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# APPENDIX B

# HAZARD CATEGORY CALCULATION

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## Revision Sheet

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| 0 | 3/21/02 | All | Issued for internal review. |
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## ACRONYMS

| | |
|---|---|
| ARF | airborne release fraction |
| CEDE | committed effective dose equivalent |
| CFR | Code of Federal Regulations |
| Ci | Curie |
| DCF | dose conversion factor |
| DOE | U.S. Department of Energy |
| DOT | U.S. Department of Transportation |
| DR | damage ratio |
| EPA | U.S. Environmental Protection Agency |
| ERPG | Emergency Response Planning Guide |
| HC | hazard category |
| IHA | Integrated Hazard Analysis |
| ISA | Interim Storage Area |
| LPF | leak path factor |
| MAR | material at risk |
| OSHA | Occupational Safety and Health Administration |
| OU | operable unit |
| pCi | Picocurie |
| PRI | potentially releasable inventory |
| RF | respirable fraction |
| RQ | reportable quantity |
| STD | standard |
| TEDE | total effective dose equivalent |
| TPQ | threshold planning quantity |
| TQ | threshold quantity |
| UCL | upper confidence level |

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## EXECUTIVE SUMMARY

The Silo 3 Facility is categorized as a radiological facility with "low" chemical hazards, since the effective dose equivalent at 30 m is less than the Hazard Category (HC) 3 threshold criteria.

The most severe radiological and chemical hazards from the Integrated Hazards Analysis (IHA), Appendix A, were selected for modeling to determine the hazard category (HC). The most significant (bounding) potentially releasable inventory is a result of a silo failure during wall cutting. An additional accident analyzed is a cargo container spill on the Interim Storage Area pad.

The hazard category "Radiological" was determined after analyzing both radiological and chemical hazards. This is shown in Section B-3.0.

The radiological analysis considered three parameters, the total activity of the various radionuclides, the total activity that could reasonably be released via the bounding scenario, and the dose to on-site personnel. Based on total activity alone the project category would be HC2. Based on the activity that could be reasonable released the project category would be HC3. However, the project category is Radiological based on the dose to a worker at 30m. The analysis based on dose was used because dose is the only one of the three parameters that properly considers the low specific activity of the material.

The chemical analysis considered two parameters, the quantities of the various hazardous chemicals present, and the concentrations that would be generated during the bounding accident. Whereas five hazardous chemicals could be released in quantities exceeding the corresponding Threshold Planning Quantities, the airborne concentrations that would result are lower than the applicable Emergency Response Planning Guides. This is because of the low concentrations of the hazardous components in the bulk material. The "low" chemical hazard category specified is conservative.

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## B-1.0 INTRODUCTION

The purpose of this hazard categorization is to ensure that the appropriate level of hazard baseline documentation and approval authority is assigned to the project based on the severity of the hazards that may be encountered.

This document establishes the hazard category (HC) designation for the Silo 3 facility in accordance with DOE-STD-3009-94 (Ref. 1) for the following activities:

- Retrieval of material from Silo 3,
- Packaging of the material in storage bags for placement into cargo containers,
- Storage of cargo containers that are awaiting shipment.

The hazard baseline for the following activities has been documented separately in SA-2001-1026, Rev. 0 (Ref. 2):

- Continued storage of material in Silo 3
- Routine maintenance and upkeep of Silo 3, support equipment, and surrounding grounds
- Continued design, procurement, construction, and system operability testing of new facilities and/or existing facilities in support of Silo 3 final remediation.

### B-1.1 PREVIOUS ANALYSES

The preliminary hazard category for Silo 3 was first documented in FEMP-2337, *Preliminary Safety Analysis Report (PSAR) for Operable Unit 4* (Ref. 3). The preliminary hazard categorization of HC2 was determined by comparing the total inventory of Silo 3 radioactive materials to the threshold quantities listed in DOE-STD-1027-92. In accordance with DOE-STD-1027-92, the PSAR established the final hazard category for Silo 3 as HC-3, based on the hazards analysis.

Subsequent safety basis documents continued to document Silo 3 as HC-3, including the *Hazards Analysis Report (HAR) for Operable Unit* 4 (Ref. 4), and the *Preliminary Hazard Analysis Report for Silo* 3 (Ref. 5). Fluor Fernald re-evaluated the hazard category calculation that considers the bounding accident identified in the PHAR. This calculation documented as SA-CALC-052, *Silo 3 Earthquake Evaluation using DOE-STD-1027-92 Meteorological Conditions*(Ref. 6), shows that the radiological dose consequence from an earthquake does not present the potential for significant localized consequences for Silo 3 in its current storage configuration. Therefore, the dose consequence is below the HC3 dose threshold.

### B-1.2 SEGMENTATION

Silo 3 has been determined to be a separate segment from other existing OU4 facilities. This document provides the hazard categorization for the Silo 3 Project. The Silo 3 structure houses the entire inventory of hazardous materials associated with current Silo 3 activities, processes, and operations. Therefore, the "facility" considered for hazard categorization is limited to the Silo 3 structure and its contents. The concept of

independent facility segments is applied *within* a facility where facility features preclude bringing hazardous materials together or causing harmful interaction from a common severe phenomenon. Therefore, the Silo 3 facility constitutes a single segment.

This Hazard Category Calculation establishes that the Silo 3 Project consists of two additional segments with respect to safety analysis for future project configurations. Therefore, there are a total of three facility segments:

A. Silo 3 (existing structure and components)

B. Process Building

C. Interim Storage Area (ISA)

The Process Building consists of a process area containing material handling and bag-out facilities, the Excavator Room, the Excavator Service Room, and the Cargo Container Bay. The building is adjacent to and integral with Silo 3. After construction of the building and operation of the pneumatic retrieval system for removing the initial waste material, an opening will be cut in the silo to provide direct access to the silo internals from the Excavator Room (Ref. 21). The ISA pad will be used for storage of filled cargo containers awaiting shipment.

