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OPERABLE UNIT 4 REMEDIAL ACTION SAFETY ASSESSMENT REVISION 0 FEBRUARY 1993

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Operable Unit 4
Remedial Action
Safety Assessment

Environmental Remedial Action Project
Fernald Environmental Management Project
Fernald, Ohio

FERMCO Subcontract No. 2-21487
February 1993
Revision 0

Operable Unit 4, Project Order 3

PARSONS

Fairfield Executive Center
6120 South Gilmore Road
Fairfield, Ohio 45014

Operable Unit 4 Remedial Action Safety Assessment
Revision 0
Fernald Environmental Management Project
Fernald, Ohio

APPROVED FOR ISSUE

2/16/93
D. L. Gross, Nuclear & Systems Safety, PARSONS — Date

2.16.93
J. J. Golyski, Engineering Manager, PARSONS — Date

2/16/93
R. A. Zieminski, CERCLA/RCRA Unit 4 Project Manager, PARSONS — Date

3-3-93
E. R. Schmidt, Safety Analysis & Risk Assessment Manager, FERMCO — Date

03/04/93
W. S. Pickles, CERCLA/RCRA Unit 4, Project Director, FERMCO — Date

Operable Unit 4
Remedial Action Safety Assessment

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LIST OF ACRONYMS

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ALARA	As Low As Reasonably Achievable
AWWT	Advanced Wastewater Treatment System
CDR	Conceptual Design Report
CEDE	Committed Effective Dose Equivalent
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
D&D	Decontamination and Decommissioning
DOE	United States Department of Energy
ERT	Emergency Response Team
EWMF	Engineered Waste Management Facility
FEMP	Fernald Environmental Management Project (formerly FMPC)
FERMCO	Fernald Environmental Restoration Management Corporation
FMPC	Feed Materials Production Center
gpm	gallons per minute
HEME	High Efficiency Mist Eliminator
HEPA	High Efficiency Particulate Air
HVAC	Heating, Ventilating, and Air Conditioning
ISF	Interim Storage Facility
IT	International Technology Corporation
kV	kilovolts
OSHA	Occupational Safety and Health Administration
OU	Operable Unit
P&ID	Piping and Instrumentation Diagram
PHA	Preliminary Hazard Assessment
PO	Project Order
PPE	Personal Protective Equipment
psi	pounds per square inch
psig	pounds per square inch gauge
QC	Quality Control
RCRA	Resource Conservation and Recovery Act
RCS	Radon Collection System
RI/FS	Remedial Investigation/Feasibility Study
RTS	Radon Treatment System
RWP	Radiation Work Permit
SBS	Submerged Bed Scrubber
SCFM	Standard Cubic Feet per Minute
tpd	tons per day
US EPA	United States Environmental Protection Agency
US NRC	United States Nuclear Regulatory Commission
WBS	Work Breakdown Structure

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SECTION 1

FACILITY AND LOCATION

Operable Unit 4 (OU-4) is located within the Fernald Environmental Management Project (FEMP) site boundaries. The Risk Assessment Work Plan Addendum (DOE 1991c) identified the OU-4 boundaries as the following Ohio state plane coordinates: North 480221.5191-481033-2719 and East 1378329.1786-1378641.5890. OU-4 is located on the west central boundary of the FEMP, west of the production area and south of the waste pit area.

The location of OU-4 within the FEMP boundaries is shown in Figure 1-1. The location of the existing and proposed major facilities is shown in Figure 1-2. The proposed OU-4 remediation facilities lie outside of the OU-4 boundaries, in Operable Unit 5 (OU-5) territory.

The major existing structures within OU-4 are four silos, and a Radon Treatment System (RTS) associated with Silos 1 and 2, which are also known as the K-65 silos. The silos are used to store the residues from the processing of K-65 pitchblende ore.

The four silos are large cylindrical concrete tanks. Each is nominally 80 feet in diameter, 36 feet high to the center of the dome, and 27 feet high to the top of the vertical walls. The walls are 8-inch-thick concrete as are the outer part of the domes. The silo domes' thickness tapers to 4 inches within approximately 4 feet of the silo side walls.

Silos 1 and 2 contain radium bearing residues from pitchblende ore processes at FEMP, Lake Ontario Ordnance Works (currently known as the Niagara Falls Storage Facility), and the Mallinckrodt Chemical Works. Silo 3 contains uranium and other metal oxides. Silo 4 has never been used to store process wastes and is empty.

The RTS building is approximately 24 feet long by 22 feet wide and is surrounded by stacked, unmortared, solid concrete masonry units which are a total of 32 inches thick. The RTS building contains two calcium sulfate canisters, eight activated carbon canisters and the associated piping required to circulate the air. The blower for circulating the silo air is located outside the RTS building for construction convenience and to make maintenance of the blower consistent with the As Low As Reasonably Achievable (ALARA) philosophy.

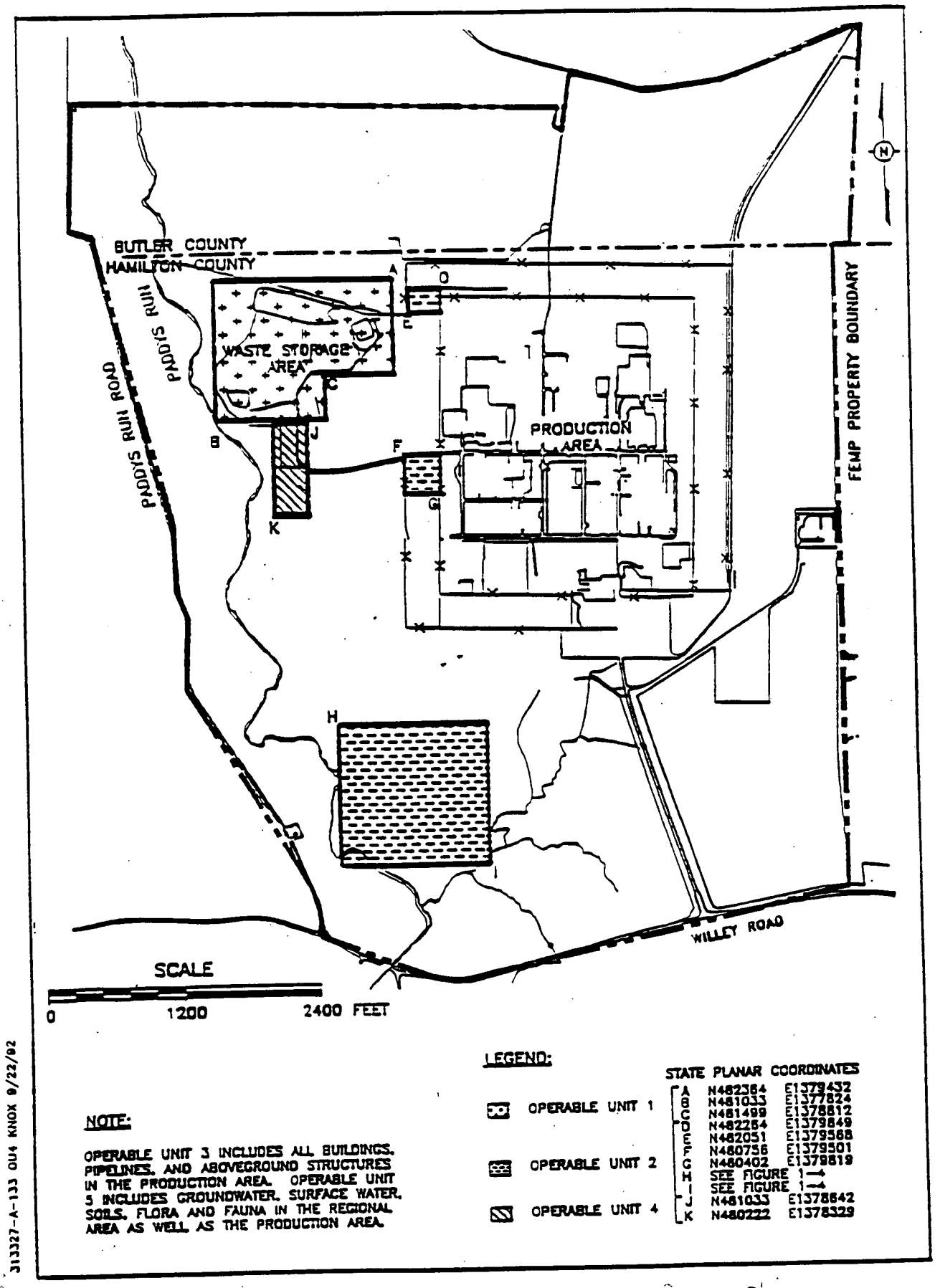

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Figure 1-1 - Source Operable Units

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The OU-4 components being addressed for remediation in the *Operable Unit 4 Remedial Action Conceptual Design Report* (PARSONS 1992d-f) are as follows:

1) The contents of Silos 1, 2, and 3

2) The structures in the OU-4 area including:
   (1) Silos 1, 2, and 3 structures and associated foundations
   (2) Decant sump tank
   (3) K-65 slurry line within OU-4 boundary
   (4) Other miscellaneous structural materials inside OU-4 boundaries

3) The existing Radon Treatment System building, foundation and associated components

4) Surrounding soils and perched water

5) Boundary fencing

6) Newly constructed remediation facilities to include but not limited to:
   (1) Hard stands
   (2) Driveways
   (3) Utility lines, water, electrical, and communication
   (4) Interim storage building
   (5) Vitrification process building and associated equipment

The remedial alternative to be designed is removal, treatment, and on-site disposal. Vitrification is the process used to stabilize the residues within Silos 1, 2 and 3. A soil washing process will be used to treat contaminated soil. A water treatment system is used to treat contaminated process and wastewater. A radon collection and treatment system is used to treat emissions from the silos, vitrification system, and storage tanks. A decontamination and decommissioning facility will be used for the following components: silo structures and related subsurface rubble, decant sump, and associated trench inside the OU-4 boundary and any other structural components encountered inside the OU-4 boundary and the components of the OU-4 remediation facility.

The remedial design for OU-4 will consist of new facilities for the vitrification of the Silo 1, 2, and 3 contents, and the interim storage of the vitrified waste material. See *Operable Unit 4 Remedial Action Conceptual Design Report*, Volume III, Revision 0 (PARSONS 1992f) for all sketches and drawings. The new facilities may be located as indicated in Figure 1-2.

