"INTERAGENCY COOPERATION IN THE DEVELOPMENT" OF A COST-EFFECTIVE TRANSPORTATION AND DISPOSAL SOLUTION FOR VITRIFIED RADIUM BEARING MATERIAL"

BY

M. L. SMITH, FERMC0
D. A. NIXON, FERMC0
T. J. STONE, FERMC0
W. G. TOPE, FERMC0
R. A. VOGEL, FERMC0
R. B. ALLEN, DOE-FN
W. D. SCHOFIELD, FOSTER WHEELER ENV. CORP.

FERMC0
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT
P.O. BOX 538704
CINCINNATI, OHIO 45253-8704

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INTERAGENCY COOPERATION IN THE DEVELOPMENT OF A COST-EFFECTIVE TRANSPORTATION AND DISPOSAL SOLUTION FOR RADIUM BEARING MATERIAL

M. L. Smith, FERMCO
D. A. Nixon, FERMCO
T. J. Stone, FERMCO
W. G. Tope, FERMCO
R. A. Vogel, FERMCO
R. B. Allen, DOE-FN
W. D. Schofield, Foster Wheeler Environmental Corp.

ABSTRACT

Fernald radium bearing ore residue waste, stored within Silos 1 and 2 (K-65) and Silo 3 waste, will be vitrified for disposal at the Nevada Test Site (NTS). A comprehensive, parametric evaluation of waste form, shielding requirements, packaging, and transportation alternatives was completed to identify the safest, 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.

Through cooperative work between the U.S. Department of Energy (DOE) and the U.S. Department of Transportation (DOT), the vitrified K-65 and Silo 3 radioactive material will be classified consistent with the regulations promulgated by DOT in the September 28, 1995 Federal Register. These new regulations adopt International Atomic Energy Agency language to promote a consistent approach for the transportation and management of radioactive material between the international community and the DOT. Use of the new regulations allows classification of the vitrified radioactive material from the Fernald silos under the designation of low specific activity-II and allows the development of a container that is optimized to maximize payload while minimizing internal void space, external surface radiation levels, and external volume. This approach minimizes the required number of containers and shipments, and the related transportation and disposal costs.

The container is being developed under a Program Research and Development Announcement (PRDA) contract sponsored by DOE-Oak Ridge Operations, administered by Martin-Marietta Energy Systems, Inc. and performed by Scientific Ecology Group, Inc., in support of the DOE-Fernald remediation program. The container development will consider the use of recycled, low-level contaminated material to minimize overall waste disposal costs.

Success of this project has been achieved through cooperative team efforts within and outside the DOE complex, between DOE sites, between DOE contractors, and between the DOE and the DOT.

INTRODUCTION

The Fernald Environmental Management Project (Fernald) is a contractor-managed DOE facility previously used for the production of purified uranium metal for use by the DOE Programs. 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 remediating under the terms of a June 1990 Consent Agreement (as amended in September 1991) between the U.S.
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 was conducted, implemented a rigid set of steps that culminated in a Record of Decision (ROD) document. A Final Record of Decision for Remedial Actions 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 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 initiated, in July 1994, to optimize these operations and costs on an integrated basis. The study evaluated packages which would be in full compliance with DOT regulations promulgated prior to September 1995, and the waste acceptance criteria (WAC) of the NTS. 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 metal boxes) for the Silo 3 material as being the most cost effective packaging scenario. A maximum of two concrete vaults or five B-25 containers would be placed in a closed transport vehicle (truck) for shipment under exclusive use conditions to the NTS.

This full compliance scenario requires approximately 924,000 3-gallon cans, 5,232 concrete vaults, and 2,730 B-25 metal boxes, resulting in approximately 3,162 truck shipments. The cost for packaging, transportation, and disposition of the material is estimated to be $121.7 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. This path forward was developed based on proposed revisions to the DOT regulations, related to the transportation of radioactive material, published 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]. The revised regulations established a new definition for low specific activity (LSA) material by dividing LSA material into three categories: LSA-I, LSA-II, and LSA-III. Included in the definition for LSA-II material, was solid material in which the average specific activity does not exceed \(10^{-4} \text{A}_2/\text{g}\), 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. Using the sum of fractions methodology, vitrified silo material from Fernald meets the above criterion for LSA-II material. Classification as LSA-II allows 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.

Because the regulations had not been promulgated, DOE and the Fernald Environmental Restoration Management Corporation (FERMCO) discussed with the DOT the option of seeking an exemption to allow use of the proposed regulations for shipping vitrified material as LSA-II material. These open discussions allowed DOE and FERMCO to initiate design of a customized container that would meet the needs of the vitrified silo material. Subsequent promulgation of the regulations in the September 28, 1995 Federal Register (60 FR 50292) [4], negated the need for an exemption and allowed DOE and FERMCO to proceed with the development of a customized container to ship vitrified silo material as LSA-II material.

Shipment of vitrified silo material from Fernald as LSA-II material under the new regulations justifies the expense to develop and 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 5,232 concrete vaults for K-65 material and 2,730 B-25 metal boxes for Silo 3 material could be reduced to an estimated 3,200 optimized containers for all vitrified silo material, and total truck shipments could be reduced to 1,600. The cost estimate for packaging, transportation, and disposition is reduced to approximately $36.1 million. A more detailed description of the waste, the regulatory drivers, and the logic follows.