### B-1.3 BOUNDING ACCIDENTS

The most severe radiological and chemical hazards from the IHA, Appendix A, were selected for modeling the potentially releasable inventory to determine the HC. These hazards were identified as significant based on the frequency of occurrence and consequences. The hazards are listed in Table B.1.1.

For Silo 3, the catastrophic failure of the silo has been previously analyzed in SA-2001-1026 *Operable Unit 4 (OU4) Silo Project Auditable Safety Record*, and the dose consequences documented in SA-CALC-052 Rev. 0, *Silo 3 Earthquake Evaluation using DOE-STD-1027 Meteorological Conditions*. The additional silo accident analyzed is the silo structural failure during cutting a wall opening (EBA-2 in Appendix G).

For the Process Building, four accidents were analyzed, all with relatively low consequences. They included hose rupture (EBA-1), spill from conveyor (EBA-3), bag breach (EBA-4), and filter failure (EBA-5).

For the ISA, a container spill that releases the entire contents of several bags (EBA-6) was analyzed.

**Table B.1.1. Bounding Hazards from the Integrated Hazard Analysis**

| Segment Item | IHA Table ID | Potential Accident | Potential Releasable Inventory | Event Selected for Further Evaluation |
|---|---|---|---|---|
| A1 | 2e | Loss of Silo 3 containment due to earthquake | Loss of complete radon inventory plus radon emanating over a 24-hour period and 5.5 percent of the impacted solids | No, previously addressed in SA-2001-1026. |
| A2 | 2e | Failure of Silo 3 containment due to degraded structural conditions | Loss of complete radon inventory plus radon emanating over a 24-hour period and less than one percent of the impacted solids | No, this accident is bound by A1. |
| A3 | 2e | Failure of Silo 3 containment due to dropped load during construction | Loss of complete radon inventory plus radon emanating over a 24-hour period and less than one percent of the impacted solids | No, this accident is bound by A1. |
| A4 | 14c | Silo containment failure while cutting silo wall opening | Loss of complete radon inventory plus radon emanating over a 24-hour period and one percent of the impacted solids | Yes, most significant unanalyzed event for the Silo 3 segment. |
| A5 | 14h | Silo depressurization and collapse during pneumatic retrieval | Loss of complete radon inventory plus radon emanating over a 24-hour period and less than one percent of the impacted solids | No, this accident is bound by A4. |
| B1 | 14b | Hose rupture during pneumatic retrieval operations | Loss of complete radon inventory plus radon emanating over a 24-hour period and solids in the vacuum extractor line | No, material and radon release limited by inventory in equipment during operation. |
| B2 | 14d | Spill of material from conveyor failure | Solids and radon in equipment in operation after failure. 24-hour radon emanation from release of solids | No, both solids and radon release limited by material inventories in equipment. |
| B3 | 14e | Package failure during transport to cargo container | Solids and radon in package plus 24-hour radon emanation from released solids | No, both solids and radon release limited by material inventories. |
| B4 | 14g | Filter system failure during retrieval operations | Solids and radon released during operation after failure | No, solid and radon release limited by material inventory in equipment during operation. |
| C1 | 14f | Cargo container spill on ISA pad | A cargo container spill results in the loss of the entire contents. | Yes, this is the bounding accident for the ISA. |

## B-1.4 HAZARD CATEGORIZATION EXISTING CONDITIONS

10 CFR 830, Subpart B, *Safety Basis Requirements,* requires facility categorization based on associated nuclear hazards. Specifically, the hazard categorization process establishes

the thresholds above which 10 CFR 830, Subpart B are relevant and applicable. As stated in §830.202 (b) (3), contractors responsible for DOE nuclear facilities are required to categorize each facility based on its potential hazards, using methodology consistent with DOE-STD-1027-92 (Ref. 7). The scope identified in §830.200 specifies that the safety basis requirements identified in 10 CFR 830, Subpart B, are applicable to Hazard Category 1, 2, and 3 DOE nuclear facilities.

10 CFR 830 defines a facility as HC2 if the hazard analysis shows "...the potential for significant on-site consequences beyond localized consequences." DOE-STD-1027-92 further interprets the HC2 categorization as applicable to:

> Facilities with a potential for nuclear criticality events or with sufficient quantities of hazardous material and energy, which would require on-site emergency planning activities.

Table 1 of 10 CFR 830 defines a facility as HC3 if the hazard analysis shows "...the potential for only local significant consequences." DOE-STD-1027-92 further interprets the HC3 categorization as applicable to:

> Facilities with quantities of hazardous radioactive materials which meet or exceed Table A.1 values (Attachment 1 of DOE-STD-1027-92).

The preliminary hazard category of HC2 documented in FEMP-2337 was determined by comparing the total inventory of Silo 3 radioactive materials to the threshold quantities listed in Attachment 1 to DOE-STD-1027-92. The preliminary hazard categorization process does not take into account material form and potential dispersiveness, preventative or mitigative features, available energy sources, or accident credibility.

Provisions have also been made that allow for the final hazard categorization of a nonreactor nuclear facility to be based on safety analysis rather than inventory comparison. DOE-STD-1027-92 refers to an Interpretation Memorandum dated June 9, 1997, Black to Psaras, for guidance regarding the hazard categorization of environmental restoration activities. This memorandum has been included in Volume 2 of DOE-STD-1120-98, *Integration of Environment, Safety, and Health into Facility Dispositioning Activities* (Ref. 8). The memorandum states:

> For an analysis intended to demonstrate that a final hazard categorization for the facility would be below Category 3 (HC3), the analysis would be for an unmitigated release, with consequences determined that could be compared to the Category 3 threshold of "The hazard analysis shows the potential for only significant localized consequences."

