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June 16, 2004

Fernald Closure Project
Letter No. C:SP:2004-0044

Mr. John Sattler
Department of Energy
Fernald Closure Project
P. O. Box 538705
Cincinnati, Ohio 45253-8705

Dear Mr. Sattler:

CONTRACT DE-AC24-01OH20115, SILO 3 N-HASP SBR/PR PCN NOTIFICATION

Reference: 1. C:SP:2004-0014, "Future Notification of a Silos-Nuclear Health & Safety Plan Page Change Notice on a Safety Basis Requirement or Process Requirement," from Dennis Carr to John Sattler, March 11, 2004

A Page Change Notice (PCN) on a Silos Project Nuclear-Health and Safety Plan (N-HASP) includes a change to a Safety Basis Requirement (SBR) and/or Process Requirement (PR), as specified in the table below. Per Reference 1, the Silos Project has agreed to notify the Department of Energy-Fernald Closure Project (DOE-FCP) of these types of page changes. The changed page(s) and supporting document/analysis for the specified SBR/PR are enclosed.

NOTIFICATION OF SILOS N-HASP PCN AFFECTING SBRs/PRs					
PCN? (Y/N)	**Silos Project N-HASP**	**Current Document No./ Revision No./ PCN No.**	**Current N-HASP Status**	**New PCN No.**	**SBR and/or PR Affected by PCN (Attach supporting document/analysis)**
Y	Silo 3	40430-PL-0010 Rev. 0	Approved	3	PR-4, PR-5, new PR-6
N	RCS	40710-PL-0015 Rev. 0 PCN 6	Approved		
N	AWR	40710-PL-0015 Rev. 1	Under DOE Review		
N	Silos 1 & 2 Remediation	40710-PL-0015 Rev. 2	In Progress		

If you have any questions, please contact Pat Fisk at (513) 648-7242.

Sincerely,

Dennis J. Carr
Senior Project Director
Silos Project

DJC:PF:dmd
Enclosures

c: Terri Binau, DOE Contracting Officer DOE-OH, MS45
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Dennis Sizemore, Fluor Fernald, Inc. Prime Contract, MS44-0-S
Project Number 40000/1.1
DOE Records Center MS45
Administrative Record MS78

Details for Silo 3 N-HASP PCN 3 Revisions to PRs-4, -5, and new PR-6

Revision to PRs-4 and 5

Added a Note under both of the Requirement that reads ". NOTE: Does not apply to Preliminary Pneumatic Retrieval and Equipment Installation."

The Note was added to allow for Preliminary Pneumatic Retrieval and Equipment Installation, as described in Section 1.4.3, beginning in the second paragraph. The preliminary retrieval is needed prior to normal pneumatic retrieval, in order to install equipment.

New PR-6

New PR-6 reads "Preliminary Pneumatic Retrieval and Equipment Installation will be performed per the OWI package as reviewed and approved by an SSA." This new PR provides for review and approval of the preliminary retrieval work by a System Safety Analyst.

TABLE 10-1: SILO 3 SYSTEM SAFETY REQUIREMENTS			
SBR, PR	**Requirement**	**Basis/Source**	**Implementation**
PR-2	Individual IP-2 bulk bags shall not exceed 7000 lbs. gross weight.	EBA-4 (App. G) Test Report for IP-2 Container Testing [Ref. 65]	• Operations procedures • Routine inspections • Engineering design • Routine calibration and maintenance
PR-3	Verify that IP-2 bulk bags/packages are sealed before transfer outside of the Cargo Bay area.	Shipping requirement	• Operations procedures • Routine inspections • Engineering design • Routine calibration and maintenance
PR-4	Visually inspect the flexible fabric boot on each vacuum wand for verification of integrity (i.e. in place, no holes). NOTE: Does not apply to Preliminary Pneumatic Retrieval and Equipment Installation.	Public and Worker Protection, Containment	• Operations procedures • Routine inspections • Engineering design
PR-5	During pneumatic retrieval operations, a vacuum relief valve must be installed on Silo 3, set to −3.0 inches of water, with alarm indication. NOTE: Does not apply to Preliminary Pneumatic Retrieval and Equipment Installation.	Dome Failure, protect Silo Dome TSR	• I-TAB • Routine inspections • Engineering design • Routine calibration and maintenance
PR-6	Preliminary Pneumatic Retrieval and Equipment Installation will be performed per the OWI package as reviewed and approved by an SSA.	Consequences bounded by EBAs in Appendix G. Public and Worker Protection, Containment	• OWI

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10.3 Silos Project Technical Safety Requirement (TSR)

Technical Safety Requirements (TSRs) are the limits, controls, and related requirements necessary for the safe operation of a nuclear facility and, as appropriate for the work and the hazards identified in the documented safety analysis for the facility, includes management controls, use and application provisions, and design features, as well as a basis appendix. TSRs are subject to 10 CFR 830, Subpart B [Ref. 6].

The Silos Project (including Silo 3) has one TSR (see **TABLE 10-2**). There are no additional TSRs specific to the Silo 3 Retrieval and Disposition Project. Planned Silo 3 operations and activities will be conducted within the umbrella of the Silos safety basis (i.e., the Silos TSR).

PCN2

SILO 3 SAFETY BASIS IMPACT SCREEN (SBIS)

Description of Activity/Design Change: Perform Page Change 3 to the Silo 3 N-HASP to 1) revise Appendices B, D, and G to reflect recent radon headspace data, and 2) incorporate headspace venting and preliminary retrieval for equipment installation into the document scope. See attached information sheets for details.

Work Plan/ Design Doc. No.:40430-PL-0010 PCN2	**Change Originator: Doris Edwards**
SBIS Originator: Bill Klein	**SBIS Date: 6/9/04**

1	Will the proposed change affect any parameters used in calculations supporting the Hazard Analysis as documented in the Silo 3 N-HASP? X **YES** ☐ **NO** / **EXPLAIN:** The revised radon headspace numbers change the consequence analyses (increase slightly) but the changes are not significant enough to alter the conclusion that facility is a Radiological facility.
2	Will the proposed change affect any of the System Safety Requirements in the Silo 3 N-HASP? • Safety Basis Requirements (SBRs)? • Process Requirements (PRs)? ☐ **YES** X **NO** / **EXPLAIN:** No SBRs or PRs are being revised or impacted in this Page Change. No new SBRs or PRs are required.
3	Does the proposed change identify a potential inadequacy (e.g., new accident, hazard) in the Silo 3 N-HASP or any potential reduction in any SBR? ☐ **YES** X **NO** / **EXPLAIN:** These revisions are clarifications, and no new accidents or hazards, or reduction in safety requirements will result from the changes.
4	Does the proposed change affect the activities or requirements of a nearby or adjacent facility or activity operating under a different safety basis (e.g., Silos 1 & 2, RCS, TTA)? **NOTE: IF** a proposed change can potentially affect the Silos, **THEN** a USQD/safety evaluation must be completed per NS-0002 (Unreviewed Safety Question (USQ) Determination. ☐ **YES** X **NO** / **EXPLAIN:** These revisions will have no impact on any facilities beyond Silo 3.
5	Does the proposed change result in a change in the inventory or amount of hazardous material? X **YES** ☐ **NO** / **EXPLAIN:** These revisions to the N-HASP include new radon headspace concentration values that are greater than the previous data. However, consequence analyses were revised and the results indicate no change to the Hazard Categorization.

IF the answer to ANY of these questions is **YES, THEN:** (1) update the analysis; (2) determine whether the change will put the project or affected project outside the safety envelope; (3) incorporate any mitigators or controls into the work plan/permit; (4) attach the updated analysis to this impact screen. **IF** the change will result in a higher hazard categorization, **THEN** a USQ must be performed per NS-0002 and submitted to the SRC, the Fluor Fernald President, and the DOE for concurrence.

6	Per this SBIS, the proposed change **X DOES** **DOES NOT** impact the Silo 3 safety basis.

Signature: P.L. Fisk / P.L.F. **Date:** 6/9/04
System Safety Analyst

SSA: Are there descriptive changes not requiring analysis, but requiring inclusion in the annual update? ☐ **Y** X **N**
They are being included in the PCN

NOTE: IF there is an impact to the safety basis, **THEN** the Project Manager's signature is required.

Signature: D. Edwards **Date:** 6/9/04
Silo 3 Project Manager

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PVF 6/9/04

2003: 40430-RD-0014, *Revised Proposed Plan for Operable Unit 4 Silo 3 Remediation Action* [Ref. 19] prepared by Flour Fernald, reviewed by DOE, and approved by USEPA and OEPA.

Draft *Record of Decision Amendment for Operable Unit 4 Silo 3 Remediation Action* [Ref. 20] prepared by Fluor Fernald and reviewed by DOE. Following incorporation of DOE comments, the document was submitted to USEPA and OEPA and is awaiting approval.

This Silo 3 Retrieval & Disposition N-HASP developed. Approved in February, 2004, this N-HASP is the documented safety analysis for Silo 3 remediation activities. Design changes will be evaluated via the Silo 3 Safety Basis Impact Screen (SBIS). If proposed changes have the potential to affect the Silos, positive screens will be evaluated using the Unreviewed Safety Question process (see Section 6.0). PCN2

1.4 Silo 3 Process Description

The Silo 3 Retrieval and Disposition Project consists of the following major activities. This Silo 3 N-HASP covers Operation and Maintenance (i.e., Material Removal and Packaging).

- STORAGE AND MAINTENANCE
- CONSTRUCTION
- OPERATION AND MAINTENANCE
  - * Material Removal
    - Pneumatic Retrieval
    - Mechanical Retrieval
  - * Packaging
    - Waste Conditioning
    - Container Filling
    - Filled Container Management
- DECONTAMINATION
- DEMOLITION

Silo 3 PHAR scope

Silo 3 N-HASP scope

When all Silo 3 material is removed, the equipment and structures will be dismantled, decontaminated (when appropriate), and dispositioned.

In the discussions that follow, refer to the following process flow diagram and fold-out pages. These graphics are provided for general information only. To obtain the latest versions, contact Silo Project Document Control.

FIGURE 1-1: SILO 3 OPERATIONS FLOW DIAGRAM
FIGURE 1-2: SILO 3 CIVIL SITE PLAN
FIGURE 1-3: EAST ELEVATION
FIGURE 1-4: 1ST FLOOR PLAN
FIGURE 1-5: SECTION A
FIGURE 1-6: SECTION C
FIGURE 1-7: SECTION D

1.4.1 Basic Silo 3 Operation

To understand the Silo 3 radiological hazards, one must first understand the basic Silo 3 retrieval and disposition operation (see the flow diagram in **FIGURE 1-1**). Waste retrieval is accomplished by pneumatic retrieval and mechanical retrieval (the material was originally transferred into Silo 3 pneumatically). Some material handling and packaging equipment is shared by both systems. The silo itself is enclosed in a fabric structure, which provides protection from the elements to personnel operating the pneumatic retrieval system. Before Silo 3 is accessed for waste retrieval, radon concentrations in the silo headspace will be reduced by venting through the Silo 3 stack. Calculations show that release of all accumulated radon through the stack will not exceed the RQ of .1 Ci (see Appendix D, Table D.3.3).

Retrieval begins with the Vacuum Wand Management System (VWMS) and the Pneumatic Retrieval System (PRS). The VWMS consists of vacuum wands inserted through existing manways on the silo dome. The VWMS is tied to the PRS inlet, which vacuums material through the manways and transfers it to the Process Building for packaging. The VWMS and PRS are also used to remove material behind the silo wall before creating a wall opening for the mechanical retrieval system. PCN3

After a reinforced concrete framework is installed on the silo wall, and a section of the silo wall is removed, the Mechanical Retrieval System (MRS) begins operation (see Section 1.4.2 on the Silo 4 Mock-up). According to 40430-PL-0002, *Access and Retrieval Strategy for the Silo 3 Project* [Ref. 21], it can be concluded that the reinforced silo (with the wall section removed) will be more structurally robust than the present (unmodified) silo wall. A mechanical excavator retrieves compacted material from the silo and transfers it to a bin located in the Excavator Room. Conveyors feed the material to the adjacent Process Building for packaging.

From a design point of view, the PRS and MRS are redundant systems. Either system has the capacity for retrieving the entire store of Silo 3 waste material. Current plans call for the PRS to be used prior to, and in conjunction with, the MRS.

A Feed Conveyor in the Process Building receives material from the PRS or MRS and discharges it to two Package Loading Stands. Each station is a semi-automated system with loading spouts, loading stands, thumper tables, weighing scales, radio frequency (RF) sealer, and motorized roller conveyors for transporting the filled soft-sided containers away. An aqueous solution of ferrous sulfate and sodium lignosulfonate will be sprayed onto the material in the fill chutes to reduce the material's dispersibility and RCRA metal (chromium) mobility. No credit was taken for waste conditioning in the hazard category calculations.

6. After the final brace design is received, revise the construction traveler to incorporate redline comments and revised work steps. (A construction traveler is a subcontractor-produced, FCP-reviewed/approved work plan that outlines how construction will perform work safely.)

7. Evaluate the need for vertical as well as horizontal braces.

8. Update the safety briefing on equipment and the construction traveler. Prior to initiating Silo 3 penetration, show that the activity can be performed as planned per the Operations Work Instructions specified in this N-HASP (TABLE 10-1, SBR-1).

1.4.3 Silo 3 Material Retrieval and Packaging Activities

This section provides a more detailed explanation of the operational steps of Silo 3 material retrieval and packaging.

Preliminary Pneumatic Retrieval and Equipment Installation

Before routine pneumatic retrieval of material can begin, some preliminary retrieval must be done without the vacuum ventilation ring and the vacuum wand boot.