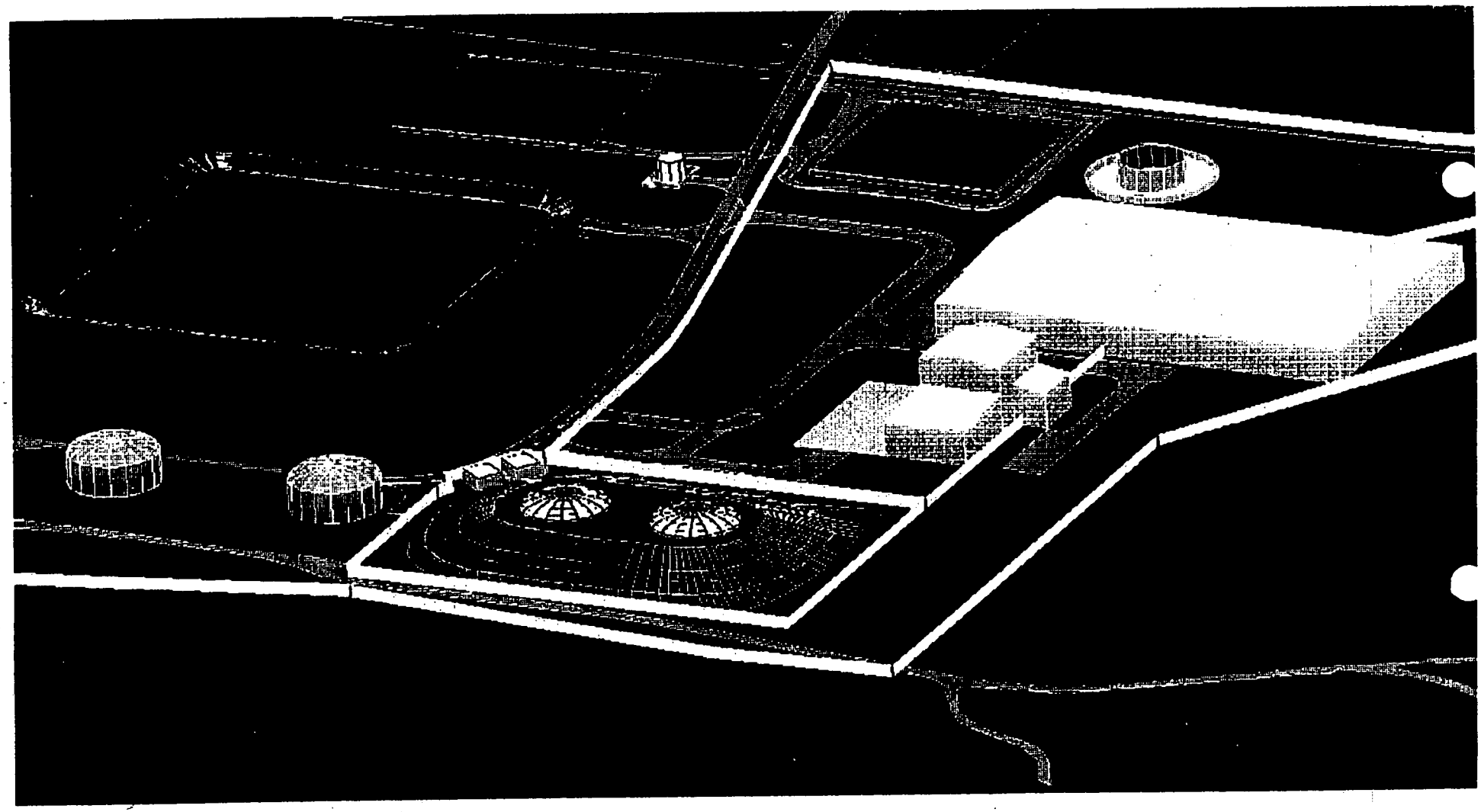

Figure 1-2 - OU-4 Proposed Remediation Facilities

SECTION 2

FACILITY LOCATIONS AND SEGMENTS

For the purposes of this safety assessment there will be no facility segmenting. The structures will be assessed as one facility for the purposes of facility hazard classification. The overall facility will be assessed supporting one Hazard Classification.

One segment is used due to the similar purpose, close proximity, and common hazards of the structures. The primary purpose of all facilities and activities is the remediation of OU-4 (Silos 1, 2, and 3).

SECTION 3

DESCRIPTION OF OPERATION

The following subsections describe the operations associated with the major activities identified in the project WBS.

3.1 Site Preparation, Utilities, and Security

Conceptual siting plans are not finalized, but will identify all required site improvements and earthwork (including surface and subsurface drainage), paving, and surfacing. A geotechnical report is required to support the building foundation, utility, and road designs. The proposed site plan is shown in SK-G-00173.

Utilities are required for both the construction and operation phases. Utility plans must be developed to identify the specific utilities and quantities required. The plans will include the extension of required utilities from the existing source to the required location in accordance with the CDR plan.

A security plan and required design details will be developed. The existing security fence will be the primary security system. This system must be operational during construction, operation of the remediation facility, and subsequent interim storage.

3.2 Process Systems and Facilities

In this section, the primary treatment processes and facilities required for the remediation of OU-4 are presented.

A system will be provided to monitor, report, and control the operation of all the primary remediation system processes (the vitrification system, radon collection systems, residue removal and transfer system, water treatment system, and soil washing system).

3.2.1 Vitrification System and Building

The vitrification system will be capable of processing Silo 1, 2, or 3 material. The throughput capacity will be at least 15 tpd (dry) of Silo 1 or 2 material. The processing rate for Silo 3 material will be approximately 7.5 tpd (dry) due to the quantity of the additives required for processing Silo 3 material. The vitrification system includes receipt of the slurry from the residue removal and transfer system, feed preparation, vitrifying the feed in the electrically heated melter, and discharge of the vitrified glass into containers for appropriate disposition.

The vitrification facility consists of the melter and all required associated components (tanks, piping, pumps, support structures, shielding, materials handling equipment for boxes, etc.). The melter, controls, and some of the support equipment will be enclosed in a building as illustrated on Sketch SK-M-00231. The building will be located as indicated on Sketch SK-G-00173.

Residue Removal, Slurry Treatment, and Dewatering

The recovered slurry is transferred from the removal system to the slurry thickener. The residue removal and transfer is described in Section 3.3. In the thickener, the entrained solids separate from the dilute feed slurry by gravity into a dense underflow slurry. The thickener rake mechanism moves the settled solids and conveys them as a thickened slurry into the underflow discharge. Water containing a small quantity of solids remains at the top of the thickener and overflows a circular weir to the wet well. The wet well receives the thickener overflow and other process condensates. The wet well is equipped with pumps to recycle the water to the hydraulic mining operation in the silo.

The density of the thickener underflow is monitored and controlled. When the solids content is 55 percent by weight, the underflow pumps move the heavy slurry to the next unit operation. If the slurry density is not correct, or if the downstream operation cannot accept the feed, the pumps transport the slurry back to the thickener through a recirculation line.

Vapor from above the thickener and the wet well is drawn off to a knock-out drum where entrained moisture and solids are removed and returned to the thickener. The vapor from the knock-out drum is drawn to the radon off-gas treatment system (covered in Section 3.2.2).

The Silo 1 and 2 slurry removal, transfer, and dewatering are shown on Sketch SK-F-00161. Silo 3 handling and additive blending is shown on Sketch SK-F-00279.

Feed Preparation

The Silos 1 and 2 residues will require a single additive material to feed the melter. The additive storage bin is equipped with a dust collector to remove the entrained particles from the vented air. A pneumatic feeding system is used to transfer material from the storage bin to a smaller additive bin. This additive bin is equipped with load cells for accurate weighing of the feed quantity passing to the melter feed make-up tanks.

For Silo 3, the original storage bin remains operational, but six more bins are provided to store and feed additional required additive materials. The seven bins require individual but integrated feed controls and an agitator in the feed make-up tanks to blend the various materials into a suitable homogeneous feed.

The Vitrification Off-gas System is integrated into the design of the Vitrification Facility as shown on SK-M-00231.

Silo Radon Collection System

The Silo RCS is a recirculating system which must be activated before the silo can be opened and operations such as residue removal can start. A recirculation loop between the carbon units and the silos lowers radon concentration in the air headspace to an equilibrium point that will minimize potential worker exposure hazards. This includes keeping the silos at a negative pressure relative to atmosphere. It is anticipated that 2 to 4 hours of recirculation are required before the commencement of any process activity (including residue removal) from inside the silo. The RCS must continue to run during any operation involving opening of a silo port or any activity inside of the silo.

Air drawn off the silo headspace is assumed to be saturated at 100 percent relative humidity. In order for the carbon adsorption beds to function properly, the relative humidity must be lowered to a maximum of 50 percent. Incoming saturated air is first cooled, where the condensate drains to a storage tank and is pumped to the vitrification wet well. The air is then reheated by an electric heater to a temperature which will limit the air moisture to 50 percent relative humidity. The air then passes through one of the two carbon units (the second is on standby) where the radon is adsorbed. Most of the treated air is then recirculated to the silo. Some of it, however, is bled off through a HEPA (High Efficiency Particulate Air) filter to the atmosphere to maintain the system at a negative pressure. The Silo RCS is shown in Sketches SK-F-00158 and SK-N-00256.

The Vitrification Off-Gas Treatment Systems

The melter off-gas requires processing to remove radon gas and its decay products before it can be vented to the atmosphere. The high temperature off-gas exits the melter and is mixed with cool air to reduce the temperature. This is then blended with the small amount of vessel off-gas required to keep the process at a slightly negative pressure, thus controlling or preventing radon emissions from the vessel headspace.

The off-gas process for Silos 1 and 2 material starts with the treatment by a submerged bed scrubber (SBS). This unit receives the off-gas and passes it through a submerged packed bed, which filters out particulates and cools the gas. The resulting solids slurry and water condensate are recycled to the melter feed tanks and wet well, respectively. A High-Efficiency Mist Eliminator (HEME) removes entrained water from the off-gas product. In the case of Silo 3, an extra venturi scrubber is added to remove SO_2 from the off-gas (see Sketch SK-F-00281).

After the scrubber and HEME gas cleaning, the exit off-gas is passed through a chilled water gas cooler. The condensed moisture is collected in a storage tank and recycled to the thickener wet well. The cooled

The underflow slurry from the thickener is mixed with the proper additive(s) in the feed make-up tanks. Three feed tanks operating on alternating cycles are provided: one for continuous feed to the melter, one for preparation of the next batch of feed, and one for receiving slurry underflow from the thickener. The feed preparation for Silos 1 and 2 is shown on Sketch SK-F-00162. The feed preparation for Silo 3 is shown on Sketches SK-F-00279 and SK-F-00280.

Melter

The electric, joule-heated melter is a closed refractory-lined furnace. The melter is fed through water-cooled feed injectors. A set of electrodes provides the heat source for melting.

The primary product of the melter is glass. It is also anticipated that there will be an occasional discharge of "off-quality" product.

The hot off-gases will require decontamination before exhausting to atmosphere. The treatment of melter off-gas is described in Subsection 3.2.2.

Glass Discharge and Inspection

The molten glass product is discharged into metal containers for cooling and Quality Control (QC) testing prior to interim storage. The off-quality product from the melter will also be placed in suitable storage for future recycling or final disposal. Periodic purges to discharge the metallic residues from the bottom of the melter will also be required. This purged material will be placed in boxes for testing and disposition.

3.2.2 Radon Collection and Off-Gas Treatment Systems

The radium-bearing residues in the OU-4 area emit radon gas; that is, gas collects in the "headspace" of the silos, and any other vessels containing the residues. Two independent systems are provided for the radon and off-gas control of the OU-4 Remediation System: the Silo Radon Collection System (RCS) and the Vitrification Off-Gas System. These systems are based on activated carbon adsorption technology. In general, the gas to be "treated" is drawn through carbon adsorption units where the radon is adsorbed. The radon decays in the carbon unit and the decay products remain in the carbon bed. These systems are described in greater detail below.

The Silo RCS is a dedicated system located on the east side of the OU-4 boundary as shown on SK-G-00173. This system requires shielding, independent structural supports, pumps, valves, piping, monitoring instruments, controls, and alarm systems.

off-gas is then reheated in an electric air heater to yield gas at a maximum of 50 percent relative humidity.

The gas is then introduced into activated carbon adsorption canisters. The carbon removes radon from the off-gas. Two carbon units are arranged in parallel, one operational, and one on standby. When one unit has reached the optimal quantity of radon adsorption, as measured by radioactivity analysis in the exhaust, the operating unit is stopped and the standby unit is brought on-line to continue operation. The radon on the carbon decays to daughter products, allowing self-regeneration of the carbon filter.

The decontaminated off-gas is next passed through HEPA filters which remove any remaining particulates prior to venting to the atmosphere through a stack.

3.2.3 Water Treatment System

A water treatment system is required to treat contaminated process and wastewater. This system will receive water from the process areas. The treated water will be returned to the processes for reuse or discharged to the OU-5 Advanced Wastewater Treatment System (AWWT), as required.

