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TRANSMITTAL OF FINAL REPORT FOR THORIUM NITRATE TANK T-2, COMPLETED UNDER REMOVAL ACTION NO. 9, REMOVAL OF WASTE INVENTORIES

02/15/96

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REPORT

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FEB 15 1996

DOE-0531-96

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Dear Mr. Saric and Mr. Schneider:

TRANSMITTAL OF FINAL REPORT FOR THORIUM NITRATE TANK T-2, COMPLETED UNDER REMOVAL ACTION NO. 9, REMOVAL OF WASTE INVENTORIES

Enclosed is the Final Report for the Thorium Nitrate Tank T-2 project, completed under Removal Action No. 9, Removal of Waste Inventories and the approved Project Specific Plan (PSP) dated August 1995. Submittal of the Final Report completes the requirements for the Thorium Nitrate Tank T-2 project, as referenced in the PSP, which requires submittal by February 22, 1996, and describes how the removal action was completed and how removal action objectives were met.

If you have any questions or comments regarding this document, please contact Chris White at (513) 648-3172 or Robert Danner at (513) 648-3167.

Sincerely,

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Fernald Remedial Action
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FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

THORIUM NITRATE SOLIDIFICATION FINAL REPORT COMPLETED UNDER REMOVAL ACTION NO. 9

FEBRUARY 1996

U.S. DEPARTMENT OF ENERGY

Thorium Nitrate Solidification
Final Report
February 1996

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ACRONYMS AND ABBREVIATIONS

ACA	Amended Consent Agreement
ALARA	As Low As Reasonably Achievable
CERCLA	Comprehensive Environmental Restoration, Compensation, and Liability Act
CFR	Code of Federal Regulations
cm	centimeter
CNSI	Chem-Nuclear Systems, Inc.
COC	Constituents of Concern
DAC	Derived Air Concentration
DF&O	Director's Findings and Orders
DOE	Department of Energy
dpm	disintegrations per minute
FEMP	Fernald Environmental Management Project
FERMCO	Fernald Environmental Restoration Management Corporation
FR	Federal Register
g/l	grams per liter
HEPA	High Efficiency Particulate Air
HWMU	Hazardous Waste Management Unit
LDR	Land Disposal Restrictions
LLRW	Low-Level Radioactive Waste
ml	milliliter
mrem	millirem
N	Normality
NRC	Nuclear Regulatory Commission
NTS	Nevada Test Site
OAC	Ohio Administrative Code
OEPA	Ohio Environmental Protection Agency
OU	Operable Unit
PEP	Project Execution Plan
P&ID	Process and Instrumentation Diagram
PPE	Personal Protective Equipment
PSP	Project Specific Plan

ACRONYMS AND ABBREVIATIONS

QA	Quality Assurance
RA	Removal Action
RAWP	Removal Action Work Plan
RCRA	Resource Conservation and Recovery Act
rpm	revolutions per minute
SSOP	Site Standard Operating Procedure
TC	Toxicity Characteristic
TN	Thorium Nitrate
TNSP	Thorium Nitrate Solidification Project
U.S. EPA	United States Environmental Protection Agency
UTS	Universal Treatment Standards
uR	microrem
VOC	Volatile Organic Compound
WAC	Waste Acceptance Criteria
WL	Working Levels
WMB	White Metal Box

EXECUTIVE SUMMARY

Removal Action (RA) No. 9, Removal of Waste Inventories, was identified in the September 1991, Amended Consent Agreement (ACA) to address inventories of thorium and low-level radioactive waste (LLRW) remaining at the Fernald Environmental Management Project (FEMP). LLRW includes wastes containing constituents regulated under the Resource Conservation and Recovery Act (RCRA), as amended, and the Ohio Environmental Protection Agency (OEPA) Hazardous Waste Management Program. The ACA, as negotiated, requires the Department of Energy (DOE) to submit an annual compendium of existing procedures and documentation for the LLRW and Thorium Management Program, in lieu of a Removal Action Work Plan (RAWP). Additionally, Project Specific Plans (PSPs) for projects involving mixed waste treatment and disposition, including the Thorium Nitrate Solidification Project (TNSP), were submitted as specified in Removal Action Memorandum Addendum No. 1 (March 10, 1995). The Thorium Nitrate Tank T-2, Hazardous Waste Management Unit (HWMU) No. 54, contained mixed waste and fell within the scope and administration of RA No. 9.

The objectives of the TNSP encompassed safely removing the waste from Tank T-2, treating the waste for disposal, and decontaminating the tank to meet the clean closure requirements of the HWMU, while maintaining radiation exposures to personnel As Low As Reasonably Achievable (ALARA). All objectives of the TNSP were met. The following information summarizes the project results and conclusions.

- There was an outstanding safety record during this project. Radiologic controls were implemented and all safety issues listed in the PSP were complied with. There were no lost time work accidents, no first aid cases, personnel contaminations, or environmental releases. The TNSP was controlled, well-planned, and safe.

- The thorium nitrate was safely removed from Tank T-2. Small, nonreportable spills that occurred during this operation were contained and safely cleaned to background levels.

- The thorium nitrate and rinse water were solidified. Minor changes in the original solidification formulation, developed during bench-scale testing, were required. All drums of solidified waste hardened completely and contained no free liquids.

- Based on analytical data and process knowledge, underlying hazardous constituents for the thorium nitrate were chromium and cadmium. The Universal Treatment Standards (UTS) limits are 860 μg/l for chromium and 190 μg/l for cadmium. Analytical results indicate that all drums of solidified thorium nitrate are below regulatory limits. The solidified waste is not corrosive and meets land disposal criteria.

- Tank T-2 and the process system was decontaminated by flushing the entire system with water to meet OEPA Closure Standards. Clean closure of Tank T-2 was achieved after four rinses. Tank T-2 was rinsed an additional four times to reduce radiologic contamination levels from thorium residue in the tank.

- Results from air and radiological monitoring indicate that no control levels specified in the PSP were exceeded. The cumulative exposure received by project personnel was well below the goal of 1.9 man-rems specified in the project ALARA review. Contact dose-rates on the drums of final product were in the range of 10 -15 mrem/hour, with dose rates less than 5 mrem/hour at 30 centimeters. General area dose-rates in the project area were typically less than 5 mrem/hour. The derived air concentration (DAC) for Thorium-232 (Class W soluble) was applied for radiation protection purposes on this project. In addition, a DAC of 1.0 working levels (WL) was applied for thoron progeny. Average concentrations on the project perimeter were less than ten percent for each DAC.

Thorium Nitrate Solidification
Final Report
February 1996

1.0 INTRODUCTION

The Tank T-2 Thorium Nitrate Project Specific Plan (PSP) described actions encompassing safely removing the waste from the tank, treating the waste for disposal, and decontaminating the tank to meet the clean closure requirements of the Hazardous Waste Management Unit (HWMU), while maintaining radiation exposures to personnel As Low As Reasonably Achievable (ALARA).

This document provides a summary of the activities conducted during the course of the Tank T-2 removal action and closure. Section 1.0 describes the history and background of the HWMU, waste characterization, and the RCRA/CERCLA Integrated Closure Director's Findings and Orders (DF&O) (hereafter called DF&O). Section 2.0 describes the removal action. Section 3.0 summarizes the conclusions and Section 4.0 contains references.