The contour of material in Silo 3 is estimated to be variable with piles located below the fill manways and center access, leaving very little headspace. This material contour may interfere with the operation of the pressure monitoring instrumentation and the pressure control valve. The pressure control valve (PSV-SILO-10-5070B) and the pressure monitoring instrument (PIT-SILO-10-5070) are needed to ensure that silo pressure does not become excessively negative during pneumatic retrieval. PSV design function is dependent on free communication to each of the vacuum wand manways. If the material contour creates a pocket between a manway and the PSV, an out-of-specification vacuum could be drawn in a small portion of the dome and the PSV would not sense it. As seen during mock operations, controlling vacuum pressure within the silo is critical when there is little headspace. During mock operations, two events occurred during pneumatic retrieval that resulted in pressures reaching −3.5 INWC and container deformation. This lesson learned clearly shows the requirement for the PSV to have free communication throughout the Silo dome. Therefore, sufficient material must be retrieved at each manway to allow for: (1) unobstructed airflow between the dome locations where the pressure control valve and pressure monitoring instrument will be installed; (2) unobstructed airflow from each of the manways to the pressure control valve and pressure monitoring instrument; and (3) installation of the camera and lighting in the center manway. The camera and lighting assembly will be used to verify that a clear airflow path exists to each of the manways. To achieve this, sufficient material must be removed prior to the dome and accesses being sealed with collars and boots.

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To accomplish initial headspace ventilation and pneumatic retrieval for equipment installation, temporary alternative ventilation will be provided. Two Silo Ventilation Hose Connections with isolation valves will be installed near the center manway on two existing six-inch flanges. Once installed, initial ventilation of the silo headspace will be performed using the Auxiliary PRS Blower (BLR-10-5008). This initial venting will reduce the accumulated radon in the headspace through the stack. Positioning the bypass on the Pneumatic Retrieval System (PRS) line to the Supply

HEPA (FLT-10-5070) will control the amount of vacuum (cfm). This method of ventilation was verified during the receipt of fly ash into the Silo 3 Mockup Sea/Land.

During the pneumatic retrieval of material for equipment installation, local ventilation will be provided by the Process Ventilation System (PVS) via the Silo Ventilation Hose Connections. Also, a temporary blanket for covering the manway will be used to minimize airborne contamination. While maintaining ventilation on Silo 3 via the PVS, the center manway will be opened, pulling air into the manway. The PRS will then be started to remove enough material to allow the installation of the Camera and Lighting Assembly into the center manway (approximately eight feet below the manway flange).

PCN3

While continuing to maintain ventilation on the silo via the PVS, each of the remaining five (5) manways will be opened one at a time. Once the manway cover is removed, enough material will again be removed to allow airflow to the center manway. This level will be determined using the center manway camera. Once this level is achieved, a Manway Vacuum Wand Management System will be installed on the manway. This will continue until all five Manway Vacuum Wand Systems are installed.

Pneumatic Retrieval

Note: Prior to construction, the design of the pneumatic retrieval components will be evaluated against, and conform to, the Technical Safety Requirement (TSR) specified in Section 10.3. The pneumatic retrieval strategy has a demonstration plan [Ref. 25] for vacuum wand retrieval and will separately document the results.

The VWMS is installed on the silo dome beneath a fabric enclosure structure that provides protection from the weather. The VWMS consists of flexible hoses and metal tubes (vacuum wands) that will be inserted through the six existing silo dome manways. A motorized hoist will be used at each manway to assist operators in manipulating the VWMS hoses/wands. Video cameras to allow for remote viewing.

At each vacuum wand (and associated manway), an enclosure is provided with passive air supply (inlet) and process vent (outlet) hose connections. A coated fabric flexible boot is installed on the top of each enclosure to seal around the vacuum wand and prevent particulate emissions from the silo, particularly during times when the vacuum retrieval is not running.

In order to keep silo pressure from becoming too negative, the passive air supply (from a HEPA filter) will replace air displaced during pneumatic retrieval and process vent operations. The process vent connection will normally be used to provide slight negative pressure when vacuum wand sections are added and when the pneumatic retrieval (vacuum) system is not in operation.

A vacuum relief valve on the passive air supply piping will open at 3 inches water column (WC) vacuum in the event the HEPA filter becomes plugged or does not allow sufficient air flow to alleviate silo negative pressure.

In the event of a failure of the passive air supply and/or the vacuum relief valves, the fabric flexible boots around the wands should fail (thus relieving silo negative pressure) before a silo failure occurs. Additionally, there is a pressure transmitter on the silo dome to provide an alarm if the silo pressure becomes greater than 3 inches WC vacuum. The pneumatic system also has a low-pressure switch on the blower inlet that will open a blower inlet relief valve, and a low-flow switch to shut down the blower in the event of a plug in the pneumatic system or the passive air supply.

The PRS is contained in a steel beam/metal-sided building (the Process Building) adjacent to the silo. The PRS provides pneumatic, vacuum flow using rotary blowers. From the VWMS, the material/air stream enters the PRS baghouse collector, where material is separated from the air stream and fed by a screw conveyor and rotary airlock to the packaging screw conveyor. The air stream from the PRS baghouse collector passes through a cartridge filter, a high-efficiency particulate air (HEPA)/ ultra-low penetrating air (ULPA) filter, and rotary blower and is discharged via the Silo 3 exhaust stack. Material collected by the cartridge filter is fed by the same screw conveyor and rotary airlocks to the packaging screw conveyor.

Pneumatic retrieval will be performed to the extent practicable (i.e., as long as material can be safely and effectively removed by vacuum). Of significant importance is the use of the VWMS/PRS for removal of material from behind the silo wall, at the proposed access location, to permit safe wall opening for mechanical retrieval. The VWMS/PRS can be used prior to the MRS and in conjunction with it.

Mechanical Retrieval

The Mechanical Retrieval System (MRS) is housed in a robust concrete structure (Excavator Building) attached to the silo structure. When free-flowing material has been removed from the silo to expose the inside of the silo wall, and pneumatic retrieval is no longer practical, an opening will be cut into the exposed silo wall to enable the use of a mechanical excavator (see Section 1.4.2). Compacted material remaining behind the wall will not prevent initiation of wall removal.

The selected excavator has an additional articulating joint. This provides a range of motion that allows it to work within the silo and adjoining excavator room. The machine can also articulate in a horizontal plane. This provides flexibility for supporting retrieval if only portion of the wall can be removed due to material impacted behind the wall.

The excavator can reach into the silo and loosen compacted material for vacuuming. Video cameras to allow for remote viewing. The excavator may also be used to manipulate the VWMS wand/hose to facilitate pneumatic retrieval. The remotely-operated excavator will enter the silo and dig into the waste pile. Removed material will be placed in a below-grade bin in the Excavator Room and then moved to the two packaging stations via four conveyors. Three of the conveyors are screw-type, and one is a pocketed sidewall belt conveyor. The last of the screw-type conveyors is common to the PRS.

Waste Conditioning

As the Silo 3 material is containerized, it will be conditioned by the addition of an aqueous solution to reduce dispersibility and metals mobility. The solution of ferrous sulfate, sodium lignosulfonate, and water will be sprayed onto the material in the fill chutes at the packaging stations. No credit was taken for waste conditioning in the hazard category calculations.

FIGURE 6-1: SILO 3 SAFETY BASIS IMPACT SCREEN (SBIS)

Description of Activity/Design Change:	
Work Plan/ Design Doc. No.:	**Change Originator:**
SBIS Originator:	**SBIS Date:**

1	Will the proposed change affect any parameters used in calculations supporting the Hazard Analysis as documented in the Silo 3 N-HASP? ☐ **YES** ☐ **NO** / **EXPLAIN:**
2	Will the proposed change affect any of the System Safety Requirements in the Silo 3 N-HASP? • Safety Basis Requirements (SBRs)? • Process Requirements (PRs)? ☐ **YES** ☐ **NO** / **EXPLAIN:**
3	Does the proposed change identify a potential inadequacy (e.g., new accident, hazard) in the Silo 3 N-HASP or any potential reduction in any SBR? ☐ **YES** ☐ **NO** / **EXPLAIN:**
4	Does the proposed change affect the activities or requirements of a nearby or adjacent facility or activity, operating under a different safety basis (e.g., Silos 1 & 2, RCS, TTA)? **NOTE: IF** a proposed change can potentially affect the Silos, **THEN** a USQD/safety evaluation must be completed per NS-0002 (Unreviewed Safety Question (USQ) Determination. ☐ **YES** ☐ **NO** / **EXPLAIN:**
5	Does the proposed change result in a change in the inventory or amount of hazardous material? ☐ **YES** ☐ **NO** / **EXPLAIN:**

IF the answer to ANY of these questions is **YES**, **THEN:** (1) update the analysis; (2) determine whether the change will put the project or affected project outside the safety envelope; (3) incorporate any mitigators or controls into the work plan/permit; (4) attach the updated analysis to this impact screen. **IF** the change will result in a higher hazard categorization, **THEN** a USQ must be performed per NS-0002 and submitted to the SRC, the Fluor Fernald President, and the DOE for concurrence.

6	Per this SBIS, the proposed change ☐ **DOES** ☐ **DOES NOT** impact the Silo 3 safety basis.

Signature: _____ **Date:**
System Safety Analyst

SSA: Are there descriptive changes not requiring analysis, but requiring inclusion in the annual update? ☐ **Y** ☐ **N**

NOTE: IF there is an impact to the safety basis, **THEN** the Project Manager's signature is required.

Signature: _____ **Date:**
Silo 3 Project Manager

7.0 HAZARDS ASSESSMENT

The hazards assessment associated with this N-HASP will focus on the activities necessary to support operations and maintenance of Silo 3. To date, fourteen Silo 3 operations tasks have been identified for routine performance by Fluor Fernald maintenance and operations personnel, and one by construction personnel (#15):

NOTE: The hazards associated with these tasks may act as initiators for potential nuclear accidents; if so, they are addressed in Appendices A, B, and G.

1. Truck transport of empty containers and containerized additive materials
2. Receipt of Silo 3 bulk chemicals
3. Manipulation of the Pneumatic Retrieval System (PRS) vacuum wand and hose
4. Maneuvering of the Mechanical Retrieval System (MRS) remote control vehicle
5. Conditioning and packaging of retrieved waste
6. Loading of containerized material
7. On-site transportation of containerized waste materials
8. Maintenance of the Pneumatic Retrieval System (PRS), Air Handling Systems, and Process Vent System
9. Maintenance of motorized vehicles
10. Maintenance of conveyors, feeders, and packagers
11. Maintenance of cranes
12. Maintenance of Waste Additive System and Wastewater System
13. Maintenance of Plant/Breathing Air System
14. Shift-by-shift surveillance of Silo 3
15. Cutting a hole in the Silo 3 wall structure (Note: This is Construction work)
16. Headspace venting, preliminary pneumatic retrieval, and equipment installation

PCN3

The identified hazards listed below are based on the potential exposure of personnel to the Standard Industrial Hazards, chemical hazards, and radiological hazards posed during Silo 3 operations and maintenance activities. A brief description of the expected hazards and their associated controls are provided in Section 8.0. A Hazards Control Matrix is presented in Section 9.0. This matrix identifies the above tasks in conjunction with their hazards and their controls/ mitigators. The matrix forms the basis for employee briefings.

1. Slips, trips, and falls
2. Noise
3. Housekeeping
4. Illumination
5. Ergonomics
6. Head impact
7. Pinch/Crush Points
8. Ladders
9. Hand and power tools
10. Electrical
11. Hazardous energy
12. Hoisting and rigging
13. Confined space
14. Flammable material
15. Hot work
16. Compressed gas
17. Biological
18. Environmental
19. Heat and cold stress
20. Heavy Equipment
21. Radiological
22. Chemical

Radiological Hazard Controls

As a result of the radiological hazards discussed above, several engineering controls were designed into the system to contain and confine the material, and to handle the material indirectly via specialized equipment. **TABLE 8-23** lists the engineering controls designed into the project to help minimize the exposure potential and help maintain radiation exposures ALARA.

NOTE: The Radiological Control Requirements in Table 8-23 do not comprise the complete list of relevant controls for this hazard topic. The items below have been identified as key elements for the Silo 3 Project. For a complete list of applicable radiological controls, see RM-0020, *Radiological Controls Requirements Manual* [Ref. 52].

TABLE 8-23: RADIOLOGICAL HAZARD CONTROLS	
Engineering Controls	
1	Project ventilation is designed to maintain negative airflow with respect to atmospheric pressure. Silo 3 and the Process Building have 10,000 CFM of building ventilation, which can assist in the control of airborne radioactivity in the event of leakage. Building ventilation is pulled through a HEPA filter by an exhaust fan and discharged via the 125-foot monitored stack. Both the HEPA assembly and fan are redundant to provide for continuous operation during maintenance and filter changes. The system is set up with pick-up points throughout the building to provide good air changes to eliminate or minimize the build-up of airborne radioactivity. The exhaust stack provides for dispersal of trace radon and any particulates not collected elsewhere within the process ventilation. Temporary ventilation can be used for special work (e.g., headspace venting, equipment installation).
2	The Vacuum Wand Management System (VWMS) limits personnel exposures to bulk amounts of waste.
3	Excavation is done remotely. The excavator also includes features such as self-lubricating, camera usage, and interchangeable attachments. Maintenance and inspections are still required.
4	Video cameras provide viewing for the remote excavator. Other cameras will be used to allow for remote viewing of personnel and operations. Cameras will help to reduce the number of individuals and the time required inside the Silo 3 Project work areas.
5	Hoods and enclosures minimize airborne contamination. The Excavator Room hood is positioned near the silo wall opening to capture dust generated during silo wall intrusion.
6	The vacuum wand uses a containment system. The retrieval bin uses a hood to minimize generation of airborne material at the source during mechanical retrieval. The primary and secondary rotary feeders are enclosed and act as airlocks between the relatively-high vacuum of the collector and the ambient pressure of the Feed Conveyor. The Inclined Conveyor is contained within an enclosure.

