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Silo 3 Conditioning Report

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ACRONYMS AND ABBREVIATIONS

AEA	Atomic Energy Act
C	Celsius
CFR	Code of Federal Regulations
DOE	Department of Energy
EP Tox	Extraction Procedure Toxicity Test
FEMP	Fernald Environmental Management Project
F	Fehrenheit
FS	Feasibility Study
g	grams
g/cm^3	grams per cubic centimeter
HEPA	High Efficiency Particulate Air
J&J	Jenike and Johanson, Inc.
lbs	pounds
ml	milliliters
NTS	Nevada Test Site
PSD	Particle size distribution
ppm	Parts per million
PVC	Polyvinyl Chloride
ROD	Record of Decision
RCRA	Resource Conservation and Recovery Act
RI	Remedial Investigation
SRS	Savannah River Site
TC	Toxicity Characteristic
TCLP	Toxicity Characteristic Leaching Procedure
WAC	Waste Acceptance Criteria
$	Dollars

Chemicals

As	Arsenic
Ba	Barium
Cd	Cadmium
Cr	Chromium
Pb	Lead
Se	Selenium
Ag	Silver
Hg	Mercury
H_2O	Water

1.0 Summary

Fluor Fernald's Silo 3 Project investigated augmenting the dedusting formula described in the "Silo 3 Dedusting Report"[1], Document No. 40430-RP-0016, with heavy metal stabilization agents. The purpose is to achieve the agglomeration seen in the dedusting report with the chemical stabilization achieved in the "Silo 3 Design Data Development Report"[2], Document No. 40430-RP-0015. To achieve the conditioning of Silo 3 material the project investigated using a combination of water, ferrous sulfate, and sodium lignosulfonate solution. A second group of conditioning solutions, from an external vender, called Maectite A, B, & C were tested. The conditioning agents were applied to the Silo 3 material, and the samples were analyzed for the Resource Conservation and Recovery Act (RCRA) heavy metals of concern. One successful formula from each supplier was selected for determination of optimum percent moisture using sieve analysis on "just mixed" and dried samples to assess the extent of agglomeration. A moisture migration test was performed on Silo 3 material with water and a successful conditioning solution to determine how the solution would migrate to dryer areas of material. Finally, a moisture loss test was conducted to determine the amount of water incorporation into the conditioned material and at specified temperatures how much moisture could be driven off.

All conditioning solutions tested reduced the leachability of chromium below the Toxicity Characteristic Leaching Procedure (TCLP) limit of 5 ppm. All selenium results were similar to untreated Silo 3 material. The final formulation was based on the cost and effectiveness of heavy metal stabilization, the ability of the solution to agglomerate Silo 3 material, and ease of delivery and storage. The recommended conditioning formula should be 20 parts water, and 0.108 parts sodium lignosulfonate, 8 parts of 15% ferrous sulfate solution to 100 parts Silo 3 material.

Sieve analysis of the conditioned "just mixed" product showed a significant increase in material agglomeration at the optimum percent moisture. The increase in agglomeration was enough to satisfy the Nevada Test Site's (NTS) waste acceptance criteria (WAC)[3] of no more than "...15 weight percent of less-than-200-micrometer-diameter particles..." Sieve analysis of "dried" conditioned samples showed a significant increase in material agglomeration compared to the unconditioned Silo 3 material, but did not satisfy the NTS WAC without the planned packaging. Although the existing packaging system design for Silo 3 material meets the NTS requirement for immobilization of dusty waste, agglomeration using water and binding agents is an additional level of protection.

The moisture migration tests showed that the conditioning solution migrated through 55.7% of the total volume of Silo 3 material, leaving only 44.3% dry Silo 3 material. This shows mechanical mixing is not necessary to effectively condition the bagged material.

The moisture loss test showed 30% moisture was incorporated into the conditioned Silo 3 material and only lost between 11 and 18% when exposed to a running high efficiency particulate air (HEPA) fume hood at 15° C (59° F) for 12 hours. At desert conditions, i.e. 60° C (140° F), the moisture loss was twice that, 27 and 32.5%. The results show that the conditioned material can incorporate and retain moisture, but does release that moisture when

subjected to desert field conditions. Significant agglomeration of conditioned Silo 3 material was seen when compared to unconditioned Silo 3 material even after simulated desert field conditions.

Waste loading of the final conditioned product ranged between 79 and 68 percent dependent on the amount of in-situ moisture present in the Silo 3 material.