1.1 History and Background

1.1.1 Unit Description

Tank T-2 is located in Operable Unit 3 (OU3) on the west side of the Pilot Plant (Figure 1-1). The thorium nitrate stored in Tank T-2 was residual material received from the Department of Energy (DOE) Hanford facility as part of the DOE-wide research program with the Thorium Breeder Reactors, which originated in the late 1950's and extended into the early 1970's. Material from Hanford was accumulated in Tank T-2 and other tanks to await program needs. When the program was discontinued, material in process continued to be sent to Fernald, the United States thorium repository. When funding was terminated, the material in Tank T-2 remained.

Tank T-2 is a flat-bottomed stainless steel, 8,000 gallon tank measuring 10'(D) x 14'(H). Tank T-2 contained 6,003 gallons of thorium nitrate waste containing 374 grams per liter (g/l) thorium in 0.7 N (Normal) nitric acid. The depth of thorium nitrate in Tank T-2 was approximately 1.1 feet. There was no ancillary equipment, flanges, or piping associated with Tank T-2, as it had previously been isolated. The tank is mounted on a 1'10" thick concrete pad inside a containment area with 2'3" walls. The containment area is 28' (W) x 45' (L) and has a capacity of approximately 21,000 gallons (Figure 1-2). Figure 1-3 shows Tank T-2 inside the secondary containment area. In this photograph, the green hose outside of secondary containment was part of the passive air ventilation system. Tanks T-3, T-4, T-5,

Figure 1-1: Tank T-2 Location

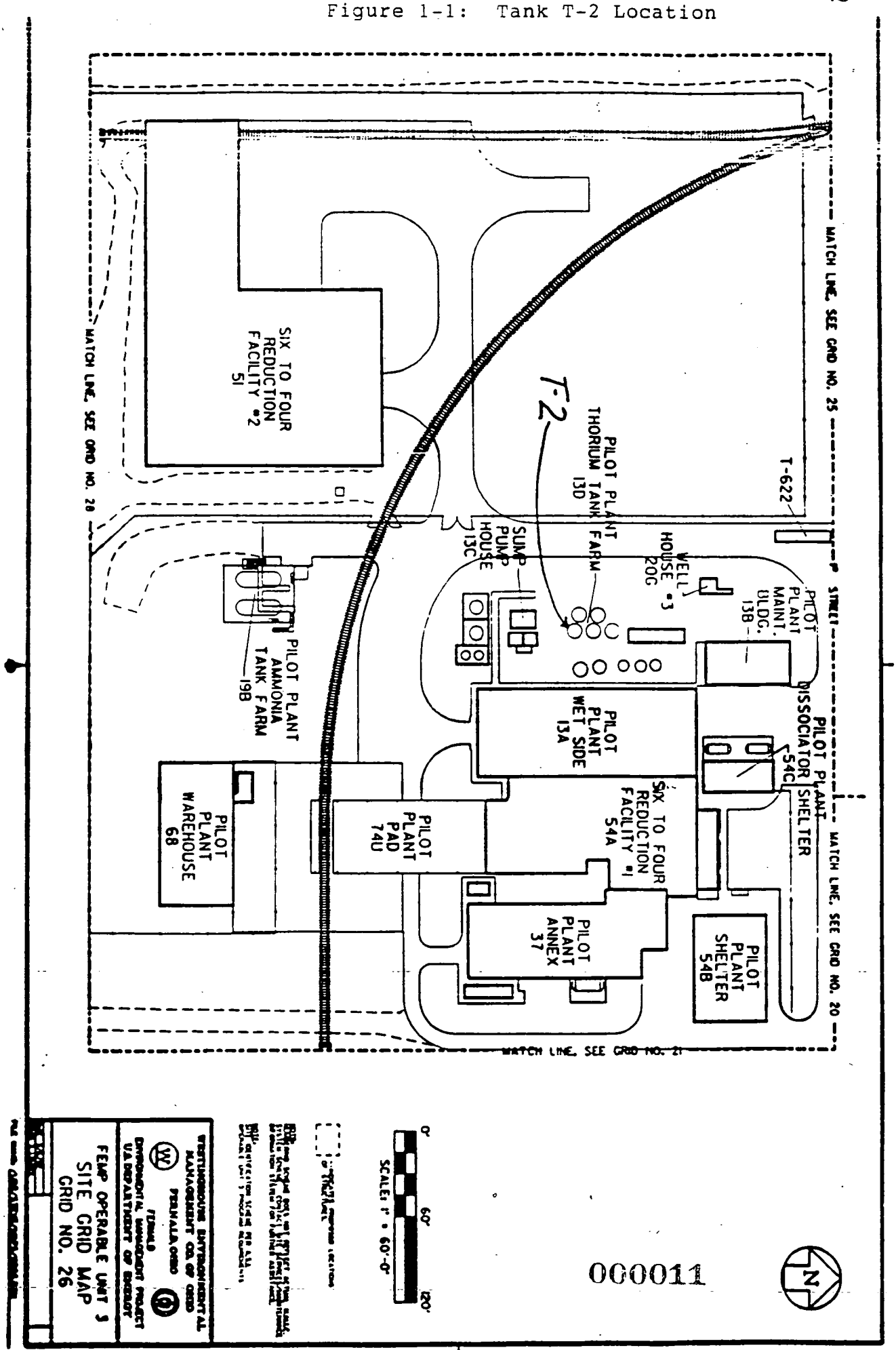

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Figure 1-2: Tank T-2 Dimensions