Therefore, a facility with radiological material inventories in excess of HC3 material TQs can be categorized less than HC3 if a safety analysis (accident analysis) demonstrates

that, for a credible unmitigated release, a potential for significant localized consequences does not exist (i.e., TEDE is less than 10 rem at 30 m). In this context, "unmitigated" is meant to consider material quantity, form, location, depressiveness, and interaction, but is not meant to consider designed facility safety features (i.e., ventilation, fire suppression, etc.).

On this basis, the purpose of this Hazard Category Calculation is to determine if, due to Silo 3 retrieval and packaging operations, a credible accident scenario exists which has a risk of causing significant localized consequences, i.e., radiation doses in excess of 10 rem at 30 m, or concentrations of hazardous chemicals greater than Emergency Response Planning Guide (ERPG) guidelines.

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## B-2.0 DESCRIPTION OF HAZARDS

### B-2.1 RADIOACTIVE MATERIALS INVENTORY

The concentrations (pCi/g) of radionuclides found in Silo 3 material are shown in Table B.2.1. The radionuclide inventories are derived from the specific activity results obtained from the core sampling of Silo 3, which are tabulated in Table 42 of the *Remedial Investigation Report for OU4* (Ref. 9).

Silo 3 contains U-238, U-235 and Th-232 radionuclides and their daughter products (daughter products with half-lives of less than one hour are not included;...→ denotes other short-lived radionuclides in the chain), as indicated below:

U-238 ... → U-234 → Th-230 → Ra-226 → Pb-210

U-235 ... → Pa-231 → Ac-227

Th-232 → Ra-228 ... → Th-228 → Ra-224

The 95 percent upper confidence limit (UCL) concentrations of 12 radionuclides in the Silo 3 material are taken from Table 41 ("Summary of Radionuclide Analysis for Silo 3 Material") from the *Remedial Investigation Report for OU4* (Ref. 9). A 13$^{th}$ radionuclide, U-236, is included because the analytical results report U-235/U-236 together. U-236 is a daughter product of Pu-240 and does not routinely occur in nature. This hazard category calculation assumes the reported activity in this case is U-235. Other radionuclides in the U-238, U-235, and Th-232 series including the short-lived daughters are also considered for categorization. The length of time for these radionuclides to reach secular equilibrium ranges from 30 to 100 years. The short-lived daughter products in each series are considered to be in secular equilibrium with their parents. 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 radionuclide concentrations are shown in Table B.2.1 and the total activity concentration of all radionuclides is calculated to be 97.4 nCi/g. The short-lived daughters not listed in Table B.2.1 include Po-218, Rn-219, Po-215, Bi-211, Tl-207, Po-216, Po-212, and Tl-208.

The Remedial Investigation conducted for Silo 3 reports that the silo contains approximately 5,088 yd$^3$ of residue, ranging in material density from 29 to 58 lb/ft$^3$. Based on the maximum estimated density, the available silo material weighs a maximum of 3,993 tons (7.99 x 10$^6$ lb.). The total activity of all the radionuclides is calculated as 370 Ci, as shown in Table B.2.1.

The Process Building and Cargo Container Bay inventory is estimated based on the material volumes in the various stages of retrieval and packaging, which is approximately 2,100 cf. During pneumatic retrieval, material is present in the Pneumatic Retrieval Collector, Cartridge Filter, Discharge Feeder, Feed Conveyor, and Packaging System. During mechanical retrieval, material is present in the Retrieval Bin, Inclined Conveyor, Transfer Conveyor, Feed Conveyor, and Packaging System. It is assumed that up to 16 full bags are in the Cargo Container Bay, which comprises the majority of the building

inventory. Material is also present in the Process Vent Dust Collectors. Based on the maximum density, the silo material inventory in the Process Building and Cargo Container Bay is approximately 121,800 lb, or 5.64 Ci.

In the ISA, each cargo container can physically hold up to 8 storage bags. Each storage bag can physically be filled with 96 $ft^3$ of Silo 3 material. Therefore, each container may have up to 44,544 lbs (at 58 $lb/ft^3$), or 2.06 Ci. A comparision of inventory, as a function of number of containers, to HC thresholds will be performed in the next section.

