CONF-950401--11

FEMP-2388

RADIUM BEARING WASTE DISPOSAL

BY

W. G. TOPE, FERMCO, SPONSORING ACS MEMBER
D. A. NIXON, FERMCO
M. L. SMITH, FERMCO
T. J. STONE, FERMCO
W. D. SCHOFIELD, FOSTER WHEELER ENV. CORP.
R. A. VOGEL, FERMCO

FERMCO
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT
P.O. BOX 538704
CINCINNATI, OHIO 45253-8704

FOR PRESENTATION AT THE
1995 AMERICAN CERAMIC SOCIETY
97TH ANNUAL MEETING AND EXPOSITION
CINCINNATI, OHIO
4/29/95 THRU 5/4/95

*Fernald Environmental Restoration Management Corporation with the U.S. Department of Energy under Contract No. DE-AC-24-92OR21972

DISCLAIMER

DISCLAIMER

RADIUM BEARING WASTE DISPOSAL

W. G. Tope, FERMCO, Sponsoring ACS Member
D. A. Nixon, FERMCO
M. L. Smith, FERMCO
T. J. Stone, FERMCO
W. D. Schofield, Foster Wheeler Environmental Corp.
R. A. Vogel, FERMCO

ABSTRACT

Fernald radium bearing ore residue waste, stored within Silos 1 and 2 (K-65) and Silo 3, will be vitrified for disposal at the Nevada Test Site (NTS). A comprehensive, parametric evaluation of waste form, packaging, and transportation alternatives was completed to identify the most cost-effective approach. The impacts of waste loading, waste form, regulatory requirements, NTS waste acceptance criteria, as-low-as-reasonably-achievable principles, and material handling costs were factored into the recommended approach.

INTRODUCTION

The Fernald Environmental Management Project (Fernald) is a contractor-managed United States Department of Energy (DOE) facility previously used for the production of purified uranium metal for use by the DOE and United States Department of Defense. The 425 hectares (1050 acres) site is located in a rural area approximately 27 km (17 mi) northwest of Cincinnati, Ohio. Production operations ceased in July of 1989. Currently the site is being remediated under the terms of a June 1990 Consent Agreement (as amended in September 1991) between the United States Environmental Protection Agency (USEPA) and the DOE with the Comprehensive Environmental Response Compensation and Liability Act (CERCLA) being the primary regulatory driver. Compliance with the requirements of the Resource Conservation and Recovery Act (RCRA) has been delegated to the State of Ohio, and is administered by the Ohio Environmental Protection Agency (OEPA).

In accordance with CERCLA, the remedial activities have addressed radium bearing wastes in a waste storage area of Fernald known as Operable Unit 4 (OU4). The CERCLA process for selecting the remedial actions that will be conducted implements a rigid set of steps that culminates in a Record of Decision (ROD) document. These steps have been completed for Fernald radium bearing wastes. A *Final Record of Decision for Remedial Action at Operable Unit 4* was approved by the USEPA in December 1994 [1]. For the contents of Silos 1, 2, and 3 the identified remedial actions consist primarily of the removal, stabilization by vitrification, and off-site disposal at the Nevada Test Site (NTS).

SUMMARY

The radium bearing wastes currently stored at Fernald are residues that resulted from the chemical extraction of uranium from pitchblende ore. These ore residues are currently stored in two above ground, concrete silos that are numbered Silos 1 and 2, but also identified as the K-65 Silos which is the original code name for this ore residue material. Additional radioactive material from the chemical processing of the ore is stored in another silo, Silo 3. The Silo 3 material is a fine particulate mixture of metal oxides and salts that resulted from the calcination of a liquid raffinate processing stream. These waste residues will be vitrified, packaged, transported, and buried at the NTS.

To minimize the packaging, transportation, and burial costs of the vitrified waste a study was conducted to optimize these operations and costs on an integrated basis. The study resulted in identifying 3-gallon Type A containers overpacked in a concrete vault [Scientific Ecology Group (SEG) Squarepak™ SQ-112] for the K-65 waste and a metal box (B-25 overpack) for the Silo 3 material as being the most cost effective packaging scenario. This configuration is in full compliance with current United States Department of Transportation (DOT) regulations, and the waste acceptance criteria (WAC) of the NTS. A maximum of two concrete vaults or six B-25 containers would be placed in a closed transport vehicle (truck) for shipment under exclusive use conditions to the NTS.

