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REMOVAL SITE EVALUATION PLANT 1 ORE SILOS AUGUST, 1991

08-014-1991

DOE-FSO/WEMCO
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ENCLOSURE

[redacted]

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REMOVAL SITE EVALUATION

PLANT 1 ORE SILOS

FERNALD SITE OFFICE (FSO)

FERNALD, OHIO

AUGUST, 1991

U. S. DEPARTMENT OF ENERGY

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1.0 INTRODUCTION

The Plant 1 Ore Silos were constructed in 1953. The earliest use of these bins was to store Q11 ore concentrate for use in the refinery, Plant 2/3. The last operational use during 1955-1958 was to store overflow cold metal oxides which were primarily transferred from Plant 2/3 to Silo 3 in the Waste Storage Area. In 1962, the Plant 1 Ore Silos were emptied and the material was shipped off-site.

There are four 44 feet high silos and four 10 feet high silos constructed of glazed tile mounted on a steel structure. There are also six 10 feet high reinforced concrete silos. The structures elevate the silos, so the bases are above the ground level for material handling purposes. The supporting structures for the tile silos are about 38 feet high as shown in Figure 1. Figure 2 is a map which shows the configuration of the Silos and their spacial relationship to various surrounding structures at the Fernald Site (FS). Figure 3 is a plan drawing which includes the equipment number, F2-25 etc.; and the number sequence (1-14) used to designate each one of the Silos.

The Silo contents included residues which were the cold metal oxide by-products from the processing of pitchblende and lower grade ores. As part of the refinery processes, the more soluble radionuclide forms, including isotopes of radium, were dissolved from feed material. At times, the Silos contained the Q-11 ore concentrates prior to processing.

The analytical data for these residues is limited. Since there are process similarities, the silo residues may resemble those in Silo 3. If so, the materials can be expected to be approximately 25% phosphate salts, 25% sulfate salts and 17% silicon dioxide (percentage by weight). In addition, about 30% is in the form of metals including iron, magnesium, calcium, sodium, and aluminum.

The processing of these materials ceased during the 1960's, and the silos were declared to be "abandoned in place." Residues remaining in the silos range from negligible quantities to an approximate depth of 3.5 feet in the conical bases.

1.1 Status of Plant 1 Ore Silos

On February 6, 1991, leakage of residues from the Silos was discovered and reported (CERCLA Section 302). Approximately 2,600 pounds of residues had been released and were located below Silos 1, 2 and 5. These residues were sampled and cleaned-up (recovered). In addition, plates were welded at the base of each silo to prevent any further release, and plates were also placed at the tops of the Silos to prevent intrusion of precipitation and to assure containment.

During mid-March, more detailed radiation surveys were made, and samples were collected from the silos to characterize the contents. Subsequent sampling continued through May 1, 1991. 3

The preliminary assessment of the silos included a structural analysis. Wind load stresses are critical for the 44 feet tall tile

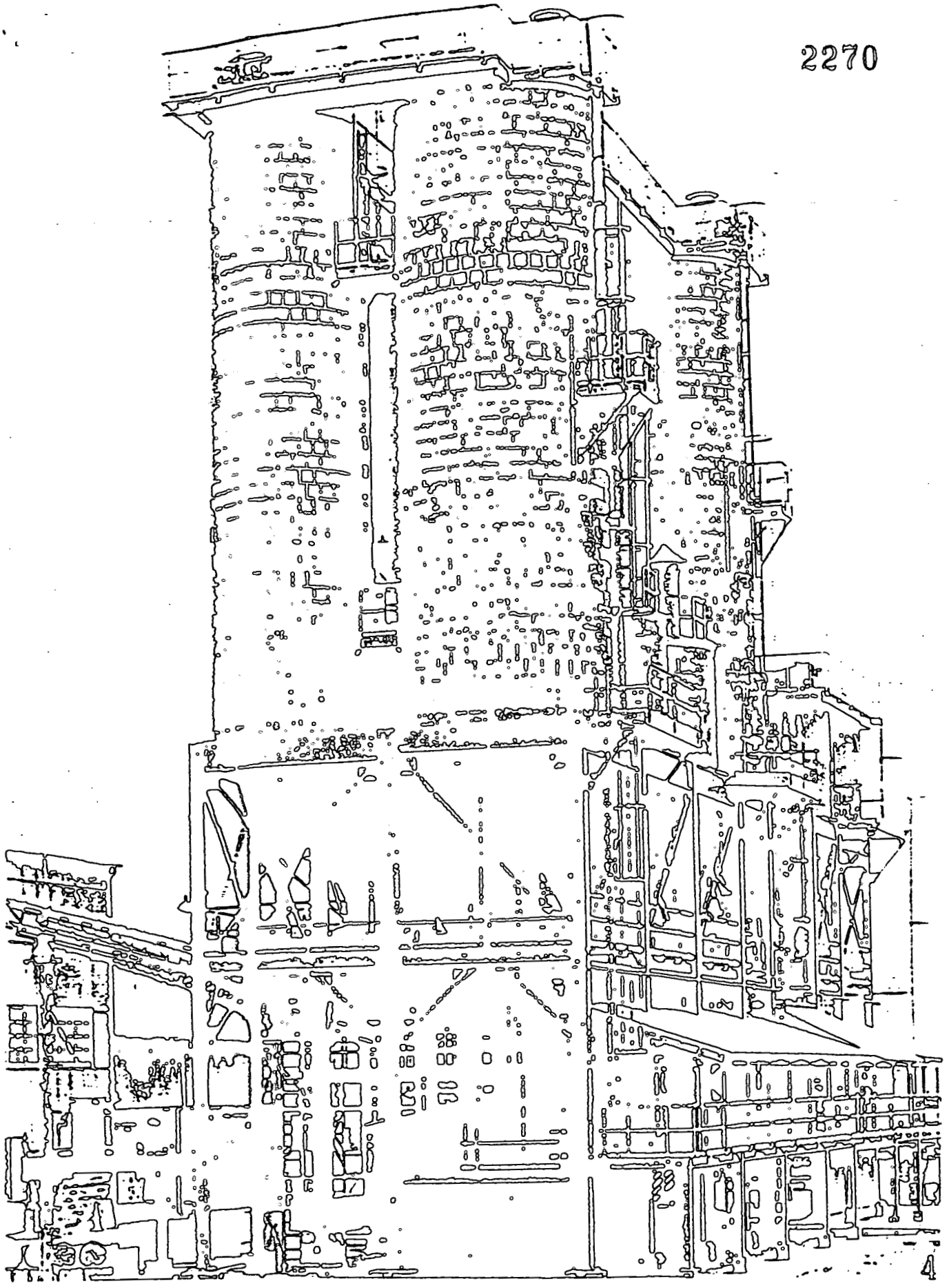
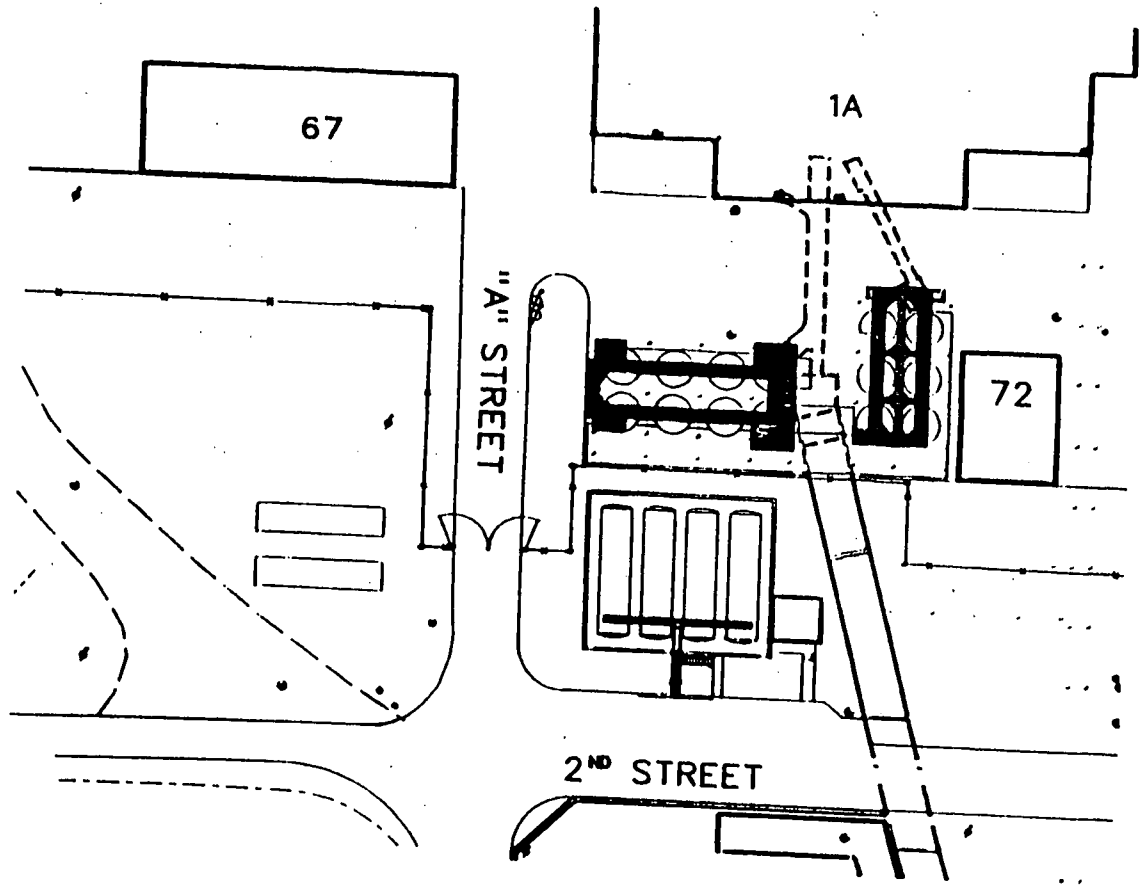


