JACOBS

APPENDIX D

ALARA ANALYSIS

Document No. 40430-PL-0007
August 1, 2003
Revision 2

FERNALD
Environmental Management Project

Prepared Under DOE

Contract No. DE-AC24-01OH20115

Revision	Prepared by:	Reviewed by:	Approved by:	Date:	Pages Affected:
0	KH	KE	BL	3/21/02	All
1	SL	KE	KE	3/14/03	All
2	Scott LaBry	Kenneth J. Eger	Kenneth J. Eger	8/01/03	All

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Revision Sheet

Revision	Date	Pages Affected	Reason for Revision
0	3-21-02	All	Issued for internal review.
1	3-14-03	All	Issued for development of NHASP with current design.
2	8-01-03	All	Resolution of comments.

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ATTACHMENTS

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Attachment 2: Application of ALARA Features

Attachment 3. Silo 3 Dose Rate Calculation

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ACRONYMS

ACL	administrative control level
ALARA	as low as reasonably achievable
ALI	annual limit on intake
Anti-C	Anti-contamination clothing
CEDE	committed effective dose equivalent
CFR	*Code of Federal Regulations*
CPC	constituent of primary concern
DAC	derived air concentration
DOE	U.S. Department of Energy
DRD	direct reading dosimeter
EDE	effective dose equivalent
FCP	Fernald Closure Project
FMPC	Feed Materials Production Center
HEPA	high-efficiency particulate air
HVAC	Heating, ventilation, and air conditioning
ICRP	International Commission on Radiological Protection
OU	operable unit
PPE	personal protective equipment
PSHPP	project-specific health physics plan
RAZ	radiation access zones
RC	radiological control (dept.)
RPP	radiological protection program
RWP	radiological work permit
TEDE	total effective dose equivalent
TLD	thermoluminescent dosimeter
TRU	Transuranic
UCL	upper confidence level
ULPA	Ultra-low penetrating air
WL	working level

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EXECUTIVE SUMMARY

This appendix reflects the results of extensive analyses to minimize dose while optimizing the design and operation of the Silo 3 facility. The purpose of this analysis is to assure that the Silo 3 Project tasks have been designed and specified in a manner that will keep worker and co-located worker radiation doses ALARA. Silo 3 is a phased project consisting of construction, waste retrieval, and finally decommissioning of the retrieval facilities. This analysis does not address the radiation exposure associated with the construction or decommissioning.

Each task where significant radiation exposure is expected has been described and analyzed to determine or estimate the number of workers involved, whether personal protective equipment and clothing is required, the time required to complete the task, the total number of times the task will be performed (frequency) during the Silo 3 Project, and the total person-hours of exposure in areas with radiation dose rates above background. The radiation dose rates in each of these areas will be reflected in Radiation Zone Drawings. The dose rate estimates were made on the basis of the Silo 3 final design. Collective dose estimates were calculated for each task based on the current data, and these estimates were summed for operations, maintenance, and other routine tasks. However, whenever there was uncertainty in estimates, assumptions were made that would conservatively overestimate the radiation doses. Finally, the total collective dose estimate or the collective dose budget for the Silo 3 Project was calculated to be approximately 6.9 person-rem. The results of this ALARA analysis can be summarized as follows:

- The collective operations dose during the entire retrieval and packaging evolution is conservatively estimated to be 6.25 person-rem.

- The collective maintenance dose during the retrieval and packaging evolution is conservatively estimated to be 0.66 person-rem.

Because the estimated total collective dose for the Silo 3 Project exceeds 2 person-rem, the ALARA trigger level used at Fernald, a formal ALARA Committee Review will be required. Furthermore, this analysis shows that expected radiation doses are large enough that engineering and operational controls will be needed to keep radiation doses to workers ALARA.

The scope of this ALARA Analysis is focused on support of the development of the final design. The analysis includes equipment installation and other operations and maintenance functions generated as the design matured. Details of the latest design have been incorporated as much as possible into this ALARA Analysis. Further detail required to clearly define operation and maintenance of equipment is generally contained in vendor's operating and maintenance manuals, which are not yet available. Thus, conservative assumptions about the frequency, duration, and complexity of operations and maintenance have been made and used in this analysis. As the construction proceeds and

vendor manuals become available, this ALARA Analysis will be further refined to more clearly define operations and maintenance functions and/or to further reduce the degree of conservatism in the assumptions.

D-1.0 INTRODUCTION

The As Low As Reasonably Achievable (ALARA) Analysis addresses radiological controls for the operational, and facility shutdown phases of the Silo 3 Project. The purpose of this analysis is to ensure that the Silo 3 Project tasks have been designed and specified in a manner that will keep project workers and collocated worker radiation doses ALARA. Alternatives for dose reduction were assessed and optimum controls were selected.

D-1.1 SCOPE

The scope of this ALARA Analysis is limited to the Silo 3 Project area within Operable Unit (OU) 4. The radiation protection requirements discussed herein, however, apply to all operations at the Fernald Closure Project (FCP). The scope of existing or expected radiological conditions is also limited to occupational exposures of Silo 3 Project workers and collocated workers to ionizing radiation. Environmental releases of radon and any radiation exposure to the off-site population will be addressed in an ALARA Evaluation (Ref. 1). This Occupational ALARA Analysis addresses radiation protection measures required for equipment, engineering design, and packaging of Silo 3 Project material.

Each task has been described and analyzed to determine or estimate the number of workers involved, the require personal protection equipment (PPE), the time required to complete the task, and the total number of person-hours of exposure in areas with radiation dose rates above background levels. The radiation dose rates in each of these areas were estimated in the Radiation Zone Drawings and incorporated by reference in this ALARA Analysis. Refinements to the dose rate estimates will be based on the final design information, when available. From these data, collective dose estimates were calculated for each task, and these estimates were summed for operation, maintenance and inspection, and other routine tasks. Finally, the total collective dose estimate or the collective dose budget for the project was calculated.

D-1.2 BACKGROUND INFORMATION

FCP, formerly known as the Feed Materials Production Center (FMPC), processed three basic classes of materials:

- Pitchblende ores as they were mined and shipped to the FMPC
- Uranium ore concentrates that had already been refined to some degree at the mill site
- Uranium process residues generated from FMPC metal production operations.

Uranium-bearing ores, as they are mined, contain not only uranium, but also equilibrium concentrations of uranium progeny (i.e., the isotopes of other elements formed through the sequential radioactive decay chains that begin with ^{235}U and ^{238}U). These progeny,

which include radium, are mostly removed either in a preliminary milling process or in the refining process (if the ores are not preprocessed through a mill).

When the FMPC processed uranium ore concentrates that had been preprocessed through a uranium mill, a significant portion of the ^{226}Ra and the gamma-emitting progeny had been removed and were thus termed "cold" feed material. However, some of the thorium progeny of uranium (i.e., ^{230}Th) remained within the uranium concentrates due to the inefficiency of the mill in removing this metal, so even though the materials are termed "cold," they are radioactive.

Following solvent extraction processing for uranium removal, the residual metals and other impurities that were also present in the ore concentrates were subjected to further processing for nitrate recovery and to remove slightly soluble organic compounds present from the solvents used in extraction. After a series of filtration steps, the raffinate stream and the filtrate were fed into a series of evaporators, reducing the volume by 90 percent. The concentrates from the evaporation process were transferred to either a spray calciner or a rotary drum drier, depending on the years of operation, to remove the remaining liquids. A rotary calciner was used to convert the metal nitrates in the concentrates to oxides. The spray calciner operated at a temperature of 510°C (950°F), and the rotary calciner operated at a temperature of 650°C (1200°F) to 820°C (1500°F). After calcining, the finely powdered, dried metal oxides were pneumatically transferred by pipeline to Silo 3. No material, except samples, has been removed from Silo 3 since filling operations ceased in 1957.

D-1.3 PROCESS DESCRIPTION

The Silo 3 remediation process consists of two basic parts: retrieval and packaging. When all of the material is removed from Silo 3, the equipment and structures will be dismantled, decontaminated, and dispositioned. The process flow diagram is shown in Figure D-1. The facility layout is shown in Figure D-2.

Retrieval is accomplished in two ways. The pneumatic retrieval system is contained in a steel beam/metal-sided building adjacent to the silo. The pneumatic wands access the silo material through the silo dome, through existing manways. The mechanical retrieval system is housed in an adjacent robust concrete structure. Some material handling and packaging equipment is shared with the pneumatic retrieval system. The silo itself is enclosed in a fabric structure, which provides protection from the elements to personnel operating the pneumatic retrieval system and some measure of containment should any of the waste material escape from the silo.

First, material will be removed from the top of the silo using a vacuum wand through a man-way in the top of the silo. The entrained material will be transported to a pneumatic retrieval collector. A baghouse in series with a cartridge filter will collect any material remaining airborne, where a filter assembly (consisting of a roughing filter, a high-efficiency particulate air (HEPA) filter, and an ultra-low penetrating air (ULPA) filter) will

reduce the amount of particulate material released to the atmosphere. Screw conveyors and rotary feeders will transfer the waste to one of two packaging stations where the waste will be dropped into a lined, soft-sided container. The 96 ft^3 bag is a sturdy, soft-sided container, which meets the transportation requirements for an IP-2 package. The liner, of polyethylene or similar polymer, will be filled using a "bag-out" procedure to ensure that none of the powdered waste is released to the adjacent work area.