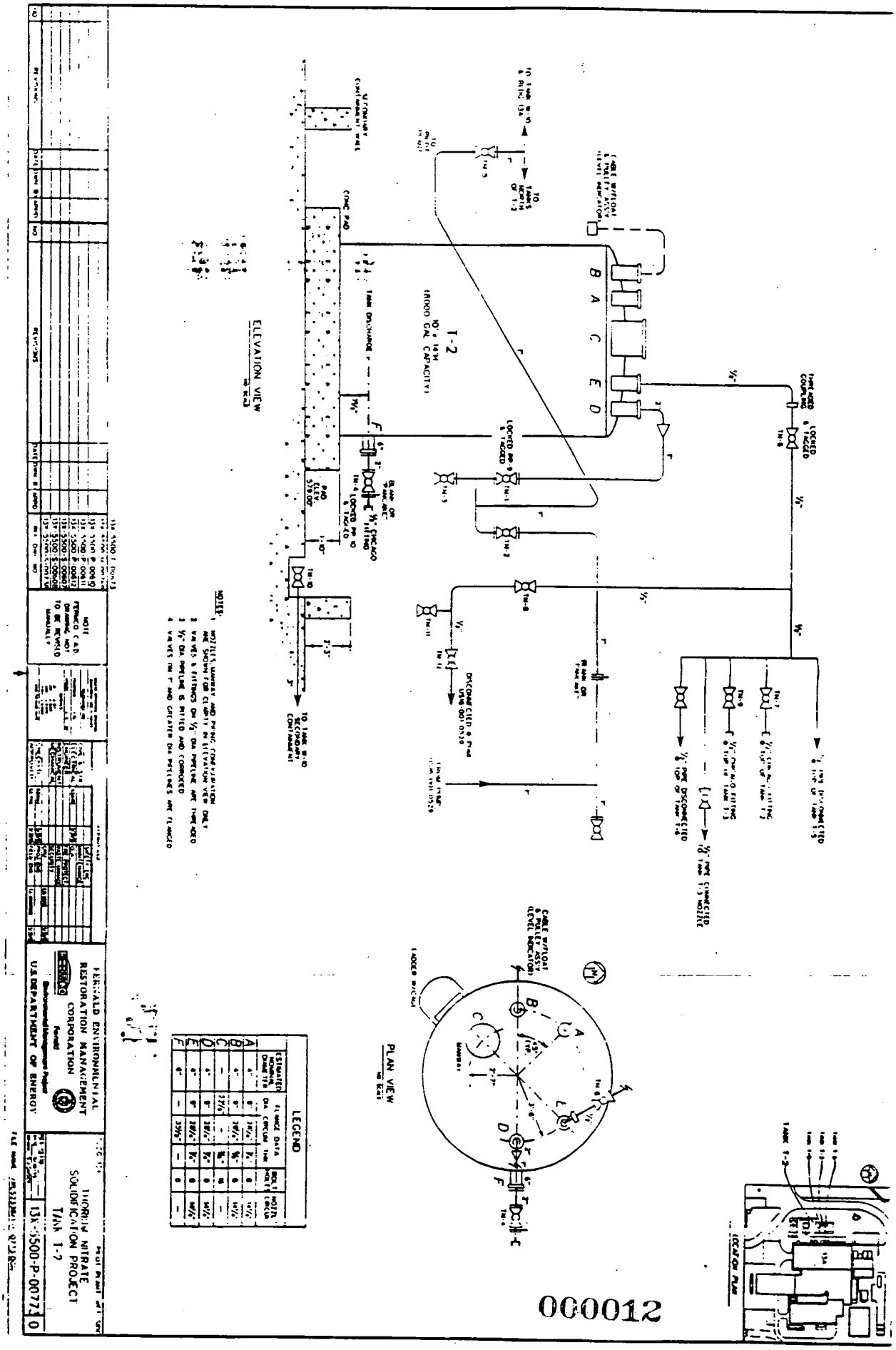
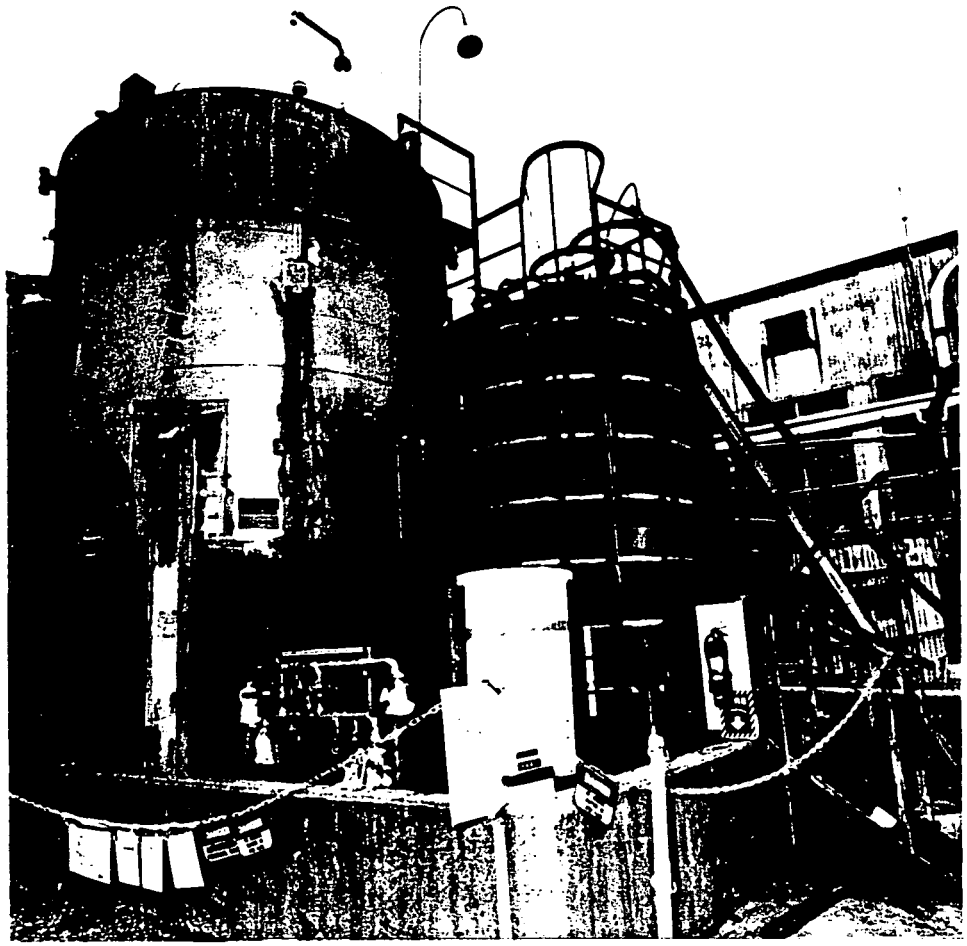


Figure 1-3 Tank T-2 (on right) Inside Secondary Containment



and Tank T-6 are also located inside this containment area. Access to the inside of Tank T-2 is by four ports on the top (9" diameter each) and a manway (22" diameter). Approximately 6" above the ground, at the base of Tank T-2, is a 6" diameter side discharge.

1.1.2 Waste Characterization and Inventory

In November 1993, Tank T-2 underwent ultrasonic thickness testing and visual inspection. Although Tank T-2's original shell thickness is not available, test results showed Tank T-2 to be structurally sound. Tank T-2 was inspected daily and visual examination and review of Fernald Environmental Management Project (FEMP) spill reports indicated no evidence of leaks. Tank T-2 was sampled in January 1993 and 1995. The isotopic thorium and RCRA Toxicity Characteristic Leaching Procedure (TCLP) metal data from the January 1993 sampling of Tank T-2 are listed in Table 1-1 of the PSP. These constituents were not reanalyzed in 1995. Due to the time the thorium had been in Tank T-2, it was approaching secular equilibrium with its decay daughters. These decay products increased the dose rate emitted from Tank T-2.

In 1995, a 16-ounce surface sample (grab) was collected and screened for volatile organic compounds (VOCs). No organics were present in Tank T-2, as anticipated based on process knowledge. Five one-gallon treatability samples and five 16-ounce characterization samples were collected from incremental depths (1', 3.25', 5.5', 7.75', and 10') within the tank contents. Five characterization samples were collected and analyzed for total thorium and density. The samples confirmed that the tank's contents were homogeneous and not stratified. A composite sample was prepared from the five depth samples and analyzed for isotopic uranium, isotopic plutonium, isotopic radium (fissionable radionuclides), Normality, and nitrates. A gamma screen for fission products was also performed. Percent acid was calculated from Normality. Based on the form and concentration of the thorium nitrate in the tank, there was no potential for a nuclear criticality.