**Table B.2.1. Silo 3 Radioactive Material Inventories**

| Radio-nuclide | Silo 3 Activity Concentrations (pCi/g) | Silo 3 Radionuclide Inventory (Ci) | Building Inventory (Ci) | ISA Inventory per Cargo Container (Ci) |
|---|---|---|---|---|
| Ac-227 | 925 | 3.4 | 5.11E-02 | 1.87E-02 |
| Ac-228 | 406 | 1.5 | 2.25E-02 | 8.21E-03 |
| Bi-210 | 3,480 | 12.6 | 1.92E-01 | 7.04E-02 |
| Bi-212 | 367 | 1.3 | 2.03E-02 | 7.42E-03 |
| Bi-214 | 3,870 | 14.0 | 2.14E-01 | 7.83E-02 |
| Fr-223 | 13 | 0.0 | 7.19E-04 | 2.63E-04 |
| Pb-210 | 3,480 | 12.6 | 1.92E-01 | 7.04E-02 |
| Pb-211 | 925 | 3.4 | 5.11E-02 | 1.87E-02 |
| Pb-212 | 367 | 1.3 | 2.03E-02 | 7.42E-03 |
| Pb-214 | 3,870 | 14.0 | 2.14E-01 | 7.83E-02 |
| Po-210 | 3,480 | 12.6 | 1.92E-01 | 7.04E-02 |
| Pa-231 | 627 | 2.3 | 3.47E-02 | 1.27E-02 |
| Pa-234 | 2 | 0.0 | 1.11E-04 | 4.04E-05 |
| Pa-234m | 1,778 | 6.4 | 9.83E-02 | 3.60E-02 |
| Ra-223 | 925 | 3.4 | 5.11E-02 | 1.87E-02 |
| Ra-224 | 367 | 1.3 | 2.03E-02 | 7.42E-03 |
| Ra-226 | 3,870 | 14.0 | 2.14E-01 | 7.83E-02 |
| Ra-228 | 406 | 1.5 | 2.25E-02 | 8.21E-03 |
| Th-227 | 925 | 3.4 | 5.11E-02 | 1.87E-02 |
| Th-228 | 747 | 2.7 | 4.13E-02 | 1.51E-02 |
| Th-230 | 60,200 | 218.3 | 3.33E+00 | 1.22E+00 |
| Th-231 | 117 | 0.4 | 6.47E-03 | 2.37E-03 |
| Th-232 | 842 | 3.1 | 4.66E-02 | 1.70E-02 |
| Th-234 | 1,780 | 6.5 | 9.84E-02 | 3.60E-02 |
| U-234 | 1,730 | 6.3 | 9.57E-02 | 3.50E-02 |
| U-235/236 | 117 | 0.4 | 6.47E-03 | 2.37E-03 |
| U-238 | 1,780 | 6.5 | 9.84E-02 | 3.60E-02 |
| Rn-220 | 838 | 3.0 | 4.54E-02 | 1.66E-02 |
| Rn-222 | 3870 | 14.0 | 2.14E-01 | 7.81E-02 |
| **Total (Ci)** | **97,400** | **370** | **5.64** | **2.06** |
| Mass (lbs) | | 7,986,600 | 121,800 | 44,544 |
| Volume (cf) | | 137,400 | 2,100 | 768 |

## B-2.2 CHEMICAL INVENTORIES

Chemical constituents are present in the Silo 3 material. In addition, process chemicals will be brought into the facility.

### B-2.2.1 Silo 3 Waste

A total of 22 metals have been identified in the chemical composition of this waste. Previous analyses indicate that the material contains up to 15 percent sulfate and has undergone calcination in temperatures up to 820°C (1,500°F). At this temperature, elements are chemically bonded with their sulfate and oxide compounds. If the sulfate is not stable, it will convert into oxide and sulfur dioxide (gas). Any volatile organic compounds (VOC) present would have completely decomposed during calcination.

Silo 3 elemental concentrations (mg/kg) are shown in Table B.2.2. These concentrations are converted into potentially releasable inventory (PRI) for comparison to thresholds. The PRI assumes 3,993 tons of Silo 3 material and an estimated damage ratio of 5.5%, which is material release determined for the earthquake silo failure in the Auditable Safety Record.

No compounds listed in 29 CFR 1910.119 (Ref. 10) are contained in the Silo 3 waste material. The potential chemical compounds are compared against the Reportable Quantities (RQs) in 40 CFR Part 302.4 (Ref. 11) for a preliminary hazard screening per DOE-EM-STD-5502-94. The results of this comparison indicate eighteen chemical compounds may be present in inventories exceeding the RQ values. Moreover, of the chemical compounds, five compounds exceed threshold planning quantity (TPQ) values established in 40 CFR 355 (Ref. 12), as shown in Table B.2.2.

Materials released in excess of the reportable quantity are of regulatory concern. In addition, these compounds are toxic and of a health concern from OSHA and American Conference of Governmental Industrial Hygienists (ACGIH) points of view and must be given proper consideration during the development of the project-specific health and safety plan.

The 40 CFR 355 TPQ values are listed for the compounds of five metals, arsenic, cadmium, mercury, thallium, and vanadium. Based on this comparison, compounds for all these five elements are above the TPQ values, for the catastrophic silo failure. These compounds are vanadium pentoxide, arsenic trioxide, cadmium oxide, mercuric oxide, and thallium sulfate.

There are no values listed for the remaining 17 elements as sulfates or oxides. Since the preliminary hazard categorization would be driven to HC3 if the size of the inventory were to be considered alone, the concentrations of arsenic trioxide and vanadium pentoxide are assessed in the accident analyses.

Table B.2.2. Inventory of Inorganic Chemicals

| Inorganic Chemical | Concentration[a] (mg/kg) | Total Elemental Mass[b] (kg) | Potentially Releasable Inventory[c] (kg) | Table 40 CFR 302.4 | | | 40 CFR 355 | |
|---|---|---|---|---|---|---|---|---|
| | | | | RQ[d] (kg) | Applicable Chemical Compound[e] | Exceed RQ | TPQ[d] (kg) | Exceed TPQ |
| Aluminum | 29,500 | 106,965 | 5,883 | 2,270 | Aluminum sulfate | Yes | n.l. | |
| Arsenic | 7,270 | 26,360 | 1,450 | 0.454 | Arsenic trioxide | Yes | 45.4 | Yes |
| Barium | 57 | 207 | 11 | Not listed | | | n.l. | |
| Beryllium | 9.2 | 33 | 2 | 4.54 | Beryllium powder | Yes | n.l. | |
| Cadmium | 343 | 1,244 | 68 | 0.454 | Cadmium oxide | Yes | 45.4 | Yes |
| Calcium | 57,500 | 208,490 | 11,467 | Not listed | | | n.l. | |
| Chromium | 823 | 2,984 | 164 | Not listed | | | n.l. | |
| Cobalt | 6,280 | 22,771 | 1,252 | Not listed | | | n.l. | |
| Copper | 7,360 | 26,687 | 1,468 | 4.54 | Copper sulfate | Yes | n.l. | |
| Iron | 113,000 | 409,729 | 22,535 | 454 | Ferric sulfate | Yes | n.l. | |
| Lead | 6,800 | 24,656 | 1,356 | 4.54 | Lead sulfate | Yes | n.l. | |
| Magnesium | 120,000 | 435,110 | 23,931 | Not listed | | | n.l. | |
| Manganese | 13,200 | 47,862 | 2,632 | Not listed | | | n.l. | |
| Mercury | 1,740 | 6,309 | 347 | 4.54 | Mercuric sulfate | Yes | n.l. | |
| | | 35,860 | 1,972 | 0.454 | Mercuric oxide | Yes | 227 | Yes |
| Nickel | 9,890 | 287,173 | 15,794 | 45.4 | Nickel sulfate | Yes | n.l. | |
| Potassium | 79,200 | 3,271 | 180 | Not listed | | | n.l. | |
| Selenium | 902 | 3,013 | 166 | 4.54 | Selenium dioxide | Yes | n.l. | |
| Silver | 831 | 333,947 | 18,367 | Not listed | | | n.l. | |
| Sodium | 92,100 | 591 | 33 | Not listed | | | n.l. | |
| Thallium | 163 | 39,522 | 2,174 | 45.4 | Thallium oxide or sulfate | Yes | 45.4 | Yes |
| Vanadium | 10,900 | 3,078 | 169 | 454 | Vanadium pentoxide | No | 45.4 | Yes |
| Zinc | 849 | 106,965 | 5,883 | 454 | Zinc sulfate | No | n.l. | |