2.0 Background

According to Remedial Investigation/Feasibility Study (RI/FS)[4] data, Silo 3 material failed to meet Extraction Procedure Toxicity Test (EP Tox) standards for arsenic, cadmium, chromium and selenium. Although the material is classified as 11(e)(2) byproduct, Record of Decision (ROD) was negotiated to treat for heavy metals to meet RCRA TCLP limits, as they were adopted as an appropriate performance standard for treatment. A treatability study was conducted to develop a formulation to satisfy the ROD, and the results can be found in "Silo 3 Design Data Development Report", Document No. 40430-RP-0015. Subsequently, a revision of the disposal waste acceptance criteria at NTS, and confirmation of material by the Department of Energy (DOE) as 11(e)(2) byproduct material under the Atomic Energy Act of 1954 (AEA), exempted Silo 3 material from regulation as solid waste under RCRA, 40 CFR Part 261.4(a)(4).

The result was a proposed ROD amendment not to treat Silo 3 material for heavy metal stabilization. To alleviate a stakeholder concern raised regarding the spread of contamination in the event that the container is breached during transit, conditioning of the Silo 3 material to reduce its dispersability was proposed. A dedusting investigation was conducted onsite and produced a formulation that agglomerated the Silo 3 material by the addition of water and lignosulfonate, an organic binder (see "Silo 3 Dedusting Report", Document No. 40430-RP-0016). The degree of agglomeration of Silo 3 material was compared to the NTS limit on fine particles, as a measure of the effectiveness of polymeric organic binding agents. NTS WAC Rev. 4, 2002, Section 3.1.6, Particulates states: "Fine particulate waste ***shall*** be immobilized so that the waste package contains no more than 1 weight percent of less-than-10-micrometer-diameter particles, or 15 weight percent of less-than-200-micrometer-diameter particles...Secure packaging may be used in place of immobilization...Drums and wooden boxes with sealed 6-mil (minimum) liners will also satisfy this requirement."

Jenike and Johanson, Inc. (J&J) was hired to investigate methods and location for the application of a binder solution within the existing packaging system design. J&J was tasked with investigating the spray process and modification to the packaging system. Their recommendations are detailed in 40430-RP-0021, "Pretreatment of Silo 3 Material with Lignosulfonate Solution"[5]. The system selected for implementation involves installing a spray system in the container loading spout and using it to wet the material as it is being loaded into the soft sided bag. Under these conditions it is expected that the system would result in an uneven distribution of the liquid in the powder, which would be acceptable.

The Ohio EPA suggested using this dedusting process design to incorporate the addition of chemical solutions that may result in successful stabilization of all or some heavy metals of concern, specifically chromium and selenium. Stabilization agents would be incorporated into

the lignosulfonate solution that is used to agglomerate the material. Based on the stabilization work detailed in reference 2, the stabilization additive selected for incorporation with the lignosulfonate solution is Ferrous Sulfate, a water-soluble chromium reducing agent. In addition, Sevenson Company was solicited for technical advice and recommended three proprietary additives that may be suitable for this application. The investigation of conditioning the Silo 3 material with heavy metal stabilization agents in addition to the water and organic binder is the subject of this report.

3.0 Goals of Study

The goal of this study was to augment the existing formula from the dedusting investigation by the addition of heavy metal stabilization agents to reduce the leachability of heavy metals during TCLP analysis. The chemical stabilization agents evaluated were Ferrous Sulfate, a water-soluble chromium reducing agent, and three Maectite solutions provided by Sevenson. Specific objectives are:

- Determine the compatibility of the dedusting formula with heavy metal stabilization agents. Compatibility includes pH, temperature change and off gas generation.
- Determine effectiveness of the stabilization agents.
- Determine the effects of moisture on the particle size distribution (PSD) of Silo 3 material through sieve analysis.
- Determine the upper limit of moisture content in product to keep the material "soil-like."
- Determine moisture migration within the Silo 3 material from areas of high moisture to areas of low moisture to understand the behavior of the expected uneven moisture distribution in the powder during the full-scale operation.
- Determine moisture loss at various temperatures.

4.0 Experimental set-up

The materials and equipment used in the treatability studies are described in the following sections:

Silo 3 Material

Material for this study came from the Small-Scale Waste Retrieval effort collected from the side of Silo 3 in 1997 and stored in drums. This material was fine-grained, dry, very loose, and represented the material located in the middle to lower portions of the silo. Material for the conditioning testing originated from Silo 3 drum number W195435 (55-gallon drum inventory number) which was previously homogenized by Clemson Environmental Technologies Laboratory as part of a study conducted for the Westinghouse Savannah River Company (SRS)[6] in December 2000. The material in drum number W195435 was divided evenly into five sub drums numbered W210394, 395, 396, 397 and 398 to inspect the contents and facilitate material handling and taking of samples.