FIGURE 1

Overview of Plant 1 Silos Looking East



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PLANT ONE SILOS
FIGURE 2
SCALE: 1" = 64'

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FERNALD PLANT 1 SILOS

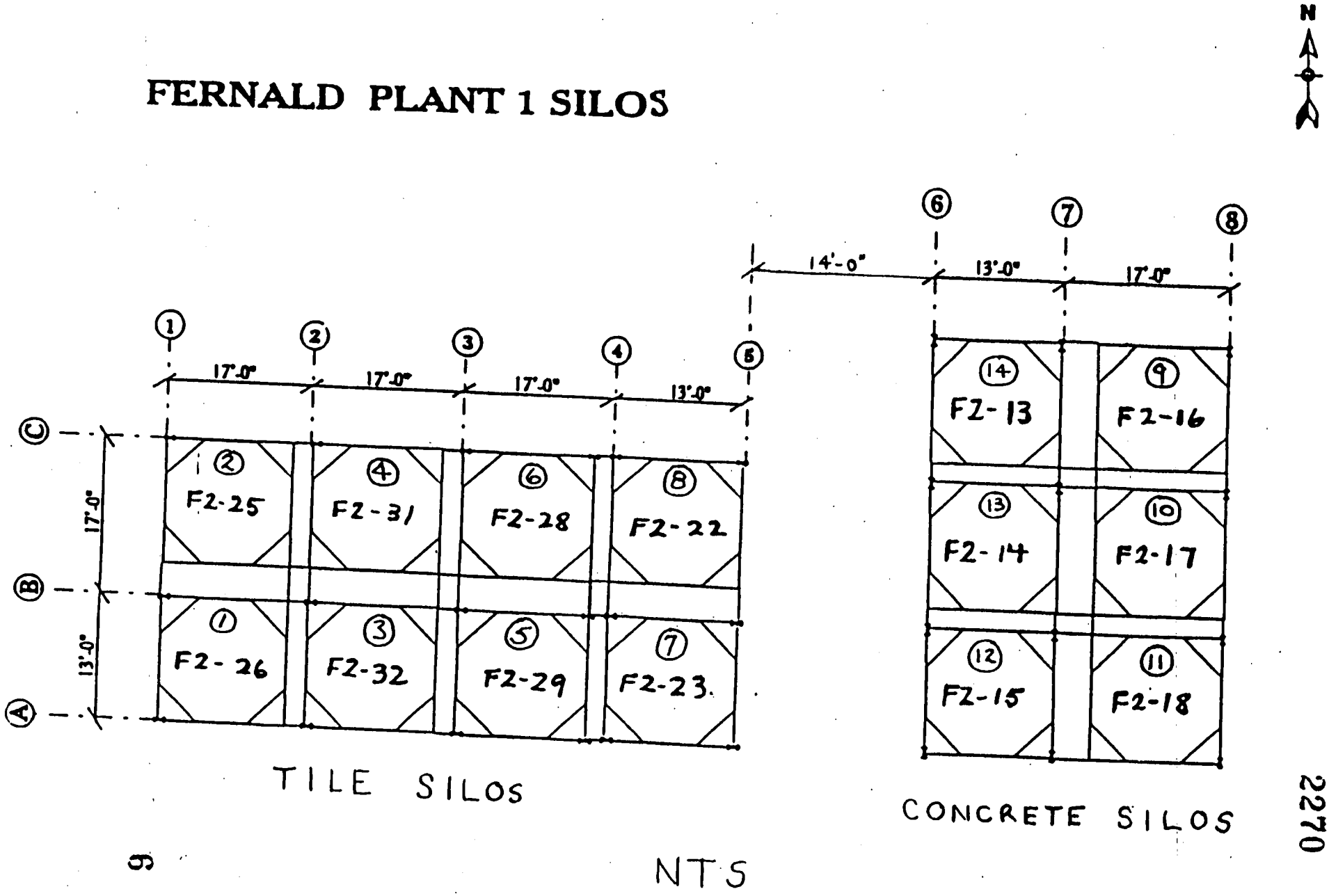

FIGURE 3

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silos. They could fail by overturning at the base if subjected to 90 mph basic wind speed loading. Relative to all eight of the tile silos, the support beams are adequate to support the empty silos and to transmit lateral forces to the braced frame lines by weak axis bending without overstress. However, the end connections of these beams are inadequate for the axial loads induced by truss action. The weakest points are the eccentric single plate connections of the diagonal beams and has a directional aspect. The longitudinal frame action is adequate for east-west winds. Transverse frame action of the end frames is inadequate to resist north-south wind loads. In addition, the lower platform level floor deck plate connections have been degraded by rust, and there is some breaking of welds with plate displacement. If the Silos are left in place, and/or while being dismantled, there is some threat to four adjacent facilities: 1) Uranyl Nitrate Tanks; 2) Building 67; 3) Building 72; and 4) Plant 1.

1.2 Status of Adjacent Facilities

1.2.1 Uranyl Nitrate Tanks

There are 15 tanks containing uranyl nitrate solutions in the area. These are the subject of another Removal Site Evaluation - Processing of Refinery Solutions[1]. Four of these tanks F2-605, F2-606, F2-607, and F2-608 are about 30 feet immediately south of the eight tile silos. If demolition of the Silos is pursued, it would be reasonable to first remove the uranyl nitrate solutions from the four nearby tanks.

