the calcium hydroxide was free to interact with the TCLP acid and with the other it is not. When grout samples have cured and reached strength, the sample is less like to break apart and disburse during the TCLP test. Therefore, Extraction Fluid No. 1 is more likely to be used.[17] If the sample has not cured, the grout can freely mix with and react with the TCLP acids. Therefore, Fluid No. 2 is more likely to be used.

At first glance of data in Table 3 one might conclude that result get better with curing. However, one needs to remember that these recipes were formulated to hit the minimum

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[16] Calcium hydroxide is added before the filter press and directly to the grout mixer. The actual amount calcium hydroxide that is in the grout depends on how much of the calcium hydroxide is retained in with the filter cake in the filter press. Range given covers none to all of the calcium hydroxide is retained.

[17] This scenario will happen only with grouts containing lower concentrations of binders. With higher concentrations, Extraction Fluid No. 2 will always be required because the basic binders will overwhelm the acid pretest.

point of the sodium acetate curve in Figure 3 with a well-defined surrogate. Uncompensated small variations in the actual material could result in large variations in the TCLP.

The pH and acid neutralization strength of grouts diminish with aging due to weathering and long curing process of cement. For example, Reaction 4 (mentioned earlier) consumes calcium hydroxide and is a very slow process that frequently takes months to happen. Also, chemicals in the waste are known to consume calcium hydroxide because lime (calcium hydroxide) was originally added to residues to precipitate the lead and other metals prior to placement in the silos. Also, aging of the residues has resulted in the formation calcium carbonate nodules that are now found in Silo residue samples in varying concentration.

5. COMPARISON TO VITRIFICATION

Lead is chemically and physically bound in the glass matrix. Glass is, essentially, chemically inert and does not react with the chemistry of the TCLP test. Hence, the pH of TCLP does not significantly affect the leach rates from glass.

Even though the leach rate of glass is low, most glasses will weather quicker, through the decades, under high (or basic) pH conditions. Glass weathers by acquiring a "rainbow" iridescent patina on the surface. Eventually some of the patina may flake off. However, this rate is so slow that, essentially, no lead or radionuclides are released to the environment.

6. CONCLUSION

This study has shown that:

(1) Lead leaching is sensitive to pH and the acid-neutralization (buffering) ability of the grout. The K-65 material should be processed in batches with the batches analyzed for its acid-neutralization strength before treatment. Routine sampling of feed

streams and quality process control are important in ensuring that the grout will pass the TCLP. Bench and pilot studies imply that grout formulations need to be "tuned" to meet the TCLP. For example, too little binders can be just as bad at meeting the TCLP. The formulations can be sensitive to fluctuations to acid-neutralization strength changes in the Silo Residues and binders used. Sampling, analysis, and process controls will need to be able to measure these "acid neutralization strength" changes and make the appropriate changes in the process to ensure the final product meets the TCLP. The operating window for the Chemical Stabilization – Cement Technology is narrow and may be very difficult to maintain tolerance with the variability in the feed composition and quantity measurement. The operating window for the Chemical Stabilization – Other technology looks wider than the Chemical Stabilization – Cement Technology. However, a study should be done to determine the Chemical Stabilization – Other Technology grout recipe will produce acceptable grouts with the known variations in the Silo Residues.

(2) TCLP results are sensitive to when the TCLP test is run on the samples for slow curing grouts. Fully-cured samples can give drastically different results from partially-cured samples.

(3) Chemical reduction (i.e., phosphate) of the lead is ineffective. Proper control of pH is more important as stated in the paper "Solidification/Stabilization: Is It Always Appropriate?" by C.C. Wiles and E. Barth[18].

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[18] Wiles, C.C. and Barth, E. "Solidification/Stabilization: Is It Always Appropriate?" *Stabilization and Solidification of Hazardous, Radioactive, and Mixed Wastes, 2nd Volume, ASTM STP 1123*, T.M. Giliam and C.C. Wiles, Eds. American Society for Testing and Materials, Philadelphia, 1992, pp. 18-32.