1.2 RCRA Classification

The thorium nitrate was suspected to exhibit the toxicity characteristic (TC) for chromium (D007) and cadmium (D006), and was classified as corrosive (D002) under RCRA. The chromium and cadmium concentrations reported in Table 1-1 of the PSP may have been falsely elevated due to laboratory difficulty in analyzing trace metals in high thorium concentration solutions.

1.3 Regulatory Status

Tank T-2 was declared a HWMU for the storage of hazardous waste greater than 90 days. The DF&O currently being developed by the Ohio Environmental Protection Agency (OEPA) and the FEMP lists the Tank T-2 HWMU as requiring closure through a RCRA/CERCLA integrated approach. The TNSP was conducted as a CERCLA removal action and applied this RCRA/CERCLA integrated approach. Clean closure performance standards in OAC 3745-66-11 (40 CFR 265.11) have been met by identifying, isolating, removing, treating hazardous constituents present in Tank T-2, and decontaminating the tank. Stormwater from Tank T-2's concrete secondary containment was analyzed and showed that the stormwater had effectively rinsed the secondary containment to below RCRA rinse standards. Documentation to satisfy the administrative requirements for closure of this HWMU will be completed in accordance with the proposed DF&O.

The project was completed using Chem-Nuclear Systems's, Inc. (CNSI's) Nuclear Regulatory Commission (NRC) field license to meet DOE requirements for handling radioactive material. DOE and NRC requirements implemented by CNSI during the project were shown to be equivalent for project management systems; the quality assurance program; environmental, safety and health programs; training; and conduct of operations. The project site was designated a "NRC compound" for processing thorium nitrate. CNSI's license requirements applied in this compound in conjunction with the DOE requirements.

2.0 DESCRIPTION OF REMOVAL ACTION

2.1 Project Set-up

2.1.1 Solidification Bench-Scale Testing

Bench-scale solidification testing of the thorium nitrate was performed by CNSI in May 1995, to determine a suitable slurry formulation that would stay workable in the mixing equipment, cure to a hard waste product, and pass TCLP. The final waste form was designed to meet both the TCLP and the Nevada Test Site (NTS) Waste Acceptance Criteria (WAC). Fernald Environmental Restoration Management Corporation (FERMCO) provided CNSI with two 500 milliliter (ml) composite samples of thorium nitrate from Tank T-2 to complete the bench-scale testing. Bench-scale testing was conducted as described in Section 2.1 of the PSP and results are summarized in the Bench-Scale Test Report.

Based on bench-scale testing, the optimal mix contained approximately 22 gallons of thorium nitrate, weighing approximately 305 pounds; 18 gallons of 25% sodium hydroxide (NaOH), weighing 190 pounds; and 170-190 pounds of the solidification additive (60% Portland cement/40% flyash). This mix was developed to produce one full 55-gallon drum of solidified waste with a net weight of approximately 685 pounds. Based on this formulation, approximately 310 drums of solidified waste were expected to be produced from the TNSP, including the equipment decontamination and flush rinse water.

2.1.2 Selection of Solidification Process and Subcontractor

Several solidification formulas were bench-scale tested. Based on the bench-scale test results, the thorium nitrate solidification process developed by CNSI was determined to best meet the closure objectives and FERMCO's criteria for feasibility, implementability, compliance with NTS WAC, and waste volume.

CNSI is a NRC-licensed contractor. CNSI was selected as the subcontractor to perform the TNSP because of their previous experience in safely and effectively solidifying thorium nitrate.

2.1.3 Process Equipment

The solidification process tanks, equipment, and layout used during this project are described in Section 2.2 of the PSP. The process equipment was pressure tested at the CNSI facility. Equipment that contacted the thorium nitrate during this project was new and was evaluated for compatibility with thorium nitrate. The equipment was set up at the FEMP and leak tested with water. After completing the leak test, a system Operational Readiness Assessment was conducted prior to beginning thorium nitrate processing. Figure 2-1 shows the TNSP work area. Figure 2-2 shows the TNSP neutralization tanks and associated equipment (the hose outside secondary containment is a process water line).

2.1.4 Safety

One safety issue concerned the radiological contents of the waste being processed. A Safety Assessment for the TNSP evaluated the radiological contents of Tank T-2 to assess system and worker safety. The safety basis for this project was documented in an Auditable Safety Record (ASR). Worker safety and personal protective equipment (PPE) requirements were addressed in the Project Specific Health and Safety Plan prepared for the TNSP. This ensured worker protection from the hazards of the process. There was an outstanding safety record during this project. Radiologic controls were implemented and all safety issues listed in the PSP were complied with. There were no lost time work accidents, no first aid cases, personnel contaminations, or environmental releases.

2.1.5 Secondary Containment Analyses

The drain in the concrete secondary containment around Tank T-2 was closed for the duration of the TNSP. Stormwater was periodically emptied from the secondary containment and placed in portable dumpsters and analyzed for the Tank T-2 HWMU No. 54 constituents of concern (COC). The COC data from this stormwater, found in Table 2-1, shows the secondary containment area is below RCRA rinse standards as stated in the September 1993, Interim Final, Closure Plan Review Guidance for RCRA Facilities for HWMU No. 54 COCs. The stormwater effectively rinsed the entire secondary containment. Therefore, this secondary containment achieves OEPA closure requirements[1] and requires no further rinsing.

1/ Tank T-2's secondary containment also contains Tanks T-5 (HWMU No. 31) and T-6 (HWMU No. 32). The secondary containment was previously shown to meet the clean standards for the COCs for HWMUs 31 and 32 in the amendment to the closure plan for these HWMUs submitted to OEPA in November 1993.

Table 2-1 Tank T-2 Secondary Containment Rinse Analyses

Analyte	Result (mg/l)	Rinseate Limit (mg/l)
Cadmium	0.055	0.075
Chromium	0.141	1.0
pH*	11.3	2 ≤ pH ≥ 12.5

Note: * Average of three samples, maximum pH of 12.43.

2.2 Waste Treatment Operation and Summary

2.2.1 Chronology of Removal Action

A chronology of significant events during the TNSP is provided in the following table.

Treatability	
CNSI Quality Assurance Plan	02/17/95 - 03/03/95
CNSI workplan	02/17/95 - 03/03/95
Thorium nitrate samples to vendor	04/06/95 - 04/07/95
CNSI lab test	04/07/95 - 05/17/95
Lab results	05/17/95
CNSI prepare treatability report/FERMCO comments	05/19/95 - 07/21/95
Solidification Activities	
NRC/CNSI/DOE/FERMCO meeting on license amendment	04/12/95
Notice of intent to U.S. EPA and OEPA	04/15/95 - 04/15/95
Complete Auditable Safety Record	04/24/95 - 08/18/95
RA No. 9 amendment to DOE	05/11/95 - 07/20/95
FERMCO train CNSI personnel	05/31/95 - 06/15/95
Equipment procurement	05/31/95 - 07/25/95
Develop work packages	05/31/95 - 07/31/95
Equipment PM plans	06/13/95 - 09/08/95
Equipment leak test at Barnwell	08/07/95 - 08/09/95