WASTE DESCRIPTION

Silos 1 and 2 contain approximately 6,120 m³ (216,300 ft³) of waste materials. The materials are primarily a sludge like residue with an average moisture content of 30 percent. The silos contain more than 4,500 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 3,900 m³ (137,500 ft³) 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 FERMCO tasked the Foster Wheeler Environmental Corporation to perform a detailed waste container and transportation optimization study [5]. This optimization study evaluated various packaging and transportation scenarios that were in full compliance with DOT shipping regulations, promulgated prior to September 1995, 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.

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

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>K-65 Material</th>
<th>Silo 3 Material</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Concentration in Silo Material (pCi/g)</td>
<td>Concentration in Glass (pCi/cc)</td>
</tr>
<tr>
<td>Ac-227</td>
<td>7,670</td>
<td>21,363</td>
</tr>
<tr>
<td>Bi-214*</td>
<td>441,000</td>
<td>1,228,278</td>
</tr>
<tr>
<td>Pa-231</td>
<td>4,040</td>
<td>11,252</td>
</tr>
<tr>
<td>Pb-210</td>
<td>202,000</td>
<td>562,612</td>
</tr>
<tr>
<td>Pb-211*</td>
<td>19,000</td>
<td>52,919</td>
</tr>
<tr>
<td>Pb-214*</td>
<td>281,000</td>
<td>782,644</td>
</tr>
<tr>
<td>Po-210</td>
<td>281,000</td>
<td>782,644</td>
</tr>
<tr>
<td>Ra-223*</td>
<td>16,000</td>
<td>44,563</td>
</tr>
<tr>
<td>Ra-226</td>
<td>477,000</td>
<td>1,328,545</td>
</tr>
<tr>
<td>Th-228</td>
<td>7,360</td>
<td>20,499</td>
</tr>
<tr>
<td>Th-230</td>
<td>76,200</td>
<td>212,233</td>
</tr>
<tr>
<td>Th-232</td>
<td>1,110</td>
<td>3,092</td>
</tr>
<tr>
<td>U-234</td>
<td>1,160</td>
<td>3,231</td>
</tr>
<tr>
<td>U-235/236</td>
<td>94</td>
<td>262</td>
</tr>
<tr>
<td>U-238</td>
<td>1,120</td>
<td>3,119</td>
</tr>
</tbody>
</table>

* Calculated radioactive decay chain value at equilibrium.

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).

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 1996-1997, the study identified several aspects that make gems the leading 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 definition of LSA material under regulations promulgated prior to September 1995, and presented in 49 CFR § 173.403(n) [6], 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 A2 curie limit(s) presented in 49 CFR § 173.435, or determined by the methodology of 49 CFR § 173.433. Quantities greater than the A2 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 unloading liners from Type B packages at the NTS creates additional worker exposure concerns as well as additional costs due to the increase in material handling requirements. 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 A2 curie value, calculations were performed, and a 3-gallon container was identified as being the maximum size that would guarantee filling without exceeding the A2 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 millirem per hour (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 mrem/hr at one meter from the external surface of the package. Packages which exceed the above limits must be shipped under exclusive use conditions. Since the TI associated with K-65 silo material will be greater than 10, all vitrified material will be shipped under exclusive use conditions, where the conveyance will be used only for the shipment of vitrified silo material, 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 nominal thick-walled container (6-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. The path forward proposes implementation of these items in the development of a customized container.

PATH FORWARD

The opportunity with the greatest cost reduction potential required obtaining an exemption from the DOT from the definition of low specific activity material presented in the regulations promulgated prior to September 1995. This would allow elimination of inner packagings required by these regulations, and allow for optimization of the customized containers to minimize void space and disposal costs. Specifically, DOE, through active discussions with the DOT, sought 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. Since the regulations were promulgated on September 28, 1995 (60 FR 50292) an exemption request will no longer be required to allow their use in shipping the vitrified radioactive material.

Under the new regulations, as well as IAEA Safety Series No.6, vitrified material would be classified as LSA-II material. Specifically, vitrified material can be defined as "material in which the activity is distributed throughout and the estimated average specific activity does not exceed \(10^{-4} \text{A}_{2}/\text{g for solids}\)", 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 support and strengthen the classification 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. Standard
radiological risk model calculations show that classifying vitrified silo material from Fernald as LSA-II material would not pose a significant increase in risk to human health or to the environment.

Technical development being performed under the PRDA contract uses the SEG Squarepak™ SQ-112 as a starting point, and includes shielding materials, such as steel fibers, in the concrete mix, in the design of a stronger, thinner walled, lighter weight container certified as a DOT Specification 7A Type A package. 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.

CONCLUSION

Results of this project indicate cost avoidances can be realized through thorough evaluation of alternatives, proper planning, and open communication between DOE facilities and other government agencies. Because of the initiative of team members involved with this project, interagency, cooperative efforts between the DOE and the DOT, as well as the intraoffice cooperative efforts within the DOE complex, development of a customized container was able to proceed prior to knowledge of the promulgated regulations. As a result, possible impacts to the remediation schedule due to development of the container have been negated.

The ability to transport vitrified silo material in customized DOT Specification 7A Type A packages as LSA-II material under the new regulations has resulted in a potential cost savings of approximately $85 million compared to transporting the vitrified material in overpacked 3-gallon Type A containers as normal form radioactive material under the regulations promulgated prior to September 1995.

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REFERENCES