The scope of the system includes all associated components: pumps, tanks, filters, piping, valves, reagent preparation equipment, local controls and monitoring equipment, mounting skids, etc.

The thickener overflow from soil washing and the filtrate from soil leaching (Subsection 3.2.4) are to be treated prior to reuse as process water. These two streams are mixed on a continuous basis in a pH adjustment tank. A flocculent is added in the precipitation tank overflow line to aid in the formation and settling of suspended particles, which are then filtered out using multimedia filters.

The surge/recycle tank receives the filtered water and any necessary make-up water. This is pumped on an as-needed basis back to the various processes. A portion of the surge/recycle water is bled off to the ion exchange units and sent to the AWWT. The surge/recycle tank also provides backwash water to clean out the trapped solids in the multi-media filters. The filter backwash is sent to a sump and pumped to the vitrification process for treatment.

3.2.4 Soil Treatment System

A soil treatment system will be provided to clean contaminated soil during the remediation of OU-4. The scope of this system includes receipt of contaminated soil in containers, treatment of soil, and the return of clean soil to the OU-4 area for use as backfill. Any remaining contaminated soil will be placed in containers for transfer to the vitrification facility, the interim storage facility, or the Engineered Waste Management Facility (EWMF), as appropriate.

The scope includes all associated components, including pumps, filters, piping, valves, reagent storage and preparation equipment, containers, mounting skid, local controls and monitoring equipment, etc.

Contaminated soil from the OU-4 area will be water washed and acid leached to remove contaminants and produce soil clean enough for use as backfill. This contaminated soil is first fed into a trommel screen where it is water-washed and separated into oversize and undersize material.

The oversize material is conveyed into containers and manually sampled. Analytical test results determine if the soil can go to backfill, or if it needs to be further treated. The undersize material passes to the spiral classifier where it is again washed and separated into oversize and overflow material. Material classified as oversize is collected in containers where it is manually sampled and dealt with in the same manner as trommel screen oversize material.

Overflow from the spiral classifier containing the soil fines and contaminants is collected in a sump and pumped to a thickener. Thickener overflow is collected in a second sump and partially recycled to the trommel screen, or bled off to the OU-4 wastewater treatment facility.

Thickener underflow is pumped into an acid leach tank where it is mixed with nitric acid from the acid storage tank (as shown on SK-F-00168). This mixture is then pumped to a belt filter where the filter cake is washed in stages prior to discharge of the solids by a screw conveyor. The clean filter cake is conveyed into containers, manually sampled, tested, and then either sent to backfill or an additional treatment process. This alternate treatment process may be required as determined by future soil analysis. The belt filtrate containing the dissolved contaminants is sent to the water treatment facility.

3.2.5 Interim Storage Facility

The remediation of OU-4 will produce treated materials prior to the availability of long-term storage or disposal. The vitrified, contained waste will need interim storage for some period before long-term storage is available at the FEMP site. The period of interim storage is designed for an 18-month period. The interim storage facility will function as a warehouse in which containers will be stacked by a fork-lift truck and later transferred to long-term storage or disposal. The ongoing DOE-US EPA discussions on the application of ARARs and the application of 40 CFR 191 Subpart B as an ARAR may influence the design of the Interim Storage Facility (ISF).

All waste material stored in the ISF will be in containers and in a noncombustible, solid form. Liquid waste and combustible materials will not be stored in the ISF. The building will be approximately 27,000 square feet and will handle approximately 2,100 B-12 boxes stored in groups four high.

Stacking of boxes will provide visual inspection of at least one side of each box. Most boxes will not be able to be removed without first rearranging other boxes.

The building will be a pre-engineered metal building and will have 18-inch thick shielding walls of normal weight concrete construction to the level of the stacked boxes of vitrified glass. As part of the radiation protection requirements, a perimeter security fence located 40 feet away from the building will be provided. At each doorway, a concrete barrier, located to permit access to the building, will be provided to shield the opening. The entire building will be a radiologically-controlled area with restricted access.

The building will have minimal lighting, ventilation, and fire protection. Overhead doors will be remotely operated.

3.3 Residue Removal and Transfer System

The function of the Residue Removal and Transfer System is to remove residue from the silos and deliver it to the vitrification facility. The system includes the support structure and hydraulic mining equipment for the removal of residue from Silos 1, 2, and 3.

Residues will be removed from the silos by hydraulic methods. The removal system will provide enough material for the continuous operation of the vitrification melter. The system will convey the residues to the moisture control system. The contaminated perched water below the silos will be removed by extraction wells. This water will be used as makeup for the residue treatment process. The quality of the water used during the removal operations will be maintained within process and/or regulatory limits by characterizing the wastewater streams and processing the required make-up or blowdown volumes.

The Residue Removal and Transfer System will have the following features:

1) The residue removal equipment is operated remotely.

2) Additives (water) introduced into the silo for removal operations and the quantity of material pumped into and out of the silos will be recorded.

3) The equipment removes and supplies residue to match the following feed requirement of the melter:
   (1) 15 tons of dry residue per day (Silos 1 or 2 material)
   (2) 24 hours of operation per day
   (3) 7 days of operation per week
   (4) 275 days of operation per year

4) Removal techniques do not compromise the structural integrity of the silos.

5) Stand-by power ensures that the transfer system will not be plugged in the event of a power failure.

6) Residue removal equipment is designed for ease of retrieval from silos for maintenance.

7) Residue removal equipment (located within the silos) can be removed from silos without the need for personnel to enter the silos in case of malfunction.

8) TV cameras are installed for observation and control of residue removal operations. The cameras are operated remotely.

9) The radon collection system remains operational during residue removal operations.

10) Systems preclude the release of radon to the atmosphere. Sealing devices or glove boxes are used for removal or insertion of equipment into the silos. In addition, the silo is kept at a negative pressure to create an inflow of air into the silo during operations.

11) Residue removal equipment is proven. State-of-the-art technologies incorporating commercially available equipment are employed.

12) It is not imperative that a single device be used to reclaim all of the material from the silos. If multiple devices are employed, the resultant increase in complexity will be considered.

13) The berm soil is removed in coordination with the removal of silo residues.

3.4 Soil and Perched Water Removal and Transfer Systems

Perched water and contaminated soil in the OU-4 area will be removed and treated during the remediation. Contaminated perched water will be used as makeup for the residue treatment process. The quantities of contaminated material and the concentrations of contaminants will be determined during the sampling and characterization being performed during the Remedial Investigation/Feasibility Study (RI/FS) effort.

3.4.1 Soil Treatment System

Soil underneath the silos and within the berms around the silos that does not meet the remedial standards will be excavated and sent to an extraction facility for treatment. Soils not amenable to extraction and extraction process sludges will be vitrified or boxed for storage in interim storage or in the EWMF. Soil that does not require treatment will be stockpiled and may be used as backfill.

The Soil Extraction System will have the following features:

1) Soil that requires treatment may be boxed in a staging area prior to treatment. The staging area will be a concrete pad with runoff control. A temporary fabric, sprung-structure building may be provided over the staging area to control dust emissions.

2) Process equipment located outside will be provided with rain and freeze protection, as required.

3) The extraction system will be designed to be portable (trailer-mounted).

3.4.2 Perched Water Removal

The Perched Water System will remove and transfer water in the OU-4 area above the aquifer. Based on a preliminary analysis, the quantity of perched water will initially be less than 1,000 gallons per day, and will decrease over the first 3 years to less than 500 gallons per day. Because of the small quantity of water, and because the vitrification system uses water, the perched water will be pumped into the vitrification wet well for use as process water.

3.5 Decontamination and Decommissioning Effort

The following components will require decontamination and decommissioning (D&D) as part of the remediation process:

1) The silo structures (Silos 1, 2, and 3) and the associated buried concrete transfer trench and decant sump, the contaminated foundations and associated soils, and other items identified on field investigations such as the sump pump pit and existing radon treatment system.

2) All equipment used in the residue removal process.

3) The temporary facilities built to process the Silo residues and soils. These include the Radon Collection Facility, the Vitrification Facility, the Wastewater Treatment Facility, the Soil Washing Facility, the Interim Storage Facility, and the associated utility services.

Prior to the start of these activities, a complete structural and radiological characterization must be performed. This will provide baseline information and may influence decisions regarding decontamination equipment, techniques, and procedures that are most appropriate.

The principal objectives of this effort are:

1) To decontaminate the facilities and equipment for reuse or release to the greatest extent possible, while minimizing exposure to individuals.

2) To determine the levels of radiological/chemical contamination of the silo structures and to dispose of these structures in the most effective manner.

3) To demolish the silo structures while maintaining control of the process, both radiologically and physically.

4) To perform all work in such a manner as to minimize, to the extent possible, the quantity of waste to be packaged for interim storage on site.

5) To perform all work in compliance with regulatory and site requirements commensurate with maintaining ALARA principles.

3.5.1 D&D of the In Situ Components

This section identifies the D&D equipment and procedures for dismantlement of the silo structures. The sequence of operations could consist of processing the remaining waste, preparing the surfaces for demolition, demolishing, removing, and packaging the silo structures and systems, and performing a final assessment prior to storage or disposal. Considerations during the D&D activities include the volume and type of waste generated, the radiological monitoring requirements for the various activities, and worker exposure.

After the removal of the residue and prior to the start of the dismantlement activities, a complete structural and radiological characterization of the silo will be performed using samples taken from the concrete by coring. This will provide baseline information and will determine selection of decontamination equipment and technique. More extensive core sampling may be recommended in order to determine the structural and radiological condition, and to facilitate the selected cutting process. Core samples can be taken from the top part of the silo walls without significantly affecting structural integrity. When the characterization of the silos is complete, proper evaluation of the radiological control can be established. Manual and/or remote methods may be used. The details of the conceptual design will be refined during Title design when characterization and structural integrity are better understood.

When a silo is empty, initial D&D efforts may begin. An initial step will be to remotely decontaminate and stabilize the silo and to prepare the structure for decommissioning. Following stabilization, the domes will be removed, followed by the sides, floors, piping, drainage ditches, foundations, and finally the associated underlying rubble. This approach will minimize the potential for a structural failure and maintain control of the process during the silo structure demolition.

To assure that an accident during Silo 1 D&D will not impact residue removal from Silo 2, the demolition of Silo 1 will not be performed until the residue removal operations from Silo 2 are complete.

With the proper environmental controls (sealing the structural surfaces with paint prior to demolition, proper monitoring) the demolition of the silo structures will be performed without environmental isolation enclosures. The level of personal protection needed will depend on the potential level of exposure during the operation and the level of particulate matter generated and released into the air. Personnel shall minimize the potential for internal exposure by using sound radiological work practices, adhering to established procedures, using respiratory protection, and complying with all Health Physics requirements.

3.5.2 D&D of the Remediation Components

The D&D of the remediation components follows the same basic philosophy as the D&D of the in situ OU-4 components.

The following section identifies the equipment and activities necessary for the D&D of the temporary facilities, equipment, services, and utilities. The effort consists of stabilization and manual decontamination, processing of the resultant waste, preparation of the surfaces for demolition; and the actual demolition (where required), removal, and packaging of the facilities, equipment, services, and utilities; and performance of a final assessment of the site(s). Because new pieces of process equipment have been designed with D&D in mind, only the equipment in direct contact with the residue material will be significantly contaminated. The rest of the structures and equipment may be suitable for free release.

3.5.2.1 Preparation for D&D

Following the removal and treatment of the silo residues and the D&D of the silos, the D&D of the equipment used during the remediation will begin. This equipment includes the Vitrification Facility Equipment, the Radon Collection Equipment, the Material Handling Equipment, and the associated miscellaneous material and utility services for the temporary remediation facilities.