1.2.2 Building 67

The second nearby facility, Building 67, is a thorium storage warehouse. The contents are approximately 6,000 drums of thorium oxides and other forms of thorium. Building 67 is part of another Removal Site Evaluation - Thorium Storage Warehouses[2]. The possible collapse of a silo (as is or during dismantling) is not an immediate threat to Building 67 because the nearest corner of the building is more than 70 feet to the northwest of the closest tile silo (Silo #2/F2-25). However, the nature of the contents of Building 67 must be considered for potential effects during any adjacent demolition or stabilization activities.

1.2.3 Building 72

Building 72 is to the east, immediately adjacent (about 10 feet) from the concrete, Plant 1 Ore Silos (#9, 10 & 11). This building could be easily damaged because of its proximity. Slightly enriched uranium (2% to 19.9% U-235) is stored in Building 72. This material is stored in approximately 88 containers, including 10, 30 and 55 gallon sizes, and a number of uranium rods in "birdcages" (framed container to allow standoff). 7

1.2.4 Plant 1

Plant 1 is the "sampling plant" for the Fernald Site, and due to the proximity to the silos, this building could be damaged. Plant 1 is the location for sampling of uranium metal, process residue, and waste materials. At any point in time, there are three or four skids of drums (four drums per skid) in Plant 1. Enriched uranium is stored on the third floor of Plant 1; there are approximately 220 containers (many are "birdcages") including metals, oxides, and uranium rods.

1.3 Basis for the Removal Site Evaluation

This Removal Site Evaluation is developed in accordance with 40 CFR 300.410. Section 2.0 characterizes the source term for any potential release. Appendix A summarizes analytical data for residue samples, and Appendix B summarizes the data used to estimate the Source Term. Section 3.0 evaluates the potential threat through any release of the source term.

2.0 SOURCE TERM

Visual inspection of the contents of each silo, after the February release, permitted an estimate of residue volumes. These are presented in Table 1. There are two identifiers for each silo: one is a numbering system (1-14) that was developed during the facility operation, and the second is the equipment identification noted in the plan view. Both of the silo identifiers are also shown on Figure 3. Tile silos 1, 2, 7 and 8 are 44 feet high, the tile silos 3-6 are 10 feet high, and the concrete silos are 10 feet high.

Table 1. Estimated Residue Volumes in the Plant 1 Silos

Tile Silo Identification	Est. Volume (cubic ft.)	Concrete Silo Identification	Est. Volume (cubic ft.)
#1 F2-26	Empty	#9 F2-16	Empty
#2 F2-25	1.0	#10 F2-17	8.9
#3 F2-32	0-29.7*	#11 F2-18	20.9
#4 F2-31	14.0	#12 F2-15	1.0
#5 F2-29	0-29.7*	#13 F2-14	1.0
#6 F2-28	8.9	#14 F2-13	8.9
#7 F2-23	29.7		
#8 F2-22	3.0		

* inspection not possible

Silo 1 did not contain any cold metal oxide residue on February 6, 1991. Maintenance personnel could "see daylight" from the bottom before sealing with a welded plate. The laboratory analytical data that are shown in Appendix A.1 and utilized in the Appendix B Source Term are the results of the analyses of the material that had leaked from Silo 1 and was discovered underneath this silo on February 6. Since this residue had the highest concentration, it is used for the "unknown silos."

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It was not possible to see inside to inspect the contents of Silos 3 and 5. Thus, a range is assumed which extends from empty to the largest quantity which was observed in Silo 7. Although it was not possible to estimate the volume of residue in these two silos, a sample of the

residues was obtained from the bottom of the silo before a plate was welded in place. A visual inspection of Silo 8 was made and residues were observed; but the bottom was already closed and a sample could not be obtained. Thus, the activity determined for the maximum sample (Silo 1) has been used.

Silo 9 was also determined to have no residues, and only evidence of roosting birds was observed.

The maximum estimated total residues for all Silos is 156.7 cubic feet (5.8 cubic yards), and the minimum estimate, based on observable residues, is 97.3 cubic feet (3.6 cubic yards).

The complete analytical results for residue samples are given in Appendix A. An estimate of the radionuclide inventory in each Silo is made by:

1. Multiplying the estimated volumes by an estimated density of the material.

2. Multiplying the resultant mass by the specific radionuclide concentration from the analytical data. (Appendix A.1).

Since the residues are similar to those found in Silo 3, a density of 2.5 g/cc was used as a basis for the calculations. Four samples from Silo 3 average 2.33 g/cc and one composite showed 2.75 g/cc.

Table 2. Estimated Radionuclide Quantities
Total for All Silos
(millicuries)

Isotope	Maximum	Minimum
Thorium-230	406	81
Radium-226	6.6	5.8
Thorium-232	6.0	0.72
Radium-228	0.23	0.25
Thorium-228	1.9	0.42
Uranium-238	2.7	0.20
Uranium-234	2.5	0.19

At most, the total inventory is less than 0.5 Ci, and there may be less that 100 mCi. At the present time, there are relatively limited chemical analytical results for residue samples. Appendix A.2 provides those results. As expected from the processes, there are relatively few organic compounds with concentrations exceeding the detection limits. There are significant concentrations of metals in the residues, and those are summarized in the following Table 3.

The analytical results indicate detection of low concentrations of plutonium-239,40, technetium-99, and neptunium-237. From process knowledge, it is not possible that these radionuclides are present. The analytical discrepancies will not be resolved since they are an insignificant component of the source term.

Table 3. Metals Concentrations in Silo Residues (micrograms per kilogram)

Silo No.	As	Ba	Cd	Cr	Pb	Se	Hg
1	<15	216	<0.5	<4.6	441	<2.1	<0.05
2	960	64.4	<0.5	733	7780	891	0.883
3	<15	<0.3	<0.5	95.3	739	<2.1	<0.05
4	<15	<0.3	<0.5	46.5	354	<2.1	0.295
5	64.4	119	6.1	305	8730	4090	1.8
6	<15	30.7	<0.5	70.6	386	<2.1	<0.05
7	<15	47	3.8	152	3370	81	0.1
8	(Silo closed, no sample taken)						

The only sample data available for Toxicity Characteristic Leaching Procedure (TCLP) concentrations, at this time, are for samples from the concrete silos. Those results are summarized in the following Table 4.

Table 4. Sample Concentrations Compared to TCLP Results

Silo No.	Parameter	Residue Concentration (ug/g)	TCLP Concentration (ug/L)	(Limit)	*Ratio (ug/L ug/g)
9	(Silo empty, no sample taken)				
10	Lead	1043	441	(5,000)	0.42
	Barium	34.4	216	(100,000)	6.3
11 (Dup.)	Selenium	114	<420	(1,000)	<3.7
	Lead	896	462	(5,000)	0.52
	Barium	15.4	252	(100,000)	16
11 (Dup.)	Selenium	161	738	(1,000)	4.6
12	Lead	556	462	(5,000)	0.83
	Barium	115	252	(100,000)	2.2
13	Lead	561	203	(5,000)	0.36
14	Barium	10.4	213	(100,000)	20

* Note the "dilution" of roughly 500 if the sample density is 2 g/cc and the TCLP solution density is 1 g/cc.

There is no current evidence that the residues are radioactive mixed RCRA wastes. The volume of residues is estimated to be less than six cubic yards. They would have to be placed in appropriate containers and then sampled. Analytical results, coupled with process knowledge, will permit a conclusion and proper disposition.

Source terms that are related to adjacent facilities include the four tanks containing uranyl nitrate solutions located immediately south of the tile silos. The inventories within those tanks are summarized in the following Table 5.