The full compliance scenario requires approximately 924 000 3-gallon cans, 3550 concrete vaults, and 2750 B-25 boxes, resulting in approximately 2230 truck shipments. The cost for packaging, transportation, and disposition of the material is estimated to be $83.2 million in current dollars.

The study also identified a path forward that provides a means of reducing costs associated with transportation and disposal of the material. The path forward requires either promulgation of a currently proposed revision to DOT regulations, related to the transportation of radioactive material, presented in the November 14, 1989 Federal Register (54 FR 47454) [2], and consistent with international shipping requirements under International Atomic Energy Agency (IAEA) Safety Series Number 6 [3], or DOT granting DOE an exemption request to allow use of the proposed regulations. Specifically, the proposed regulations allow classification of the vitrified material as low specific activity-II (LSA-II) material. Classification as LSA-II would allow the vitrified material to be placed directly into containers that meet Industrial Package-Type 2 specifications, and eliminate the need for inner containers. Labor, material handling, transportation, and disposition costs would be reduced because the number of shipping containers and trips would decrease.

Shipment of vitrified material as LSA-II material under the proposed regulations would justify the expense required to customize the concrete vault design to maximize the payload by minimizing the void space, and by reducing the container weight. The controlling factor in this scenario is the maximum allowable weight limit for over the road trucks. In this scenario, the previously required 3550 concrete vaults for K-65 material and 2750 B-25 boxes for Silo 3 material could be reduced to a total of 2384 optimized containers for all silo material, and total truck shipments could be reduced to 1192. The cost estimate for packaging, transportation, and disposition is reduced to $25.3 million. A more detailed description of the waste, the regulatory drivers, and the logic follows.

WASTE DESCRIPTION

Silos 1 and 2 contain approximately 6120 m^3 (216 300 ft^3) of waste materials. The materials are primarily a sludge like residue with an average moisture content of 30 percent. The silos contain more than 4500 curies of radium-226 and other radionuclides shown in Table I. The radionuclides of concern from a transportation perspective are Ac-227, Bi-214, Pb-210, Pb-214, Ra-226, and Th-230. RCRA significant metals include arsenic, barium, and lead.

Silo 3 contains approximately 3900 m^3 (137 500 ft^3) of calcined residues consisting of various oxide compounds of aluminum, calcium, iron and magnesium; sodium salts; 18 000 kg each of uranium and thorium; and a relatively small amount of radium and other metal oxides. The radionuclides of concern from a transportation perspective are Pb-210, Ra-226, and Th-230. RCRA significant metals include arsenic, cadmium, chromium, lead, and selenium.

Table I presents a list of the predominant radionuclides known to be present in the K-65 and Silo 3 material. In addition, Table I presents the concentration of these radionuclides detected in the vitrified glass product from bench-scale vitrification studies.

STUDY METHODOLOGY AND RESULTS

To further refine prior analysis performed to support the ROD, the Fernald Environmental Restoration Management Corporation (FERMCO) commissioned the Foster Wheeler Environmental Corporation to perform a detailed waste container and transportation optimization study [4]. This optimization study evaluated various packaging and transportation scenarios that were in full compliance with current DOT shipping regulations as well as the NTS WAC. The goal was to identify the most cost effective, regulatory compliant scenario using commercially available containers that are acceptable for disposal at the NTS.

Key components of the study consisted of waste form, applicable DOT regulations, certified waste container designs, container and material handling costs, transportation costs, the NTS WAC, and maintaining radiation exposure to as-low-as-reasonably-achievable (ALARA).

Table I - Isotopic Activities of K-65 and Silo 3 Materials

	K-65 Material		Silo 3 Material	
Radionuclide	Concentration in Silo Material (pCi/g)	Concentration in Glass (pCi/cc)	Concentration in Silo Material (pCi/g)	Concentration in Glass (pCi/cc)
Ac-227	7 670	21 363	925	2 570
Bi-214*	441 000	1 228 278	3 870	13 059
Pa-231	4 040	11 252	627	2 778
Pb-210	202 000	562 612	3 480	27 229
Pb-211*	19 000	52 919	600	1 667
Pb-214*	281 000	782 644	4 600	12 781
Po-210	281 000	782 644	3 480	27 229
Ra-223*	16 000	44 563	700	1 945
Ra-226	477 000	1 328 545	3 870	13 059
Th-228	7 360	20 499	747	2 076
Th-230	76 200	212 233	60 200	394 547
Th-232	1 110	3 092	842	2 339
U-234	1 160	3 231	1 730	4 807
U-235/236	94	262	117	325
U-238	1 120	3 119	1 780	7 502

* Calculated radioactive decay chain value at equilibrium.