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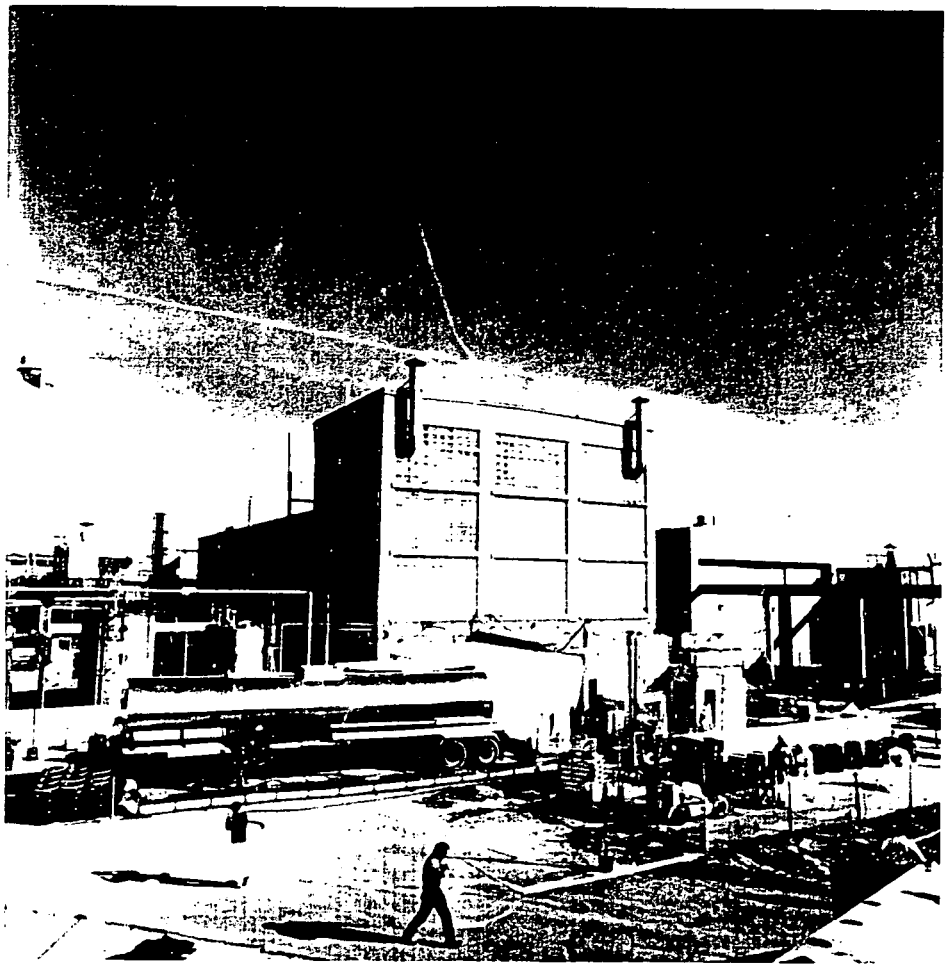

Figure 2-1
Thorium Nitrate
Solidification
Project Area

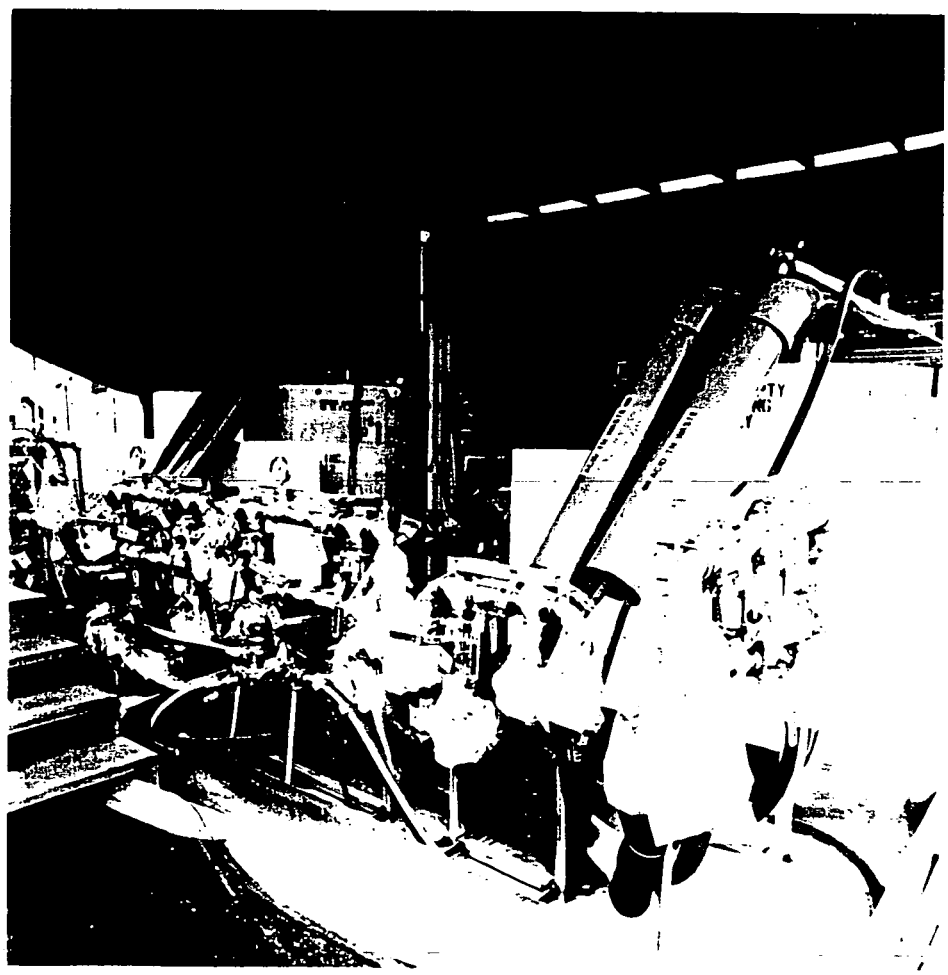

Figure 2-2
TNSP Neutralization
Tanks and Associated
Equipment

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(Chronology continued)

Thorium nitrate site prep	07/20/95 - 07/26/95
Setup system at Barnwell	07/26/95 - 08/08/95
Project Execution Plan complete	07/28/95
System setup	08/14/95 - 09/15/95
Operator table top reviews with CNSI	08/16/95 - 08/30/95
CNSI began training FERMCO personnel	08/16/95
14-day notification to operate to NRC	08/22/95
OEPA approval of PSP	08/23/95
Operator field walkdown with CNSI	08/31/95 - 09/01/95
Leak test system piping	09/01/95 - 09/7/95
Readiness implementation plan complete	09/07/95
Ready to operate letter	09/11/95
Readiness Assessment	09/11/95 - 09/14/95
U.S. EPA approval of PSP	09/13/95
DOE authorization to proceed	09/15/95
CNSI/FERMCO process thorium nitrate	09/16/95
Complete closure of Tank T-2	11/14/95
Complete additional rinses for ALARA	11/16/95
Complete disassembly of equipment	11/20/95 - 12/08/95
CNSI/FERMCO system dismantlement	11/26/95
NTS initial audit of waste application	11/29/95 - 12/02/95

2.2.2 Operations Summary

This section contains a description of the operations process. Field changes made during this project are summarized and discussed in Section 2.2.3 of this report.