Table 5. Uranyl Nitrate Storage Tank Contents

Tank No.	U-238 (Ci)	U-235 (Ci)	U-234 (Ci)	Pu-239 (mCi)	Np-237 (mCi)
F2-605	1.88	0.12	1.88	5.1	1.8
F2-606	2.96	0.19	2.96	8.1	2.8
F2-607	1.92	0.12	1.92	5.1	1.8
F2-608	2.33	0.15	2.33	6.3	2.2

The thorium storage Building 67 is northwest of the Plant 1 Silos and contains the inventory given in Table 6.

Table 6. Contents of Building 67
(6,004 containers: oxides and other forms)

Thorium-232	16 Ci
Radium-228	16 Ci
Thorium-228	16 Ci
Thorium-230	2 Ci
Uranium-233	0.2 Ci

The contents of Building 72, 10 feet to the east of the concrete silos #9, 10 & 11 and Plant 1 are generally described in paragraphs (1.2.3 and 1.2.4)

Process material conveyers appear in Figures 1 and 2 which enter Building 1A; thus, any activity in Building 1A may be affected by a removal action.

3.0 EVALUATION OF POTENTIAL THREAT

There is a remote, but finite, probability that a tile silo could collapse and cause the release of the uranyl nitrate solution from the adjacent storage tanks. There is a concern for occupational exposure to chemicals. From the Thorium Storage Building RSE, average meteorology estimates a dilution factor (CHI/Q) of 1.8E-13 to the nearest off-site receptor at 1,700 meters from Building 67. (See Figure 4). Given conditions, a small fraction of the uranium would become airborne for transport off-site. The pH of the solution would be raised when contacted with soil and penetration to ground water, or surface water runoff, would be slowed. The spill would be cleaned up relatively quickly and result in minimal environmental impact. In the context of this RSE, it would be logical to first remove the uranyl nitrate solutions from the tanks prior to activities with the tile silos.

Actions following the February spill prevented any subsequent or ongoing releases from the silos. Some other action, such as earthquakes, high winds, or tornadoes, might cause the collapse of one of the tile silos. It is possible that the further degradation of tile silo structures could result in "spontaneous" collapse or similar failure as the result of relatively minor forces.

The extent of such a potential threat can be assessed using the contents of Silo residues. The highest potential occupational exposure would likely occur with the failure of Silo 5 because it contains the highest radionuclide concentrations. With relatively dusty conditions, air mass loading can be estimated to be 0.2 mg/m3. This is the default value from the Argonne National Laboratory version of RESRAD[3]. Given these assumptions, the expected airborne concentrations can be calculated and compared to the airborne limits for occupational exposure from DOE Order 5480.11[4]. Table 7 provides that comparison.

Table 7. Estimated Airborne Concentrations Compared to Table 1 of Attachment 1 of DOE Order 5480.11

	Airborne Concentrations (uCi/ml)		
Isotope	Estimated	DOE Order 5480.11	Fraction
Th-230	2.8E-11	3.0E-12	9.3E+00
Ra-226	4.2E-14	3.0E-10	1.4E-04
Th-232	5.0E-13	5.0E-13	1.0E+00
Ra-228	1.4E-13	5.0E-10	2.8E-04
U-238	2.2E-13	2.0E-11	1.1E-02
U-234	2.0E-13	2.0E-11	1.0E-02
			10.3

These airborne concentrations from an accidental release would be temporary while the DOE Order values are based upon continuous occupational exposure. However, the comparison shows that the total represents 10.3 times the DOE airborne limits. The use of respiratory protection would limit occupational exposure during the limited work period.

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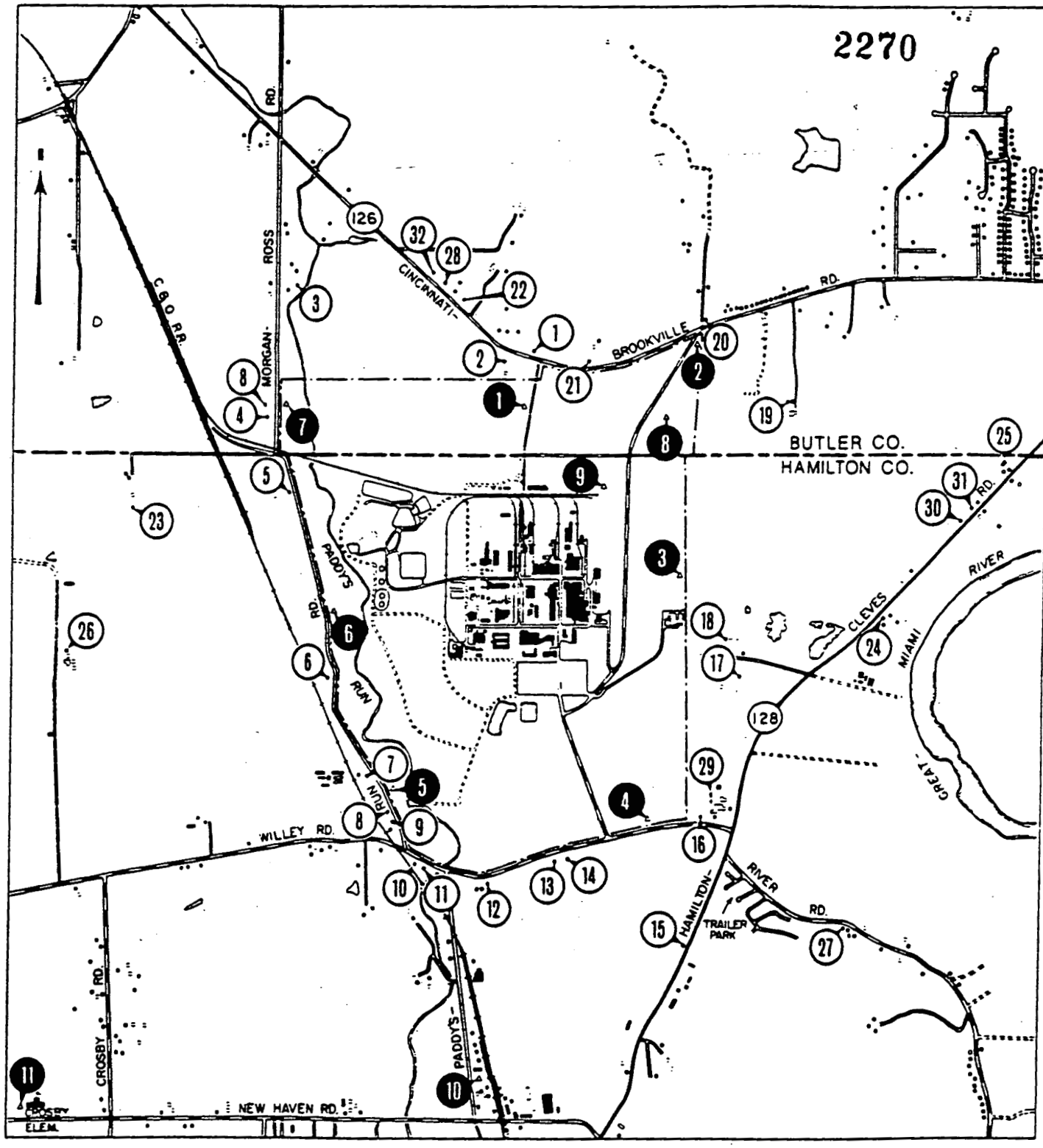

0 1/2 1 2

SCALE OF MILES

LEGEND

- Heavy Duty Roads
- Medium Duty Roads
- Light Duty Roads
- Fixed Air Monitoring Stations
- Numbered Residence
- FMPC Boundary

FIGURE 2

A conservative estimate of the potential threat to the public can be made using the silo with the largest estimated quantity of radionuclides. While a sample was collected and analyzed from Silo 5, it was not possible to view the residues to estimate the volume. It was, therefore, assumed to have residues equal to the largest quantity observed among all silos (Silo 7). An estimate of the potential dose to the nearest off-site receptor (1700 meters) can be made by assuming the estimated contents of Silo 5 are released and that ten percent become airborne and are transported to the receptor. Only the two most abundant isotopes, thorium-230 and thorium-232 are used for this analysis. The atmospheric diffusion calculations from the Thorium Storage Building RSE can be used to estimate the airborne concentration, the radiation dose equivalent and the risk by both the HEAST Slope Factors and by the NCRP risk coefficient. Table 8 summarizes those results.