PCN3

TABLE 8-23: RADIOLOGICAL HAZARD CONTROLS	
7	Enclosed conveyors contain powders during material movement.
8	Thick PVC bag liners deter radon diffusion and provide containment of silo waste so that completed packages will meet the off-site waste acceptance criteria (WAC).
9	The packaging "bag-out" system controls contamination by providing a heat seal that allows the PVC liner to be severed from the packaging station.
10	Air locks between the Packaging Station Area and the Cargo Bay minimize the spread of contamination.
11	The Silos Project has temporary shielding available, (e.g., lead blankets). However, it is not anticipated that shielding will receive widespread use due to the generally low overall radiation levels that are expected.
12	Particulate air sampling and radon monitoring will be conducted in selected areas in the facility. In addition, Continuous Air Monitors (CAMs) will be used for early indication of elevated particulate airborne radioactivity.
Administrative Controls	
1	Bag-out procedures will be used for the removal of filters from the redundant Process HEPA filter banks (i.e., the stack filters), the Process Vent System, and the building ventilation system to minimize the potential for spread of contamination and generation of airborne radioactivity.
2	Access Controls/Postings/Labeling (see relevant sections in this table)
3	RWPs/Updated Radiological Surveys will be used for: • entry into any radiological area. • breaching of any process line, tank, vessel, or enclosure containing radioactive material that may become loose or airborne during work activities. • any work within the Controlled Area on contaminated or potentially-contaminated equipment where safety precautions are not adequately discussed in Radiological Control-approved technical work documents. • digging or disturbing soil in a Soil Contamination area. • breaching the barrier of a Fixed Contamination Area.
4	Area Radiation/Contamination Monitoring: As part of the Radiological Controls Program, Radiological Control Technicians (RCTs) monitor radiation levels and surface contamination. The Silo 3 Project Radiological Engineer, in conjunction with other safety professionals, determines the required PPE, thermoluminescent dosimeters (TLDs), and any other special radiological precautions. These requirements are controlled and specified on a RWP for each task.

TABLE 9-1: SILO 3 HAZARDS CONTROL MATRIX

Task	Hazard	Mitigators/Controls	Permits/ Guid. Docs
Task 14 (cont.): Shift-by-shift surveillance of Silo 3	Head impact	• Workers will be trained to perform tasks safely • Workers will perform tasks in accordance with standard operating procedures • Head protection will be worn by personnel when the potential for falling objects or head injuries due to impact exist.	SPR
	Biological	• On-site personnel are instructed to use discretion and avoid all contact with wild animals. • If insects present a problem, insect sprays will be used to remove them. • Workers will be instructed on how to recognize poisonous plants and to avoid contact with them. When found, these hazards will be removed.	SPR
	Environmental	• In the event of adverse weather conditions, the Fluor Fernald S&H Representative will determine if operations may continue without the potential for injury to personnel.	SPR
	Illumination	• Work area lighting levels optimal for performing remote operation of excavator • Industrial Hygiene lighting surveys performed to ensure compliance	HFE SOP Standing Orders S&H Procedures

TABLE 9-1: SILO 3 HAZARDS CONTROL MATRIX			
Task	**Hazard**	**Mitigators/Controls**	**Permits/ Guid. Docs**
Task 15: Cutting a Hole in the Silo 3 Wall Structure	See the Silos Construction HASP	Hole cutting is a construction activity performed by construction labor. The associated hazards and their controls/mitigators are addressed in Silos Construction HASP [Ref. 38]. The Silo 4 mock access demonstration was performed during the construction of the retrieval facility. However, Silo 3 wall access will occur after the operations phase has begun because the plan calls for pneumatic retrieval of material behind the intended wall opening. Therefore, there will be a short window of time when operations (authorized by this N-HASP) and construction work will overlap.	See the Silos Const. HASP
Task 16: Headspace Venting, Preliminary Pneumatic Retrieval, and Equipment Installation	Illumination	• Work area lighting levels optimal for performing the activity • Industrial Hygiene lighting surveys performed to ensure compliance	HFE SOP Standing Orders S&H Procedures
	Falls	• Fall protection system silo 3 dome	SOP SPRs FCP Work Permit
	Hoisting and rigging: Operating hoist over each manway to assist vacuum wand/hose handling	• Workers will be trained to perform tasks safely • Workers will perform tasks in accordance with standard operating procedures	SOP Pre-job Briefing

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TABLE 9-1: SILO 3 HAZARDS CONTROL MATRIX			
Task	**Hazard**	**Mitigators/Controls**	**Permits/ Guid. Docs**
Task 16 (cont.): Headspace Venting, Preliminary Pneumatic Retrieval, and Equipment Installation	Radiological: Airborne radioactivity, contamination, radiation	• Blanketed system to enclose retrieval equipment and to minimize the generation of airborne radioactivity and control the spread of contamination • Temporary ventilation for reduction of headspace radon • Temporary ventilation to prevent excessive vacuum in silo • Workers will be trained to perform tasks safely • Workers will perform tasks in accordance with procedures • Workers will qualify as 40-hr HAZWOPER/Rad Worker • Workers will use good radiological work practices to prevent the spread of radioactive material and use containments when practical • Protective clothing and equipment will be used as prescribed by Radiological Controls • Work area contamination levels will be kept to a minimum • RCTs will perform contamination surveys to determine work area control levels • RCT oversight • Workers will doff potentially contaminated PPE per posted instructions • Vacuum wand sections to be decontaminated, as needed, when removed from silo penetration	FF RWP ALARA Analysis HPP SOP Pre-job Briefing

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TABLE 9-1: SILO 3 HAZARDS CONTROL MATRIX			
Task	**Hazard**	**Mitigators/Controls**	**Permits/ Guid. Docs**
Task 16 (cont.): Headspace Venting, Preliminary Pneumatic Retrieval, and Equipment Installation	Ergonomics: Lifting/holding/ manipulating wand for extended periods	• Workers will be trained to perform tasks safely • Work durations will be administratively controlled/limited via worker rotation • Mechanical devices (jig) to be used to minimize moment on lower back	HFE SOP Standing Orders Pre-job briefings
	Biological	• On-site personnel are instructed to use discretion and avoid all contact with wild animals. • If insects present a problem, insect sprays will be used to remove them. • Workers will be instructed on how to recognize poisonous plants and to avoid contact with them. When found, these hazards will be removed.	SPR
	Heat stress Cold stress	• Implementation of the FCP cold/heat stress programs	Pre-job Briefing S&H Procedures SPRs
	Housekeeping	• Maintain work areas and personnel access-ways free of obstructions and debris	SPR

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TABLE 9-1: SILO 3 HAZARDS CONTROL MATRIX			
Task	**Hazard**	**Mitigators/Controls**	**Permits/ Guid. Docs**
Task 16 (cont.): Headspace Venting, Preliminary Pneumatic Retrieval, and Equipment Installation	Pinch/crushing points	• Workers will be trained to perform tasks safely • Workers will perform tasks in accordance with standard operating procedures • Workers will wear proper PPE	SOP Standing Orders FCP Work Permit Pre-job Briefing
	Hand and power tools	• Workers will be trained to perform tasks safely • Workers will perform tasks in accordance with procedures	SOP Vendor procedures
	Hazardous energy: Electrical shock/ inadvertent equipment start-up	• Energy isolation will be performed per site procedures • Only trained personnel will perform work on locked-out/tagged-out equipment	EIP/SOP
	Hazardous energy: Static electricity	• Equipment properly grounded prior to chemical delivery	Vendor procedures

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10.2 Silo 3 System Safety Requirements

The matrix in **TABLE 10-1** has been developed to identify Silo 3 System Safety Requirements, reference the origin of the requirements, and identify the method(s) of control and implementing document(s), as appropriate. These System Safety Requirements are provided for Defense-in-Depth. Table 10-1 is the requirements matrix pursuant to the DOE-approved *Decision Basis Document Implementation of 10 CFR 830 Safe Harbor Requirements for the Silos Projects,* 40000-RP-0034 [Ref. 1]. Table 10.1 identifies the requirements of the written site safety and health program and project specific requirements that relate to system safety and are relied upon for maintaining the safety envelope.

As identified in Appendix G, *Silo 3 Accident Analysis*, there are no safety class or safety-significant components associated with the Silo 3 Retrieval and Disposition Project. This is based on the fact that Silo 3-initiated accident scenarios do not yield consequences that would exceed on-site dose limits, nor was any mitigation credit taken for these systems, structures, and components in the consequence analysis. However, SBRs and PRs were developed around some components to provide defense-in-depth.

TABLE 10-1: SILO 3 SYSTEM SAFETY REQUIREMENTS

SBR, PR	Requirement	Basis/Source	Implementation
SBR-1	Wall cutting activity, for mechanical retrieval, must be authorized by updated documentation, including but not limited to an Unreviewed Safety Question Determination (USQD) and Operations Work Instructions.	Although consequences are analyzed in this document as EBA-2 (see Appendix G), the wall cutting activity is authorized in the Silo 3 PHAR [Ref. 14] and the work will be done by Construction.	• NS-0002 • Management assessment
PR-1	The Silo 3 stack monitoring capability will be maintained within defined operability parameters, with established action level thresholds and operating limits. Operating data from the particulate filtering system (i.e., pressure differential) can be relied upon during maintenance events on the stacks samplers.	Public and Worker Protection, Environmental Protection Agency (EPA) Required	• 40000-PL-012, *Silos Engineering Project Execution Plan* (i.e. Silos Design Change Notice) • Operations procedures • Routine calibration and maintenance • Routine inspections • Engineering design

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TABLE 10-1: SILO 3 SYSTEM SAFETY REQUIREMENTS			
SBR, PR	**Requirement**	**Basis/Source**	**Implementation**
PR-2	Individual IP-2 bulk bags shall not exceed 7000 lbs. gross weight.	EBA-4 (App. G) Test Report for IP-2 Container Testing [Ref. 65]	• Operations procedures • Routine inspections • Engineering design • Routine calibration and maintenance
PR-3	Verify that IP-2 bulk bags/packages are sealed before transfer outside of the Cargo Bay area.	Shipping requirement	• Operations procedures • Routine inspections • Engineering design • Routine calibration and maintenance
PR-4	Visually inspect the flexible fabric boot on each vacuum wand for verification of integrity (i.e. in place, no holes). NOTE: Does not apply to Preliminary Pneumatic Retrieval and Equipment Installation.	Public and Worker Protection, Containment	• Operations procedures • Routine inspections • Engineering design
PR-5	During pneumatic retrieval operations, a vacuum relief valve must be installed on Silo 3, set to -3.0 inches of water, with alarm indication. NOTE: Does not apply to Preliminary Pneumatic Retrieval and Equipment Installation.	Dome Failure, protect Silo Dome TSR	• I-TAB • Routine inspections • Engineering design • Routine calibration and maintenance
PR-6	Preliminary Pneumatic Retrieval and Equipment Installation will be performed per the OWI package as reviewed and approved by an SSA.	Consequences bounded by EBAs in Appendix G. Public and Worker Protection, Containment	• OWI

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10.3 Silos Project Technical Safety Requirement (TSR)

Technical Safety Requirements (TSRs) are the limits, controls, and related requirements necessary for the safe operation of a nuclear facility and, as appropriate for the work and the hazards identified in the documented safety analysis for the facility, includes management controls, use and application provisions, and design features, as well as a basis appendix. TSRs are subject to 10 CFR 830, Subpart B [Ref. 6].

The Silos Project (including Silo 3) has one TSR (see **TABLE 10-2**). There are no additional TSRs specific to the Silo 3 Retrieval and Disposition Project. Planned Silo 3 operations and activities will be conducted within the umbrella of the Silos safety basis (i.e., the Silos TSR).

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TABLE A.4-1: FINAL HAZARD ASSESSMENT FOR THE SILO 3 PROJECT

ID No.	Hazard Type	Initiating Event	Consequence (Unmitigated)	SIH * Yes/No	Frequency	Severity	Significant Hazard	Comments, Mitigators, Controls, Actions, and/or Justification
14g	Radiation exposure	Dust collector failure	Potential to exceed dose limits	N	Anticipated	Low	Yes	Approved procedures, training, process and equipment design.
14h	Radiation exposure	Silo collapse due to pressure differential during headspace venting, preliminary pneumatic retrieval, and equipment installation, or routine pneumatic retrieval	Potential to exceed dose limits	N	Pressure issues Anticipated	Low	Yes	General: Approved procedures, operator training, process and equipment design, and structure over silo. Preliminary Pneumatic Retrieval: OWI. Routine Pneumatic Retrieval: silo pressurization is mitigated by the maximum achievable pressure, which is within failure limits, and by the relief valves. Depressurization requires multiple failures and could result in a pressure differential exceeding failure limits.
16a	Exposure to toxic materials	Use of concrete, paints, chemicals, fuel, oil, silica	Skin irritation, respiratory system damage, or other physical effects	Y	-	-	SIH	Use appropriate PPE, MSDS.
16b	Exposure to toxic materials	Spill of ferrous sulfate	Skin irritation, respiratory system damage, or other physical effects	N	Anticipated	Low	Yes	Approved procedures, training, equipment design, use appropriate PPE.