The silo 3 material will be conditioned by the addition of a binding agent for dust control and stabilization. The binding agent is a ferrous sulfate and sodium lignosulfonate solution that will be sprayed into the fill chutes. Each of the two Package Loading Stands is a semiautomated system with loading spouts, loading stands, thumper tables, weighing scales, and motorized roller conveyors for transporting the filled bags away from the station.

When sufficient material has been removed from the silo to expose the inside of the silo wall, a second process will be used to retrieve the remaining waste. An opening will be cut into the exposed wall of the silo to enable the use of a mechanical excavator. The remotely operated excavator will enter the silo and dig into the waste pile. Removed material will be placed in a below-grade bin and moved from there to the packaging stations by four conveyors. Three of the conveyors are screw-type, and one is a pocketed sidewall belt conveyor. This conveyor has a mating belt that covers the material during transfer. The last of the screw-type conveyors is common to the pneumatic retrieval system.

In both cases, i.e., pneumatic and mechanical retrieval, the end product is an IP-2-approved soft-sided container or bulk bag containing a sealed plastic bag full of Silo 3 material. The packages will be surveyed, decontaminated if necessary, and transferred to a cargo container. When a container is full, i.e., approximately 7 of the bags, it will be removed and staged for final shipment to off-site.

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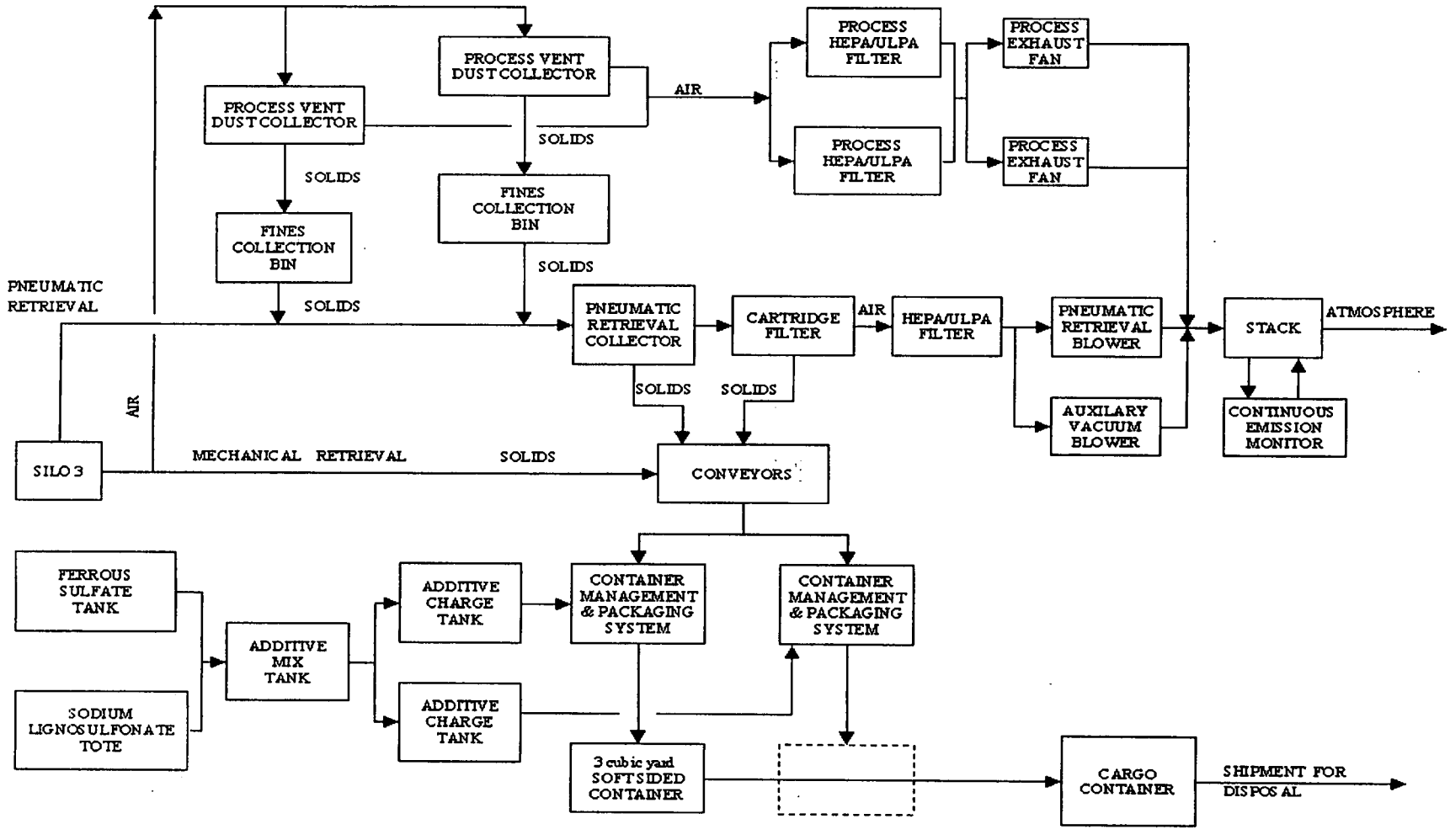

Figure D-1. Silo 3 Process Flow Diagram

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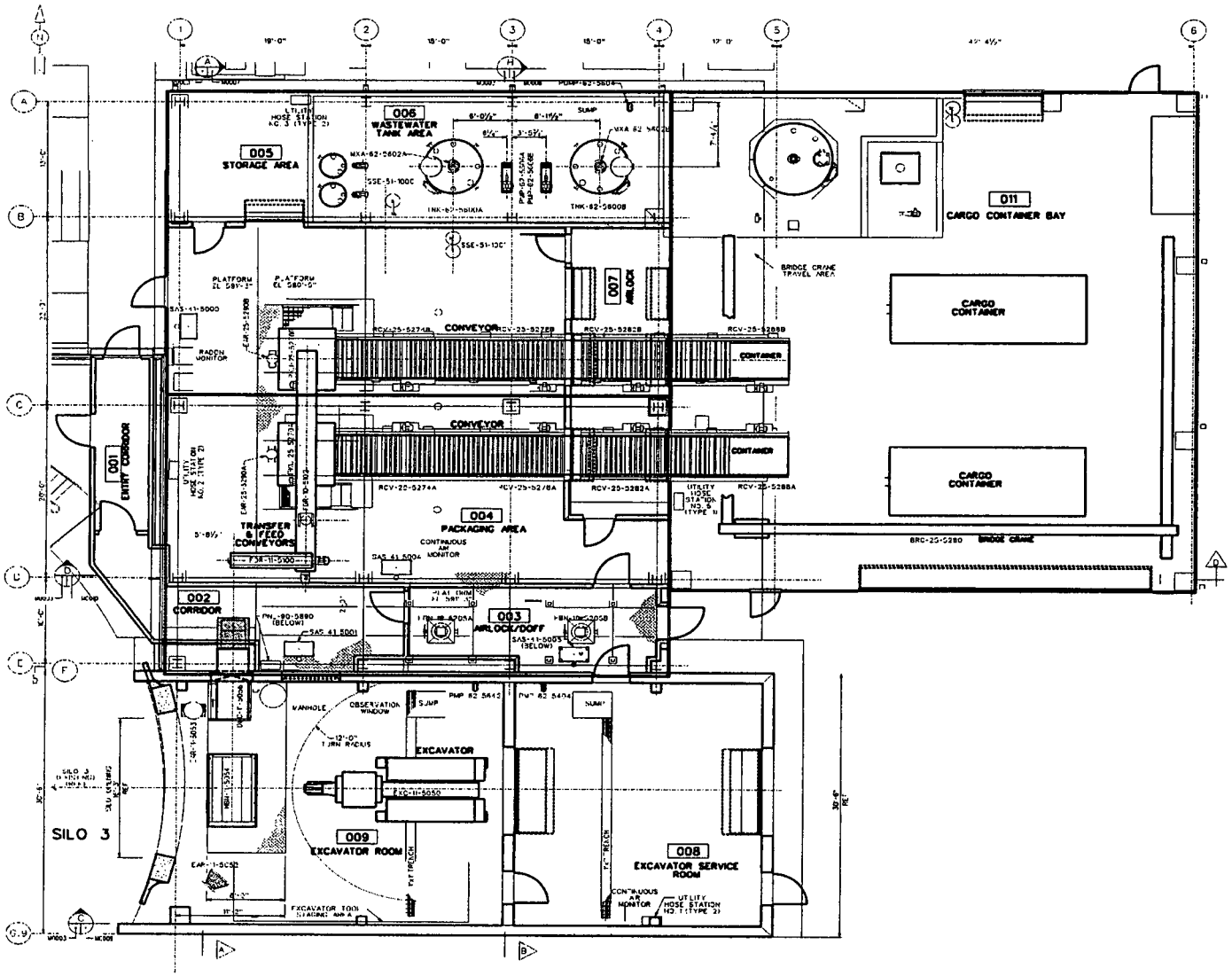

Figure D-2. Silo 3 Process Building Layout

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D-2.0 GENERAL REQUIREMENTS

The radiological requirements for design ensure that all functions and activities are performed to maintain exposure ALARA. The ALARA philosophy requires any exposure to ionizing radiation by general employees or the public be minimized to the extent that social, technical, economic, practical, and public policy considerations allow. Project management is committed to keeping exposure ALARA through engineering (design), management (administrative controls), and supervision (procedures). This principle is implemented by six key elements (Ref. Attachment 1), which are:

- Reduce the time spent within radiological areas (i.e., remote excavation and excavator service room)
- Reduce the source(s) of radioactivity (i.e., ventilation filters, exhaust stack)
- Increase the distance from sources of radioactivity (i.e., remote excavation)
- Provide containment of, and shielding from, sources of radioactivity (i.e., enclosed conveyors, retrieval bin hood)
- Minimize internal exposures through the use of confinement and ventilation (i.e., packaging bag-out system)
- Reduce the labor requirements for operations in radiological areas (i.e., vacuum wand management system).