The sieved analysis data shown in Table I was generated using Fluor Fernald's Determination of Particle Size in Soils, Sieve Method, Document Number 6532. Sieving was used to establish a particle distribution for a sample of unconditioned Silo 3 material so that a comparison could be made with Silo 3 material agglomerated with the conditioning solution. Sieve analysis is dependent on shaking (whether by hand or mechanical), time, sieve sizes and sample type. Sieve analysis was determined to be an acceptable measurement the change in particle agglomeration between conditioned and unconditioned Silo 3 material.

The data show that over 75.5 weight percent of the material was below the 75 micrometer-diameter sieve and 1.5 weight percent was retained above the 212 micrometer-diameter sieve.

TABLE I
SILO 3 MATERIAL PHYSICAL CHARACTERIZATION *

Characteristics	**Units**	**Total**
Moisture	%	2.8
ph of 10% suspension		5.86
Bulk density (compacted)	g/cm^3	0.76

TCLP Results for Silo 3 residues - 2001

	As	Ba	Cd	Cr	Pb	Se	Ag	Hg
Silo 3 material, ppm	0.313	0.234	0.043	7.56	0.093	1.23	0.002	0.082
Limit, ppm	5.0	100	1.0	5.0	5.0	1.0	5.0	0.2

Sieve Data

Mesh No.	**Microns**	**% Retained**
20	850	NA
40	425	NA
70	212	1.5
100	150	2
200	75	19.4
Pan	<75	75.5
Total		98.4

* Sieve data was performed on the as-is Silo 3 material by Fluor Fernald for this report: "Silo 3 Design Data Development Report", Document No. 40430-RP-0015

Reagents

Reagents were selected because they are either proven industry reagents as in the case of REAX, a dust suppressants, or known for their heavy metal reducing properties. Under normal operating conditions the reagents are non-toxic, easily handled and applied, plus are cost effective.

REAX SN, Sodium Lignosulfonate Solution is a polymeric organic binder produced by MeadWestvaco Corporation. The solution 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.

Ferrous Sulfate Solution, $FeSO_4$. This reagent was obtained from EagleBrook® Company in the form of a solution composed of 13.0% to 16.3% ferrous sulfate and less than 6% sulfuric acid having a pH of less than 1.0. It was used to reduce chromium.

Ferrous sulfate is the most common reducing agent and is the least expensive of those tested in this report. It is known to be effective in reducing Cr^{+6} to Cr^{+3} at low or neutral pH levels, but may be less effective at high pH levels. Cr^{+3} is more amenable to stabilization with alkaline bonding agents than Cr^{+6}.

Maectite Solutions. Sevenson has successfully provided heavy metal stabilization reagents for contaminated soil here at Fernald, specifically the treatment of Pb contaminated soil from the outdoor firing range. Sevenson developed three heavy metal stabilization agents in their laboratory, based on Silo 3 material information provided by Fluor Fernald. Solutions A & B are low pH solutions, similar in color and viscosity to $FeSO_4$. Maectite Solution C has a high pH, orange and has a phosphorus order. Chemical compositions of these products are trade secrets of the Sevenson Corporation.

Water, H_2O. Tap water was used in the tests.

Equipment

The following equipment was used in the tests.

Daigger® No. LX1140A balance was used to weigh out Silo 3 material and chemicals. The electronic balance could weigh 300 g maximum with 0.01 g resolution.

12" sieves,
Plastic bags supplied by Ziploc®, and
Fisher aluminum dishes

5.0 Tests Performed and Results

Phase I: Compatibility Testing

Phase I consisted of testing the compatibility of lignosulfonate with other heavy metal stabilization additives, including ferrous sulfate and Maectite solutions. The heavy metal stabilization agents were added to the lignosulfonate solution and the mixtures were checked for pH, temperature change and off-gas generation. The compatibility testing consisted of mixing fixed amounts of the conditioning solution reagents in various orders and monitoring the pH and temperature change and any off-gas generation of the solution. Table II shows the results from the phase I testing.

TABLE II COMPATIBILITY TESTS						
Formula						
ID	Silo 3 (g)	$FeSO_4$ Solution* (g)	REAX SN (g)	H_2O (g)	Maectite (ml)	
					A/B	C
1	0	12	0.108	11.34	0	0
2	0	0	0.108	0	30	0
3	0	0	0.108	0	0	12.5

* Ferrous sulfate as a 15% solution

TABLE III COMPATIBILITY RESULTS			
ID	PH	Temperature (° C)	Off – gas * (PPM)
1	0.24 and 0.28	13-15	None
2	2.1/ 3.3	18	None
3	11.8	18	None

* Off – gas monitoring include ammonia, nitrous oxide, and sulfur dioxide.