Two alternatives are currently being evaluated for the vitrified waste form; monolith and gems (gems are quasi-hemispherical in shape approximately 1.25 cm in diameter). While a monolith form has the advantage of possessing the highest waste loading per unit volume, it has disadvantages related to material handling aspects, process control, and process operations - especially the recycle of off-specification product. Multi-sized gems, on the other hand, possess excellent material handling properties, rejects are easily recycled, and packaging efficiencies can approach 75 percent of that of a monolith. While both waste forms will be evaluated during pilot plant operation in 1995, the study identified several aspects that make gems the preferred waste form.

The DOT regulations that apply to the shipment of radioactive materials, when coupled with the commercial availability of certified waste container types, severely limits waste packaging choices. A multi-step selection process was used to select the optimum packaging configuration.

Step 1 of the process requires the generator to categorize the waste as "LSA", "special form", or "normal form" material as defined by DOT regulations. The current definition of

LSA material under 49 CFR § 173.403(n) [5] prevents classification of OU4 vitrified material as LSA material because the concentration of Ra-226 in K-65 material and Th-230 in Silo 3 material exceeds the definition limits. Special form radioactive material as defined in 49 CFR § 173.403(z) must pass the testing requirements of 49 CFR § 173.469. These tests involve an impact test, a percussion test, a bending test, a heat test, and a leaching test. Normal form is defined as any radioactive material that does not qualify as special form radioactive material. Because of the glass like characteristics of the vitrified material, compliance with the impact and the percussion tests for special form material is extremely unlikely (e.g., the glass will fracture). Therefore, the study focused on normal form shipping requirements.

Step 2 of the process requires the generator to evaluate package type. DOT regulations require shipment of normal form radioactive material in a DOT certified Type A or Type B container. For normal form waste, Type A packages may not contain radioactivity in quantities greater than the A_2 curie limit(s) presented in 49 CFR § 173.435, or determined by the methodology of 49 CFR § 173.433. Quantities greater than the A_2 limit for normal form wastes require a Type B package.

Type B packages are expensive to manufacture because of the stringent design specifications imposed by the DOT. Commercial availability of these containers is quite limited. Since procurement costs are very high, to be cost effective, Type B containers are normally recycled and reused. The vast distance between Fernald and the NTS leads to a significant cost element when recycling empty Type B containers, and presently the NTS is not equipped to unload overpacked waste. Therefore, based on these constraints, Type B packaging was not considered to be a viable, cost effective option. This scenario also introduces an increased potential for worker exposure related to the extra handling required for loading the Type B containers at Fernald and removing the waste at the NTS. Material handling costs would increase to implement ALARA principles.

A variety of large and small capacity certified Type A containers are commercially available, including several designs that provide shielding. Their cost supports the one way transportation concept which, in turn, results in reduced materials handling costs and reduced worker risk to radiation exposure. Since the contents of the Type A package are limited to the A_2 curie value, calculations were performed, and a 3-gallon container was identified as being the maximum size that would guarantee filling without exceeding the A_2 curie limit for K-65 material, for Silo 3 material, or for any mixture of the two materials.

Step 3 of the process requires the generator to select a packaging configuration that provides sufficient shielding to be in compliance with the radiation limits of 49 CFR § 173.441 while allowing the truck to transport the maximum permissible payload for a legal-weight truck. For shipment under normal conditions, the DOT has established a radiation level limit of 200 mrem/hr on the external surface of a package and a transport index (TI) that does not exceed 10 for each package of radioactive material. The TI expresses the maximum radiation level in millirem per hour at one meter from the external surface of the package. Since the TI associated with K-65 silo material will be greater than 10, all vitrified material will be shipped by exclusive use shipment with the following radiation level limitations: 1) 200 mrem/hr on the external surface of the package for non-closed transport vehicles and 1000 mrem/hr for closed transport vehicles; 2) 200 mrem/hr at any point of the outer surface of the vehicle, including top and underside surfaces; 3) 10 mrem/hr at any point 2 meters from the outer lateral surfaces of the vehicle, excluding the top and underside surfaces; and 4) 2 mrem/hr in any normally occupied space. In addition, the NTS WAC prefers a 100 mrem/hr or less contact field.