These six key elements are weighed against economic factors, technical feasibility, practicality, public policy, and social needs in implementing the best design.

Management is committed to reducing radiation exposures by applying the ALARA process to design, construction, operation, maintenance, and demobilization of the project. These exposures shall be maintained as far below the DOE occupational exposure limits as social, technical, economic, practical, and public policy considerations permit.

Three approaches are incorporated in the designing, commissioning, operating, maintenance, and decommissioning phases of the Silo 3 Project facility:

- Facility design or modifications and radiation-exposure-causing activities are systematically evaluated with radiological and safety considerations as the highest priorities to keep exposures to individuals and releases to the environment ALARA.
- Personnel are trained in ALARA principles and practices. Additionally, personnel shall adhere to radiological control requirements during operations, maintenance, and support activities to minimize radiation exposures.

- Personnel and facilities at the Silo 3 Project are monitored for radiation hazards. This monitoring is documented to verify that exposures are ALARA.

D-2.1 DESIGN CRITERIA

ALARA considerations are an integral part of the design process. Qualitative and quantitative analyses are performed on proposed design features to choose an engineered and/or administrative control that will provide a radiological work environment that is ALARA. To capture the ALARA analyses that were performed as part of the design process, a checklist was used for each Silo 3 Project area. The radiation exposure associated with each system and the dose reduction options were considered. Attachment 1 identifies the features designed to keep exposures ALARA and the associated rationale. Attachment 2 shows where the Silo 3 ALARA features apply.

D-2.1.1 External Exposure and Shielding Criteria

The criteria for the Silo 3 Project design will be in accordance with the requirements of 10 CFR 835.1002(c), Facility Design and Modifications (Ref. 2). Specifically, the design objective for controlling personnel exposure from external sources of radiation in areas of continuous occupancy (2,000 hours per year) shall be to maintain dose rates below an average of 0.5 mrem per hour and as far below this limit as is reasonably achievable. Therefore, the continuous occupancy design objective for the gamma radiation exposure rate is established at 0.5 mR/hour. Areas with exposure rates in excess of the 0.4 mR/hour objective are intended to be controlled through administrative and work improvement processes, ensuring personnel exposures are minimized. The Silos 3 Project has adopted a more restrictive dose objective of 0.4 mR/hour to allow for an offset of the expected annual dose from airborne radon. An exposure rate of 0.4 mR/hour is assumed equivalent to a dose rate of 0.4 mrem/hour.

D-2.1.2 Control of Airborne Radioactive Materials

The criteria for new facility design shall be in accordance with the requirements of 10 CFR 835.1002(b), Facility Design and Modifications (Ref. 2). Specifically, the design objective of confinement and ventilation for the control of airborne radioactive material shall be, under normal conditions, to avoid releases to the workplace atmosphere and in any situation, to control the inhalation of such material by workers to levels that are ALARA. Confinement and ventilation shall normally be used.

The design has been reviewed to ensure that concentrations of radioactive materials, especially radon, in occupied areas during normal operating conditions are ALARA. The airborne concentrations are not expected to exceed 10 percent of the derived air concentration (DAC) listed in 10 CFR 835, Appendix A. Therefore, respirators would not normally be required. However, alpha Continuous Air Monitors will be used to provide an alert and a respiratory protection program will be in place.

Design features have been incorporated to prevent the buildup and spread of contamination. Surfaces from which radioactive material can be resuspended are

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minimized (e.g., scaffolding, open rafters, hanging light fixtures, cable runs). The ventilation system and facility layout design will ensure that:

- Appropriate pressure differential exists between the areas of high contamination and the outside to prevent the spread of contamination. It is required that the isolation area (work area) have a pressure difference of 0.1 to 0.5 in. water gauge relative to its adjacent area.

- The potentially contaminated airflow is directed away from the worker's breathing zone and is designed to minimize resuspension of contamination. Room air may be recirculated if adequate HEPA filtration and monitoring are provided. Recirculation from an area of higher contamination to an area of lower contamination is prohibited.

- The capture velocity of a hood, hose, or plenum used to capture and redirect suspended contamination is equal to or greater than 150 ft/minute as measured at the source.

- Potentially radioactive particulate effluent discharges are minimized by using HEPA/ULPA filtration. The discharge from ventilation systems is directed away from potential sources of contamination to prevent resuspension.

- The facility layout includes a series of barriers enclosing the various zones that are classified according to the potential level of contamination. The number of barriers depends upon the sources of contamination, the confinement efficiency of each barrier, and the number and types of penetrations. The process equipment provides primary confinement; secondary confinement is provided by the enclosure containment. The ventilation system will be designed to assist the physical barriers within the facility in maintaining zone confinement.

D-2.1.3 Design Development

The Silo 3 Project Radiological Engineering Group reviews and ensures that radiological control requirements are incorporated during the facility design. The normal design process involves the following major steps, each of which requires an appropriate level of radiological review, input, and concurrence:

- functional design criteria,

- preconceptual design,

- conceptual design,

- preliminary design [preliminary hazard analysis report or safety assessment],

- final design [final hazard analysis report or safety assessment],

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- documented technical safety requirements, and
- operational readiness assessment or review.

The radiological engineering review focuses on the applicable design criteria contained within DOE Order 420.1, *Facility Safety*, Section 4.1, "Nuclear and Explosives Safety Design Criteria" and those listed in this ALARA Analysis.

D-2.2 RADIATION PROTECTION

The essential features of the radiological protection program used to protect workers, the environment, and the public from exposure to radiation address the following issues:

- The requirements for radiation protection;
- Description of the design features, programs, and procedures to control radiation sources;
- The radiation protection organization and how the Silo 3 project is integrated with the site-wide programs for maintaining exposures ALARA, training, dosimetry, and record-keeping; and
- Description of how radiological releases are monitored and controlled.

The radiological protection requirements for the Silo 3 Project will be documented in a project-specific health physics plan (PSHPP), Appendix H of the NHASP. The PSHPP will describe the radiological hazards and controls for the operational, shutdown, and demobilization phases of the Silo 3 Project.

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D-3.0 EXISTING RADIOLOGICAL CONDITIONS

D-3.1 SILO 3 MATERIAL

Silo 3 contains about 5,100 yd^3 of calcined byproduct material from uranium ore concentrate processing. Because of the evaporation and calcinations of this material, the water content is low, ranging between 3.7 and 10.2 percent (Ref. 3). Initial tests at the FCP have shown that approximately 90 percent of the Silo 3 residues pass through a 200-mesh sieve indicating that the majority of the contents are silt size or less (Ref. 3). More recent particle size analysis shows that Silo 3 material size distribution includes a significant fraction of the particles are less than 1 micron. The untreated material is easily dispersed. The hygroscopic material exposed to atmospheric humidity will clump and become less easily dispersed.

The specific activities of individual CPCs found in Silo 3 material are shown in Table D.3.1. The radionuclide inventories are derived from the specific activity results from the sampling of Silo 3 material. These data represent the 95 percent upper confidence limit (95% UCL) on the mean of sample data results. The data used in radiological calculations are based on the 95% UCL on the mean of sample data results. The arithmetic mean values of the sample data are shown for comparison. Shaded rows indicate actual measured concentrations. The remaining radionuclides are decay products assumed to be in secular equilibrium. The length of time for these radionuclides to reach secular equilibrium ranges from 30 to 100 years. Daughter nuclide concentrations vary by only a few percent over this range. In the case where analytical results do not agree with equilibrium calculations, the more conservative values (larger values typically from equilibrium calculations) are used for daughter product concentrations.

The table shows that Silo 3 radionuclides consist mainly of alpha emitters and that Th-230 provides over half the total specific activity. More than 80 percent of the relative dose fraction from an uptake of Silo 3 material into the body would result from Th-230. Therefore, survey techniques, contamination controls, and airborne radioactivity controls will be based on those limits set for Th-230.