Process Description

The thorium nitrate and rinseates from Tank T-2 were solidified by a team of CNSI and FERMCO personnel. Processing was conducted in accordance with CNSI's NRC license and DOE Orders. The general process involved five steps:

- Thorium nitrate waste transfer to the batch neutralization tanks.
- Neutralization of the thorium nitrate waste.
- Transfer of the neutralized waste to 55-gallon drums.
- Addition and mixing of dry chemicals in a 55-gallon drum.
- Transfer of the drum of solidified waste to a staging area for curing.

Solidification Formula Field Testing

Prior to full-scale operations, the bench-scale test formula developed by CNSI was field tested to verify results obtained in the laboratory. After the first two batches of thorium nitrate were recirculated and transferred to both of the neutralization tanks, samples of the liquid from each tank was collected from a sample port on the valve manifold. Slightly varying quantities of NaOH and solidification chemicals were added to the samples to confirm and/or refine the chemical quantities established during bench-scale testing. This process was completed every five to ten batches to confirm the formulation. The test was also completed before the rinseate was processed.

Field testing of the formulation using the full-scale chemical additives and thorium nitrate from the recirculated tank showed that adjustments to the batch formula were required to produce a workable product in the field. The original lab formulation, when used in the field, created too much precipitate during neutralization. This precipitate was not pumpable and would have clogged the lines in the neutralization tanks. The adjusted batch formula consisted of 200 gallons of thorium nitrate, 95 gallons of NaOH, and 68 gallons of water. The original lab formulation did not require the addition of water. Each batch consisted of approximately 365 gallons of partially neutralized thorium nitrate solution. Each batch generated approximately ten drums of solidified waste, containing approximately 35 gallons of neutralized waste and 170-190 pounds of solidification additive.

Thorium Nitrate Transfer and Neutralization

Before transfer, Tank T-2 was recirculated approximately 30 minutes per 1,000 gallons of liquid remaining in Tank T-2 to ensure homogeneity. Approximately 200 gallons of thorium nitrate were pumped from Tank T-2 to one of the neutralization tanks in the CNSI processing area. With the mixer operating, water and 25% NaOH were added to the neutralization tank

to raise the pH of the solution to between 1.8 and 3. The maximum solution temperature encountered during neutralization was 99° F, which was below the PSP established control limit of 110° F. Activation of the chiller was never required because the liquid never exceeded 110° F during neutralization.

Transfer of Neutralized Thorium Nitrate to the Drumming Station

A 55-gallon drum with mixing blades was placed in the drumming station and secured to the drum fill head. The partially neutralized thorium nitrate was transferred to the drum by a chemical resistant hose and variable speed pump through an inlet on the fill head. The drumming station was enclosed by a temporary tent structure with secondary containment and maintained at a negative pressure by a high efficiency particulate air (HEPA) exhaust system.

Addition and Mixing of Solidification Dry Chemicals

The fill head contained a mixer drive unit, dry chemical inlet, waste inlet, and ventilation outlet, connected to the HEPA exhaust system. The mixing unit was attached to a disposal shaft and mixing blades that remained in the drum with the solidified material for disposal. With the mixer and ventilation system operating, approximately 170-190 pounds of dry chemicals were gradually added to each drum. The dry chemicals were supplied by an enclosed screw conveyor from a dry chemical hopper. The contents of the drum were mixed continuously during the addition of the dry chemicals and for approximately 5-10 minutes after the dry chemical addition was complete.

Transfer of Drums to the Staging Area

After mixing was complete, the drum fill head was removed and a curing lid was installed on the drum. The curing lid consisted of a modified shipping lid with a charcoal filtered vent to release the heat of the exothermic curing reaction. The filled drums of slurried waste were manually pushed along a conveyor to a staging area to cure for approximately 12 hours. Figure 2-3 shows TNSP workers inspecting the cured waste. After this initial curing, the drums were weighed and then moved to an interim staging area. The drums remained in this area for approximately two to three days (until the exothermic reaction had peaked). After inspection to ensure that the material had hardened, permanent shipping lids were installed, and the drums were palletized and transferred to the Plant 1 Pad storage area on site.

Figure 2-3 Inspecting the Cured Waste

2.2.3 Field Changes

During execution of the TNSP, several field modifications from the PSP were required to accommodate conditions encountered in the field during full-scale processing. These modifications, summarized below, were generally provided to U.S. EPA and OEPA in DOE weekly project reports.

- Two field modifications to the process system were made (the TNSP process description is in Section 2.3 of the PSP.) The first modification was to add a siphon break to Tank T-2 to prevent uncontrolled flow of thorium nitrate out of the tank. The second modification was the addition of a water line to the neutralization tank. This was required as a result of modifications made to the bench-scale solidification formula (Section 2.2.2).

- During field verification testing of the solidification formula, one drum (No. 3) did not solidify properly (PSP, Section 4.0, Waste Management, page 4-1). The solution in Drum No. 3 underwent the thixotropic reaction more rapidly than expected. This reaction did not allow the addition of the prescribed amount of solidification additive. CNSI determined that the dry chemicals must be added slowly and gradually with intermittent periods of mixing. Additionally, the rotation speed of the mixer blade was increased. This drum eventually solidified to prescribed standards after more cement was added and the drum contents mixed manually.

- The PSP stated (Section 4.1.2, In-Processing Sampling and Analysis, page 4-1) the pH of the neutralized thorium nitrate solution should be greater than 3 based on the original solidification formula developed during bench-scale testing. However, modifications to the solidification formula were required during field testing as discussed previously. As a result of reducing the amount of NaOH and adding water to eliminate the heavy precipitation, the pH of the solution did not rise. As a result, the pH range was changed to between 1.5 and 3. This modification did not present a corrosion problem for the carbon steel drums or agitators and prevented precipitation during neutralization. The actual pH during the TNSP ranged from 1.8 to 3.

- A temperature limit of 110° F (PSP, Section 2.4.1, Maximum Thorium Nitrate Temperature, page 2-11) in the neutralization tanks prior to transfer to the 55-gallon drums was set to ensure worker safety and consistent operational performance. Temperature instrumentation was installed on each tank. Since the temperature in the tank did not exceed 110° F, the chiller was not required.

- It was noted during processing that in five of the drums, although hardened, and in every aspect homogeneous and equivalent to the other 164 drums, the mixing blade stopped sooner than expected. It is believed that the blade stopped early on these five drums because it was rotating too slowly (manual motor controller) and the cement was added too rapidly.

2.3 Waste Management

2.3.1 Waste Sampling and Data

Verification of Bench-Scale Results

Sampling and analysis was conducted during the solidification operations to ensure that the final product was consistent with the bench-scale results. Wastes generated from the process were characterized in accordance with Site Standard Operating Procedure (SSOP-0002).

To verify that the solidification formulation was correct prior to solidification, a sample from the first batch of neutralized thorium nitrate was taken and mixed with the solidification additives. This process was repeated every five to ten batches to verify the recipe remained correct. No changes to the formulation were required after the first test described in Section 2.2.2.

NTS WAC

All drums of waste were visually inspected to verify that solidification had occurred and no free liquids remained. Initial drums underwent real-time radiography to ensure the process solidified the drums completely. All drums of waste were completely solidified and contained no free liquids.