[a]The 95th percentile concentrations are taken from WSRC-TR-2000-00523, Appendix 3 (Ref. 13).
[b]Total Elemental Mass (kg) = Concentration (mg/kg) x 3,993 tons material x 908 kg/ton x kg/$10^6$mg
[c]Potentially Releasable Inventory (kg) = Total Elemental Mass x Damage Ratio of 5.5%
[d]RQ is taken from Table 40 CFR 302.4 (Final RQ); TPQ taken from 40 CFR 355, Appendix A
[e]Sulfate or oxide compound assumed based on process chemistry (beryllium powder assumed here for conservatism)

### B-2.2.2 Process Chemicals

In addition to the chemical constituents in the waste, process chemicals are brought into the Process Building. The Silo 3 materials will be pretreated with sodium lignosulfonate solution. The solution is a polymeric organic binder, which is 47-weight percent sodium lignosulfonate. The solution is a lignin waste product of pulp and paper processing; it is dark brown with a characteristic vanilla-like odor.

The solution will be delivered in 275 gal. containers. One container will be staged in the Cargo Container Bay and 30 gal/day will be used. The inventory is estimated to be approximately 300 gal. sodium lignosulfonate is not listed in 40 CFR 355 or 40 CFR 302.4.

Ferrous sulfate will also be used in the pretreatment. A 4,500 gal storage tank is located in the Cargo Container Bay and 340 gal. will typically be present in the wastewater tank area. The 40 CFR 302.4 RQ is 1,000 lb; therefore, the inventory exceeds the RQ. Ferrous sulfate is not listed in 40 CFR 355. Ferrous sulfate has irritating fumes, and must be stored in a cool, dry, ventilated area.

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## B-3.0 CALCULATIONS

Hazard categorization is dependent upon nonstandard hazards (such as chemical or radionuclide releases), and the short-term exposure to a nearby human receptor.

The method used in this section is to calculate, for the selected accident scenarios, the potentially releasable radiological inventory and compare to the threshold values in DOE-STD-1027-92 (Ref. 7). The HC3 threshold criterion is based on an exposure less than 10 rem at 30 m in 24 hours. The HC2 threshold criterion is based on an exposure less than 1 rem at the nearest off-site location in 2 hours. Therefore, in addition to comparing potentially releasable inventories to threshold values, exposures will also be calculated using site-specific parameters for comparison to dose criteria.

For chemical hazards, the potentially releasable chemical inventory is compared to the 40 CFR 302 reportable quantity values and the 40 CFR 355 threshold planning quantities. Once it is determined that the threshold values have been exceeded, an evaluation of the consequence severity from those chemicals is performed by comparing accident concentrations to Emergency Response Planning Guide (ERPG) limits.

### B-3.1 PRELIMINARY HAZARD CATEGORIZATION

The preliminary hazard categorization is based on comparing the total inventory in each segment to the values listed in DOE-STD-1027-92, Attachment 1, Table A.1. The sum of the fractions for the Silo 3 inventory, 370 curies, is presented in Table B.3.1. The sum of the fractions exceeds one for HC2; therefore, the preliminary categorization of the Silo is HC2.

The amount of Silo 3 material inventory required to exceed the HC3 threshold is 0.7 curies. The material inventory that exceeds the HC2 threshold is 93 curies. Therefore, the preliminary categorization of the Process Building, which contains up to 5.64 curies, is HC3. The preliminary categorization of one cargo container, which contains 2.06 curies, is also HC3. The preliminary categorization of the ISA, which could physically contain up to approximately one half the entire silo inventory, is HC2.