Table 8. Risk and Dose Equivalent for Potential Release from the Silo 5 Estimated Source Term

	Thorium-230	Thorium-232
Ten Percent Release	29 mCi	0.53 mCi
Receptor Airborne	5.2E-03 pCi/m3	9.5E-05 pCi/m3
HEAST Slope Factor	3.1E-08	1.1E-07
HEAST Risk	1.3E-06	8.4E-08
Dose Equivalent	10.9 mRem	0.88 mRem
	HEAST total risk	1.4E-06
	NCRP total risk	1.5E-06

The EPA has indicated that the acceptable risk range is from 1E-04 to 1E-06[5]; and this calulated risk is near the lower end of that range.

Therefore, the NCP lists a lifetime cancer risk to an individual to a range of 1E-04 to 1E-06. It is emphasized that this estimate in Table 8 was based upon the Silo 5 contents which are not confirmed. Silo 7 contains the largest known quantities which is roughly one tenth of the Silo 5 estimate.

4.0 ASSESSMENT OF THE NEED FOR A REMOVAL ACTION

The Plant 1 Ore Silos represent a minimal risk based upon the assessment of the contaminated residue contents. Collapse of the 44 foot tile silos is possible with injury of workers in the vicinity and with the potential to damage adjacent uranyl nitrate storage tanks which could result in a release of their contents. Nitric acid fumes would result in an immediately dangerous environment to workers in that area. Any release to the off-site population would be minimal given conditions and the likelihood of prompt cleanup. Potential problems could be removed by removal and treatment of the uranyl nitrate solutions. This is the subject of another RSE which might be further motivated by the poor structural condition of the tile silos. Once completed, residues could be removed from the Plant 1 Ore Storage Silos, hazardous structures dismantled, and the present minimal risk reduced to near zero.

Consistent with Section 40 CFR 300.410 of the National Contingency Plan, the DOE shall determine the appropriateness of a removal action. The eight factors to be considered in this determination are listed in 40 CFR 300.415 (b) (2). The following apply to the Plant 1 Ore Silos:

Sub-paragraph (iii)
Hazardous substances or pollutants or contaminants in drums, barrels, tanks, or other bulk storage containers, that may pose a threat of release.

Sub-paragraph (viii)
Other situations or factors that might pose threats to public health or welfare or the environment.

Relative to (viii) is the potential for collapse of the tile silos with:

the potential for serious injury to workers
and
the potential to damage adjacent uranyl nitrate storage tanks with exposure to workers.

5.0 APPROPRIATENESS OF A RESPONSE

If it is determined that response actions are appropriate due to current conditions, a number of actions may be required to address the situation.

If a planning period of less than six months exists prior to initiation of a response action, DOE will issue an Action Memorandum. The Action Memorandum will describe the selected response(s) and provide supporting documentation for the decision(s).

If it is determined that there will be a planning period of greater than six months before response(s) is initiated, DOE will issue an Engineering Evaluation/Cost Analysis (EE/CA) Approval Memorandum. This Memorandum is to be used to document the threat to public health and to the environment and to evaluate viable alternative response actions. It will also serve as a decision document to be included in the Administrative Record.

Based upon evaluation of all of the above factors, a Time Critical Removal Action is required.

REFERENCES

1. Removal Site Evaluation - Processing of Refinery Solutions, WMCO:EMT:91-154, June 27, 1991.

2. Removal Site Evaluation - Thorium Storage Buildings, WMCO:EMT:91-279, June, 1991.

3. Yu, C. et. al., A Manual for Implementing Residual Radioactive Material Guidelines, DOE/CH/8901, Argonne National Laboratory, U.S. Department of Energy, June, 1989.

4. DOE Order 5480.11, Radiation Protection for Occupational Workers, U.S. Department of Energy, December 21, 1989.

5. National Emission Standards for Hazardous Air Pollutants; Radionuclides; Final Rule and Notice of Reconsideration, 40 CFR Part 61. Fed. Reg. Vol. 54, No. 240, 51654-51715, December 15, 1989.

APPENDIX A
(APPENDIX A.1 & A.2 TO FOLLOW)

RESIDUE SAMPLE ANALYTICAL RESULTS

APPENDIX A

Appendix A.1 provides the Radiochemical Analytical Results and Appendix A.2 provides the Chemical Analytical Results.

The last table in Appendix A.1 provides the typical or expected analytical sensitivities for the specific radionuclides. Analytical results for samples may show concentrations lower than the analytical sensitivities when a specific analytical procedure has had unusually beneficial experience. For example, chemical recoveries may be higher than typical, backgrounds may be lower than typical, and occasionally analyses will have larger than normal sample aliquots and may have experienced longer count times. In a similar fashion, some analytical results may show sensitivities that are high in comparison to the expected analytical sensitivities. The adversity may be due to lower than expected chemical yield, background may be higher than usual, and the sample quantity may restrict the size of the sample aliquot used for a procedure.

TABLE 2
PLANT 1 SILO
Summary
Radioanalytical Results (pCi/g)

		Uranium-238	Thorium-230	Radium-226	Thorium-232
Fraction Detectable	[1]	(11/14)	(14/14)	(14/14)	(14/14)
Mean + 1 Std. Dev.	[2]	183 + 318.9	31556 + 56538	516 + 577	377 + 858
High	[3]	1100(EM-2507)	160000(EM-2001)	1600(EM-2001)	2500(EM-2507)
Low	[3]	5.3(EM-2505)	630(EM-2510)	25(EM-2506)	7.4(EM-2575)
Concentrations Greater Than Mean + 1 Std. Dev.	[3]	1100(EM-2507)	100000(EM-2504) 140000(EM-2504) 160000(EM-2507)	1200(EM-2509) 1200(EM-2570) 1400(EM-2571) 1600(EM-2001)	2300(EM-2504) 2500(EM-2507)

		Radium-228	Thorium-228	Plutonium-239,40	Plutonium-238
Fraction Detectable	[1]	(14/14)	(14/14)	(14/14)	(14/14)
Mean + 1 Std. Dev.	[2]	31.6 + 38.6	189.3 + 440.1	0.33 + 0.29	0.18 + 0.065
High	[3]	130(EM-2001)	1600(EM-2504)	1.2(EM-2571)	0.4(EM-2508)
Low	[3]	3.6(EM-2506)	5(EM-2574)	0.12(EM-2001) 0.12(EM-2504) 0.12(EM-2505) 0.12(EM-2507) 0.12(EM-2509)	0.14(EM-2573)
Concentrations Greater Than Mean + 1 Std. Dev.	[3]	79(EM-2570) 83(EM-2571) 130(EM-2001)	660(EM-2507) 1600(EM-2504)	1.2(EM-2571)	0.4(EM-2508)

		Neptunium-237	Cesium-137	Technetium-99	Plutonium-239
Fraction Detectable	[1]	(12/14)	(2/14)	(12/14)	(6/14)
Mean + 1 Std. Dev.	[2]	5.06 + 4.75	3.1 + 0	18.5 + 16.1	0.517 + 0.355
High	[3]	13(EM-2507)	3.1(EM-2571) 3.1(EM-2571) 3.1(EM-2571) 3.1(EM-2571)	55(EM-2572)	1.2(EM-2571)
Low	[3]	0.4(EM-2574)		5.2(EM-2504) 5.2(EM-2506)	0.37(EM-2573)
Concentrations Greater Than Mean + 1 Std. Dev.	[3]	10(EM-2570) 11(EM-2504) 13(EM-2507)		43(EM-2571) 55(EM-2572)	1.2(EM-2571)