Because of the high concentrations of gamma emitters, primarily Bi-214 and Pb-214, in the K-65 material, a thick-walled container (5-inches thick reinforced concrete) is required to provide the shielding necessary to meet the DOT regulations. The concentration of gamma emitters in the Silo 3 material are much lower, and therefore require less shielding.

A survey of commercially available containers was conducted, and two configurations were identified that best met the selection criteria; Type A 3-gallon containers overpacked in either a SEG Squarepak™ SQ-112 for the K-65 waste or a B-25 metal box for the Silo 3 material. However, during the course of the study, it became obvious that significant cost reductions could be attained by further optimization of the packaging configuration.

PATH FORWARD

The opportunity with the greatest cost reduction potential requires obtaining an exemption from the DOT from the current definition of low specific activity material. This would allow elimination of inner packagings required under current regulations, and allow for optimization of the customized containers to minimize void space and disposal costs. Specifically, DOE is actively seeking permission to ship in compliance with the regulations proposed in 54 FR 47454, which are more consistent with the requirements established by the IAEA in Safety Series No. 6. However, since the regulations are "proposed", either promulgation or an exemption request will need to be approved by the DOT to allow their use in shipping the vitrified radioactive material.

Under the proposed regulations, as well as IAEA Safety Series No.6, vitrified material would be classified as LSA-II material. Specifically, vitrified material would be defined as "material in which the activity is distributed throughout and the estimated average specific activity does not exceed 10^{-4} A_2/g for solids", where the A_2 value is the curie limit for normal form radioactive material, determined in accordance with DOT regulations, permitted in a single Type A package. The intent of this requirement is to minimize the radiological hazards that can arise from the dispersal of material following failure of a package during an accident. Radionuclide activity limitations on the contents of a package are derived primarily on the basis of whether the material is dispersable or non-dispersable. More restrictive limits are placed on dispersable materials because of the increased number of potential pathways for radiological exposure, such as ingestion and inhalation, when compared to non-dispersable material that poses primarily an external radiation dose hazard.

Although the vitrified material would not meet the stringent criteria for special form material, vitrified material has sufficient non-dispersable characteristics (e.g., it is hard, durable, leach resistant and stable) to justify an exemption request to be classified as LSA-II material. In addition, the optimum package configuration minimizes the number of shipments to the NTS, and is consistent with DOE ALARA principles related to dose exposure from material handling to workers and the general public. Radiological risk model calculations show that granting the exemption would not pose a significant increase in risk to human health or to the environment.

Receiving an exemption would justify the development of a customized DOT Type A certifiable container design. Using the SEG Squarepak™ SQ-112 as a starting point, and including shielding materials, such as steel fibers, in the concrete mix, a stronger, thinner walled, lighter weight container could be designed and certified as a Type A container. Also the interior and exterior dimensions could be optimized to reduce void space and final disposal volume, respectively, which would further reduce the container weight and allow for an increased payload weight while not exceeding DOT highway vehicle gross weight limits. This combination is the path forward that is currently being pursued. Assuming that all of the waste is packaged, transported, and buried in these optimized concrete vaults, the projected cost savings from the full regulatory compliance case is approximately $58 million.

REFERENCES

1 U.S. Department of Energy, Final Record of Decision for Remedial Actions at Operable Unit 4, Fernald Field Office, Fernald, Ohio, December 1994.

2 U.S. Department of Transportation Research and Special Programs Administration, Notice of Proposed Rulemaking: Transportation Regulations; Compatibility with Regulations of the International Atomic Energy Agency, 47454-47490, Federal Register, 54, Washington, D.C., November 14, 1989.

3 International Atomic Energy Agency, Safety Series Number 6 "Regulations for the Safe Transport of Radioactive Material", 1985 edition (as amended 1990), IAEA, Vienna, Austria, 1990.

4 Foster Wheeler Environmental Corporation, "Final Report on Container Optimization for Vitrified K-65 and Silo 3 Residues", Fairfield, Ohio, February 1995.

5 U.S. Department of Transportation Research and Special Programs Administration, 49 Code of Federal Regulations Subchapter C Hazardous Materials Regulations Part 173 Subpart I Radioactive Materials, Washington, D.C., October 1993.