An equipment inventory and radiological characterization will be completed in order to determine the decontamination techniques and final disposition for each piece of equipment and structure. A complete history of the facility's condition including construction, equipment, contamination levels, and operating

history will be evaluated to establish the clean up levels and final disposition of the equipment. Final disposition may include:

1) Free release

2) Boxed for disposal in an on-site disposal facility

3) Reusable items by others on-site (certain utilities, power station, forklifts, other equipment, melter and associated components)

The final step is to establish health physics and operating procedures to comply with the radiological conditions of the facility as well as the regulatory requirements for the D&D of the facility. The Health Physics and pertinent operating procedures include area monitoring requirements, surface contamination area control, radiation area control, and airborne radioactivity area control. With these systems operational, identification and disposal of the surplus materials and equipment in the facility can be accomplished.

Process flow diagrams and the services drawings will aid in the determination of the order of disconnection of services. The sequence of demolition will consider the need for staging areas for box transport and the movement of personnel.

Work will proceed from the most to least contaminated area. Demolishing, treating, and boxing activities for on-site use/storage must be set up with the contamination level in mind. Furthermore, classification of all materials into appropriate categories will be made as follows:

1) Contaminated, for processing and/or storage in the ISF
2) Non-contaminated, non-reusable
3) Non-contaminated, reusable
4) Contaminated/reusable

Standby utilities will be included for critical D&D operations. Standby lighting will allow egress with a failure of the normal lighting system. Self-powered lighting will be provided in areas where normal egress is hindered by airlocks, walls, doors, and corridors. Standby power for the HVAC, decontamination equipment, etc. is required for any system that may cause personnel exposure or environmental contamination. Standby power is also required for discharge radiological instrumentation.

Monitoring before, during, and after the D&D operation is important. Surface monitoring of the equipment and material assures that proper cleaning/stabilization has occurred to minimize contamination spread. Monitoring of all personnel prior to leaving the change/decontamination area is also required.

Monitoring of all material (prior to boxing) and the monitoring of the exterior of the package is needed for inventory control records.

3.5.2.2 D&D of Equipment and Facilities

The D&D of the process equipment will occur in three distinct steps:

1) Equipment Removal

If the equipment is shielded, the shielding must be removed. Surveys of the shielding surrounding the pieces of equipment will determine if the shielding is potentially reusable by others on-site. General equipment removal will involve monitoring the equipment exterior, isolating the equipment from other processes, ensuring all tanks, vessels, and storage bins are empty by visual inspections. Volume reduction of large equipment prior to packaging may require size reduction prior to removal. Smaller equipment may be boxed whole.

2) Facility D&D

General facility D&D will involve preparing and cleaning the services and the demolition of the structures. Cleaning of all exposed surfaces (piping, conduit, ventilation ducts) will be performed. Stabilization of contaminated surfaces (paint, seal, etc.) including exposed horizontal surfaces (window sills, counter tops, tops of door frames), and cleaning around floor drains, light fixtures, exhaust fans, and electrical penetrations will also be performed. All piping will be flushed with the water going to the water treatment facility. Duct work and piping will be removed by cleaning and sealing the ends. During the removal of strippable coatings, special care will be taken to avoid creating any unnecessary dust. Extra care will be required around exposed welds, bolt threads, and the duct work flanges.

3) Building Demolition

Demolition of the building will start with cleaning debris off the floor, monitoring the area, and disconnecting any final service connections. Periodic monitoring of the material being removed will indicate contamination. Once the building has been emptied, the roof and walls will be removed. The floor, foundation, and slab will be removed using the same basic sequences as described in the silo removal section. As material is brought into the holding or staging areas, the material and the exterior of the package will be surveyed and the pertinent data recorded for inventory control. When D&D of the holding or staging area begins, the boxes/packages will be segregated and transported from the holding area to another transfer location. When all demolition activity is complete and all associated contaminated soils removed, a complete and

final assessment of the site will be performed. Complete description of all D&D activities as well as ongoing and final assessment results will be recorded.

3.5.2.3 Reusable Equipment and Facilities

Minimization of the waste quantities to be packaged for on-site interim storage has been incorporated through innovative use of the concept of "recycle and reuse." This minimization has been accomplished by segregation of the waste streams. The identification of non-contaminated equipment and material for potential reuse on site by other OUs will reduce the total waste quantity for interim on-site storage, while providing overall cost savings. This cost savings will be realized in the reduced cost for storage and by the avoidance of future procurement of this reusable material and equipment within the FEMP site.

Many components used in the remediation of the silo contents and structures have been identified as being potentially reusable for other on-site remediation projects and/or at other DOE facilities. The items identified are as follows:

1) Wastewater Treatment Facility (trailer mounted)

2) Soil Treatment Facility (trailer mounted)

3) The melter and associated control equipment from the Vitrification Facility

4) Material Handling Items
   (1) Frontloaders
   (2) Backhoes
   (3) Forklifts
   (4) Hydraulic Platforms

5) Miscellaneous equipment and removal

Before actual D&D of equipment is performed, an equipment inventory and characterization must be completed to determine the disposal techniques used for each piece of equipment. The equipment should be characterized and determination made whether or not the equipment is reusable. This equipment may be stored if it can't be reused immediately.

3.6 Final Grading and Landscaping

The final grading and landscaping will not be completed prior to soil removal or prior to perched water operations. Grading and landscaping plans include the following:

1) Plot plans to identify location and types of grass, plants, shrubs, and trees.

2) Contour plans to identify the finished contours and profiles.

3) Grading to minimize the alteration of existing surface drainage courses.

SECTION 4

MAJOR EQUIPMENT

A list and description of the major equipment can be found in the Material and Equipment List of the *Operable Unit 4 Remedial Action Conceptual Design Report, Volume II, Revision No. 0*, (PARSONS 1992e).

SECTION 5

NUMBER AND CLASSIFICATION OF OPERATING PERSONNEL

Estimates of the number and classification of operating personnel has been made for the vitrification system. Table 5-1 shows the number and classification of operating personnel.

Table 5-1 - Operating Manpower Requirements for the OU-4 Remediation (excluding D&D)

	Crew A	Crew B	Crew C	Crew D	Total
Plant Supervisor/Deputy	2				2
Operations: (7 days/week)					
Chief Operator	1	1	1	1	4
Residue Removal/Feed Preparation	2	2	2	2	8
Vitrification					
Feed System	1	1	1	1	4
Glass Discharge	1	1	1	1	4
Product Handling	2	2	2	2	8
Melter Off-gas and Radiation Collection	2	2	2	2	8
Soil Work (5 days/week)					
Soil Excavation	2	2	2		6
Handling	1	1	1		3
Soil Wash	2	2	2		6
Product Handling	2	2	2		6
Interim Storage	2	2	2		6
Handling and Storage	1	1	1		3
Sampling and Assay	2	2	2		6
Chemical Lab (7 days/week)					
Auto Assay	1	1	1	1	4
Wet Assay	2	2	2	2	8
Radiation Monitor	2	2	2	2	8
Ready Maintenance Crew(1)/Spare	5	5	5	2	17
Instrumentation Technician(1)	1	1	1	1	4
Electrical Technician(1)	1	1	1	1	4
Health/Safety Engineer(1)	1	1	1	1	4
	36	34	34	19	123

(1) These positions may be available from the central FEMP operations group.

SECTION 6

INTERACTION WITH OTHER FACILITIES

The OU-4 remediation facilities may interact with OU-5 facilities due to the location of the remediation facilities within OU-5 boundaries.

The electrical power supply for the vitrification system interfaces with the site power 13.2 kV supply.

After pretreatment in OU-4 facilities, treated wastewater will be sent to the OU-5 Advanced Waste Water Treatment Facility.

Site water is required for input to the remediation facilities at several points.

OU-4 communications shall also be connected to the FEMP sitewide communication system.

The glass product will require final disposition following interim storage. This may be disposed of on site or transported off site for disposal.

The treated and washed soil will require final disposition.

SECTION 7

NUCLEAR/RADIOACTIVE MATERIALS

The radioactive materials within OU-4 are primarily contained within Silos 1, 2 and 3. The concentrations and estimated volumes of these materials for Silos 1, 2, and 3 and the vitrification facility are shown in Table 7-1. Additional radioactive materials are present in the soils and other structures within OU-4 as residual contaminants only. The concentrations and thus the hazards associated with these residual contaminants are less than the radionuclide concentration in the Silos.

The remediation system for OU-4 will not change the total quantity of radionuclides present within OU-4. The remediation effort will change the form of the radioactive material so that it is immobilized and the radon emissions will be reduced.

The vitrified form of the OU-4 radionuclides will significantly reduce the inherent hazards of the material. The size of the glass blocks would render the radionuclides into a form such that dispersion into the atmosphere is not a reasonable scenario. The most significant hazards present are due to the radionuclides in their present state within the silos.

The source term present within any given component in the vitrification system will be less than the content of the silos. In addition, the form of the material in the vitrification system, being high in water content, is in a less hazardous state than within the silos. The solids being suspended in a slurry are not susceptible to dispersion during the hypothesized accidents. The vitrified material in block form is a large consolidated solid and is not susceptible to resuspension or dispersion in an accident situation. However, the radioactive material within each component of the system presents an external hazard.

The soils in the berm contain low levels of radionuclides. The source term within the berms is small in comparison to the residue within the silos.

Table 7-1 - Volume and Radionuclide Concentrations for Major Components of the Vitrification System

	Silo 1	Silo 2	Silo 3	Thickener		Well (mostly runoff)	Slurry Surge	Feed Makeup (2 units)
				Silos 1&2	Silo 3			
Mass (ton)	4,000	5,700	4,200	167	167		84	84
Volume (yd^3)	4,291[4]	3,720[4]	5,200[2]	124	124	124	62	62
Pa-231 (pCi/g)[3]	13,622[1]	10,100[1]	931[1]	8,773	707		707	707
Pb-210 (pCi/g)	386,400[1]	194,700[1]	6,427[1]	164,611	4,884		4,844	4,844
Ra-224 (pCi/g)	923[1]	657[1]	453[1]	582	344		344	344
Ra-226 (pCi/g)	890,700[1]	481,000[1]	6,435[1]	493,222	4,890		4,890	4,890
Ra-228 (pCi/g)	2,472[1]	1,468[1]	559[1]	1,429	424		424	424
Ac-227 (pCi/g)	11,130[1]	10,450[1]	1,363[1]	8,153	1,035		1,035	1,035
Po-210 (pCi/g)	1,020,000[1]	390,000[1]	-	492,708	-		-	-
Th-228 (pCi/g)	42,800[1]	8,600[1]	996[1]	53,064	757		757	757
Th-230 (pCi/g)	105,372[1]	160,000[1]	71,650[1]	104,577	54,454		54,454	54,454
Th-232 (pCi/g)	44,000[1]	2,900[1]	1,451[1]	15,010	1,102		1,102	1,102
U-234 (pCi/g)	1,570[1]	1,945[1]	1,935[1]	1,361	1,470		1,470	1,470
U-235/236 (pCi/g)	256[1]	130[1]	158[1]	138	120		120	120
U-238 (pCi/g)	1,560[1]	1,925[1]	2,043[1]	1,349	1,552		1,552	1,552

1 *Remedial Investigation Report for Operable Unit 4, Draft*, dated October 1992, United States Department of Energy, Appendix A.

2 *Table 4-2 - RI/FS for OU-4 Task 6 Report*, October 10, 1990b

3 Note: RI/FS reports Pa-237 which is not naturally occurring. This is assumed to be a typo and Pa-231 is assumed.

4 Silos 1 and 2 Volumetric Results from Surface Mapping, Letter from D.L. Jacoboski to W.G. Tope, April 4, 1992

SECTION 8

TOXIC AND FLAMMABLE SUBSTANCES

The toxic and flammable substances which may be present in the OU-4 remediation facility are listed in Table 8-1. The chemical contents of the Silos are shown in Table 4-2 of the Site-Wide Characterization Report Volume 2 (Draft) (DOE 1992).