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Table D.3.1. Silo 3 Material-Specific Activity[a]

Radionuclide[b]	Radiation Emitted	Activity Fractions	Arithmetic Mean (pCi/g)	95% Upper Confidence Level of Arithmetic Mean[c] (pCi/g)
Ac-227	β	0.0079	618	925
Ac-228	β	0.0071		839
Bi-210	β	0.0296		3,480
Bi-211	α	0.0079		925
Bi-212	β	0.0071		838
Bi-214	β	0.0329		3,870
Fr-223	β	0.0001		13
Pa-231	α	0.0053	487	627
Pa-234	β	<0.0001		3
Pa-234m	β	0.0151		1,780
Pb-210	β	0.0296	2,620	3,480
Pb-211	β	0.0079		925
Pb-212	β	0.0071		838
Pb-214	β	0.0329		3,870
Po-210	α	0.0293		3,480
Po-211	α	<0.0001		3
Po-212	α	0.0046		537
Po-214	α	0.0329		3,870
Po-215	α	0.0079		925
Po-216	α	0.0071		838
Po-218	α	0.0329		3,870
Ra-223	α	0.0079		925
Ra-224	α	0.0071	290	838
Ra-226	α	0.0329	3,970	3,870
Ra-228	β	0.0071	297	839
Rn-219	α	0.0079		925
Rn-220	α	0.0071		838
Rn-222	α	0.0329		3,870
Th-227	α	0.0079		925
Th-228	α	0.0071	590	838
Th-230	α	0.5119	51,200	60,200
Th-231	β	0.0010		117
Th-232	α	0.0072	656	842
Th-234	β	0.0151		1,780
Tl-207	β	0.0079		925
Tl-208	β	0.0026		301
U-234	α	0.0147	1,480	1,730
U-235/236	α	0.0010	93.6	117
U-238	α	0.0151	1,500	1,780
Total		1.0000		117,596

[a]Derived from the Remedial Investigation Report for OU4 (November 1993) (Ref. 9)
[b]Radionuclides are assumed to be in secular equilibrium with their parent radionuclides.
[c]Where laboratory analysis disagrees, a conservative decision was made to use daughter product concentrations consistent with equilibrium values.

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Table D.3.2 is reconstructed from Table 9.9 of the *Technical Basis for Internal Dosimetry at the FEMP (Ref. 10);* thorium (Th-230) is the most limiting CPC for Silo 3.

Table D.3.2. Silo 3 Relative Dose Fractions

Radionuclide	Assumed Inhalation Class*	Relative Dose Fraction (CEDE)
Uranium	W	0.022
Ac-227	Y	0.062
Pa-231	Y	0.028
Pb-210	D	0.002
Ra-224	W	0.0001
Ra-226	Y	0.007
Ra-228	W	0.0001
Th-228	Y	0.013
Th-230	Y	0.812
Th-232	Y	0.050

*Most restrictive solubility class is assumed unless technical basis exists. D, W, and Y describe the clearance of inhaled radionuclides from the lung. Clearance times are <10 days, from 10 to 100 days, and >100 days respectively for D, W, and Y. For thorium isotopes, Class Y is assumed based on "Technical Basis for Internal Dosimetry at the FEMP" (Ref. 10). For Ra-226, Class Y is assumed and the dose conversion factor is obtained from CAP88-PC, Version 2.1.

D-3.2 RADON

Within Silo 3, Radon-222 (3.8-day half-life and 5.5-day mean-life) is in secular equilibrium with its radium-226 parent. The nature of radon, being an inert radioactive gas, results in the continual release of the radionuclide from the residues into Silo 3. The actual quantity of radon present within the silo headspace is determined by the production rate (secular equilibrium) and the loss rate. There are essentially two loss mechanisms: the natural decay of the radon gas and the escape of the gas through degraded portions of the concrete silo structure. After a period of time, there is a steady-state quantity of radon within the silo headspace. Table D.3.3 shows the radon inventory details.

Silo 3 retrieval and packaging activities are expected to be impacted somewhat by radon released from the other silos. Workers will receive a small radiation dose from radon diffusing into the atmosphere from Silos 1 and 2, while the total inventory of radon present in the headspace of Silo 3 will be released to the atmosphere under controlled conditions via the exhaust stack. In addition, the radon emission rate may increase slightly during the agitation of Silo 3 material as it is removed from the silo. The radon from Silo 3 will be released via the exhaust stack.

Table D.3.3. Silo 3 Radon Inventories and Emissions

Parameter	Silo 3 Storage	At Start of Retrieval Operations
Headspace concentration (pCi/L)	300,000 [a]	212 [e]
Headspace volume (ft^3)	5600 [a]	5600
Headspace activity (Ci)	0.0476 [b]	3.36×10^{-5} [f]
Radon generation rate (pCi/min)	1.78×10^9 [c]	1.78×10^9
Radon transfer rate to headspace (pCi/min)	6.0×10^6 [d]	6.0×10^6
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. Design Basis and Requirements Document for the Silo 3 Project (Ref. 3).
b. 300,000 pCi/L x 5,600 ft^3 x 28.32 L/ft^3 = 0.0476 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 = 0.0476 Ci x 0.693/5500 min = 6.0×10^6 pCi/min (assumes no leakage and to be the same value during retrieval)
e. C = E/Q = 6.0×10^6 pCi/min x 1/1000 ft^3/min x 1/28.3 L/ft^3 = 212 pCi/L
f. 212 pCi/L x 5,600 ft^3 x 28.32 L/ft^3 = 3.36×10^{-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. 9).

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 Attachment 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 Table. 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 FCP site procedure, "Radiological Work Permitting and Authorization," RP-0020 (Ref. 11). The RWP system ensures that the ALARA process is used in work planning.

"Radiological Control Requirements," RM-0020 (Ref. 4), establishes occupational ALARA trigger levels intended to provide an intervention point at which the application of occupational ALARA is included in planning and/or evaluating a project. The occupational ALARA trigger levels are:

- Exposure rates >0.5 mrem/hr on average AND an individual is likely to exceed 200 mrem in a year
- Exposure rates >0.5 mrem/hr on average AND the collective dose is likely to exceed 2 person-rem in a year
- An individual is likely to accumulate more than 4 DAC-hours in a week (applying the appropriate respiratory protection factor)
- Entry into areas where dose rates exceed 1 rem/hr
- Reasonable potential for the release of radioactive material (e.g., liquid, airborne) from a system or container to an uncontrolled area in the absence of a release permit or transfer from a controlled or radiological area to an uncontrolled area.

The first two trigger levels will clearly be exceeded in the Silo 3 Project; thus this occupational ALARA analysis is required.

D-4.2 ALARA COMMITTEE REVIEW

Each of the routine operation and maintenance tasks in the Silo 3 Project has been evaluated for exposure time, potential dose rate, and estimated collective dose. To accurately estimate exposure times, it was necessary to evaluate each operation, and maintenance task to determine the number of workers necessary, whether they will be wearing PPE, the time required for the task, and the frequency of the task. However, detailed operations and maintenance manuals that would provide these data are not yet available from the manufacturers of each piece of equipment. Therefore, the data provided in this ALARA analysis are based on conservative estimates and general knowledge of comparable operations and equipment. The potential dose rates are conservative estimates based on the shielding calculations, including self-shielding and geometry considerations.

The collective dose estimates in Table D.5.1 have been summed to give a projection of the Silo 3 Project total collective dose. An assessment of these projected collective doses gives the relative impact of each task and suggests the level of analysis necessary to ensure that the collective and individual doses are maintained ALARA.

The ALARA Committee, made up of a variety of specialists from operations, maintenance, health physics, industrial hygiene, and industrial safety, critically reviews this analysis. Committee comments are reviewed and responses developed and incorporated to create a well-established starting point for initiation of physical work.

ALARA analysis is a continuous process that is repeated whenever additional data become available that enable refinements in estimates and calculations. As the project proceeds and operations and maintenance manuals are received, specific procedures will be developed that will better define tasks to be conducted in radiological areas. This additional information will be used to refine individual and collective dose estimates and generally reduce the degree of conservatism in the ALARA Analysis.

D-5.0 SILO 3 FACILITY ALARA ANALYSIS RESULTS

This section presents results of the ALARA analyses. Each task of the waste retrieval and packaging that involves significant radiation exposure has been reviewed and analyzed to calculate collective doses with an emphasis on those that pertain to the final design. These analyses are estimates for ALARA purposes.

D-5.1 DURATION OF SILO 3 PROJECT TASKS

The duration of the Silo 3 Project operation tasks was determined from the Silo 3 current baseline schedule. Construction of the Silo 3 waste retrieval and packaging facility began in the fall of 2002 and operations are scheduled in 2004.

The process for the removal and packaging of Silo 3 waste is subdivided into the following three divisions:

- Pneumatic retrieval of Silo 3 waste by a vacuum wand inserted through a manway in the Silo 3 dome,
- Mechanical retrieval of waste through the side of the silo and material handling of the captured solids to a packaging area where it is placed in bags, and
- Bagged waste is containerized and stored in shipping containers for final transport to an off-site disposal facility.

A plan view of the retrieval/package building first floor, Figure D-2, shows the process equipment layout.

D-5.2 INTERNAL EXPOSURE TO RADON AND OTHER RADIONUCLIDES

Headspace radon and radon generated during mechanical processing of the retrieved, dry waste will be collected in exhaust hoods and ventilated to the atmosphere by the Silo 3 exhaust stack. Calculations of the atmospheric release and dispersion of radon from the exhaust stack show that doses to potential off-site recipients would be negligible (Ref. 14).

Very few project operations will be conducted in airborne radioactive areas where the radon concentrations will exceed 10 percent of the DAC and require respiratory protection. In these cases, the selection and use of respiratory protection equipment will be designed to prevent internal exposure to radon and its decay products. Fixed radon monitors installed in the Process Building and the Excavator Service Room will be supplemented with portable working level monitors to monitor radon and daughter product concentrations (Reference Appendix H).