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TABLE A.4-1: FINAL HAZARD ASSESSMENT FOR THE SILO 3 PROJECT

ID No.	Hazard Type	Initiating Event	Consequence (Unmitigated)	SIH * Yes/No	Frequency	Severity	Significant Hazard	Comments, Mitigators, Controls, Actions, and/or Justification
16c	Exposure to chemicals such as lead and beryllium	Spill or release of Silo 3 material.	Personnel injury	Y			SIH	Use appropriate PPE, approved procedures, equipment design.
16d	Exposure to exhaust from forklift-CO	Poor work practice	Personnel injury	Y			SIH	Maintain forklifts properly, approved procedures
17a	Exposure to poison ivy, snake bites, insect stings	Work outdoors	Personnel injury	Y	-	-	SIH	PPE, repellants. Removal of potential hazards (snakes, ivy, etc.)
21a	Exposure to welding operations	Welding and torch cutting	Eye injury, burns, respiratory, fire	Y	-	-	SIH	Training, qualified welders, PPE, fire watch
21b	Confined space	Const., maint., ops, inspections requiring confined space entry	Asphyxiation, injury, or death	Y	-	-	SIH	Training, PPE, ventilation, retrieval and rescue provisions
21c	Traffic	Material delivery, transport, construction, demolition	Personnel injury, equipment damage	Y	-	-	SIH	Observe speed limits; establish/maintain appropriate traffic patterns, traffic control devices, warning equipment, and backup warning devices.

*SIH = standard industrial hazards, Y = yes, N = no
CFR = *Code of Federal Regulations*
D&D = decontamination and decommissioning
MSDS = Material Safety Data Sheets
NFPA = National Fire Protection Association
OSHA = Occupational Safety and Health Administration
PPE = personal protective equipment
RWP = radiological work permit
TLD = thermoluminescent dosimeter

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Radon Released

The initial radon release from the silo failure during wall cutting is conservatively assumed as 0.0356 Ci, which assumes a maximum headspace concentration, where no silo ventilation was in operation. In addition to the initial radon release, radon would be released from the remaining silo material at a rate of 4.7×10^6 pCi/minute over the next 24 hours.

B-3.2.3 Hazard Categorization Based on Radiological Dose Criteria

To demonstrate no significant localized consequences, dose consequences are determined for workers at 30 m, for comparison to the dose threshold criteria of DOE HC-3 facilities (10 rem over a 24-hour exposure).

The methods used to determine the dose consequence or committed effective dose equivalent (CEDE) for each accident scenario use variations of the following general equation [Ref. 16]:

$$CEDE = \sum (MAR * DCF * DR * BR * ARF \text{ or } ARR * LPF * RF * (\chi/Q) * T)_i$$

where:

MAR	=	amount of a radionuclide available to be acted upon by a physical stress (pCi)
DCF	=	dose conversion factor in mrem/pCi
DR	=	damage ratio or the fraction of the MAR actually impacted by accident conditions
BR	=	breathing rate of a reference person considered = 3.33×10^{-4} m^3/sec
ARF	=	airborne release fraction
ARR	=	airborne release rate
LPF	=	leak path factor or the fraction of material transported through some confinement
RF	=	respirable fraction
χ/Q	=	long-term dispersion factor in sec/m^3
T	=	exposure time in hours
i	=	each radionuclide

The dispersion factor (χ/Q) for a straight line, ground level release, is determined from a Gaussian plume model for continuous point source emission in accordance with Nuclear Regulatory Commission's *Regulatory Guide 1.145* [Ref. 17]. A wind speed of 1.0 m/second and D stability class was used at a distance of 30 m, which is consistent with the recommendations of DOE-STD-1027-92 [Ref. 4], for HC-3 criteria. A wind speed of 4.5 m/sec and D stability class was used at 100 m, which is consistent with the recommendations of DOE-STD-1027-92 for HC-2 calculations. The χ/Q is 1.77×10^{-2} at 30 m and 1.05×10^{-3} at 100m.

For a continuous release, the receptor is assumed to be exposed for 24 hrs at 30 m and 2 hrs at 100 m and 330 m. For an instantaneous release, the material is assumed to be completely released within 1 hour. The receptor is exposed during this hour to the instantaneous release, and for the entire exposure period to resuspended solids that are emitted continuously.

All Silo 3 material is in powder form. For EBA-2, dose resulted from powders impacted by falling objects, radon release, and radon flux. The ARF for powders impacted by a falling object (Page 4-85, HDBK-3010), is 1×10^{-3} and the RF is 0.1.

The DCFs were obtained from Federal Guidance Report No. 11, *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion* [Ref. 18]. The Ra226 DCF, lung clearance class Y, is obtained from CAP88-PC Version 2.1, which was determined using the RADRISK code.

The dose from exposure to radon is determined from the Radon Modeling Report [Ref. 19].

Dose results for hazard categorization purposes are presented in **TABLE B.3-2**.

TABLE B.3-2: RADIOLOGICAL DOSE CONSEQUENCES

Receptor Distance	Solids Results	Radon Results for Initial Release	Radon Results for Flux	Total CEDE (rem)
	Dose (mrem)	Dose (mrem)	Dose (mrem)	
Silo Failure During Wall Cutting (EBA-2 Appendix G)				
30 m (HC-3)	273	41	6.8	0.32
100 m (HC-2)	16	8.4	0.1	0.03

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The total dose is the sum of the dose from solids, the dose from radon released initially, and the dose from radon released continuously. These results demonstrate no significant localized consequences and therefore support a hazard categorization of Radiological (RAD) for the Silo 3 retrieval and disposition activity.

B-3.3 COMPARISON OF CHEMICAL CONSTITUENTS TO THRESHOLDS

Radiological facilities with inventories of hazardous materials at or above the levels specified in 40 CFR 355, *Emergency Planning and Notification,* shall develop the same safety documentation as required for "non-nuclear" facilities.

TABLE D.3-3: SILO 3 RADON INVENTORIES AND EMISSIONS

Parameter	Silo 3 Storage	At Start of Retrieval Operations
Headspace concentration (pCi/L)	1,000,000 [a]	466 [e]
Headspace volume (ft^3)	3720 [a]	3720
Headspace activity (Ci)	0.105 [b]	4.91×10^{-5} [f]
Radon generation rate (pCi/min)	1.78×10^9 [c]	1.78×10^9
Radon transfer rate to headspace (pCi/min)	1.32×10^7 [d]	1.32×10^7
Headspace ventilation rate (ft^3/min)	0	1,000
Emission rate silo leakage (Ci/yr)	2 [h]	-
Emission rate stack exhaust (Ci/yr)	-	6 [g]
Dose at site boundary (330 m) (mrem)	<0.1	<0.1 [g]

a. SD-2089 "Radiological Considerations For The Controlled Release Of The Silo 3 Radon Laden Headspace, dated 6/09/04

b. 1,000,000 pCi/L x 3,720 x 28.32 L/ft^3 = 0.105 Ci.

c. 3,870 pCi/g x 7.99×10^6 lb x 454 g/lb = 14.1 Ci Ra226. 14.1 Ci x 0.693/5500 min = 1.78×10^9

d. A = 0.105 Ci x 0.693/5500 min = 1.32×10^7 pCi/min.

e. C = E/Q = 1.32×10^7 pCi/min x 1/1000 ft^3/min x 1/28.32 L/ft^3 = 466 pCi/L.

f. 466 pCi/L x 3,720ft^3 x 28.32 L/ft^3 = 4.91×10^{-5}Ci.

g. Stack emission calculation (40430-CA-0003), assuming 35% emanation rate, 100% transfer rate to the headspace. Stack emission rate of 1×10^8 pCi/min for 1000 operating hours.

h. Remedial Investigation Report for Operable Unit 4 [Ref. 5].

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D-4.0 ALARA ANALYSIS AND REVIEW PROCESSES

The ALARA Analysis presents estimates of the radiation dose rates, the concentrations of radon in the air, and the duration of exposures. Each Silo 3 Project task was reviewed relative to individual as well as collective doses. Shielding requirements were considered for all the higher dose rate tasks and ventilation requirements were considered for all tasks, where radon concentrations greater than 0.01 WL are expected in the air in occupied spaces. Other factors were considered in the ALARA analyses to determine the duration of exposures, such as the frequency of maintenance tasks, access to equipment that requires maintenance, the path taken to reach the equipment, the complexity and duration of maintenance tasks, local ventilation, and PPE requirements.

For example, consider the preventive maintenance required on a conveyor as a means of describing the methodology of ALARA analyses. The manufacturer's specifications and instructions for the conveyor will give the recommended maintenance frequency, the maintenance procedure, and any special tool or material requirements. The procedure will lead to an estimate of the time, personnel, skills, training, and tools required for a maintenance cycle. Radiological conditions in the vicinity of the conveyor, including dose rates at various distances, decay time, and radon concentrations, will be estimated. Other factors (such as access to the conveyor, stay time limits, temporary shielding, remote tools, PPE, and other) provide the basis for initial individual and collective dose estimates. Consideration will then be given to ways to reduce exposure times, add shielding, improve tools, or other means to reduce the estimated exposures. A collective dose will be calculated for the conveyor maintenance task and all such task, collective doses will be summed for an overall Silo 3 Project collective dose estimate for other waste treatment tasks.

The tasks with the highest collective dose estimates and tasks in the highest dose rate areas will be given the most rigorous technical reviews. Innovative methods and equipment will be incorporated when reasonably achievable to reduce worker exposures to radiation (see TABLE D.2-1).

D-4.1 ALARA Review Criteria

The safety envelope has been defined to include Silo 3 Project operations and maintenance activities that are described in SECTION D-5.4 and tabulated in **TABLE D.5-1**, ALARA Analysis Matrix. The radiological controls necessary for the activities listed in TABLE D.5-1 will be specified in RWPs that will be developed in accordance with RP-0020, *Radiological Work Permitting and Authorization* [Ref. 7]. The RWP system ensures that the ALARA process is used in work planning.

E-4.0 REFERENCES

1. 40430-CA-0003, Rev. 3, *Radioactive Particulate and Radon-222 Stack Release Considerations for the Silo 3 Remedial Action Project*, Flour Fernald; June, 2004

2. 40430-RP-0012, *Timed Estimate of Secondary Waste for Silo 3*, Fluor Fernald; September 5, 2002

3. 10 CFR 835, *Occupational Radiation Protection*, Title 10 Code of Federal Regulations, Part 835, DOE; July, 2001

4. DOE Order 5400.5, *Radiation Protection of the Public and the Environment*; Figure IV-1, *Surface Contamination Guidelines*; DOE, February 8, 1990

5. 40430-PL-0005, *Fernald Silo 3 Project Environmental Control Plan*, Fluor Fernald; October 13, 2003

6. RM-0047, *Fugitive Dust Control Requirements*, Fluor Fernald

7. PL-3083, *Storm Water Pollution Prevention Plan*, Fluor Fernald

G-2.3 Common Assumptions

The accident scenarios were analyzed using several common assumptions:

- The Silo 3 material is assumed to contain 3,870 pCi/g of ^{226}Ra and its progeny are in complete equilibrium unless otherwise noted in the scenario.

- The Silo 3 material bulk density ranges from 29 to 58 lb/ft^3. The average bulk density is 42.4 lb/ft^3 (0.68 g/cm^3). A bulk density of 50 lb/ft^3 was used in the analyses, conservatively bounding the average. This ensures that an operational condition does not occur in which the safety basis may be inadequate, or results in a "potential inadequacy of the safety analysis".

- All Silo 3 material is in powder form. The airborne release fraction (ARF) and respirable fraction (RF) of the solid powder material is obtained from DOE-HDBK-3010-94 [Ref. 2]. The inputs are summarized in **TABLE G.2-1**. The bounding ARF for a free-fall spill of uncontained powders, page 4-77 of DOE-HDBK-3010-94, is 2×10^{-3}. An RF of 0.3 was used for free fall spill of powders. These values were obtained from experiments performed using up to 1,000 g. TiO_2, material density 4.2 g/cm^3, from a spill height of 3 m. Recalculation of EBAs where free-fall spills were modeled was performed with more conservative bounding values, as discussed in SECTION G-3.0.

- The ARF for powders impacted by a falling object is 1×10^{-3} and the RF is 0.1. DOE-HDBK-3010-94, page 4-85, provides a basis for choosing an ARF and RF from impacts due to large falling objects and induced air turbulence. Tests were performed on a variety of materials to simulate the release of powders. All the tested materials were free-flowing (non-cohesive) powders, the most dispersible of which was Al_2O_3, with an ARF of 1×10^{-3}. The nature of this release scenario is to provide some confinement of its inner volume. DOE-HDBK-3010-94 also considers other material configurations in which some material protection is available. Additional tests were performed by dropping heavy objects on cans of powder. The highest RF value from the contained set was 0.07. DOE-HDBK-3010-94 concludes that, in cases where some material protection is afforded, the appropriate bounding ARF*RF is the highest ARF from the uncontained data set (1×10^{-3} for uncontained Al_2O_3) used in conjunction with the largest RF from the contained experiments (rounded to 0.1). As a result, an ARF of 1×10^{-3} with a RF of 0.1 was assessed to be appropriate for this release scenario.

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- The summation of CEDEs for each radionuclide results in a CEDE for Silo 3 material of 19.8 rem/g inhaled (without radon and daughters). This is shown in **TABLE G.2-2**. The DCFs were obtained from Federal Guidance Report No. 11, *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion* [Ref. 10], which is based on ICRP 30. The selected lung clearance class was based on the presence of oxides. The Ra226 DCF, lung clearance

class Y, is obtained from CAP88-PC Version 2.1, which was determined using the RADRISK code. Short-lived radionuclides are not included because of the negligible dose contribution.