Table 8-1 - Toxic and Flammable Substances

Q.C. Laboratory	Misc. chemicals
Cooling Tower	Misc. water additives
Radon Control System	Activated carbon
Off-Gas System	Activated carbon
Wastewater Treatment	NaOH, concentrated, 5,100 gallons H_2SO_4, concentrated, 55-gallon drum Flocculent, powder, 100-gallon, agitated Radium removal resin, 2 vertical columns
Soil Washing	HNO_3, concentrated, 5,350 gallons Possible additional reagent, 350 gallons
Silo 3 Additives	Coal, 750 cubic feet SiO_2, 750 cubic feet Al_2O_3, 750 cubic feet CaO, 750 cubic feet Fe_2O_3, 750 cubic feet B_2O_3, 750 cubic feet Na_2CO_3, 750 cubic feet
HVAC Emergency Exhaust	Activated carbon
Electrical Stand-by Generator	Diesel fuel
HVAC Air Dryer	Desiccant

SECTION 9

UNIQUE/UNUSUAL SAFETY PROBLEMS

This section identifies the aspects of the facility that involve hazards that are not normally encountered in industry. These hazards are assessed to determine the hazard classification of the facility.

9.1 Preliminary Hazard Assessment

A Preliminary Hazard Assessment (PHA) was performed to develop a list of potential hazards associated with the remediation of OU-4. This PHA was performed by a team of design professionals familiar with the proposed design. The results of the PHA are presented in Tables 9-1 through 9-4.

A Preliminary Hazard Analysis was used to identify the "raw" unmitigated hazards present with the project conceptual design. The identification of hazards consists of a "brainstorm" process where no effort was made to analyze the probability and consequence of the identified hazards.

The PHA focuses on the hazardous materials and major plant elements based on the CDR, since Title Design has not begun, and there are no procedures developed. The PHA consists of formulating a list of the hazards related to:

1) Raw materials, intermediate and final products
2) Plant equipment
3) Interfaces among system components
4) Operating environment
5) Operations

Where mitigative measures have been identified in the design, they are listed in the PHA. However, no credit is claimed for these items in the consequence analysis.

Table 9-1 - Preliminary Hazard Assessment (Common Hazards)

Hazard	Cause(s)	Major Effect(s)	Mitigative Measures
1. Internal Radiation Exposure	1. Inhalation of radionuclide bearing dust residues 2. Radiation Work Permit (RWP) is not updated as work progresses 3. Silo material exposed to atmosphere	1. Potential to exceed site dose limits	1. Contaminated dust control 2. Personal protective equipment 3. RM-0009, "Radiation Control Manual" 4. Radiation Work Permit 5. Project Specific Health and Safety Plan 6. Construction Environmental Health and Safety Work Survey 7. Ventilation system samples and removes contaminants 8. Pipes with contaminated material in controlled areas above ground 9. Silo Radon Collection System 10. Silo material maintained in wet sheltered condition
2. External Radiation Exposure	1. Presence of penetrating radiation 2. Radiation Work Permit (RWP) is not updated as work progresses 3. Buildup of radon 4. Radon daughters in head space above equipment or tanks 5. High level of radon, radium daughter or thorium products in the final waste form	1. Potential to exceed site dose limits	1. Application of As Low As Reasonably Achievable (ALARA) principles 2. RM-0009, "Radiation Control Manual" 3. Radiation Work Permit 4. Project Specific Health and Safety Plan 5. Construction Environmental Health and Safety Work Survey 6. Shielding to be installed 7. Off-gas system 8. Silo Radon Collection System operation
3. Operational Releases of Contaminated Dust	1. Work in the area 2. Excavation of contaminated soil 3. Handling of contaminated soil	1. Internal exposure to contaminated dust	1. Contaminated dust control 2. Personal protective equipment

Table 9-1 - Preliminary Hazard Assessment (Common Hazards)

Hazard	Cause(s)	Major Effect(s)	Mitigative Measures
4. Fire/Explosion	1. Vehicle Fire 2. Electrical fire 3. Local refueling 4. Engine fire 5. Stored fuels 6. Oil	1. Possible personnel injury/death 2. Potential release of airborne contaminants 3. Equipment damage 4. Loss of material and equipment 5. Local fire	1. Flammable material to be kept to the minimum practical amount 2. Fire protection program 3. Implementation of proper use and maintenance procedures 4. Equipment inspection 5. Fire protection system. 6. The FEMP maintains a 24-hour emergency response team (ERT) in addition to 24-hour fire inspection and response capability 7. Project Specific Health and Safety Plan 8. Construction Environmental Health and Safety Work Survey
5. Personnel Injury (Industrial)	1. Improper use of electrical supply, equipment, safety devices due to human error 2. Equipment left running during maintenance and repair operations 3. Slip, trip and fall accidents 4. Material handling equipment is less-than-adequate 5. Vehicle impact	1. Possible personnel death/injury 2. Airborne release	1. Personnel operate equipment as designed 2. Personnel use recommended safety devices correctly 3. Personnel utilize equipment as designated the procedures 3. Equipment inspection 4. Supervisor shall verify and ensure that workers have received general site worker training in addition to task specific training as listed in the Project Specific Health and Safety Plan 5. Personnel shall be trained on procedures. 7. Project Specific Health and Safety Plan 8. Construction Environmental Health and Safety Work Survey

Table 9-1 - Preliminary Hazard Assessment (Common Hazards)

Hazard	Cause(s)	Major Effect(s)	Mitigative Measures
6. Personnel falling into silo	1. Poor workmanship while repositioning the removal equipment and associated supports	1. External and possible internal contamination	1. Personnel safety restraints will be worn
7. Silo Containment Breached	1. Tornado 2. Rigging failure	1. Possible personnel death/injury 2. Equipment damage/loss 3. Spread of airborne contamination 4. Internal/external exposure 5. Loss of containment	1. Site tornado warning system 2. FEMP Emergency Response Plan 3. Training
8. Electricity	1. Shorts in electrical cables	1. Possible personnel injury/death 2. impact on site safety function 3. Loss of power for production 4. Local fire 5. Airborne release 6. Solidification in vitrifier 7. Loss of safety functions	1. Electrical interface is reviewed by supervisor prior to implementation 2. Project Specific Health and Safety Plan 3. Construction Environmental Health and Safety Work Survey 4. Backup power to critical functions 5. Vitrifier maintain in safe condition for long period 6. Process system shuts down to safe condition
9. Vehicle Traffic	1. Vehicle collision 2. Traffic patterns used by operations 3. Operator error	1. Possible personnel injury/death 2. Equipment failure 3. Possible release of radioactive or hazardous contaminants	1. Vehicle safety training 2. Project Specific Health and Safety Plan 3. Construction Environmental Health and Safety Work Survey 4. Designated personnel walkways 5. Necessary traffic barriers are in place

Table 9-1 - Preliminary Hazard Assessment (Common Hazards)

Hazard	Cause(s)	Major Effect(s)	Mitigative Measures
10. Hoisting and Rigging	1. Equipment failure 2. Operator error 3. Lack of maintenance of lifting equipment	1. Possible personnel injury/death 2. Equipment failure 3. Possible release of radioactive or hazardous contaminants	1. Project Specific Health and Safety Plan 2. Construction Environmental Health and Safety Work Survey 3. Operator training 4. Equipment maintenance and training
11. General Lighting	1. Inadequate lighting	1. Possible personnel injury 2. Equipment damage 3. Possible release of radioactive or hazardous contaminants	1. FERMCO will ensure that adequate lighting is available 2. Project Specific Health and Safety Plan 3. Construction Environmental Health and Safety Work Survey
12. Equipment or Materials in the Walkways	1. Personnel walking around equipment and materials and tripping	1. Possible personnel injury	1. Identify and mark or remove tripping hazards 2. Project Specific Health and Safety Plan 3. Construction Environmental Health and Safety Work Survey
13. Loss of normal electrical distribution power	1. Equipment failure 2. Human error 3. Natural catastrophe	1. Loss of electrically operated equipment and instrumentation	1. Backup power for critical functions including melter heating
14. Loss of containment on high-pressure water line	1. Over-pressurization of line 2. Weld or seam failure 3. Material defect	1. Release of water which contains radionuclides 2. Potential personnel injury	1. Pre-operational testing 2. Leak Detection System 3. Contaminated pipes in controlled areas
15. Failure of site emergency system	1. Poor planning 2. Loss of power to sirens and systems	1. Potential personnel exposure	1. Backup power for critical functions 2. Testing of procedures and equipment
16. Noise	1. Fans 2. Heavy equipment	1. Loss of hearing	1. Working conditions monitored for OSHA compliance

Table 9-1 - Preliminary Hazard Assessment (Common Hazards)

Hazard	Cause(s)	Major Effect(s)	Mitigative Measures
17. Heat stress	1. Working in PPE 2. Heat buildup from vitrification system	1. Worker stay time limited based on temperature 2. Heat stress 3. Heat stroke	1. Ventilation system 2. Working conditions monitored and controlled
18. Loss of Containment (Building)	1. Building collapse 2. Release of material held up inside the dust collection system.	1. Release of dust and radium-bearing residues 2. Potential internal exposure	1. Adherence to project procedures 2. Contaminated dust control 3. Personal protective equipment 4. RM-0009, "Radiation Control Manual" 5. Radiation Work Permit 6. Project-Specific Health and Safety Plan 7. Construction Environmental Health and Safety Work Survey

Table 9-2 - Preliminary Hazard Assessment (Site Preparation)

Hazard	Cause(s)	Major Effect(s)	Mitigative Measures
1. Fire/Explosion	1. Local refueling 2. Vehicle fire 3. Engine fire 4. Stored fuels	1. Possible personnel injury/death 2. Potential release of airborne contaminants 3. Equipment damage	1. Fire protection system 2. Fire protection program
2. Loss of containment of boxes used to store contaminated soil excavated during site preparation or construction	1. Box dropped during handling 2. Poor welds or seals	1. Personnel exposure to contaminated dust	1. Operating procedures 2. Ventilation/off-gas systems
3. Contaminated dust released to the air from preparation activities	1. Work in the area 2. Excavation and handling of contaminated soil	1. Personnel exposure to contaminated dust	1. Wetdown soil
4. Personnel injury from electrical supply	1. Improper use of electrical supply due to human error	1. Possible death/serious injury	1. Training 2. Administrative Tagout Procedures 3. Construction Environmental Health and Safety Work Survey
5. Water erosion of contaminated soil	1. Construction and site preparation remove vegetation	1. Spread of contaminated soil to areas which may be clean	1. Ensure vegetation and erosion controls are in place
6. Loss of containment from unknown tanks in the area	1. Construction activities result in a breach of an unknown tank releasing contaminants	1. Spread of contamination 2. Potential on-site exposure to personnel	1. Containment basins

Table 9-2 - Preliminary Hazard Assessment (Site Preparation) (Continued)

Hazard	Cause(s)	Major Effect(s)	Mitigative Measures
7. Damage to the sump trench in OU-3	1. Construction related damage	1. Potential regulatory and project impact	1. Standard construction practices 2. Construction Environmental Health and Safety Work Survey
8. Electrical interface causes the site to be dropped from the distribution grid	1. 13.2 kV lines shorted due to human error, faulty equipment, etc.	1. Impact on site safety functions. Loss of power to other components on site	1. Stand-by power for critical functions
9. Schedule impact	1. Excavating OU-5 soil during OU-4 remediation	1. No place to handle the OU-5 soil generated	1. None at this time.
10. Excavated soil cannot meet clean-up criteria	1. Technology inadequate	1. Additional storage required	1. None at this time.