		Uranium-234	Uranium-235	Uranium-236
Fraction Detectable	[1]	(11/14)	(11/14)	(11/14)
Mean + 1 Std. Dev.	[2]	167.4 + 291.2	8.36 + 14.2	0.433 + 0.579
High	[3]	1000(EM-2507)	49(EM-2507)	2.1(EM-2507)
Low	[3]	1.6(EM-2505)	0.24(EM-2505)	0.001(EM-2570)
Concentrations Greater Than Mean + 1 Std. Dev.	[3]	1000(EM-2507)	49(EM-2507)	2.1(EM-2507)

[1] Detected / Total Samples
[2] + = Tolerance, plus or minus with 68% confidence
[3] Sample number in parenthesis

TABLE 3
PLANT 1 SILO
Summary

METALS (ug/g)		Arsenic	Barium	Cadmium	Chromium	Lead	Selenium	Silver	Mercury
Fraction Detectable	[1]	(8/14)	(14/14)	(9/14)	(13/14)	(15/15)	(9/14)	(6/14)	(11/14)
Mean + 1 Std. Dev.	[2]	166.7 + 321.5	52.5 + 59.3	16.0 + 9.1	188.1 + 178.0	3973 + 8342	664.3 + 1328.3	15.91 + 4.31	0.66 + 0.48
High	[3]	960(EM-2504)	216(EM-2001)	24.6(EM-2572)	733(EM-2504)	32518(EM-2584)	4090(EM-2507)	21.69(EM-2575)	1.8(EM-2507)
Low	[3]	27.9(EM-2574)	7.92(EM-2573)	3.2(EM-2504)	43.9(EM-2510)	354(EM-2506)	3.5(EM-2574)	11.59(EM-2573)	0.1(EM-2509)
Concentrations Greater Than Mean + 1 Std. Dev.	[3]	960(EM-2504)	115(EM-2572) 119(EM-2507) 216(EM-2001)	-	733(EM-2504)	32519(EM-2584)	4090(EM-2507)	20.53(EM-2572) 21.69(EM-2575)	1.8(EM-2507)

TCLP EXTRACT (ug/L)		Arsenic	Barium	Cadmium	Chromium	Lead	Selenium	Silver	Mercury
Fraction Detectable	[1]	(0/14)	(4/14)	(0/14)	(0/14)	(4/14)	(0/14)	(0/14)	(1/14)
Mean + 1 Std. Dev.	[2]		233.3 + 21.7			392 + 126			0.2 + 0
High	[3]		252(EM-2572) 252(EM-2575)			462(EM-2572) 462(EM-2575)			0.2(EM-2571)
Low	[3]		213(EM-2574)			203(EM-2573)			0.2(EM-2571)
Concentrations Greater Than Mean + 1 Std. Dev.	[3]		-			-			-

ORGANICS (ug/g)		Methyl Ethyl Ketone	Tetrachlorethane	Acetone	Toluene	Cycloheranone	2-Nitropropane	Total Xylenes
Fraction Detectable	[1]	(1/14)	(3/14)	(1/14)	(2/14)	(1/14)	(1/14)	(1/14)
Mean + 1 Std. Dev.	[2]	83 + 0	86.0 + 86.1	31 + 0	16 + 4.24	263 + 0	34 + 0	14 + 0
High	[3]	83(EM-2571)	181(EM-2509)	31(EM-2507)	19(EM-2509)	263(EM-2508)	34(EM-2508)	14(EM-2509)
Low	[3]	83(EM-2571)	13(EM-2506)	31(EM-2507)	13(EM-2507)	263(EM-2508)	34(EM-2508)	14(EM-2509)
Concentrations Greater Than Mean + 1 Std. Dev.	[3]	-	181(EM-2509)	-	-	-	-	-

[1] Detected / Total Samples
[2] + = Tolerance, plus or minus with 68% confidence
[3] Sample number in parenthesis

APPENDIX A.1

RADIOCHEMICAL ANALYTICAL RESULTS

PLANT 1 TILE SILO RESIDUES
(picocures per gram)

SILO NO. DRAWING NO.	EM SAMPLE NO. LABORATORY NO.	Th-230	Ra-226	Th-232	Th*tot	Ra-228	Th-228	U-238	U*tot
1 F2-26	EM-2001 910207-059	160,000	1,600	64	592	130	64	280	832
2 F2-25	EM-2504 910318-077	100,000	560	2,300	453	6.1	1,600	140	427
3+ F2-32	EM-2505 910318-078	960	30	21	<45	<7.4	24	5.3	16
3+ F2-32	EM-2510 910318-83	630	39	18	<45	7.8	43	24	73
4 F2-31	EM-2506 910318-79	1,400	25	49	48	3.6	17	10	31
5 F2-29	EM-2507 910318-080	140,000	210	2,500	2,402	29	660	1,100	3,281
6 F2-28	EM-2508 910318-081	3,900	59	96	<45	5.7	97	25	74
7 F2-23	EM-2509 910318-082	14,000	1,200	170	111	14	85	90	271
8 F2-22	(SILO CLOSED NO SAMPLE)								

* Units = ug/g + = Duplicate Sample

PLANT 1 TILE SILO RESIDUES
(picocures per gram)

SILO NO. DRAWING NO.	EM SAMPLE NO. LABORATORY NO.	U-234	U-235	U-236	Pu-238	Pu-239,40	Np-237	Tc-99
1 F2-26	EM-2001 910207-059	310	13	<0.53	<0.17	<0.12	---	---
2 F2-25	EM-2504 910318-077	140	6.5	0.16	<0.17	<0.12	11	<5.2
3+ F2-32	EM-2505 910318-078	1.6	0.24	0.048	<0.17	<0.12	---	---
3+ F2-32	EM-2510 910318-083	18	1.1	0.34	<0.19	<0.20	0.77	8.5
4 F2-31	EM-2510 910318-079	13	0.66	0.18	<0.18	0.56	0.74	<5.2
5 F2-29	EM-2507 910318-80	1,000	49	<2.1	<0.17	<0.12	13	<5.4
6 F2-28	EM-2508 910318-081	20	1.2	0.18	<0.40	<0.20	<0.76	<5.4
7 F2-23	EM-2509 910318-082	80	4.1	0.42	<0.17	<0.12	3.3	11
8 F2-22	(SILO CLOSED NO SAMPLE)							

+ = Duplicate Sample

PLANT 1 CONCRETE SILO RESIDUES
(picocures per gram)

SILO NO. DRAWING NO.	EM SAMPLE NO. LABORATORY NO.	Th-230	Ra-226	Th-232	Ra-228	Th-228	U-234	U-235	U-236
10 F2-17	EM-2570 910501-040	4,700	1,200	12	79	14	61	3.5	<0.001
11+ F2-18	EM-2571 910430-112	4,800	1,400	18	83	8.4	170	12	<0.48
11+ F2-18	EM-2575 910430-111	4,200	436	7.4	31	10	N/A	N/A	N/A
Rinseate**	EM-2576 910501-044	<0.010*	<0.0006*	<0.010*	<0.003*	0.013*	N/A	N/A	N/A
Rinseate**	EM-2577 910501-045	<0.003*	<0.0007*	<0.004*	<0.0024*	0.011*	<0.87*	<0.018*	<0.019*
12 F2-15	EM-2572 910501-041	1,700	81	9.1	7.4	13	28	0.64	0.32
13 F2-14	EM-2573 910501-042	3,600	310	15	32	9.7	N/A	N/A	N/A
14 F2-13	EM-2574 910501-043	1,900	79	9.2	6.4	5	N/A	N/A	N/A