The sequence to completely dissolve the REAX solution is as follows: water, REAX solution, and then ferrous sulfate solution. The pH test results for test 1 was very low due to the sulfuric acid in the ferrous sulfate solution. The pH in ID 2 and 3, Maectite A/B and C, were inline with expected levels.

The temperature increase of 2° C is not a significant increase in the solution with $FeSO_4$. No temperature change was observed in Maectite A/B or C. There were no visible signs that any of the solutions reacted in an exothermic manner.

Drager tubes used to detect ammonia, nitrous oxides, and or sulfur dioxide gas, showed no indication of off-gas generation of the solutions.

Phase II: Reduction in Leachability of Heavy Metals

Phase II consisted of determining the effectiveness of the ferrous sulfate and three different solutions, labeled Maectite A, B and C, in reducing the leachability of the heavy metals of concern. A solution of water, binder and reducing agents was mixed at different concentrations as shown in Table IV. A Silo 3 material sample was weighed in either an aluminum dish or an empty Ziploc® bag. A portion of the conditioning solution was applied to Silo 3 material in increments and hand mixed until the pre-weighed amount of conditioning solution was used. The samples were sent to an off-site laboratory for TCLP analysis. Three different concentrations of ferrous sulfate solutions and Maectite A, B and C (at vendor recommended concentrations) were tested to determine their effectiveness in reducing the leachability of chromium and selenium, the two heavy metals of concern. It was expected that the ferrous sulfate would act on chromium only, but the effect of Maectite products on either metal was unknown. The TCLP limits for all the metals in Silo 3 are shown in Table I. Table IV

shows the tests conducted, sample formulas and TCLP results for the RCRA heavy metals of concern.

TABLE IV
Chromium Reduction Agent Determination

FORMULA									TCLP RESULTS			
ID	Silo 3 Material	% Moisture	REAX SN (g)	$FeSO_4$ (g)	H_2O (g)	Maectite (ml)			TCLP, ppm			
						A	B	C	As	Cd	Cr	Se
1	50	20.0	0.054	2	10.9	-	-	-	0.50	0.085	4.7	1.4
2	50	20.0	0.054	4	9.3	-	-	-	0.50	0.087	3.4	1.2
3	50	20.0	0.054	6	7.7	-	-	-	0.50	0.11	2.4	1.3
4	50	30.0	0.054	2	19.95	-	-	-	0.50	0.095	4	1.2
5	50	30.0	0.054	4	18.35	-	-	-	0.50	0.086	2.9	1.1
6	50	30.0	0.054	6	16.8	-	-	-	0.50	0.11	2.1	1.1
7	50	20	0.054	-	-	15	-	-	0.50	0.10	1.6	1.2
8	50	20	0.054	-	-	-	15	-	0.50	0.099	1.6	1.3
9	50	20	0.054	-	8.75	-	-	6.25	0.50	0.042	0.13	1.2
10	50	20	-	-	-	15	-	-	0.50	0.090	1.2	1.1
11	50	20	-	-	-	-	15	-	0.50	0.092	1.8	1.3
12	50	20	-	-	8.75	-	-	6.25	0.50	0.045	0.048	1.2

All samples passed TCLP for chromium. All samples failed for selenium, the results were similar to unconditioned Silo 3 material. Results for arsenic and cadmium are below the TCLP limit, similar to the to the unconditioned Silo 3 material (see Table 1). Maectite C reduced leachable chromium better then the ferrous sulfate solution and Maectite A/B. These selenium results were not surprising, based on the challenges encountered during the study described in the Design Data Development Tests. Eight percent ferrous sulfate solution to 100 parts Silo 3 material was chosen for future conditioning formulas based on the TCLP results.

Phase III: Optimum Moisture Determination

Phase III consisted of determining the optimum moisture content and the upper moisture limit in the powder by mixing Silo 3 material with various percentages of solution. The Design Data Development Report, 40430-RP-0015, Rev. 0 indicated that the stabilization formulation containing Silo 3 material changes to a paste at 40-45% moisture content. The stabilization formulation mix included ferrous sulfate solution, lime, Portland cement and tap water.