Radon will continue to emanate from silo material that is involved in spills or is open to the environment. The radon emanation rate from a solid material is 35 percent of the generation rate, based on experimental studies [Ref. 11 and 12]. The measured values for emanation fraction are derived or measured from mill tailings, which are similar to Silo 1 and 2 material in terms of composition, particle size, density, and porosity. However, Silo 3 contains calcined material that has a significantly different porosity, density, and particle size distribution. Since an experimentally determined emanation rate does not exist for Silo 3 material, 35 percent was used. The 35 percent emanation rate is the best experimentally based value available, although it may not be conservative.

TABLE G.2-1: DISPERSION ANALYSIS INPUTS

Release Mode or Type	Distance (m)	Application	Wind Speed (m/sec)	Stability Class	ARF	RF
Gaussian Ground Level Solids Release	30	HC-3	1.0	D	2E-3	0.3
	100	HC-2	4.5	D		
	350	MOI	1.0	F		
Gaussian Stack Solids Release	30	HC-3	1.0	D	2E-3	0.3
	100	HC-2	4.5	D		
	350	MOI	1.0	F		
Radon Release	30	HC-3	1.8	F	1	1
	100	HC-2				
	350	MOI				

Notes:
1. An ARF of 1×10^{-3} and an RF of 0.1 is used for EBA-2.
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TABLE G.2-2: SILO 3 MATERIAL DOSE CONVERSION

Nuclides	95% UCL Specific Activity [a] (pCi/g)	Fed Guide 11 Inhalation DCF [b] (mrem/pCi)	Silo 3 CEDE without radon (mrem/g)
Actinium-227	**925**	1.29E+00	1,194
Actinium-228	406	1.25E-04	<0.1
Bismuth-210	3,480	1.96E-04	1
Bismuth-212	367	1.91E-05	<0.1
Bismuth-214	3,870	6.22E-06	<0.1
Francium-223	13	6.22E-06	<0.1
Protactinium-231	**627**	8.58E-01	538
Protactinium-234	2	8.14E-07	<0.1
Protactinium-234m	1,778	8.14E-07	<0.1
Lead-210	**3,480**	1.36E-02	47
Lead-211	925	8.70E-06	<0.1
Lead-212	367	1.69E-04	<0.1
Lead-214	3,870	7.81E-06	<0.1
Polonium-210	3,480	8.58E-03	30
Radium-223	925	7.84E-03	7
Radium-224	**367**	3.16E-03	1
Radium-226	**3,870**	1.4E-01	542
Radium-228	**406**	4.77E-03	2
Thorium-227	925	1.62E-02	15
Thorium-228	**747**	3.42E-01	255
Thorium-230	**60,200**	2.62E-01	15,748
Thorium-231	117	8.77E-07	<0.1
Thorium-232	**842**	1.15E+00	969
Thorium-234	1,780	3.50E-05	<0.1
Uranium-234	**1,730**	1.32E-01	229
Uranium-235/236	**117**	1.23E-01	14
Uranium-238	**1,780**	1.18E-01	211
TOTAL			**19,805**

a. Actual measured values are in bold type.
b. Federal Guidance Report No. 11 [Ref. 10] for all values except Ra226. The Ra226 DCF is from CAP88-PC, Version 2.1, class Y.

G-3.0 ACCIDENT ANALYSES

The accidents analyzed include (1) hose rupture during pneumatic transfer, (2) silo wall containment failure while cutting an opening, (3) spill of material due to conveyor failure, (4) breach of a full soft-sided package, (5) failure of the collectors in the pneumatic retrieval system, and (6) spill contents of a cargo container. These accident scenarios and analysis results are described in the following sections.

Safety analysis presented here relies on DOE-HDBK-3010-94 for established values for airborne release fractions (ARF) for free-fall spills and respirable fractions (RF). The dose consequences presented in this Appendix were derived applying the factors presented in DOE-HDBK-3010-94 for solid powders [Ref. 2]. The factors presented in this reference guide were developed in part on empirical testing of the properties of the oxides of the elements aluminum, silicon, titanium and uranium. The materials present in Silo 3, largely oxides or sulfates of magnesium, iron, sodium, calcium and aluminum, were byproducts of the extraction of uranium from milled ores and ore concentrates. Following extraction, the residues were subsequently calcined in the presence of lime and pneumatically conveyed into the silo. As a result of the waste generating process, concern was expressed by some internal reviewers that the application of the factors recommended in DOE-HDBK-3010-94 may not be appropriately representative of the characteristics of the waste. The most significant difference is the unusually low bulk density of the Silo 3 waste, e.g., about half the bulk density of sand. At this lower bulk density it is possible that a larger airborne release fraction could occur as the result of an accident than indicated in the experiments reported in the HDBK.

To ensure that the dose consequences derived through the hazard calculations for the selected accident scenarios were appropriately representative of the waste materials involved and present reasonable bounding values, the total dose was calculated twice. First, by applying the experimentally determined factors reported in DOE-HBDK-3010-94, and then separately by utilizing the bounding values given in the HDBK. The bounding values used were an airborne release fraction of 0.01 for free-fall spills of powder, and a respirable fraction of 0.36. The results of these analyses are a simple linear increase by a factor of 6 (2E-3x0.3 versus 0.01x0.36); however, the increase was not significant enough to result in any change to the Hazard Categorization conclusions. These results are presented in each affected EBA Table (EBA 1, 3, 4, 5 and 6) under "Solids Results", along with those derived utilizing the factors presented in DOE-HBDK-3010-94. For EBA 2 the results of using a bounding RF of 0.36 (ARF was not questioned) is presented in TABLE G.3.2 along with those derived utilizing the factors presented in DOE-HBDK-3010-94.

G-3.1 EBA-1: Hose Rupture During Pneumatic Retrieval

In this accident scenario, the Pneumatic Retrieval System has been in use for two hours when the hose carrying Silo 3 material to the Pneumatic Retrieval Collector, DCL-10-5002, breaks at a location inside the fabric structure. A conservative assumption is used that the fabric structure is open to the environment. When the line breaks, the motive force for material removal is stopped. However, all the material in the line between the vacuum

wand and the pneumatic retrieval collector is assumed to be released to the atmosphere inside the fabric structure. All solids and radon present are assumed to be released to the environment.

The vacuum line is 150-ft long by 6 in. in diameter. With an airflow of 1,200 cfm and a solids removal rate of 10 yd^3 per hour, and based on a bulk density of 50 lb/ft^3, the air will have a density of 0.188 lb/ft^3:

$$50\ lb/ft^3 \times 10\ yd^3/hr \times min/1200\ ft^3 \times 27ft3/yd3 \times hr/60min = 0.188\ lb/ft^3$$

Therefore, 5.56 lb will be released from the 150-ft length.

The initial radon release is conservatively assumed as 0.105 Ci, which is the headspace inventory based on 1,000,000 pCi/L and a headspace volume of 3720 ft^3. In addition to the initial radon release, radon will be released from the remaining silo material at a rate of 1.32×10^7 pCi/minute over the next 24 hours. The emission rate is based on the headspace inventory, where emission rate equals decay rate. The decay rate is 0.0475 Ci x 0.693/5500 min. PCN3

The solids dispersion is modeled using the Gaussian plume model for ground-level releases. The radon dispersion is modeled using the Fernald radon model [Ref. 6]. The receptors are assumed to be within the airborne solids plume for 1 hour. The receptors are assumed to be in the initial radon release plume for 1 hour and in the residual flux radon plume for 24 hours. **TABLE G.3-1** summarizes the scenario results; the spreadsheets are provided in ATTACHMENT 1.

TABLE G.3-1: HOSE RUPTURE DURING TRANSFER SCENARIO RESULTS

Receptor Distance	Solids Results			Radon Results for Initial Release		Radon Results for Flux		Total[1] CEDE (mrem)	Total[2] CEDE (mrem)
	X/Q	Dose[1] (mrem)	Dose[2] (mrem)	Conc. (pCi/L)	Dose (mrem)	Conc. (pCi/L)	Dose (mrem)		
30 m (HC-3)	1.77E-2	0.176	1.06	652	54	4.5	9	63	64
100 m (HC-2)	1.05E-3	0.01	0.06	135	11	0.9	0.16	11	11
350 m (MOI)	9.0E-4	0.009	0.054	26.3	2	0.2	0.03	2	2

PCN3

1 Based on ARF of 2E-3, RF of 0.3 from DOE-HDBK-3010-94. See SECTION G-3.0 for explanation.
2 Based on ARF of 0.01, RF of 0.36, bounding. See SECTION G-3.0 for explanation.

G-3.2 EBA-2: Silo Wall Containment Failure

In this accident scenario, the Pneumatic Retrieval System has been used to remove enough Silo 3 material to allow removal of a portion of the silo wall. The wall section removal allows the use of a mechanical excavator. An historic calculation performed by Parsons determined that during a seismic event, the higher stressed lower portion of the walls would crack at approximately 5 to 10 ft above floor level [Ref. 13]. Continued seismic shaking would propagate the crack sufficiently for the dome to fall downward, allowing some solid material to spill out from the full silo. For the EBA-2 scenario, either during the cutting operation or during excavation, an unanticipated relief of stress in the silo wall occurs adjacent to the concrete cut, a crack propagates, and the dome collapses inward impacting the remaining material. PCN2

The solids release for EBA-2 is estimated in a similar manner to the Parsons-analyzed seismic event. For the EBA-2 scenario, the material has been removed in the vicinity of the wall cut before performing the wall cut operation; therefore, the silo material volume is less for this accident. It is assumed that 25 percent of the original silo material volume has been removed before the collapse. The configuration of the remaining silo material is such that the angle of repose from the floor area at the wall opening to the high solids level at the center of the silo is less than 45 degrees. Material release at the time of collapse would result from material falling toward the wall opening. The Silo 3 solid metal oxides will not slough more than 45 degrees, as documented in WSRC-TR-2000-00523, *Characterization of Fernald Silo 3 Wastes* [Ref. 14]. Therefore, the material spilling out of the collapsed region would be minimal and it is conservatively assumed that 1 percent of the silo material volume, at the time of collapse, spills outside the silo and into either the excavator area or fabric structure, depending upon the nature of the failure.

The solids release is 5,100 yd^3 x 0.75 x 0.01, which equals 38.3 yd^3 (1,033 ft^3). The initial radon release is conservatively assumed as 0.079 Ci, which assumes that no silo ventilation was in operation. In addition to the initial radon release, radon would be released from the remaining silo material at a rate of 9.9 x 10^6 pCi/minute over the next 24 hours. These values are 75% of the values obtained with the original material volume. PCN3

The solids dispersion is modeled using the Gaussian plume model for ground-level releases. The radon dispersion is modeled with the Fernald radon model. **TABLE G.3-2** summarizes the scenario results; the spreadsheets are provided in ATTACHMENT 2 of APPENDIX G. PCN2

TABLE G.3-2: SILO WALL FAILURE SCENARIO RESULTS

Receptor Distance	Solids Results			Radon Results for Initial Release		Radon Results for Flux		Total[1] CEDE (mrem)	Total[2] CEDE (mrem)
	X/Q	Dose[1] (mrem)	Dose[2] (mrem)	Conc. (pCi/L)	Dose (mrem)	Conc. (pCi/L)	Dose (mrem)		
30 m (HC-3)	1.77E-2	273	983	488	41	3.4	6.8	321	1031
100 m (HC-2)	1.05E-3	16	58	101	8.4	0.7	0.1	25	67
350 m (MOI)	9.0E-4	14	50	20	1.6	0.1	<0.1	16	52

PCN3

Chemicals	Concentration				ERPG-1 (mg/m³)	ERPG-2 (mg/m³)	ERPG-3 (mg/m³)
	On-site [1] (mg/m³)	On-site [2] (mg/m³)	Off-site [1] (mg/m³)	Off-site [2] (mg/m³)			
Arsenic trioxide	6.62E-02	2.38E-01	6.56E-03	2.36E-02	0.03	1.4	5
Cadmium oxide	2.31E-03	8.32E-03	2.29E-04	8.24E-04	0.03	0.05	12.5
Mercuric oxide	1.11E-02	4.00E-02	1.10E-03	3.96E-03	0.025	0.1	10
Thallium sulfate	1.42E-03	5.11E-03	1.40E-04	5.04E-03	0.3	2	15
Vanadium pentoxide	1.16E-01	4.18E-01	1.15E-02	4.14E-02	0.15	0.5	35

1 Based on ARF of 1E-3, RF of 0.1 from DOE-HDBK-3010-94. See SECTION G-3.0 for explanation.
2 Based on RF of 0.36, bounding. See SECTION G-3.0 for explanation.

Of the chemical constituents in the waste, five exceed the threshold planning quantity (TPQ) values in 40 CFR 355 [Ref. 15]. After further evaluation of these five compounds, none exceed the criteria for a "low" chemical hazard classification based on Emergency Response Planning Guide (ERPG) values. The criteria for "low" chemical hazard on-site is less than ERPG-3 and off-site is less than ERPG-2.

G-3.3 EBA-3: Spill Of Material From Conveyor Failure

In this accident scenario, there is a total break in conveyor containment while removing material with the excavator at the intersection of the inclined conveyor and the transfer conveyor. The conveyed material is released directly into the interior of the process building packaging area for 15 minutes before action is taken to stop the conveyor. The transfer rate for the conveyor is 10 yd³ per hour; therefore, 2.5 yd³ or 3,375 lb of material is released. The solids that become airborne are released to the ventilation system. It is conservatively assumed that the filter system fails to remove the material and all materials are passed through the ventilation system and released from the 125-ft stack.