* = pci/ml
+ = Duplicate Sample

PLANT 1 CONCRETE SILO RESIDUES
(picocures per gram)

SILO NO. DRAWING NO.	EM SAMPLE NO. LABORATORY NO.	U-238	Pu-238	Pu-239	Pu tot	Np-237	Cs-137	Tc-99	Th tot	U tot
10 F2-17	EM-2570 910501-040	75	<0.15	<0.38	<0.53	10	N/A	<19	417 ppm	225 ppm
11+ F2-18	EM-2571 910430-112	250	<0.15	1.2	<1.4	9.8	<3.1	<43	491 ppm	750 ppm
11+ F2-18	EM-2575 910430-111	N/A	<0.15	<0.38	<0.53	4.9	<3.1	<19	583 ppm	584 ppm
Rinseate**	EM-2576 910501-044	N/A	<0.0004*	<0.001*	<0.0014*	0.01	N/A	<0.66	<0.0004 g/L	.0001 g/L
Rinseate**	EM-2577 910501-045	<0.83*	<0.0004*	<0.001*	<0.0014*	0.04*	N/A	<0.66*	<0.0004 g/L	<1 ppm
12 F2-15	EM-2572 910501-041	14	<0.15	<0.38	<0.53	<0.40	N/A	<55	152 ppm	42 ppm
13 F2-14	EM-2573 910501-042	N/A	<0.14	<0.37	<0.51	5.7	N/A	<18	225 ppm	36 ppm
14 F2-13	EM-2574 910501-043	N/A	<0.15	<0.39	<0.54	<0.40	N/A	<27	101 ppm	24 ppm

* = pci/ml
\+ = Duplicate Sample

RI Analytical Detection (Soil Samples)

Radionuclide Containment	Detection Limit	Background Concentrations
	(mg/kg)	(mg/kg)
Total U	1	0.29–11 (2.7)
Total Th	18	
Isotope	(pCi/g)	(pCi/g)
Cs137	<1.0	<1
Np237	<0.1	<0.1
Pb210	<1.0	<2.5
Pu238	<0.1	<0.1
Pu239,240	<0.1	<0.1
Ra226	<1.0	<1.5
Ra228	<4	<4
Sr90	<0.5	<0.5
Tc99	9	<1
Th228	1	<1
Th230	<1	<0.1
Th232	<11	<11
U234	1	0.1–4.0 (0.9)
U235	1	<1
U235,236	1	<1
U238	1	0.1–4.0 (0.9)

APPENDIX A.2

CHEMICAL ANALYTICAL RESULTS

PLANT 1 TILE SILOS RESIDUES

(micrograms per gram)

SILO NO. DRAWING NO.	EM SAMPLE NO. LABORATORY NO.	PARAMETER	DETECTION LIMIT	CONCENTRATION
1 F2-26	EM-2001 910207-059	Barium	200	216
		Lead	200	441
2 F2-25	EM-2504 910318-077	Arsenic	15	960 N
		Barium	0.3	64.4
		Cadmium	0.5	3.2 N
		Chromium	4.6	733
		Lead	9	7,780
		Selenium	2.1	891 N
		Mercury	0.05	0.883
3 F2-32	EM-2505 910318-078	Barium	0.3	21.4
		Chromium	4.6	95.3
		Lead	9	739
4 F2-31	EM-2506 910318-079	Tetrachlorethene	5	13
		Barium	0.3	16.8
		Chromium	4.6	46.5
		Lead	9	354
		Mercury	0.05	0.295
5 F2-29	EM-2507 910318-080	Acetone	10.3	31
		Toluene	5.1	13
		Arsenic	15	64.4
		Barium	0.3	119
		Cadmium	0.5	6.1 N
		Chromium	4.6	305
		Lead	9	8,730
		Selenium	2.1	4,090
		Mercury	0.05	1.8

+ = Duplicate Sample
(Note: N=?; to be determined)

PLANT 1 TILE SILOS RESIDUES
(micrograms per gram)

SILO NO. DRAWING NO.	EM SAMPLE NO. LABORATORY NO.	PARAMETER	DETECTION LIMIT	CONCENTRATION
6 F2-28	EM-2508 910318-081	Cyclohexanone	10.1	263
		2-Nitropropane	20.2	34
		Tetrachloroethene	5.1	64
		Barium	0.3	30.7
		Chromium	4.6	70.6
		Lead	9	386
7+ F2-23	EM-2509 910318-082	Toluene	5.1	19
		Tetrachloroethene	5.1	181
		Total Xylenes	5.1	14
		Barium	0.3	47
		Cadmium	0.5	3.8 N
		Chromium	4.6	152
		Lead	9	3,370
		Selenium	2.1	81 N
		Mercury	0.05	0.1
7+ F2-23	EM-2510 910318-083	Barium	0.3	15.9
		Chromium	4.6	43.9
		Lead	9	464
		Mercury	0.05	0.199
8 F2-22	(SILO CLOSED NO SAMPLE)			

+ = Duplicate Sample

PLANT 1 CONCRETE SILOS RESIDUES
(micrograms per gram)

SILO NO. DRAWING NO.	EM SAMPLE NO. LABORATORY NO.	PARAMETER	CONCENTRATION
10 F2-17	EM-2570 910501-040	Arsenic	43.8
		Mercury	0.3
		Selenium	35
		Lead	1042.68
		Silver	16.03
		Barium	34.37
		Cadium	17.3
		Chromium	125.72
11+ F2-18	EM-2575 910430-111	Arsenic	79.9
		Mercury	1.08
		Selenium	114
		Lead	895.69
		Silver	21.69
		Barium	15.35
		Cadmium	19.99
		Chromium	170.61
11+ F2-18	EM-2571 910430-112	Arsenic	95.2
		Mercury	0.76
		Selenium	161
		Lead	1218.04
		Silver	20.53
		Barium	21.16
		Cadmium	20.78
		Chromium	183.9

+ = Duplicate Sample

PLANT 1 CONCRETE SILOS RESIDUES
(micrograms per gram)

SILO NO. DRAWING NO.	EM SAMPLE NO. LABORATORY NO.	PARAMETER	CONCENTRATION	
Rinseate	EM-2576 910501-044	Arsenic	<10	ug/L
		Mercury	<0.2	ug/L
		Selenium	<17	ug/L
		Lead	<6	ug/L
		Silver	<3.0	ug/L
		Barium	<25000	ug/L
		Cadium	<200	ug/L
		Chromium	<1000	ug/L
Rinseate	EM-2577 910501-045	Arsenic	<10	ug/L
		Mercury	<0.2	ug/L
		Selenium	<17	ug/L
		Lead	<6	ug/L
		Silver	<3.0	ug/L
		Barium	<25000	ug/L
		Cadmium	<200	ug/L
		Chromium	<1000	ug/L
Silo Paint	EM-2584 910502-072	Lead	32518.6	

+ = Duplicate Sample

PLANT 1 CONCRETE SILOS RESIDUES
(micrograms per gram)

SILO NO. DRAWING NO.	EM SAMPLE NO. LABORATORY NO.	PARAMETER	CONCENTRATION
12 F2-15	EM-2572 910501-041	Arsenic	30.2
		Mercury	0.57
		Selenium	8.41
		Lead	555.81
		Silver	12.53
		Barium	115.03
		Cadium	24.6
		Chromium	171.98
13 F2-14	EM-2573 910501-042	Arsenic	32.2
		Mercury	0.56
		Selenium	18
		Lead	560.52
		Silver	11.59
		Barium	7.92
		Cadmium	24.16
		Chromium	182.06
14 F2-13	EM-2574 910501-043	Arsenic	27.9
		Mercury	0.67
		Selenium	3.5
		Lead	546.81
		Silver	13.09
		Barium	10.44
		Cadmium	24.32
		Chromium	165.03