Sampling and analysis plans were prepared and implemented to verify that the solidified waste form met off-site disposal criteria. Samples of the solidified material were collected from each thorium nitrate batch and sent for TCLP analysis to verify the solidified waste was not a RCRA hazardous waste and would be below the Universal Treatment Standards (UTS). The

sampling procedure used is provided in Attachment B of the PSP. Documentation for waste acceptance at NTS is ongoing.

UTS Results

The RCRA Land Disposal Restriction (LDR) rules (40 CFR 268; OAC 3754-59) specify treatment standards for hazardous waste to be land disposed. For corrosive wastes, the treatment standard is deactivation (treatment of the waste until it is no longer corrosive [i.e., pH above 2]). For TC wastes, the treatment standards are expressed as maximum concentrations that cannot be exceeded. Waste must be treated to meet all applicable standards before it can be land disposed.

Under a rule promulgated May 24, 1993 (58 FR 29860), corrosive wastes must be treated to meet the treatment standards for any "underlying hazardous constituents" besides being treated to remove the corrosive characteristic. A rule promulgated September 19, 1994 (59 FR 47982), established new treatment standards called UTS. This rule defines an underlying hazardous constituent as any constituent listed in the UTS rules that can reasonably be expected to be present in the waste (before treatment) at levels above the UTS.

Based on analytical data and process knowledge, underlying hazardous constituents for the thorium nitrate are chromium and cadmium. The UTS limits are 860 μg/l for chromium and 190 μg/l for cadmium. All drums of solidified thorium nitrate were below these limits (Table 2-2).

2.3.2 Container Disposition Summary

Three hundred seventy one drums of solidified material were produced from the TNSP. The drums are staged on-site on the Plant 1 Pad storage area pending shipment to an appropriate disposal facility. The drums are shielded to reduce radiation exposure to workers.

2.3.3 Other Waste Streams

Incidental waste

Equipment used in the thorium nitrate solidification process that was not economically feasible to decontaminate and reuse, was disposed of consistent with FEMP site procedures. Waste, such as PPE, secondary containments, hoses, and other wastes generated throughout the operations of the TNSP were disposed of consistent with FEMP site procedures.

TABLE 2-2 TANK T-2 REGULATORY METALS ANALYSES

Universal Treatment Std. Limits (ug/L)		190	860
Sample Number	Customer Number	Cadmium (ug/L)	Chromium (ug/L)
200182874	95-1112-1	4.7	42.8
200182876	95-1112-2	6.4	37.4
200182878	95-1112-3	< 40.0	110
200182880	95-1112-4	< 40.0	185
200182882	95-1112-5	< 40.0	171
200182884	95-1112-6	< 40.0	186
200182886	95-1112-7	< 4.0	11.3
200182888	95-1112-8	< 4.0	245
200182890	95-1112-8D	< 4.0	248
200182892	95-1112-9	< 4.0	220
200182894	95-1112-10	< 4.0	30.4
200182896	95-1112-11	< 4.0	39.3
200182898	95-1112-12	< 4.0	37.2
200183797	95-1112-13	< 4.0	30
200183799	95-1112-14	< 4.0	36.1
200183801	95-1112-15	< 4.0	31.4
200183803	95-1112-16	< 4.0	24.2
200183805	95-1112-17	< 4.0	41.8
200183807	95-1112-18	< 4.0	29.8
200183809	95-1112-19	< 4.0	48.3
200183811	95-1112-20	< 4.0	35.1
200183813	95-1112-21	< 4.0	23.1
200183815	95-1112-22	< 4.0	133
200183817	95-1112-23	< 4.0	251
200183819	95-1112-24	67.6	338
200183821	95-1112-X	61.3	312
200183823	95-1112-24D	< 4.0	220
200183825	95-1112-25	< 4.0	241
200196133	95-1112-26	< 4.0	25.7
200195077	95-1112A-27	61.3	244
200195078	95-1112A-28	58.1	377
200195079	95-1112A-29	< 2.0	52.6
200195080	95-1112A-30	< 2.0	35.5
200195081	95-1112B-31	< 2.0	55.1
200195082	95-1112B-32	< 2.0	17.8
200195083	95-1112B-33	< 2.0	59.2
200195084	95-1112B-34	30	70
200198810	95-1112B-35	< 14.0	106

Decontamination Verification Rinseate Samples

The Tank T-2 rinse water samples were collected after each decontamination effort, as described in the CNSI Sampling Plan, Attachment B. To ensure that a representative sample was obtained, samples were taken from a valve installed in the Tank T-2 recirculation line. Samples were collected during recirculation of the rinseate in the tank.

Rinse water samples were analyzed in the field for pH using SW-846, Method 9040. When the final decontamination rinseate field analysis showed that the rinse water pH was above 2, a sample was sent to a laboratory for analysis as described in Section 4.4 of the PSP.

The following chart provides a summary of TNSP wastes generated and waste disposition.

Table 2-3 TNSP Wastes Generated and Waste Disposition

Material	Quantity	Disposition
Thorium Nitrate	6,003 gallons	Plant 1 Pad Low Level Waste to NTS
Tank T-2 Rinse Water	500 gallons	
Additional Tank T-2 Rinse Water for ALARA	500 gallons The above listed waste equaled 371 (55-gallon) drums of solidified material (2,968 cubic feet)	
Compactible Trash Rags/PPE	150 85-gallon drums (2,100 cubic feet)	Plant 1 Pad Low Level Waste to NTS
Noncompactible Trash Wood/Cement (nonthorium)	6 small white metal boxes (capacity inside each box is 81 cubic feet)	Plant 1 Pad Low Level Waste to NTS
Process Equipment	2 sea/land containers (capacity inside each container is 1,250)	Reuse

2.3.4 System Dismantlement and Disposition

Tank T-2 and Process System Decontamination

After the thorium nitrate was removed, Tank T-2 was decontaminated by flushing the entire system with water to meet OEPA Closure Standards as specified in the PSP. Starting at the tank, the system was flushed to ensure that no thorium nitrate or neutralized thorium nitrate residue remained in the system. Clean closure of Tank T-2 was achieved after four rinses (Table 2-4). Tank T-2 was rinsed an additional four times to reduce contamination levels of the thorium residue in the tank. After decontamination, the equipment was evaluated to determine if the process piping and equipment could be used for other projects within the controlled area. The flush and rinse waters were also managed through the system and solidified.

System Dismantlement

After clean closure limits in Tank T-2 were achieved and verified, the clean rinseates were solidified, and the treatment system drained and disassembled. The majority of the draining process was accomplished by disconnecting the hoses and "walking" the hose toward the process drum to drain the liquid into the drum. After draining, the hoses and equipment were capped/plugged. The liquid from the hoses and equipment was accumulated into three drums and then solidified. The system equipment has been stored for reuse. Components that could not be reused have been dispositioned in accordance with FEMP procedures and managed as contaminated trash.

2.4 Environmental Monitoring

2.4.1 Air and Radiological Monitoring Data

NO_x

Both the neutralization and solidification reactions generated heat. With agitation and an increase in temperature due to neutralization, there was a potential for No_x generation. Process knowledge, laboratory testing, and actual operation of the system has shown that No_x generation due to heating is minimal below a solution temperature of 160° F. Field monitoring detected no No_x generation associated with the TNSP.