In all cases where workers are exposed to Silo 3 material, they will be required by RWP to wear full PPE and respirators to prevent skin contamination and inhalation of airborne

radioactive material. Thus, the probability of project workers being internally contaminated is low. Nevertheless, all project radiological workers will participate in the FCP bioassay program as required.

Radiological Control Technicians will also measure radon concentrations and determine the requirements for respiratory protection for any planning to access areas. The objective of monitoring and respiratory protection is to prevent exposures to radon concentrations in excess of 10 percent of a DAC and to ensure that internal exposures to radon concentrations less than 10 percent of a DAC are maintained ALARA.

D-5.3 CHANGING RADIOLOGICAL CONDITIONS

The Radon Control System will begin operation in 2003, which will decrease the leakage of radon from Silos 1 and 2. Radon that is not adsorbed by the Radon Control System will be dispersed via the Accelerated Waste Retrieval stack, resulting in a net reduction in the local radon and progeny concentrations.

Before Silo 3 operations conclude in 2004, the transfer of slurry from Silos 1 and 2 to the Tank Transfer Area will begin. Exposed double-wall pipelines carrying the slurry and sluice water will generate some direct radiation exposure. The lines are about 57 feet above grade and greater than 125 feet away from the nearest part of the Silo 3 facility, i.e., the pad containing the heating, ventilation and air conditioning (HVAC) fans, the Pneumatic Retrieval System, the Process Vent System, and the Exhaust Stack. The dose rate at this distance is negligible. Because of the low dose rate, the limited project overlap (in time), and the infrequent occupancy of the ventilation equipment pad this dose contribution was not included in the analysis.

D-5.4 EXTERNAL RADIATION EXPOSURE

The individual and collective dose estimates are detailed in this section. The collective dose estimates in Table D.5.1 have been summed to give a projection of the total collective dose for major project phases (i.e., operation and maintenance). Assessment of these projected collective doses gives the relative impact of each task and suggests the level of analysis necessary to ensure that the collective and individual doses are maintained ALARA. These estimates will also provide input to the development of project ALARA goals. The dose rate estimates were determined from calculations, existing survey data, and qualitative approximations. During operations, actual doses will be compared to estimated doses to analyze trends and measure performance against ALARA goals. Actual dose data will be used to refine dose estimates and make adjustments where necessary.

The scope of this ALARA Analysis is focused on the retrieval and packaging of the Silo 3 material. Further detail required to clearly define operation and maintenance of equipment is generally contained in vendor's operating and maintenance manuals, which are not yet available. Thus, conservative assumptions about the frequency, duration, and complexity of operations and maintenance have been made by the design engineers and used in this analysis. As vendor manuals become available, this ALARA Analysis will be further refined

to more clearly define operations and maintenance functions and/or to further reduce the degree of conservatism in the assumptions.

The number of workers involved in the Silo 3 Project tasks is generally limited to only those workers who actually enter radiological areas to perform work. The "buddy system" of using two workers on a task will be used only when absolutely necessary for safety or efficiency. Supervisors, engineers, trainers, and trainees are not expected to be exposed to the same radiation levels as the primary workers. Furthermore, the estimated exposure times for workers performing radiological work are limited to the actual time spent in radiation areas. It is assumed that workers will perform efficiently and minimize the time spent in these areas because of their skills and training and because the tasks will have been practiced on "cold" systems.

The remainder of this section is focused on external radiation exposures to the Silo 3 Project workers. Radiation doses estimated in this section are taken from Calculation 40430-CA-0016 (Ref. 12), where available, and from Radiation Zone Drawings (Ref. 13). Radiation exposures to workers will be controlled by means of RWPs, including stay-time limits and local temporary shielding requirements. Actual radiation exposures to workers will be measured by dosimeters, and dosimetry records will be analyzed to ensure that worker exposures are maintained ALARA.

D-5.4.1 Operations

The Silo 3 Project will operate for several months performing material retrieval, treatment, and packaging. The pneumatic retrieval system and the mechanical retrieval system each have a material removal design capacity of 10 yd^3 per hour and a normal operating capacity of 6 yd^3 per hour. Therefore, the entire 5,100 yd^3 material removal could be accomplished in 510 hours at design capacity or 850 hours at normal operating capacity. The exposure durations used in this analysis conservatively assume 1000 operating hours to account for the retrieval operations and routine support activities. This is segmented into 300 operating hours for pneumatic retrieval and 700 operating hours for mechanical retrieval. The schedule duration is assumed to be 6 months, with the understanding that while not operating, the personnel will not always be located in areas with dose rates above background levels. Although a decision may be made by Operations to perform more pneumatic retrieval and less mechanical retrieval, the impact on total collective dose would be small.

The Pneumatic Retrieval System uses a vacuum wand (i.e., vacuum wand management system) to remove the Silo 3 material via five man-ways on the top of the silo dome. This system will operate for approximately 300 hours. Two operators will be on the dome at any given time, at an approximate dose rate of 1.9 mrem/hr, and will rotate out with a relief crew. The "off-duty" crew will spend the off hours in the Operations Support Trailer (dose rate of 0.1 mrem/hr). A pneumatic retrieval collector will collect and separate the air-entrained waste. The pneumatic retrieval discharge feeder and the primary and secondary rotary feeders will then move the waste material to the Container Management System.

The Mechanical Retrieval System uses a remotely operated mechanical excavator to remove the silo material through an opening in the side of the silo wall. Once sufficient material has been pneumatically removed from behind the wall opening, the silo wall is cut and wall sections are removed to allow excavator access. The 15 ft wide by 20 ft high section is removed in sections with a diamond wire saw. The wall removal operation was estimated to require 4 personnel a duration of 170 hours at an average dose rate of 0.8 mrem/hr. This average dose rate is based on the time durations with the wall in place and with sections removed. Approximately 95 percent of the effort will be performed with the wall in place (i.e., 0.5 mrem/hr). Approximately 5 percent of the effort will be performed with the wall sections removed (5 mrem/hr).

The Mechanical Retrieval System will be operated for approximately 700 hours. Two operators will operate the excavator remotely, observing the operations via a viewing window adjacent to the Excavator Room. The excavator operators will be exposed to a dose rate of 0.4 mrem/hr, which is based on approximately 5 to 6 cubic yards of material in the excavator room at any given time, and at a distance of approximately 15 ft. The calculated dose rate from a bag was used as guidance in estimating the dose rate to these operators. The "off-duty" relief crew will spend off hours in the Operations Support Trailer. A retrieval bin will receive the waste from the excavator and the retrieval bin discharge feeder located beneath the retrieval bin will move the waste material to the inclined conveyor. The inclined conveyor will transport the waste material upwards to a transfer conveyor, which will in turn move the waste to the Container Management System.

The container management system will require 2 packaging room operators to operate conveyors and the packaging equipment. The packaging room operators will be exposed to an average dose rate of 0.4 mrem/hr, assuming an average distance of 7 ft from each bag. In addition, 2 cargo container bay operators will convey the filled bags into the cargo containers via the crane and move containers with a forklift. The cargo container operators will be exposed at approximately 1.8 mrem/hr for 50 percent of the time (based on a distance of 7 ft from a full cargo container) and 0.4 mrem/hr for 50 percent of the time (based on a distance of 18 ft from a full cargo container). One-half hour per bag is assumed based on the throughput rate. Additional operators can be utilized to rotate personnel. In addition, localized shielding could be provided on the forklift to reduce the dose rate to the operator.

Vendors will deliver approximately 270 empty containers, at 0.5 hours per container, in a dose rate of approximately 0.08 mrem/hr. These same containers will be picked up be a driver, at 0.5 hours per container, in a dose rate of approximately 0.1 mrem/hr. Approximately 25 chemical deliveries are estimated, at 1 hour per delivery, in a dose rate of approximately 0.08 mrem/hr.

An RCT will perform routine surveys of the facility and will support work activities. The routine surveys are expected to consist of 2 hours daily in areas at 0.4 mrem/hr, and 2 hours daily in areas at 2 mrem/hr. Operations support activities are estimated to require 2

hours daily in areas at 1 mrem/hr. The remainder of the RCTs time will be in the operations support trailer. The duration of RCT support is 6 months or 132 days.

D-5.4.2 Maintenance and Inspection

The Silo 3 Project process equipment generally consists of specialized waste removal equipment (pneumatic and mechanical), process piping, waste material packaging system, pumps, valves, conveyor systems, process parameter and equipment sensors, air compressors, air filtration systems, miscellaneous electrical switchgear, and fire and radiological monitoring equipment and systems. The frequency and type of maintenance required for this equipment vary, but the maintenance is typically performed monthly and generally consists of the inspection and replacement (as necessary) of seals, impellers, packing, motors, limit switches, bearings, sensors/ transmitters, filters, etc. Maintenance activities also include regularly scheduled equipment testing including limit switches, transmitters, sensors, and alarm setpoints. The durations of the maintenance activities ranged from 1 to 10 hours a month and required 1–2 workers for each maintenance activity. Each equipment item was reviewed to determine maintenance requirements, location of equipment items, and radiation exposure rates at specific maintenance locations. The period of operation was also considered in the descriptions that follow.

The Silo 3 Project is comprised of several major systems: the Pneumatic Retrieval System, the Mechanical Retrieval System, the Container Management System, the Additive System, the Wastewater System, the Process Vent System, the plant/breathing air system, and the HVAC system. Each of these components includes equipment that may require preventative maintenance, and these requirements are considered in the following paragraphs.