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Table 9-3 - Preliminary Hazard Assessment (Residue Removal System)

Hazard	Cause(s)	Major Effect(s)	Mitigative Measures
1. Fire	1. Hydraulic oil 2. Electrical fire from faulty wiring in lights, pumps, valves, etc.	1. Personnel injury 2. Potential release of contamination into the air	1. Fire protection system 2. Fire protection program 3. Water-base oil to be used
2. Loss of containment on high-pressure water line	1. Overpressurization of line 2. Weld or seam failure 3. Material defect	1. Release water which contains high concentration of radionuclides 2. Potential personnel injury	1. Operational readiness review 2. Pre-operational testing
3. Dome collapse causes loss of containment in the headspace	1. Failure of superstructure, natural degradation, earthquake, tornado, etc.	1. Release of radon inventory from the silos head space plus release of additional radon gas emanating from the silos	1. Operational readiness review 2. Pre-operational testing
4. Slurry line from the silos fails	1. Poor material, workmanship, overpressure, etc.	1. Release of slurry with K-65 residues causing spread of contamination 2. Potential personnel exposure	1. Isolated from uncontrolled areas 2. Air flow from clean to contaminated 3. Operational readiness review 4. Pre-operational testing

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Table 9-3 - Preliminary Hazard Assessment (Residue Removal System) (Continued)

Hazard	Cause(s)	Major Effect(s)	Mitigative Measures
5. Failure of site emergency system when required	1. Poor planning 2. Loss of power to sirens and systems	1. Possible exposure of personnel or off-site individuals	The need for the site emergency system is reduced by: 1. Access zones 2. Leak detection system 3. Pipes easily inspectable 4. Freeze protection on pipes 5. Surge capacity 6. Spare Parts 7. Allocated maintenance time
6. External hazard due to radiation emitted from contaminated slurry pump	1. Radon daughters plate out on pump 2. Potential for residues to come in contact with pump	1. External radiation hazard	1. Shielding and radiological control zones
7. Silo wall and dome collapse	1. Removal of the berm or natural degradation causes a failure of post-tensioning wires and silo walls. 2. Failure of superstructure causes unusual loadings on silo wall and dome. 3. Dome and wall failure due to earthquake or tornado loadings.	1. Release radon inventory in silo head space 2. Additional radon emanation from the residues 3. Potential release and spread of the residues 4. Radiation hazard	1. Drains, curbs, and retention basins to prevent runoff and erosion from spreading contaminants off site 2. Berm removal procedures

Table 9-4 - Preliminary Hazard Assessment (Feed Preparation/Melter/Glass Discharge)

Hazard	Cause(s)	Major Effect(s)	Mitigative Measures
1. Explosion in furnace	1. Overpressurization due to steam buildup	1. Glass lava spills out of furnace 2. Failure of adjacent equipment, piping, or support structure 3. Potential death and injury to on-site personnel 4. Spread of Contamination	1. The furnace design is not finalized. Typical protective measures are engineered means of relief and measures to prevent liquid entering containment basins for molten glass 2. Ventilation/off-gas system 3. Electrical temperature controls/interlocks 4. Melter is double-contained with spill control
2. Leak or spill of molten glass from furnace	1. Loss of containment due to cracking, or faulty workmanship in furnace construction	1. Fire due to molten glass release 2. Potential death and injury	1. Containment dikes and spill barriers 2. Combustible materials in the area of the vitrifier are minimized
3. Melter surface temperature is too high	1. Loss of coolant to the furnace	1. Potential burn injury or death to personnel	1. Insulation 2. Electrical interlocks/control 3. Fire protection system 4. Fire protection program
4. Damage to the furnace causing schedule loss	1. Loss of electricity to the melter	1. Molten glass would solidify in place causing irreparable damage to the melter	1. Operation restricted without stand-by power available 2. Melter insulated
5. External dose hazard from the glass blocks	1. High radium and radium daughter products in the vitrified glass	1. Difficulty in handling of material 2. Personnel exposure	1. Mix of lower level contaminated soil 2. ALARA program

Table 9-4 - Preliminary Hazard Assessment (Feed Preparation/Melter/Glass Discharge) (Continued)

Hazard	Cause(s)	Major Effect(s)	Mitigative Measures
6. High radon emanation from the glass block	1. Failure of the glass matrix to trap radon	1. Difficulty in storage and handling of the glass blocks 2. Personnel exposure	1. Radon flux to be measured and surface contamination to be checked prior to transport to the storage facility
7. Loss of containment of the stored caustic materials used as feed to the vitrification system	1. Drop or spill of materials during handling	1. Personnel exposure	1. Retention basins and dikes 2. Operating procedures 3. Ventilation/off-gas system 4. Leak detection system

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Table 9-5 - Preliminary Hazard Assessment (Radon Collection and Off-gas Treatment)

Hazard	Cause(s)	Major Effect(s)	Mitigative Measures
1. High gamma dose rate from equipment	1. Buildup of radon and radon daughters in head space above equipment or tanks due to blower failure	1. Personnel exposure and maintenance problems due to higher than expected dose rates	1. Design confirmation of acceptable levels 2. ALARA program 3. Temporary shielding
2. High radon levels in the process building	1. Radon emanation from equipment 2. Vacuum loss 3. Leak from RCS to the building	1. Internal hazard to personnel working in the building	1. HVAC switches to charcoal canisters to filter radon from building air
3. Carbon in the RCS canisters catches fire	1. Off-gas temperature which enters the carbon canisters is above the ignition temperature of the carbon due to cooler failure or scrubber failure (350-450 degrees C)	1. Fire and rupture of the canisters causes large radon release 2. Potential hazard to on-site and off-site persons	1. Fire protection system 2. Fire protection program 3. Controls and interlocks
4. High gamma radiation levels from carbon canisters	1. Radon and radon daughter products trapped on carbon	1. External hazard to on-site personnel	1. Periodic radiological monitorir 2. Operation monitor of system parameters

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9.2 Radiological Source Terms

This subsection of the assessment determines the radiological source terms for the facility.

The residue which is removed from the silos and contained within the vitrification facility is not readily dispersible due to its physical form. The material will be in a slurry form ranging from 20 to 55 percent residue with the remainder being water or it will be in a molten or solidified glass form. This material is not readily suspended and dispersed for the accidents considered except under extremely high wind conditions. A facility wide explosion is assumed to be an incredible event due to the lack of a source for such an explosion. Other accident events are of low energy impact and likely to result in lesser consequences than the tornado event.

The reasonable worst case accident scenario is considered to be the collapse of all three silo domes due to a tornado followed by a 1 hour period of high winds (31 m/s) that removes 0.67 percent (based on 0.05 m/hr release rate) (Sandia 1991) of the contents from each silo. The amount of material suspended and transported due to a tornado and high wind following a tornado has not been discussed extensively in the technical literature and is therefore difficult to determine. However, a basis for the hazard classification is the work performed by Sandia National Laboratory which evaluated the removal of residue by tornadoes from the K-65 silos and was used in the *Silos 1 and 2 Facility Safety Analysis Report* (PARSONS 1991a).

Sandia National Lab (Sandia 1991) estimated that a layer approximately 0.05 meters thick per hour would be released from one silo during the period of consideration. The high winds associated with a tornado are likely to last approximately 1 hour. This results in a release of 0.05 meters (0.16 ft) of material.

The material within the K-65 Silos has been covered by a layer of bentonite clay which varies in thickness from about 1 foot to 5 feet. This material is a consolidated solid which is not readily suspended from within the silos.

Due to the nature of the K-65 Silos material, the source term will be developed based on the contents of the residue from one K-65 Silo with 90 percent of its bentonite cover intact (the residue will be removed from beneath the bentonite, leaving the bentonite cover partially intact) and the contents of Silo 3.

Procedure SP-A-01-013 suggests using a fractional release of 0.01 (1 percent) for solid unconsolidated material and 0.001 (0.1 percent) for consolidated material due to tornado/high wind conditions when the NUREG 1320 - Nuclear Fuel Cycle Facility Accident Analysis Handbook does not readily apply. The estimated release fraction will be based on Sandia's estimate of 0.67 percent which is within the range provided in SP-A-01-013.

Silo 3 contains the dry metal oxides which have a dry powdery consistency similar to the material modeled by Sandia. The Sandia estimated release will be applied to Silo 3 as well.

Calculation Methodology

The guidance in Procedure SP-A-01-013 for facility hazard classification, recommends the use of AIRDOS or GENII for the determination of the dose to the receptor. The rigid application of the codes would not allow for the determination of the maximum dose or radionuclide concentration. This special scenario of simultaneous collapse of the silo domes during extremely turbulent conditions was evaluated by using the methodology employed by AIRDOS in the Silos 1 and 2 Facility Safety Analysis Report (PARSONS 1991a). AIRDOS was not used but the methodology was used and applied to the accident conditions.

The following conditions and assumptions were utilized:

1) The Gaussian plume equation was modified to average the radionuclide concentration over a 60 degree sector to account for the extreme turbulence and expected wind fluctuations to occur during the release period used.

3) The plume was assumed to be a point release from ground level (the base of the silos) at the center of the silo areas.

3) The receptor was assumed to be at the same height as the release.

4) The tornado/high winds scenario from SP-A-01-013 (as modeled in PARSONS 1991a)
   (1) Stability class Pasquill A was used
   (2) Wind speed 31 m/s
   (3) Nearest on-site receptor is at 100 meters
   (4) Nearest off-site receptor is at 500 meters

5) Sample data as found in Section 7 will be used.

6) The receptors' breathing rate is assumed to be 1.0 m^3/hr.

7) All material released from the silos is assumed to be respirable.

8) The release of the residues occurs over a 1-hour period.

9) The release of the radon from the silo's headspace is negligible compared to the material released. This is due to the removal of radon by filtering and the reduction in headspace concentration due to the bentonite layer.

The above assumptions are believed to result in a reasonable maximum calculated dose from a release of materials from OU-4 as a result of a tornado/high winds accident. To ensure a conservative result, all materials released were assumed to be respirable and no deposition from the plume was considered.

The sector averaging of the dispersed material was performed because the distribution of residue would not be Gaussian. The extreme turbulence caused by the high winds/tornado and fluctuations in the direction of the force of these winds results in a the materials being nearly uniformly distributed within the plume. The sector angle size was determined using engineering judgement based on the magnitude of off axis dispersion calculated by a standard Gaussian distribution. The dilution factor (X/Q) developed in the *Silos 1 and 2 Facility Safety Analysis Report* (PARSONS 1991a) was used for this assessment.

The Committed Effective Dose Equivalent (CEDE) on site at 100 meters is 1.5 rem and the CEDE off site at 500 meters is 1.8E-2 rem. The CEDE is shown in Table 9-6.

9.3 Chemical Source Terms

This subsection of the assessment determines the chemical source terms for the facility. This is done in a similar manner to that of Section 9.2. None of the chemicals listed exceeds the criteria for a low hazard facility as found in Tables 5.3-2 and 5.3-3 of the Site Safety Analysis Report (Draft) (PARSONS 1992g). Table 9-7 shows the amounts of chemicals potentially inhaled by the hypothetical receptors.

9.4 Other Non-Standard Hazards

The non-standard hazards associated with the remediation of OU-4, other than those present due to the radioactive and chemical hazards described in Subsections 9.2 and 9.3, are listed in the Preliminary Hazard Assessment. Aside from the chemical and radioactive hazards, the other major non-standard hazards are the dangers associated with working with the high temperature melter and accidents associated with the release of a molten glass.