+ = Duplicate Sample

TCLP ANALYSIS OF
PLANT 1 TILE CONCRETE SILO RESIDUES
(ug/L)

SILO NO. DRAWING NO.	EM SAMPLE NO. LABORATORY NO.	PARAMETER	DETECTION LIMIT*	CONCENTRATION*	REGULATORY LIMIT
9 F2-16	(SILO EMPTY NO SAMPLE)				
10 F2-17	EM-2510 910501-040	Barium	200	216	100,000
		Lead	200	441	5,000
11+ F2-18	EM-2575 910430-111	Barium	200	252	100,000
		Lead	200	462	5,000
11+ F2-18	EM-2571 910501-112	Methyl Ethyl Ketone	50	83	200,000
		Selenium	420	738	1,000
		Mercury	0.2	0.2	200
12 F2-15	EM-2572 910501-041	Barium	200	252	100,000
		Lead	200	462	5,000
13 F2-14	EM-2573 910501-042	Lead	200	203	5,000
14 F2-13	EM-2574 910501-043	Barium	200	213	100,000

+ = Duplicate Sample

APPENDIX B

SOURCE TERM

APPENDIX B SOURCE TERM
TABLE 1
INVENTORY OF PRINCIPLE RADIONUCLIDES IN THE TILE SILOS

	SILO 1 EMPTY		SILO 2 7.08E+04g		SILO 3 2.1E+06g*		SILO 4 9.91E+05g	
	CONCENTRATION (pCi/g)	TOTAL (mCi)	CONCENTRATION (pCi/g)	TOTAL (mCi)	CONCENTRATION (pCi/g)	TOTAL (mCi)	CONCENTRATION (pCi/g)	TOTAL (mCi)
Th-230			1.00E+05	7.1E+00	9.60E+02	2.0E+00	1.40E+03	1.4E+00
Ra-226			5.60E+02	4.0E-02	3.0E+01	6.3E-02	2.5E+01	2.5E-02
Th-232			2.30E+03	1.6E-01	2.1E+01	4.4E-02	4.9E+01	4.9E-02
Ra-228			6.1E+00	4.3E-04	<7.4E+00	<1.5E-02	3.6E+00	3.6E-03
Th-228			1.60E+03	1.1E-01	2.4E+01	5.0E-02	1.7E+01	1.7E-02
U-238			1.40E+02	9.9E-03	5.3E+00	1.1E-02	1.0E+01	9.9E-03
U-234			1.40E+02	9.9E-03	1.6E+00	3.4E-03	1.3E+01	1.3E-02

	SILO 5 2.1E+06g*		SILO 6 6.30E+05g		SILO 7 2.10E+06g		SILO 8** 2.12E+05g	
	CONCENTRATION (pCi/g)	TOTAL (mCi)	CONCENTRATION (pCi/g)	TOTAL (mCi)	CONCENTRATION (pCi/g)	TOTAL (mCi)	CONCENTRATION (pCi/g)	TOTAL (mCi)
Th-230	1.40E+05	2.9E+02	3.90E+03	2.5E+00	1.40E+04	2.9E+01	1.60E+05	3.4E+01
Ra-226	2.10E+02	4.4E-01	5.9E+01	3.7E-02	1.20E+03	2.5E+00	1.60E+03	3.4E-01
Th-232	2.50E+03	5.3E+00	9.6E+01	6.0E-02	1.70E+02	3.6E-01	6.4E+01	1.4E-02
Ra-228	2.9E+01	6.1E-02	5.7E+00	3.6E-03	1.4E+01	2.9E-02	1.30E+02	2.8E-02
Th-228	6.60E+02	1.4E+00	9.7E+01	6.1E-02	8.5E+01	1.8E-01	6.4E+01	1.4E-02
U-238	1.10E+03	2.3E+00	2.5E+01	1.6E-02	9.0E+01	1.9E-01	2.80E+02	5.9E-02
U-234	1.00E+03	2.1E+00	2.0E+01	1.3E-02	8.0E+01	1.7E-01	3.10E+02	6.6E-02

* Quantity Unknown. Assumed to be Equal to the Maximum Observed (Silo 7).

** Not Sampled. Assumes Highest Concentrations Equal to the Silo 1 Recaptured Residue Sample (Silo 1 is empty).

APPENDIX B SOURCE TERM
TABLE 2
INVENTORY OF PRINCIPLE RADIONUCLIDES IN THE CONCRETE SILOS

	SILO 9 EMPTY		SILO 10 1.48E+06g		SILO 11(A) 1.48E+06g	
	CONCENTRATION (pCi/g)	TOTAL (mCi)	CONCENTRATION (pCi/g)	TOTAL (mCi)	CONCENTRATION (pCi/g)	TOTAL (mCi)
Th-230			4.70E+03	7.0E+00	4.5E+03	6.7E+00
Ra-226			1.20E+03	1.8E+00	9.18E+02	1.4E+00
Th-232			1.2E+01	1.8E-02	1.3E+01	1.9E-02
Ra-228			7.9E+01	1.2E-01	5.7E+01	8.4E-02
Th-228			1.4E+01	2.1E-02	9.2E+00	1.4E-02
U-238			7.5E+01	1.1E-01	1.9E+01(E)	2.8E-02
U-234			6.1E+01	9.2E-02	1.9E+01(E)	2.8E-02

	SILO 12 7.08E+04g		SILO 13 7.08E+04g		SILO 14 6.30E+05g	
	CONCENTRATION (pCi/g)	TOTAL (mCi)	CONCENTRATION (pCi/g)	TOTAL (mCi)	CONCENTRATION (pCi/g)	TOTAL (mCi)
Th-230	1.7E+03	1.2E-01	3.6E+03	2.5E+01	1.90E+03	1.2E+00
Ra-226	8.1E+01	5.7E-03	3.1E+02	2.2E-02	7.9E+01	5.0E-02
Th-232	9.1E+00	6.4E-04	1.50E+01	1.1E-03	9.2E+00	5.8E-03
Ra-228	7.4E+00	5.2E-04	3.2E+01	2.3E-03	6.4E+00	4.0E-03
Th-228	1.3E+01	9.2E-04	9.7E+00	6.9E-04	5.0E+00	3.2E-03
U-238	1.4E+01	1.0E-03	1.5E+01(E)	1.1E-03	8.0E+00(E)	5.0E-03
U-234	2.8E+01	2.0E-03	1.5E+01(E)	1.1E-03	8.0E+00(E)	5.0E-03

(E) Estimated, Analyses Not Completed.

(A) Concentrations are Average of Duplicate Sample.

APPENDIX B SOURCE TERM
TABLE 3
ESTIMATED TOTALS OF PRINCIPLE RADIONUCLIDES

	TILE SILOS		CONCRETE SILOS		ALL SILOS	
	MAXIMUM (mCi)	MINIMUM* (mCi)	MAXIMUM (mCi)	MINIMUM* (mCi)	MAXIMUM (mCi)	MINIMUM* (mCi)
Th-230	366	41	40	40	406	81
Ra-226	3.4	2.6	3.2	3.2	6.6	5.8
Th-232	6	0.68	0.04	0.04	6	0.72
Ra-228	0.14	0.04	0.09	0.09	0.23	0.13
Th-228	1.7	0.38	0.02	0.02	1.7	0.4
U-238	2.6	0.06	0.14	0.14	2.7	0.20
U-234	2.4	0.07	0.12	0.12	2.5	0.19

* Minimum assumes that Silos 3 & 5 are empty and the concentrations in Silo 8 are minimum, e.g., + Silo 4 contents analyses rather than the maximum = Silo 1 the recovered residue analyses.