Maintenance on the vacuum wand will require two workers in PPE approximately 10 hours a month. The vacuum wand will be pulled off the silo dome for any maintenance. The Pneumatic Retrieval Collector, the discharge feeder, and the rotary feeders will each require two workers approximately 5 hours a month. The exposure rate during maintenance on the vacuum wand system will be 0.1 mrem/hr and for the rest of the equipment will be approximately 0.4 mrem/hr.

Maintenance on the retrieval bin and feeder will each require two personnel in PPE approximately 1 and 2 hours a month, respectively. The exposure rate at each of these pieces of equipment will be approximately 3 mrem/hr. Maintenance on the bottom portion of the inclined conveyor will require 2 personnel in PPE approximately 2.5 hr a month. The dose rate in this area will be approximately 1.0 mrem. Maintenance on the transfer conveyor will require two personnel in PPE approximately 5 hr a month. The exposure rate in this area will be approximately 0.4-2 mrem/hr and average 1 mrem/hr. Maintenance on the mechanical excavator will require two personnel in PPE approximately 10 hours once during mechanical retrieval. The mechanical excavator will be pulled into the Excavator Service Room for maintenance, where the exposure rate will be approximately 1.0 mrem/hr. The rollup doors in the Excavator Service Room will require two personnel in PPE approximately 0.5 hr each door a month.

The Container Management System receives the waste material from either the pneumatic retrieval system or the mechanical retrieval system and packages, weighs, and samples the waste prior to loading the packaged wastes (3 yd^3 bags) into cargo containers. This system is located in the Packaging Area and the Cargo Container Bay. Maintenance on the upper portion of the inclined conveyor and the feed conveyor and associated feed discharge valves requires two personnel in PPE approximately 2.5 hr a month, 5 hr a month, and 1 hr a month, respectively. The exposure rate in this area will be approximately 0.4-2.0 mrem/hr and average 1.0 mrem/hr. Maintenance on each package loading stands will require two personnel approximately 5 hr a month, where the exposure rate is 0.2 mrem/hr. Maintenance on the remainder of the conveyors will each require two personnel approximately 0.5 hr a month, at 0.1 mrem/hr. Maintenance on the bridge crane, forklift, loading crane, will each require two personnel approximately 1 hr a month, at 0.1 mrem/hr. Maintenance of the rollup doors will require 2 workers approximately 2 hours per month, at 0.1 mrem/hr.

The Process Vent System collects and filters air contaminated with radon and metal oxide dust from various process points in the waste retrieval and packaging facility. The air collection registers are located throughout the building to reduce the potential for the spread of contamination in areas where metal oxides are exposed to atmosphere (i.e., mechanical excavation retrieval bin, the excavator room, and the packaging stations). Maintenance on the retrieval bin and excavator room registers will each require one person in PPE approximately 1 hr a month. The exposure rate at these registers will be approximately 3.0 mrem/hr. Maintenance on the process vent dust collectors and the fines collection bins will require two personnel in PPE approximately 1 hr a month and 2 hr a month, respectively. The exposure rate at these pieces of equipment will be approximately 2 mrem/hr. Maintenance on the packaging station registers will require one person in PPE approximately 1 hr a month. The exposure rate at the packaging station registers will be approximately 1.0 mrem/hr. Maintenance on the Process Vent System HEPA prefilters and exhaust fans located south of the Excavator Room will require two personnel approximately 1.5 hrs a month for the prefilters and 2 hr a month for each fan, respectively. The exposure rate at this equipment will be approximately 2.0 mrem/hr at the filters and 0.4 mrem/hr at the fans.

The Wastewater System receives wastewater from the Excavator Room and Excavator Service Room resulting from equipment wash down or excessive misting. The system also receives water from the Additive System sump pump and the Wastewater System sump pump, which is located in the diked area surrounding the Wastewater Tank. Maintenance on the wastewater tank agitator and the wastewater tank pump will each require two personnel approximately 2 hr a month. The exposure rate will be 0.1 mrem/hr. Maintenance on the Wastewater Tank sump pump will require two personnel approximately 1 hr a month, and exposure rate in the area will be 0.1 mrem/hr. Maintenance on the Excavator Room and Excavator Service Room sump pumps requires two personnel in PPE approximately 1 hr a month. The exposure rate for the excavator room will be approximately 3 mrem/hr and for the excavator service room, 0.1 mrem/hr.

The Waste Additive System adds two liquid reagents to the waste material as it is added to the waste bags to reduce fugitive emissions and condition the waste. Reagent totes are delivered and stored in the Cargo Container Bay along with associated metering pumps and a sump pump. The ferrous sulfate tank and pump receive ferrous sulfate from a tanker truck parked outside. The reagents are pumped to an additive tank and additive charge tanks located in the Storage Area. Two metering pumps in this room pump the reagents into the waste material as it is added to the waste bags. Each piece of equipment requires one person approximately 1 hr a month to maintain, and the exposure rate in the area of this equipment is 0.1 mrem/hr.

Air for the HVAC System is supplied via three air conditioning units adjacent to the Wastewater Tank room. Two building filtration exhaust fans are located adjacent to the Excavator Room. In addition, there is a Cargo Container Bay air handling unit, three Cargo Container Bay exhaust fans, and two Wastewater Tank exhaust fans. Two ultra-low penetrating air (ULPA)/HEPA filters are located on the roof of the Excavator Room. General maintenance will require two personnel for each of the units (i.e., 1 hr a month for each of the exhaust fans; 2 hours per month for the air handling unit, and 2 hr a month for each of the air conditioning units). The workers will not require PPE, and the exposure rate in the area will be 0.1 mrem/hr. Maintenance on the ULPA/HEPA exhaust prefilters will require two personnel in PPE 1 hr/month and the exposure rate will be 0.4 mrem/hr.

Electrical switchgear in the Electrical Building provides power to the facility. Maintenance for the electrical switchgear requires two workers without PPE approximately 1 hour a month. The exposure rate in this area will be 0.1 mrem/hr.

Electrical and mechanical equipment used for monitoring and alarming radiological (e.g., radon monitors, continuous air monitors,) and fire parameters will require two workers approximately 4 hours a month. These workers will require PPE approximately 50 percent of the time. Exposure rates will be 0.1 mrem/hr.

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Table D.5.1. ALARA and Exposure Analysis Table

Silo 3 Project Operations	No. of Workers (1)	PPE Req'd (2)	Time Duration (hr) (3)	Frequency of Tasks (4)	Person-Hours (5)	Dose Rate (6) (mrem/hr)	Collective Dose (7) (person-rem)	Notes/ Location
FACILITY OPERATIONS								
Pneumatic Retrieval Operations								
Pneumatic removal wand operator control from top of dome	2	Yes	300	1	600	1.9	1.14	Top of Silo Room 3
Operations support trailer activities	2	No	300	1	600	0.1	0.06	Support trailer
Mechanical Retrieval Operations								
Perform Wall Cutting Operation	4	Yes	170	1	680	0.8	0.544	Silo 3
Mechanical excavator operations	2	No	700	1	1,400	0.4	0.56	Room 2
Operations support trailer activities	2	No	700	1	1,400	0.1	0.14	Support trailer
Packaging Room Operations								
Bag out, inspection, swipes, installation, weighing, sampling, post-fill swipes, labeling (1885 bags)	2	Yes	0.5	1885	1,885	0.4	0.754	Room 4
Cargo Container Bay Operations								
Position and fill cargo containers and stage and load cargo containers	2	No	0.5	1885	1,885	1.1 average	2.074	Room 7
Truck Drivers								
Transport 270 empty containers	1	No	0.5	270	135	0.08	0.011	East of Room 7
Pickup 270 full containers	1	No	0.5	270	135	0.1	0.014	

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Silo 3 Project Operations	No. of Workers (1)	PPE Req'd (2)	Time Duration (hr) (3)	Frequency of Tasks (4)	Person-Hours (6)	Dose Rate (8) (mrem/hr)	Collective Dose (7) (person-rem)	Notes/ Location
Deliver waste additives (25 deliveries)	1	No	1	25	25	0.08	0.002	East of Room 7
Radcon Technician	**(6 months or 132 days)**							
Health physics surveys	1	No	2	132	264	0.4	0.1056	Room 4
Health physics surveys	1	No	2	132	264	2	0.528	Room 11
Area Surveys operation support	1	No	2	132	264	1	0.264	Various
Operations support trailer activities	1	No	4	132	528	0.1	0.0528	Support trailer
Operations Subtotal							**6.25**	
MAINTENANCE/INSPECTION								
Pneumatic Retrieval System	**(2 months)**							
Maintain vacuum wand management system	2	Yes	10	2	40	0.1	0.004	
Maintain pneumatic retrieval collector	2	Yes	5	2	20	0.4	0.008	Room 4
Maintain pneumatic retrieval collector discharge feeder	2	No	5	2	20	0.4	0.008	
Maintain primary rotary feeder	2	No	5	2	20	0.4	0.008	
Maintain secondary rotary feeder	2	No	5	2	20	0.4	0.008	
Mechanical Retrieval System	**(4 months)**							
Maintain retrieval bin	2	Yes	1	4	8	3	0.024	Room 9
Maintain retrieval bin discharge feeder	2	Yes	2	4	16	3	0.048	Room 9