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Table B.3.1. Preliminary Hazard Categorization

| Radio-nuclide | Silo 3 Radionuclide Inventory (Ci) | HC-3 Threshold (Ci) | HC-2 Threshold (Ci) | Fraction of HC-3 Threshold | Fraction of HC-2 Threshold |
|---|---|---|---|---|---|
| Ac-227 | 3.4 | 0.042 | 4 | 7.99E+01 | 7.80E-01 |
| Ac-228 | 1.5 | 940 | 430,000 | 1.57E-03 | 3.42E-06 |
| Bi-210 | 12.6 | 320 | 150,000 | 3.94E-02 | 8.41E-05 |
| Bi-212 | 1.3 | 2,000 | 430,000 | 6.65E-04 | 3.09E-06 |
| Bi-214 | 14.0 | 8,200 | 430,000 | 1.71E-03 | 3.26E-05 |
| Fr-223 | 0.0 | 8,200 | 430,000 | 5.75E-06 | 1.10E-07 |
| Pb-210 | 12.6 | 0.36 | 2,200 | 3.51E+01 | 5.74E-03 |
| Pb-211 | 3.4 | 6,200 | 430,000 | 5.41E-04 | 7.80E-06 |
| Pb-212 | 1.3 | 320 | 430,000 | 4.16E-03 | 3.09E-06 |
| Pb-214 | 14.0 | 8,200 | 430,000 | 1.71E-03 | 3.26E-05 |
| Po-210 | 12.6 | 1.9 | 350 | 6.64E+00 | 3.61E-02 |
| Pa-231 | 2.3 | 0.2 | 55 | 1.14E+01 | 4.13E-02 |
| Pa-234 | 0.0 | 1,520 | 430,000 | 4.77E-06 | 1.69E-08 |
| Pa-234m | 6.4 | 1,520 | 430,000 | 4.24E-03 | 1.50E-05 |
| Ra-223 | 3.4 | 62 | 3,800 | 5.41E-02 | 8.83E-04 |
| Ra-224 | 1.3 | 200 | 9,900 | 6.65E-03 | 1.34E-04 |
| Ra-226 | 14.0 | 12 | 55 | 1.17E+00 | 2.55E-01 |
| Ra-228 | 1.5 | 12 | 55 | 1.23E-01 | 2.68E-02 |
| Th-227 | 3.4 | 32 | 55 | 1.05E-01 | 6.10E-02 |
| Th-228 | 2.7 | 1 | 92 | 2.71E+00 | 2.94E-02 |
| Th-230 | 218.3 | 0.62 | 89 | 3.52E+02 | 2.45E+00 |
| Th-231 | 0.4 | 12,000 | 430,000 | 3.54E-05 | 9.87E-07 |
| Th-232 | 3.1 | 0.1 | 18 | 3.05E+01 | 1.70E-01 |
| Th-234 | 6.5 | 2,800 | 430,000 | 2.31E-03 | 1.50E-05 |
| U-234 | 6.3 | 4.2 | 220 | 1.49E+00 | 2.85E-02 |
| U-235/236 | 0.4 | 4.2 | 240 | 1.01E-01 | 1.77E-03 |
| U-238 | 6.5 | 4.2 | 240 | 1.54E+00 | 2.69E-02 |
| Rn-220 | 3.0 | 2 | 55 | 1.49E+00 | 5.42E-02 |
| Rn-222 | 14.0 | 10 | 260,000,000 | 1.40E+00 | 5.38E-08 |
| Total (Ci) | 370 | | | | |
| Mass (lbs) | 7.99E+06 | | | | |
| | | | Sum of the Fractions | 526 | 4.0 |

## B-3.2 FINAL HAZARD CATEGORIZATION

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The potentially releasable inventory (PRI) is the amount of radioactive or hazardous material that can be released and present a respirable hazard. The PRI is compared to the applicable threshold quantities (TQs) for constituents listed in DOE-STD-1027-92 Table A-1 (Ref. 3) for HC3 and HC2 facilities.

### B-3.2.1 Material at Risk

The material at risk (MAR) is the inventory of Silo 3 material in each segment. As shown in Table B.2.1, the radiological inventory in Silo 3 is 370 Ci, the inventory in the Process Building and Cargo Container Bay is 5.64 Ci, and the inventory in one storage container is 2.06 Ci. The inventory in the ISA could equal approximately one-half the silo inventory of 370 Ci, based on storage capacity.

The MAR for the silo failure during wall cutting will be reduced. Some material has been removed from the vicinity of the wall cut before performing the wall cut operation. It is assumed that 25 percent of the original silo material volume has been removed before the collapse.

### B-3.2.2 Potentially Releasable Inventory

The PRI is that portion of the MAR source term released external to the facility. It is a function of the accident, the release fraction or rate, and the facility leak path factor.

The silo failure due to an earthquake was analyzed previously in the ASR. The silo failure during wall cutting operations is analyzed in this calculation. The Process Building accidents are bound by the silo accidents. The cargo container accident on the ISA is also analyzed.

#### B-3.2.2.1 Solids Released

The silo failure during wall cutting results in the release of solids. 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 collapsed region. The material spilling out of the collapsed region would be minimal and it is conservatively assumed that 1 percent of the silo MAR, at the time of collapse, spills outside the silo. The solid mass released is $7.99 \times 10^6$ lb x 0.75 x 0.01 = 59,930 lb.

The cargo container accident results in a spill of material from the container. The 8 bags, at 96 $ft^3$ each, have a total volume of 768 $ft^3$ and a total material mass of 44,544 lbs (at 58 $lb/ft^3$). The fraction of bags that open (damage ratio) is assumed as 100%. The fraction of material that leaks from the packages (leakpath factor) is assumed as 50%.

#### B-3.2.2.2 Radon Released

The initial radon release from the silo failure 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 x $10^6$ pCi/minute over the next 24 hours. These values are 75% of the values obtained with the original material volume.

Radon present in the spilled cargo container material void spaces and radon generated over the next 24 hours is released to the atmosphere. The 768 $ft^3$ of spilled material contains 0.078 Ci $Ra^{226}$, at the maximum material density.

### B-3.2.3 Potentially Releasable Inventory Comparison Results

Potentially releasable inventories are shown in Table B.3.2. As detailed in Section B.3.1, the inventory of Silo 3 material required to exceed HC3 thresholds is 0.7 Ci. Therefore, the PRI of these accidents exceed HC3.