Phase III tests included sieve analysis on the conditioned samples that were dried under various conditions. Some samples were placed in a drying pan and allowed to sit uncovered in the HEPA Hood while others were placed in an oven and dried for at least 12 hours at 110° C to compare the moisture loss and sieve analysis under both drying conditions. The sieving method used was Fluor Fernald's Determination of Particle Size in Soils, Sieve Method,

Document Number 6532. The following sized mesh sieves were used: 20, 40, 100, and the pan.

Moisture addition was investigated to determine a level that will produce an agglomerated "soil-like" product from the dry powdery Silo 3 material and to determine the level of liquid addition at which the material starts to fluidize. Experience from the de-dusting investigation indicated that use of moisture levels of 20%, 30%, 32.5% and finally 35% in the formulations would cover the range of interest. Samples at these levels of moisture were mixed and sieved immediately after mixing or allowed to dry in the hood or the oven before sieving. Unconditioned Silo 3 material sieve analysis has shown that 94.9 weight% of the material is below 150 microns. Sieve analysis results for each formulation and drying conditions can be found in Table V.

TABLE V
MOISTURE DETERMINATION

Formula											Sieve results in percent retained				
ID	Silo 3 Material (g)	Percent Moisture	REAX Solution (g)	$FeSO_4$ Solution (g)	H_2O (g)	Maectite (g) A	B	C	Percent moisture Hood	Oven	Microns / Mesh No. 850/ 20	425/ 40	150/ 100	Pan	Sum *
1	50	30.0	0.054	4	18.3	-	-	-			62.7	25.7	5.6	0.1	94.1
1	50	30.0	0.054	4	18.3	-	-	-	20.6		57.2	15.3	23.6	3.2	99.3
1	50	30.0	0.054	4	18.3	-	-	-		<1	47.5	6.1	11	33.9	98.4
1b	50	32.5	0.054	4	21	-	-	-		<1	68	5	5	25	103
2	50	35.0	0.054	4	23.9	-	-	-		2.1	Monolith did not sieve				
2c	50	20.0	0.054	4	9.3	-	-	-			31.4	50	15.5	5.3	102.2
6	50	29.8	0.054	-	7.9	15	-	-			74.5	19.2	5.4	0.04	99.1
6	50	29.8	0.054	-	7.7	15	-	-	22.6		54	22.2	20.7	1.7	98.6
6	50	30.0	0.054	-	7.7	15	-	-		<1	59	10	11.6	18.9	99.5
7	50	35.0	0.054	-	13.5	15	-	-		<1	58.3	5.3	11.1	24.4	99.1
8	50	30.0	0.054	-	16.3	-	-	6.25		1.4	39.4	13.4	19.7	27.5	100

Microns and micrometers are the same unit of measurement.
Oven dried = material dried in oven for at least 12 hours at 110° C.
According to the sieve procedure if the sum of the fractions do not equal 95-105% of the original sample mass, the results are invalid.

Formulation 2c, at 20% moisture and without drying, had 5.3 wt% below 150 microns, compared with 94.6 wt% for dry silo 3 material. The results also show that this formulation can meet the NTS WAC requirement for "15 weight percent of less-than-200-micrometer-diameter particles", without secured packing.

Formulations 1, 6 and 8 compare the effect of ferrous sulfate and Maectite solutions A, B and C on agglomeration at the same moisture level of 30 weight percent and at different drying

conditions. The results show that the degree of agglomeration is affected more by the residual moisture and less by the type of stabilization chemical. In general, higher residual moistures in non-dried and hood-dried samples, resulted in higher level of agglomeration that can meet the NTS WAC requirement as indicated by the fine particles fraction ranging from 0.04 to 5.3 weight percent. The samples that were dried in the oven lost more moisture then the in-situ Silo 3 material this resulted in a larger fine particles fraction ranging from 18.9 to 33.9 weight percent, substantially lower than the 94.6 weight percent for dry silo 3 material.

Formulations 2 and 7 compare the effect of mixing energy on the consistency of the mix at 35 weight percent. During the stabilization formulation development work performed earlier and described in the Design Data Report, it was observed that, when a certain moisture level is reached in a relatively dry mix formulated with Silo 3 material and other ingredients, the mix can become dough-like by longer or more intense mixing. This observation was again made with formulations 2 and 7, where at 35 weight percent formulation 7 with normal mixing went through the stack of sieves, but turned into a soft material with more mixing as shown in test 2. During the full scale process, no mixing will be performed after spraying the conditioning formulation on the material. These results indicate that the upper moisture limit for free water separation in the mix is higher than 35 weight percent.