9.5 Non-Reactor Nuclear Facility Determination

The remediation of OU-4 qualifies as a non-reactor nuclear facility under the definition in DOE Order 5480.5. Portions of the Remediation Facility are classified as Division 13 Special Facilities by DOE Order 6430.1A. The special facility classifications of the portions of the remediation facilities are shown in Table 9-8.

Table 9-6 - Radiological Consequences of a Tornado/High Wind Event

Radionuclide	Release (pCi/event)	DCF mrem/pCi	On-site Dose mrem	Off-Site mrem
Pa-231	7.2E+10	1.3E+00	7.8E+01	9.7E-01
Pb-210	1.4E+12	2.1E-02	2.4E+01	3.0E-01
Ra-224	1.6E+10	—	—	—
Ra-226	3.1E+12	7.9E-03	2.0E+01	2.5E-01
Ra-228	2.4E+10	4.5E-03	8.9E-02	1.1E-03
Ac-227	7.7E+10	6.7E+00	4.3E+02	5.3E+00
Th-228	2.1E+11	3.1E-01	5.5E+01	6.8E-01
Th-230	2.4E+12	3.2E-01	6.4E+02	7.9E+00
Th-232	1.7E+11	1.6E+00	2.3E+02	2.8E+00
U-234	6.0E+10	1.3E-01	6.5E+00	8.0E-02
U-235/236	5.2E+09	1.2E-01	5.2E-01	6.5E-03
U-238	6.3E+10	1.2E-01	6.3E+00	7.7E-02
		Total	1.5E+03	1.8E+01

Table 9-7 - Toxicological Consequences of a Tornado/High Wind Event

	Release (mg)	On-Site Exposure	Off-Site Exposure
		mg	mg
Aroclor -1260	8.3E+02	6.9E-07	8.5E-09
Aroclor -1254	2.4E+04	2.0E-05	2.5E-07
Aroclor -1248	1.8E+04	1.5E-05	1.8E-07
2-Butanone	4.6E+05	3.8E-04	4.7E-06
4-Methyl-2-Pentanone	6.6E+03	5.5E-06	6.8E-08
Acetone	3.2E+05	2.7E-04	3.3E-06
Bis(2-Ethylhexyl)phthalate	1.6E+04	1.3E-05	1.6E-07
Chloroform	2.4E+04	2.0E-05	2.5E-07
Chloromethane	3.6E+02	3.0E-07	3.7E-09
Di-n-octylphthalate	2.0E+03	1.7E-06	2.1E-08
Methylene Chloride	8.7E+04	7.2E-05	8.9E-07
Styrene	8.5E+02	7.1E-07	8.8E-09
Toluene	1.7E+05	1.5E-04	1.8E-06
Total Xylenes	4.9E+02	4.1E-07	5.0E-09
Trichloroethane	2.9E+02	2.4E-07	3.0E-09
Aluminum	6.1E+08	5.1E-01	6.3E-03
Antimony	1.8E+04	1.5E-05	1.8E-07
Arsenic	1.7E+08	1.4E-01	1.7E-03
Barium	2.9E+07	2.4E-02	3.0E-04
Beryllium	1.0E+06	8.6E-04	1.1E-05
Cadmium	5.3E+06	4.4E-03	5.4E-05
Calcium	1.8E+09	1.5E+00	1.8E-02
Chromium	1.5E+07	1.2E-02	1.5E-04
Cobalt	9.6E+07	8.0E-02	9.9E-04
Copper	1.8E+08	1.5E-01	1.9E-03
Cyanide	1.1E+04	9.1E-06	1.1E-07
Iron	1.9E+09	1.6E+00	2.0E-02
Lead	3.2E+08	2.7E-01	3.3E-03
Magnesium	2.1E+09	1.7E+00	2.1E-02
Manganese	1.7E+08	1.4E-01	1.7E-03
Mercury	2.3E+04	1.9E-05	2.4E-07
Nickel	1.6E+08	1.4E-01	1.7E-03
Potassium	5.8E+08	4.9E-01	6.0E-03
Selenium	9.4E+06	7.8E-03	9.6E-05
Silver	6.6E+05	5.5E-04	6.8E-06
Sodium	1.4E+09	1.1E+00	1.4E-02
Thallium	1.9E+06	1.6E-03	1.9E-05
Uranium	1.3E+08	1.0E-01	1.3E-03
Vanadium	1.2E+08	9.7E-02	1.2E-03
Zinc	1.8E+07	1.5E-02	1.8E-04
H2SO4	3.8E+07	3.2E-02	3.9E-04
HNO3	3.0E+09	2.5E+00	3.1E-02
NaOH	4.1E+09	3.4E+00	4.2E-02

Table 9-8 - Facility and Special Facility Classification

Facility	Special Facility Classification
Silos 1 and 2	Radioactive Liquid Waste
Silo 3	Radioactive Solid Waste
Vitrification Facility (Including Residue Removal and Radon Collection and Treatment Systems)	Radioactive Liquid Waste
Water Treatment Facilities	Radioactive Liquid Waste
Soil Treatment Facility	Radioactive Liquid Waste
Interim Storage	Radioactive Solid Waste
Soil and Perched Water Removal Facility	Radioactive Liquid Waste

SECTION 10

EXISTING SAFETY DOCUMENTATION

The existing safety documentation prepared for the OU-4 remediation facilities is listed below.

1) PARSONS, 1991. *Silos 1 and 2 Facility Safety Analysis Report, Revision 2*

2) PARSONS, 1991. *Silos 1 and 2 Removal Action Final Safety Assessment, Revision 3.*

3) PARSONS, 1991. *Silos 1 and 2 Operational Safety Requirements, Revision 4.*

The safety documentation prepared to date exists solely for Silos 1 and 2 including the existing Radon Treatment System. A safety analysis report for the remediation of OU-4 is required under DOE Order 5820.2A, Chapter III and DOE Order 5480.23. The development of a large-scale waste treatment facility is also expected to be addressed in the National Environmental Policy Act cleanup environmental impact statement.

SECTION 11

CONCLUSIONS

11.1 Facility Hazard Classification

The hazard classification was determined by quantitatively assessing the reasonable worst case source term developed in Section 9. The remediation activities in OU-4 are Category 3 (low hazard).

11.2 Non-Reactor Nuclear Facility Determination

As Section 9.5 notes, the remediation of OU-4 qualifies as a nonreactor nuclear facility under DOE Order 5480.5. Section 9.5 also identifies the facility classification of each subsystem that comprises the OU-4 remediation efforts.

11.3 Safety Documentation

The remediation of OU-4 requires a Safety Analysis Report to be prepared under DOE Orders 5480.23 and 5820.2A, Chapter III.

11.4 Design Criteria

The remediation facilities for OU-4 qualify as Non-Reactor Nuclear Facilities in accordance with Division 13, Special Facilities/Decommissioning, Section 1300-11 of DOE Order 6430.1A, General Design Criteria.

SECTION 12

REFERENCES

(DOE 1986) United States Department of Energy, September 1986. *Nonreactor Nuclear Facilities: Standards and Criteria Guide, Revision 1.* DOE/TIC-11603.

(DOE 1987) ——, 1987. "Safety Analysis and Review System," DOE Order 5481.1B

(DOE 1989a) ——, November 1989. "Guidance for the Preparation of Safety Analysis Reports," DOE/OR-901.

(DOE 1989b) ——, 1989. "Requirement for Radiation Protection," DOE Order 5480.11.

(DOE 1989c) ——, 1989. "General Design Criteria," DOE Order 6430.1A.

(DOE 1990a) ——, 1990. "Environment, Safety, and Health Program for Department of Energy Operations," DOE Order 5480.1B.

(DOE 1990b) ——, October 1990. *Remedial Investigation Report for Operable Unit 4.*

(DOE 1991a) ——, 1991. "Safety of Nuclear Facilities," DOE Order 5480.5.

(DOE 1991b) ——, 1991. "SOP Guidelines for the Preparation of Safety Assessments," SP-A-01-013.

(DOE 1991c) ——, 1991. *Risk Assessment Work Plan Addendum.* Fernald: DOE.

(DOE 1992a) ——, 1992. *Site-Wide Characterization Report.* Fernald: DOE.

(DOE 1992b) ——, 1992. *Remedial Investigation Report for Operable Unit 4, Draft.*

(PARSONS 1991a) PARSONS, 1991. *Silos 1 and 2 Facility Safety Analysis Report, Revision 2*

(PARSONS 1991b) ——, 1991. *Silos 1 and 2 Removal Action Final Safety Assessment, Revision 3.*

(PARSONS 1991c) ——, 1991. *Silos 1 and 2 Operational Safety Requirements, Revision 4.*

(PARSONS 1992d) ——, 1992. *Operable Unit 4 Remedial Action Conceptual Design Report, Volume I, Revision 0.*

(PARSONS 1992e) ——, 1992. *Operable Unit 4 Remedial Action Conceptual Design Report, Volume II, Revision 0.*

(PARSONS 1992f) ——, 1992. *Operable Unit 4 Remedial Action Conceptual Design Report, Volume III, Revision 0.*

(PARSONS 1992g) ——, 1992. *Site Safety Analysis Report, Volume I, Revision C.*

(Sandia 1991) Sandia National Laboratories, 1991. *Review of the K-65 Silo Studies, Draft.*

(US EPA 1990) United States Environmental Protection Agency, March 1990. *Exposure Factors Handbook.*

(US NRC 1988) United States Nuclear Regulatory Commission, May 1988. *Nuclear Fuel Cycle Facility Accident Analysis Handbook.* NUREG-1320.

ATTACHMENT 1

CALCULATIONS

PARSONS
ERA PROJECT

ENGINEERING CALCULATIONS TITLE AND SUMMARY SHEET

5233

Date 12/10/92

Revision No. 0
Sheet 1 of 8

Proj. Order No. PO-3 Calculation No. PO-3 #1

Project Title OU-4 Remedial Action Safety Assessment

Calculation Subject Dose Assessment . . . Date Verified/Checked 2/9/93

STATUS: PRELIMINARY _____ FINAL X SUPERSEDED _____ VOID _____

STATEMENT OF PROBLEM

The consequences of a tornado/high wind event in the OU-4 area during remediation is to be assessed.

SUMMARY OF CONCLUSIONS	Originator's Signature and Date
The total on-site and off-site dose from the OU-4 Silo Remediation Facility due to a tornado/high wind accident was determined to be 1,500 mrem on-site and 18 mrem off-site.	12/10/92

CHECKING METHOD		Checker's Signature and Date
1. Review	X	Lane B. Robbin 2/9/93
2. Alternate Calculation		
3. Performance Test		Lead Discipline Engineer's Signature and Date

Rev. No.	Sheet No.	Description	Reviser's Signature/Date	Checker's Signature/Date	Approved by Signature/Date

PARSONS
ERA PROJECT

5233

ENGINEERING CALCULATIONS BASIS SHEET

Revision No. 0
Sheet 2 of 8

Proj. Order No. 3 Calculation No. PO-3-1

Project Title OU-4 Remedial Action Safety Assessment

Calculation Subject Dose Assessment . . . Date Checked/Verified DL for LR 2/

Performed By: J. Zimmerman Checked/Verified By: DL for LR 2/

Date 12/10/92

SUMMARY OF INFORMATION SOURCES - CODES - ASSUMPTIONS

See Section 3.0 and 7.0 for information.

REV	BY	DATE	CK	DATE	TITLE Dose Assessment of Tornado/High Wind Accident Scenario for OU-4 Silo Remediation Facility			
0	[illegible]	12/[illegible]/93	LR	2/9/93				
								CRU-4
					AUTHOR J. Zimmerman	SHEET 3	OF 8	PO-3

1.0 Objective/Purpose

The purpose of this calculation is to determine a realistic assessment of the dose associated with a release of material from the OU-4 Silo Remediation Facility due to a tornado/high wind accident scenario. This is to include both chemical and radiological dose.