**Table B.3.2. Potentially Releasable Inventory Comparison to DOE STD-1027-92**

| Nuclide | PRI for Silo Failure during Wall Cutting (Ci) | PRI for Cargo Container Spill (Ci) |
|---|---|---|
| Ac-227 | 2.52E-02 | 9.35E-03 |
| Ac-228 | 1.10E-02 | 4.11E-03 |
| Bi-210 | 9.46E-02 | 3.52E-02 |
| Bi-212 | 9.98E-03 | 3.71E-03 |
| Bi-214 | 1.05E-01 | 3.91E-02 |
| Fr-223 | 3.54E-04 | 1.31E-04 |
| Pb-210 | 9.46E-02 | 3.52E-02 |
| Pb-211 | 2.52E-02 | 9.35E-03 |
| Pb-212 | 9.98E-03 | 3.71E-03 |
| Pb-214 | 1.05E-01 | 3.91E-02 |
| Po-210 | 9.46E-02 | 3.52E-02 |
| Pa-231 | 1.71E-02 | 6.34E-03 |
| Pa-234 | 5.44E-05 | 2.02E-05 |
| Pa-234m | 4.84E-02 | 1.80E-02 |
| Ra-223 | 2.52E-02 | 9.35E-03 |
| Ra-224 | 9.98E-03 | 3.71E-03 |
| Ra-226 | 1.05E-01 | 3.91E-02 |
| Ra-228 | 1.10E-02 | 4.11E-03 |
| Th-227 | 2.52E-02 | 9.35E-03 |
| Th-228 | 2.03E-02 | 7.55E-03 |
| Th-230 | 1.64E+00 | 6.09E-01 |
| Th-231 | 3.18E-03 | 1.18E-03 |
| Th-232 | 2.29E-02 | 8.51E-03 |
| Th-234 | 4.84E-02 | 1.80E-02 |
| U-234 | 4.70E-02 | 1.75E-02 |
| U-235/236 | 3.18E-03 | 1.18E-03 |
| U-238 | 4.84E-02 | 1.80E-02 |
| Rn-220 | 2.24E-02 | 1.66E-02 |
| Rn-222 | 1.05E-01 | 7.81E-02 |
| Total (Ci) | 2.78 | 1.08 |

### B-3.2.4 Hazard Categorization Based on Radiological Dose Criteria

Dose consequences are determined for workers at 30 m, for comparison to the dose threshold criteria of DOE HC3 facilities, which is 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. 4):

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

where:

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

The dispersion factor ($\chi/Q$) 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. 14). 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. 6), 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 $\chi/Q$ is $1.77 \times 10^{-2}$ at 30 m and $1.05 \times 10^{-3}$ 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. The airborne release fraction (ARF) and respirable fraction (RF) of the solid powder material is obtained from DOE-HDBK-3010-94, *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities* (Ref.

15). The bounding ARF for a free-fall spill of uncontained powders, page 4-77 of Ref. 15, is 2 x $10^{-3}$. 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 3.0 of Appendix G.

The ARF for powders impacted by a falling object, page 4-85 of Ref. 15, is 1 x $10^{-3}$ and the RF is 0.1. The airborne release rate (ARR) due to aerodynamic resuspension of spilled powders due to ambient wind stresses is detailed on page 4-96 of Ref. 15. The ARR is assumed to be 4E-5/hr and the RF is 1.0.

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. 16). 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 Fernald Radon Model,* to estimate radon air concentrations at different site locations for various release scenarios and dose conversions described in Appendix G (Ref. 17).

**Table B.3.3. 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 | 18 | 3 | 0.3 |
| 100 m (HC-2) | 16 | 4 | < 1 | 0.02 |
| **Cargo Container Spill (EBA-6, Appendix G)** | | | | |
| 30 m (HC-3) | 1585 | 12 | 2 | 1.6 |
| 100 m (HC-2) | 41 | 3 | < 1 | 0.04 |

The total dose is the sum of the dose from solids, the dose from radon released initially, and the dose from radon released continuously. At 30 m, the dose from each event is less than the dose limit of 10 rem. At 100 m dose from each event is less than the dose limit of 1 rem. Since the dose consequences are less than the criteria, the Silo 3 facility is categorized as a Radiological Facility.

## 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.

Once it is determined that the threshold values have been exceeded, an evaluation of the consequence severity is conducted to properly classify the hazard as high, medium, or low. Non-nuclear facilities are classified as either having high, moderate, or low hazards, based on the following guidelines and those provided in Table B.3.4.

- High: hazards with a potential for on-site and off-site impacts to large numbers of persons or for major impacts to the environment
- Moderate: hazards that present considerable potential on-site impacts to people or the environment, but most only minor off-site impacts
- Low: hazards which present minor on-site and negligible off-site impacts to people and the environment

The high, moderate, and low health consequences may be related to an Emergency Response Planning Guide (ERPG) system (Ref. 18), where the ERPGs are the only well-documented parameters developed to date specifically for use in evaluating the health consequence of the general public to accidental releases of hazardous chemicals. Within the ERPG system, three biological reference values are defined as follows:

- ERPG-1: The maximum concentration in air below which it is believed nearly all individuals could be exposed for up to one hour without experiencing other than mild transient adverse health effects or perceiving a clearly defined objectionable odor;
- ERPG-2: The maximum concentration in air below which it is believed nearly all individuals could be exposed for up to one hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action;
- ERPG-3: The maximum concentration in air below which it is believed nearly all individuals could be exposed for up to one hour without experiencing or developing life-threatening health effects.