The sieve analysis results in this report are similar to those found in Silo 3 Dedusting Report, Document No. 40430-RP-0016. None of the samples in the dedusting report were oven dried. They were all dried uncovered in the HEPA hood.

Phase IV: Moisture Migration

Phase IV testing was designed to study moisture migration within the Silo 3 material from areas of high moisture to areas of low moisture. A 100 g sample of Silo 3 material and 42 ml of solution, an amount of the treatment solution corresponding to 30% treatment, were weighed. The solution was placed in a graduated cylinder and enough Silo 3 material was added to obtain a saturated mix. The volume of the saturated sample in the graduated cylinder was recorded. The remaining portion of the dry Silo 3 material was added to the cylinder and the volume recorded. The increase in wet volume in the graduated cylinder was recorded with time as a measure of the moisture migration.

The goal of the moisture migration test was to observe how moisture migrates within the Silo 3 material in order to predict the behavior of the uneven moisture distribution expected in the powder during the full-scale operation. The results as shown in Table VI suggest a similar migration of both water and conditioning solutions. The initial wet volume represented 42.3% of the total sample. The moisture migration reached equilibrium at 55.7% of the total sample volume leaving 44.3% of the sample volume dry. The table below shows formulas and migration of moisture in milliliters.

TABLE VI MOISTURE MIGRATION									
ID	Silo 3 Material (g)	Percent Moisture	REAX Solution (g)	$FeSO_4$ Solution (g)	H_2O (g)	Initial wet volume (ml)	Final wet volume (ml)	Total dry/wet volume (ml)	Total (ml) moisture migration
1	100	30	0.108	8	36.62	55	72.5	130	17.5
2	100	30	-	-	42.85	52	73	130	21

Phase V: Moisture Loss

Phase V, moisture loss testing was performed to determine whether conditioned Silo 3 material would hydrate, and at what temperature the waters of hydration would be driven from the material, simulating field conditions that may be seen during transportation. Silo 3 material was conditioned and placed in the following environmental conditions: uncovered in the running HEPA hood at a estimated temperature of 15°C (59°F), placed uncovered in an oven at a constant temperature of 60°C (140°F) and then again in the oven at a constant temperature of 110°C (230°F). Each sample spent at least 12 hours in each environmental condition and then was weighed for weight percent moisture loss/(gain).

Table VII shows the results when Silo 3 material was conditioned and placed in the various environmental conditions. The percent moisture for each sample does not include the estimated 2-3 percent in-situ moisture content of the Silo 3 material.

TABLE VII MOISTURE LOSS								
Formula (g)						Results - Weight % moisture Loss / (Gained)		
ID	Silo 3 Material	Percent Moisture	REAX Solution	$FeSO_4$ Solution	H_2O	15°C 59°F	60°C 140°F	110°C 230°F
1	100	-	-	-	-	(1.76)	1.1	2.4
2	100	30	-	-	42.85	11.2	27.6	29
3	100	30	0.108	8	39.9	17.9	32.5	33.7
The following samples were allowed to site for 14 days to allow solution to incorporate								
A	100	30	-	-	42.85	14.9	30.1	30.8
B	100	30	0.108	8	39.9	12.8	29.2	30.2

The results indicate that sample 1 at 15° C (59° F) absorbs moisture from the surrounding air. This is not unexpected considering the low percent moisture of the Silo 3 material and the results observed by SRS that states, "Silo 3 waste absorbs moisture from humid air ...the amount of absorption or hydration depends on the humidity and on exposure time."

The results for test 2 and A show between 11.2 and 15 weight percent loss while the samples were exposed to 15° C (59° F) in the running HEPA hood. The results indicate that given time moisture may incorporate into the material allowing additional moisture to be retained.

The results for test 3 and B show between 18 and 12.8 weight percent losses respectively while the samples were exposed to 15° C (59° F) in the running HEPA hood. These results differ from test 2 and A in the fact that incorporation time did not indicate that more moisture was retained. It showed that 5-weight-percent more moisture was retained without incorporation time. Additional testing would be needed to determine if incorporation time was an effective way to retain additional moisture in this environment.

The results indicate that at 60° C (140° F) all samples retain roughly 1 to 2 weight percent moisture. There could be moisture incorporated in the material as it hydrates.

The results indicate that at 110° C (230° F) roughly all moisture is lost. There could be a small amount of moisture incorporated in the material as it hydrates that does not degrade at such high temperatures.

6.0 Safety

Reagent handling reviewed by Industrial Health.