2.0 Background and Approach

This calculation will use the results of a previous calculation (PO-23 #2) to assess the dispersion associated with a tornado/high wind accident scenario for the OU-4 Silo Remediation Facility.

3.0 Assumptions

The maximum radionuclide concentration measured in the Silo's 1, 2, and 3 residue as reported in reference 1 (DOE 1992). See Table 7-1 of the OU-4 S.A.)

The chemical contents of the silos are based on the data shown in Table 4-2 of the Site Wide Characterization Report, Volume 2 (Draft) (DOE 1992). Estimates of process chemicals are in Table 8-1 of the OU-4 S.A. The receptor's respiration rate is assumed to be 1.0 m^3/hr.

The release of radon from the silo's headspace is assumed to be negligible due to the bentonite effectiveness and the use of radon filtering devices.

The bentonite layer in one silo is assumed to remain intact throughout the event.

The release fraction from Silo 1 is 0.0067 (Calc PO-23-2) (0.67%) of the material with an assumed 10% of the silo's bentonite cover removed to allow the slurry pump access to the residues.

This is reasonable due to the slurry pump removing a portion of the bentonite and then "burrowing" to the bottom of the silo until it rests on the concrete. The current design is to leave a significant portion of the bentonite layer intact. Silo 2 is assumed to release no residue due to the presence of the bentonite.

The release fraction of residues from Silo 3 is 0.0067 (0.67%) (Calc. PO-23-2). There is no cover material to alternate residue removal from Silo 3. All other components containing residue as a slurry are assumed to have a release fraction of 0.01 (1%) per SP-A-01-013.

4.0 Radiological Dose Determination

The material within the K-65 Silos has been sampled. The samples indicate a varying degree of physical characteristics (varying from a crust, to a soupy mass, to a peanut butter-like consistency. The release is to be between 0.01 Non-consolidated and 0.001 consolidated). Silo 3 material is assumed to be like a dry powder. The dilution factors to be used are:

100m (on-site) $\frac{X_{ave}}{Q} = 3.06 \times 10^{-6}$ s/m^3 (from Calculation PO-23#2)

500m (off-site) $\frac{X_{ave}}{Q} = 3.7 \times 10^{-8}$ s/m^3

The dose conversion factors used are 50 yr. committed effective dose equivalent found in reference 4.

REV	BY	DATE	CK	DATE	TITLE Dose Assessment of Tornado/High Wind Accident Scenario for OU-4 Silo Remediation Facility	
0	JZ	12/10/93	LR	2/9/93		
						CRU-4
					AUTHOR J. Zimmerman SHEET 4 OF 8	PO-3

The dose is determined by EQN. 1

$$CEDE = B \times C \times DCF \times ED \qquad (1)$$

Where B (Breathing Rate) = 1.0 m^3/hr.

C (Concentration) = $\frac{Xave}{Q} \times Q$

DCF (Dose Conversion Factor) = Ref. 1

ED (Exposure Duration) = 3600 Sec. = 1 hr.

$\frac{Xave}{Q}$ = s/m^3 dilution factor

Q = pCi/s release rate

An Excel 4.0a spreadsheet was developed to calculate the CEDE for this scenario. The results are shown in Table 1.

Example Radiological Dose Calculation (Pa-231)

$$\text{Release Rate} = \frac{\text{fraction releases x inventory pCi}}{\text{event duration(s)}} \qquad (2)$$

$$= [0.0067 \times 0.1 \times (1.4\times10^4 pCi/g) \times (3.6\times10^9 g) + 0.0067 \times (9.3\times10^2 pCi/g) \times (3.8\times10^9 g) + 0.01 \times (8.8\times10^3 pCi/g) \times (1.5\times10^6 g) + 0.01 \times (7.1\times10^2 pCi/g) \times (1.5\times10^6 g) + 0.01 \times (7.1\times10^2 pCi/g) \times (7.6\times10^7 g)]/3600s$$

$$= \frac{7.2\times10^{10} pCi\ Pa\text{-}231}{3600s} = 2 \times 10^7 pCi/s$$

Concentration in on-site air is:

$$C = Q \times \frac{Xave}{Q} \qquad (3)$$

$$= (2\times10^7 pCi/s) \times (3\times10^{-6} s/m^3) = 6\times10^1 pCi/m^3$$

Dose is then found using equation (1)

$$CEDE = 1.0\ m^3/hr \times (6\times10^1 pCi/m^3) \times 1\ hr \times 1.3\ mrem/pCi\ inhaled$$

$$= 78\ mrem$$

This is within the rounding and error range of the spreadsheet.

REV	BY	DATE	CK	DATE	TITLE Dose Assessment of Tornado/High Wind Accident Scenario for OU-4 Silo Remediation Facility	
0	[illegible]	12/10/92	LR	2/4/93		
						CRU-4
					AUTHOR J. Zimmerman SHEET 5 OF 8	PO-3

Table 1 - Radiological Consequences

	Release	DCF	On-site Dose	Off-Site
	(pCi/event)	mrem/pCi	mrem	mrem
Radionuclide				
Pa-231	7.2E+10	1.3E+00	7.8E+01	9.7E-01
Pb-210	1.4E+12	2.1E-02	2.4E+01	3.0E-01
Ra-224	1.6E+10	—	—	—
Ra-226	3.1E+12	7.9E-03	2.0E+01	2.5E-01
Ra-228	2.4E+10	4.5E-03	8.9E-02	1.1E-03
Ac-227	7.7E+10	6.7E+00	4.3E+02	5.3E+00
Th-228	2.1E+11	3.1E-01	5.5E+01	6.8E-01
Th-230	2.4E+12	3.2E-01	6.4E+02	7.9E+00
Th-232	1.7E+11	1.6E+00	2.3E+02	2.8E+00
U-234	6.0E+10	1.3E-01	6.5E+00	8.0E-02
U-235/236	5.2E+09	1.2E-01	5.2E-01	6.5E-03
U-238	6.3E+10	1.2E-01	6.3E+00	7.7E-02
		Total	1.5E+03	1.8E+01

REV	BY	DATE	CK	DATE	TITLE Dose Assessment of Tornado/High Wind Accident Scenario for OU-4 Silo Remediation Facility	
0	[illegible]	12/10/93	LR	2/9/93		
						CRU-4
					AUTHOR J. Zimmerman SHEET 6 OF 8	PO-3

5.0 Chemical Dose Determination

The chemical dose is found in a similar manner to the radiological dose. The total mass of each constituent inhaled is calculated using an Excel spreadsheet and Equation 4.

$$\text{Inhaled amount} = \text{release rate (mg/s)} \times \frac{\chi_{ave}}{Q}\ (s/m^3) \times B\ (m^3/hr) \times ED\ (hr.)$$

$$\text{release rate} = \frac{\text{fraction released} \times \text{inventory (mg)}}{\text{release duration(s)}}$$

release duration = 3600s

B = breathing rate = 1.0 m^3/hr.

ED = exposure duration 1 hr.

The results of the spreadsheet calculation can be seen in Table 2.

for example:

H_2SO_4 in remediation facility

$$\text{release rate} = 0.1 \times 55\ \text{gal.} \times 3.785\ \text{e/gal} \times \frac{1000\text{cc}}{\text{e}} \times 1.841\ \text{g/cc} \times 1/3600\text{s}$$

$$= 10.6\ \text{g/s} = 10.6 \times 10^3\ \text{mg/s}$$

$$\text{inhaled amount} = (10.6 \times 10^3\ \text{mg/s}) \times (3 \times 10^{-6}\ \text{s/m}^3) \times 1.0\ \text{m}^3/\text{hr} \times 1\ \text{hr} = 3.2 \times 10^{-2}\ \text{mg}$$

REV	BY	DATE	CK	DATE	TITLE Dose Assessment of Tornado/High Wind Accident Scenario for OU-4 Silo Remediation Facility	
0	[illegible]	12/10/93	[illegible]	2/9/93		
						CRU-4
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Table 2 - Toxicological Consequences

	Release (mg)	On-Site Exposure	Off-Site Exposure
		mg	mg
Aroclor -1260	8.3E+02	6.9E-07	8.5E-09
Aroclor -1254	2.4E+04	2.0E-05	2.5E-07
Aroclor -1248	1.8E+04	1.5E-05	1.8E-07
2-Butanone	4.6E+05	3.8E-04	4.7E-06
4-Methyl-2-Pentanone	6.6E+03	5.5E-06	6.8E-08
Acetone	3.2E+05	2.7E-04	3.3E-06
Bis(2-Ethylhexyl)phthalate	1.6E+04	1.3E-05	1.6E-07
Chloroform	2.4E+04	2.0E-05	2.5E-07
Chloromethane	3.6E+02	3.0E-07	3.7E-09
Di-n-octylphthalate	2.0E+03	1.7E-06	2.1E-08
Methylene Chloride	8.7E+04	7.2E-05	8.9E-07
Styrene	8.5E+02	7.1E-07	8.8E-09
Toluene	1.7E+05	1.5E-04	1.8E-06
Total Xylenes	4.9E+02	4.1E-07	5.0E-09
Trichloroethane	2.9E+02	2.4E-07	3.0E-09
Aluminum	6.1E+08	5.1E-01	6.3E-03
Antimony	1.8E+04	1.5E-05	1.8E-07
Arsenic	1.7E+08	1.4E-01	1.7E-03
Barium	2.9E+07	2.4E-02	3.0E-04
Beryllium	1.0E+06	8.6E-04	1.1E-05
Cadmium	5.3E+06	4.4E-03	5.4E-05
Calcium	1.8E+09	1.5E+00	1.8E-02
Chromium	1.5E+07	1.2E-02	1.5E-04
Cobalt	9.6E+07	8.0E-02	9.9E-04
Copper	1.8E+08	1.5E-01	1.9E-03
Cyanide	1.1E+04	9.1E-06	1.1E-07
Iron	1.9E+09	1.6E+00	2.0E-02
Lead	3.2E+08	2.7E-01	3.3E-03
Magnesium	2.1E+09	1.7E+00	2.1E-02
Manganese	1.7E+08	1.4E-01	1.7E-03
Mercury	2.3E+04	1.9E-05	2.4E-07
Nickel	1.6E+08	1.4E-01	1.7E-03
Potassium	5.8E+08	4.9E-01	6.0E-03
Selenium	9.4E+06	7.8E-03	9.6E-05
Silver	6.6E+05	5.5E-04	6.8E-06
Sodium	1.4E+09	1.1E+00	1.4E-02
Thallium	1.9E+06	1.6E-03	1.9E-05
Uranium	1.3E+08	1.0E-01	1.3E-03
Vanadium	1.2E+08	9.7E-02	1.2E-03
Zinc	1.8E+07	1.5E-02	1.8E-04
H2SO4	3.8E+07	3.2E-02	3.9E-04
HNO3	3.0E+09	2.5E+00	3.1E-02
NaOH	4.1E+09	3.4E+00	4.2E-02

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						CRU-4
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6.0 Results

The results are shown in Tables 1 and 2. These tables show the consequences of a tornado striking the OU-4 area followed by high winds for a one hour period.

7.0 References

Ref 1. Remedial Investigation Report for Operable unit 4, Appendix A, U.S. Department of Energy, October 1992.

Ref 2. Site Wide Characterization Report, Volume 2 (Draft) U.S. Department of Energy, August, 1992.

Ref 3. Silos 1 and 2 Facility Safety Analysis Report, Calculation PO-23-2, PARSONS, June 1991.

Ref 4. "A Manual for Implementing Residual Radioactive Material Guidelines", U.S. Department of Energy, June 1998.

Ref 5. Operable Unit 4 Remedial Action Safety Assessment Rev B, PARSONS 1992.