Radon present in the spilled material void spaces and radon generated over the next 24 hours is released to the ventilation system. The 2.5 yd^3 spilled material contains 0.0059 Ci Ra^{226}. Assuming 35 percent of the radon generated emanates to the void spaces, the spill will result in a release of 2.07 x 10^{-3} Ci instantaneously. The radon emanation from the remaining solids will be 260,000 pCi/min over the next 24 hours.

The solids dispersion is modeled using the Gaussian plume model for stack releases, with stability class G and wind speed of 0.5 m/second. The radon release is significantly lower than that released in EBA-1; therefore, the radon dose is negligible. **TABLE G.3-3** summarizes the scenario results; the spreadsheets are provided in ATTACHMENT 3.

TABLE G.3-3: SPILL OF MATERIAL FROM CONVEYOR SCENARIO RESULTS

Receptor Distance	Solids Result			Total [1] CEDE (mrem)	Total [2] CEDE (mrem)
	X/Q	Dose [1] (mrem)	Dose [2] (mrem)		
30 m (HC-3)	2.75E-2	167	1002	167	1002
100 m (HC-2)	7.8E-3	47.4	284	47	284
350 m (MOI)	2.24E-3	13.6	81.6	14	82

1 Based on ARF of 2E-3, RF of 0.3 from DOE-HDBK-3010-94. See SECTION G-3.0 for explanation.
2 Based on ARF of 0.01, RF of 0.36, bounding. See SECTION G-3.0 for explanation.

G-3.4 EBA-4: Breach Of Full Package

In this accident scenario, a bridge crane or forklift is assumed to be transferring a full soft-sided package. The package is either not sealed, or gets caught on a sharp edge and is ripped open. The material in the soft-sided container spills out and lands in a pile on the floor.

The cargo container bay is effectively open to the environment so that what little radon is present and the airborne solids leak from the room. It is assumed that the package volume spilled to the ground is 96 ft^3, having a bulk density of 56.3 lb/ft^3 for the treated material, for a total spill of 5,405 lb. Assuming untreated material has a density of 50 lb/ft^3, the silo 3 material comprises 89 percent of the total treated material mass. Therefore, the mass of silo 3 material released is 4810 lb (2.18 x 10^6 g).

Radon present in the spilled material void spaces and radon generated over the next 24 hours is released to the ventilation system. The 96 ft^3 of spilled material contains 0.0084 Ci Ra^{226}. Assuming 35 percent of the radon generated emanates to the void spaces, the spill will result in a release of 2.94 x10^{-3} Ci instantaneously. The radon emanation from the remaining solids will be 370,400 pCi/min over the next 24 hours.

The solids dispersion is modeled using the Gaussian plume model for ground-level releases. The radon release is significantly lower than that released in EBA-1; therefore, the radon dose is negligible. The same accident could be postulated for the ISA, with identical

consequences (but less likely because bags meet DOT requirements (are sealed) before transfer fo the ISA. The same scenario with more than one bag, although extremely unlikely, would have consequences that increase linearly (i.e. two bags would double the consequence). **TABLE G.3-4** summarizes the results; the spreadsheets are provided in ATTACHMENT **4**.

TABLE G.3-4: BREACH OF A FULL PACKAGE SCENARIO RESULTS

Receptor Distance	Solids Result			Total [1] CEDE (mrem)	Total [2] CEDE (mrem)
	X/Q	Dose [1] (mrem)	Dose [2] (mrem)		
30 m (HC-3)	1.77E-2	152	912	152	912
100 m (HC-2)	1.05E-3	9.1	54.6	9	55
350 m (MOI)	9.0E-4	7.8	46.8	8	47

1 Based on ARF of 2E-3, RF of 0.3 from DOE-HDBK-3010-94. See SECTION G-3.0 for explanation.
2 Based on ARF of 0.01, RF of 0.36, bounding. See SECTION G-3.0 for explanation.

G-3.5 EBA-5: Failure Of Collectors In Pneumatic Retrieval System

Ordinarily, the material collected by the Pneumatic Retrieval System is removed from the airstream using several unit operations in series. First is the Pneumatic Retrieval Collector consisting of a bag-house. The collector is followed by a cartridge filter and a filter housing, which contains a high-efficiency particulate air (HEPA) filter, two graded prefilters, and an ultra-low-penetrating air filter.

During extraction, an abrupt pressure change causes a blowout of the downstream filters and disables the Pneumatic Retrieval Collector. The extracted material flows directly to the stack and is emitted to the atmosphere. The material and associated radon are released at the design flow-rate of 1,200 ft^3/minute of air containing 0.188 lb solids/ft^3.

50 lb/ft^3 x 10 yd^3/hr x min/1200 ft^3 x 27ft3/yd3 x hr/60min = 0.188 lb/ft^3

The accident is unmitigated for 15 minutes, resulting in a release of 3,384 lbs of solids.

The initial radon release is conservatively assumed as 0.105 Ci, which is the headspace inventory based on 1,000,000 pCi/L and a volume of 3720 ft^3. In addition to the initial radon release, radon will be released from the remaining silo material at a rate of 6.26 x 10^6 pCi/minute over the next 15 minutes. The total radon release is 0.048 Ci. PCN3

The solids dispersion is modeled using the Gaussian plume model for stack releases, with stability class G and wind speed of 0.5 m/second. The radon dispersion is modeled with the Fernald radon model. **TABLE G.3-5** summarizes the scenario results; the spreadsheets are provided in ATTACHMENT 5.

TABLE G.3-5: FAILURE OF PRS COLLECTORS SCENARIO RESULTS

Receptor Distance	Solids Results			Radon Results for Initial Release		Total [1] CEDE (mrem)	Total [2] CEDE (mrem)
	X/Q	Dose [1] (mrem)	Dose [2] (mrem)	Concentration (pCi/L)	Dose (mrem)		
30 m (HC-3)	2.75E-2	167	1002	652	54.3	221	1056
100 m (HC-2)	7.8E-3	47.5	285	135	11.3	59	296
350 m (MOI)	2.24E-3	13.6	81.6	26.3	2.2	16	84

1 Based on ARF of 2E-3, RF of 0.3 from DOE-HDBK-3010-94. See SECTION G-3.0 for explanation.
2 ased on ARF of 0.01, RF of 0.36, bounding. See SECTION G-3.0 for explanation.

PCN3

G-4.0 CONCLUSIONS

Analysis of five accident scenarios produced the radiological dose estimates for workers, co-located workers, and off-site populations that are presented in **TABLES G.4-1** and **G.4-2**. Workers are defined as any personnel performing work on the Silo 3 project within the boundaries of the facility (30 m receptor). Co-located workers are defined as other workers located within the boundaries of the FCP site, but not performing work on the Silos 3 project (100 m receptor). The off-site population is defined as all non-workers who reside or are otherwise located outside the FCP site boundaries. The nearest off-site point for the MOI is approximately 350 m west of the silos. **TABLE G.4-1** provides calculated internal dose estimates for individuals located at 30, 100, and 350 m from the point of the release. The offsite dose estimate is compared to the 25 rem EG established by DOE-STD-3009-94 [Ref. 1].

TABLES G.4-1 and G.4-2 provide calculated internal dose estimates for individuals located at 30, 100, and 350 m from the point of the release. The offsite dose estimate is compared to the 25 rem EG established by DOE-STD-3009-94. TABLE G.4.1 presents the dose estimates using ARF and RF values from DOE-HDBK-3010-94 [Ref. 2], and **TABLE G.4-2** presents the dose estimates using the more bounding ARF and RF values. As expected, the bounding ARF and RF factors resulted in higher dose consequences; however both sets of dose estimates support the conclusion that the final hazard categorization of Radiological is appropriate, and no safety-class structures, systems, and components (SSC) or technical safety requirements are needed.

Of the chemicals present, five exceed the TPQ values in 40 CFR 355. Further evaluation of these five compounds determined that none exceed the on-site and off-site criteria for a "low" chemical hazard classification based on ERPG values.

TABLE G.4-1: DOSE FOR COMPARISON TO DOSE TO EMERGENCY GUIDELINE

Event	Radiological Dose CEDE at various distances (mrem)		
	30 m	100 m	350 m*
EBA-1	63	11	2
EBA-2	321	25	16
EBA-3	167	47	14
EBA-4	152	9	8
EBA-5	221	59	16

PCN3

* Nearest off-site location is 350 m, which is the MOI. DOE-STD-3009-94 Public EG is 25 rem.

TABLE G.4-2: DOSE FOR COMPARISON TO EMERGENCY GUIDELINE USING CONSERVATIVE ASSUMPTIONS

Event	Radiological Dose CEDE at various distances (mrem)		
	30 m[a]	100 m[a]	350 m[b]
EBA-1	64	11	2
EBA-2	1031	67	52
EBA-3	1002	284	82
EBA-4	912	55	47
EBA-5	1056	296	84

[a] ARF = 0.01 and RF = 0.36 for free fall spill of powders
[b] Nearest off-site location is 350 m, which is the MOI. DOE-STD-3009-94 Public EG is 25 rem.

PCN3

The conclusion that can be drawn from the analyses is that none of the accident scenarios analyzed yield consequences that would require "safety-class" controls as DOE-STD-3009-94, since the off-site EGs are not challenged.

ATTACHMENT 1
EBA-1 SPREADSHEETS

PCN3

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Accident Dose Calculations for Silo 3 Project - Solids Ground Release

References:

Dose conversion factors for inhalation are from Table 2.1, EPA-520/1-88-020 (Federal Guidance Report 11).
The DCF lung clearance class was selected for oxides.
The values for ARF and RF from DOE-HDBK-3010
Atmospheric stability D: Ref. DOE-STD-1027-92, Attachment 1, pages A-6 and A-7, for hazard categorization.

Dose Methodology:

DOSE = Q * X/Q * BR * DCF * t

where:

BR =	3.33E-04 m^3/s	Breathing Rate (a constant)
DCF =	rem/Ci	Dose Conversion Factor (varies)
t =	*exposure time*	
Q =	Airborne Source Term	

Q = MAR * DR * LPF * ARF * RF

where:

MAR =		material at risk of release
DR =	1	damage ratio
LPF =	1	leak path factor
ARF*RF=		airborne release fraction x respirable fraction

X/Q Methodology:

A Gaussian dispersion model is used to determine the dispersion loss between the release and receptor.
The methodology allows a comparison of the effects of plume meander and wake effects. (Ref. NRC Reg Guide 1.145)

Equation 1 X/Q = 1/(U *(pi * sig-y * sig-z +(A/2)))
Equation 2 X/Q = 1/(U * (3 * pi * sig-y * sig-z))
Equation 3 X/Q = 1/(U * pi * E-y * sig-z)

The higher value from equation 1 and 2 is selected. This value is compared with the value from equation 3 and the lower value is selected as the appropriate X/Q value.

A =		cross-sectional area of structure, m^2	
d =		downwind distance to evaluation point, m	User Input
		Atmospheric stability class (D, E, F, G)	
sig-y =		lateral plume spread, m	Constant
sig-z =		vertical plume spread, m	
E-y =		lateral plume spread with wake effects, m	Calculated
U =		10 meter above grade wind speed, m/sec	

Dispersion Calculations:

A =	100	m^2
pi =	3.14159	
d =	30	m
	D	
sig-y =	3.67	m
sig-z =	1.63	m
E-y =	7.35	m
U =	1	m/s

A =	100	
pi =	3.14159	
d =	100	
	D	
sig-y =	10.34	
sig-z =	4.95	
E-y =	12.39	
U =	4.5	

A =	100	
pi =	3.14159	
d =	350	
	F	
sig-y =	14.04	
sig-z =	6.30	
E-y =	56.18	
U =	1	

X/Q sec/m^3	
(Eqn.1) =	1.45E-02
(Eqn.2) =	1.77E-02
(Eqn.3) =	2.65E-02
Selected EQN =	Eqn.2
X/Q =	1.77E-02

X/Q sec/m^3	
(Eqn.1) =	1.05E-03
(Eqn.2) =	4.61E-04
(Eqn.3) =	1.15E-03
Selected EQN =	Eqn.1
X/Q =	1.05E-03

X/Q sec/m^3	
(Eqn.1) =	3.05E-03
(Eqn.2) =	1.20E-03
(Eqn.3) =	9.00E-04
Selected EQN =	Eqn.3
X/Q =	9.00E-04

Accident Dose Calculations for Solids Release

Dose Calculation:

EBA-1 Solids Release

Solids Activity (pCi/cc) equals solids activity (pCi/g) x solids density
Source Term (MAR) equals solids activity (pCi/cc) x solids volume
Airborne Source Term (Q) equals the MAR x ARF x RF x DR x LPF
The DCF is listed for each isotope.
DOSE = Q * X/Q * BR * DCF * t

Dry Solid Density 0.8 g/cm^3
wt % solids 100 g solid/g slurry
Solid Density = 0.188 lb/ft^3
Release Volume = 0.8 m^3
29.5 cf

50 lb/ft3 x 10 yd3/hr x min/1200 ft3 x 27ft3/yd3 x hr/60min = 0.188 lb/ft3

ARF =	2.00E-03	
RF =	0.3	
DR =	1.0	
LPF =	1.0	
BR =	3.33E-04	m^3/s

Distance (m)	Stability Class	Wind Spd (m/s)	X/Q (s/m3)	Time (hours)
30	D	1	1.77E-02	1
100	D	4.5	1.05E-03	1
350	F	1	9.00E-04	1