Ferrous Sulfate Solution
This material is a strong acid, very corrosive to the skin and can cause irreversible eye damage. Use impervious gloves, clothing and goggles when handling this material. A face shield may be needed if there is a danger of being splashed. Inhalation of the fumes of this material may irritate the respiratory tract. Respirators may be required if the material becomes aerosolized. If the skin comes into contact with this material, flush the skin and/or eyes for at least 15 minutes. This material is a strong acid and may splatter upon contact with water or water-containing chemicals and solvents. It reacts violently with bases. Contact with metals may produce hydrogen gas that is flammable. Safety showers and eye washes should be available in areas where this material is handled. Containers should be stored in a cool, dry, well-ventilated area. This material exhibits the RCRA characteristic of corrosivity and any disposal must comply with hazardous waste disposal requirements.

REAX SN Solution
This material is a dark brown liquid with a vanilla-like odor. It may be irritating to the skin and eyes. If the skin comes into contact with this material, flush the skin and/or eyes for at least 15 minutes. Goggles may be required if there is a potential for splashing. Impervious gloves are required when handling this material. Eyewashes should be available in areas where this material is handled.

Maectite C Concentrate
This material is a highly concentrated base, very corrosive to the skin and can cause irreversible eye damage. Use impervious gloves, clothing and goggles when handling this

material. A face shield may be needed if there is a danger of being splashed. Inhalation of the fumes of this material may irritate the respiratory tract. Respirators may be required if the material becomes aerosolized. If the skin comes into contact with this material, flush the skin and/or eyes for at least 15 minutes. Avoid having this material come into contact with acids. This material is a highly concentrated base that will generate toxic hydrogen sulfide gas if it is mixed with an acid. A vigorous chemical reaction and flammable gases can result from the mixture. Safety showers and eyewashes should be available in areas where this material is handled. Containers should be stored in a cool, dry, well-ventilated area.

Maectite A/B
This material is a strong acid and may splatter upon contact with water or water-containing chemicals and solvents. It reacts violently with bases. This material is very corrosive to the skin and can cause irreversible eye damage. Use impervious gloves, clothing and goggles when handling this material. A face shield may be needed if there is a danger of being splashed. Inhalation of the fumes of this material may irritate the respiratory tract. Respirators may be required if the material becomes aerosolized. If the skin comes into contact with this material, flush the skin and/or eyes for at least 15 minutes. Contact with metals may produce hydrogen gas that is flammable. Safety showers and eyewashes should be available in areas where this material is handled. Containers should be stored in a cool, dry, well-ventilated area.

7.0 Implementation

Design information

The following are recommended design considerations to the current Jacobs Engineering design for implementation of the findings in this report.

- The recommended formula to use is as follows: not more than 20 parts water, 0.108 parts sodium lignosulfonate, 8 parts ferrous sulfate solution and finally 100 parts Silo 3 material.

- The order of reagent addition to prepare the conditioning formula should be as follows: water and sodium lignosulfonate and agitate to dissolve the sodium lignosulfonate. Finally add ferrous sulfate solution and agitate. Mixing should occur in a separate tank prior to being sprayed on the Silo 3 material. Note: sodium lignosulfonate will not properly dissolve in the conditioning solution if added to the water after ferrous sulfate.

- Undiluted sodium lignosulfonate is viscous and will become very sticky, then eventually harden by evaporation when exposed to air. We suggest recirculation to prevent this from occurring.

- Ferrous sulfate solution, 15% ferrous sulfate, is successful at stabilization of leachable chromium at eight parts per 100 parts waste.

- The amount of conditioning solution should not exceed 35 weight percent moisture. By

keeping total water in the conditioning solution to 20 parts water to 100 parts waste we will not exceed this limit even at 12 percent in-situ moisture of Silo 3 material. Total water should include any rinse water used to keep spray nozzles from plugging.

- Rinse water from the spray nozzles should be added to the shipping liner only after all the Silo 3 material is in the liner. This will aid heat-sealing by eliminating dry powdery Silo 3 material clinging to the sides of the liner.

- Migration study indicates that conditioning solution spray can be course if needed.

8.0 Operating Cost

Reagents

The table below shows the raw material costs to produce a conditioned product with 25-weight percent moisture, without taking into consideration the in-situ percent moisture of Silo 3 material.

Process water should not exceed 20 parts of H_2O to 100 parts of Silo 3 material. Even if in-situ Silo 3 material has ten percent moisture the total moisture would not exceed 35 percent. If the in-situ Silo 3 material had zero percent water the total moisture would be slightly less than 24 percent.