TABLE 2-4 THORIUM NITRATE TANK T-2 RINSE SAMPLING

Analytes	Clean Level	Rinse 3	Rinse 4	Rinse 8*
pH (pH units)	> 2.0	1.82	2.36	-
Cadmium (mg/L)	< 0.075	< 0.035	< 0.035	-
Chromium (mg/L)	< 1.0	0.115	< 0.035	-
Total Thorium (mg/L)	NR	11,000	3,400	26.2
Thorium 228 (pCi/L)	NR	920,000	290,000	-
Thorium 230 (pCi/L)	NR	240,000	69,000	-
Thorium 232 (pCi/L)	NR	1,000,000	310,000	-

Each rinse consisted of 125 gallons of process water.

NR = Not Required for clean closure of Tank T-2. This data has been reported for information purposes.

* - Clean closure of Tank T-2 was reached after Rinse 4. Tank T-2 was rinsed 4 more times in order to reduce ALARA concerns with the thorium contaminated residual in the tank.

Radiation

The TNSP ALARA plan estimated that cumulative radiologic exposure would not exceed 1.9 man-rems from all tasks associated with equipment setup, processing the thorium nitrate, demobilization, and handling all drums of the final product for release from the project area to a designated storage area. The cumulative exposure received by project personnel was well below 1.9 man-rems, with no individual exceeding the project administrative control limit of 100 mrem. Monitoring was performed over a four month period, from mobilization through demobilization of the TNSP.

The project area was posted as a Radiation Area, with maximum exposure rates of 35 mrem/hour on the exterior of Tank T-2 at the onset of thorium nitrate processing. Contact dose-rates on the drums of final product were in the range of 10 - 15 mrem/hour on contact, with dose rates less than 5 mrem/hour at 30 centimeters. General area dose-rates in the project area were typically less than 5 mrem/hour.

The drums of final product are stored at the Plant 1 Pad in the radiologically controlled area of the FEMP. The storage area is posted as a Radiation Area, with general area dose-rates ranging from 5 - 10 mrem/hour. The dose-rate at the Controlled Area boundary, west of this storage area, is approximately 20 uR/hour.

Contamination

Removable surface contamination was limited to 20 dpm/100 cm^2 (alpha, thorium) outside the posted Contamination Area perimeter boundary. This limit was not exceeded at surveyed locations outside the project area perimeter fence.

There were no personnel contamination events during, or as a result, of the TNSP. Personnel performed whole-body surveys with appropriate monitoring devices and were limited to 500 dpm/100 cm^2 (alpha).

Airborne Radioactivity

The Derived Air Concentration (DAC) for Thorium-232 (Class W soluble) was applied for radiation protection purposes on this project. The DAC for Class W Th-232 is 5×10^{-13} microcuries/ml, as listed in Appendix A of 10 CFR 835. In addition, from Appendix A of 10 CFR 835, a DAC of 1.0 working levels (WL) was applied for thoron progeny.

2.4.2 Nonreportable Spills

The following information describes minor nonreportable spills that occurred during the TNSP. These spills were safely cleaned to background levels and no personnel contamination events occurred.

- Operations were stopped on September 16, 1995, due a problem with the siphon break line. A very small amount of thorium nitrate or thorium nitrate acid vapor corroded through a brass fitting and broke the vacuum for the suction side of the pump. Less than 20 ml of thorium nitrate or condensed thorium nitrate vapor dripped into the secondary containment for Tank T-2. The material was cleaned up using an absorbent pad. Radiological levels after clean up did not exceed background levels.

- On September 30, 1995, after transferring 200 gallons of thorium nitrate from Tank T-2, a very small leak was noticed at the Kam-lock fitting for valve WS-6. Less than 30 ml of thorium nitrate dripped into the secondary containment pan. The material was cleaned up and the plastic wrap around the Kam-lock fitting was reinstalled.

- On October 9, 1995, CNSI found a small quantity of neutralized thorium nitrate (less than 10 ml) had stained the outside of the Kam-lock fittings of the mixer and chiller pumps. The two peristaltic pumps were replaced with double diaphragm pumps. The pumps were located between the neutralization tanks where radiation levels were 16 mrem per hour. To ensure worker safety and reduce radiation exposures, the leaking joint was wrapped and contained and both neutralization tanks were emptied. The pumps were replaced on October 11, 1995, with dose rates less than 4 mrem per hour.

- On October 25, 1995, approximately 700 ml of thorium nitrate was released (600 ml into secondary containment, 100 ml outside secondary containment) as a result of an error in valve alignment and the use of an aluminum cap to blank off the end of a two inch stainless steel leg on the valve manifold. The partially neutralized thorium nitrate corroded through the aluminum cap, resulting in the small nonreportable spill. The nonreportable spill was contained, cleaned up, and the area was decontaminated.

- On October 26, 1995, due to a cumulative error in a flow meter, a neutralization tank overflowed into its secondary containment vessel. 25 - 50 gallons of partially neutralized thorium nitrate was contained in the secondary containment vessel.

3.0 CONCLUSIONS

All objectives specified in the PSP were met. The following summarizes the TNSP results and conclusions.

- The entire TNSP had an outstanding safety record. Radiologic controls were implemented and all safety issues listed in the PSP were complied with. There were no lost time work accidents, no first aid cases, personnel contaminations, or environmental releases. The TNSP was controlled, well-planned, and safe.

- The thorium nitrate was safely removed from Tank T-2. Minor nonreportable spills occurred during this operation. However, these spills were safely cleaned to background levels and no personnel contamination events occurred.

- The thorium nitrate and rinse water were solidified. Minor changes in the original solidification formulation, developed during bench-scale testing, were required. 371 drums of solidified waste hardened completely and contained no free liquids.

- Based on analytical data and process knowledge, underlying hazardous constituents for the thorium nitrate were chromium and cadmium. The UTS limits are 860 μg/l for chromium and 190 μg/l for cadmium. Analytical results indicated that the drums of solidified thorium nitrate were below regulatory limits. The solidified waste is not corrosive and meets the criteria for land disposal.

- Tank T-2 and its treatment system piping were decontaminated by flushing the entire system with water to meet OEPA Closure Standards. Clean closure of Tank T-2 was achieved after four rinses. Tank T-2 was rinsed an additional four times to reduce ALARA concerns with the thorium residue in the tank.

- Results from air and radiological monitoring indicate no control levels were exceeded. The cumulative exposure received by project personnel was well below 1.9 man-rems. Contact dose-rates on the drums of final product are in the range of 10-15 mrem/hour on contact, with dose rates less than 5 mrem/hour at 30 centimeters. General area dose-rates in the project area were typically less than 5 mrem/hour. The DAC for Thorium-232 (Class W soluble)

was applied for radiation protection purposes on this project. In addition, a DAC of 1.0 WL was applied for thoron progeny. Average concentrations on the project perimeter were less than ten percent for each DAC.

4.0 REFERENCES

Chem-Nuclear Systems, Inc. (CNSI). Treatability Study Report for Thorium Nitrate (TN). June 16, 1995.

FERMCO. Thorium Nitrate Tank T-2 Project Specific Plan (PSP). Resubmittal August, 1995.