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Silo 3 Project Operations	No. of Workers (1)	PRE Req'd (2)	Time Duration (hr) (3)	Frequency of Tasks (4)	Person-Hours (5)	Dose Rate (6) (mrem/hr)	Collective Dose (7) (person-rem)	Notes/ Location
Maintain inclined conveyor	2	Yes	2.5	4	20	1	0.02	Room 9
Maintain/inspect excavator tools	2	Yes	1	4	8	1	0.008	Room 9
Maintain transfer conveyor	2	Yes	5	4	40	1	0.04	Room 4
Maintain excavator	2	Yes	10	1	20	1	0.02	Room 8
Maintain excavator service room rollup doors (2)	2	Yes	1	4	8	1	0.008	Room 8
Packaging/Loading System	**(6 months)**							
Maintain inclined conveyor	2	Yes	2.5	6	30	1	0.03	Room 4
Maintain feed conveyor	2	Yes	5	6	60	1	0.06	Room 4
Maintain feed conveyor discharge valves	2	Yes	1	6	12	1	0.012	Room 4
Maintain loading stands (2)	2	No	10	6	120	0.2	0.024	Room 4
Maintain intermediate packaging conveyors (2)	2	No	1	6	12	0.1	0.0012	Room 4
Maintain packaging staging conveyors (2)	2	No	1	6	12	0.1	0.0012	Room 4
Maintain airlock conveyors (2)	2	No	1	6	12	0.1	0.0012	
Maintain off-loading conveyors (2)	2	No	1	6	12	0.1	0.0012	Room 7
Maintain bridge crane	2	No	1	6	12	0.1	0.0012	Room 11
Maintain heavy-duty forklift	2	No	1	6	12	0.1	0.0012	Room 11
Maintain loading crane	2	No	1	6	12	0.1	0.0012	Room 11
Maintain airlock rollup doors (4)	2	No	2	6	24	0.1	0.0024	Room 7

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Silo 3 Project Operations	No. of Workers (1)	PPE Req'd (2)	Time Duration (hr) (3)	Frequency of Tasks (4)	Person-Hours (5)	Dose Rate (6) (mrem/hr)	Collective Dose (7) (person-rem)	Notes/ Location
Process Vent System (PVS)								
Maintain retrieval bin register	1	Yes	1	6	6	3	0.018	Silo opening
Maintain excavator room register	1	Yes	1	6	6	3	0.018	Room 8
Maintain process vent dust collectors (2)	2	No	2	6	24	2	0.048	Room 4
Maintain fines collection bins (2)	2	No	4	6	48	2	0.096	Room 4
Maintain packaging station exhaust registers (2)	1	No	1	6	6	1	0.006	Room 4
Maintain PVS HEPA prefilters	2	Yes	1.5	6	18	2	0.036	Adjacent to Room 9
Maintain PVS exhaust fans (2)	2	No	4	6	48	0.4	0.0192	Adjacent to Room 9
Wastewater System								
Maintain wastewater tank agitator	2	No	2	6	24	0.1	0.0024	Room 6
Maintain wastewater pump	2	Yes	2	6	24	0.1	0.0024	Room 6
Maintain wastewater tank area sump pump	2	Yes	1	6	12	0.1	0.0012	Room 6
Maintain excavator room sump pump	2	Yes	1	6	12	3.0	0.036	Room 9
Maintain excavator service room sump pump	2	Yes	1	6	12	0.1	0.0012	Room 8
Waste Additive System								
Maintain Waste additive metering pumps (2)	1	No	2	6	12	0.1	0.0012	Room 11
Maintain waste additive sump pump	1	No	1	6	6	0.1	0.0006	Room11

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Silo 3 Project Operations	No. of Workers (1)	PPE Req'd (2)	Time Duration (hr) (3)	Frequency of Tasks (4)	Person-Hours (5)	Dose Rate (6) (mrem/hr)	Collective Dose (7) (person-rem)	Notes/ Location
Maintain wastewater additive tank	1	No	1	6	6	0.1	0.0006	Room 5
Maintain waste additive change tanks	1	No	2	6	12	0.1	0.0012	Room 5
Maintain waste additive change tank metering pumps	1	No	2	6	12	0.1	0.0012	Room 5
HVAC System								
Maintain cargo container bay exhaust fans	2	No	3	6	36	0.1	0.0036	Cargo bay roof
Maintain cargo container bay air handling unit	2	No	2	6	24	0.1	0.0024	Adjacent to cargo bay
Maintain packaged air circulation units	2	No	6	6	72	0.1	0.0072	Adjacent to Room 8
Maintain building filtration exhaust fans	2	No	2	6	24	0.1	0.0024	Room 8 roof
Wastewater tank area exhaust fan	2	No	2	6	24	0.1	0.0024	Room 6
Maintain ULPA/HEPA exhaust filters	2	Yes	1	6	12	0.4	0.0048	Room 8 roof
Electrical Building								
Maintain miscellaneous electrical switchgear	2	No	1	6	12	0.1	0.0012	
Radiological/Fire Monitoring Equipment								
Maintain miscellaneous fire protection and radiological protection equipment	2	Yes	4	6	48	0.1	0.0048	
M&I Subtotal							**0.66**	

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Silo 3 Project Operations	No. of Workers (1)	PPE Req'd (2)	Time Duration (hr) (3)	Frequency of Tasks (4)	Person-Hours (5)	Dose Rate (6) (mrem/hr)	Collective Dose (7) (person-rem)	Notes/ Location
Overall Total							6.9	

Notes:

(1) No. of Workers = number of workers that will actually receive radiation exposure during the task

(2 PPE Required = personal protective equipment required, typically two pairs of coveralls, shoe covers, gloves, hood, and respirator

(3) Time Duration = the actual exposure time in the radiation field

(4) Frequency = the number of times the task must be performed during the entire duration of the Silo 3 Project

(5) Person-Hours = the collective exposure time in the radiation field

(6) Dose Rate = the estimated whole body dose rate (mrem/hr) at the location where the task is to be performed

(7) Collective Dose = the product of Person-Hours and Dose Rate in units of person-rem

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D-6.0 REFERENCES

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3. Fluor Fernald, Inc., *Design Basis and Requirements Document for the Silo 3 Project*, 40430-DC-001, Fernald OH, February 2002.

4. Fluor Fernald, Inc., *Radiological Control Requirements Manual,* RM-0020, Revision 1, Fernald Environmental Management Project, Fernald, OH, June 2003.

5. DOE, *Radiological Control*, DOE-STD-1098-99, Department of Energy, Washington DC, July 1999.

6. *Limits for Intakes of Radionuclides by Workers.* Volume 6, No. 2/3 of *Annals of the ICRP.* ICRP Publication 30 Part 3, 1981.

7. *Practices for Respiratory Protection*, ANSI Z88.2-1999, American National Standards Institute, 1999.

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10. Fluor Daniel Fernald, *Technical Basis for Internal Dosimetry at the FEMP*, SD-2008, Fernald Environmental Management Project, Fernald, OH, April 1997.

11. Fluor Fernald, Inc., *Radiation Work Permitting and Authorization,* RP-0020, Fernald Environmental Management Project, Fernald, OH.

12. Jacobs, *Silo 3 Area Dose Rate Calculation*, 40430-CA-0016, August 2003.

13. Jacobs, *Silo 3 Radiation Zone Drawings,* 94X-3900-M-05216, M-011 through M-016, December 2002.

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ATTACHMENT 1

ALARA FEATURES

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Attachment 1. ALARA Features

	System	Features
1	Silo enclosure	Protects workers from weather
2	Pneumatic retrieval collector and process vent dust collectors	Removes high concentrations of particulates from air stream
3	HEPA/ULPA filters and prefilters retrieval	Removes particulates from air stream in each ventilation system
4	Pneumatic retrieval blower and auxiliary vacuum blower	Provides for optimum ventilation system performance
5	Building ventilation system	Directs ventilation air from cleaner areas to more contaminated areas, to air treatment systems, and the stack
6	Retrieval bin hood	Reduces airborne concentrations in excavation room
7	Enclosed conveyors	Contains powders during material movement
8	Inclined conveyor double belt	Limits material spillage during lifting of material
9	Gravity flow of material and primary and secondary	Limits equipment and associated containment problems
10	Rotary feeders in-series	Prevents overfilling of bags
11	Excavator service room	Provides for excavator maintenance in cleaner area
12	Polyethylene bag liner	Delays diffusion of radon and provides dust control and containment
13	Local shielding	Reduces dose rates in work areas near large volumes of waste where appropriate
14	Remote excavation	Minimizes personnel exposure to bulk waste
15	Exhaust stack (125 ft high)	Provides for dispersal of trace radon and particulates not collected elsewhere
16	Isokinetic stack monitor	Provides real-time assessment of release rates
17	Retrieval and processing areas	Provides secondary control of contamination
18	Vacuum wand management system	Limits personnel exposure to bulk amounts of waste
19	Packaging bag-out system	Controls contamination during packaging
20	Sumps and wastewater tanks	Collects and holds wash water for disposal
21	Process vent system	Provides venting of equipment to capture airborne material

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ATTACHMENT 2

APPLICATION OF ALARA FEATURES

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Attachment 2. Application of ALARA Features from Attachment 1