MeadWestvaco is the supplier of REAX solution, sodium lignosulfonate solution, which can be supplied in totes that are made of Polyvinyl Chloride (PVC) and wire mesh. The totes hold 2,500 lbs. Sodium lignosulfonate solution cost is based on 0.108 parts of solution to 100 parts waste. There is an additional shipping cost of $300 to $500 from Charleston, SC. One-week notice for reorders is requested.

EagleBrook® Company is one supplier of ferrous sulfate solution, which can deliver 4500-gallon per tanker truck, depending on the project's schedule. The shelf life does not appear to be an issue in the effectiveness of the solution. Ferrous sulfate solution is based on eight parts to 100 parts of Silo 3 material.

Sevenson Corporation provided the Maectite solution and cost information, which includes delivery costs over 30-weeks.
Incorporated

TABLE VIII COST INFORMATION TO CONDITION 5,783,400 LBS OF SILO 3 MATERIAL							
Option	Water (gallons)	REAX (lbs)	$FeSO_4$ (lbs)	Maectite A (lbs)	Maectite C (lbs)	Cost of reagents minus H_2O ($)	Cost per ton of product
1	138,690	6,246	462,672	-	-	35,300	12.20
2	127,123	6,246	-	760,000	-	126,400	43.70
3	144,853	6,246	-	-	866,000	165,300	57.20

9.0 Conclusions

Conclusions are based on 1) RCRA regulatory limits of the TCLP test method for heavy metals, 2) the NTS WAC for particle size of 15 weight percent of less-than-200-micrometer-diameter particles, and 3) Safety

- The heavy metal stabilization agents are compatible with the REAX SN solution, sodium lignosulfonate solution, 47% sodium lignosulfonate. There were no significant exothermic reactions with conditioning agents and REAX SN solution. Likewise, there was no generation of off-gasses. Ferrous sulfate solution was selected as the heavy metal stabilization agent. The sequence of addition is as follows: water, REAX solution, agitation for two minutes and then ferrous sulfate solution.

- The heavy metal stabilization agent reduced Chromium below the TCLP regulatory limits. Arsenic, Cadmium and Selenium results were similar to untreated Silo 3 material. Arsenic and Cadmium were below but Selenium was not below the TCLP regulatory limit.

- A REAX SN solution is needed to achieve agglomeration of the material when the material is allowed to dry. An increase in REAX solution may be considered if conditions would simulate hot dry desert conditions.

- Adding a sodium lignosulfonate binder solution at a dilution factor as large as 200:1 to raise the Silo 3 material moisture content to optimum moisture, allows the material to meet the particle size requirements of the NTS WAC.

- Agglomeration of Silo 3 material occurs with the conditioning solution using the heavy metal stabilization agent at the optimum percent moisture. Silo 3 meets the NTS WAC for particulates with the current design's packaging system, which does not include waste conditioning.

- The optimum moisture should not exceed 35 weight percent to solids. To achieve this, process water (including rinse water) should not exceed 20 parts of H_2O to 100 parts of

Silo 3 material.

- Ferrous sulfate solution, 15% ferrous sulfate, is the most cost effective heavy metal stabilization solution. Recommendation is 8 parts of 15% ferrous sulfate solution to 100 parts Silo 3 material.

- Moisture migration in the final product shows that the recommended conditioning formula can reach 55 percent of the total volume of product when sprayed, without physical or mechanical mixing.

- Proper safety procedures, training and safe handling of chemicals during unloading and maintenance activities will reduce unsafe conditions.

- The waste loading range is between 79 and 68 percent, dependent on the in-situ percent moisture of Silo 3 material.

- To achieve waste loading the recommended conditioning formula is as follows: not more than 20 parts water, 0.108 parts sodium lignosulfonate, 8 parts ferrous sulfate solution added and finally 100 parts Silo 3 material.

10.0 References

1) Silo 3 Dedusting Report, Fluor Fernald Document Number, 40430-RP-0016, Rev 0, November 2002.

2) The Design Data Development Report, Fluor Fernald Document Number, 40430-RP-0015, Rev. 0, August 2002.

3) Nevada Test Site, Waste Acceptance Criteria, Rev. 4, Section 3.1.6, Particulates, 2002.

4) Remedial Investigation Report for Operable Unit 4, volume 2 of 3, U.S. Department of Energy, Fernald Field Office, November 1993.

5) Pretreatment of Silo 3 Material with Lignosulfonate Solution, Jenike and Johanson, Inc., Revision August 2002.

6) C.A. Langton and C.G. May, Characterization of Fernald Silo 3Waste (U), Westinghouse Savannah River Company, Savannah River Site, SC, December 28, 2000.