**Table B.3.4. Chemical Hazard Classification Guidelines**

| Hazard | On-Site Concentration | Off-Site Concentration |
|---|---|---|
| High | N/A | Greater than ERPG-3 |
| Moderate | Greater than ERPG-3 | From ERPG-2 to ERPG-3 |
| Low | From ERPG-2 to ERPG-3 | From ERPG-1 to ERPG-2 |

### B-3.3.1 Comparison of Potentially Releasable Hazardous Chemicals to Thresholds Limits

Of the 22 chemicals listed in Section B.2, only five exceed the TPQ values, for the silo failure resulting from an earthquake as shown in Section B.2. The five include arsenic, cadmium, mercury, nickel, and vanadium. For conservatism, these 5 will be considered

for analysis of the less severe accidents. In addition, ferrous sulfate will be analyzed further, since it exceeded the RQ, and the results are shown in Table B.3.6.

### B-3.3.2 Evaluation of Chemical Consequence Severity and Hazard Categorization

The evaluation guidelines used for determining toxic chemical hazard classification are provided by *Toxic Chemical Hazard Classification and Risk Acceptance Guidelines for Use in DOE Facilities* (Ref. 19). The consequence severity is determined by evaluating each hazardous chemical in which the PRI exceeds the TPQ.

The peak airborne concentration available to on-site and off-site receptors, is estimated by a straight-line Gaussian dispersion model for each hazardous chemical in which the PRI exceeds the TPQ. The dispersion model uses stability class F and a 1 m/second wind speed. The on-site receptor is assumed to be located downwind at a centerline plume distance of 100 m; while the off-site receptor is located at 350 m (site boundary). Both receptors assume ground level concentrations.

The peak chemical concentrations are then compared to the primary concentration guidelines to determine the appropriate hazard rating (high, moderate, or low).

**Chemical Dispersion Model**

Chemical concentrations were determined using a similar approach to that used for radioactive solids. The peak chemical concentrations (C) for each chemical (i) are determined by the following equation:

$$C_i = \frac{MAR_i \cdot ARF \cdot RF \cdot LPF \cdot DR \cdot \frac{\chi}{Q}}{t}$$

where:

$C_i$ is the concentration (mg/m$^3$) of the chemical constituent at the receptor,

t is the time the release is integrated over

The dispersion parameter ($\chi$/Q) used for chemical dispersion is the same value as used for radiological solids dispersion. A wind speed of 1.0 m/second and F stability class was used. The $\chi$/Q is 9.08 x $10^{-3}$ at 100m and 9.0 x $10^{-4}$ at 350 m. Table B.3.5 lists the required parameters.

**Table B.3.5. Parameters for Calculating Chemical Concentrations**

| Parameter | Initial Release | Ferrous Sulfate Spill |
|---|---|---|
| MAR (kg) | Chemical specific | 32,000 kg (4,500 gal) |
| Release duration (t in hrs) | 1 | 1 |
| ARF | 1E-3 | 5E-5 |
| RF | 0.1 | 0.8 |
| LPF | 0.01 | 1 |

| | | |
|---|---|---|
| DR | 1 | 1 |
| X/Q @ 100 m | 9.08E-3 | 9.08E-3 |
| X/Q @ 350 m | 9.0E-4 | 9.0E-4 |

The five chemical compounds are released as a result of the silo failure during wall cutting. The ferrous sulfate spill assumes the 4,500 gal. tank ruptures spilling the entire contents into the Cargo Container Bay. The ARF and RF values are obtained from DOE-HDBK-3010-94, *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities* (Ref. 15), for a free fall spill of a liquid. It is assumed that the structure provides no containment.

Table B.3.6 provides the maximum concentrations of chemical compounds from the postulated scenarios at distances of 100 and 350 m for comparison to the ERPG values for those chemicals.

**Table B.3.6. Chemical Concentration Comparison to ERPGs**

| Chemicals | Concentration | | ERPG-1 ($mg/m^3$) | ERPG-2 ($mg/m^3$) | ERPG-3 ($mg/m^3$) |
|---|---|---|---|---|---|
| | On-site ($mg/m^3$) | Off-site ($mg/m^3$) | | | |
| | | | | | |
| Arsenic trioxide | 5.61E-02 | 5.56E-03 | 0.03 | 1.4 | 5 |
| Cadmium oxide | 1.96E-03 | 1.94E-04 | 0.035 | 0.05 | 12.5 |
| Mercuric oxide | 9.42E-03 | 9.34E-04 | 0.075 | 0.1 | 10 |
| Thallium sulfate | 1.20E-03 | 1.19E-04 | 0.3 | 2 | 15 |
| Vanadium pentoxide | 9.83E-02 | 9.75E-03 | 0.075 | 0.5 | 35 |
| | | | | | |
| Ferrous Sulfate | 3.26 | 0.32 | 7.5 | 12.5 | 350 |

The on-site concentrations are below ERPG-2 and the off-site concentrations are below ERPG-1. As shown in Table B.3.4, these concentrations result in a "Low" chemical hazard classification.

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## B-4.0 FINAL HAZARD CATEGORY

The results of these analyses demonstrate that the Silo 3 Facility may be reasonably categorized as a Radiological Facility with a "low" chemical hazard. Anticipated dose consequences do not exceed the associated dose guidelines, i.e., 10 rem at 30 m and 1 rem at 100 m, and anticipated chemical concentrations do not exceed the corresponding ERPG concentrations.

These analyses are appropriate for the development of graded safety analysis required by 10 CFR 830 Appendix A, Table 2 (Ref. 20). Detailed accident analyses are provided in Appendix G of the Silo 3 Nuclear Health and Safety Plan, although not required for radiological facilities, to give a better understanding of the material that can be physically released from the facility and the associated risks to workers, the public, and the environment.

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## B-5.0 REFERENCES

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19. *Toxic Chemical Hazard Classification and Risk Acceptance Guidelines for Use in DOE Facilities*, WSRC-MS-92-206, Revision 2, March 1995.

20. *Code of Federal Regulations*, Title 10. Part 830, Nuclear Safety Management.

21. Jacobs, *Access and Retrieval Strategy for the Silo 3 Project*, 40430-PL-0002, July 2002.