Radionuclide	Solids activity pCi/g	Solids activity pCi/cc	Source Term (MAR) pCi	Airborne Source Term (Q) pCi/s	DCF (mrem/pCi)	Dose @ 30 (mrem)	Dose @ 100 (mrem)	Dose @ 350 (mrem)
Ac-227	925	2.79E+00	2.33E+06	3.88E-01	1.29E+00	1.06E-02	6.33E-04	5.40E-04
Ac-228	406	1.22E+00	1.02E+06	1.70E-01	1.25E-04	4.51E-07	2.69E-08	2.30E-08
Bi-210	3,480	1.05E+01	8.76E+06	1.46E+00	1.96E-04	6.06E-06	3.62E-07	3.09E-07
Fr-223	13	3.92E-02	3.27E+04	5.46E-03	6.22E-06	7.19E-10	4.29E-11	3.66E-11
Pa-231	627	1.89E+00	1.58E+06	2.63E-01	8.58E-01	4.78E-03	2.85E-04	2.43E-04
Pa-234	2	6.03E-03	5.04E+03	8.39E-04	8.14E-07	1.45E-11	8.63E-13	7.37E-13
Pb-210	3,480	1.05E+01	8.76E+06	1.46E+00	1.36E-02	4.21E-04	2.51E-05	2.14E-05
Po-210	3,480	1.05E+01	8.76E+06	1.46E+00	8.58E-03	2.65E-04	1.58E-05	1.35E-05
Ra-223	925	2.79E+00	2.33E+06	3.88E-01	7.84E-03	6.45E-05	3.85E-06	3.28E-06
Ra-224	367	1.11E+00	9.24E+05	1.54E-01	3.16E-03	1.03E-05	6.15E-07	5.25E-07
Ra-226	3,870	1.17E+01	9.74E+06	1.62E+00	1.40E-01	4.82E-03	2.87E-04	2.45E-04
Ra-228	406	1.22E+00	1.02E+06	1.70E-01	4.77E-03	1.72E-05	1.03E-06	8.77E-07
Th-227	925	2.79E+00	2.33E+06	3.88E-01	1.62E-02	1.33E-04	7.95E-06	6.78E-06
Th-228	747	2.25E+00	1.88E+06	3.13E-01	3.42E-01	2.27E-03	1.36E-04	1.16E-04
Th-230	60,200	1.81E+02	1.52E+08	2.53E+01	2.62E-01	1.40E-01	8.37E-03	7.14E-03
Th-231	117	3.53E-01	2.95E+05	4.91E-02	8.77E-07	9.12E-10	5.44E-11	4.64E-11
Th-232	842	2.54E+00	2.12E+06	3.53E-01	1.15E+00	8.61E-03	5.14E-04	4.38E-04
Th-234	1,780	5.36E+00	4.48E+06	7.47E-01	3.50E-05	5.54E-07	3.30E-08	2.82E-08
U-234	1,730	5.21E+00	4.36E+06	7.26E-01	1.32E-01	2.03E-03	1.21E-04	1.03E-04
U-235/236	117	3.53E-01	2.95E+05	4.91E-02	1.23E-01	1.28E-04	7.63E-06	6.51E-06
U-238	1,780	5.36E+00	4.48E+06	7.47E-01	1.18E-01	1.87E-03	1.11E-04	9.51E-05
TOTAL	8.62E+04	2.60E+02	2.17E+08	3.62E+01	4.47E+00	**1.76E-01**	**1.05E-02**	**8.97E-03**

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Silo 3 Project
EBA-1 Hose Rupture - Instantaneous Radon Release

Spreadsheet EBA 1 Radon Inst

FERNALD RADON MODEL

$\ln C = A_0 + A_1\ln(Q) + A_2DW + A_3XW + A_4\ln(u_s) + A_5\ln(C_{lag})$

Where:
- C = concentration (pCi/L)
- Q = uniform emissions rate (uCi/sec)
- DW = $\ln(x^2)$ = downwind dilution term
- XW = $(y/x)^2$ = crosswind dilution term
- u_s = the mean wind speed (m/s)
- x = the downwind distance (m)
- y = the crosswind distance (m)

Coefficients		Inputs			
A0	8.1624	Q =	2.92E+01	uCi/sec	0.105 Ci/hr
A1	1.0158	Wind Speed	1.8	m/s	
A2	-0.6537	y (m) =	0		
A3	-0.9789	x (m)	30		
A4	-1.1262	C lag =	0	pCi/L	
A5	N/A				

Result: C = 6.52E+02 pCi/L @ 30 m.

Dose Conversion:

The ^{222}Rn DAC = 3×10^{-8} uCi/mL, resulting in 5 rem, for 2000 hrs exposure (Ref. 10 CFR 835, Appendix A)
The ALI for ^{222}Rn is 4 WLM. 4 WLM = 5 rem, 1 WLM = 1.25 rem.

Approach 1

WLM =	CFT / KN	C =	6.52E+02	pCi/L
		Equilibrium Factor (F) =	1	
		Time =	1	hr
WLM =	3.84E-02	K =	17000	pCi/L /WL hr/mo
Dose =	4.79E-02 rem	N =	1	
		1 WLM =	1.25	rem

Approach 2

# of DAC =	C/DAC	C =	6.52E+02	pCi/L
# of DAC	2.17E+01	1 DAC =	3.00E-08	uCi/mL
Dose =	# DAC*F*DF*T	1 DAC =	30	pCi/L
Dose =	5.43E-02 rem	Equilibrium Factor (F) =	1	
		DAC DF =	2.5	mrem/hr
		Time =	1	hr

x (m)	Wind Speed (m/s)	C (pCi/L)	X/Q	#DAC	Ingrowth Time (min)	F equil	Time (hr)	Dose (mrem)
30	1.8	6.52E+02	2.24E-02	2.17E+01	N/A	1	1	5.43E+01
100	1.8	1.35E+02	4.63E-03	4.50E+00	N/A	1	1	1.13E+01
350	1.8	2.63E+01	9.00E-04	8.75E-01	N/A	1	1	2.19E+00

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Silo 3 Project
EBA-1 Hose Rupture - Radon Flux

Spreadsheet EBA 1 Radon Flux

FERNALD RADON MODEL

$\ln C = A_0 + A_1\ln(Q) + A_2DW + A_3XW + A_4\ln(u_s) + A_5\ln(C_{lag})$

Where:
- C = concentration (pCi/L)
- Q = uniform emissions rate (uCi/sec)
- DW = $\ln(x^2)$ = downwind dilution term
- XW = $(y/x)^2$ = crosswind dilution term
- u_s = the mean wind speed (m/s)
- x = the downwind distance (m)
- y = the crosswind distance (m)

Coefficients		Inputs			
A0	8.1624	Q =	2.20E-01	uCi/sec	1.32E+07 pCi/min
A1	1.0158	Wind Speed	1.8	m/s	
A2	-0.6537	y (m) =	0		
A3	-0.9789	x (m)	30		
A4	-1.1262	C lag =	0	pCi/L	
A5	N/A				

Result: C = 4.55E+00 pCi/L @ 30 m.

Dose Conversion:

The ^{222}Rn DAC = 3×10^{-8} uCi/mL, resulting in 5 rem, for 2000 hrs exposure (Ref. 10 CFR 835, Appendix A)
The ALI for ^{222}Rn is 4 WLM. 4 WLM = 5 rem, 1 WLM = 1.25 rem.

Approach 1

WLM =	CFT / KN	C =	4.55E+00	pCi/L
		Equilibrium Factor (F) =	1	
		Time =	1	hr
WLM =	2.68E-04	K =	17000	pCi/L /WL hr/mo
Dose =	3.35E-04 rem	N =	1	
		1 WLM =	1.25	rem

Approach 2

# of DAC =	C/DAC	C =	4.55E+00	pCi/L
# of DAC	1.52E-01	1 DAC =	3.00E-08	uCi/mL
Dose =	# DAC*F*DF*T	1 DAC =	30	pCi/L
Dose =	3.79E-04 rem	Equilibrium Factor (F) =	1	
		DAC DF =	2.5	mrem/hr
		Time =	1	hr

x (m)	Wind Speed (m/s)	C (pCi/L)	X/Q	#DAC	Ingrowth Time (min)	F equil	Time (hr)	Dose (mrem)
30	1.8	4.55E+00	2.07E-02	1.52E-01	N/A	1	24	9.10E+00
100	1.8	9.43E-01	4.29E-03	3.14E-02	N/A	1	2	1.57E-01
350	1.8	1.83E-01	8.33E-04	6.11E-03	N/A	1	2	3.06E-02

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ATTACHMENT 2
EBA-2 SPREADSHEETS

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Accident Dose Calculations for Solids Release

Dose Calculation:

EBA-2 Solids Release

Solids Activity (pCi/cc) equals solids activity (pCi/g) x solids density
Source Term (MAR) equals solids activity (pCi/cc) x solids volume
Airborne Source Term (Q) equals the MAR x ARF x RF x DR x LPF
The DCF is listed for each isotope.
DOSE = Q * X/Q * BR * DCF * t

Dry Solid Density	0.80	g/cm^3
wt % solids	100	g solid/g slurry
Solid Density =	50.0	lb/ft^3
Solid Volume =	3900.8	m^3

5100 cy

137700 cf

ARF =	1.00E-03	
RF =	0.1	
DR =	0.75	
LPF =	0.01	
BR =	3.33E-04	m^3/s

Distance (m)	Stability Class	Wind Spd (m/s)	X/Q (s/m3)	Time (hours)
30	D	1	1.77E-02	1
100	D	4.5	1.05E-03	1
350	F	1	9.00E-04	1

Radionuclide	Solids activity pCi/g	Solids activity pCi/cc	Source Term (MAR) pCi	Airborne Source Term (Q) pCi/s	DCF (mrem/pCi)	Dose @ 30 (mrem)	Dose @ 100 (mrem)	Dose @ 350 (mrem)
Ac-227	925	7.41E+02	2.89E+12	6.02E+02	1.29E+00	1.65E+01	9.82E-01	8.38E-01
Ac-228	406	3.25E+02	1.27E+12	2.64E+02	1.25E-04	7.00E-04	4.18E-05	3.56E-05
Bi-210	3,480	2.79E+03	1.09E+13	2.27E+03	1.96E-04	9.40E-03	5.61E-04	4.79E-04
Fr-223	13	1.04E+01	4.06E+10	8.46E+00	6.22E-06	1.11E-06	6.65E-08	5.68E-08
Pa-231	627	5.02E+02	1.96E+12	4.08E+02	8.58E-01	7.42E+00	4.43E-01	3.78E-01
Pa-234	2	1.60E+00	6.25E+09	1.30E+00	8.14E-07	2.24E-08	1.34E-09	1.14E-09
Pb-210	3,480	2.79E+03	1.09E+13	2.27E+03	1.36E-02	6.53E-01	3.89E-02	3.32E-02
Po-210	3,480	2.79E+03	1.09E+13	2.27E+03	8.58E-03	4.12E-01	2.46E-02	2.10E-02
Ra-223	925	7.41E+02	2.89E+12	6.02E+02	7.84E-03	1.00E-01	5.97E-03	5.09E-03
Ra-224	367	2.94E+02	1.15E+12	2.39E+02	3.16E-03	1.60E-02	9.54E-04	8.14E-04
Ra-226	3,870	3.10E+03	1.21E+13	2.52E+03	1.40E-01	7.47E+00	4.46E-01	3.80E-01
Ra-228	406	3.25E+02	1.27E+12	2.64E+02	4.77E-03	2.67E-02	1.59E-03	1.36E-03
Th-227	925	7.41E+02	2.89E+12	6.02E+02	1.62E-02	2.07E-01	1.23E-02	1.05E-02
Th-228	747	5.98E+02	2.33E+12	4.86E+02	3.42E-01	3.52E+00	2.10E-01	1.79E-01
Th-230	60,200	4.82E+04	1.88E+14	3.92E+04	2.62E-01	2.17E+02	1.30E+01	1.11E+01
Th-231	117	9.37E+01	3.66E+11	7.62E+01	8.77E-07	1.41E-06	8.44E-08	7.20E-08
Th-232	842	6.74E+02	2.63E+12	5.48E+02	1.15E+00	1.34E+01	7.97E-01	6.80E-01
Th-234	1,780	1.43E+03	5.56E+12	1.16E+03	3.50E-05	8.59E-04	5.13E-05	4.37E-05
U-234	1,730	1.39E+03	5.41E+12	1.13E+03	1.32E-01	3.15E+00	1.88E-01	1.60E-01
U-235/236	117	9.37E+01	3.66E+11	7.62E+01	1.23E-01	1.98E-01	1.18E-02	1.01E-02
U-238	1,780	1.43E+03	5.56E+12	1.16E+03	1.18E-01	2.90E+00	1.73E-01	1.47E-01
TOTAL	8.62E+04	6.91E+04	2.69E+14	5.61E+04	4.47E+00	**2.73E+02**	**1.63E+01**	**1.39E+01**

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Silo 3 Project
EBA-2 Silo Failure - Instantaneous Radon Release

Spreadsheet EBA 2 Radon Inst

FERNALD RADON MODEL

$\ln C = A_0 + A_1\ln(Q) + A_2DW + A_3XW + A_4\ln(u_s) + A_5\ln(C_{lag})$

Where:
- C = concentration (pCi/L)
- Q = uniform emissions rate (uCi/sec)
- DW = $\ln(x^2)$ = downwind dilution term
- XW = $(y/x)^2$ = crosswind dilution term
- u_s = the mean wind speed (m/s)
- x = the downwind distance (m)
- y = the crosswind distance (m)

Coefficients	
A0	8.1624
A1	1.0158
A2	-0.6537
A3	-0.9789
A4	-1.1262
A5	N/A

Inputs			
Q =	2.19E+01	uCi/sec	0.079 Ci/hr
Wind Speed	1.8	m/s	
y (m) =	0		
x (m)	30		
C lag =	0	pCi/L	

Result: C = 4.88E+02 pCi/L @ 30 m.