Exposure Route	System		
	Pneumatic Retrieval	Mechanical Retrieval	Packaging and Container Management
External	19, 14, 21	15, 14, 21	14, 21
Surface contamination	4, 5, 7, 9, 10, 18, 21	4, 5, 6, 7, 8, 9, 11, 12, 18, 21	9, 10, 18, 20, 21
Airborne contamination	2, 3, 4, 5, 6, 7, 9, 10, 18	3, 4, 5, 6, 7, 8, 9, 11, 12, 18, 21	3, 4, 5, 9, 10, 18, 20, 21
Environmental release (particulate)	2, 3, 16, 17, 18, 21	3, 16, 17, 18, 21	13, 16, 17, 18, 21
Environmental release (radon)	16, 17	16, 17	3, 16, 17
Environmental release (water)		21	

Reference: Attachment 1

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ATTACHMENT 3

Silo 3 Dose Rate Calculation

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JACOBS

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JACOBS ENGINEERING® Engineers and Constructors	Calculation No: 40430-CA-0016	Page: 1 of 6
	Rev. No.: 1	Revision Date: 8/1/03
Calculation Cover Sheet	Previous Revision Date: 12/20/02	Current Revision Date: 8/1/03
Issuing Department: *Oak Ridge Design Engineering*	Supersedes: Revision 0	
Client: Fluor Fernald Project Title: Silo 3 Project Number: 35H19605 System: Various	Engineering Discipline: Nuclear Engineering	

Calculation Title: Silo 3 Area Dose Rate Calculation

Purpose:

The purpose of this calculation is to determine the external dose rate at various Silo 3 project locations.

Prepared by: SL Date: _____

Checked by: DG Date: _____

Engineering Managers Approval: KC Date: _____

Revision History:

Pages Affected By Revision	Revised/Added/Deleted	Description of Revision
Revision 1 - All	Revised	Revise bulk density from 42.4 lb/cf to 50 lb/cf. Decrease the amount of Silo 3 material in each bag due to treatment.

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Description of Calculation:

This calculation determines the dose rate at various locations in the Silo 3 Project Facility. The MicroShield code is used to model the source term, given various expected geometries, to provide the calculated dose rates.

Assumptions:

- The Silo 3 material was sampled in 1989 and the measured radionuclide concentrations in the Silo 3 material are delineated in Table 1 (Reference 1). These radionuclides are decayed, for 10 years, in the MicroShield code to result in 37 radionuclides as the source term.

Table 1. Measured Radionuclides in the Silo 3 Material

Nuclides	95% UCL Specific Activity (pCi/g)
Actinium-227	925
Protactinium-231	627
Lead-210	3,480
Radium-224	367
Radium-226	3,870
Radium-228	406
Thorium-228	747
Thorium-230	60,200
Thorium-231	117
Thorium-232	842
Uranium-234	1,730
Uranium-235	117
Uranium-238	1,780

- The bulk density range of in-situ Silo 3 material is 29 to 58 lb/ft^3. The average silo waste material bulk density is 42.4 lb/ft^3 (0.68 g/cm^3) (Reference 1). A density of 50 lb/ft^3 (0.8 g/cm^3) was utilized in this calculation since it conservatively bounds the average.
- Silo 3 contains 5,100 cubic yards of material.
- The Silo 3 material storage bags measure 4 ft x 6 ft x 4 ft high. The bags will typically be filled with 3 cubic yards (81 cubic feet) of Silo 3 material and additives(Reference 2).
- The number of bags of treated material is 1885 (Reference: Tish Rhodus e-mail to Pat Fisk, July 25, 2003). Therefore, each bag will contain approximately 2.7 cubic yards of Silo 3 material. (5100 cy/1885 bags).
- The cargo container measures 8 ft x 20 ft x 8.5 ft high. Seven storage bags will typically be placed in each container.

Calculation Inputs:

The assumed constituent concentrations, material density, dimensions, and capacities listed in the Assumptions Section are used as calculation inputs.

Software:			
Title	**Developer**	**Versions**	**Revision Level**
MicroShield	Grove Engineering	5 - October 1996	N/A

Calculation Section:

A. Exposure Rates from a Single Storage Bag

The rectangular volume geometry is entered into MicroShield – 4 ft x 6 ft x 3.0 ft high, corresponding to 2.7 cubic yards. A volume of 2.7 cubic yards at the Silo 3 material in-situ radiological concentration and density was chosen for modeling, as opposed to 3 cubic yards at a reduced radiological concentration. The source term is based on 0.8 g/cm^3. The density of 0.8 g/cm^3 is entered for a proxy material of concrete. The source term is entered and decayed 10 years to ensure all daughters are included. The material selected for buildup is the source.

Constituent Activity = specific activity (pCi/g) x 0.8 g/cm^3 x 2.7 cy x 27 cf/cy x 28317 cm^3/cf

Table 2. Source Term of One Bag

Nuclides	95% UCL Specific Activity (pCi/g)	Activity (mCi)
Actinium-227	925	1.53
Protactinium-231	627	1.04
Lead-210	3,480	5.76
Radium-224	367	0.61
Radium-226	3,870	6.40
Radium-228	406	0.67
Thorium-228	747	1.24
Thorium-230	60,200	99.6
Thorium-231	117	0.19
Thorium-232	842	1.39
Uranium-234	1,730	2.86
Uranium-235	117	0.19
Uranium-238	1,780	2.95

The resultant exposure rates are summarized as follows:

Table 3. Exposure Rate from One Bag

Distance from a Single Bag (ft)	Exposure Rate (mR/hr)
0.1	8.4
1	4.0
2.5	1.2
5	0.71
7.5	0.33
10	0.23

B. Exposure Rates from a Cargo Container

The typical waste loading is expected to be 7 bags per container. This analysis assumes 8 bags per container for a convenient modeling geometry. The rectangular volume geometry assumes 4 bags side by side, stacked 2 high, for a modeled geometry of 16 ft x 6 ft x 6 ft high. Assume negligible shielding.

Table 4. Source Term of Cargo Container

Nuclides	95% UCL Specific Activity (pCi/g)	Activity (mCi)
Actinium-227	925	12.2
Protactinium-231	627	8.3
Lead-210	3,480	46.1
Radium-224	367	4.86
Radium-226	3,870	51.2
Radium-228	406	5.37
Thorium-228	747	9.89
Thorium-230	60,200	797
Thorium-231	117	1.55
Thorium-232	842	11.1
Uranium-234	1,730	22.9
Uranium-235	117	1.55
Uranium-238	1,780	23.6

The resultant exposure rates are summarized as follows:

Table 5. Exposure Rate from a Cargo Container

Distance from a Cargo Container (ft)	Exposure Rate (mR/hr)
0.1	9.8
1	7.0
6.7	1.8
10	1.0
17.6	0.41
20	0.32
25	0.21
30	0.15

The exposure rate for a receptor located between 2 cargo containers depends upon the distance between the containers and the location of the receptor. The data in the previous table can be used to approximate the dose between the containers. For example, a receptor located in the center between 2 containers spaced 20 ft apart will be exposed to 2.0 mR/hr.

C. Exposure Rates Near the Silo

Silo 3 contains 5,088 cubic yards of material. The source term was calculated assuming 0.8 g/cm^3. At 80 ft diameter, the material height is approximately 27 ft., which corresponds to the wall height. The concrete silo wall thickness is 8 in. The exposure rate in the vicinity of the wall is calculated to be approximately **0.44 mR/hr**. The receptor distance used in MicroShield was 3 to 4 ft, since the closer distances provide an erroneous value due to the close distance, relative to the size of the source.

Personnel may access the silo top. The top of the silo is 33 ft high. The concrete thickness is 4 in. in the silo center. The exposure rate on the Silo 3 center top is calculated to be **1.9 mR/hr.**

An opening will be cut in the silo wall to enable mechanical retrieval. The exposure rates in the excavator room, located next to the wall opening, are approximated by assuming the full silo geometry with no wall shielding. This is conservative since a portion of the silo 3 material will have been previously removed via vacuum extraction prior to the wall cut.

The resultant exposure rates are summarized as follows:

Table 6. Exposure Rate due to Silo Wall Opening

Distance from the Silo 3 Wall Opening (ft)	Exposure Rate (mR/hr)
5	5.3
10	3.5
15	2.6
20	2.0
25	1.6
30	1.3
35	1.05
40	0.87

The exposure rate to the excavator operators is determined by assuming

D. Exposure Rates in Process Areas

The material inventories in the process conveyors, collectors, and other process equipment will be less than that in a material storage bag. Therefore, the general area dose rates in the process areas will be less than 5 mrem/hr, where the highest dose rates would be in close proximity to equipment. The majority of the process areas will have dose rates less than 0.4 mrem/hr.

Conclusions/Recommendations:

This calculation provides calculated exposure rates for various locations within the Silo 3 Project Facility. Specifically, exposure rates are provided in the vicinity of a storage bag, a cargo container, the silo (including wall opening). All general area dose rates are expected to be less than 5 mrem/hr.

References:

1. Design Basis and Requirements Document for the Silo 3 Project, 40430-DC-0001, Fernald Environmental Management Project, February 2002.
2. Container Management and Packaging System Equipment Specification, 40430-ES-JM-RCV-25-5270.
3. Process Description for the Silo 3 Project, 40430-RP-0003, July 2002.