Dose Conversion:

The ^{222}Rn DAC = 3×10^{-8} uCi/mL, resulting in 5 rem, for 2000 hrs exposure (Ref. 10 CFR 835, Appendix A)
The ALI for ^{222}Rn is 4 WLM. 4 WLM = 5 rem, 1 WLM = 1.25 rem.

Approach 1

WLM = CFT / KN

WLM = 2.87E-02

Dose = 3.59E-02 rem

C =	4.88E+02	pCi/L
Equilibrium Factor (F) =	1	
Time =	1	hr
K =	17000	pCi/L /WL hr/mo
N =	1	
1 WLM =	1.25	rem

Approach 2

# of DAC =	C/DAC
# of DAC	1.63E+01
Dose =	# DAC*F*DF*T
Dose =	4.07E-02 rem

C =	4.88E+02	pCi/L
1 DAC =	3.00E-08	uCi/mL
1 DAC =	30	pCi/L
Equilibrium Factor (F) =	1	
DAC DF =	2.5	mrem/hr
Time =	1	hr

x (m)	Wind Speed (m/s)	C (pCi/L)	X/Q	#DAC	Ingrowth Time (min)	F equil	Time (hr)	Dose (mrem)
30	1.8	4.88E+02	2.23E-02	1.63E+01	N/A	1	1	4.07E+01
100	1.8	1.01E+02	4.61E-03	3.37E+00	N/A	1	1	8.43E+00
350	1.8	1.97E+01	8.96E-04	6.56E-01	N/A	1	1	1.64E+00

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Silo 3 Project
EBA-2 Silo Failure - Radon Flux

Spreadsheet EBA 2 Radon Flux

FERNALD RADON MODEL

$\ln C = A_0 + A_1 \ln(Q) + A_2 DW + A_3 XW + A_4 \ln(u_s) + A_5 \ln(C_{lag})$

Where:
- C = concentration (pCi/L)
- Q = uniform emissions rate (uCi/sec)
- DW = $\ln(x^2)$ = downwind dilution term
- XW = $(y/x)^2$ = crosswind dilution term
- u_s = the mean wind speed (m/s)
- x = the downwind distance (m)
- y = the crosswind distance (m)

Coefficients	
A0	8.1624
A1	1.0158
A2	-0.6537
A3	-0.9789
A4	-1.1262
A5	N/A

Inputs			
Q =	1.65E-01	uCi/sec	9.90E+06 pCi/min
Wind Speed	1.8	m/s	
y (m) =	0		
x (m)	30		
C lag =	0	pCi/L	

Result: C = 3.40E+00 pCi/L @ 30 m.

Dose Conversion:

The ^{222}Rn DAC = 3×10^{-8} uCi/mL, resulting in 5 rem, for 2000 hrs exposure (Ref. 10 CFR 835, Appendix A)
The ALI for ^{222}Rn is 4 WLM. 4 WLM = 5 rem, 1 WLM = 1.25 rem.

Approach 1

WLM =	CFT / KN	C =	3.40E+00	pCi/L
		Equilibrium Factor (F) =	1	
		Time =	1	hr
WLM =	2.00E-04	K =	17000	pCi/L /WL hr/mo
Dose =	2.50E-04 rem	N =	1	
		1 WLM =	1.25	rem

Approach 2

# of DAC =	C/DAC	C =	3.40E+00	pCi/L
# of DAC	1.13E-01	1 DAC =	3.00E-08	uCi/mL
Dose =	# DAC*F*DF*T	1 DAC =	30	pCi/L
Dose =	2.83E-04 rem	Equilibrium Factor (F) =	1	
		DAC DF =	2.5	mrem/hr
		Time =	1	hr

x (m)	Wind Speed (m/s)	C (pCi/L)	X/Q	#DAC	Ingrowth Time (min)	F equil	Time (hr)	Dose (mrem)
30	1.8	3.40E+00	2.06E-02	1.13E-01	N/A	1	24	6.80E+00
100	1.8	7.04E-01	4.27E-03	2.35E-02	N/A	1	2	1.17E-01
350	1.8	1.37E-01	8.30E-04	4.56E-03	N/A	1	2	2.28E-02

Accident Dose Calculations for Chemical Release for Silo Failure During Wall Cutting

EBA-2 Chemical Release

Dose Calculation:

The MAR is 3825 cy (75% of 5100 cy at time of wall failure during cutting)
Chemical inventory equals concentration x solids mass
Concentration = (Compound mass x ARF x RF x DR x LPF x X/Q) / t

MAR =	3825 cy
Solid Density =	50 lb/ft^3
Solid Mass =	4.4.E+06 lb
Solid Mass =	2.0.E+06 kg

ARF =	1.00E-03	
RF =	0.1	
DR =	1.0	
LPF =	0.01	

Distance (m)	Stability Class	Wind Spd (m/s)	X/Q (s/m3)	Time (hours)
100	F	1	9.08E-03	1
350	F	1	9.00E-04	1

Chemical	Concentration (mg/kg)	Chemical Inventory (mg)	Chemical Compound	Compound Mass (mg)	Concentration @ 100 (mg/m3)	Concentration @ 350 (mg/m3)
Arsenic	7.27E+03	1.70E+10	Arsenic Pentoxide	2.62E+10	6.62E-02	6.56E-03
Cadmium	3.43E+02	8.04E+08	Cadmium Oxide	9.17E+08	2.31E-03	2.29E-04
Mercury	1.74E+03	4.08E+09	Mercuric Sulfate	4.41E+09	1.11E-02	1.10E
Thallium	1.63E+02	3.82E+08	Thallium Sulfate	5.62E+08	1.42E-03	1.40E-04
Vanadium	1.09E+04	2.56E+10	Vanadium Pentoxide	4.60E+10	1.16E-01	1.15E-02

Accident Dose Calculations for Ferrous Sulfate Release

MAR =	4500 gal
Solid Density =	1.9 g/ml
Solid Mass =	3.2.E+04 kg

ARF =	5.00E-05	
RF =	0.8	
DR =	1.0	
LPF =	1.00	

Chemical	Concentration mg/kg	Chemical Inventory mg		Concentration @ 100 (mg/m3)	Concentration @ 350 (mg/m3)
Ferrous Sulfate	1.00E+06	3.24E+10		3.26E+00	3.24E-01

ATTACHMENT 5
EBA-5 SPREADSHEETS

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Accident Dose Calculations for Solids Release

Dose Calculation:

EBA-5 Solids Stack Release

Solids Activity (pCi/cc) equals solids activity (pCi/g) x solids density
Source Term (MAR) equals solids activity (pCi/cc) x solids volume
Airborne Source Term (Q) equals the MAR x ARF x RF x DR x LPF
The DCF is listed for each isotope.
DOSE = Q * X/Q * BR * DCF * t

Solid Density = 0.188 lb/ft^3
Release Volume = 509.9 m^3
18000 cf

ARF =	2.00E-03	
RF =	0.3	
DR =	1.0	
LPF =	1.0	
BR =	3.33E-04	m^3/s

Distance (m)	Stability Class	Wind Spd (m/s)	X/Q (s/m3)	Time (hours)
30	G	0.5	2.75E-02	1
100	G	0.5	7.80E-03	1
350	G	0.5	2.24E-03	1

Radionuclide	Solids activity pCi/g	Solids activity pCi/cc	Source Term (MAR) pCi	Airborne Source Term (Q) pCi/s	DCF (mrem/pCi)	Dose @ 30 (mrem)	Dose @ 100 (mrem)	Dose @ 350 (mrem)
Ac-227	925	2.79E+00	1.42E+09	2.37E+02	1.29E+00	1.01E+01	2.86E+00	8.19E-01
Ac-228	406	1.22E+00	6.24E+08	1.04E+02	1.25E-04	4.28E-04	1.22E-04	3.48E-05
Bi-210	3,480	1.05E+01	5.35E+09	8.91E+02	1.96E-04	5.75E-03	1.63E-03	4.68E-04
Fr-223	13	3.92E-02	2.00E+07	3.33E+00	6.22E-06	6.82E-07	1.94E-07	5.55E-08
Pa-231	627	1.89E+00	9.63E+08	1.61E+02	8.58E-01	4.54E+00	1.29E+00	3.69E-01
Pa-234	2	6.03E-03	3.07E+06	5.12E-01	8.14E-07	1.37E-08	3.90E-09	1.12E-09
Pb-210	3,480	1.05E+01	5.35E+09	8.91E+02	1.36E-02	3.99E-01	1.13E-01	3.25E-02
Po-210	3,480	1.05E+01	5.35E+09	8.91E+02	8.58E-03	2.52E-01	7.15E-02	2.05E-02
Ra-223	925	2.79E+00	1.42E+09	2.37E+02	7.84E-03	6.12E-02	1.74E-02	4.98E-03
Ra-224	367	1.11E+00	5.64E+08	9.40E+01	3.16E-03	9.78E-03	2.78E-03	7.96E-04
Ra-226	3,870	1.17E+01	5.95E+09	9.91E+02	1.40E-01	4.57E+00	1.30E+00	3.72E-01
Ra-228	406	1.22E+00	6.24E+08	1.04E+02	4.77E-03	1.63E-02	4.64E-03	1.33E-03
Th-227	925	2.79E+00	1.42E+09	2.37E+02	1.62E-02	1.26E-01	3.59E-02	1.03E-02
Th-228	747	2.25E+00	1.15E+09	1.91E+02	3.42E-01	2.15E+00	6.12E-01	1.75E-01
Th-230	60,200	1.81E+02	9.25E+10	1.54E+04	2.62E-01	1.33E+02	3.78E+01	1.08E+01
Th-231	117	3.53E-01	1.80E+08	3.00E+01	8.77E-07	8.65E-07	2.46E-07	7.04E-08
Th-232	842	2.54E+00	1.29E+09	2.16E+02	1.15E+00	8.17E+00	2.32E+00	6.65E-01
Th-234	1,780	5.36E+00	2.73E+09	4.56E+02	3.50E-05	5.25E-04	1.49E-04	4.28E-05
U-234	1,730	5.21E+00	2.66E+09	4.43E+02	1.32E-01	1.93E+00	5.47E-01	1.57E-01
U-235/236	117	3.53E-01	1.80E+08	3.00E+01	1.23E-01	1.21E-01	3.45E-02	9.88E-03
U-238	1,780	5.36E+00	2.73E+09	4.56E+02	1.18E-01	1.77E+00	5.03E-01	1.44E-01
TOTAL	8.62E+04	2.60E+02	1.32E+11	2.21E+04	4.47E+00	**1.67E+02**	**4.75E+01**	**1.36E+01**

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Silo 3 Project
EBA-5 Collector Failure - Instantaneous Radon Release

Spreadsheet EBA 5 Radon Inst

FERNALD RADON MODEL

$\ln C = A_0 + A_1\ln(Q) + A_2DW + A_3XW + A_4\ln(u_s) + A_5\ln(C_{lag})$

Where:
- C = concentration (pCi/L)
- Q = uniform emissions rate (uCi/sec)
- DW = $\ln(x^2)$ = downwind dilution term
- XW = $(y/x)^2$ = crosswind dilution term
- u_s = the mean wind speed (m/s)
- x = the downwind distance (m)
- y = the crosswind distance (m)

Coefficients	
A0	8.1624
A1	1.0158
A2	-0.6537
A3	-0.9789
A4	-1.1262
A5	N/A

Inputs			
Q =	2.92E+01	uCi/sec	0.105 Ci/hr
Wind Speed	1.8	m/s	
y (m) =	0		
x (m)	30		
C lag =	0	pCi/L	

Result: C = 6.52E+02 pCi/L @ 30 m.

Dose Conversion:

The ^{222}Rn DAC = 3×10^{-8} uCi/mL, resulting in 5 rem, for 2000 hrs exposure (Ref. 10 CFR 835, Appendix A)
The ALI for ^{222}Rn is 4 WLM. 4 WLM = 5 rem, 1 WLM = 1.25 rem.

Approach 1

WLM =	CFT / KN	C =	6.52E+02	pCi/L
		Equilibrium Factor (F) =	1	
		Time =	1	hr
WLM =	3.84E-02	K =	17000	pCi/L /WL hr/mo
Dose =	4.79E-02 rem	N =	1	
		1 WLM =	1.25	rem

Approach 2

# of DAC =	C/DAC	C =	6.52E+02	pCi/L
# of DAC	2.17E+01	1 DAC =	3.00E-08	uCi/mL
Dose =	# DAC*F*DF*T	1 DAC =	30	pCi/L
Dose =	5.43E-02 rem	Equilibrium Factor (F) =	1	
		DAC DF =	2.5	mrem/hr
		Time =	1	hr

x (m)	Wind Speed (m/s)	C (pCi/L)	X/Q	#DAC	Ingrowth Time (min)	F equil	Time (hr)	Dose (mrem)
30	1.8	6.52E+02	2.24E-02	2.17E+01	N/A	1	1	5.43E+01
100	1.8	1.35E+02	4.63E-03	4.50E+00	N/A	1	1	1.13E+01
350	1.8	2.63E+01	9.00E-04	8.75E-01	N/A	1	1	2.19E+00